Peak Heat WP1: Characterising the housing stock

Peak Heat Project

Western Power Distribution

FINAL

Report written by: Laura Glover laura.glover@delta-ee.com
Tom Jamieson tom.jamieson@delta-ee.com

Report reviewed by: Andrew Turton andrew.turton@delta-ee.com

Date of issue: 28/05/2021

Delta-EE is a leading European research and consultancy company providing insight into the energy transition. Our focussed research services include Connected Home, Electrification of Heat, Electric Vehicles, New Energy Business Models, Digital Customer Engagement and Local Energy Systems. We also provide consultancy for clients including networking companies and policymakers. Delta-EE's mission is to help our clients successfully navigate the change from 'old energy' to new energy.

Delta address and contact details

Edinburgh: Floor F Argyle House, Lady Lawson Street, Edinburgh, EH3 9DR, UK +44 (0)131 625 1011

Cambridge: Future Business Centre, Kings Hedges Road, Cambridge, CB4 2HY +44 (0)1223 781 605

London: Sustainable Workspaces, 25 Lavington Street, London, SE1 0NZ

Paris: 2 Boulevard de Strasbourg, 75010, Paris, France. +33 6 51 33 73 74

Contents

Executive summary

1

Three contrasting primary substation areas provide the focus for this project. The housing stock for these areas were characterised into eight house archetypes, detailing property type and age, heating system type, floor area, occupancy and building fabric parameters.

This report summarises the work conducted in Work Package 1 of the Peak Heat project. The focus of this work package was to select three primary substation areas from across WPD's network to focus on for the duration of this project and to characterise the housing stock in each area into house archetypes to be taken forward into WP3 (customer modelling) and WP4 (area typology modelling).

The three primary substation areas were selected based on geographical spread across the WPD network, high expected heat pump uptake and constrained transformers. These are shown in Table 1.

Table 1 Selected study areas

Primary substation	Licence area	DFES non-hybrid HP uptake (2030)*	Demand headroom (MVA)	Geography
Mackworth	East Midlands	3,135	3.32	Village / Rural
Newport East Primary	South Wales	3,443	7.1	City
Bath Road Primary	South West	2,659	0.6	Town

*Based on DFES 'Consumer Transformation' scenario WPD DFES 2020

For each of these areas, EPC and census data was gathered and analysed to inform the development of eight representative house archetypes to be taken forward into WP3 and WP4. For WP3, consistent archetypes are required across all three areas for the physical factors that influence thermal demands and heat losses due to limitations on the number of building physics model runs. These factors include building type, wall and insulation type, glazing type and building age. Other factors, such as existing system type and occupancy profile, can vary between study areas.

Figure 1 shows the steps taken to defining the archetypes.

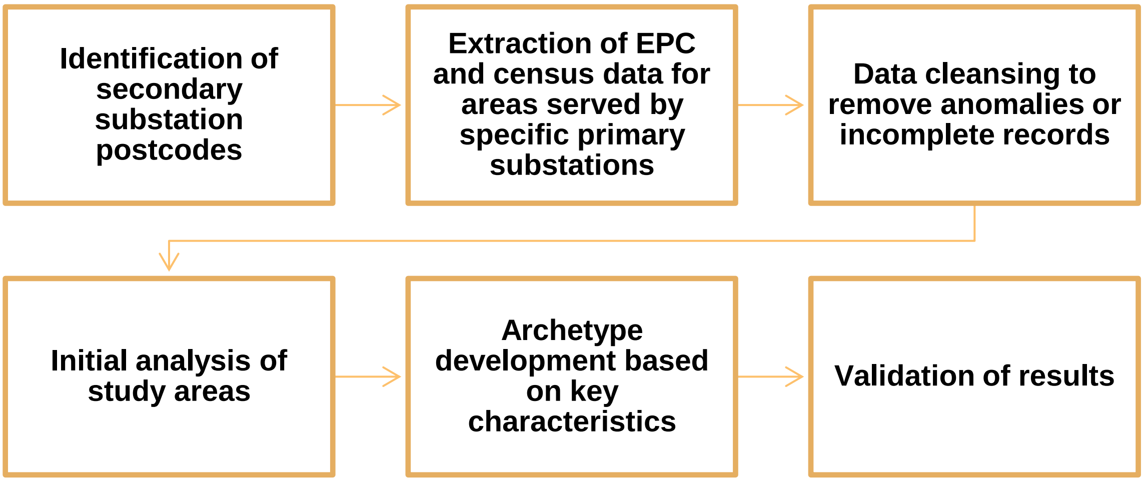

Figure 1 Flow chart of steps to determining the final house archetypes

The eight archetypes are defined primarily based on the residential building type (detached, semi-detached, mid-terraced and flats) and the building fabric performance (good/insulation present and poor/no insulation). Secondary characteristics (building age, wall type, glazing type, heating system, occupancy profile and floor area) were assigned to each of these archetypes, based on the median (floor area) and modal values (other inputs) for each archetype whilst ensuring that the distribution as a whole was representative. Differences in housing stock between the three areas are addressed by assigning a different number of properties to each archetype, as shown in Figure 2 (explanation of abbreviated archetype names are provided in Table 2).

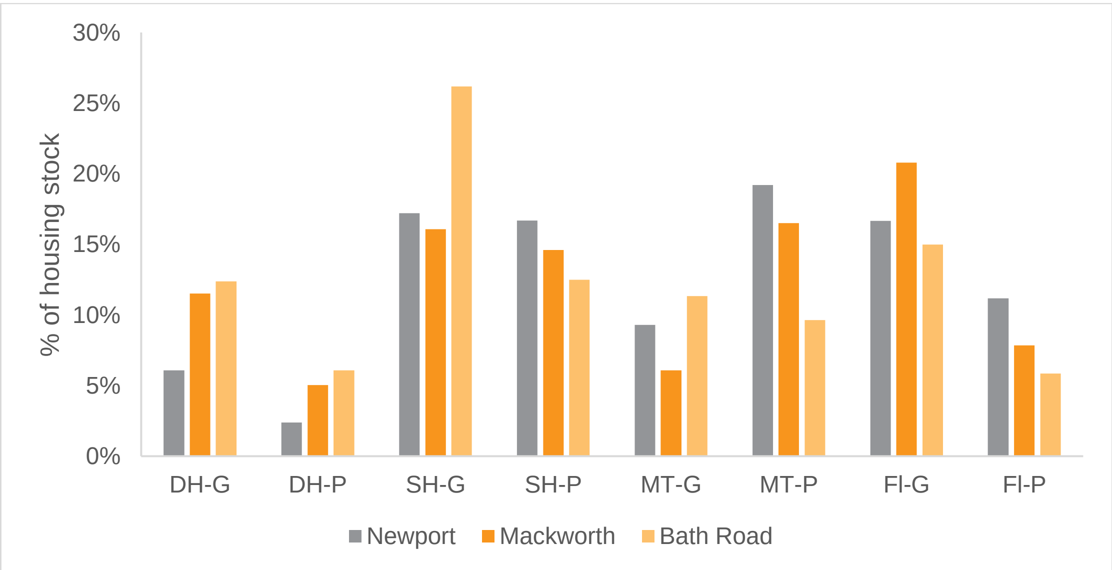

Figure 2 Distribution of properties across the eight archetypes in each study area

Table 2 Explanation of abbreviated archetype codes

House archetype code	Description
DH-G	Detached house, good wall insulation performance
DH-P	Detached house, poor wall insulation performance
SH-G	Semi-detached house, good wall insulation performance
SH-P	Semi-detached house, poor wall insulation performance
MT-G	Mid-terrace house, good wall insulation performance
MT-P	Mid-terrace house, poor wall insulation performance
FI-G	Flat, good wall insulation performance
FI-P	Flat, poor wall insulation performance

For each secondary characteristic, the total percentage of building stock for all customer archetypes with that characteristic (the modelled data) has been compared to the actual percentage of building stock with that secondary characteristic (taken from the actual EPC data) to confirm the validity of the simplifications and assumptions that have been made. The average absolute discrepancy between the actual and modelled values for each parameter across each area is less than 5%, with the largest discrepancy being -16%, found for the percentage of properties with uninsulated solid walls in Newport. This is judged to be within acceptable bounds and therefore the archetype distribution is deemed to be suitably representative of the actual stock. The results of this analysis for Newport as an example are shown in Figure 3.

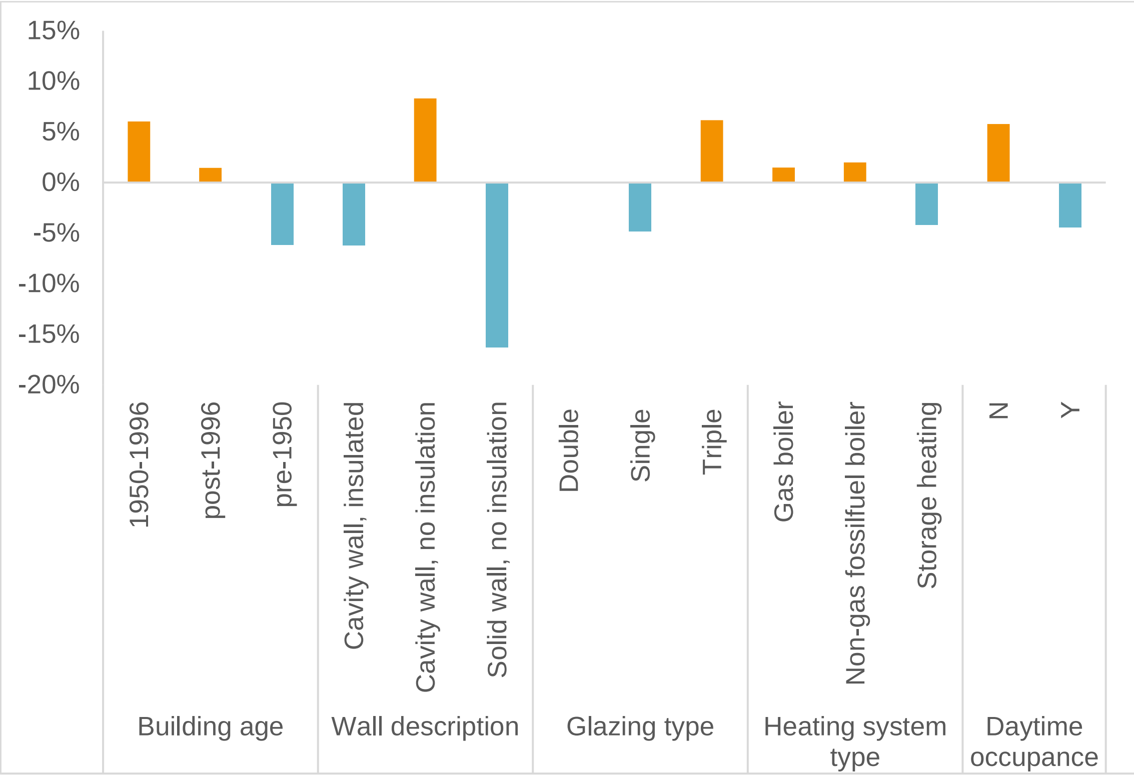

Figure 3 Percentage difference between modelled and actual values in Newport. This level of discrepancy is considered reasonably and provides a balance between accurately representing the stock whilst maintaining an appropriate level of complexity in the modelling.

1. Introduction

This report summarises the selection of study areas for the project and characterises the housing stock into representative house archetypes.

1.1. Project Scope

This is the report for the first work package (WP) in the Peak Heat project. Peak Heat is helping WPD understand the impacts of electric heating loads and domestic thermal storage on the electricity network, and the role that flexibility could take in helping to mitigate network impacts. The project fits within WPD's innovation strategy to understand the demands and usage of heat pumps and other technologies particularly in the following areas:

- Usage patterns and profiles of Heat Pumps - understanding the impact of significant Heat Pump integration on the network;
- Flexibility of heat demand - how and when can heat load be shifted through flexibility to manage network loading whilst providing the required service for customers.

This WP covers the selection of the three study areas for the modelling work for this project and characterises the housing stock in each of these three areas into representative house archetypes. The archetypes formed will be used in the modelling (WP3&4) as representative house types that typify the broader domestic building stock. Each archetype will be characterised based on the core factors that influence heating demand, such as: floor area, heating system type, hot water heating type, number of occupants and occupancy patterns, space heat demand, hot water demand and non-heating electrical demand.

The full list of work packages is as follows:

- WP1 – This work package - Identifies the study areas of WPD's network for the project and characterises the housing stock into representative house archetypes
- WP2 - characterises the range of domestic electric heating and thermal storage technologies that could be or will likely be deployed, as well outlines the ways in which these technologies may be used flexibly
- WP3 - Simulates house archetypes to identify their heat demand profiles and heat loss factors during average winter and '1-in-20'[1] peak winter conditions. Both daytime occupancy and non-daytime occupancy profiles will be explored, allowing the most suitable of these profiles to be applied in each of the study areas. The heat demand will then be used to determine the electricity demand profiles for the different archetypes by taking into account the efficiency of the different technologies as well as the impacts of thermal storage.

[1] Winter conditions that correspond with gas demand that statistically, out of a long series of winters, would be exceeded in one out of twenty winters

- WP4 – Takes representative mixes of house archetypes (provided by WP1) and combines them with information on network typologies and heat pump (and thermal storage) uptake rates to allow their aggregate impact on network infrastructure to be identified under different temperature and flexibility scenarios.

2. Selection of study areas

Three primary substation areas were selected within the WPD area, based on differing locations, high expected heat pump uptake and constrained transformers

2.1. The need for study areas

The Peak Heat project aims to help WPD understand the impacts of electric heating loads and the role that flexibility (including thermal storage) could take in helping to mitigate network impacts under peak heating conditions. To understand these impacts on typical local distribution networks, a set of WPD's primary substations were selected as study areas, and the housing stock for these areas characterised in order to create house archetypes. These archetypes will be used in the modelling in other work packages as representative house types that typify the broader domestic housing stock.

Since the project's focus is on understanding the impacts of heat electrification on the local distribution network, the study areas should focus on areas where high levels of heat pumps are likely to be installed and those areas where there will likely be significant additional demands on the network. As the impact from the additional demand due to heat electrification will be felt most acutely in areas of the network that already have constrained transformers, the areas selected for characterisation should also typify those that are highly constrained.

The project also looks to assess the impact that the electrification of heat will have on different low voltage distribution network typologies, including analysing both rural and urban areas of both northern and southern climatic regions.

The study areas should meet the following criteria:

1. Have high heat pump uptake rates
2. Already have limited headroom
3. Cover a range of geographies

2.2. Identification of study areas

To identify areas of WPD's network that met criteria 1 (i.e. where high heat pump uptake is expected), WPD's DFES data on heat pump uptake was used (downloaded from: https://www.westernpower.co.uk/smarter-networks/network-strategy/distribution-future-energy-scenarios). The 'Consumer Transformation' scenario (forecasting highest heat pump uptake of the four DFES scenarios) was used to attain (non-hybrid) heat pump uptake numbers for each Electricity Supply Area (ESA) to 2030, in each of WPD's licence areas.

Data extracted from WPD's network capacity map (https://www.westernpower.co.uk/our-network/network-capacity-map-application) was used to identify areas meeting Criteria 2 (ESAs that could have potential capacity issues on the upstream network). Demand headroom (the difference between calculated capacity of the substation and current peak demand values) was assessed. This data had to be checked with WPD, and some primaries ruled out for further analysis, as headroom for some primaries was more than indicated in the data available via this source due to the treatment of split sites (sites with split 11kV busbars).

These two datasets were combined to identify those areas where very high heat pump uptake (defined as above 2,000 per ESA by 2030) is expected and where the primary substations have limited headroom. A 'long list' of primaries meeting these criteria across all licence areas was shared with WPD, and further clarification around data associated with these primaries led to a narrowing down of this list to three primary substation areas that met criteria 1 and 2, as well as covering a range of rural and urban geographies. The primaries chosen and the key criteria associated with each are listed in the table below:

Table 3. Selected primary substation areas

ESA	Licence area	DFES non-hybrid HP uptake (2030) (Consumer Transformation)	Demand headroom (MVA)	Geography
Mackworth	East Midlands	3,135	3.32	Village / Rural
Newport East Primary	South Wales	3,443	7.1	City
Bath Road Primary	South West	2,659	0.6	Town/Rural

3. Determining house archetypes

EPC data for the primary substation regions was obtained and used to identify key trends and factors to feed into the development of eight representative house archetypes.

3.1. Introduction

This project aims to identify the impact that uptake of residential heat pumps is likely to have on the LV network and the amount of flexibility available from these properties. To identify these factors, we need to have a good understanding of the housing stock in each of the study areas. It is not possible to model the exact physical and operational characteristics of each individual house connected to the network, so houses needed to be grouped into a small number of representative house archetypes based on key factors that influence heating and electrical load on the network. Eight archetypes were selected after inspection of the available datasets, which provides a good balance between capturing enough variance within these datasets whilst simplifying as much as possible down to the key differentiating characteristics amongst houses.

Figure 4 shows the steps conducted for developing these archetypes. Further details on each step can be found in the following sections.

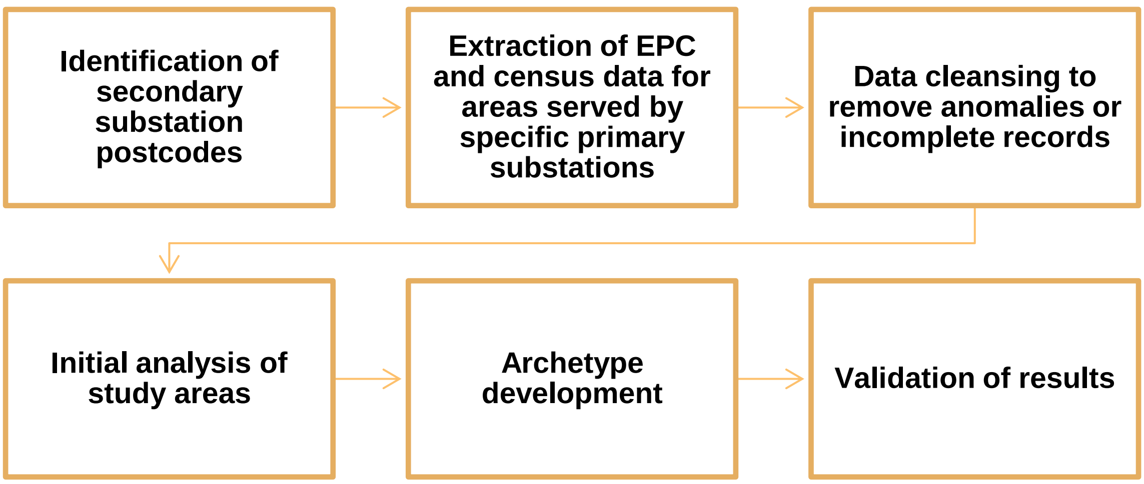

Figure 4 Flow chart of steps to determining the final house archetypes

3.2. Identification of primary substation regions

Data was provided on the secondary substations connected to each of the selected primary substations. This included the grid reference location of the secondary substation, total number of customers served by the secondary substation and the profile class of these customers. As is common with LV network data, there are some discrepancies between the sum of the number of customers from the profile class data and the total number of customers served value (provided in a report from WPD's asset management system). However, these values still provide a good guide for the characteristics and variations in this area of the network and will be used to inform the network typology in WP4.

Data was provided on the secondary substations connected to each of the selected primary substations. This included the grid reference location of the secondary substation, which could be mapped onto the postcode for that location utilising the Geodojo online converter tool[2]. This allowed the postcode sectors served by the primary substation to be identified, enabling:

- The number of customers to be cross referenced with data from the non-gas heat map total number of dwellings[3].
- EPC data for these postcode sectors[4].

It should be noted that there is not an exact geographical or time alignment between the postcode sectors, the non-gas map Lower Layer Super Output (LSOA) areas, and customers served by each primary substation, leading to small discrepancies between these values. This is especially the case for the EPC data, as postcode groups can cover a large area and are served by multiple secondary substations. In some cases, only a few of these substations are supplied by the primary substations focused on in this project. However, these values fall within the expected ranges and give confidence in the EPC data providing a reliable view of the distribution of house types in each area.

Table 4 Number of residential properties in each study area

Study area	Secondary substation details – number of PC1 and 2* customers connected	Number of EPC records	Number of dwellings identified non-gas map (inc on gas properties)
Newport	27,006	33,247	25,084
Mackworth	14,841	23,277	13,485
Bath Road	9,112	16,401	10,712

*PC = profile class, as defined by Elexon. Profile class (PC) 1 customers are domestic unrestricted customers. PC 2 are domestic economy 7 customers

The additional properties in the EPC dataset are assumed to be similar in age and characteristics to those within the study area and will not significantly affect the distribution of the housing stock archetypes identified.

2 http://www.geodojo.net/uk/converter/
3 https://www.nongasmap.org.uk/
4 https://epc.opendatacommunities.org/

3.3. Data cleansing

The key data source used for the characterisation of the housing stock was the EPC data downloaded for each area. Several steps were taken to convert the raw data file into a usable form:

- Multiple records in EPC data for same property removed, with only the most recent record retained
- Records with incomplete data in the required fields were removed
- Grouping of text input fields was completed – e.g. for Wall Type “Granite or whin, with external insulation” and “Solid brick, as built, insulated (assumed)” were both grouped as “Solid wall, insulated” and “mostly double glazing”, “partial double glazing” and “double glazing” were all grouped under “double glazing”
- Removal of outliers e.g. extreme values for floor area or energy consumption.

Occupancy information was sourced from the 2011 Census data for Local Authorities served by each primary substation area (DC1402EW - Household composition by number of bedrooms). This splits the households in the area into seven types of household composition. For each of these types we have assumed either a daytime occupancy profile or mornings and evenings only (Table 5) to reflect the key difference that different household compositions have on heat demand profiles.

Table 5 Assumed occupancy profiles for different household compositions

Household composition	Daytime occupancy?
One person household - retired	Y
One person household - working	N
Couple - no children	N
Dependents - two parents/other	Y
Dependents - lone parents	N
Retired – more than 1 person	Y
Other – no dependents*	N

*This category includes multiple person households such as student lets or flat shares

Whilst this data is now 10 years old, we have assumed that no significant changes have occurred, in absence of more recent data.

3.4. Initial comparison of study areas

An initial analysis was undertaken to identify the key characteristics of each study area. Comparison graphs and short summaries of each area can be found below.

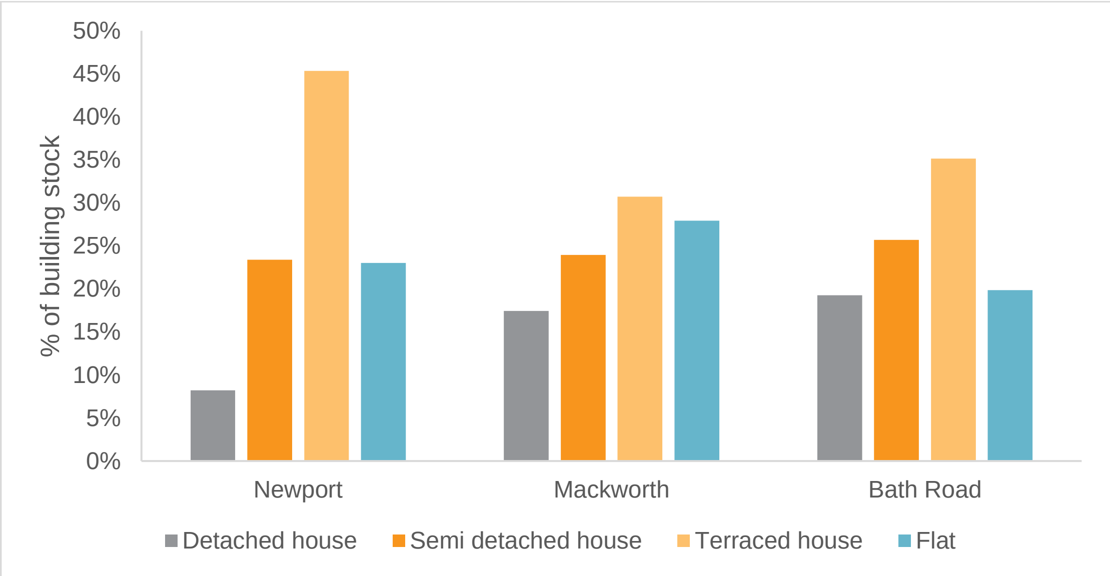

Figure 5 Distribution of property types across the three study areas

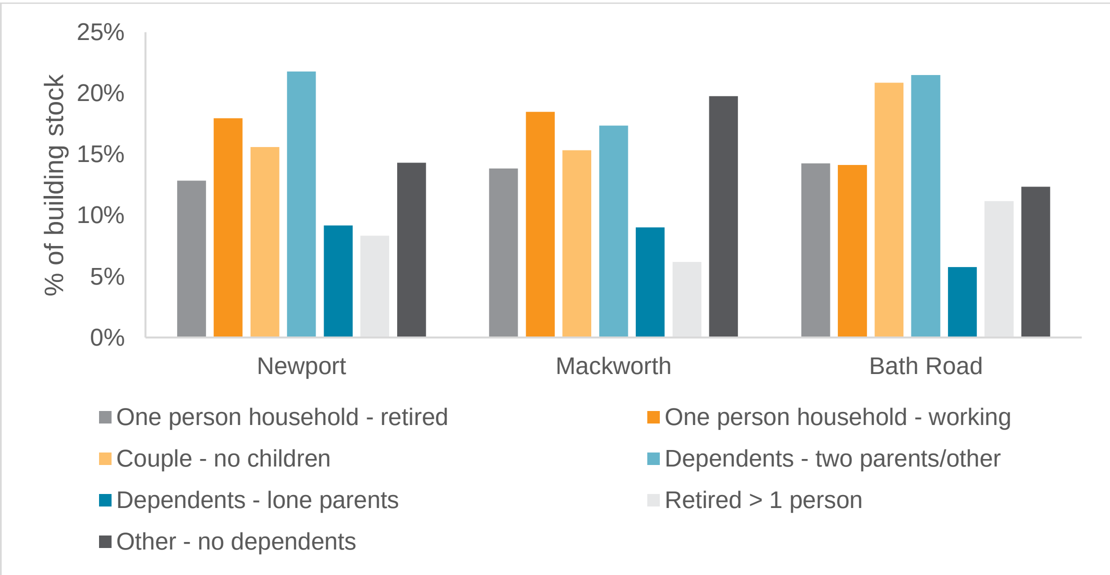

Figure 6 Distribution of occupancy profiles across the three study areas

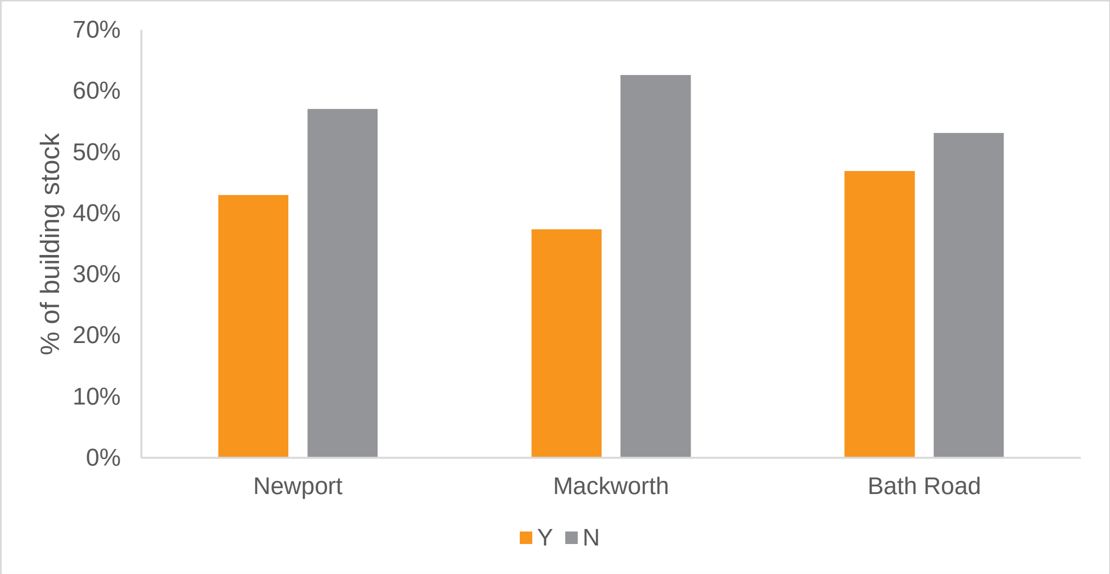

Figure 7 Proportion of dwellings with daytime occupancy across the three study areas

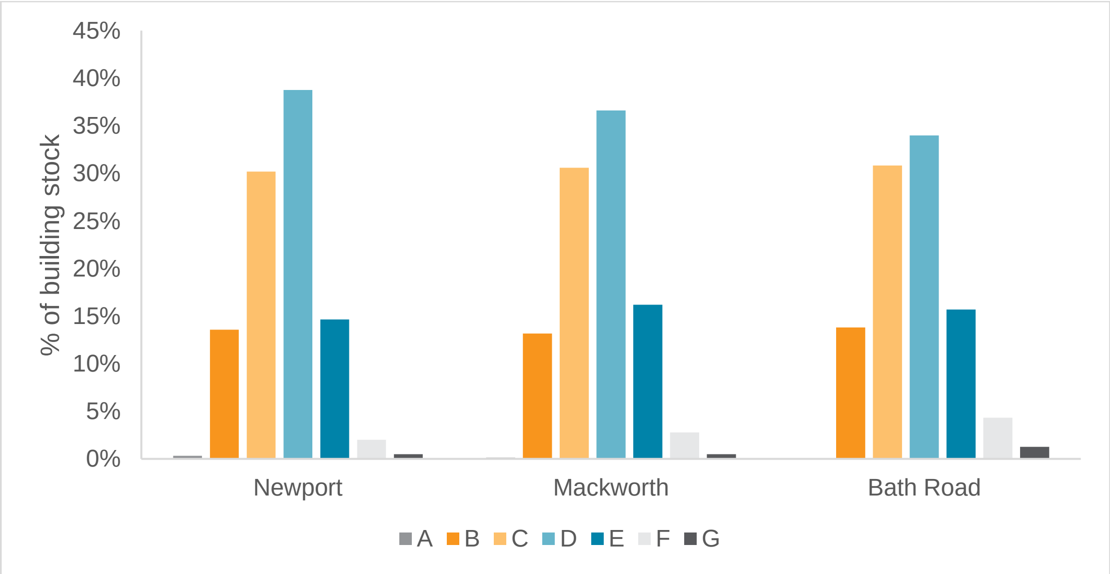

Figure 8 Distribution of EPC energy ratings in each of the three study areas

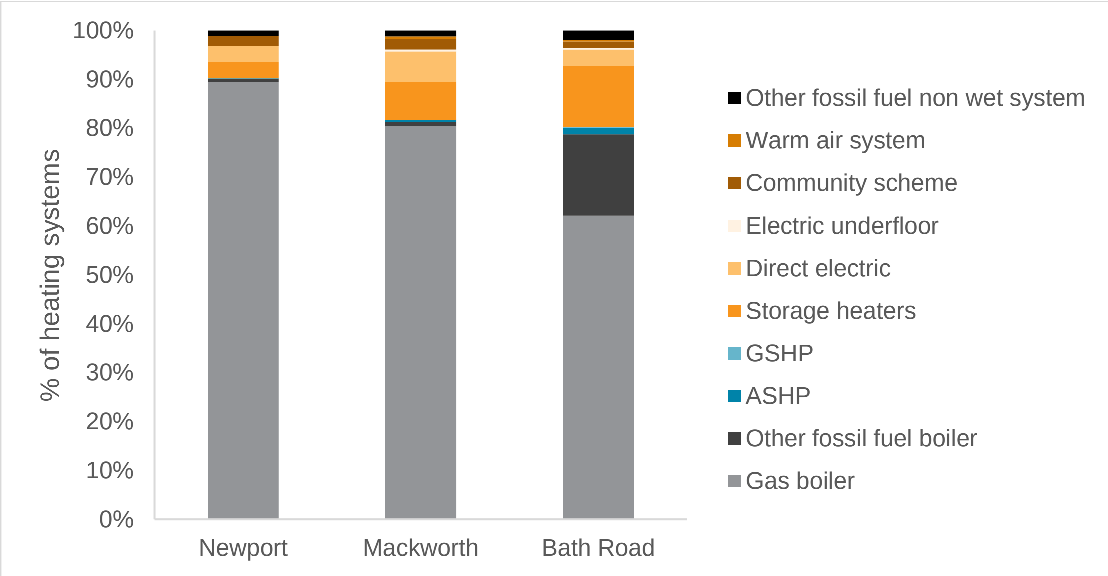

Figure 9 Distribution of heating system types across the three study areas

3.4.1. Newport overview (city typology)

Newport is a densely populated urban area, located close to the English border in South Wales. It has the highest number of dwellings being supplied by any of the three primary substations being studied. Residents are relatively evenly spread between those likely to have daytime occupancy and those likely to be out at work during the day. The mix of dwellings is dominated by gas heated, pre-1950 built terraced houses. The building fabric in the area tends to be poor, with over 65% of dwellings currently with an EPC energy rating of D or below. However, EPC assessors have determined that it is possible to improve this to 89% C or above with suitable energy efficiency and renewable energy measures installed, making it more likely that heat pumps could be more effective in these properties once these upgrades have occurred.

3.4.2. Mackworth overview (village / rural typology)

The Mackworth primary substation is located in the East Midlands, covering the western outskirts of Derby and into the more rural Derbyshire Dales. This gives it a diverse range of occupancy types and dwellings, relatively evenly split between detached, semi-detached, terraced and flats. 56% of dwellings have an EPC energy rating of D or below, with these properties split evenly between property types. With energy efficiency measures and renewable energy systems, this could be improved to 88% of dwellings being EPC energy rating C or above. The area is largely on the gas grid, with 80% of dwellings heated with a gas boiler. The remaining properties tend to be flats heated with direct electric heating or storage heaters.

3.4.3. Bath Road overview (town/rural typology)

The Bath Road primary covers an area in North Devon around the town of Bridgewater and surrounding rural area. Out of the three primary substations being studied, Bath Road supplies the smallest number of customers. The area has a newer housing stock than Newport or Mackworth, with over 70% of dwellings built after 1950. Consequentially, there is a high level of insulated cavity wall builds compared to the other study areas. The average EPC energy rating is similar to Mackworth, with 55% of properties rated D or below. With energy efficiency and renewable energy measures installed, 88% of properties could be rated C or above. The area has the lowest proportion of homes currently supplied by gas boilers at 62%, with the remaining homes being split evenly between non-gas fossil fuel boilers (predominantly oil) and electric heating.

3.5. Archetype development

The housing stock in each study area were clustered into a range of potential archetypes through an iterative trial and error approach, based on different combination of factors that impact on heat demand:

- Property type (detached house, semi-detached, mid-terraced5, flat)
- Wall energy efficiency rating
- Roof energy efficiency rating
- Glazing type
- Building age
- EPC rating

The distribution of each of these potential sets of archetypes was assessed and compared to identify (a) the correlations between these factors and (b) the percentage of the building stock covered by fewer than ten archetypes (the maximum number of archetypes that can be carried through to the WP3 analysis). For WP3, consistent archetypes are required across all three areas for the physical factors that influence thermal demands and heat losses due to limitations on the number of building physics model runs. These factors include building type, wall and insulation type, glazing type and building age. Other factors, such as existing system type, floor area and occupancy profile, can vary between study areas as these can be modified or scaled for after the building physics model is complete.

It was determined that property type and wall energy efficiency rating were key factors, with other factors tending to be linked to these. For example, a terraced house with poor wall energy efficiency is very likely to also be a pre-1950 build with solid walls without insulation. Secondary factors were assigned to each of these archetypes whilst ensuring that the distribution as a whole was representative. These secondary factors were the median value for quantitative inputs and modal value qualitative inputs. The following secondary factors were defined for each house archetype.

Factor	Average type	Range of values
Building age	Mode	pre-1950 1950-1996 post-1996
Wall type	Mode	Solid wall, no insulation Cavity wall, no insulation Cavity wall, insulated
Glazing type	Mode	Single glazing Standard double glazing Higher performance glazing

[5] End-terraced houses have similar external wall and roof configurations to semi-detached houses and have been grouped together with semi-detached for this analysis.

Factor	Average type	Range of values
Heating system type	Mode	Gas boiler Other fossil fuel boiler Electric storage heaters
Occupancy description	Mode	One person household – retired One person household – working Couple - no children Dependents - two parents/other Dependents - lone parents Retired > 1 person Other - no dependents
Occupancy profile	Assumed based on description	Daytime occupancy No daytime occupancy
Floor area	Median	Distributions of floor areas can be seen in Figure 10.

It has been assumed that by 2030 all properties will have 250mm loft insulation installed[6].

These archetypes will be used for the household level modelling in WP3. For WP4, some diversity will be reintroduced to the modelling, through scaling the heat demand and heat loss factors based on floor area. The range of floor areas across the study area can be seen in Figure 10.

[6] Based on the BEIS Clean Growth Strategy of all homes being upgraded to EPC C by 2035, where practical, cost-effective and affordable. Roof insulation is one of the most cost effective measures that could be implemented to reach this target. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

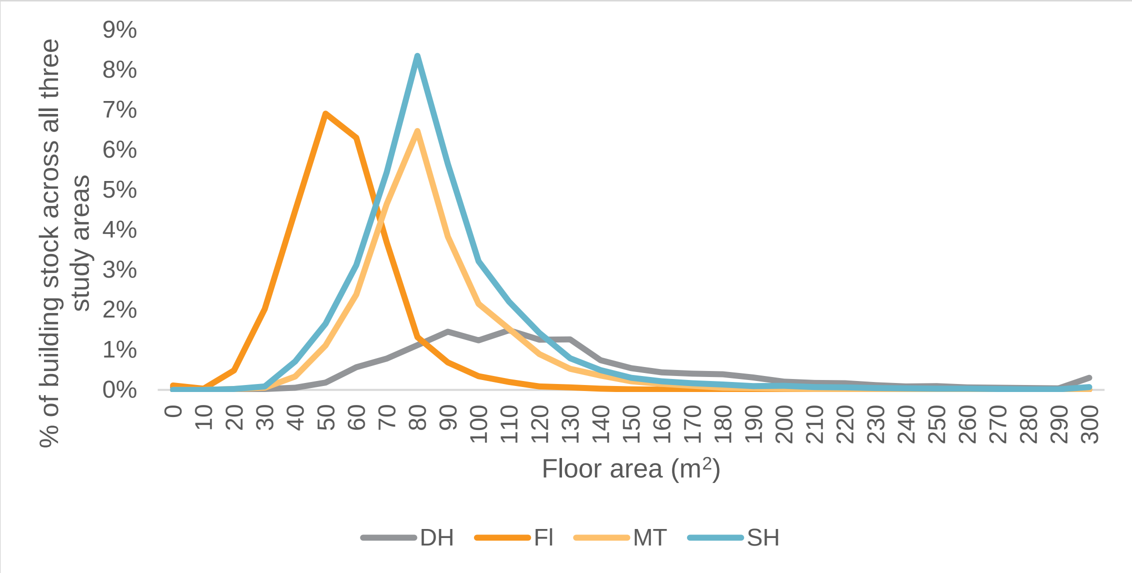

Figure 10 Distribution of floor areas by house type across all three study areas

3.5.1. Final archetype characteristics

The housing stock in each study area has been split into 8 archetypes. Between the primary substation areas investigated, the building fabric and floor area (the primary characteristics) of each archetype has been kept consistent, as required for the building physics modelling in WP3. However, occupancy profiles and existing heating types (secondary characteristics) differ between study areas to more closely reflect the actual distributions observed. In WP4 this will affect:

- the occupancy profile selected for the archetype (both occupancy profiles will be modelled for each house type in WP3)
- the archetypes first selected to be switched to heat pumps. For example, archetypes on non-gas fossil fuel boilers will be likely to be more likely to switch to a heat pump than those on the gas network.

Archetypes have been labelled based on the two primary parameters: building type and wall insulation performance.

Building type:

- Detached house (DH)
- Semi-detached house (SH)
- Mid-terrace (MT)
- Flat (Fl)

Wall insulation performance:

- Good (G)
- Poor (P)

The secondary parameters were determined for each area based on the median / modal values for each category for the properties that fall into this customer archetype, as described in Section 3.5 above. All percentage of housing stock values in the below tables represent the number of properties that satisfy the primary parameters associated with that house archetype. Assigned floor areas are the median value for each specific archetype across all three study areas.

Table 6 Details of house archetype DH-G

DH-G	Newport	Mackworth	Bath Road
% of housing stock	6%	12%	12%
Property type	Detached House		
Age	post-1996		
Wall insulation description	Cavity wall, insulated		
Roof insulation description	250 mm loft insulation		
Window description	High performance double glazing		
Heating type	Gas boiler	Gas boiler	Non-gas fossil fuel boiler
Floor area (m^2)	112.21		
Occupancy description	Other no dependents	Dependents - two parents	Dependents - two parents
Number of occupants	3	4	4
Daytime Occupancy	N	Y	Y

Table 7 Details of house archetype DH-P

DH-P	Newport	Mackworth	Bath Road
% of housing stock	2%	5%	6%
Property type	Detached House		
Age	pre-1950		
Wall insulation description	Solid wall, no insulation		
Roof insulation description	250 mm loft insulation		
Window description	Double glazing		
Heating type	Gas boiler	Gas boiler	Gas boiler
Floor area (m^2)	120.69		
Occupancy description	Dependents - two parents	Retired not 1 person	Dependents - two parents
Number of occupants	4	2	4
Daytime Occupancy	Y	Y	Y

Table 8 Details of house archetype SH-G

SH-G	Newport	Mackworth	Bath Road
% of housing stock	17%	16%	26%
Property type		Semi-detached house	
Age		1950-1996	
Wall insulation description		Cavity wall, insulated	
Roof insulation description		250 mm loft insulation	
Window description		Double glazing	
Heating type	Gas boiler	Gas boiler	Gas boiler
Floor area (m^2)		77.88	
Occupancy description	Dependents - two parents	Couple - no children	Couple - no children
Number of occupants	4	2	2
Daytime Occupancy	Y	N	N

Table 9 Details of house archetype SH-P

SH-P	Newport	Mackworth	Bath Road
% of housing stock	17%	15%	12%
Property type		Semi-detached house	
Age		pre-1950	
Wall insulation description		Cavity wall, no insulation	
Roof insulation description		250 mm loft insulation	
Window description		Double glazing	
Heating type	Gas boiler	Gas boiler	Gas boiler
Floor area (m^2)		85.33	
Occupancy description	One person household: retired	Other no dependents	Retired >1 person
Number of occupants	1	3	2
Daytime Occupancy	Y	N	Y

Table 10 Details of house archetype MT-G

MT-G	Newport	Mackworth	Bath Road
% of housing stock	9%	6%	11%
Property type	Mid-terrace house		
Age	1950-1996		
Wall insulation description	Cavity wall, insulated		
Roof insulation description	250 mm loft insulation		
Window description	Double glazing		
Heating type	Gas boiler	Gas boiler	Gas boiler
Floor area (m^2)	76.24		
Occupancy description	Dependents - lone parent	Dependents - two parents/other	One person household: working
Number of occupants	3	4	1
Daytime Occupancy	N	Y	N

Table 11 Details of house archetype MT-P

MT-P	Newport	Mackworth	Bath Road
% of housing stock	19%	16%	10%
Property type	Mid-terrace house		
Age	pre-1950		
Wall insulation description	Solid wall, no insulation		
Roof insulation description	250 mm loft insulation		
Window description	Single glazing		
Heating type	Gas boiler	Gas boiler	Gas boiler
Floor area (m^2)	81.53		
Occupancy description	Couple - no children	One person household: retired	Other no dependents
Number of occupants	2	1	3
Daytime Occupancy	N	Y	N

Table 12 Details of house archetype Fl-G

Fl-G	Newport	Mackworth	Bath Road
% of housing stock	17%	21%	15%
Property type		Flat	
Age		1950-1996	
Wall insulation description		Cavity wall, insulated	
Roof insulation description		250 mm loft insulation	
Window description		Double glazing	
Heating type	Gas boiler	Storage heating	Storage heating
Floor area (m^2)		54.00	
Occupancy description	One person household: working	One person household: working	One person household: retired
Number of occupants	1	1	1
Daytime Occupancy	N	N	Y

Table 13 Details of house archetype Fl-P

Fl-P	Newport	Mackworth	Bath Road
% of housing stock	11%	8%	6%
Property type		Flat	
Age		pre-1950	
Wall insulation description		Solid wall, no insulation	
Roof insulation description		250 mm loft insulation	
Window description		Double glazing	
Heating type	Storage heating	Gas boiler	Gas boiler
Floor area (m^2)		50.33	
Occupancy description	Retired >1 person	Dependents - lone parents	Dependents - lone parent
Number of occupants	2	3	3
Daytime Occupancy	Y	N	N

The distribution of housing stock across the eight archetypes varies between the three areas. For example, Newport has a higher proportion of terraced housing than Bath Road, where semi-detached and detached houses are more common. These variations will be taken into account in WP4.

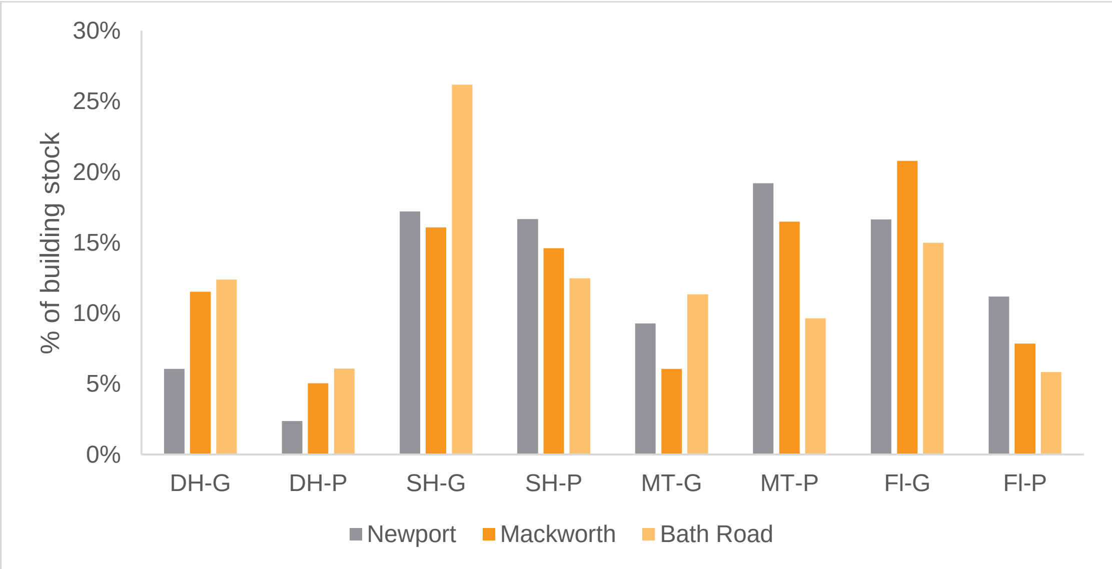

Figure 11 Archetype distributions in each study area

3.6. Validation of results

For each secondary characteristic, the total percentage of building stock for all customer archetypes with that characteristic (the modelled data) has been compared to the actual percentage of building stock with that secondary characteristic (taken from the actual EPC data) to confirm the validity of the simplifications and assumptions that have been made (Figure 12 to Figure 16). An exact match is not obtainable, due to the limited number of archetypes and the need for set parameters across the three areas. However, the average absolute discrepancy between the actual and modelled values (Figure 17) for each parameter across each area is less than 5%, with the largest discrepancy being -16%, found for the percentage of properties with uninsulated solid walls in Newport. This is judged to be within acceptable bounds and is challenging to resolve without affecting the distributions in the other two areas to a greater extent.

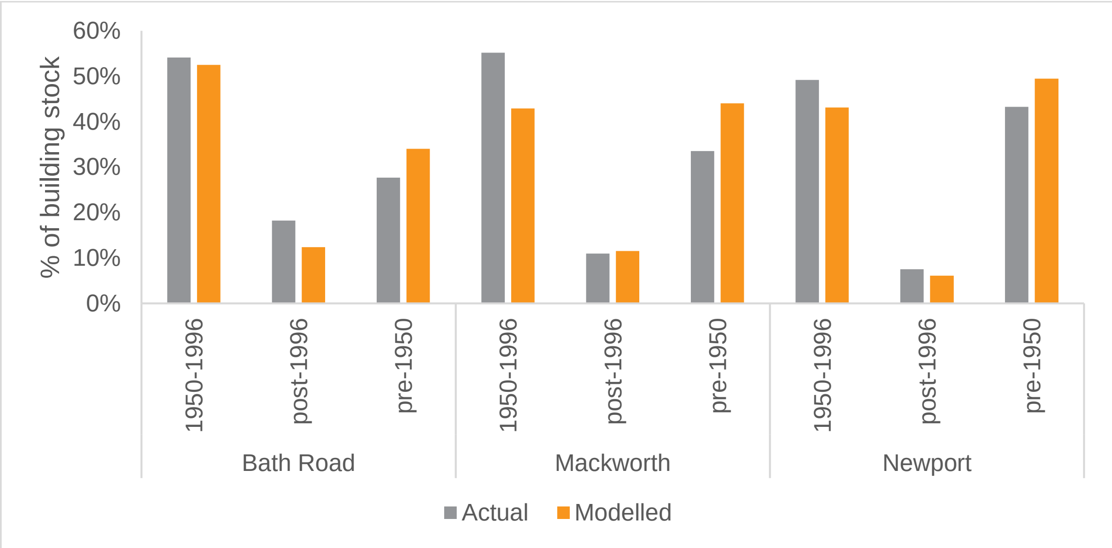

Figure 12 Comparison of the actual and modelled distribution of building age across each study area

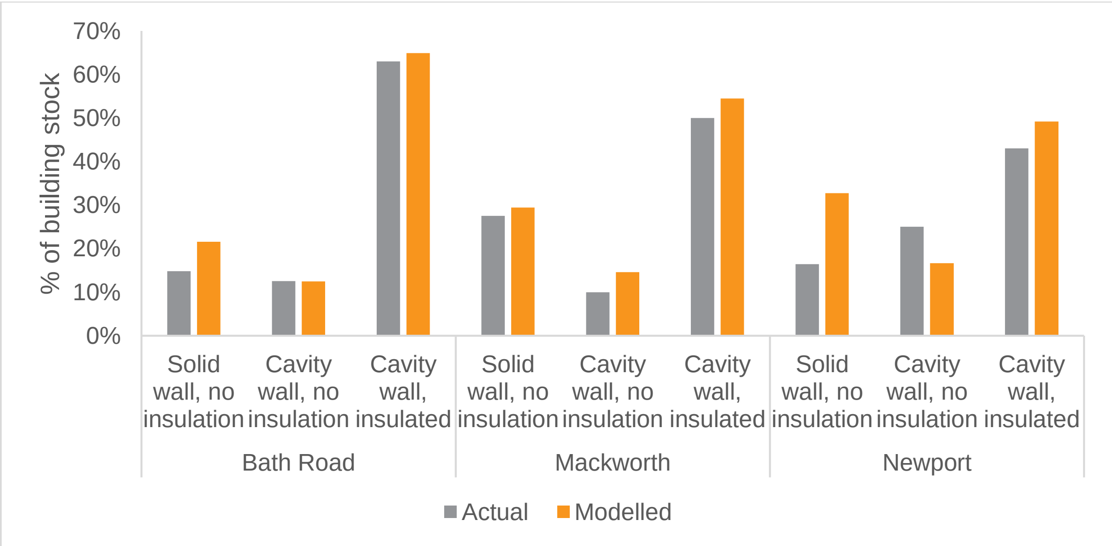

Figure 13 Comparison of the actual and modelled distribution of wall type across each study area

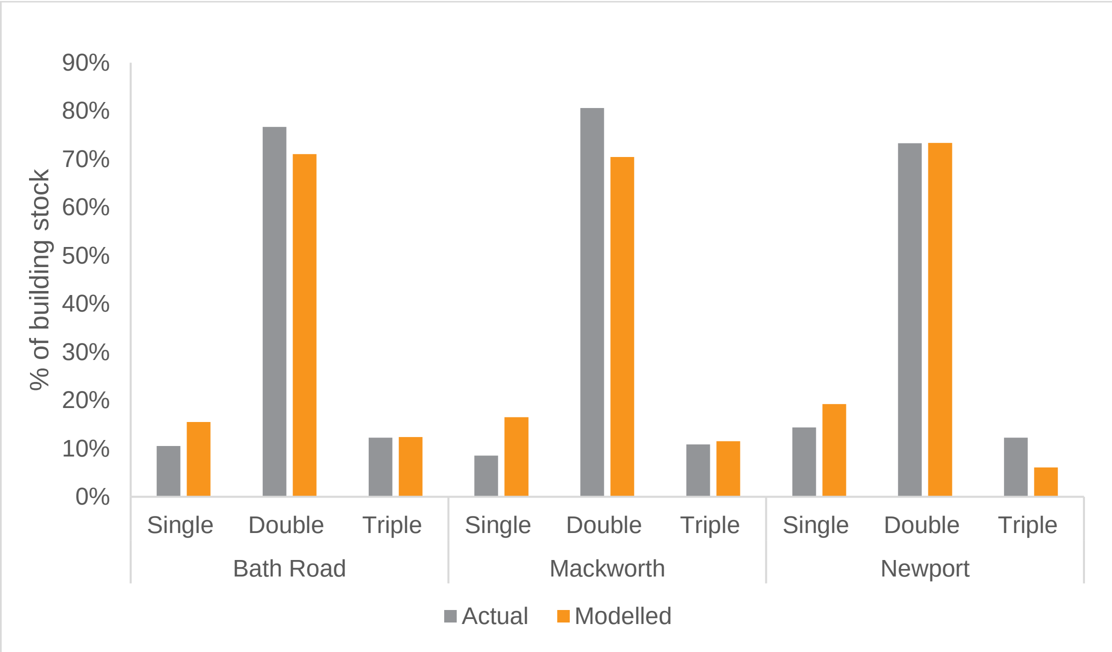

Figure 14 Comparison of the actual and modelled distribution of glazing type across each study area

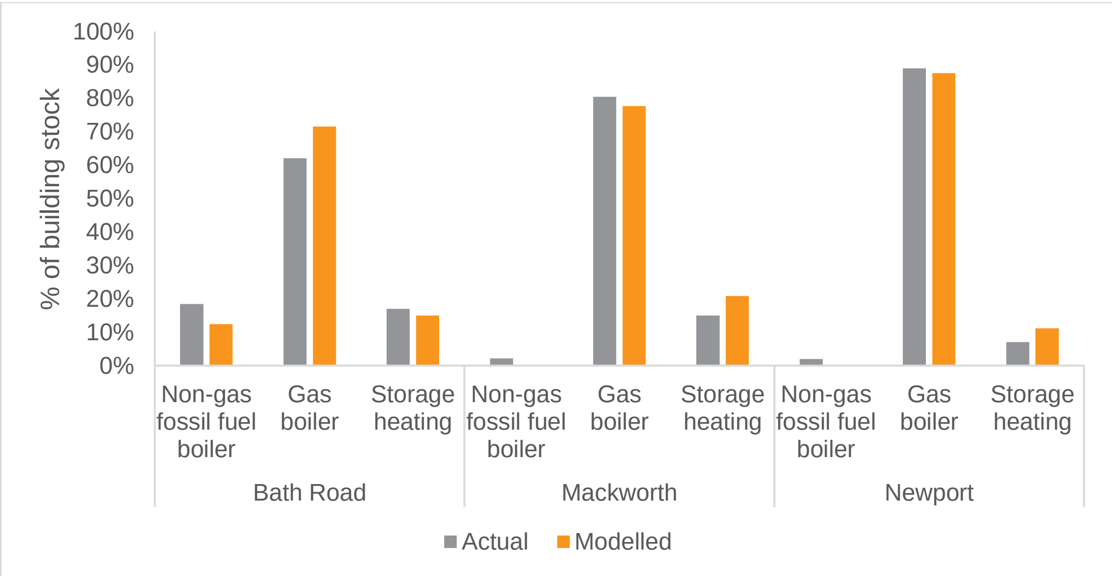

Figure 15 Comparison of the actual and modelled distribution of heating system type across each study area

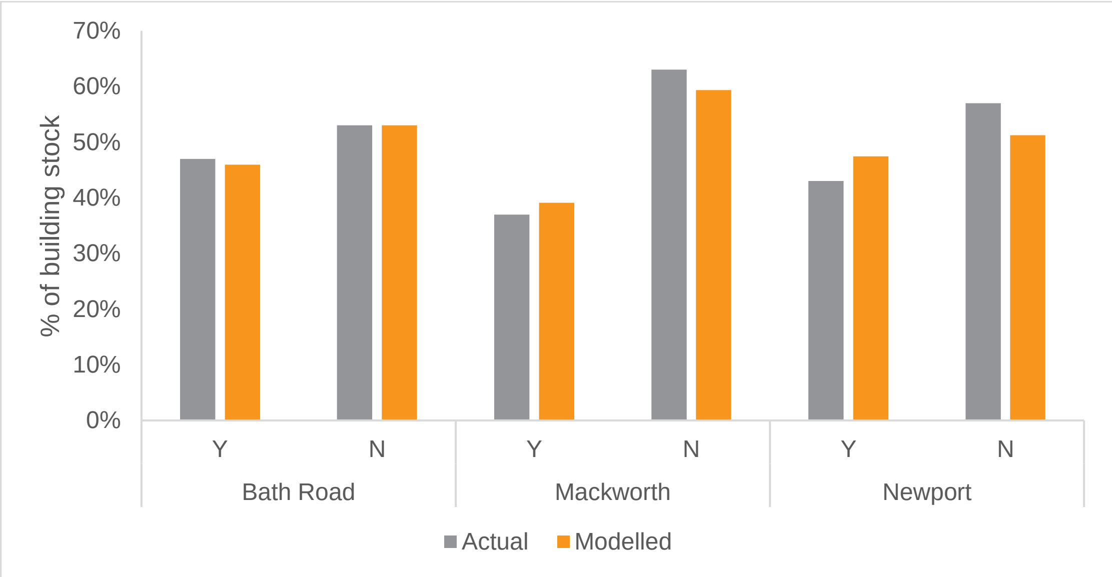

Figure 16 Comparison of the actual and modelled distribution of occupancy profiles across each study area

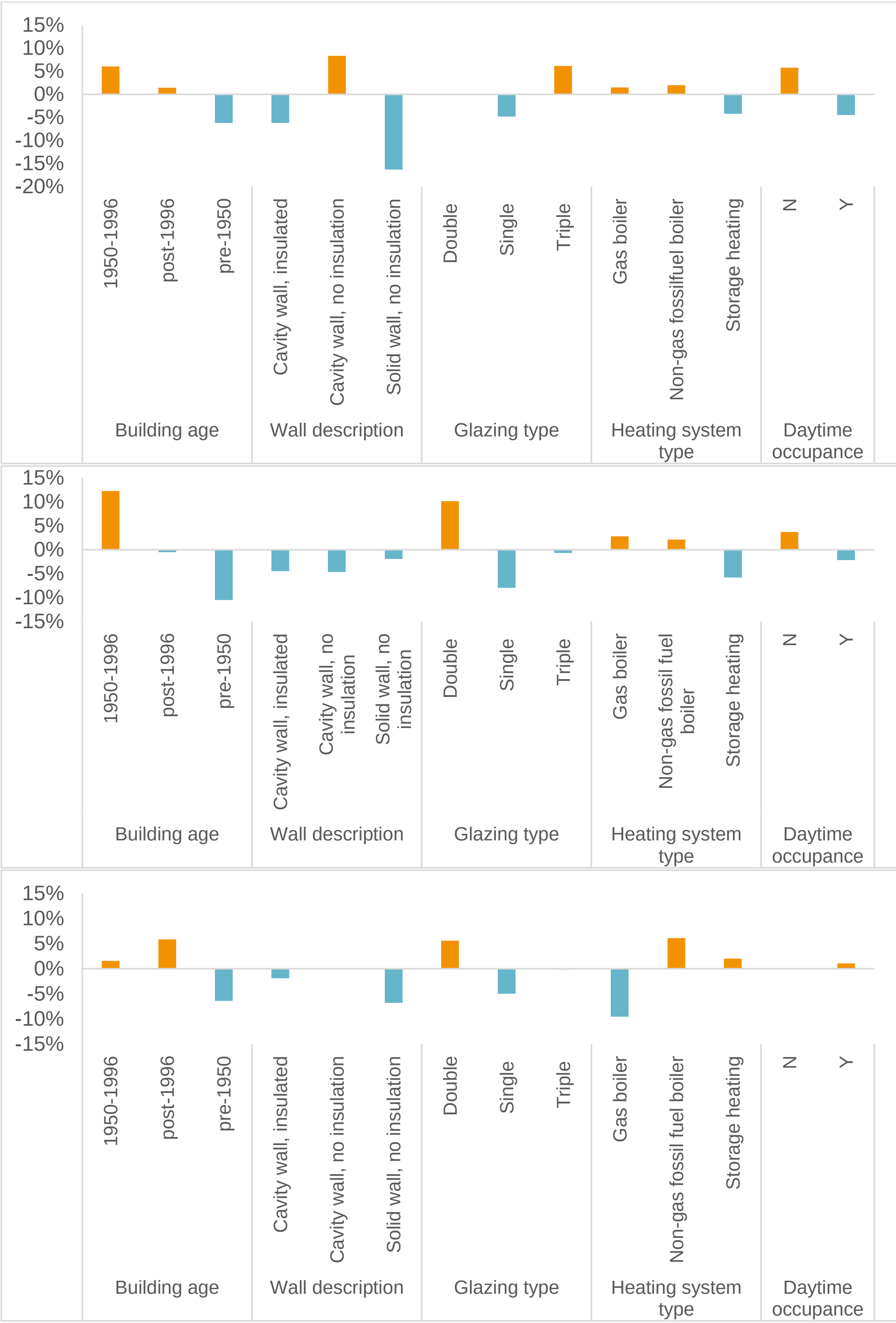

Figure 17 Percentage difference between modelled and actual values in (a) Newport, (b) Mackworth and (c) Bath Road

4. Use of archetypes in future work packages

The eight house archetypes created in WP1 will be taken forward into WP3 to identify their thermal demands and heat loss factors, and WP4 to identify the impact these houses have on network loads and flexibility provision.

4.1. The role of WP1

This work package is the first of five work packages in the Peak Heat Project and, alongside WP2 (heat market landscaping), feeds into the core modelling of the project in WP3 and WP4.

4.2. WP3: Customer Modelling

In WP3, each house archetype will be simulated in a building physics model to identify their heat demand profiles and heat loss factors during average winter and '1-in-20' peak winter conditions. Both daytime occupancy and non-daytime occupancy profiles will be explored, allowing the most suitable of these profiles to be applied in each of the study areas, as identified above. The heat demand will then be used to determine the electricity demand profiles for the different archetypes (identified in WP1) by taking into account the efficiency of the different technologies as well as the impacts of thermal storage.

4.3. WP4: Area typology modelling

Representative mixes of house archetypes will be combined with information on network typologies and heat pump uptake rates (from WP2) to allow their aggregate impact on network infrastructure to be identified under different temperature and flexibility scenarios. House archetypes will be assumed to be retrofitted with heat pumps based on the following criteria, in order of priority:

- House archetypes currently heated with non-gas boilers
- House archetypes with space for outside units (ie houses rather than flats)
- Houses archetypes with low heat loss factors

The heat demands identified in WP3 will be scaled based on floor area to reflect the median floor areas of each house archetype in each of the study areas, to increase the accuracy of the outputs. These are shown in Table 14.

Table 14 Median floor area (m^2) for each archetype by study region

House archetype code	Newport	Mackworth	Bath Road
DH-G	109	117	111
DH-P	115	116	131
SH-G	85	76	73
SH-P	88	84	84
MT-G	82	71	75
MT-P	84	78	83
FI-G	55	53	54
FI-P	56	46	49

5. Conclusions

The housing stock for three contrasting primary substation areas were characterised into eight house archetypes, detailing property type and age, heating system type, floor area, occupancy and building fabric parameters.

This report summarised the work conducted in work package 1 of the Peak Heat project. The focus of this work package was to select three primary substation areas from across WPD's network to focus on for the duration of this project and to characterise the housing stock in each area into house archetypes to be taken forward into WP3 (customer modelling) and WP4 (area typology modelling).

The three primary substation areas were selected based on geographical spread across the WPD network, high expected heat pump uptake and constrained transformers. These areas were Mackworth, Newport East Primary and Bath Road Primary. EPC data and census data was extracted for these areas and cleansed to remove anomalies or incomplete records. Analysis of this data was conducted to develop eight archetypes.

The eight archetypes have been defined primarily based on the residential building type (detached, semi-detached, mid-terraced and flats) and the building fabric performance (good/insulation present and poor/no insulation). Secondary characteristics (building age, wall type, glazing type, heating system, occupancy profile and floor area) were assigned to each of these archetypes, based on the median and modal values for each archetype whilst ensuring that the distribution as a whole was representative. Differences in housing stock between the three areas are addressed by assigning a different number of properties to each archetype, as shown in Figure 18 (explanation of abbreviated archetype names are provided in Table 15).

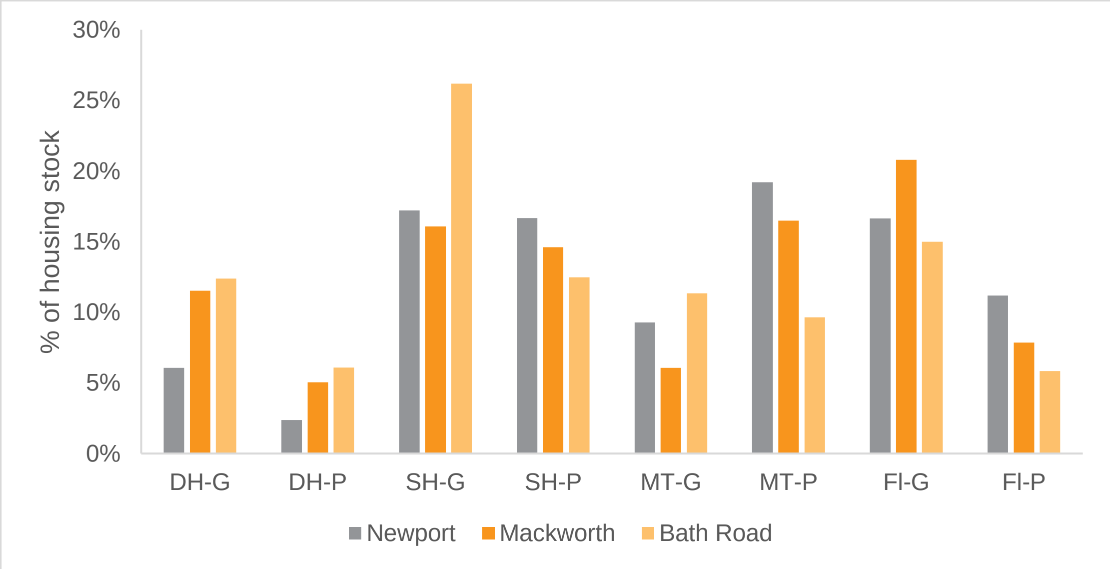

Figure 18 Distribution of properties across the eight archetypes in each study area

Table 15 Explanation of abbreviated archetype codes

House archetype code	Description
DH-G	Detached house, good wall insulation performance
DH-P	Detached house, poor wall insulation performance
SH-G	Semi-detached house, good wall insulation performance
SH-P	Semi-detached house, poor wall insulation performance
MT-G	Mid-terrace house, good wall insulation performance
MT-P	Mid-terrace house, poor wall insulation performance
FI-G	Flat, good wall insulation performance
FI-P	Flat, poor wall insulation performance

These archetypes will be taken forward to use in other work packages in the following ways:

- In WP3, each house archetype will be simulated in a building physics model to identify their heat demand profiles and heat loss factors during average winter and '1-in-20' peak winter conditions.
- For WP4, representative mixes of house archetypes will be combined with information on network typologies and heat pump uptake rates (from WP2) to allow their aggregate impact on network infrastructure to be identified under different temperature and flexibility scenarios.

Beyond this project, these archetypes could be applied to other areas of the WPD network with only minor adjustment. The EPC records or equivalent data source would need to be obtained to identify the building types and wall insulation for each property in the area to assign the correct proportion of the building stock to each archetype. To increase accuracy, it is also highly recommended that the secondary factor of heating system type is updated. There are a significant number of off gas areas in WPD's license area, and in these regions the mix of existing heating system types will vary dramatically compared to those considered in this project. As this parameter does not feed into the thermal demands and heat losses being calculated in WP3, the WP3 profiles will still be able to be applied.

