London Councils: Pathways Report

version 1.6
21th July 2021

ABOUT PARITY PROJECTS

Parity is an award-winning provider of environmental and energy solutions to the residential building sector. We help our customers identify the most effective ways to reduce the energy impact of their properties.

Our core services, Pathways and Portfolio, use our proprietary software to identify the most appropriate measures for properties based on building physics, market costs, and the clients' carbon and fuel poverty objectives.

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DOCUMENT HISTORY

This is version 1.6

Version	Author	Date	Notes
1.1	**CJN**	**14/02/21**	**Interim Report**
1.2	**CJN**	**19/02/21**	**Interim Report**
1.5	**CJN**	**14/05/21**	**Final Report**
1.6	**CJN**	**10/06/21**	**Final Report**

Distribution (all versions):

- London Councils
- Parity (internal)

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Glossary

ASHP	Air Source Heat Pump
EPC	Energy Performance Certificate
EI	Environmental Impact
FGHRS	Flue Gas Heat Recovery System
GSHP	Ground Source Heat Pump
LSOA	Lower Super Output Area
PCDF	Product Characteristics Data File (boiler database)
RdSAP	Reduced Data Standard Assessment Procedure
PV	Photovoltaic array
SAP	Standard Assessment Procedure
SAP Score	Energy Efficiency Rating (0-100 or G to A)
TRV	Thermostatic Radiator Valve

Disclaimer

The conclusions in this report are based on the data available. To be able to conduct the analysis, data may have had to be partially interpolated to fill gaps.

Section 7.3 'Data' has comments about the quality of the data on which the analysis is based, and we believe we have used best practice in the collation and analysis of this data. However, as the datasets are incomplete and not entirely verified, data collection will often reveal our estimates, including estimates of SAP rating, to be incorrect in some degree when compared with up to date and complete data collected through detailed property inspections. We believe that the approach taken by Parity has matched our briefing and has been pragmatic and appropriate given the current state of the housing data available. Throughout this report the results of our analysis should be seen as estimates.

As housing analysts we would suggest that even a complete and recent housing dataset, if large, cannot be guaranteed to be free from errors.

The report reflects Parity Projects modelling and results and do not in any way indicate any agreement by or acceptance from individual Boroughs, the GLA or London Councils.

1 Executive Summary

1.1.1 Report Aims

In 2019 London Councils issued its Joint Statement on Climate Change – agreed by London Councils' Transport and Environment Committee and the London Environment Directors' Network (LEDNet) – setting out seven pledges agreed by the London boroughs to drive action to address catastrophic climate change. Among the seven pledges is a stretching target to achieve an average Energy Performance Certification (EPC) B rating across London's building stock by 2030.

Parity Projects were commissioned to provide the data modelling necessary to inform the development of a pan-London action plan for achieving the average EPC B rating. The project is led by London Councils and the London Housing Directors' Group, and further supported by funding from the Greater London Authority and LEDNet.

The following project aims have been addressed by this report:

- Energy profiling of the housing stock in London across various metrics including SAP (or EPC) score, Environmental Impact (EI), fuel bills and CO_2 emissions. (*Sections 3.1 to 3.3*)
- Profiling the key characteristics of the London housing stock . (*Sections 3.4 to 3.9)*
- Analysis of the measures that would be required, and associated costs to meet two investment scenario targets – Average EPC B and Net Zero. (*Sections 4.1 to 4.2.7* & *4.4.1 to 4.4.9*)
- Analysis of the properties that will be difficult to reach the investment scenario targets. (*Section 4.4.7*)
- Analysis of the supply chain requirements to reach the investment scenario targets. (*Sections 4.3* & *4.5*)

It is designed to be a summary of the information provided through the subscription as opposed to a consultancy document. As such you will find that the report is fact based rather than expressing opinions or recommendations which will be provided by the subsequent project - *Expert consultancy support in developing a pan-London home retrofit action plan.*

1.1.2 Pathways Subscription

As above, this report summarises the investment scenario analysis provided to London Councils and focuses on presenting the answers to the initial questions posed.

The detail of the data held within the Pathways system allows for ongoing interrogation of the analysis and results to answer follow up questions that this initial work raises. Training will be provided to relevant Local Authority staff to allow them to do this over the software licence period.

1.2 REPORT STRUCTURE

We present a summary of the RdSAP dataset we have produced for all domestic properties. This complete dataset allows us to report on the baseline characteristics of the housing stock ("Baseline Analytics"). It is then used to model and analyse investment Pathways that will achieve an average SAP B ("Interim Target"), and Net Zero CO_2 using BEIS 2038 emissions figures ("Net Zero"). The Net Zero scenario is focused on decreasing CO_2 emissions rather than improving SAP score but also achieves an average SAP B. We explain the choice of BEIS 2038 figures in Section 4.1.1. We also provide insights into the potential employment opportunities the investment scenarios provide.

The structure of this report is organised into four sections. The first two focus on the current position of the London housing stock (see Section 1.3 for a summary) and the second two on the analysis to reach the two targets (see Section 1.4 for a summary).

- **BASELINE ANALYTICS**: Provide an estimate of various common characteristics e.g. inter alia, CO_2, estimated fuel bills, SAP score *(section 3 pages 13-28)*
- **OPPORTUNITY MAPPING**: Map a number of key opportunities by Lower Super Output Area *(section 3.9 pages 29-38)*
- **PATHWAYS**: Present an analysis of the most cost-effective application of these Measures to meet two targets (*section* 4 *pages 39-48*)
- **TRADES ANALYSIS**: For each of the Pathways, present information on the potential trades that would be required to carry out the measures identified. (*section* 4.3 *pages* 51-55 and *section* 4.5 *pages 66-68*)

Throughout the report we provide charts and graphs to display results. Where these are viewed on a smaller screen and/or zooming is not possible, then larger versions have been provided in Section 8 Appendix A.

1.3 BASELINE SUMMARY

This section sets out the average performance of Greater London properties. The reality is that there is a wide range, and this is explored in more detail in *section 3 pages 13-28*.

Figure 1

1.3.1 SAP (and EI) baseline

We estimate the average SAP score in 2020 is **62.83** (EPC Band D) and the EI score is **58.91** (Band D). The EI score is the CO_2 equivalent of the SAP score which is based on fuel bill.

1.3.2 CO_2 baseline

We estimate the average CO_2 emissions per property for primary energy use is **3.28tCO_2** using figures for 2019. In section 3.1.1 we show what this baseline figure would be expected to be using BEIS projections of the grid intensity in future years.

1.3.3 Fuel Bill baseline

We estimate that the average annual fuel bill is **£832**. Throughout the report our fuel bills, as well as all other figures, are for regulated energy use i.e. this excludes appliances and cooking. Please see Section 6 for a note on regulated and unregulated energy.

1.4 PATHWAYS SUMMARY

Our Pathways test all relevant measures in combination for every property to find the most cost-effective route to our clients' targets. Those are a less stretching carbon reduction scenario (referred to as the 'interim target' in this report) and a further net zero scenario - both of which, due to the way in which EPC ratings are calculated based on household energy costs, achieve an average EPC B across the London housing stock. We outline the rationale behind the two modelled Pathways, how they have been set them up, and detailed results in Section 44.2 pp.39-63. Below we present the headline findings.

1.4.1 Interim Target

We have modelled the cost and impact of a multi-pronged approach – 30% with measures aiming for Net Zero, 20% with reasonably deep fabric measures and 50% with typical current measures but excluding new gas connections. The following give some headline figures from the analysis.

TOTAL COST (LABOUR & MATERIALS):	£49.296 BILLION
AVERAGE COST PER RESIDENTIAL PROPERTY AFFECTED:	£13,000
MEAN TONNES OF CO_2 (2038) PER PROPERTY FOLLOWING INVESTMENT:	1.44 TONNES

TRADES ANALYSIS: AVERAGE OF 40,900 FULL TIME EQUIVALENT JOBS PER YEAR (2021-2030)

1.4.2 Net Zero

We have modelled the cost and impact of aiming for Net Zero for every property in the boroughs. The following give some headline figures from the analysis.

TOTAL COST (LABOUR & MATERIALS):	£97.957 BILLION
AVERAGE COST PER RESIDENTIAL PROPERTY AFFECTED:	£25,900
MEAN TONNES OF CO_2 (2038) PER PROPERTY FOLLOWING INVESTMENT:	0.09 TONNES

TRADES ANALYSIS: AVERAGE OF 72,723 FULL TIME EQUIVALENT JOBS PER YEAR (2021-2030)

2 Introduction

This report is a brief overview of the analysis conducted of domestic housing in the 32 London Boroughs and the City of London. Parity has used *Pathways* to model the energy use and CO_2 emissions of the housing stock.

The report is broken down into the following sections:

- **BASELINE ANALYTICS:**
  Present the key metrics for housing
  We have used a combination of multiple data sources and interpolation to generate baseline data on every property in the borough.
  This is presented in section 3 pp.13-28

- **OPPORTUNITY MAPPING:**
  Identify, map and evaluate potential for energy, SAP and CO_2 savings, together with fuel poverty and flood risks, to identify target areas in the Boroughs.
  This is presented in section 3.9 pp.29-38

- **PATHWAYS**:
  Present an analysis of the most cost-effective measures that aim for a) the Interim Target and b) separately to achieve Net Zero CO_2 emissions for each property using BEIS CO_2 grid intensity figures predicted by 2038.
  This is presented in section 44.2 pp.39-63

- **TRADES ANALYSIS**: For each of the Pathways, present information on the potential trades that would be required to carry out the measures identified.
  This is presented in section 4.3 pp.52-55 & section 4.5 pp.66-68

  Pathways generates a range of charts and maps to help identify and communicate patterns in the data.

The detail behind the report from the property level up can be investigated at pathways.parityprojects.com and is available for the duration of the ongoing Pathways licence procured for most London Boroughs as part of this work – contact chris.newman@parityprojects.com for more information.

3 Baseline Analytics

We use the term Baseline to refer to the current state of the housing stock. This section provides kits of information about the current performance – SAP, CO_2, fuel bills etc – as well as details about the characteristics of the housing stock across London – fabric and heating systems, tenure, maps etc.

Below we present this through a variety of charts and graphs to highlight the characteristics and performance of the housing stock across all the Boroughs, as well as some commentary of points to note.

The Pathways analysis has been conducted on all 3,781,477 properties in the 32 Boroughs and the City of London.

3.1 SAP AND EI

3.1.1 SAP Score & Profiling

The SAP score (or EPC score) is a standard measure for housing in the UK and reflects the primary fuel bills proportional to the floor area.

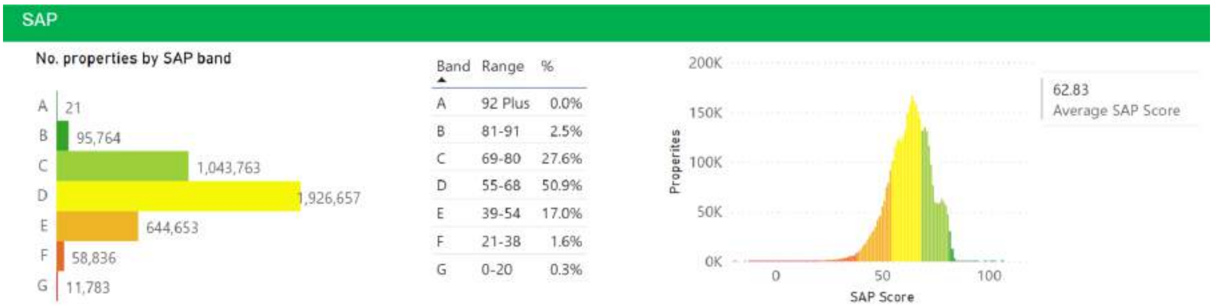


Figure 2

We estimate that an average SAP score for domestic housing in London is **62.83** (EPC D). This is based on our calculated SAP scores for every property; around 45% of properties have had some lodged EPC information provided from the Open EPC data and the remaining have required some cloning. See Section 5 page 69 for more information.

The long tail is typical of SAP profile charts.

The figures show that only 2.5% are EPC B or above. We expect this to be a slight underestimate as from the data available it is hard to model very high rated properties as these require, for example, exact information about makes and models of heating systems, which is not available. However, by the nature of these properties being very efficient they are not of great concern in the modelling of the Pathways as they will either be above the Band B target or will have a heating system improved under the Net Zero scenario.

For a few of the key property characteristics throughout the report we break out the figures by tenure. In Table 1 we have done this for SAP score to show that social housing is the best performing.

Table 1 Average SAP Score by Tenure

Socially Rented (8%)	Privately Rented (13%)	Owner Occupied (20%)	Unknown (59%)
66.52 (Band D)	63.28 (D)	60.63 (D)	62.96 (D)

3.1.2 EI Score & Profiling

The Environmental Index is like the SAP score but reflects CO_2 emissions proportional to floor area. It is an underused metric, with people preferring to measure absolute CO_2 emissions. However, we believe it is a metric that has many benefits over absolute CO_2 as it takes property size into account.

For mains gas heated properties, the EI score closely mirrors the SAP score. For other fuels they may vary – biomass will tend to have higher SAP scores compared to EI scores for instance. LPG has the opposite relationship i.e. a lower SAP compared to EI score.

Figure 3

We estimate an average EI score for domestic housing to be **58.61**.

3.1.3 SAP & EI score by Property Type

Although the SAP and EI scores take the relative size of a property into account, both scores still vary by property type due to the relative amounts of fabric proportions e.g. many flats will not have roofs unless they are top floor. The chart below shows the average SAP and EI scores by property type.

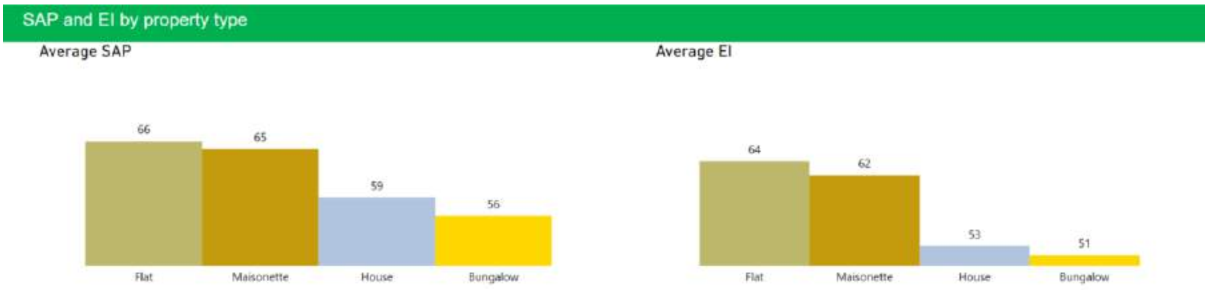


Figure 4

Bungalows are the lowest performing and flats are the highest – all other things being equal this reflects their ratio of heat loss surfaces to volume.

3.2 CO_2

3.2.1 CO_2 Baseline

Our standard measure of CO_2 uses the carbon factors for SAP10 which is based on 2019 figures. Unless stated otherwise this is used in our charts. The chart on the right below shows how the grid intensity (i.e. electricity) is predicted by BEIS to decrease over time. The reduction from SAP 2012 to SAP 10 is partially due to the reduction in coal for electricity and the increase in large scale renewables.

Figure 5

We estimate the average tCO_2 per property to currently be 3.63 tonnes, and if nothing were to change other than the grid decarbonising, this would reduce to 3.37 tonnes by 2038.

Table 2 breaks out the CO_2 figures by tenure and shows that Owner Occupied tend to have the highest emissions and Socially Rented the lowest. This will be a combination of their efficiency (see Table 1) and their size. The bottom figure for each shows the highest amount after the top 5% outliers are removed and shows that Owner Occupied have the highest spread. These figures allow you to state, for example, that the average Owner Occupied house produces around 4tonnes of CO_2 and very few produce more than 8 tonnes.

Table 2 $C0_2$ Per Property by Tenure

Socially Rented (8%)	Privately Rented (13%)	Owner Occupied (20%)	Unknown (59%)
2.36 Average tCO2 in 2019	2.80 Average tCO2 in 2019	3.88 Average tCO2 in 2019	3.31 Average tCO2 in 2019
2.14 Average tCO2 in 2038	2.49 Average tCO2 in 2038	3.60 Average tCO2 in 2038	3.04 Average tCO2 in 2038
4.38 Figure 95% are below	5.87 Figure 95% are below	8.07 Figure 95% are below	7.31 Figure 95% are below

3.2.2 CO_2 Segmentation

Here we show how CO_2 varies by characteristics in terms of total number of properties and average carbon emissions for the characteristic.

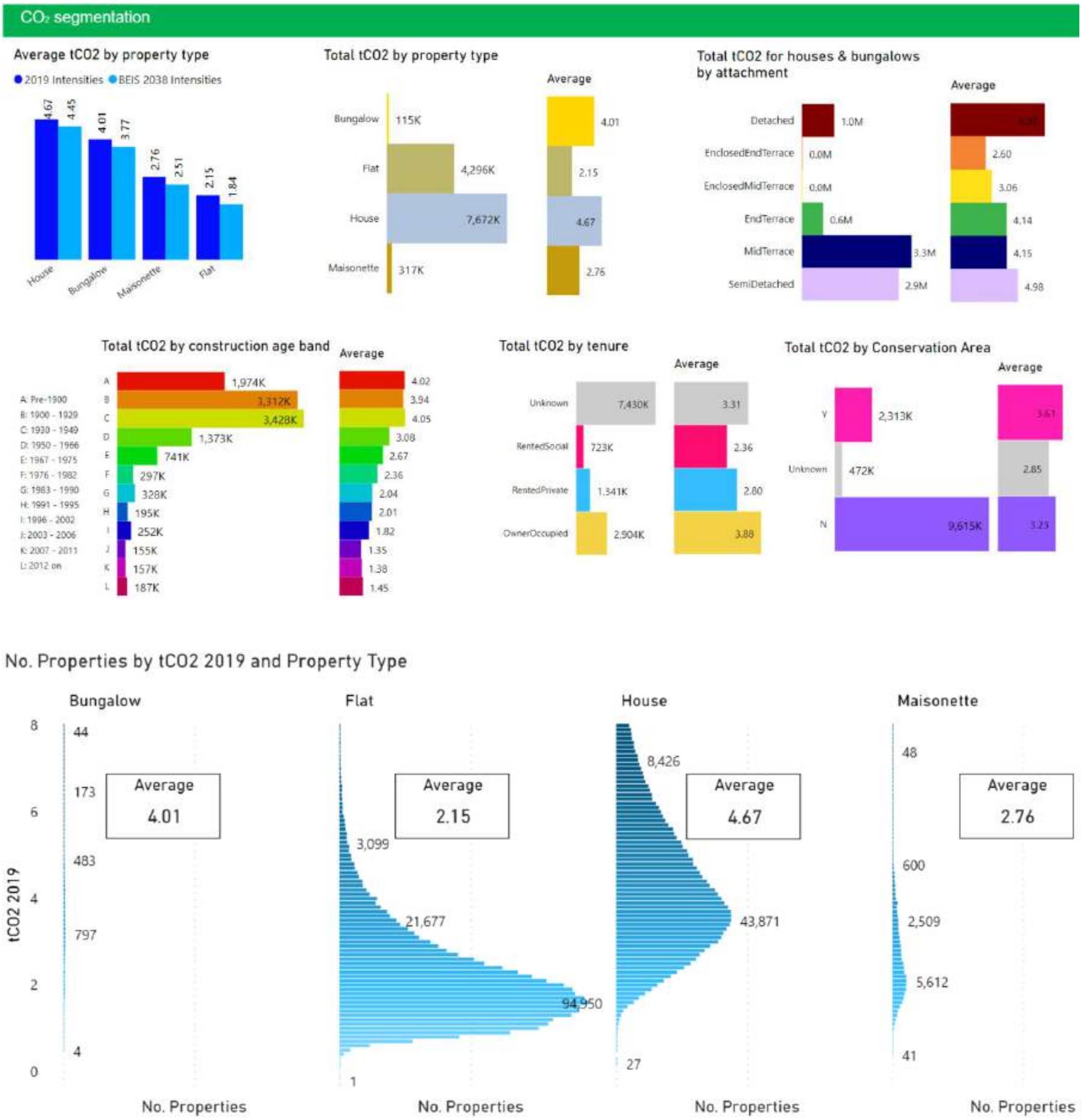


Figure 6

Some key observations:

- Average house emissions are more than double flats, and just under double in total emissions;
- Detached houses have by far the highest average CO_2 emissions;
- Properties built before 1930 tend to have double the emissions of those built after 1983 – this may partially reflect more flats in more recent times;
- Properties in Conservation Areas tend to have higher emissions – probably a combination of size and age.

3.3 OTHER KEY METRICS

3.3.1 Fuel Bills & kWh/m2

Some other useful statistics relate to fuel bills and kWh/m². kWh/m² is agnostic to the CO_2 intensity and price of the current heating source and so is a good measure of the efficiency of the building fabric – it is for this reason we have used a target of 65kWh/m2 heat demand in some of the steps of our Pathways in section 4.

The charts both highlight the long tails i.e. whilst 95% of fuel bills are below £1,455, the top 5% can be many thousands more than this.

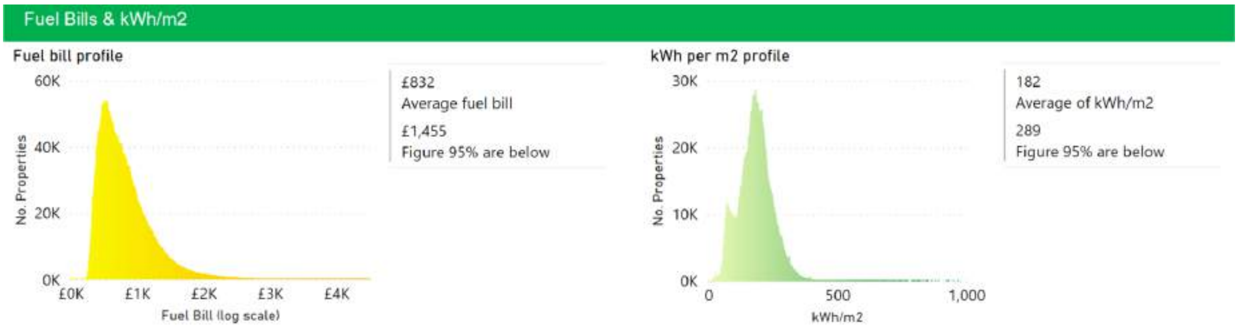


Figure 7

3.4 HOUSING PROFILING - FABRIC

3.4.1 Property Age & Tenure

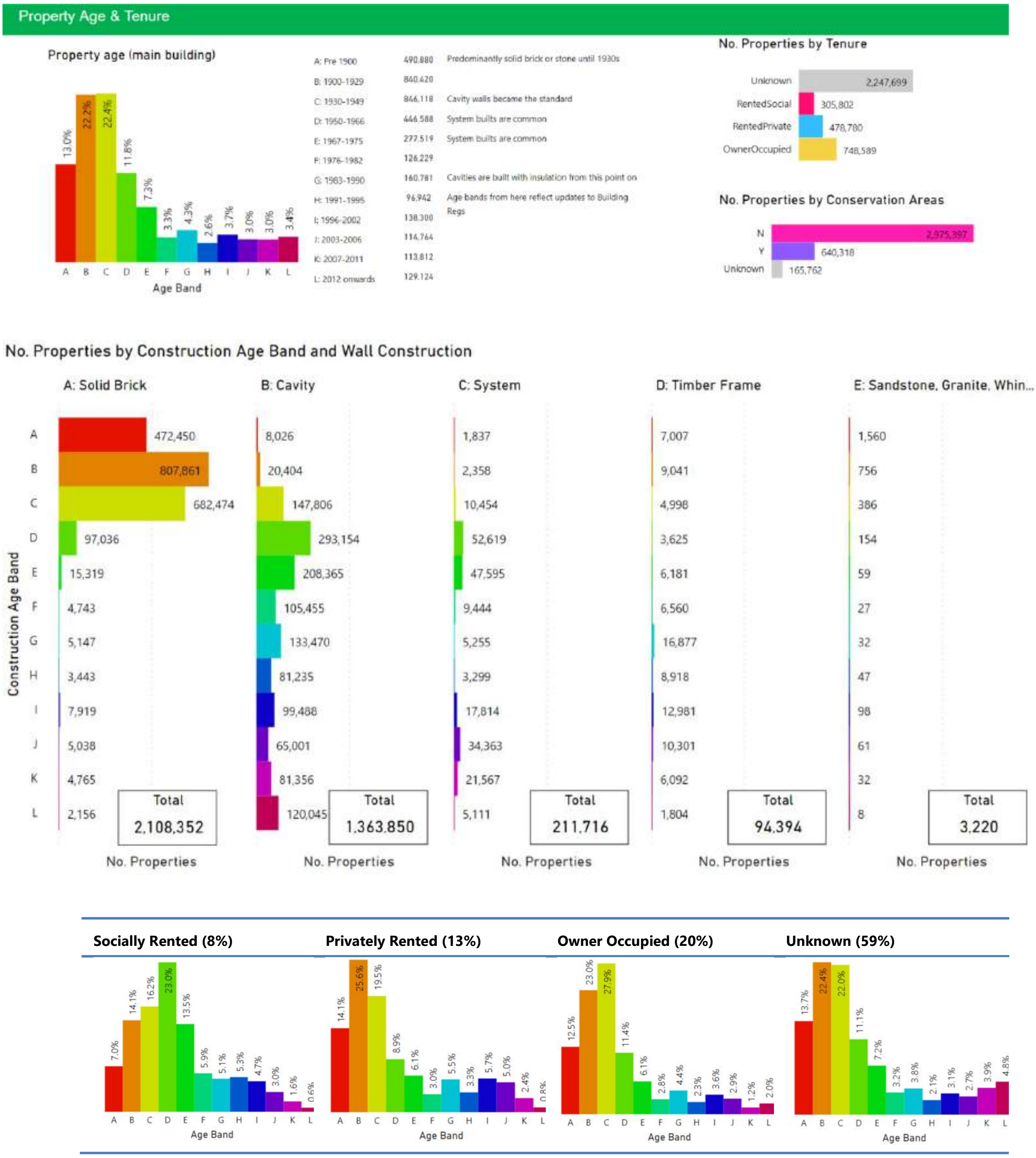


Figure 8

The most common construction periods were before 1949 when around 58% of properties were built. Only around 9% of the properties have been built since 2003.

3.4.2 Tenure

We are reliant on the tenure field from the Open EPC dataset for an indication of tenure. This data covers under 50% of properties. It further relies on the EPC surveyor completing it accurately and that nothing has changed since the EPC was produced.

We have decided not to clone out the tenure, as although social housing is often concentrated in estates this is far from always the situation. This means that for properties where there is no indication of tenure we have marked them as 'Unknown' with regard to tenure. The various charts, as well as logic, indicates that Unknown has a higher degree of Owner Occupied as they will usually have only required EPCs if the property has changed hands, but there will also be some longer term socially rented and longer term privately rented properties.

Based on the above we believe that our ability to model Tenure is still useful for understanding general differences but comes with caveats.

3.4.3 Conservation Areas

We have used Conservation Area maps to determine whether a property address is within or outside of a Conservation Area. There may be additional constraints in some areas if a property is close to but outside of a Conservation Area but visible from it. In our analysis these are marked as not being in a Conservation Area.

Conservation Areas will pose additional constraints regarding external wall insulation, photovoltaics (PV), solar thermal, air source heat pumps and windows, without some changes to many planning constraints.

3.4.4 Property Type

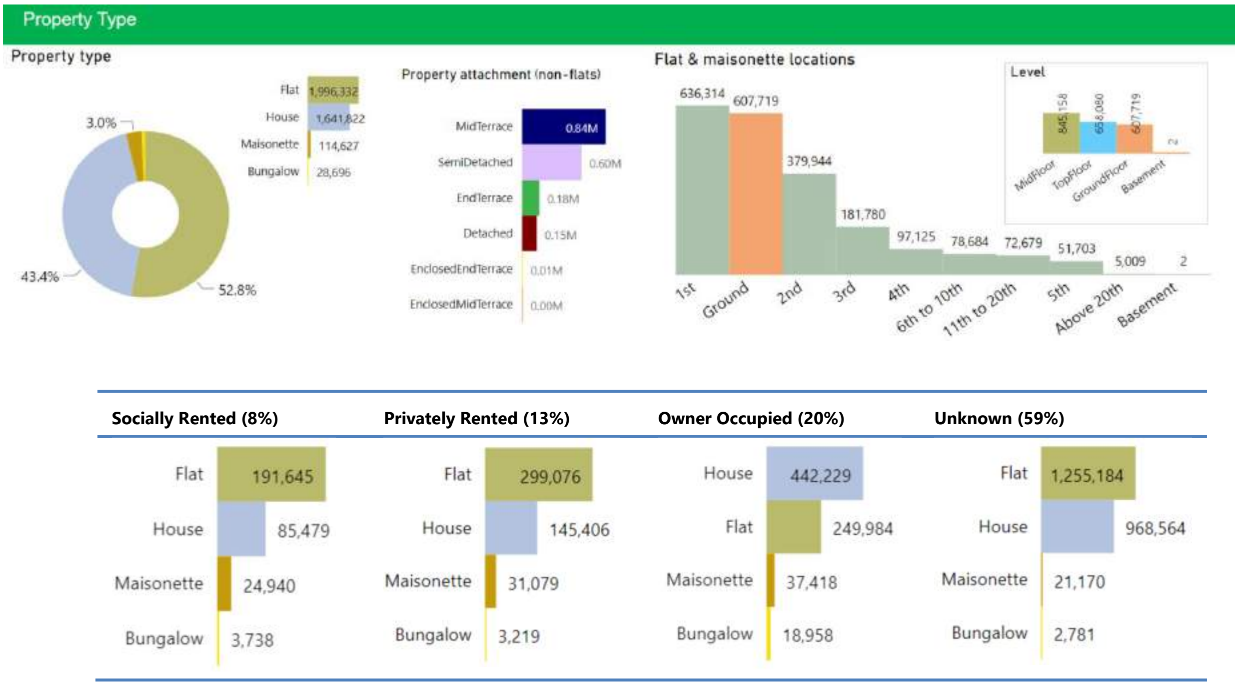
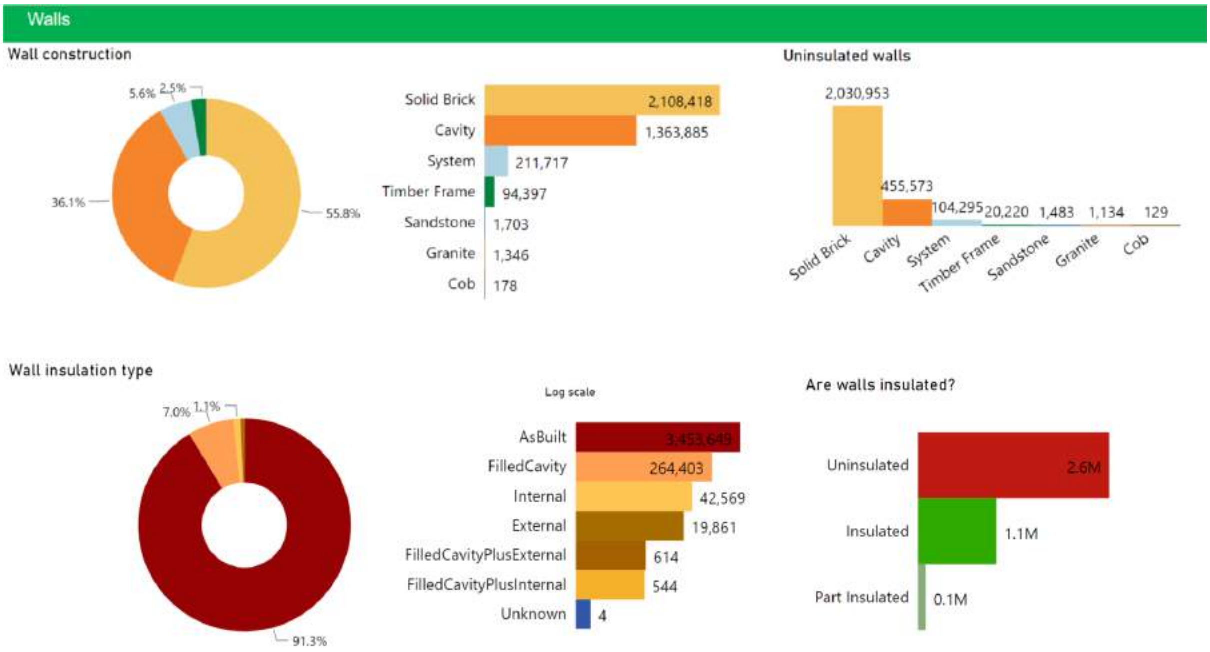


Figure 9

Flats and houses dominate and are roughly equal in number. Mid terrace houses dominate attachment type. Most flats are in low rise blocks or converted houses. There are more flats on first floors than ground floor as many premises have commercial units, plant rooms or communal space on the ground floor.

3.4.5 Walls



The topmost chart shows that solid brick walls dominate, and the bottom right indicates that most are expected to be uninsulated.

Solid walls are the dominant construction in all tenures other than social housing.

Figure 10

3.4.6 Roofs

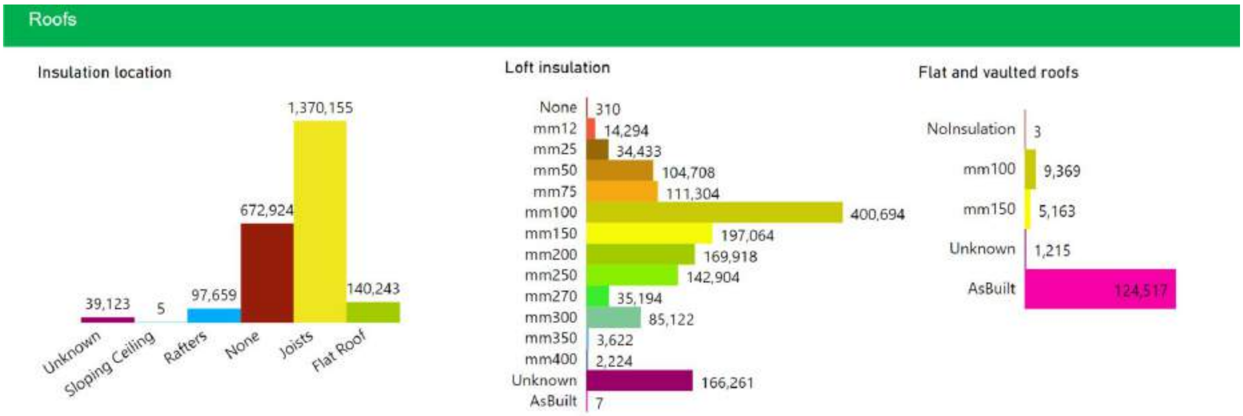


Figure 11

Pitched roofs dominate and there is a large range of expected insulation thicknesses. At least 270mm is the recommended level. Often the data available for secondary roofs is not available so the number of flat roofs is likely understated.

3.4.7 Floors

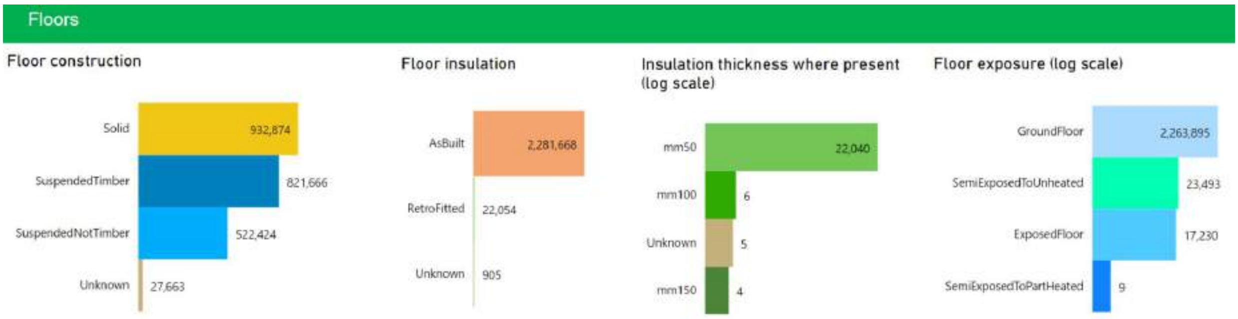


Figure 12

Floors are difficult to treat, especially solid floors, and so based on the age profile of the stock, it is expected that very few will be insulated. Those built after the mid-1980s should have some insulation from when they were constructed.

3.4.8 Windows

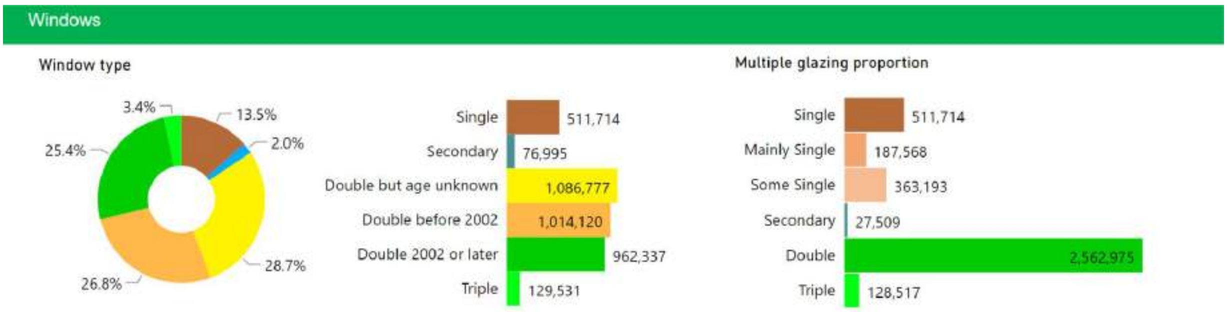


Figure 13

Most of the windows are double glazed with around 700,000 expected to still be fully or mostly single glazed ~ 18% of all properties. 205,000 are in Conservation Areas.

3.4.9 Doors & Draughtproofing

SAP methodology is reasonably weak on ventilation and infiltration. It considers draughts to some degree, from windows, doors and open chimneys. SAP also makes some assumptions based on building age, some fabric elements and location. From a practical point of view, a ventilation strategy should be considered whenever works are carried out on a building, especially when significant work that will affect infiltration are undertaken.

Figure 14

Doors and draughtproofing generally offer much more limited energy and carbon saving opportunities than other elements.

3.5 HOUSING PROFILING – HEATING & HOT WATER

3.5.1 Heating Systems

The heating system often has a major impact on the energy use and CO_2 emissions of a property, and can also be a relatively easy, if expensive, way to improve a property.

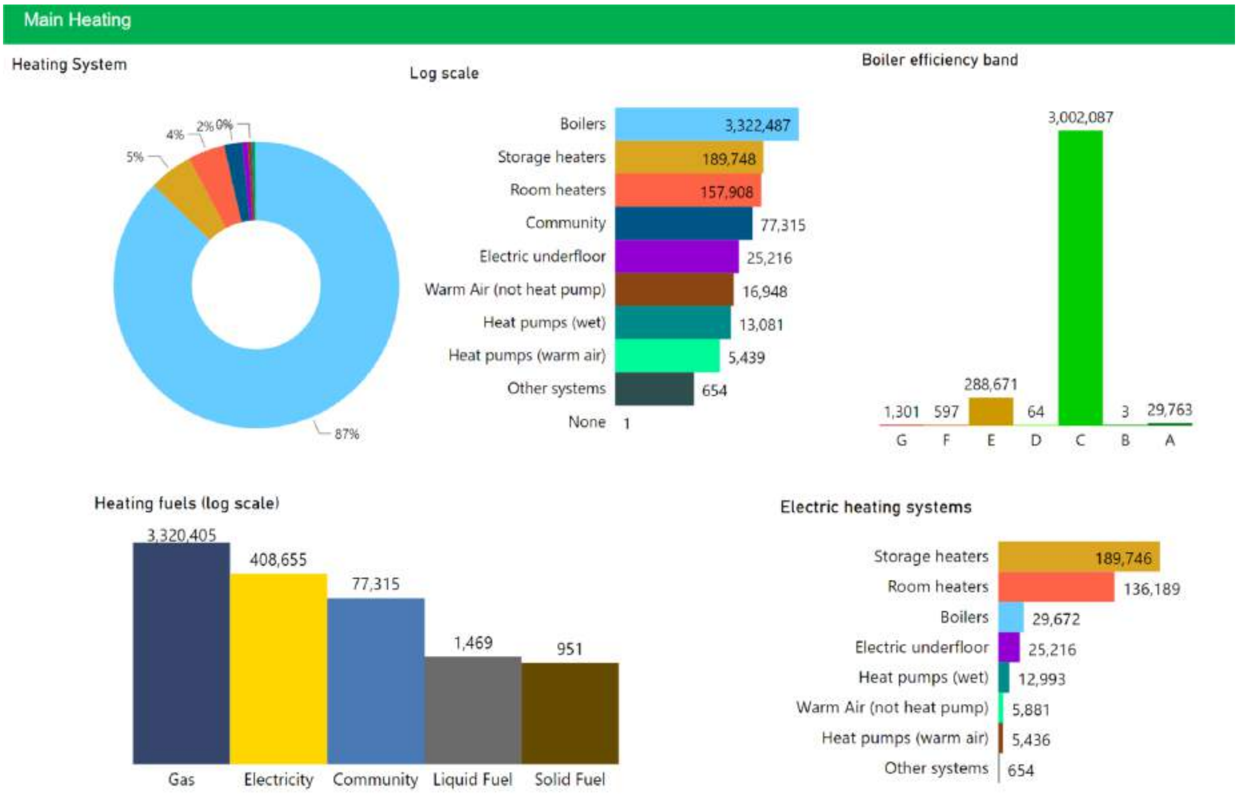


Figure 15

Mains gas with reasonable to good boilers dominate and generate significant carbon emissions. We expect there are more A and B rated boilers than the figures show but for a high rated boiler to be assigned we need the boiler make and model.

Electric storage heaters which would most likely be in flats are a distant second heat source.

3.5.2 Secondary Heating

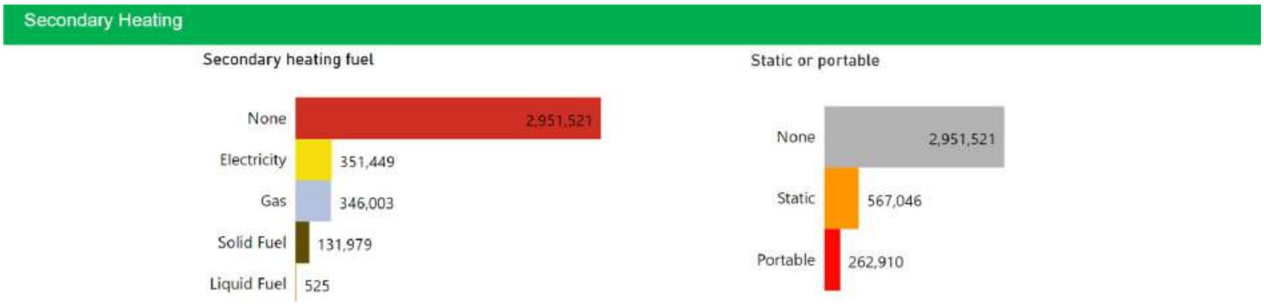


Figure 16

In many circumstances where there is a central heating system, secondary heaters are more of a lifestyle choice rather than a necessity.

3.5.3 Hot Water

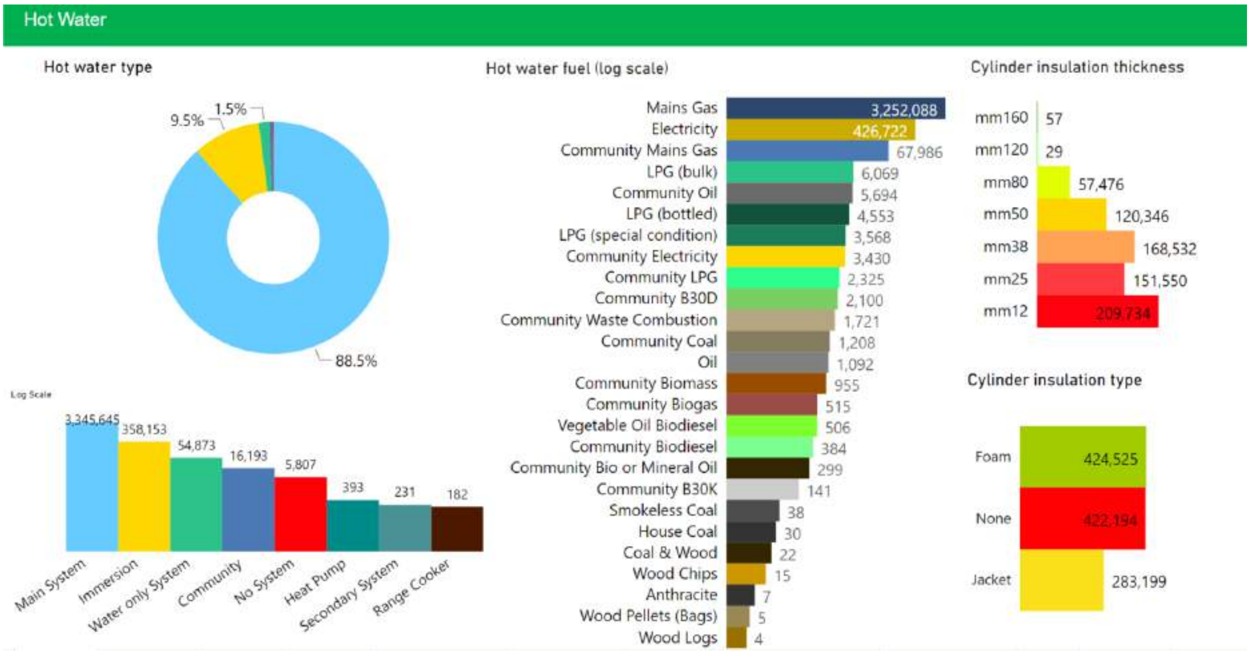


Figure 17

The same gas boilers providing the heating also dominate the provision of hot water. In other circumstances electric immersions tend to be the solution.

For hot water cylinders, foam insulation is better than a jacket, but greater than 50mm of either would be considered to be adequate.

3.6 RENEWABLES

3.6.1 Photovoltaics (PV)

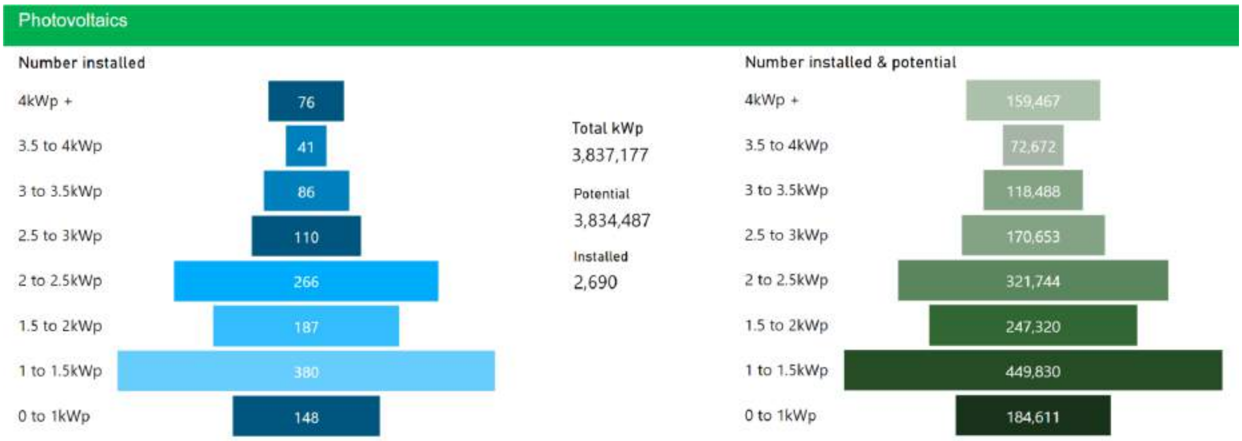


Figure 18

The left-hand chart indicates the number of installed PV systems that are known – in this case we expect this to be an underestimate as the information is not readily available for many installations. The right chart shows our analysis of the potential if all suitable roofs were utilised. A 10-panel system would be around 2.5kWp to 3kWp.

559MWh (14%) of the 3,834MWh of identified PV potential is in Conservation Areas.

3.7 FLOOD RISK

We have incorporated Open Government data to show how many properties are within given Flood Risk bands and their location. These categories represent current flood risk rather than future flood risk due to climate change e.g. sea level rise. For this reason they tend to be along river systems.

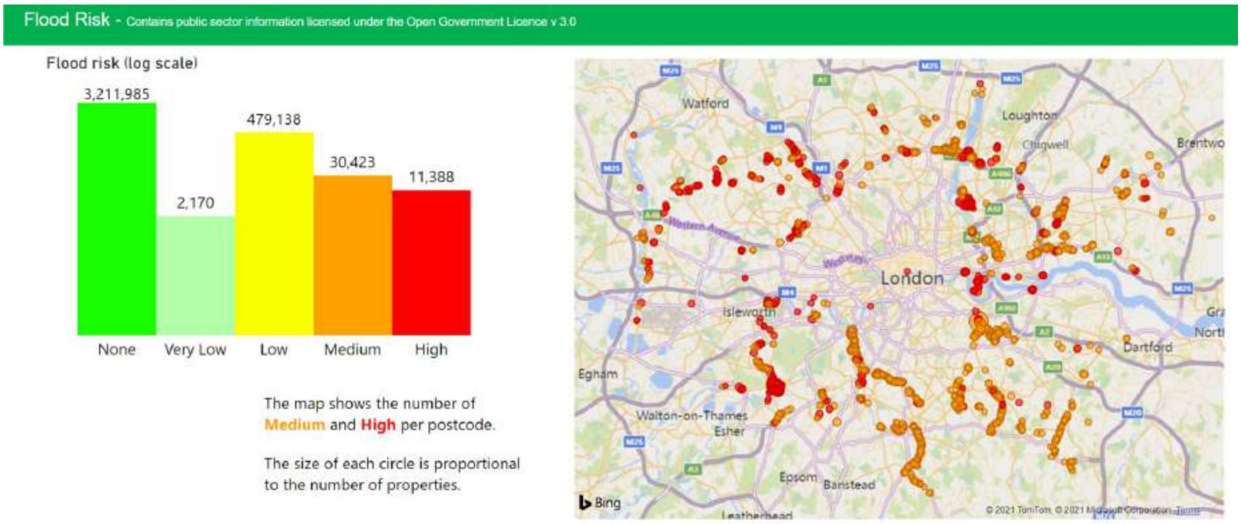


Figure 19

The figures indicate that only 11,388 properties are in high-risk postcodes and 30,423 in medium-risk. The map shows just the medium and high-risk postcodes.

3.8 FUEL POVERTY

Fuel poverty is extremely difficult to assess as it is both a factor of the energy efficiency of the property, as well as the income of the household. We do not have any information about the household incomes and so we show how many of the properties are in LSOAs with expected fuel poverty percentage rates – drawn from Government published data on the likelihood of fuel poverty in each LSOA based on national data from the English Housing Survey. The map below shows postcodes in LSOAs with a greater than 20% risk of fuel poverty.

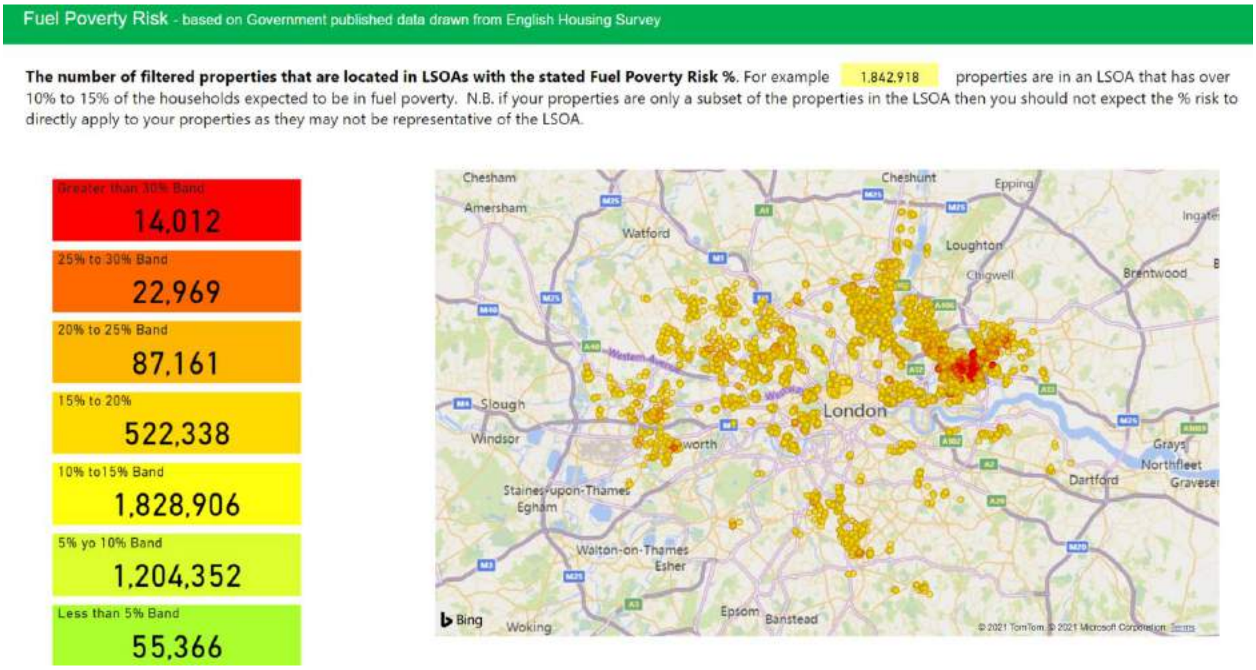


Figure 20

3.9 MAPS

An LSOA is a census area with a minimum population of 1,000 and maximum of 3,000, minimum number of households of 400 and maximum of 1,200.

In each of the maps below we show the results for the sub-regions. The numbers in the key below each map give the numbers per LSOA e.g. maximum F&G rated properties in one of the LSOAs, minimum average CO_2 per property in an LSOA etc.

3.9.1 EPC F&G rated properties by Sub Region

Figure 21 (Order: North, West, East, South West, South East)

Higher numbers of F&G properties per LSOA are in darker green

3.9.2 Average SAP by Sub Region

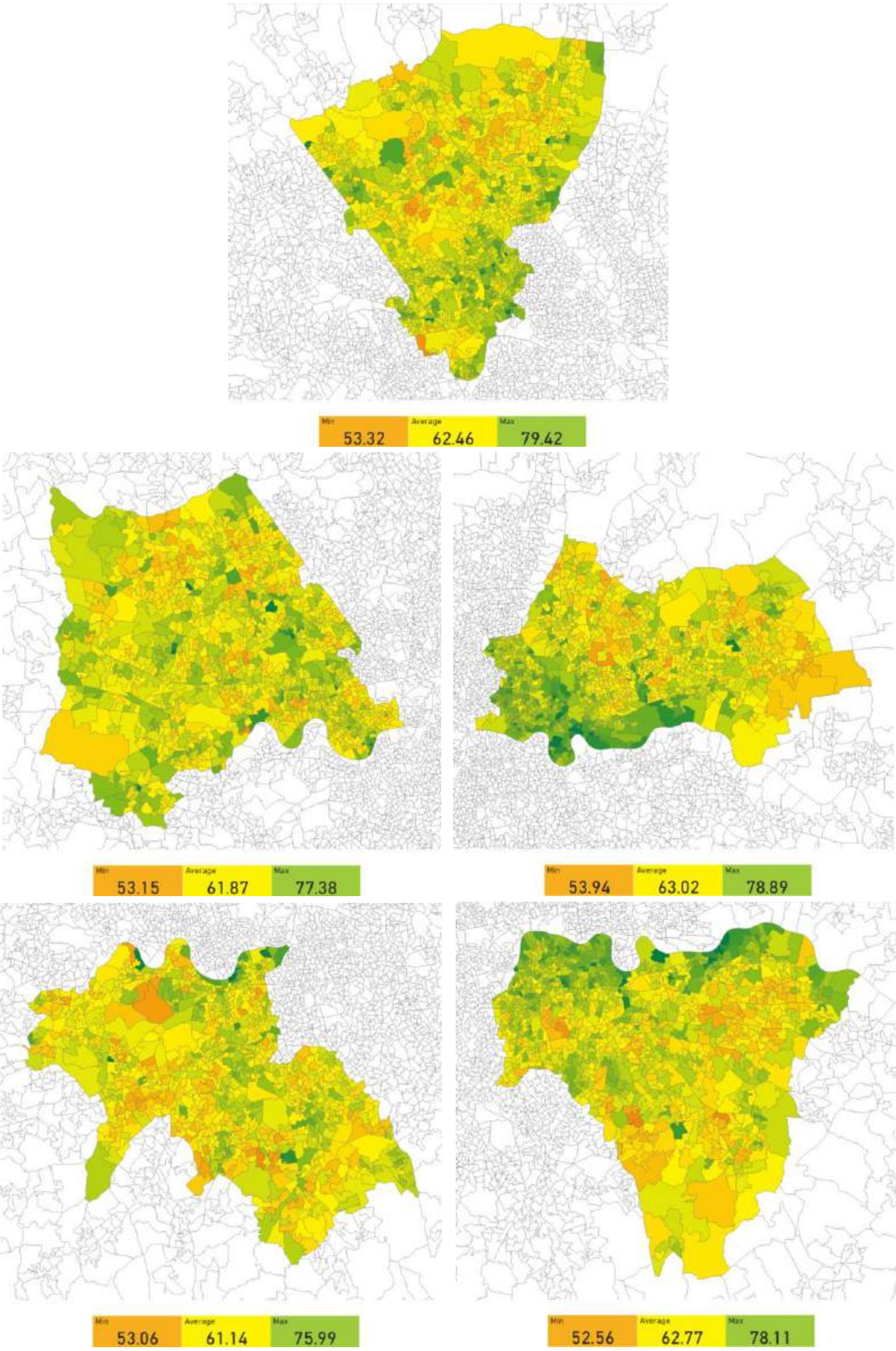


Figure 22 (Order: North, West, East, South West, South East)

Outer London tends to have higher average SAP scores. New build areas of Inner London have the highest averages.

3.9.3 Average CO_2 by Sub Region

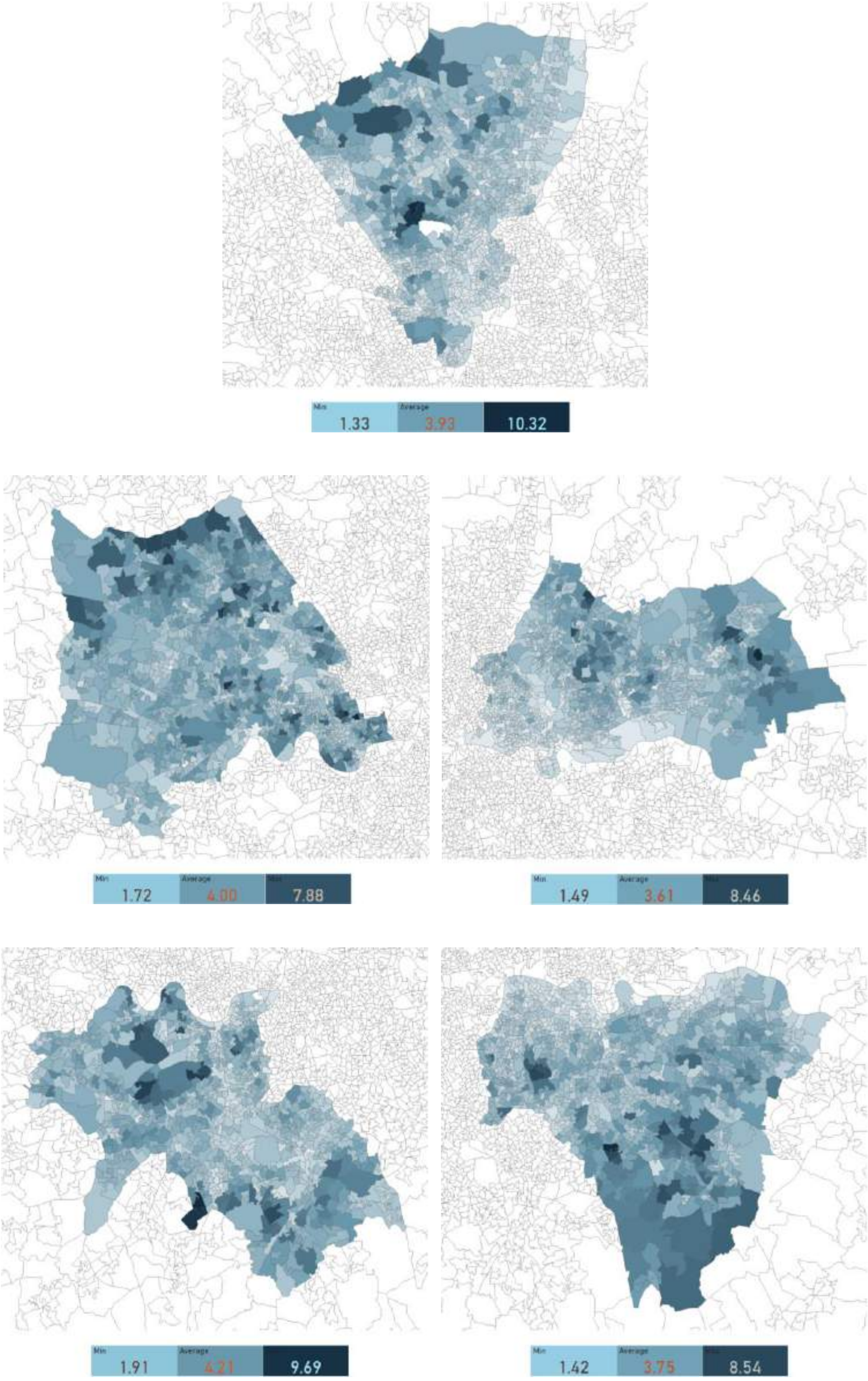


Figure 23 (Order: North, West, East, South West, South East)

Higher absolute CO_2 will be found in LSOAs with older and larger properties. All of the charts and those below use the same colour scales for all the sub-regions.

3.9.4 Average Fuel Bill by Sub Region

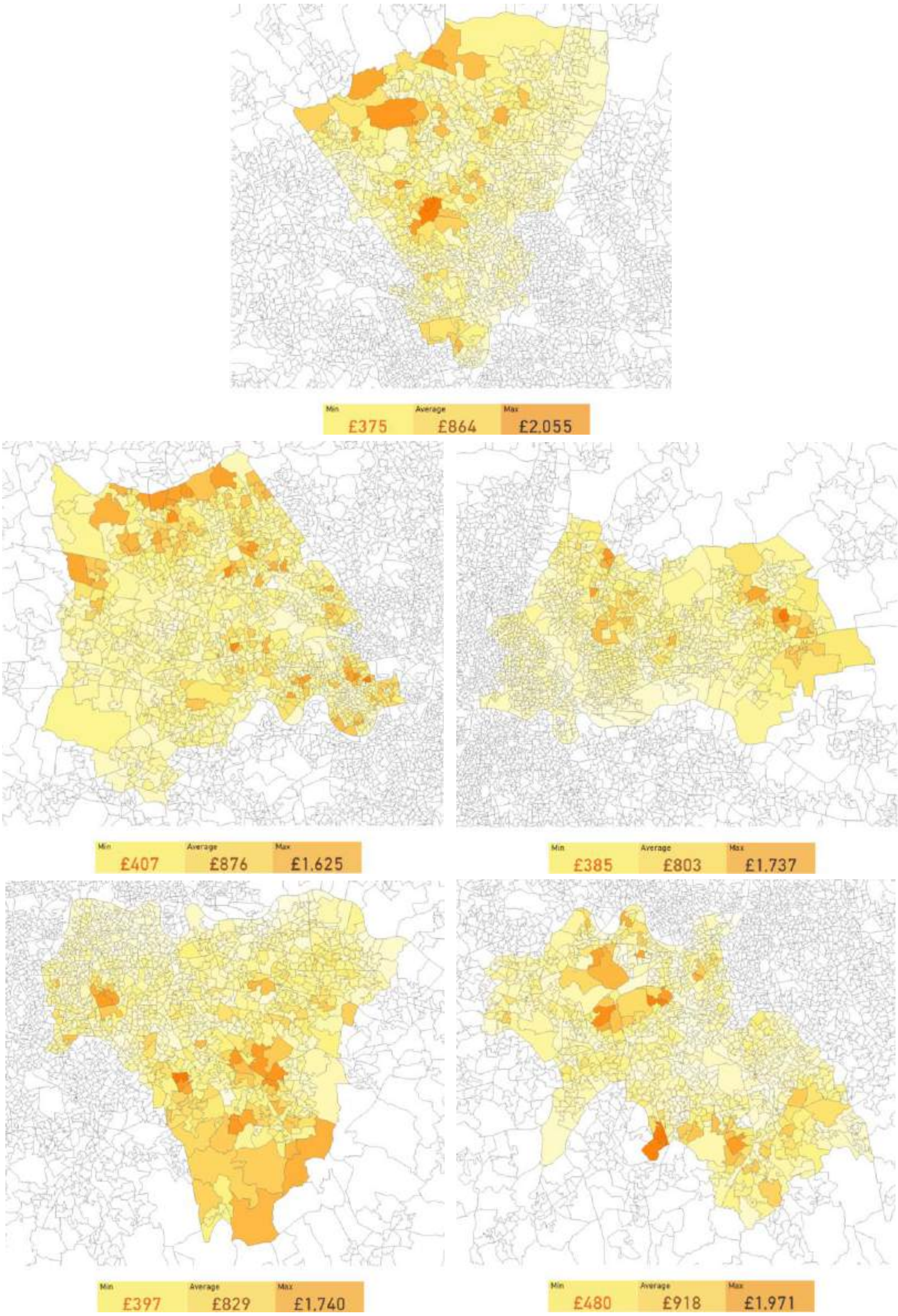


Figure 24 (Order: North, West, East, South West, South East)

Fuel bills have a similar pattern to the CO_2 map.

3.9.5 Average kWh/m² by Sub Region

Figure 25 (Order: North, West, East, South West, South East)

Slightly counterintuitively, kWh/m2 decreases with property size, all other things being equal.

3.9.6 Empty Cavities

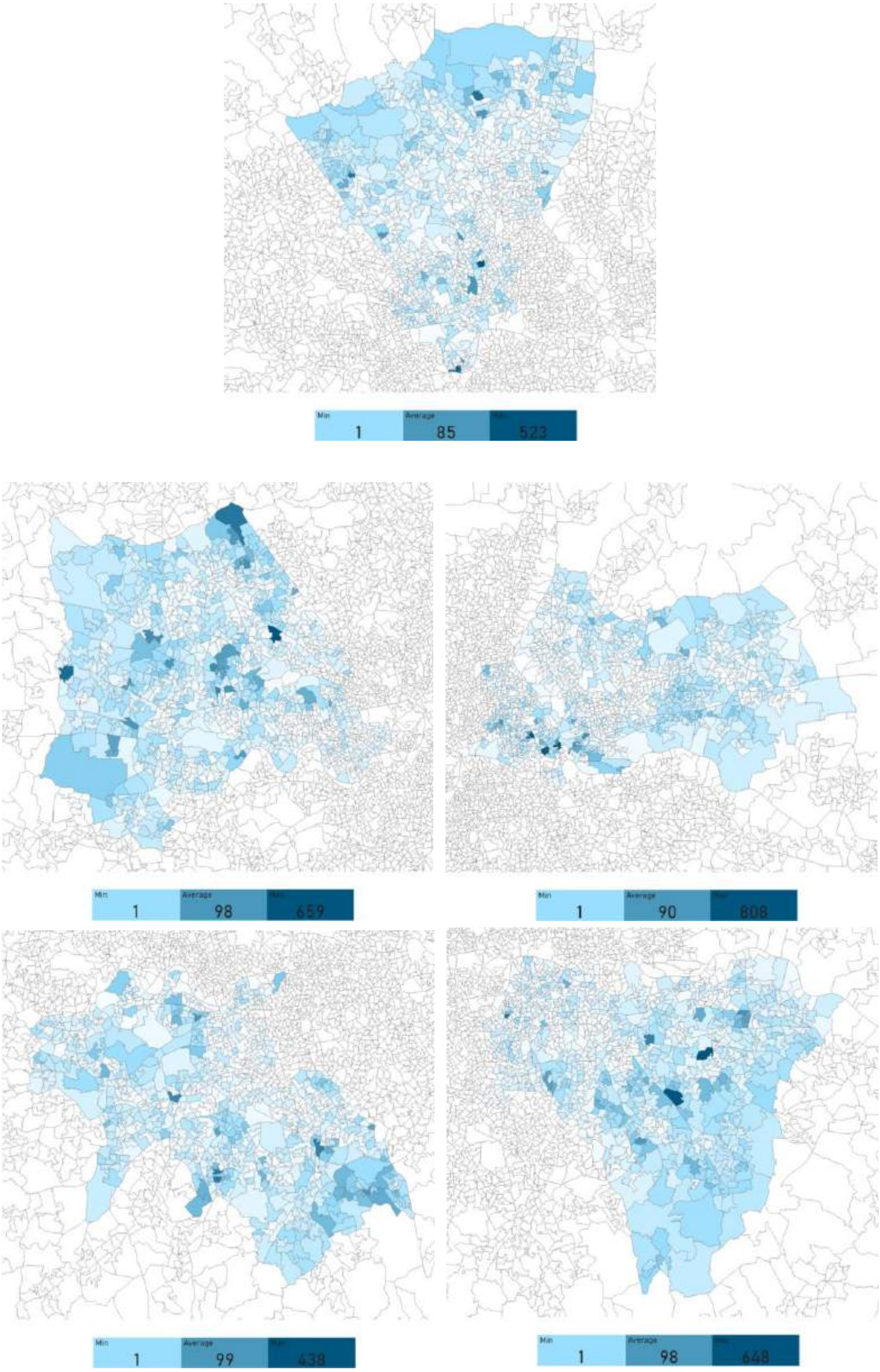


Figure 26 (Order: North, West, East, South West, South East)

Empty cavities will reflect the location of properties built between the 1930s and 1983.

3.9.7 Uninsulated Solid Walls by Sub Region

Figure 27 (Order: North, West, East, South West, South East)

The figures include solid brick, granite, sandstone and any cob walled properties.

3.9.8 Substandard Loft Insulation by Sub Region

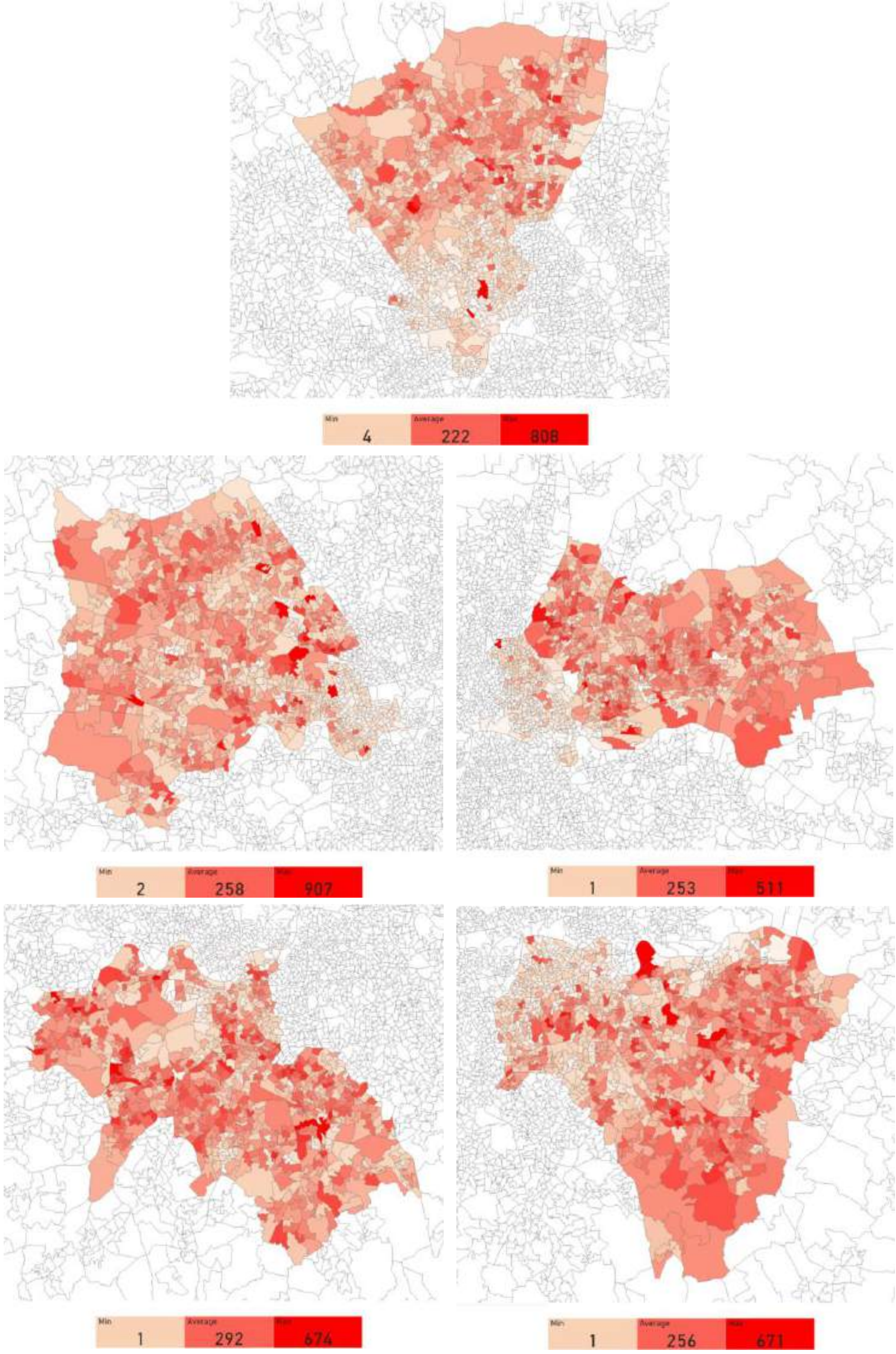


Figure 28 (Order: North, West, East, South West, South East)

The map shows loft insulation marked as 100mm or below, none or unknown. The lower proportion of flats in inner London is reflected in the maps.

3.9.9 Off Gas Properties by Sub Region

Figure 29 (Order: North, West, East, South West, South East)

The figures exclude mains gas or community heated properties. Off gas properties are concentrated in inner London where there will be more electrically heated properties in higher rise and private rental properties, and more rural areas where there will be a mixture of fuels.

4 Pathways

4.1 PATHWAYS SUMMARY

A Pathway is our term for a modelled investment scenario. This section provides summary results of the Pathways that we have modelled across all London properties – costs and impacts and maps of the Pathways well as measures and trades required to fulfil the scenarios.

The modelling involves specifying several variables which are then applied to each property to determine a cost-effective list of measures aiming for a chosen target. The results can be viewed from the property level through various portfolios (e.g. filtered by property type, characteristic, age or area), up to the whole stock level. For this report we have considered two Pathways: 'Interim Target' and aim for 'Net Zero' CO_2.

4.1.1 Grid Carbon intensity for 2038

BEIS produces figures for the expected CO_2 intensity of the grid for various dates into the future. Our modelling can use any of these projected grid intensities to determine which measures are most cost effective in terms of investment per $kgCO_2$ saved. The further into the future, the more the grid is expected to be decarbonised – with the effect that some measures become relatively more cost effective at reducing CO_2 (e.g. CO_2) and others less so (e.g. PV). In discussion with the project team, we decided not to use current grid intensities, as the results would almost immediately be out of date. We also decided not to use 2050 figures; as the grid is expected to be largely decarbonised, the modelling starts prioritising on-peak electric heating and no fabric measures - an approach that will not be sensible until near 2050.

We have therefore chosen the figures for 2038, as they take account of significant further decarbonization of the grid, but not so much as to make the measures selected irrational. Furthermore, we also chose this over 2030, as this will mean the modelled results will still be sensible for many years following the initial target date.

4.1.2 Rationale for Pathway 1: Interim Target

This Pathway has been primarily designed to meet the objective of getting the housing stock to an Average SAP B. The nature of an average score target means that there can be a myriad of underlying scores, and as such there are an infinite number of theoretical ways to achieve the target. At the project inception, additional analysis and discussions were held to agree an approach that would achieve the target, whilst also taking into account both practical considerations (e.g. phasing).

Several additional Pathways were run on a sample of data to give an understanding of varying different approaches on the overall cost, the impact on SAP score and the impact on CO_2 emissions. Please see Section 9 (Appendix B) for an overview of this research. The aim was to determine an approach that would minimally achieve the average B target. The approach was agreed by the project team and in consultation with borough officers through the home retrofit task and finish group.

The approach was to randomly assign each property to one of three groups – Group 1 covering 20% of properties, Group 2 covering 30% of properties and Group 3 covering 50% of properties. The groupings were applied at the Borough level i.e. each Borough will have the same proportional split between the groupings.

Group 1 was then modelled with the application of fabric measures only, with a target of 65kWh/m2 heat demand. The theory for this cohort is to make them 'heat pump ready' i.e. taking them part of the way on their journey to Net Zero.

Group 2 was modelled the same as Group 1, which subsequently had heating systems changed to either individual or community heat pumps, with any applicable PV installed. The theory for this cohort is to take them all the way on their Net Zero journey.

Group 3 was modelled with a target of SAP 75 but did not consider new gas installations i.e. no new connections but allowed replacements where applicable, or solid wall insulation. The theory for this cohort was to reflect a general improvement to the remaining housing stock considering measures that are currently common (i.e. business as usual for half the properties in London).

4.1.3 Pathway 1: Setup

Pathway 1: Interim Target

Steps	Target	Measures Considered	Measures Excluded
1	65 kWh/m^2 heat demand Groups 1&2: 50% of properties	Deeper fabric measures	Heating measures Renewables
2	Zero CO_2 using 2038 grid intensities Group 2: 30% of properties	Heat pumps, Community heat pumps, PV	Fabric measures
3	SAP 75 Group 3: 50% of properties	Boiler replacements Cavity wall, loft and floor insulation Glazing upgrades PV on roof in non-Conservation Areas Solar thermal in non-Conservation Areas	Solid wall insulation New gas connections

4.1.4 Rationale for Pathway 2: Net Zero

This Pathway has been designed to meet the objective of getting the housing stock to as close to Net Zero CO_2 emissions as possible. As for Pathway 1 it also achieves an average SAP B. Again, we carried out additional Pathways analysis on a sample of properties to determine a modelling approach that allowed for results that were as close to Net Zero as possible without the overall costs increasing exponentially. The approach was agreed by the project team and in consultation with borough officers through the home retrofit task and finish group.

Slightly different from Pathway 1, all properties were analysed with the same 2 steps and measures, an initial fabric target of 65kWh/m2 for heat demand, followed by heat pumps, community heat pumps and PV aiming for Net Zero. To get close to Net Zero, PV has been considered both in Conservation Areas as well as small systems on vertical walls.

4.1.5 Pathway 2: Setup

Pathway 2: Net Zero

Step	Target	Measures Considered	Measures Excluded
1	65 kWh/m2 heat demand	Deeper fabric measures	Heating measures Renewables
2	Zero CO_2 using 2038 grid intensities	Heat pumps, Community heat pumps, PV	Fabric measures

4.1.6 Impacts of the Pathways

Below we compare the relative impacts of the two Pathways with each other. The total investment and average investment per property is almost twice as large for the Net Zero scenario. Although across London the Interim Target scenario falls marginally short of Average B, this varies from Borough to Borough with some achieving it and some not - see Table 3. We outline below how targets could be flexed per borough to reach Average B. The Net Zero Target achieves a mid B average whilst also reducing the Net average CO_2 to 90kg per year per property using 2038 grid intensity projections.

Pathway 1: Interim Target   Pathway 2: Net Zero

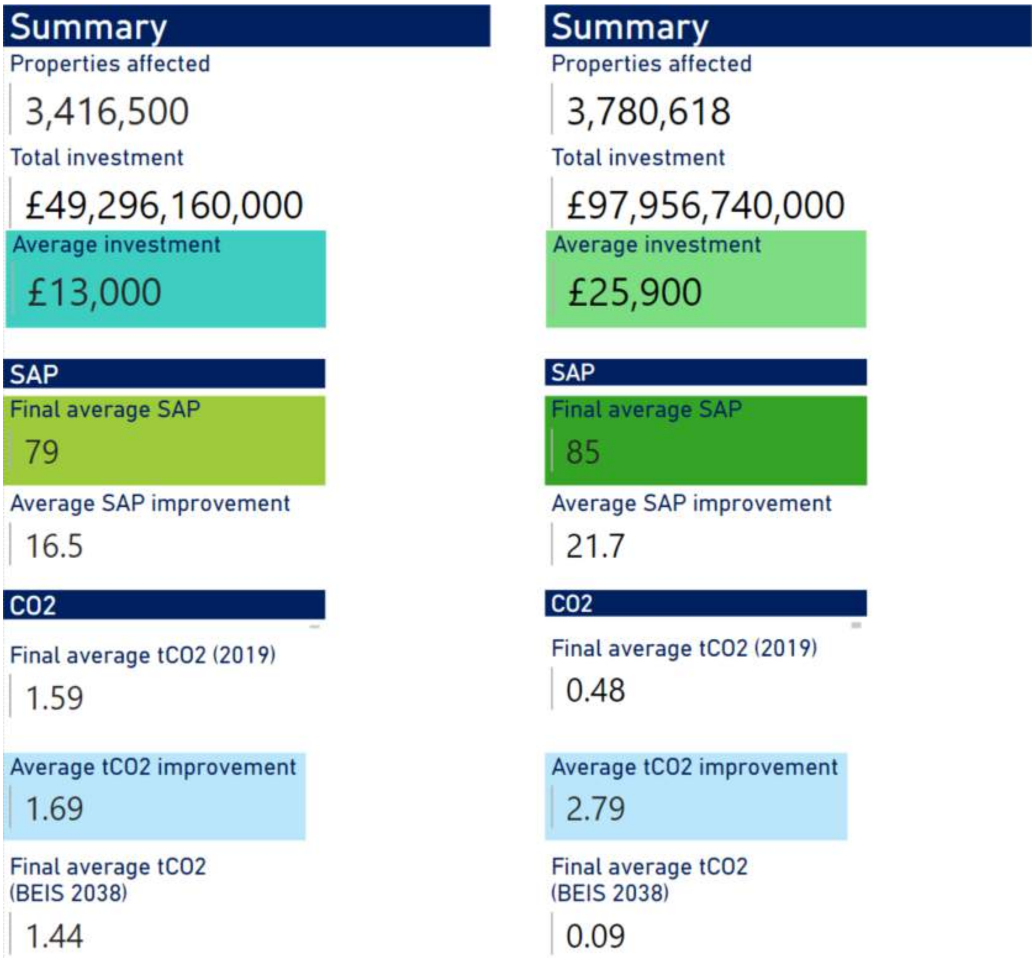


Figure 30

4.2 INTERIM TARGET PATHWAY HIGHLIGHTS

In this section we show the key impacts of the Interim Target Pathway.

4.2.1 Pathway Summary

The Pathway has been run on all properties in London but the Properties Affected figure is below this value because some properties are believed to be above the SAP 75 target already and so need no further works.

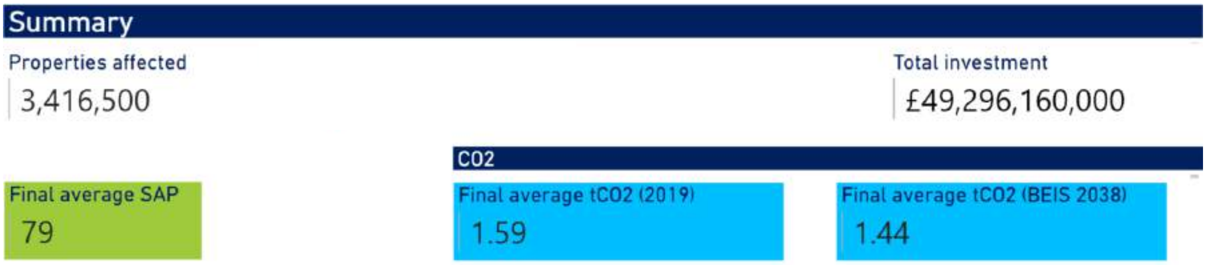


Figure 31

The final average SAP is marginally below the average B figure – a minimum SAP score of 81. We explore this in Table 3 below.

4.2.2 Investment

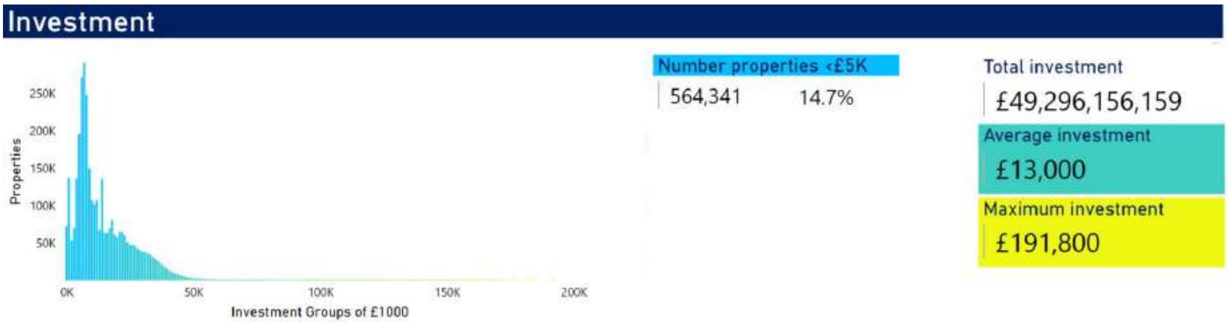


Figure 32

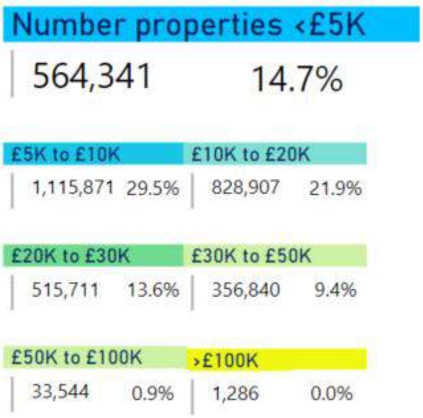


Figure 33

Figure 32 shows the number of properties in each investment group of £1,000 intervals. Figure 33 groups the number of properties by larger investment intervals.

Table 3 shows the results for each borough ranked by final SAP score. Inner London boroughs are shaded green. The final column is there to show the SAP score for affected homes as not all homes are impacted by this Pathway.

Nine of the boroughs, all in outer London, reach an average B score. Two more of the boroughs reach B for affected homes, but fall short when we include homes not affected – these are in bold in the table. 7 of the remaining boroughs are within 1 SAP point of being average B. The only inner London borough that comes close is Newham. As noted above, analysis has been applied at the Borough level so the same proportion in each will be considered for retrofit.

Once our modelling was scaled up to all properties in London, the results show that our sample approach marginally misses the Average B target – 9 Boroughs achieve it and 24 fall short. Adjusting the relative sizes of the groups outlined in Section 4.1.2 for the Interim Scenario for inner London boroughs i.e. pushing for more properties to achieve the 65kWh figure, or pushing for more heat pumps is one potential option for achieving Average B. The higher density also offers more opportunities for community heating and heat networks.

Multiple factors relating to the makeup of the housing stock in a borough will impact both the average investment and final EPC score and CO_2 emissions. Some of these are discussed in Section 4.4.8.

Table 3 Borough Interim Target Results

Borough	Total Investment (Billions)	Average Investment	Average Investment Rank (1 is lowest)	Final Average EPC Score	Final Average EPC Score for affected homes	Final tCO_2 (2038)
Kensington & Chelsea	£1.47	£15,980	27	75.3 (C)	75.3 (C)	1.54
Camden	£1.53	£13,365	7	76.0 (C)	76.0 (C)	1.36
City of Westminster	£1.71	£13,520	10	76.4 (C)	76.5 (C)	1.37
Hammersmith & Fulham	£1.23	£14,240	13	76.7 (C)	76.7 (C)	1.37
Islington	£1.31	£12,726	4	77.6 (C)	77.7 (C)	1.19
City of London	£0.10	£13,220	6	78.0 (C)	78.0 (C)	0.57
Wandsworth	£1.96	£14,070	12	78.3 (C)	78.1 (C)	1.41
Tower Hamlets	£1.13	£10,900	1	78.4 (C)	79.0 (C)	0.91
Lambeth	£1.85	£13,430	9	78.4 (C)	78.6 (C)	1.33
Hackney	£1.33	£12,460	3	78.5 (C)	78.8 (C)	1.20
Haringey	£1.64	£15,030	23	78.8 (C)	78.9 (C)	1.53
Richmond	£1.30	£16,230	32	78.8 (C)	79.2 (C)	1.71
Southwark	£1,54	£12,370	2	78.8 (C)	79.2 (C)	1.15
Kingston-upon-Thames	£1.03	£16,130	30	79.5 (C)	79.7 (C)	1.65
Ealing	£1.88	£14,690	20	79.8 (C)	80.1 (C)	1.46
Hounslow	£1.33	£14,280	14	79.9 (C)	80.3 (C)	1.39
Brent	£1.74	£14,520	17	79.9 (C)	80.1 (C)	1.60
Greenwich	£1.43	£13,710	11	79.9 (C)	80.2 (C)	1.37
Merton	£1.19	£14,860	22	80.0 (C)	80.3 (C)	1.52
Barnet	£2.26	£16,100	28	80.3 (C)	**80.6 (B)**	1.67
Croydon	£2.10	£14,310	16	80.3 (C)	80.0 (C)	1.60

Enfield	£1.74	£14,790	21	80.4 (C)	**80.7 (B)**	1.49
Newham	£1.42	£13,040	5	80.4 (C)	80.9 (B)	1.30
Sutton	£1.12	£14,520	18	80.5 (C)	80.9 (B)	1.51
Bromley	£2.11	£16,140	31	80.6 (B)	80.9 (B)	1.49
Waltham Forest	£1.46	£14,290	15	80.7 (B)	80.9 (B)	1.40
Harrow	£1.37	£16,110	29	80.7 (B)	81.0 (B)	1.70
Lewisham	£2.05	£16,510	33	80.7 (B)	80.8 (B)	1.27
Hillingdon	£1.53	£14,670	19	80.7 (B)	81.0 (B)	1.52
Barking & Dagenham	£0.93	£13,390	8	80.8 (B)	81.16 (B)	1.32
Bexley	£1.40	£15,070	24	81.1 (B)	81.40 (B)	1.60
Havering	£1.54	£15,820	26	81.5 (B)	81.78 (B)	1.68
Redbridge	£1.57	£15,743	25	81.5 (B)	81.68 (B)	1.59

4.2.3 Investment by LSOA

The Sub-Regional maps below show the LSOAs that will require higher levels of investment. Some of this will be driven by absolute numbers of properties. The darker green indicates a higher investment is required.

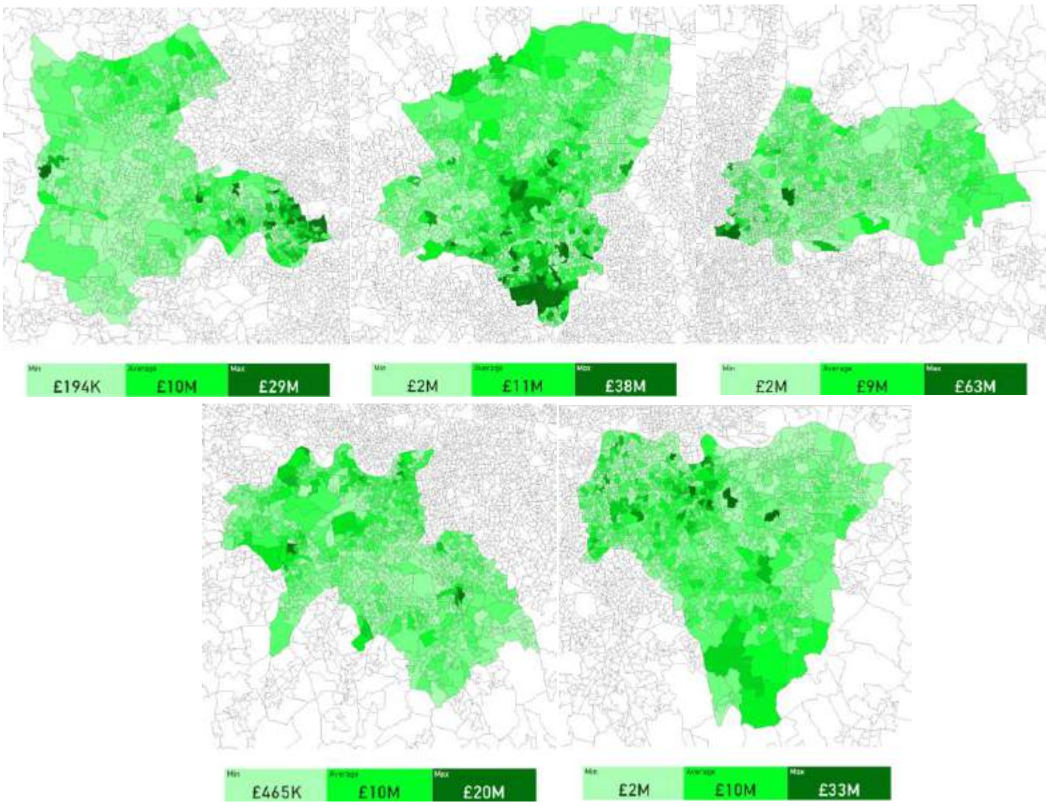


Figure 34 **(clockwise from top left – West, North, East, South East, South West)**

4.2.4 SAP Score

Figure 35 shows how the SAP profile changes from the current shape to one where all the measures identified in the Interim Target Pathway have been installed. Table 4 provides the resulting property numbers by EPC band. There are two things to note:

- there is a major peak at SAP 75 as you expect from the Scenario setup, but the chart also shows a significant amount of 'overshoot' i.e. lots with a result higher than 75. This is because you either install a measure in total or not at all e.g., you cannot install half a boiler or one panel PV system. You therefore capture all the SAP improvements from the measure, taking it above 75.
- There is a second shoulder just above 80. This is often due to the installation of a measure like PV on a roof which will move the SAP score quite a few points.

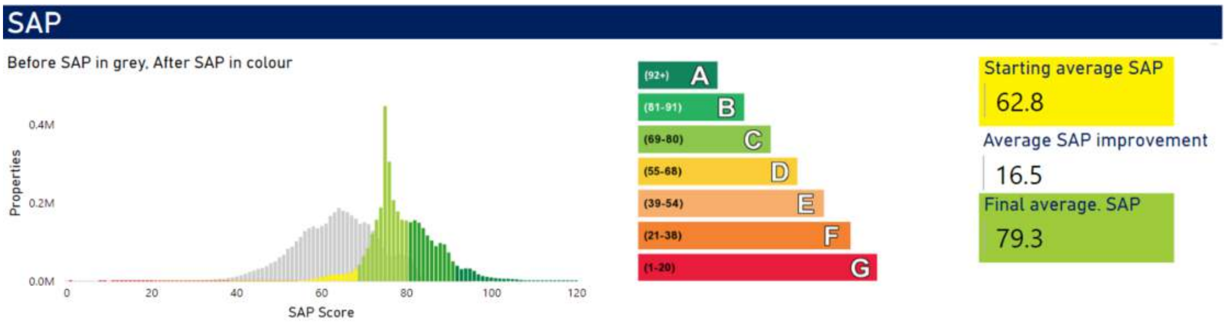


Figure 35

Table 4 Resulting Property Numbers by EPC Band after modelled measures are installed

Resulting EPC Band	Number of properties	% of stock
A	262,483	7%
B	1,216,422	32%
C	2,101,524	56%
D	187,071	5%
E	11,603	<1%
F	1,069	<1%
G	76	<1%

4.2.5 CO_2 & Other KPIs

In Figure 36 we show the resulting CO_2 profile chart using the grid intensity predicated for 2019 and in Figure 37 using figures for 2038. Figure 38 provides some other interesting KPIs related to the performance of the buildings and impact on fuel bill cost.

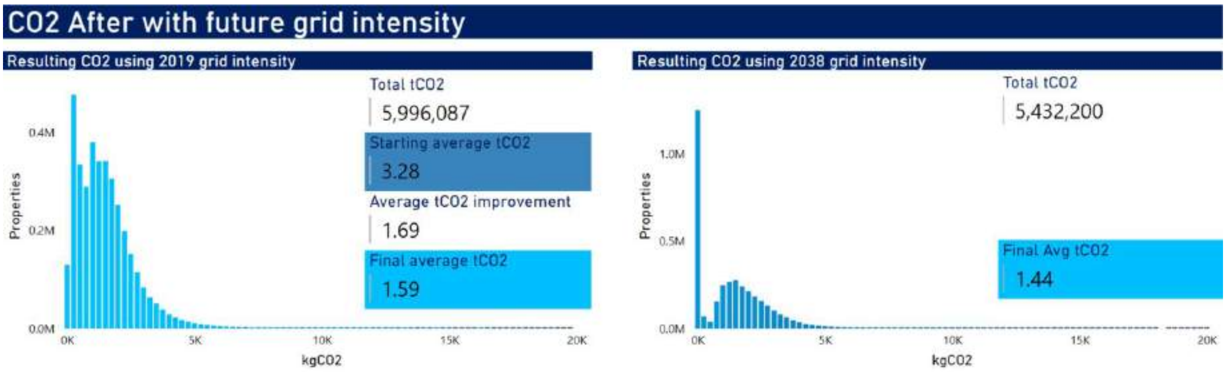


Figure 36

4.2.6 CO_2 Future Grid Intensities

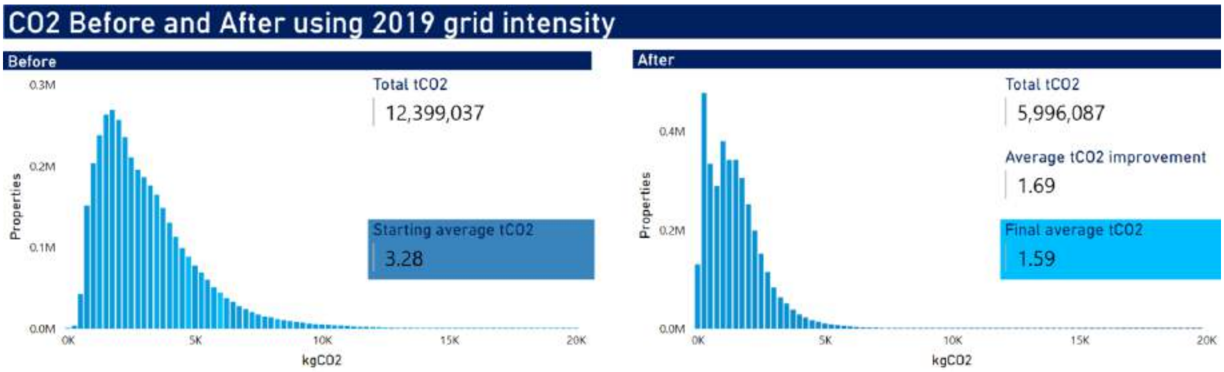


Figure 37

Figure 38

4.2.7 Measures summary

Our method of applying the Pathway criteria to each property produces an ordered list of the most cost-effective measures for every property. A hypothetical example is shown below.

Address	Measure Applied Order	Measure Outcome	Calculated Measure Cost	Cumulative Cost	Resulting SAP Score	Resulting kWh/m2 heat demand	Resulting Fuel Bill	Resulting kgCO2 (2038)
9 Acacia Avenue, BR1 1XX	1	300mm loft insulation	£706	£706	55.48 (D)	85.00	£932.19	3,789
9 Acacia Avenue, BR1 1XX	2	External wall insulation	£9,835	£10,541	66.76 (D)	24.05	£704.57	2,684
9 Acacia Avenue, BR1 1XX	3	Air source heat pump	£12,000	£22,541	68.19 (D)	43.24	£724.46	371
9 Acacia Avenue, BR1 1XX	4	Solar hot water	£4,725	£27,266	75.74 (C)	44.75	£528.80	267
9 Acacia Avenue, BR1 1XX	5	Photovoltaic array	£4,174	£31,440	85.55 (B)	44.75	£350.91	131

Figure 39

We can use these individual property results to total the number and cost of each of the measures grouped at various levels e.g. Internal solid wall insulation has been found for 287,110 properties at a cost of £3.27 billion. This is included in the total Fabric measures of 7,335,100 at a total cost of just under £24 billion. The table below gives the high-level summary and the following tables provide more detail on the measures and their costs (materials and labour). These tables are necessarily very detailed and may require zooming in to be more visible if on a smaller screen.

Table 5 Breakdown of the Pathway measures results by high level category

	Value (£ millions)	No. measures (thousands)
Fabric	23,994 (49%)	7,335 (45%)
Heating & Hot Water	16,543 (34%)	5,762 (35%)
Photovoltaics	8,486 (17%)	1,369 (8%)
Lighting	84 (0.2%)	1,811 (11%)

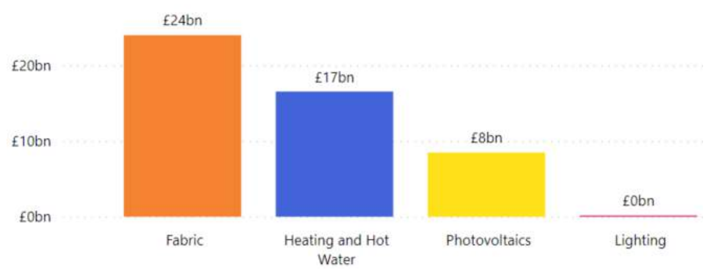


Table 6 Detailed breakdown of the Pathway results fabric measures

Fabric **£23,994M** 7,335,100 measures £3,271 average per property	Walls **£12,610M** No. 2,091,858 £6,028 av.	Cavity **£1,423M** No. 802,796 £1,773 av.	Cavity Insulation **£683M** No. 551,496 £1,238 av.
			Internal to Cavity **£89M** No. 8,658 £10,329 av.
			External to Cavity **£439M** No. 41,042 £10,707 av.
			Internal Party Wall **£212M** No. 201,600 £1,050 av.
		Solid **£10,636M** No. 996,439 £10,674 av.	Internal to Solid **£3,273M** No. 287,110 £11,399 av.
			External to Solid **£7,363M** No. 709,329 £10,381 av.
		System **£384M** No. 48,734 £7,884 av.	Internal to System **£92M** No. 13,167 £,6965 av.
			External to System **£293M** No. 35,567 £8,225 av.
		Timber **£119M** No. 12,720 £9,358 av.	Internal to Timber **£12M** No. 12,720 £9,358 av.
		Other (Internal of External) **£32M** No. 229,866 £140 av.	
	Roofs **£1,253M** No. 1,284,409 £976 av.	Loft **£899M** No.1,230,303 £731 av.	Virgin or Unknown **£476M** No. 568,361 £840 av.
			Top up **£41M** No. 661,942 £639 av.
		Flat Roof Insulation **£345M** No. 50,238 £6,868 av.	
		Rafter Insulation **£9M** No. 3,861 £2,265 av.	
	Floors **£2,745M** No. 1,260,489 £2,178 av.	Solid Floors **£1,076M** No. 488,083 £2,205 av.	
		Suspended Timber Floors **£944M** No. 497,838 £1,896 av.	
		Suspended Not Timber Floors **£568M** No. 251,278 £2,259 av.	
		Exposed Floors **£157M** No. 23,289 £6,760 av.	
	Glazing **£7,071M** No. 1,672,803 £4,227 av.	Double (A+ or A++) **£6,305M** No.1,101,779 £5,723 av.	
		Secondary **£67M** No. 40,230 £1,662 av.	
		Triple (A++ Rated) **£90M** No. 10,785 £8,312 av.	
		Doors **£610M** No. 520,009 £1,173 av.	
	Draughts **£296M** No. 1,010,257 £293 av.	Blocking Chimneys **£135M** No. 349,460 £386 av.	
		Doors and Windows **£161M** No. 660,797 £243 av.	
	Ventilation **£18M** No. 15,282 £2,400 av.	Remove Mechanical Ventilation **£18M** No. 15,266 £1,200 av.	
		Add Mechanical Ventilation £42K No. 16 £2,594 av.	

Table 7 Detailed breakdown of the Pathway results heating. lighting and PV measures

Heating and Hot Water **£16,543M** 5,761,542 measures £2,871 average per property	Community Heating **£120M** No. 44,346 £2,703 av.	Community Heating Controls **£22M** No. 21,073 £1,050 av.		
		Community Heating System **£98M** No. 23,273 £4,200 av.	Community Heat Pump **£98M** No. 23,273 £4,200 av.	
	Individual Heating and Hot Water **£15,632M** No. 5,549,661 £2,817 av.	Heating System **£14,737M** No.2,909,830 £5,065 av.	Radiator System **£1,153M** No. 320,084 £3,602 av.	Gas **£1,149M** No. 319,515 £3,596 av.
				Oil **£4M** No. 553 £7,218 av.
				All Systems £17K No. 16 £1,080 av.
			Electric Storage System **£104M** No. 138,788 £752 av.	
			Heat Pump System **£13,480M** No. 1,093,683 £12,325 av.	Air Source Heat Pump **£13,472M** No. 1,093,251 £12,323 av.
				Ground Source Heat Pump **£8M** No. 432 £19,161 av.
		Hot Water **£81M** No. 496,682 £163 av.	Cylinder Jacket **£9.8M** No. 208,860 £47 av.	
			New Cylinder **£48M** No. 74,995 £642 av.	
			Cylinder Thermostat **£7M** No. 188,780 £39 av.	
			Switch from Alternative **£16M** No. 24,047 £660 av.	
		Secondary Heating **£73M** No. 266,380 £275 av.	Remove Secondary Heating **£71M** No. 264,212 £270 av.	
			Change Secondary Heating **£2M** No. 2,168 £938 av.	
		Controls **£737M** No.1,800,255 £410 av.	Standard **£80M** No. 425,776 £188 av.	
			Zoned **£375M** No. 566,679 £661 av.	
			Compensating Controller **£283M** No. 807,800 £350 av.	
		Tariff Switch **£3M** No. 76,514 £33 av.	Single to Dual **£2M** No. 12,477 £81 av.	
			Dual to Single **£1M** No. 64,037 £24 av.	
	Solar Thermal **£791M** No. 15,427 £4,725 av.			
Lighting **£84M** 1,369,091 measures £62 average per property				
Photovoltaics **£8,486M** 1,810,679 measures £4,687 average per install				

4.3 INTERIM TARGET EMPLOYMENT ANALYSIS

4.3.1 Existing sector

The number of people employed in the existing refurbishment sector is hard to determine as ONS statistics and figures are categorised differently from what is needed e.g. they give total numbers of plasterers in all construction which will cover commercial, public sector and new build, or the value is split into public and private but not new build or refurbishment. We have therefore triangulated various numbers from the Office of National Statistics (ONS) and we estimate it currently stands at 12% of the entire UK construction industry by headcount. For the trades working in retrofit, we assume current work is 30% of the UK's construction workload by value. From this we estimate the recent make-up of the UK domestic refurbishment industry in terms of employees as shown below:

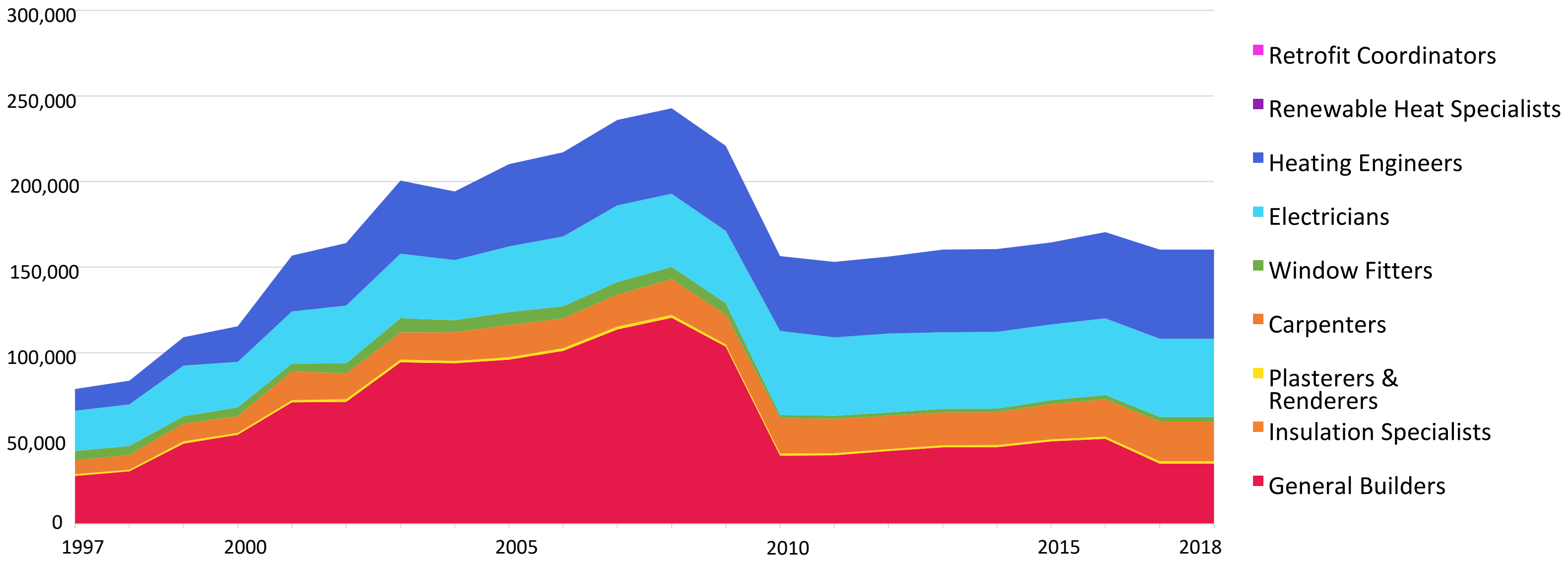


Figure 40

In 2008 there were 242,800 trades in ROOFING, INSTALLATION OF ELECTRICAL WIRING AND FITTING, PLUMBING, AND HEAT AND AIR CONDITIONING INSTALLATION, PLASTERING/RENDERER, JOINERY INSTALLATION, GLAZING, OTHER CONSTRUCTION WORK AND BUILDING INSTALLATION AND COMPLETION. There was then a large overall drop-off in 2008 that has never been recovered. It disproportionately affected general builders, but joiners, electricians and heating engineers have been reasonably steady across most of the later part of the period. We do have an underlying crisis in this sector and that is a lack of new entrants to it; a rapidly ageing workforce threatens our ability to maintain the current levels of work. For instance, the average age of a Gas Safe heating engineer is 56 and that is the age they start thinking about retirement.

4.3.2 Methodology

4.3.2.1 Current Trades

We have taken the data above for national existing trades and adjusted this proportionately to the number of properties London. Admittedly this is quite a crude approach but inevitable in the absence of considerable primary research.

4.3.2.2 Required Trades

We have determined estimated figures for trade requirements for each measure applied in our two Pathways – see example below. These are totalled and then spread over the time period to 2030 using different implementation profiles outlined below in Sections 4.3.3 & 4.5.2.

> Example
>
> Measure: "Flat Roof Insulation to existing pre 1976 to 1982 flat roofs"
>
> Assumed Trade Days required per job:
>
> - Insulation Specialist – 2 days
> - Carpenter – 2 days
> - General Builder – 2 days
>
> No. Jobs identified: 867

4.3.2.3 Retrofit Coordinators

This new professional role is critical to ensure a smooth flow of work and quality assurance at a time when ramping up volume risks the introduction of inexperienced people and poor practices. The Retrofit Coordinator will oversee the process for each householder from first introduction to sign-off of the work. We have made assumptions for Retrofit Coordinator hours for each measure type.

4.3.2.4 Average Trade Days for a 9-year programme (to 2030)

Figure 41 shows the number of different trades that would be required each year to deliver the Interim Target Programme over 9 years. In total this programme would require 40,890 full time employees each year – standard building trades dominate. The charts also show how these are split across trades.

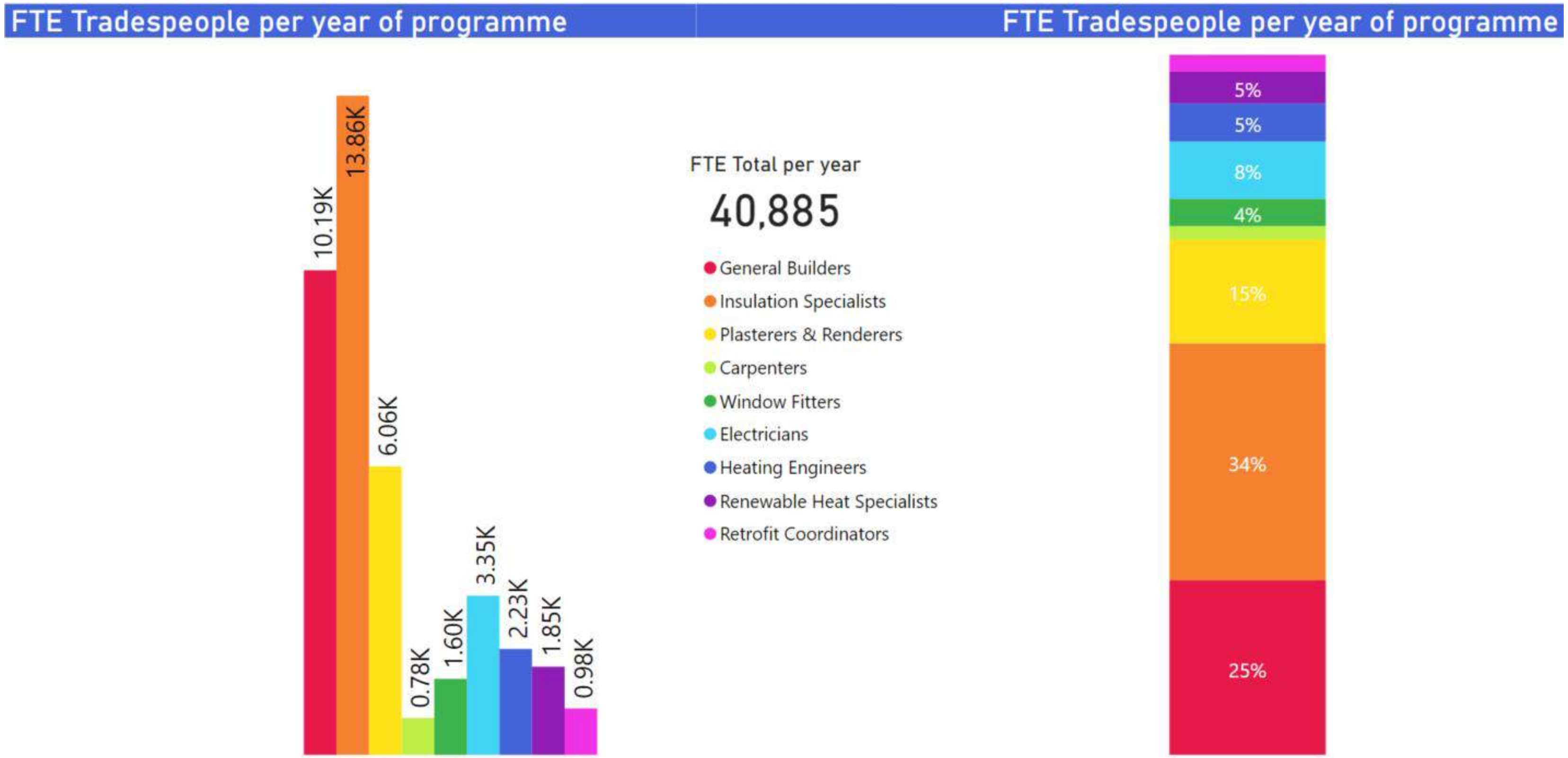


Figure 41

Alternatively, in Figure 42 we present the programme delivery in terms of individual trade days and total trade years.

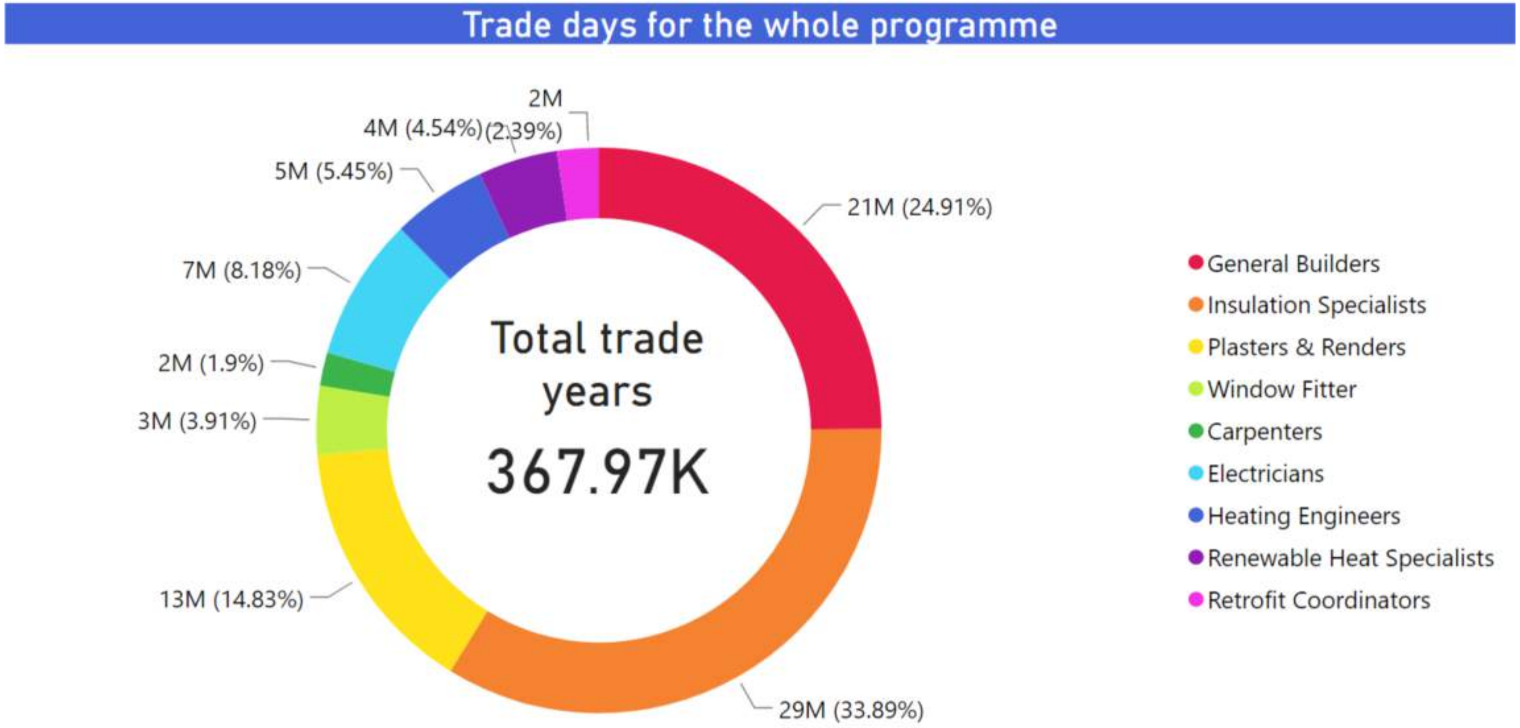


Figure 42

4.3.3 2030 Completion Target

The ambition of the London Boroughs is to complete the Interim Target by 2030 – from little more than a standing start. Below we have shown the trades required to meet the target with an implementation trajectory that ramps up to a peak by 2030. After 2030 there will be ongoing maintenance roles and so it is envisaged that this would not result in an employment cliff edge.

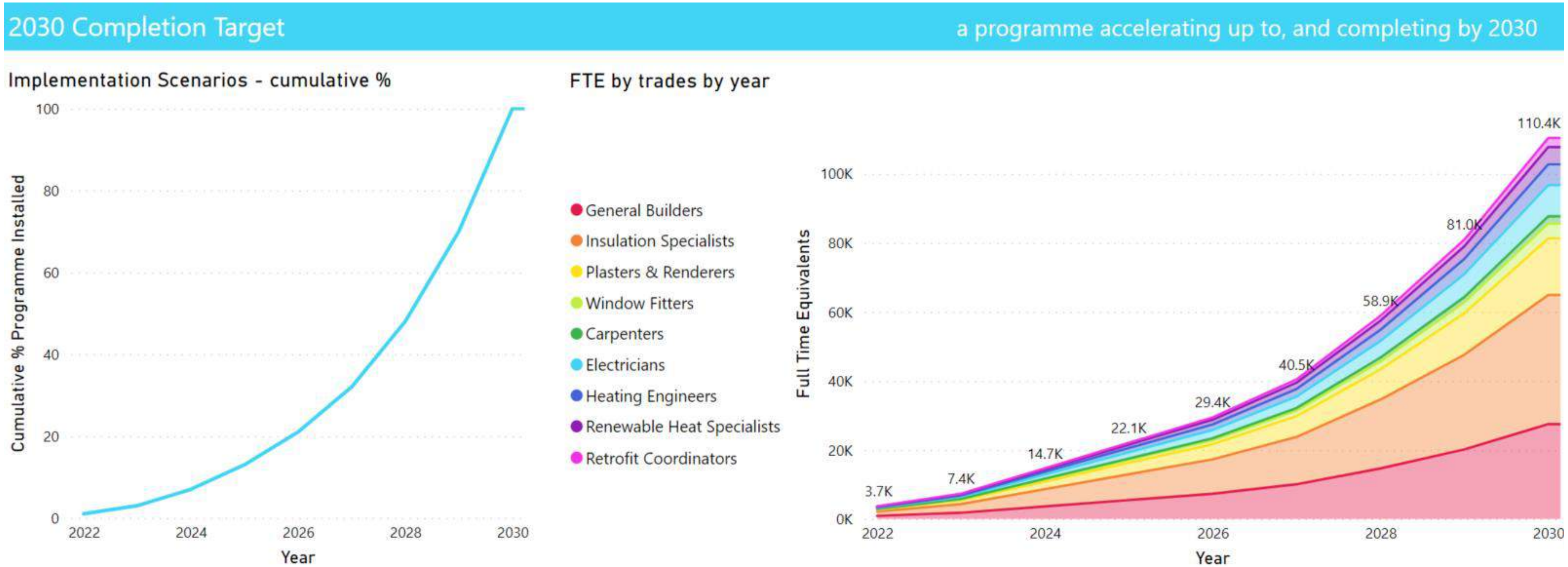


Figure 43

Table 8

	General Builders	Insulation Specialists	Plasters & Renderers	Window Fitters	Carpenters	Electricians	Heating Engineers	Renewable Heat Specialists	Retrofit Coordinators
No. FTE by 2030	49,433	66,602	30,592	4,286	1,769	17,084	5,996	16,366	4,223

4.4 NET ZERO PATHWAY HIGHLIGHTS

In this section we show the key impacts of the Net Zero Pathway. The impact of this Pathway is a SAP score of 85 which is in the middle of the EPC B band. It is worth highlighting that the final figure for tCO_2 is around 100kg per property using figures for the grid intensity in 2038. The reason it is not actually zero is because all properties will require some heating, which even if electric, will not be carbon neutral, and it is not possible to provide this electricity through on-site renewables. In addition, the figure also actually takes into account some offsetting between increased PV generation in the summer months against heating needs in the winter.

4.4.1 Pathway Summary

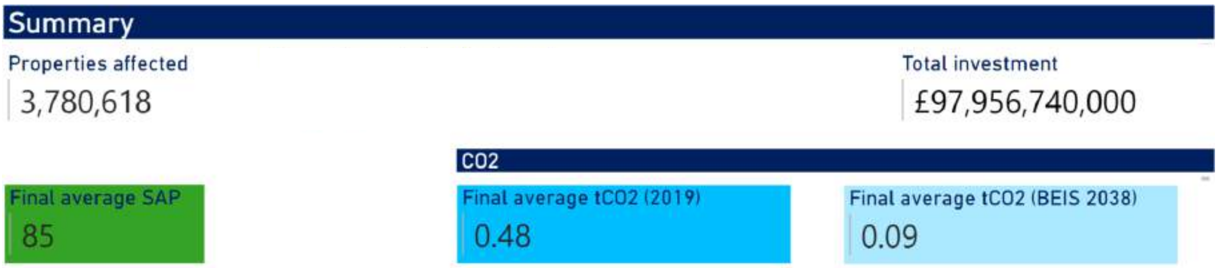


Figure 44

4.4.2 Investment

Figure 45

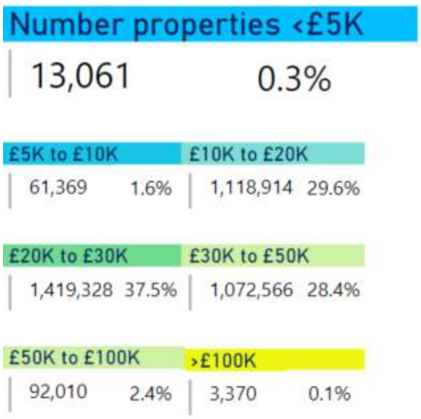


Figure 46

Figure 45 shows the number of properties in each investment group of £1,000 intervals. Figure 46 groups the number of properties by larger investment intervals. If a maximum investment were set then these could be used to determine the numbers of properties that definitely miss the target.

Table 9 has been ordered by Average Investment per property in each borough. The inner London boroughs dominate the top of the table primarily due to smaller properties and a greater proportion of flats. Multiple factors relating to the makeup of the housing stock in a borough will impact both the average investment and final EPC score and CO_2 emissions. Some of these are discussed in Section 4.4.8. For this Pathway, virtually every property is affected.

Table 9 Borough Net Zero Target Results

Borough	Total Investment (Billions)	Average Investment	Total Investment Rank (1 -lowest)	Final Average EPC Score	Final CO_2 (2038)
City of London	£0.15	£18,540	1	80.1 (C)	0.13
Tower Hamlets	£2.57	£18,870	7	83.2 (B)	0.07
Southwark	£3.23	£22,030	22	84.4 (B)	0.08
Sutton	£3.23	£22,030	23	86.5 (B)	0.08
Islington	£2.64	£22,310	9	81.9 (B)	0.10
Hackney	£2.75	£22,330	12	83.4 (B)	0.09
Camden	£2.95	£23,570	15	80.0 (C)	0.12
City of Westminster	£3.33	£23,840	24	81.2 (B)	0.11
Lambeth	£3.70	£24,290	28	83.8 (B)	0.09
Newham	£2.97	£24,340	17	85.4 (B)	0.09
Greenwich	£2.95	£24,590	16	85.1 (B)	0.09
Hammersmith & Fulham	£2.33	£24,760	4	80.9 (B)	0.11
Wandsworth	£3.88	£24,940	30	82.8 (B)	0.10
Lewisham	£3.33	£25,110	25	85.9 (B)	0.08
Hounslow	£2.69	£25,730	10	85.3 (B)	0.10
Barking & Dagenham	£1.97	£25,760	2	86.0 (B)	0.08
Kensington & Chelsea	£2.58	£26,250	8	78.8 (C)	0.14
Waltham Forest	£2.90	£26,540	14	86.1 (B)	0.08
Brent	£3.49	£26,560	26	85.3 (B)	0.09
Ealing	£3.70	£26,586	29	84.9 (B)	0.09
Merton	£2.35	£27,100	5	85.4 (B)	0.09
Haringey	£3.20	£27,180	21	83.9 (B)	0.10
Croydon	£4.42	£27,400	32	85.9 (B)	0.09
Hillingdon	£3.12	£27,620	19	86.5 (B)	0.10
Enfield	£3.51	£27,640	27	85.8 (B)	0.09
Richmond	£2.49	£28,530	6	84.2 (B)	0.11
Bexley	£2.84	£28,700	13	86.1 (B)	0.09
Kingston-upon-Thames	£2.00	£28,870	3	84.7 (B)	0.11
Barnet	£4.49	£28,900	33	86.1 (B)	0.10
Redbridge	£3.09	£29,070	18	86.3 (B)	0.09
Bromley	£4.18	£29,490	31	86.3 (B)	0.10
Harrow	£2.74	£29,560	11	86.4 (B)	0.09
Havering	£3.14	£29,620	20	87.3 (B)	0.09

4.4.3 Investment by LSOA

The sub-region maps below show the LSOAs that will require higher levels of investment with darker colours indicating higher investment required. Some of this will be driven by absolute numbers of properties.

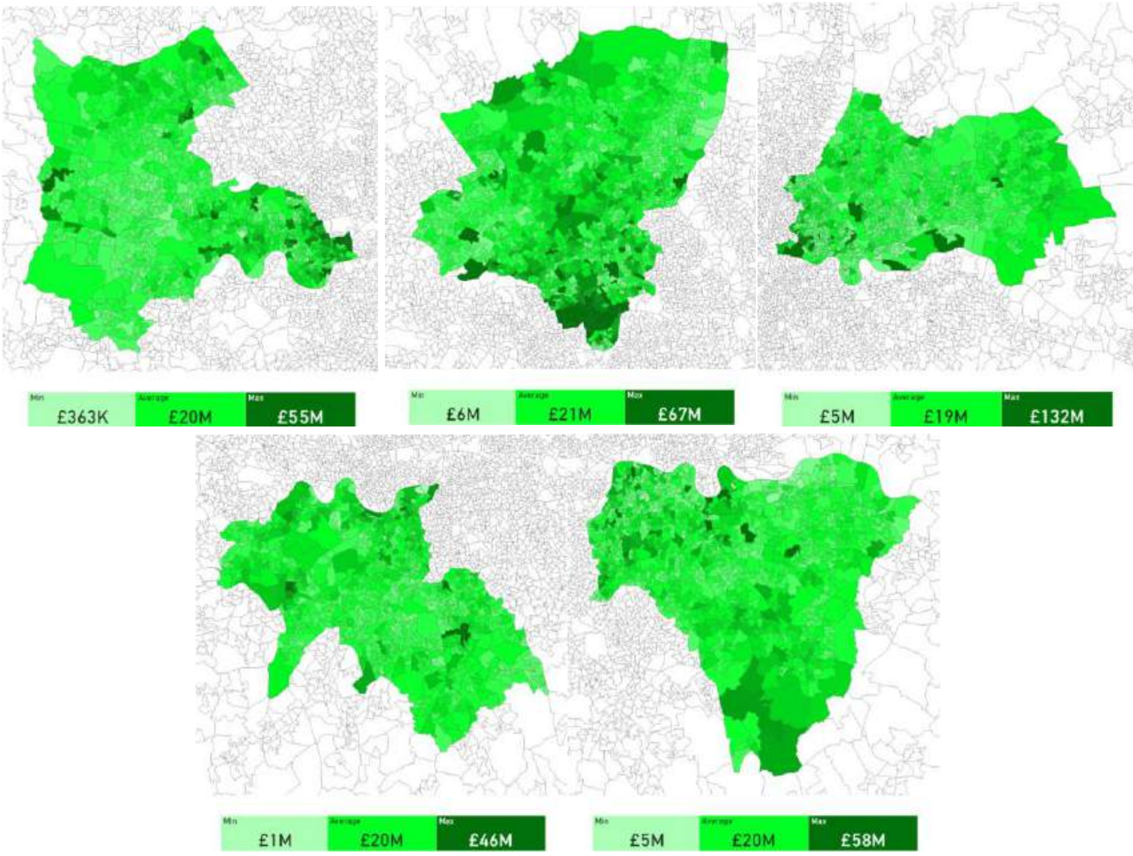


Figure 47 (clockwise from top left – West, North, East, South East, South West)

4.4.4 SAP Score

Figure 48 shows how the SAP profile changes from the current shape to one where all the measures identified in the Interim Target Pathway have been installed. Table 4 provides the resulting property numbers by EPC band.

There are two things to note:

- There are a number of peaks. It is expected that these relate to properties where PV can or cannot be installed e.g. the lower peaks relate to ground and mid floor flats.
- The average SAP score results in a mid EPC band B.

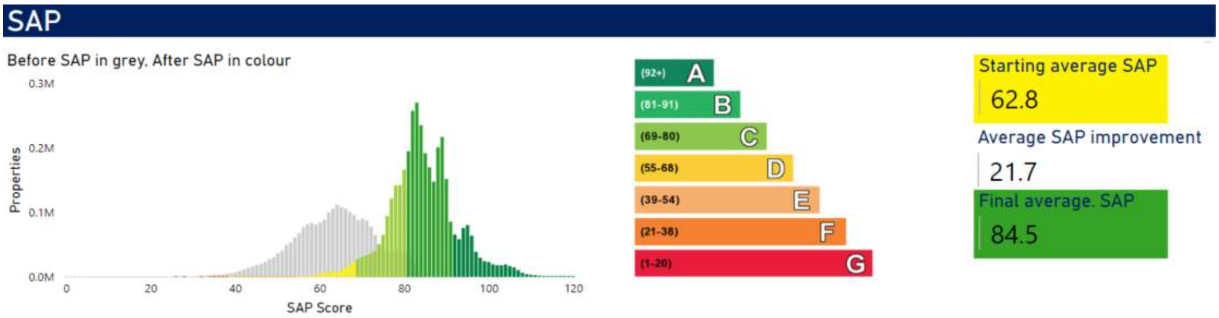


Figure 48

Table 10 Resulting Property Numbers by EPC Band

Resulting EPC Band	Number of properties	% of stock
A	602,586	16%
B	2,123,729	56%
C	949,486	25%
D	104,606	3%
E	846	<1%
F	17	<1%
G	0	0%

4.4.5 CO_2 & Other KPIs

Below we also show the resulting CO_2 profile chart using the grid intensity predicted for 2038. Figure 51 provides some other interesting KPIs related to the performance of the buildings and impact on fuel bill cost.

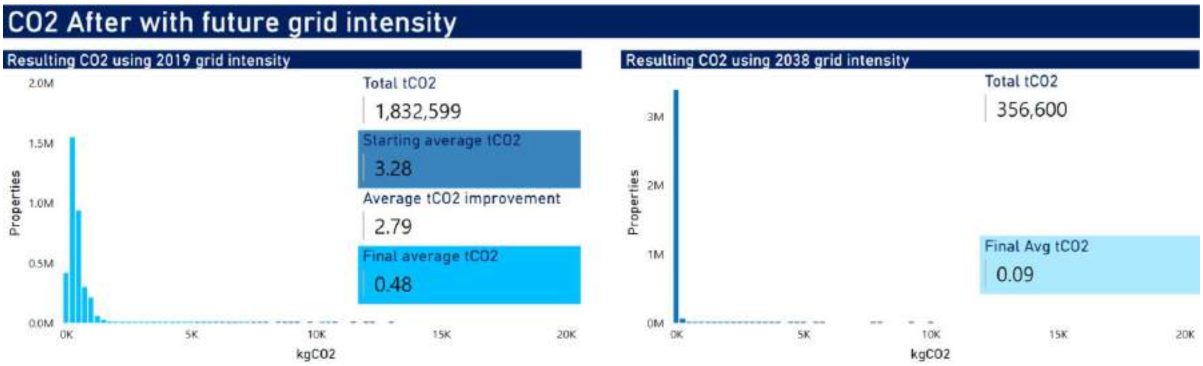


Figure 49

4.4.6 CO_2 Future Grid Intensities

Figure 50

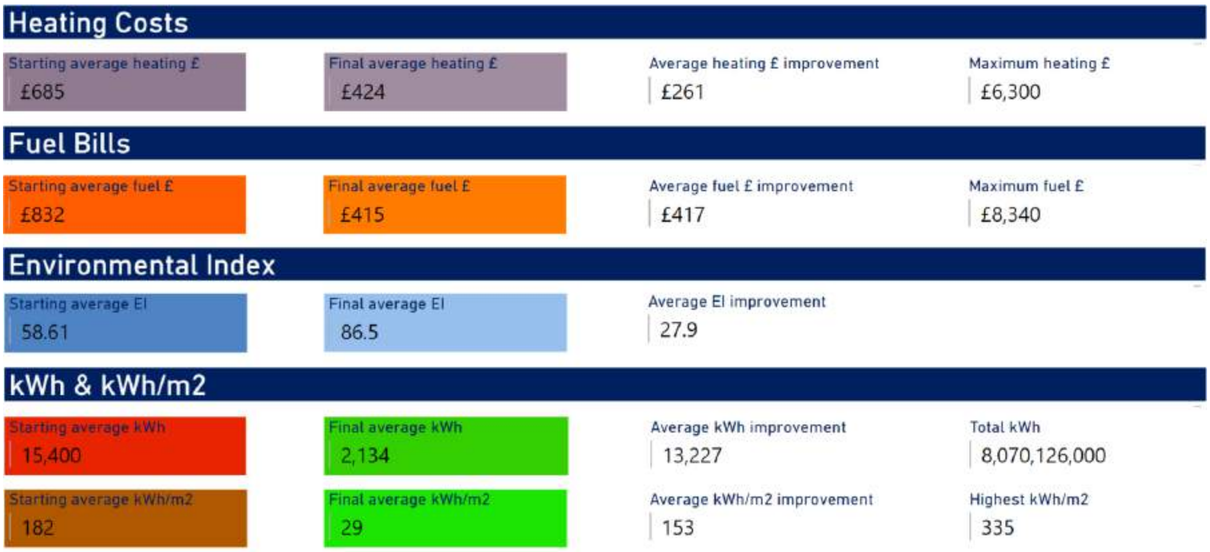


Figure 51

4.4.7 Properties resulting with high CO_2

The table below shows the figures for the number of properties that remain with substantial CO_2 emissions after the Net Zero Pathway. The key takeaway is even the number of properties with greater than 0.5 tonnes - currently that would be an extremely efficient property - is extremely small.

We have looked at the characteristics of properties remaining with over 1.5 tonnes and there do not appear to be any common features. A few selected properties were reviewed and were found to be extremely oversized. Our assumption is that some of the below will be very large properties, some will have other quirks e.g. in shape, some will have data issues and some will be properties that have essentially failed at having automated analysis, for example by having a measure applied that subsequently blocks other measure being applied. This is to be expected with a dataset of this size and we would expect most would have additional savings identified as action plans are developed in more detail.

Table 11 Number of properties by final CO_2 emissions

Residual CO_2 (2038)	>0.5t	>0.75 tonnes	>1 tonnes	>1.5 tonnes	>2 tonnes	>3 tonnes
No. Properties	35,149	29,171	23,988	8,800	1,048	81
% of stock	0.93%	0.77%	0.63%	0.23%	0.03%	0.00%

4.4.8 Trends by Total Investment

Further to this, we have looked at some key properties details for properties that fall into each of three total investment groups – those requiring below £15,000 investment, those between £15,000 and £35,000 and those over £35,000. These are shown in the table below with some commentary for each. The analysis below will go some way to explain the variance between Boroughs in Tables Table 3 & Table 9.

Table 12 Comparisons of different characteristics by required investment grouping

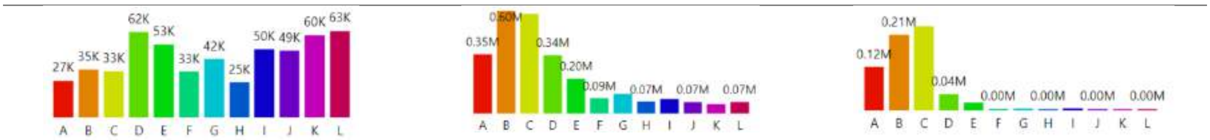
EPC Band

As you would expect, properties with lower baseline EPC scores will require more investment to bring to Net Zero

Total Investment: Less then £15,000	£15,000 to £35,000	£35,000+
No. Properties: 530,913 ~14%	2,611,140 ~68%	683,565 ~18%

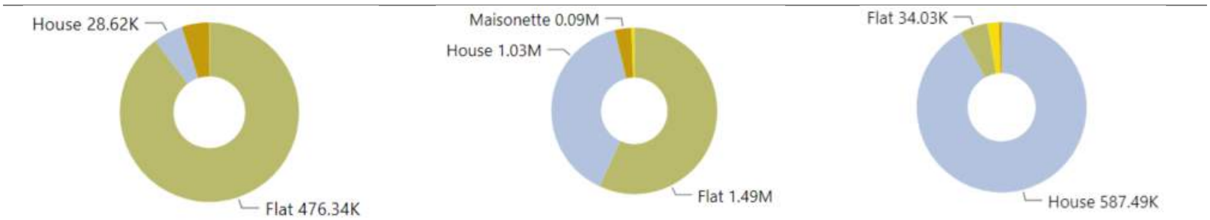
Property Age Band

Older properties tend to require more investment.



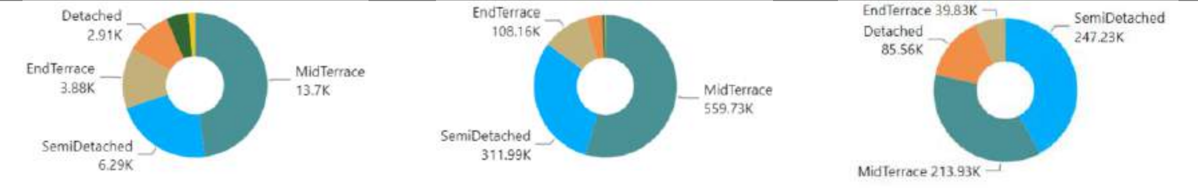
Property Type

Houses become much more dominant for the highest investment groups which will reflect the larger size and more surface area.



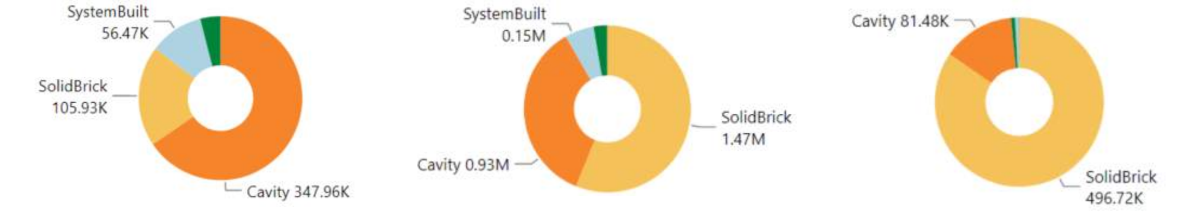
Detachment (Houses only)

For Houses, the more detached the property, the higher the investment required. This will be driven by the property size and external wall area.



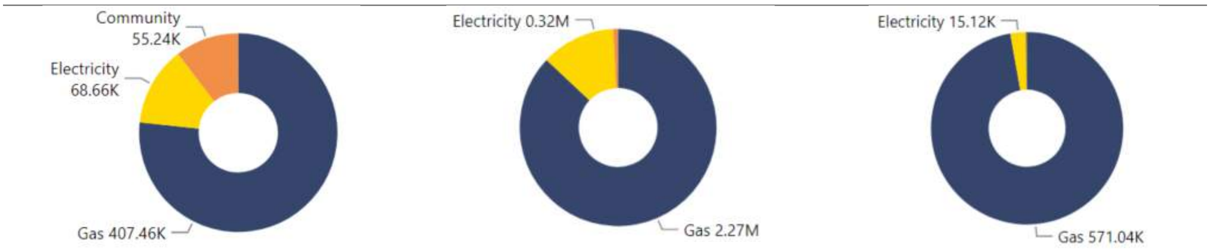
Wall Construction

Solid walls dominate the highest investment group as the costs of external or internal wall insulation will push the overall budget up significantly.



Main Heating Fuel

Individual mains gas boilers as a heating source is so dominant in London that the key trend is probably that properties with community heating and electric heating are higher proportions of the smallest investment group, although this is probably a reflection of them being much more likely to be flats.



4.4.9 Measures summary

The table below gives the high-level summary of measures employed in this scenario, and the following pages provide more detail on the measures and their costs (materials and labour).

Table 13 Breakdown of the Pathway measures results by high level category

	Value (£ millions)	No. measures (thousands)
Fabric	37,169 (38%)	9,286 (55%)
Heating & Hot Water	47,186 (48%)	4,182 (25%)
Photovoltaics	13,224 (14%)	3,178 (19%)
Lighting	12 (<1%)	226 (13%)

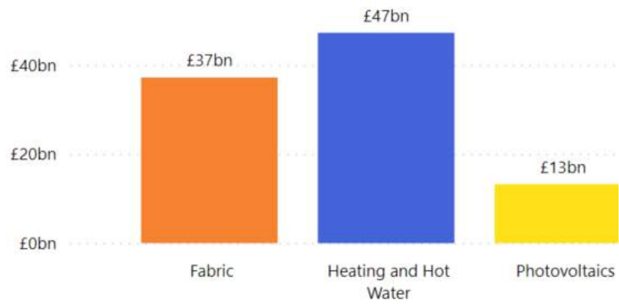


Table 14 Detailed breakdown of the Pathway results fabric measures

Fabric £37,168M 9,286,464 measures £4,002 average per property	Walls £23,942M No. 3,413,879 £7,013 av.	Cavity £1,834M No. 880,299 £2,084 av.	Cavity Insulation £742M No. 597,891 £1,241 av.
			Internal to Cavity £127M No. 9,650 £13,176 av.
			External to Cavity £748M No. 65,986 £11,336 av.
			Insulate Party Wall £217M No. 206,772 £1,050 av.
		Solid £21,027M No.1,967,704 £10,686 av.	Internal to Solid £6,450M No. 564,428 £11,428 av.
			External to Solid £14,577M No. 1,403,276 £10,388 av.
		System £757M No. 96,028 £7,885 av.	Internal to System £179M No. 25,702 £6,972 av.
			External to System £578M No. 70,326 £8,218 av.
		Timber £232M No. 24,712 £9,381 av.	Internal to Timber £232M No. 24,712 £9,381 av.
		Stone or Cob (Internal or External) £29M No. 2,591 £11,167 av.	
		Internal to Alternate Wall £62M No. 442,536 £140 av.	
	Roofs £1,608M No. 1,600,165 £1,005 av.	Loft £1,081M No.1,516,776 £713 av.	Virgin or Unknown £477M No. 568,900 £839 av.
			Top up £605M No. 947,876 £638 av.
		Flat Roof Insulation £513M No. 77,603 £6,617 av.	
		Rafter Insulation £13M No. 5,776 £2,218 av.	
	Floors £3,698M No. 1,752,288 £2,111 av.	Solid Floors £1,373M No. 640,007 £2,145 av.	
		Suspended Timber Floors £1,383M No. 740,670 £1,867 av.	
		Suspended Not Timber Floors £761M No. 344,624 £2,207 av.	
		Exposed Floors £182M No. 26,985 £6,738 av.	
	Glazing £7,603M No. 1,480,200 £5,137 av.	Double (A+ and A++) £7,015M No.1,100,129 £6,377 av.	
		Secondary £71M No. 39,123 £1,808 av.	
		Triple (A++ Rated) £47M No. 4,639 £10,131 av.	
		Doors £470M No. 336,309 £1,399 av.	
	Draughts £307M No. 1,031,832 £298 av.	Block Chimneys £151M No. 400,567 £377 av.	
		Doors and Windows £156M No. 631,265 £248 av.	
	Ventilation £10M No. 8,106 £1,207 av.	Remove Mechanical Ventilation £10M No. 8,065 £1,200 av.	
		Add Mechanical Ventilation £0.1M No. 41 £2,573 av.	

Table 15 Detailed breakdown of the Pathway results heating. lighting and PV measures

- **Heating and Hot Water** — 4,182,051 measures; £11,283 average per property — **£47,186M**
  - **Community Heating** — No. 76,681; £4,200 av. — **£322M**
    - **Community Heat Pump** — No. 7,717; £4,200 av. — **£322M**
  - **Individual Heating and Hot Water** — No. 3,613,451; £12,326 av. — **£44,541M**
    - **Heat Pump System** — No. 3,613,450; £12,326 av. — **£44,541M**
      - **Air Source Heat Pump** — No. 3,612,141; £12,324 av. — **£44,515M**
      - **Ground Source Heat Pump** — No. 1,309; £19,431 av. — **£25M**
  - **Solar Thermal** — No. 491,919; £4,722 av. — **£2,323M**
- **Lighting** — 225,727 measures; £55 average per property — **£12M**
- **Photovoltaics** — 3,177,793 measures; £4,161 average per property — **£13,224M**

4.5 NET ZERO EMPLOYMENT ANALYSIS

4.5.1 Existing Sector and Methodology

Please refer to Sections 4.3.1 and 4.3.2 for information about the current sector employment figures and our trades analysis methodology.

4.5.1.1 Average Trade Days for a 9 year programme to 2030

Figure 52 shows the number of different trades that would be required each year to deliver the Net Zero Programme over 9 years. In total this programme would require 72,723 full time employees each year – standard building trades dominate. The charts also show how these are split across trades.

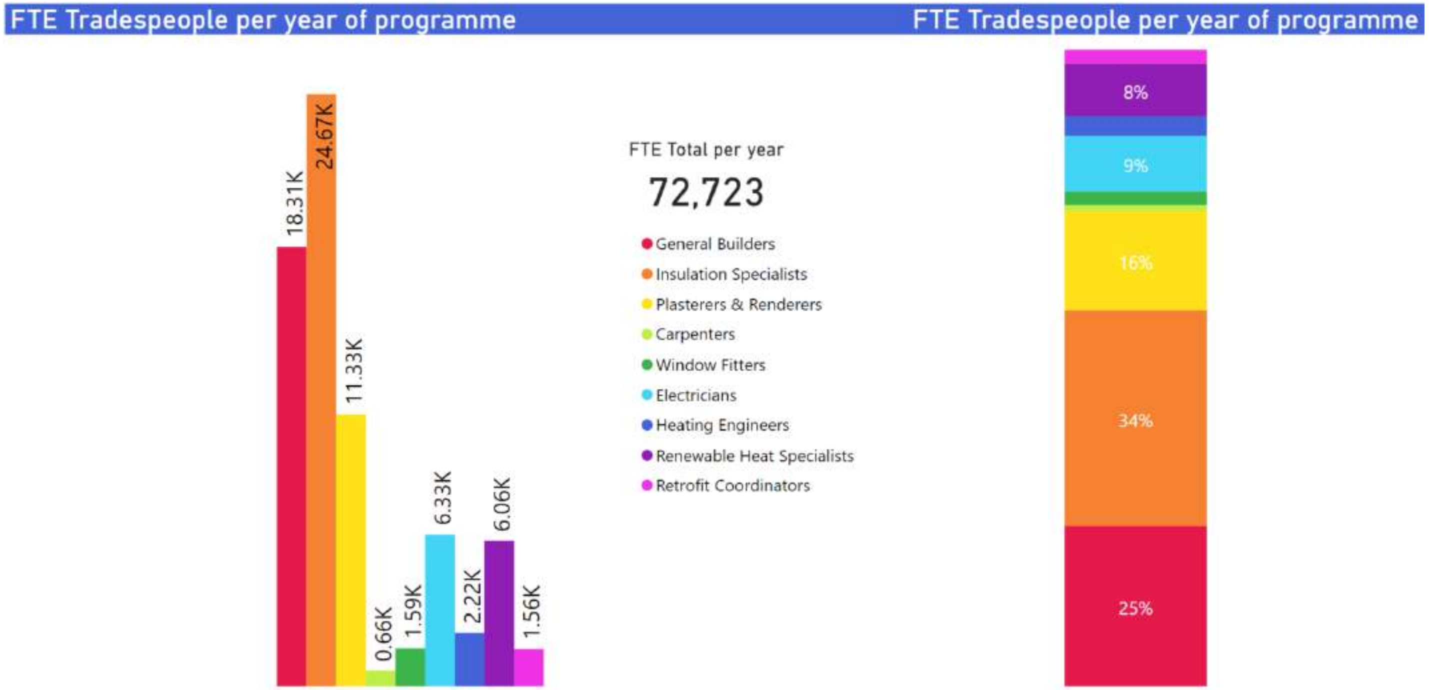


Figure 52

In Figure 53 we present the programme delivery in terms of individual trade days and total trade years.

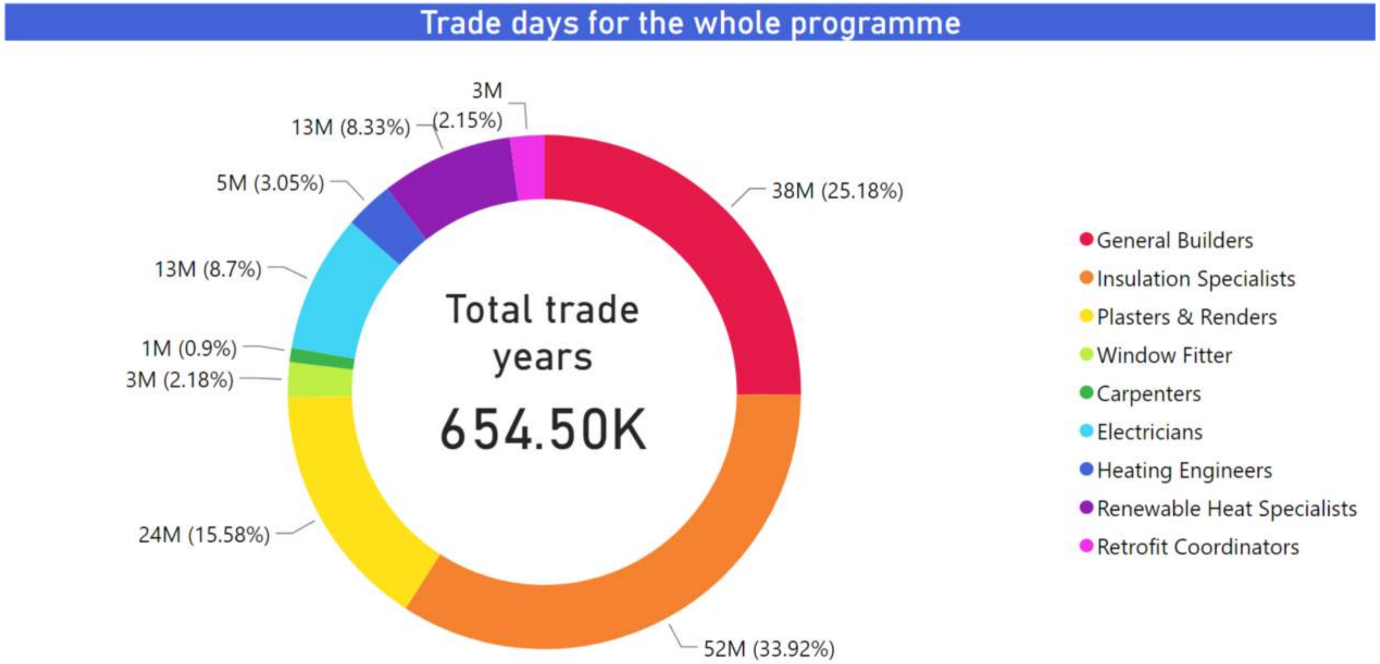


Figure 53

4.5.2 2030 Completion Target

Similar to the interim target we have applied a 2030 completion target. For Net Zero, this is well within the UK Government's 2050 target date. Below we have shown the trades required to meet the target with an implementation trajectory that ramps up to a peak at 2030. Table 16 shows the figures for the maximum trades required which occurs in 2030. In crude FTE terms the Net Zero target requires many more trades to achieve than the Interim Target.

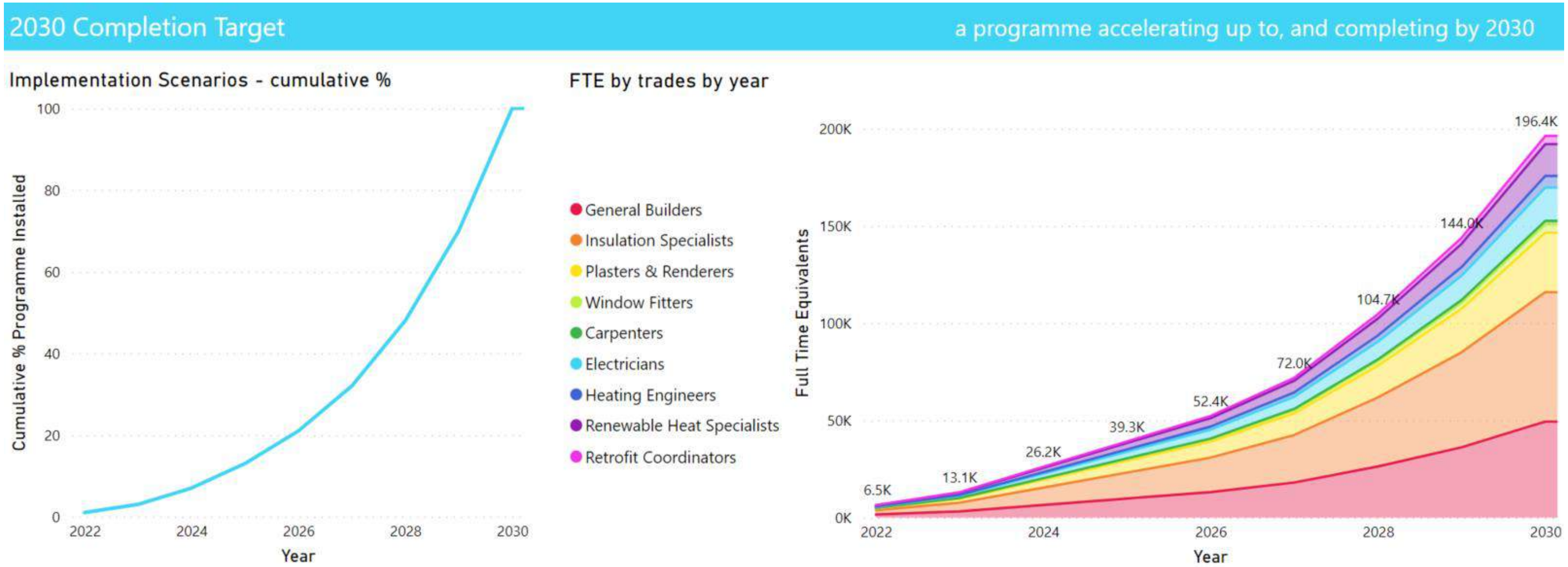


Figure 54

Table 16

	General Builders	Insulation Specialists	Plasters & Renderers	Window Fitters	Carpenters	Electricians	Heating Engineers	Renewable Heat Specialists	Retrofit Coordinators
No. FTE at the peak	49,433	66,602	30,592	4,286	1,769	17,084	5,996	16,366	4,223

5 Ventilation note

Terminology:

Infiltration – uncontrolled air ingress or loss e.g. window and door draughts, fabric holes, open chimneys, passive vents

Ventilation – controlled air movement e.g. removal of moist air from wet rooms through extractor fans, trickle vents, humidity controlled passive vents

All buildings require a certain amount of fresh air to maintain indoor air quality. In many circumstances, especially for older buildings, this is provided through infiltration and so also causes unnecessary heat loss.

Many fabric measures applied to existing buildings will by design reduce the infiltration rate. In order to maintain indoor air quality it is often therefore necessary to introduce additional controlled ventilation. There are many solutions available, and the appropriate solution should be determined for each building. Most solutions will not be excessively expensive.

It should be noted that most ventilation solutions will cause a slight increase in CO_2 emissions either through heat losses or increased electricity use and as such will not be selected as part of our automated solutions. Therefore, in reality there may be some additional measures and costs required for some of the properties to provide adequate background ventilation.

The small amount of ventilation measures identified in our automated Pathways modelling is where the software has identified energy intensive systems such as positive pressure systems whose removal would decrease the modelled CO_2 of the property.

6 Regulated and unregulated energy note

Regulated energy relates to use from fixed building services and fittings only i.e. heating and hot water, fans and pumps, ventilation and lighting. Unregulated energy relates to uncontrolled systems such as refrigeration, washing machines, computing, cooking and entertainment devices.

Our analysis is only concerned with, and only takes account of regulated energy. There will therefore be additional CO_2 associated with unregulated energy that is not included in the analysis. As the vast majority will be electricity these will necessarily reduce in emissions as the grid continues to decarbonise.

7 Methodology

7.1 OVERVIEW

The work has consisted largely of:

- Producing a dataset for each property based on the data sources listed below.
- Analysis and computer modelling of the housing in London based on the data available.

The accuracy of the findings of this report is directly related to the accuracy and level of completeness of the data available.

7.2 PATHWAYS MODEL

The Pathways model uses data about building characteristics and resident behaviour to derive an accurate estimate of the annual energy and carbon usage of dwellings. It then applies an algorithm to derive the cost, savings and payback of a very wide variety of possible carbon saving measures tailored specifically based on their applicability to the individual dwelling and to the preferences and requirements of the client. Costs can be based on dwelling characteristics (e.g. wall insulation can be based on the sum of a flat rate and a per m^2 wall area) and so are realistically applied to each building in turn. The cost rates are derived from our experience of carrying out the work, but can be revised for any situation, for instance where a framework contract is in place for installation of measures.

In addition, the model and accompanying analysis allows custom initiatives to be applied: this functionality allows any realistic change to a building to be modelled, and affords a great deal of flexibility in allowing for future scenarios such as extensions or emerging innovative measures. The calculations used by the model are based on RdSAP 2012 which is the current version in operation for generating EPCs.

Where details are unknown (e.g. loft insulation, heating type) assumptions are made based on expected proportions of houses with a particular characteristic. Where possible, this is done based on known statistics from the similar and/or surrounding stock. Where this is not possible assumptions can be made using other data sources, or based on sensible estimates. The assumptions made for this analysis are stated in the report.

Pathways produces estimated current fuel use for every dwelling considered in an area, in parallel with estimated fuel use and typical installation cost for every energy/CO_2 saving measure that can be applied to each dwelling. These model outputs can be used to derive cost savings, carbon savings, paybacks, and so on. It should be understood that where the model outputs are based on assumptions, they should be used primarily as a strategic tool as outputs for individual dwellings may have limited applicability.

7.3 DATA

In order to complete the analysis, we have populated a full RdSAP data set for each property in the borough, along with a few additional fields that allow for more granular application of measures e.g. window type.

The data sources and there uses and relative coverage are given in the table below:

Table 17 Data sources used in the analysis

Source	Key fields	Coverage	Comments
Open EPC data	Subset of RdSAP fields including Building Age, total floor area, key fabric types and efficiencies, summary level heating type and efficiencies	~40%	The complete underlying RdSAP dataset it's not available, but we have built a process to reverse engineer what is available to populate the potential options for the vast majority of RdSAP data fields.
Postcode Address File	Postal address	100%	
Conservation Areas	Shape files of Conservations areas	100%	Used alongside OS AddressBase to determine whether a property is in a Conservation Area.
OS Mastermap	Footprint of each property to inform floor area and property type and attachment.	100% of standalone properties	Also used to select nearby properties for cloning.
OS Addressbase	Location of each property	100%	
LIDAR	Provides a 3D representation of an area at reasonable resolution	100% of standalone properties	Informs storey height, roof area, roof type, roof pitch and PV suitability.
LSOA Defaults	Age, wall type, wall finish, window type, house storeys, flat type	100% at LSOA level	Informs which of the options determined from the Open EPC data to select if they are included in the options.

Once a RdSAP dataset has been completed for each property with Open EPC data, the options determined for each field are iterated five times and the corresponding SAP score compared to the one know from the Open EPC data. The combination of options that is most close to the Open EPC SAP score is then selected.

7.3.1 Data Confidence

Our methodology records a subjective confidence for each data point for each property. These can be viewed with Pathways. Because of the nature of the methods used to populate the data, properties in Pathways generally fall into two categories of confidence – those for which there was underlying EPC data and those where there is no underlying EPC data.

7.4 OVERVIEW AND EXPLANATION OF REPORT CONCEPTS / TERMINOLOGY

This section provides a brief introduction to some of the methods, concepts and terminology used in this report, and in the underlying analysis.

7.4.1 SAP

SAP stands for Standard Assessment Process. It is a method for assessing the energy performance of houses using a standard methodology specified by the UK government. The current version of SAP is SAP 2012, and it calculates a 'SAP rating' as well as an estimate of energy bills and CO_2 emissions associated with the estimated energy use.

The SAP calculations are based on building dimensions, construction (and therefore energy performance) of building elements such as walls and windows, details of the heating and hot water systems and controls, and any installed renewable technologies including solar PV panels. The number and percentage of low energy light fittings is noted, but the calculations do not take note of other electrical appliances and actual occupancy and heating usage (temperatures, heating hours, hot water usage etc.), or actual fuel tariffs (standard typical energy prices are used).

A SAP survey is a relatively time consuming process (perhaps 2 hours work), and is usually only required for new build housing etc.

7.4.2 RdSAP

RdSAP is the method used to produce Energy Performance Certificates (EPCs). RD stands for Reduced Data, and the method is designed to allow surveys to be completed more quickly and therefore more cheaply than a full SAP survey at some cost of accuracy. The reduced data survey is extrapolated up to full SAP level data using a standard set of rules before SAP calculations can be conducted. The current version of RDSAP is 9.93.

7.4.3 Link between SAP score and fuel bills

The SAP score is a number, nominally between 1 and 100, which is calculated using a slightly abstruse algorithm which takes as inputs the floor area and estimated fuel bills. The SAP score is divided into rating bands which are used in EPCs. A higher SAP score is better than a lower SAP score, and a typical Registered Provider currently has a SAP score around 70. [Note: it is theoretically possible to have a SAP score above 100 if energy bills are negative (e.g. if exported energy fees exceed bills for energy used.)]

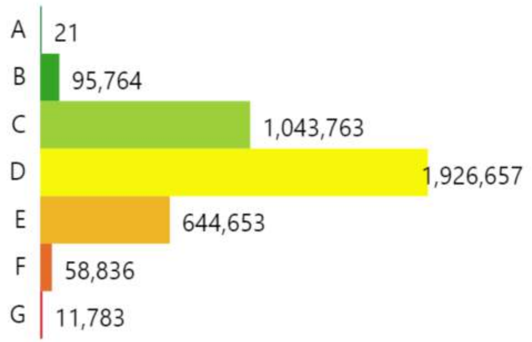
7.4.4 General Approach

Throughout our analysis we have used RdSAP as the basis for our calculations of SAP score, CO_2 emissions and fuel bills.

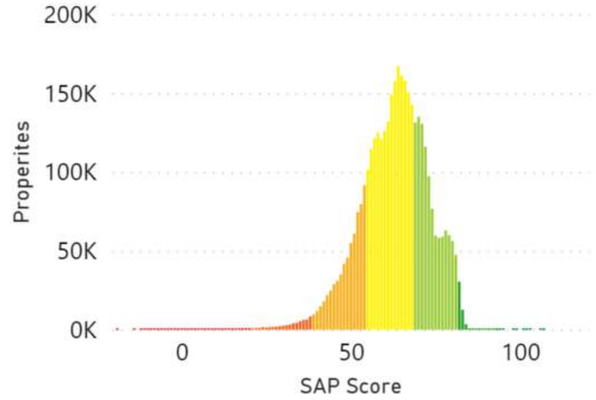
8 Appendix A – Large version figures

SAP

No. properties by SAP band



Band	Range	%
A	92 Plus	0.0%
B	81-91	2.5%
C	69-80	27.6%
D	55-68	50.9%
E	39-54	17.0%
F	21-38	1.6%
G	0-20	0.3%



62.83
Average SAP Score

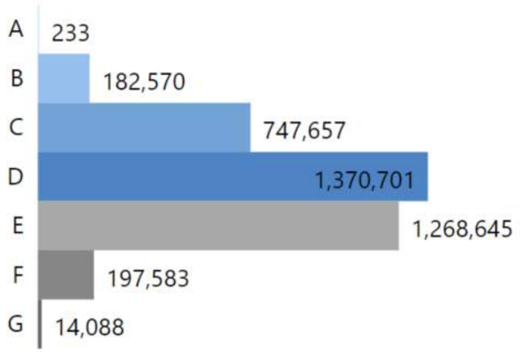
45.08
95% above this score

33.08
99% above this score

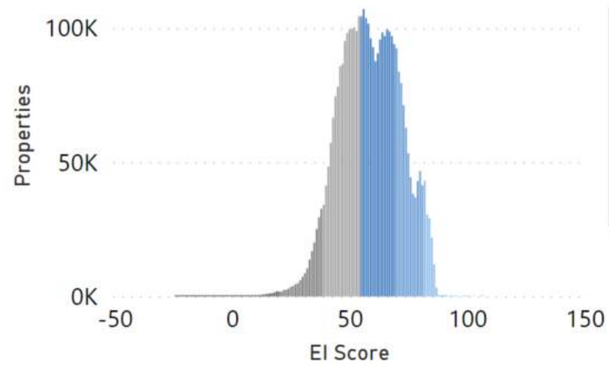
Figure 55

EI (Environmental Impact)

No. properties by EI band



Band	Range	%
A	92 Plus	0.0%
B	81-89	4.8%
C	69-80	19.8%
D	55-68	36.2%
E	39-54	33.5%
F	21-38	5.2%
G	1-20	0.4%



58.61
Average EI Score

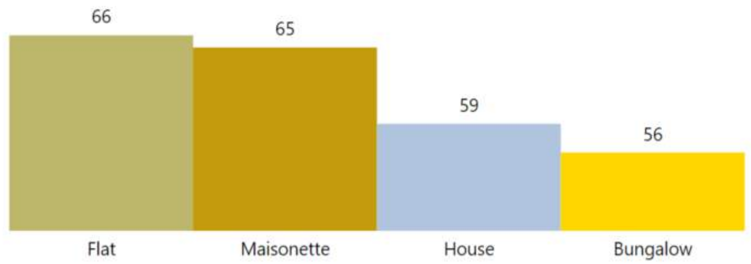
37.81
95% above this score

27.88
99% above this score

Figure 56

SAP and EI by property type

Average SAP



Average EI

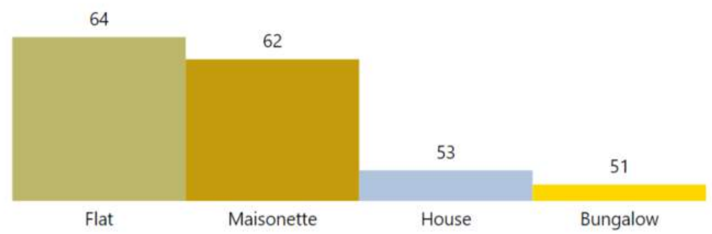
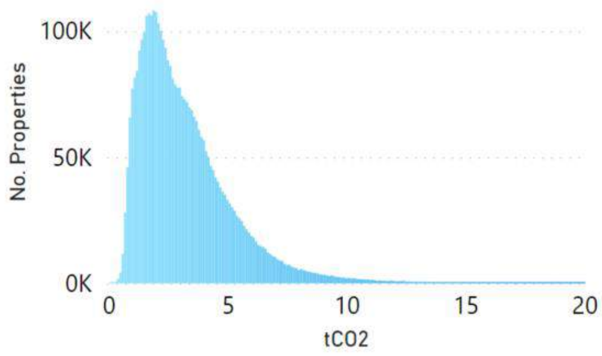


Figure 57

CO2

CO2 profile



3.28
Average tCO2 in 2019

3.01
Average tCO2 in 2038

7.17
Figure 95% are below

Grid intensity projections kgCO2e/kWh

Figure 58

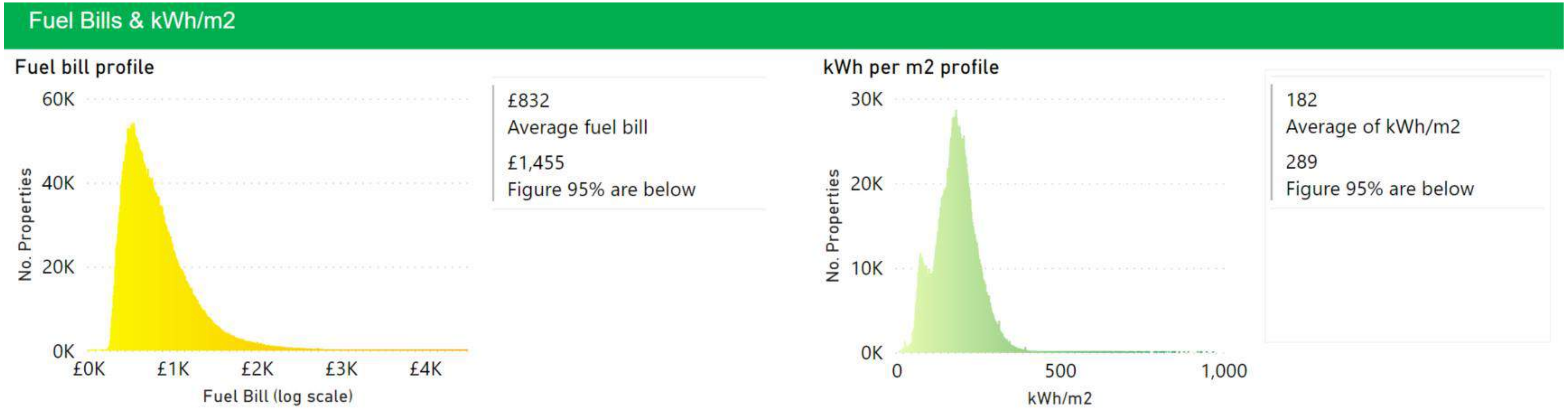

Fuel Bills & kWh/m2
Fuel bill profile
60K
40K
20K
0K
No. Properties
£0K
£1K
£2K
£3K
£4K
Fuel Bill (log scale)
£832
Average fuel bill
£1,455
Figure 95% are below
kWh per m2 profile
30K
20K
10K
0K
No. Properties
0
500
1,000
kWh/m2
182
Average of kWh/m2
289
Figure 95% are below

Figure 59

CO_2 segmentation

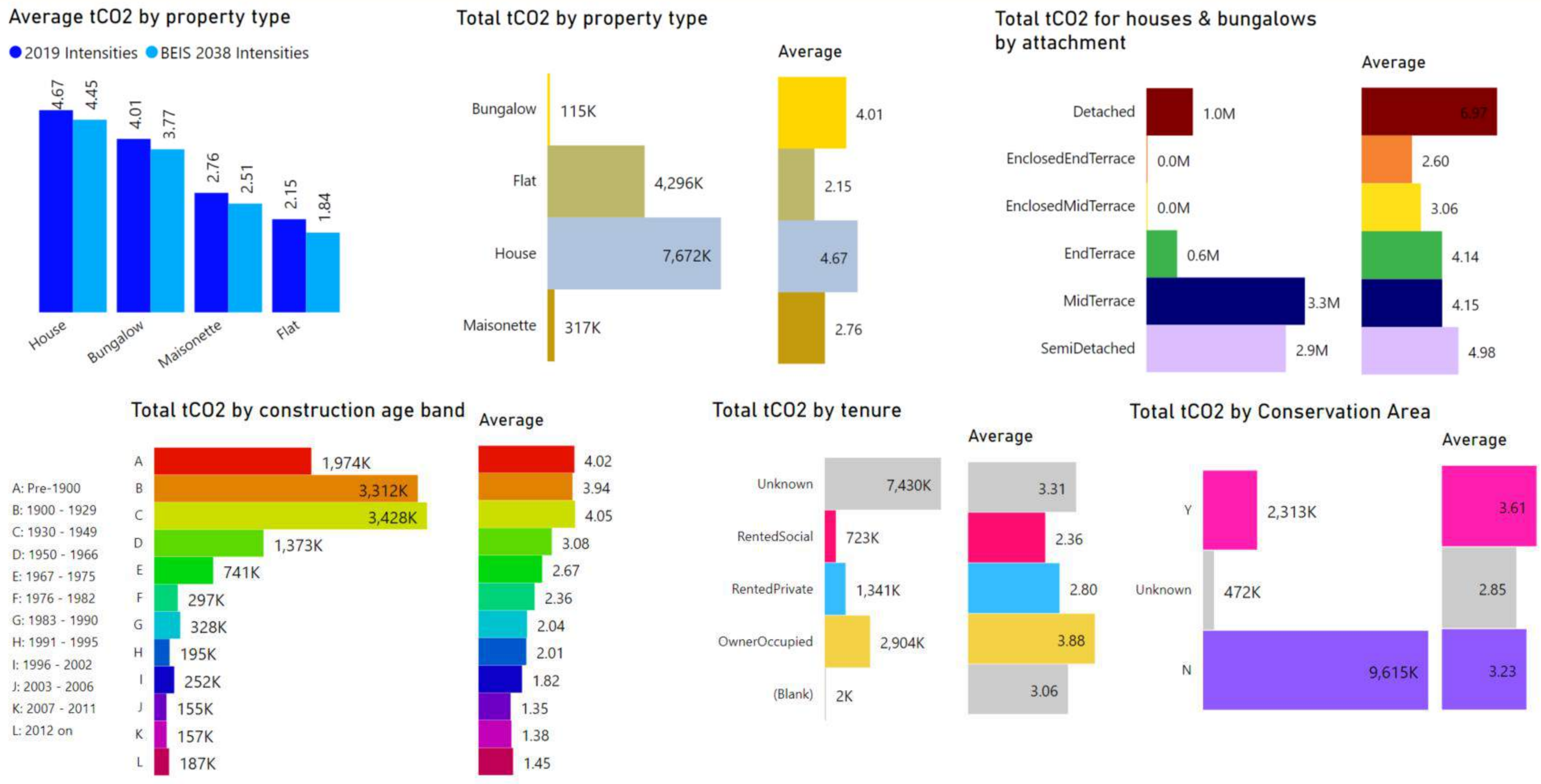
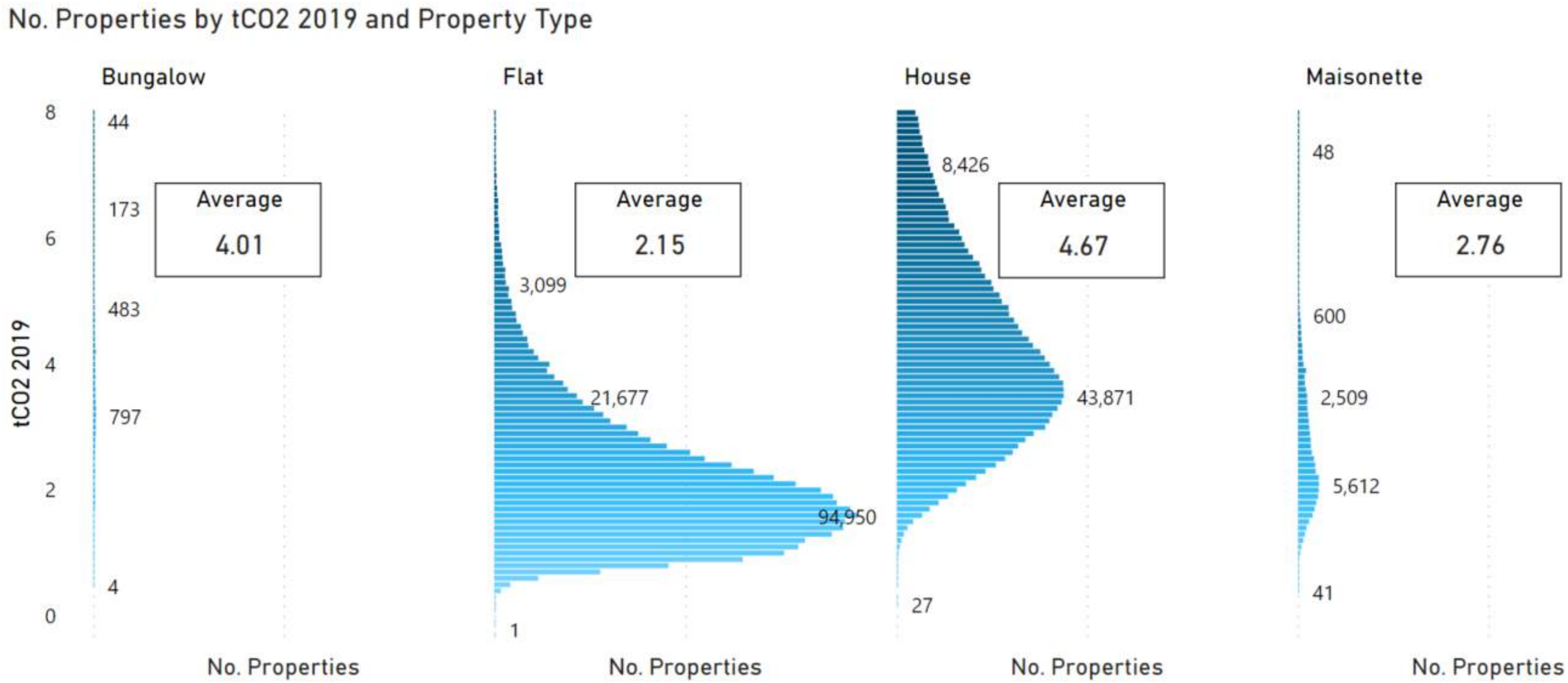


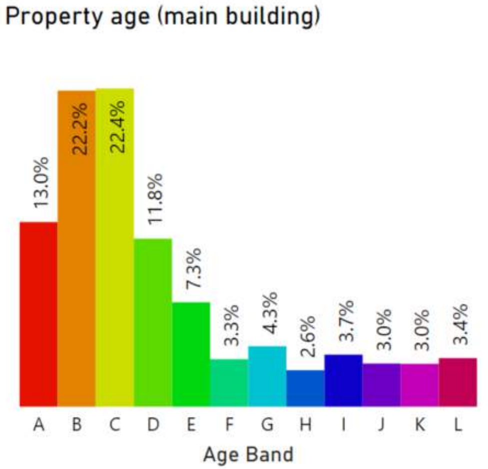
Figure 60



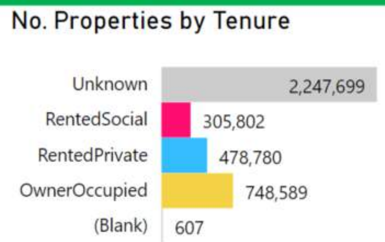
No. Properties by tCO2 2019 and Property Type
Bungalow
Flat
House
Maisonette
tCO2 2019
8
6
4
2
0
44
173
483
797
4
Average
4.01
3,099
21,677
94,950
1
Average
2.15
8,426
43,871
27
Average
4.67
48
600
2,509
5,612
41
Average
2.76
No. Properties
No. Properties
No. Properties
No. Properties

Figure 61

Property Age & Tenure



A: Pre 1900	490,880	Predominantly solid brick or stone until 1930s
B: 1900-1929	840,420	
C: 1930-1949	846,118	Cavity walls became the standard
D: 1950-1966	446,588	System builts are common
E: 1967-1975	277,519	System builts are common
F: 1976-1982	126,229	
G: 1983-1990	160,781	Cavities are built with insulation from this point on
H: 1991-1995	96,942	Age bands from here reflect updates to Building Regs
I: 1996-2002	138,300	
J: 2003-2006	114,764	
K: 2007-2011	113,812	
L: 2012 onwards	129,124	



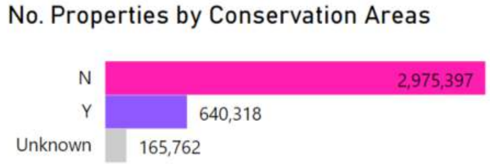
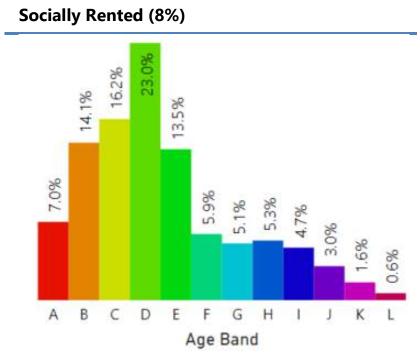
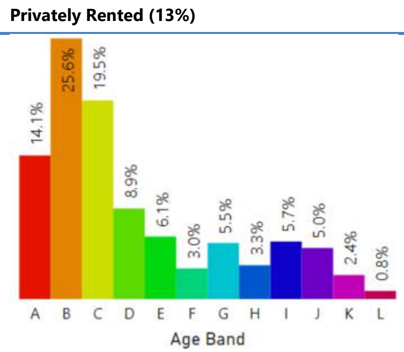
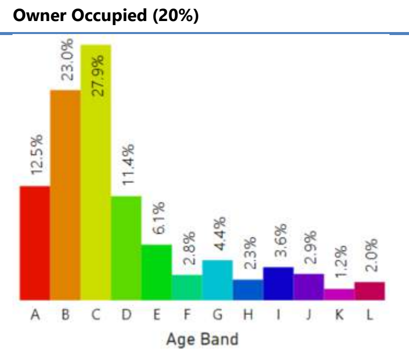


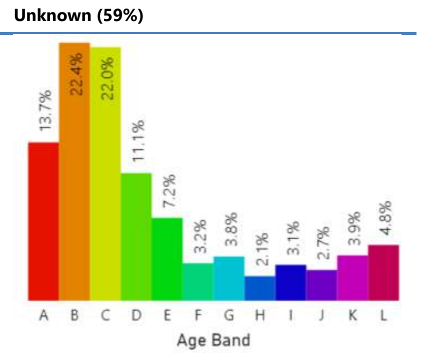
Figure 62

Table 18









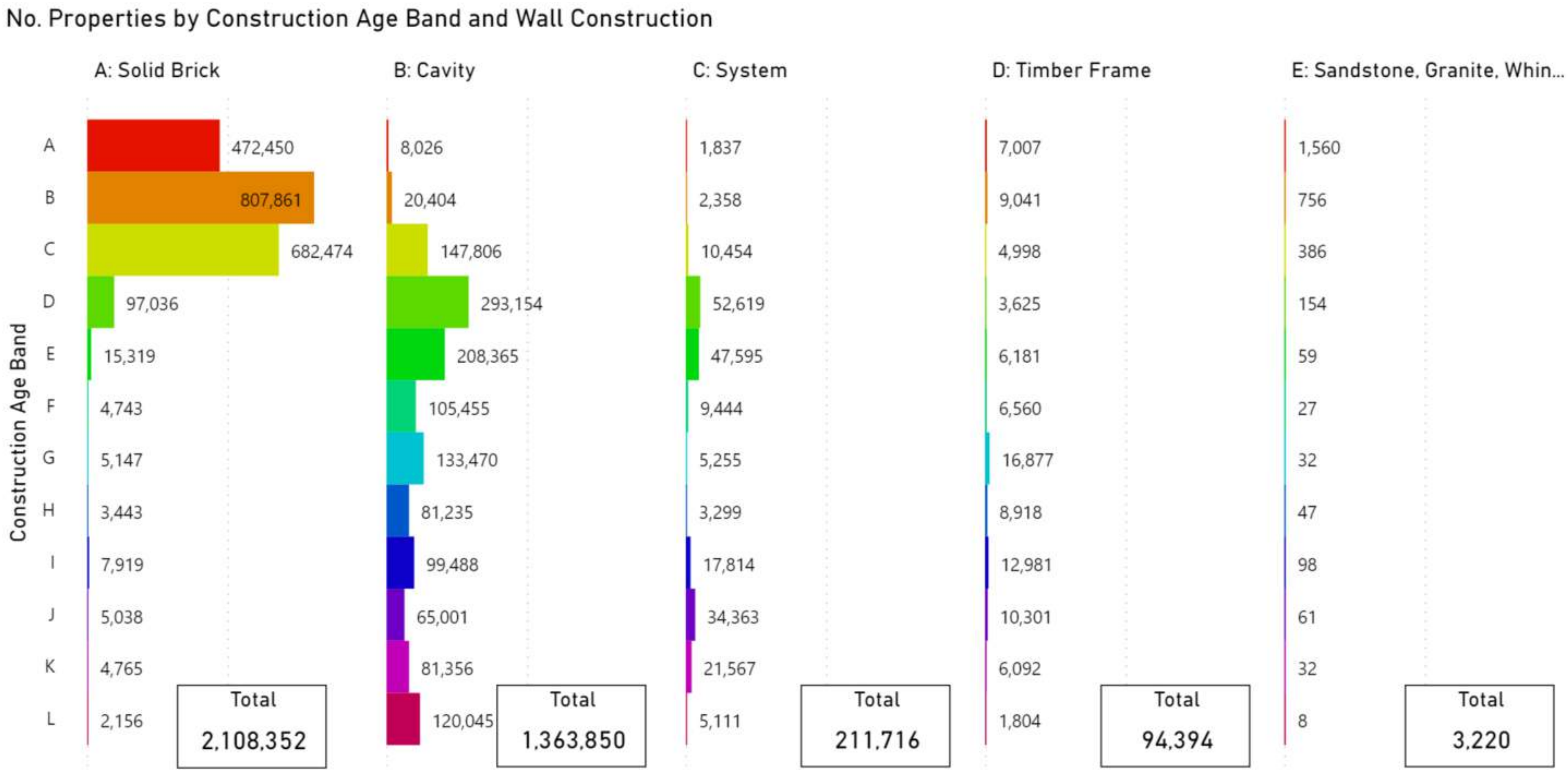

No. Properties by Construction Age Band and Wall Construction
A: Solid Brick
B: Cavity
C: System
D: Timber Frame
E: Sandstone, Granite, Whin...
Construction Age Band
A
B
C
D
E
F
G
H
I
J
K
L
472,450
807,861
682,474
97,036
15,319
4,743
5,147
3,443
7,919
5,038
4,765
2,156
Total
2,108,352
8,026
20,404
147,806
293,154
208,365
105,455
133,470
81,235
99,488
65,001
81,356
120,045
Total
1,363,850
1,837
2,358
10,454
52,619
47,595
9,444
5,255
3,299
17,814
34,363
21,567
5,111
Total
211,716
7,007
9,041
4,998
3,625
6,181
6,560
16,877
8,918
12,981
10,301
6,092
1,804
Total
94,394
1,560
756
386
154
59
27
32
47
98
61
32
8
Total
3,220

Figure 63

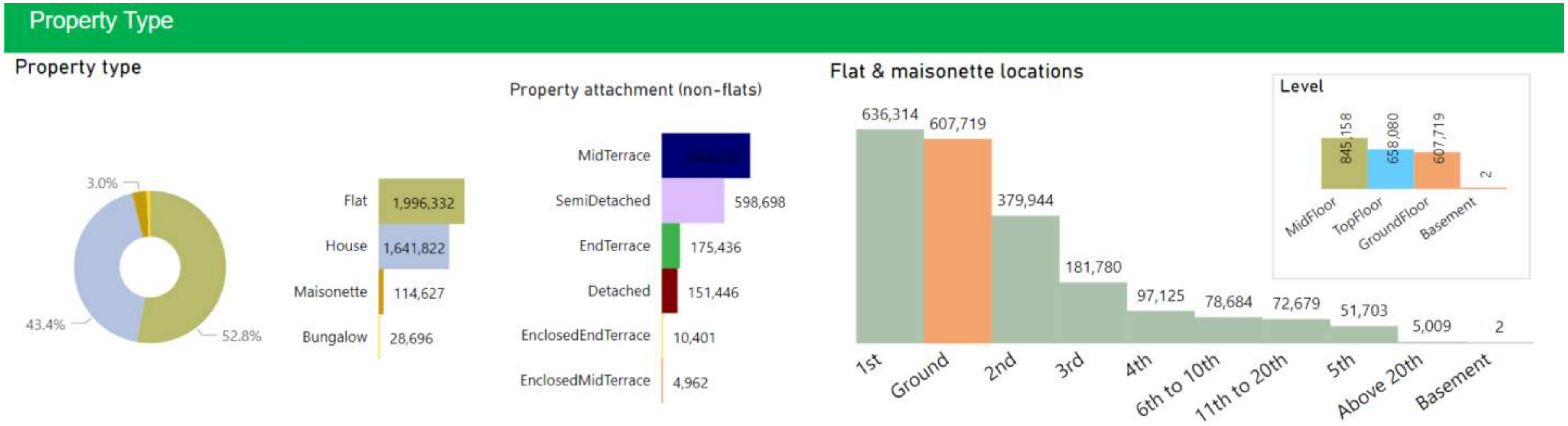


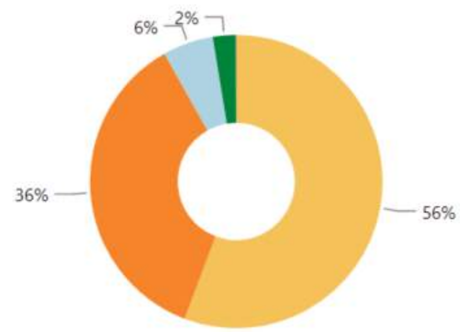
Figure 64

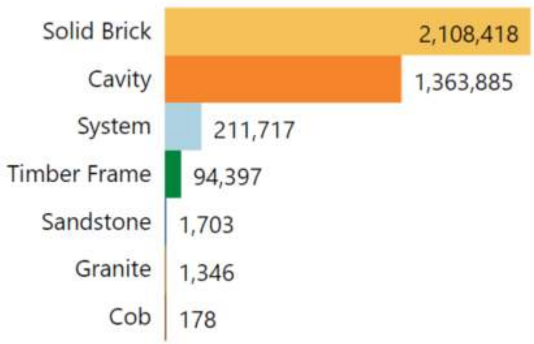
Table 19

Socially Rented (8%)		Privately Rented (13%)		Owner Occupied (20%)		Unknown (59%)	
Flat	191,645	Flat	299,076	House	442,229	Flat	1,255,184
House	85,479	House	145,406	Flat	249,984	House	968,564
Maisonette	24,940	Maisonette	31,079	Maisonette	37,418	Maisonette	21,170
Bungalow	3,738	Bungalow	3,219	Bungalow	18,958	Bungalow	2,781

Walls

Wall construction





Uninsulated walls

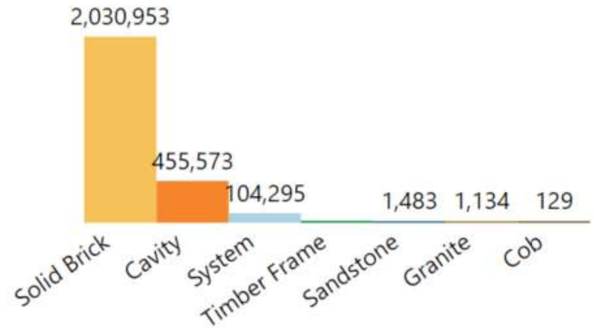
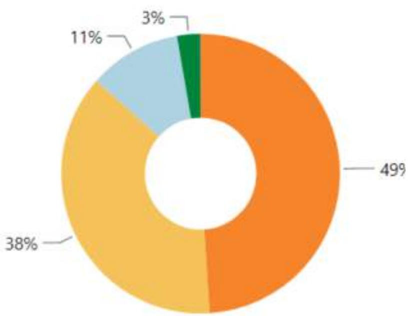
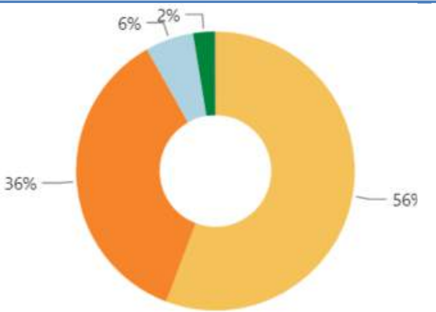
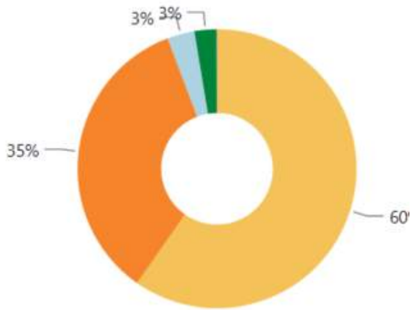
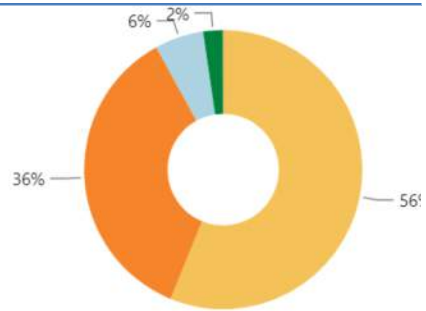


Figure 65

Table 20

Socially Rented (8%)	Privately Rented (13%)	Owner Occupied (20%)	Unknown (59%)
			

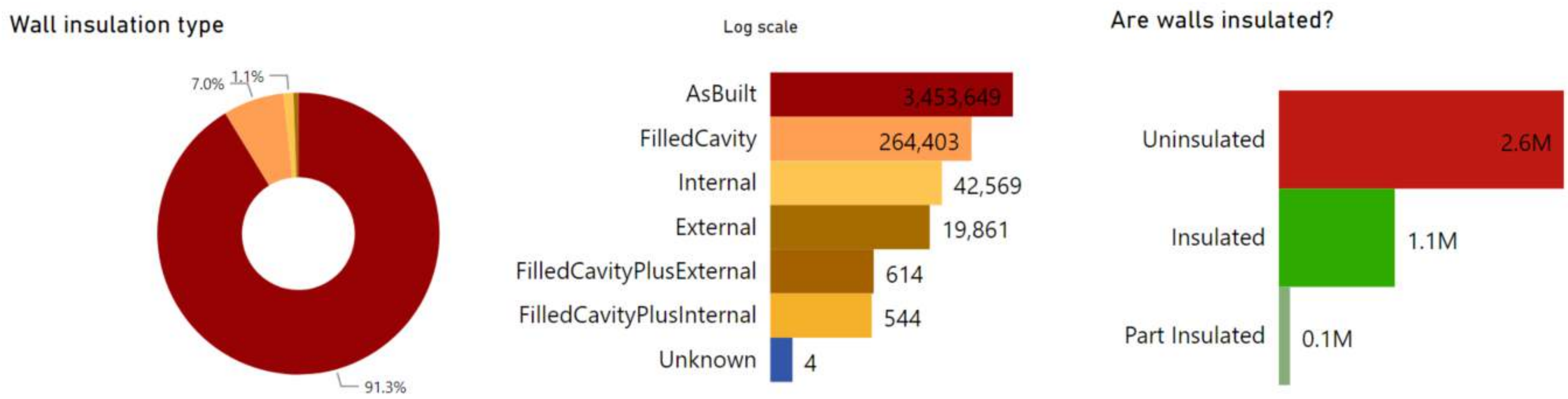

Wall insulation type
7.0%
1.1%
91.3%
Log scale
AsBuilt
3,453,649
FilledCavity
264,403
Internal
42,569
External
19,861
FilledCavityPlusExternal
614
FilledCavityPlusInternal
544
Unknown
4
Are walls insulated?
Uninsulated
2.6M
Insulated
1.1M
Part Insulated
0.1M

Figure 66

Roofs

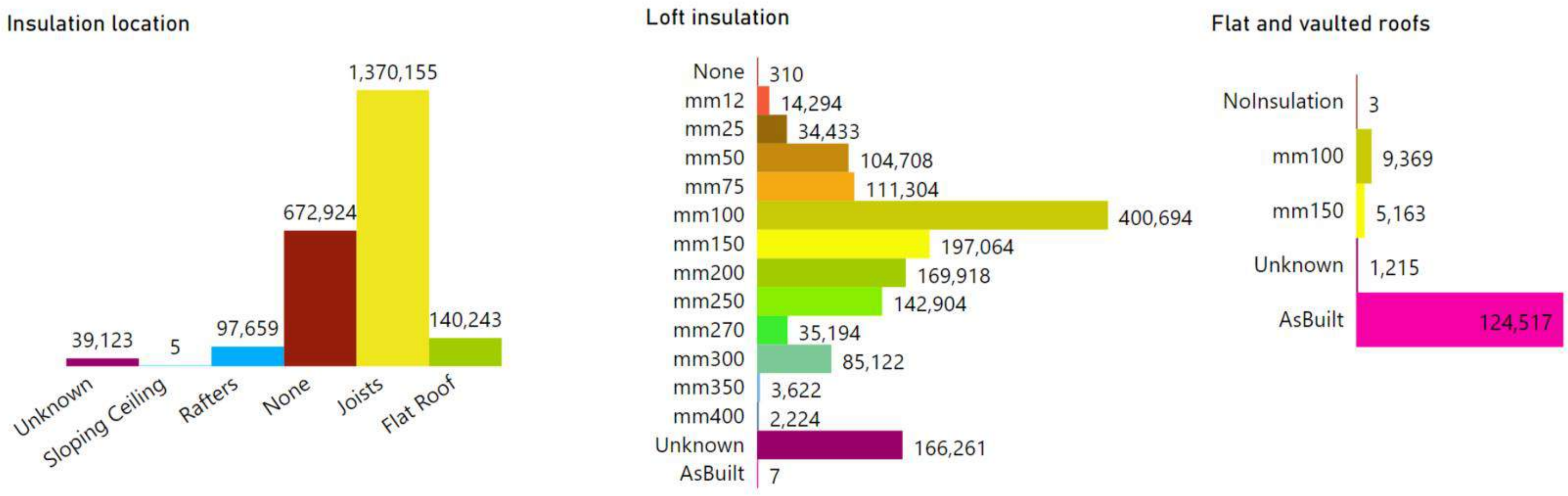


Figure 67

Floors

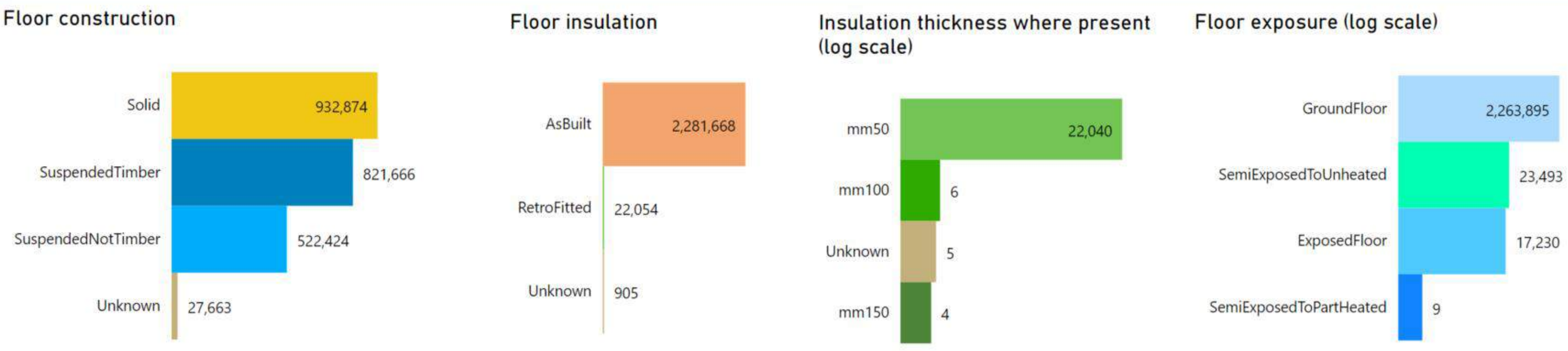


Figure 68

Windows

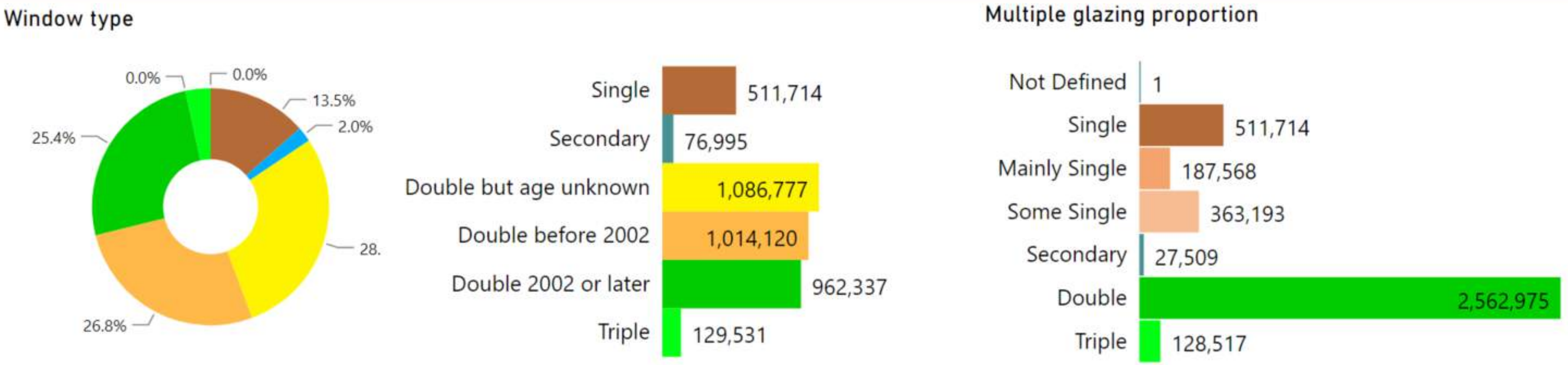
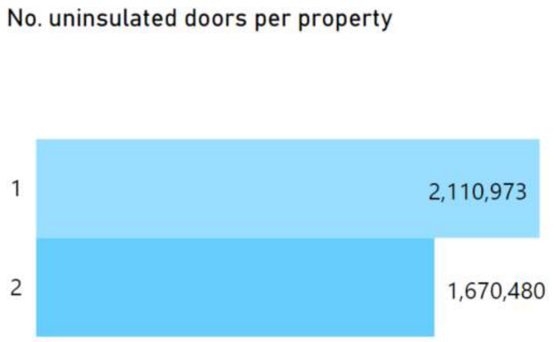


Figure 69

Doors & Draughtproofing



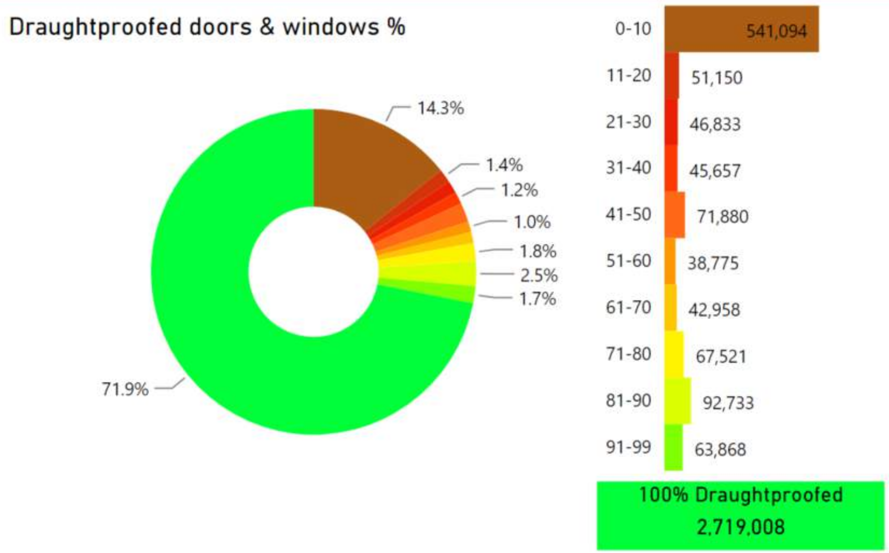


Figure 70

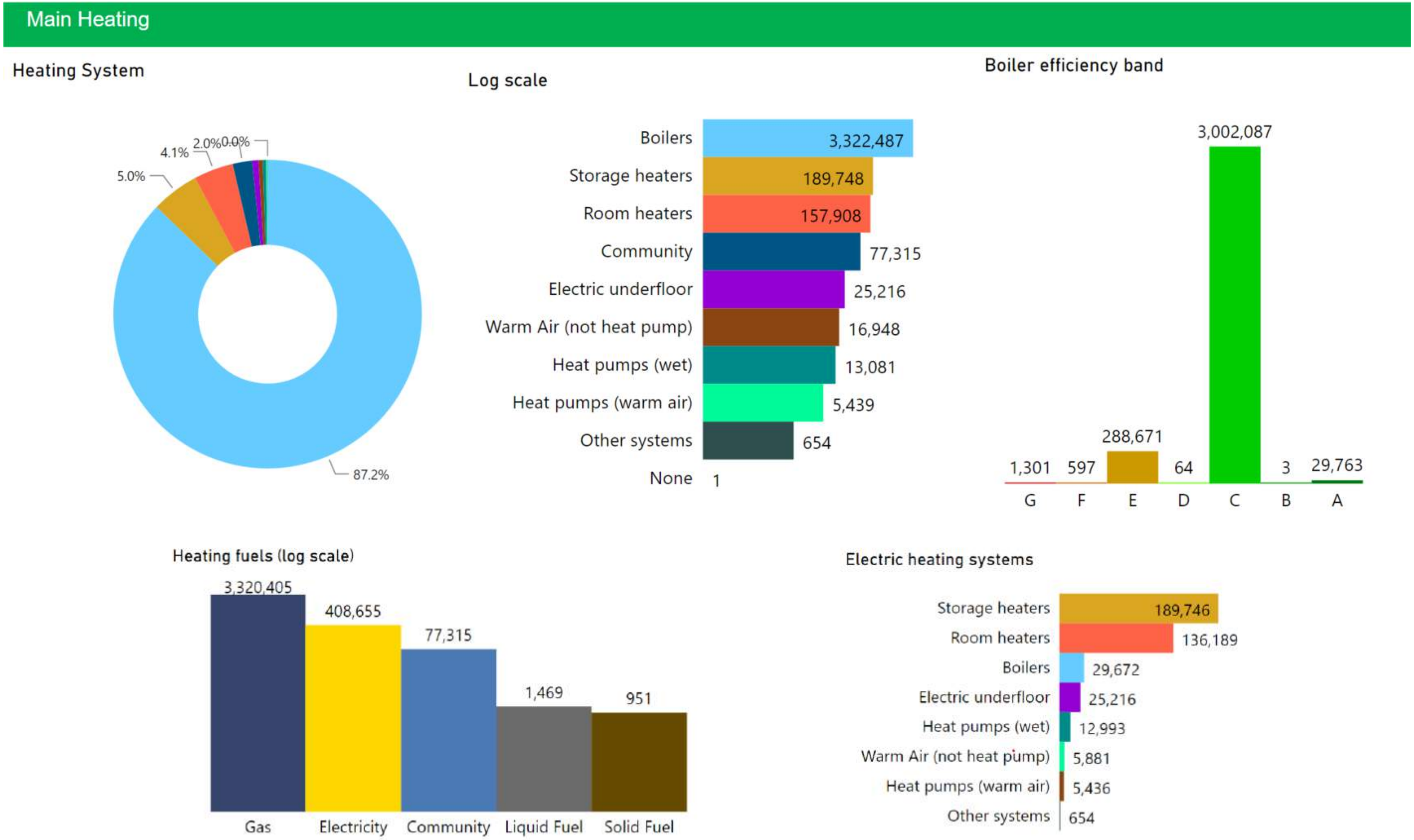
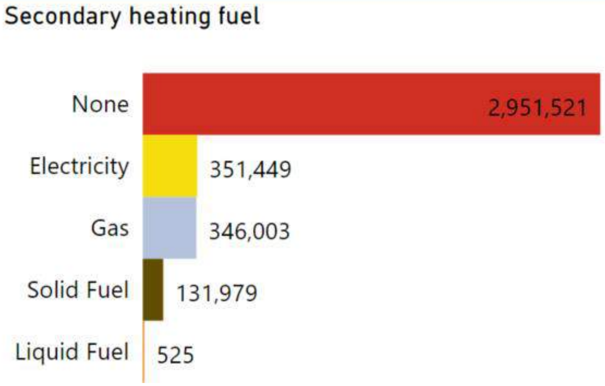

Main Heating
Heating System
4.1%
2.0%
0.0%
5.0%
87.2%
Log scale
Boilers
3,322,487
Storage heaters
189,748
Room heaters
157,908
Community
77,315
Electric underfloor
25,216
Warm Air (not heat pump)
16,948
Heat pumps (wet)
13,081
Heat pumps (warm air)
5,439
Other systems
654
None
1
Boiler efficiency band
3,002,087
288,671
1,301
597
64
3
29,763
G
F
E
D
C
B
A
Heating fuels (log scale)
3,320,405
408,655
77,315
1,469
951
Gas
Electricity
Community
Liquid Fuel
Solid Fuel
Electric heating systems
Storage heaters
189,746
Room heaters
136,189
Boilers
29,672
Electric underfloor
25,216
Heat pumps (wet)
12,993
Warm Air (not heat pump)
5,881
Heat pumps (warm air)
5,436
Other systems
654

Figure 71

Secondary Heating



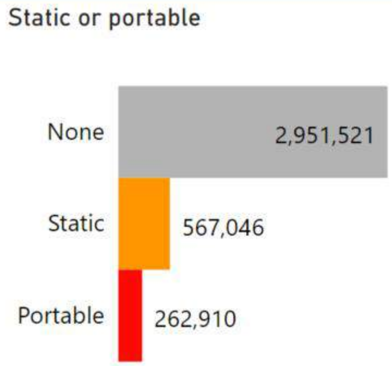
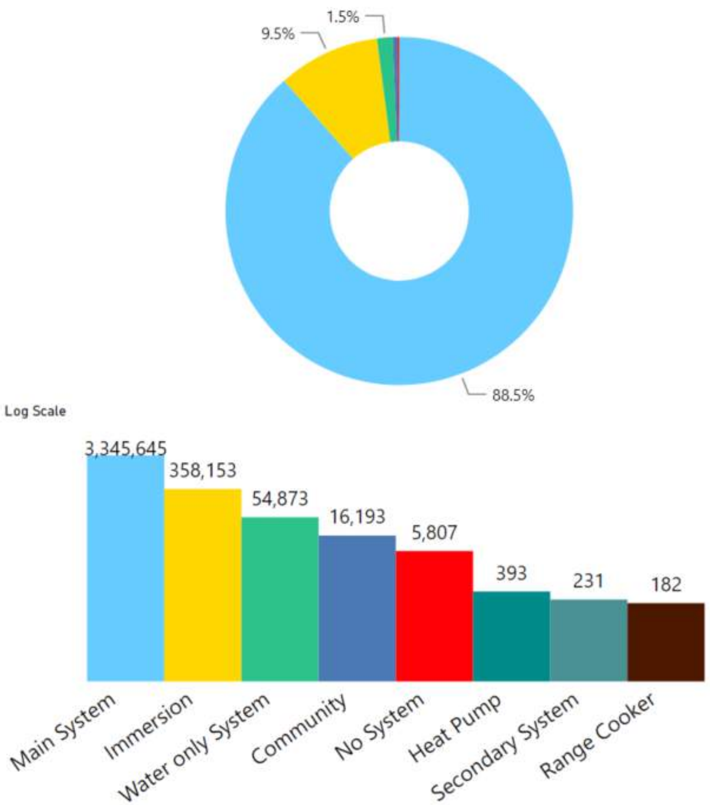


Figure 72

Hot Water

Hot water type



Hot water fuel (log scale)

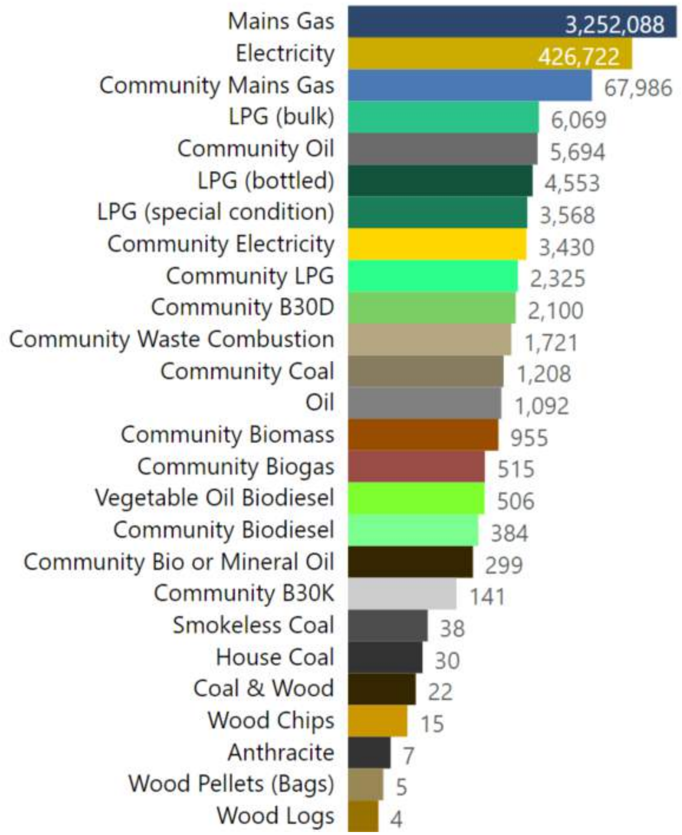
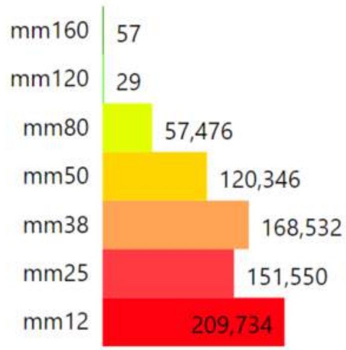
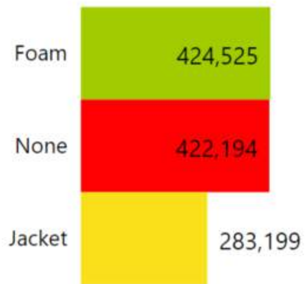


Figure 73

Cylinder insulation thickness



Cylinder insulation type



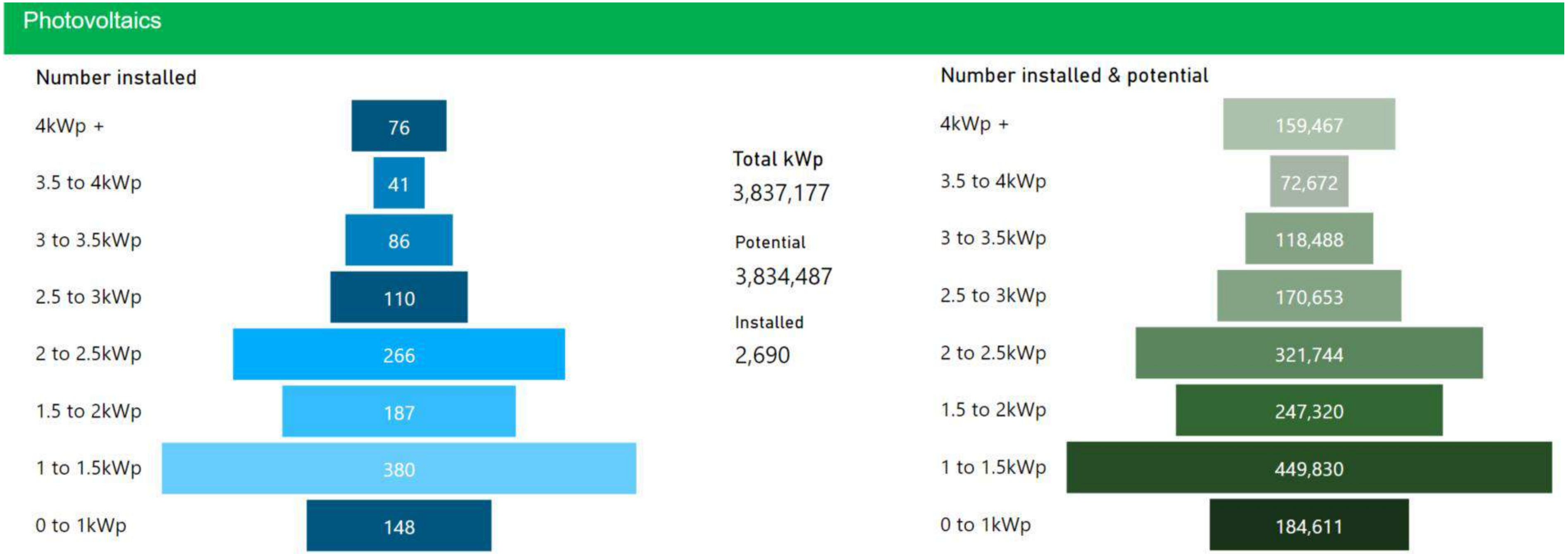
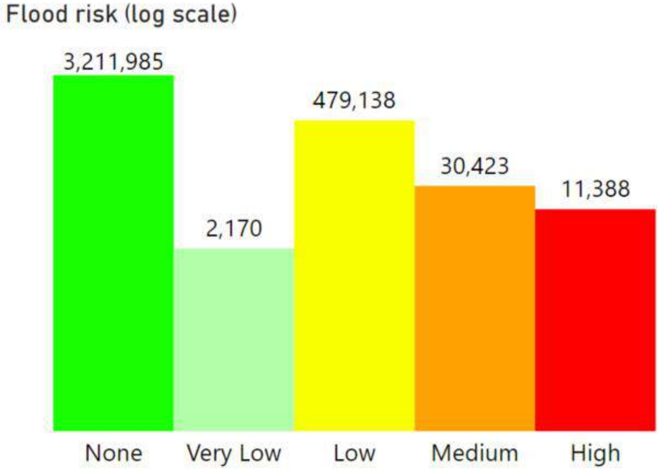

Photovoltaics
Number installed
4kWp +
76
3.5 to 4kWp
41
3 to 3.5kWp
86
2.5 to 3kWp
110
2 to 2.5kWp
266
1.5 to 2kWp
187
1 to 1.5kWp
380
0 to 1kWp
148
Total kWp
3,837,177
Potential
3,834,487
Installed
2,690
Number installed & potential
4kWp +
159,467
3.5 to 4kWp
72,672
3 to 3.5kWp
118,488
2.5 to 3kWp
170,653
2 to 2.5kWp
321,744
1.5 to 2kWp
247,320
1 to 1.5kWp
449,830
0 to 1kWp
184,611

Figure 74

Flood Risk - Contains public sector information licensed under the Open Government Licence v 3.0



The map shows the number of **Medium** and **High** per postcode.

The size of each circle is proportional to the number of properties.

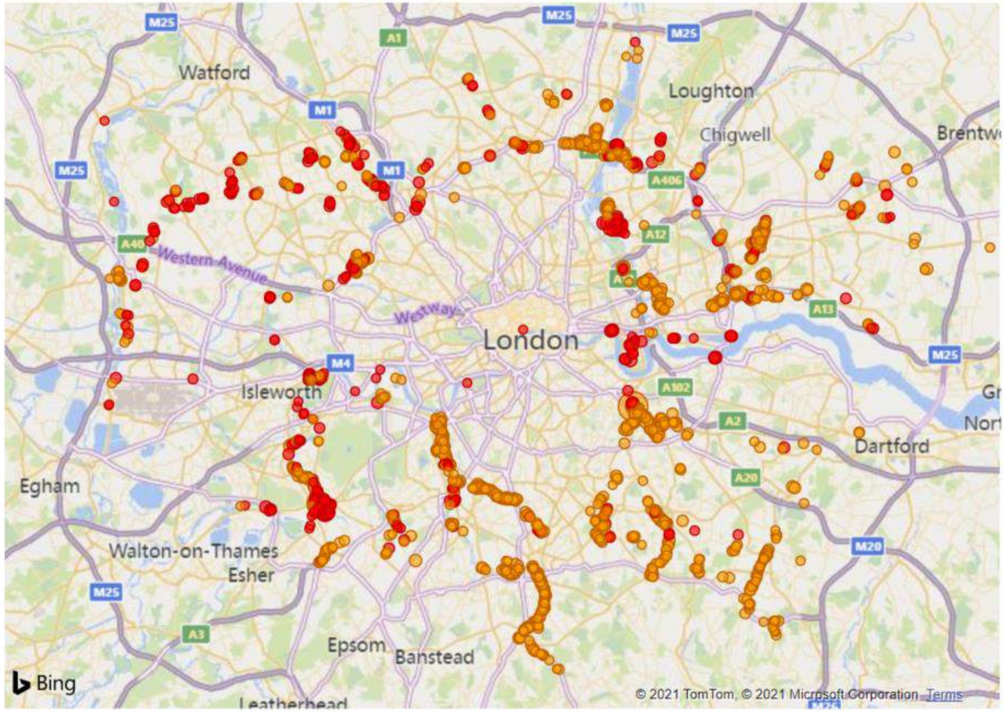


Figure 75

Fuel Poverty Risk - based on Government published data drawn from English Housing Survey

The number of filtered properties that are located in LSOAs with the stated Fuel Poverty Risk %. For example 1,842,918 properties are in an LSOA that has over 10% to 15% of the households expected to be in fuel poverty. N.B. if your properties are only a subset of the properties in the LSOA then you should not expect the % risk to directly apply to your properties as they may not be representative of the LSOA.

Band	Properties
Greater than 30% Band	14,012
25% to 30% Band	22,969
20% to 25% Band	87,161
15% to 20%	522,338
10% to15% Band	1,828,906
5% yo 10% Band	1,204,352
Less than 5% Band	55,366

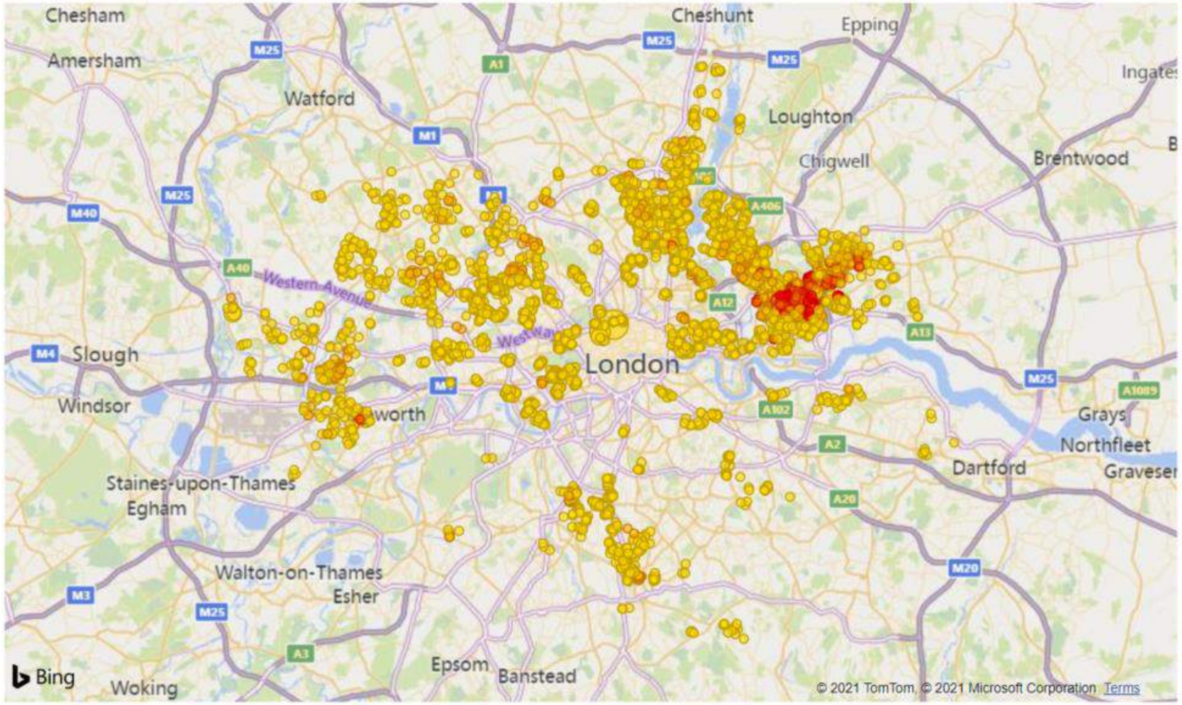


Figure 76

9 Appendix B Additional Analysis carried out by Parity Projects, Etude, RAFT & Elementa

It is crucial for the metrics used on this project to reflect its strategic objective: **addressing the climate emergency**.

Unfortunately, the EPC band and the SAP score are **energy cost** indicators. Using them as a metric for energy efficiency or carbon emissions is not appropriate.

The adjacent table summarises some of the metrics which could be used and what they would incentivise. It is clear that a single metric cannot drive all required objectives.

We therefore recommend the selection of more than one.

Would the metric incentivise...

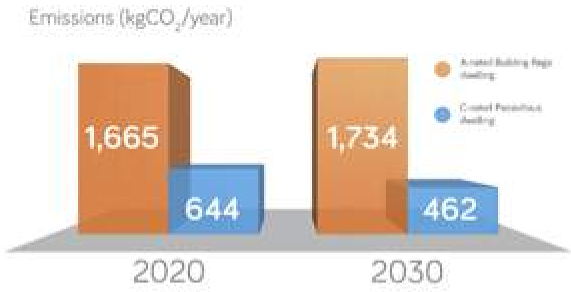
Metric ↓	... reduction of carbon emissions?	... reduction of energy use?	... reduction of energy costs?	... engagement with consumers?
EPC band or SAP Score [A-G] o [0-100]	✗	~	✓	~
Space heating demand [kWh/m²/yr]	~	✓	✓	✗
Carbon (long term) [kgCO_2/m²/yr]	✓	~	~	~
Total energy use [kWh/m²/yr]	~	✓	✓	✓
Regulated energy use [kWh/m²/yr]	~	✓	✓	✗

Why the use of an EPC metric can be misleading

These examples illustrate how the use of an energy cost metric (EPC band or SAP score) can be misleading.

It is a particular issue for addressing one of the key challenges associated with the climate emergency: the decarbonisation of heat. One of the most important challenges for Zero Carbon London is to phase out the use of gas boilers gradually, starting as quickly as we can.

If we use a metric which does not encourage that (e.g. EPC band, SAP score, space heating demand), it is crucial that the proportion of gas boilers is monitored with the aim of it reducing steadily.



Dwelling	EPC Rating	Emission Rate with 2020 SAP Figures ($kgCO_2$/year)	Emission Rate with 2030 Projections ($kgCO_2$/year)
Single storey 100m² with gas heating and hot water. Building Regulations fabric standards. 2.5kWp of PV.	A(93)	1665	1734
Two storey 100m² with electric heating and hot water. Passivhaus fabric standards. No PV.	C(80)	644	462

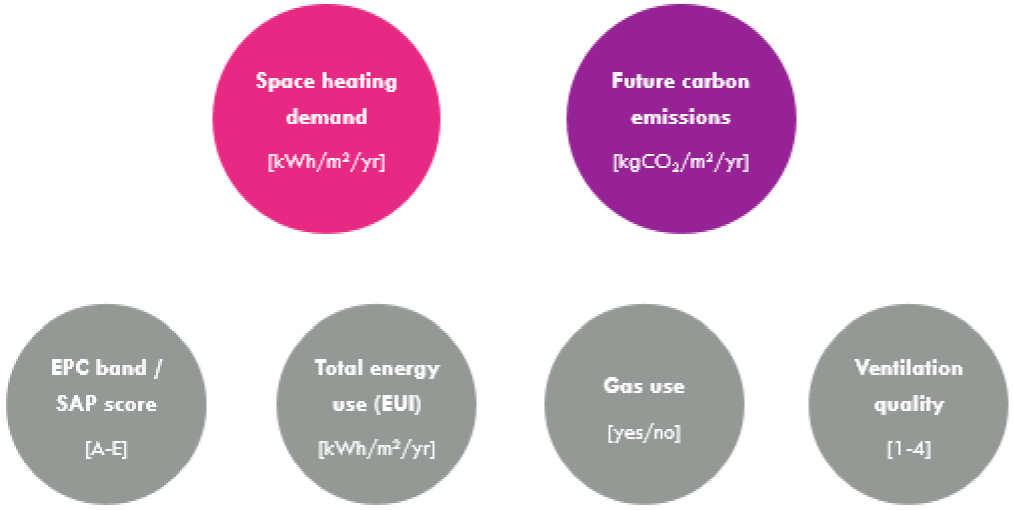
	EPC Band	Overall Energy Demand (kWh/year)
Baseline	D (58)	24,249
Energy Efficiency Measures	C (69)	16,468
Add ASHP	D (60)	7,425

We would recommend using **2 key metrics and 4 indicators.**

1. The first metric will inform choices on how to improve the **energy efficiency** of the building stock in London. For this, **space heating demand [kWh/m²/yr]** is the best metric.
2. The second metric will inform choices on the **decarbonisation of heat** and the installation of solar PVs on roofs. **Predicted future carbon emissions [kgCO_2/m²/yr]** [1] will be a suitable metric for this.

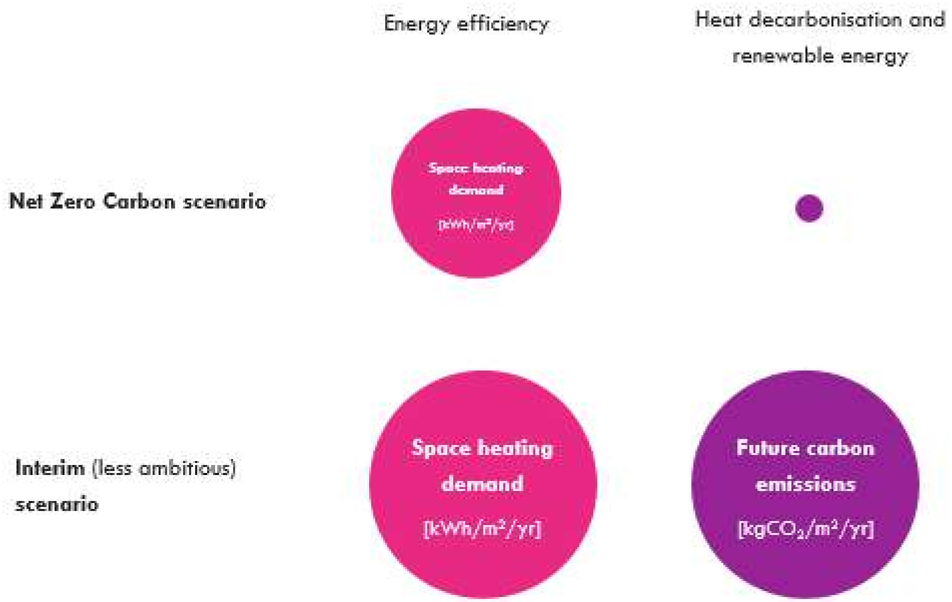
The other recommended indicators are:

- The **EPC band [A-G] or the SAP score [0-100]** as an indicator of energy costs and therefore risk of fuel poverty.
- The **total energy use** (gas and electricity) of the dwelling **[kWh/m²/yr]** as it can easily be checked post-retrofit and is becoming a key indicator in the industry.
- Whether the dwelling **uses gas [yes/no]** as it is a key marker.
- **Ventilation quality [1-4]** to ensure that insulation and airtightness improvements are accompanied by adequate ventilation.



[1] *This should be calculated using the projected carbon factors for gas and electricity published by BEIS. It would ideally be the cumulative emissions over the period 2022-2050 averaged over a year but it could also be the forecasted emissions for a particular year (e.g. 2030 or 2038)*

We would also recommend using a **Net Zero compliant scenario and a budget limited target** using the same metrics but higher (less ambitious) targets.



London Retrofit Action Plan | Which requirements?

Parity Projects have modelled some scenarios on a sample of properties in Waltham Forest to help us determine what combination of **space heating demand** and **predicted future carbon emissions** would work best to form the Net Zero Carbon scenario or the alternative scenario, and deliver an average EPC B.

Parity Projects have modelled 3 variations of each to give 6 scenario combinations, and then another 3 scenarios with dwellings split in several tranches.

The objective is to choose two sets of requirements.

-

Energy efficiency	**Heat decarbonisation and solar PVs**	**Energy costs**
Space heating demand	**Carbon emissions** (long term, e.g. 2038)	**EPC** (or SAP score)
95 kWh/m²/yr (average)	Flats 1 tCO_2 Bungalows 1.5 tCO_2 Houses 2 tCO_2	EPC C (average for all properties)
65 kWh/m²/yr (average)	Flats 0.75 tCO_2 Bungalows 1 tCO_2 Houses 1.5 tCO_2	EPC B (average for all properties)
35 kWh/m²/yr (average)	Net Zero Carbon	EPC B (minimum for all properties)

London Retrofit Action Plan | Recommendation 3 | Net Zero scenario

For the Net Zero scenario we recommend targeting:

a) A **medium space heating demand of 65 kWh/m²/yr** on average in order to improve energy efficiency.

b) **Net Zero emissions** in order to identify what would be required and by when)

c) An **EPC B** (average across all properties)

-

Energy efficiency	Heat decarbonisation and solar PVs	Energy costs
Space heating demand	**Carbon emissions** (long term, e.g. 2038)	**EPC** (or SAP score)
95 kWh/m²/yr (average)	Flats 1 tCO_2 Bungalows 1.5 tCO_2 Houses 2 tCO_2	EPC C (average for all properties)
65 kWh/m²/yr (average)	Flats 0.75 tCO_2 Bungalows 1 tCO_2 Houses 1.5 tCO_2	EPC B (average for all properties)
35 kWh/m²/yr (average)	Net Zero Carbon	EPC B (minimum for all properties)

London Retrofit Action Plan | Recommendation 4 | Interim / Less ambitious scenario

For the interim/less ambitious **scenario** we recommend targeting:

a) A **medium space heating demand of 65 kWh/m²/yr** on average in order to improve energy efficiency ONLY FOR 50% OF DWELLINGS

b) **Net Zero emissions** ONLY ON 30% OF DWELLINGS

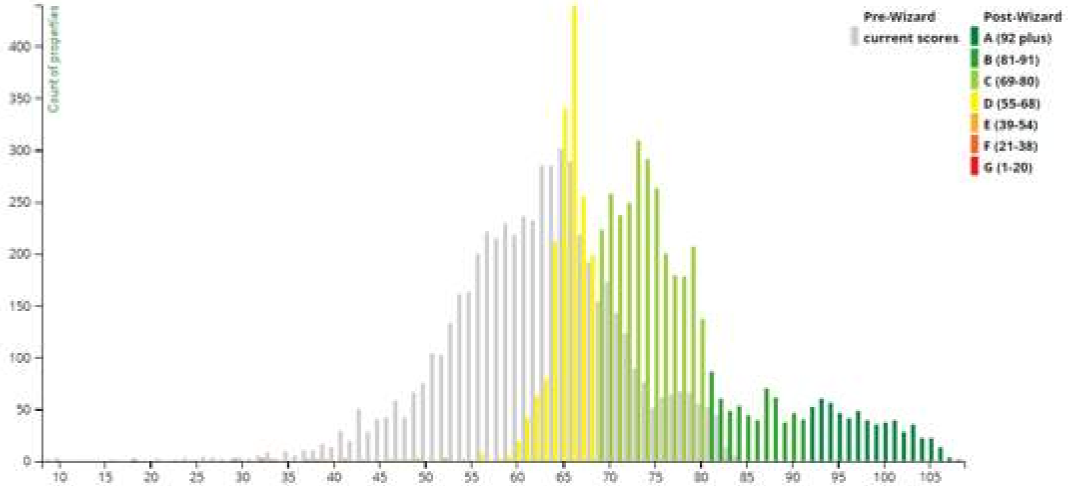
c) Minor improvements to the remaining 50% of dwellings

d) An **EPC B** (average across all properties)

Energy efficiency	**Heat decarbonisation and solar PVs**	**Energy costs**
Space heating demand	**Carbon emissions** (long term, e.g. 2038)	**EPC** (or SAP score)
95 kWh/m²/yr (average)	Flats 1 tCO_2 Bungalows 1.5 tCO_2 Houses 2 tCO_2	EPC C (average for all properties)
50% of dwellings only 65 kWh/m²/yr (average)	Flats 0.75 tCO_2 Bungalows 1 tCO_2 Houses 1.5 tCO_2	EPC B (average for all properties)
35 kWh/m²/yr (average)	**30% of dwellings only** Net Zero Carbon	EPC B (minimum for all properties)

London Retrofit Action Plan | 1 | 95 kWh/m² heating demand + Flats 0.75 tCO_2, Bungalows 1, Houses 1.5

		£95 Million
Average Investment		**£17,200**
Mean SAP	**75 C**	
Mean 2038 tCO2		**0.369**
Mean kWh per m2:		**58**



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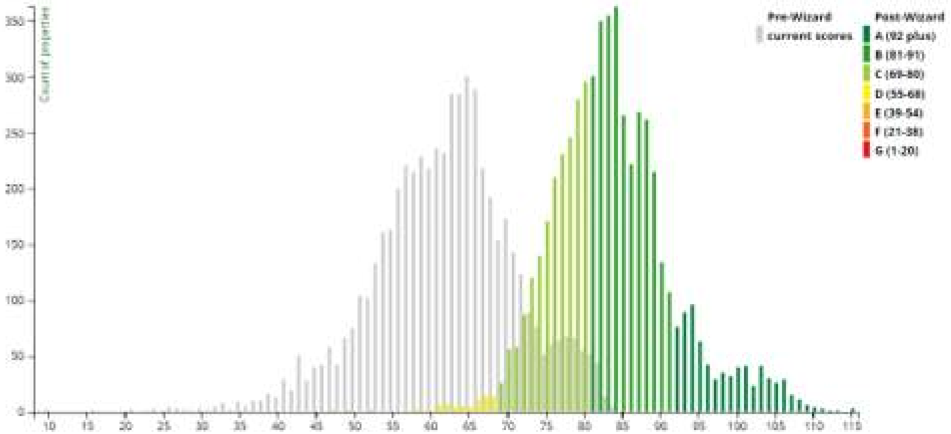
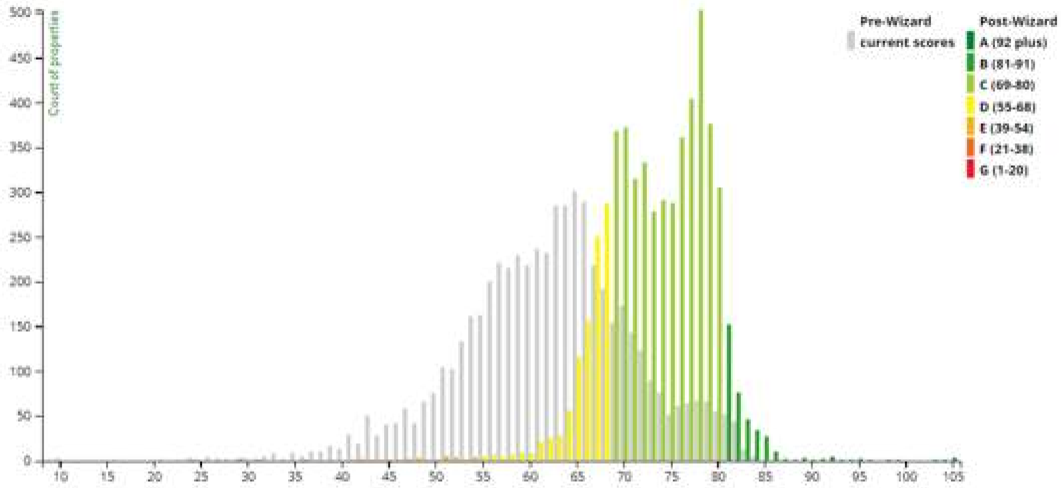
London Retrofit Action Plan | 2 | 95 kWh/m² heating demand + Net Zero Carbon objective

		£127 Million
Average Investment		**£22,800**
Mean SAP	**84 B**	
Mean 2038 tCO2		**0.105**
Mean kWh per m2:		**29**

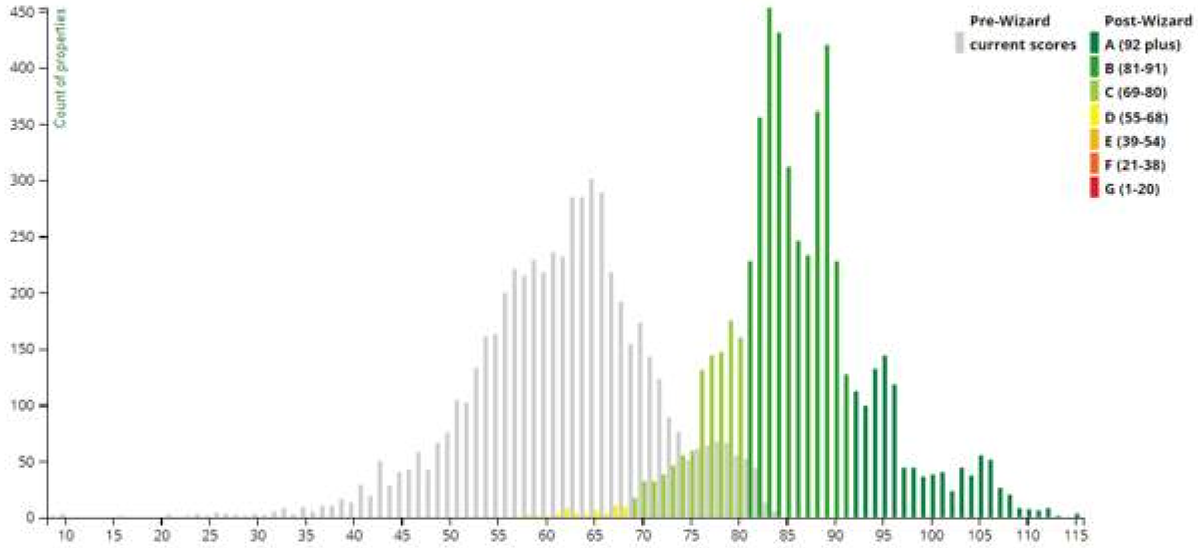


		£123 Million
Average Investment		£22,700
Mean SAP	74 C	
Mean 2038 tCO2		0.229
Mean kWh per m2:		56



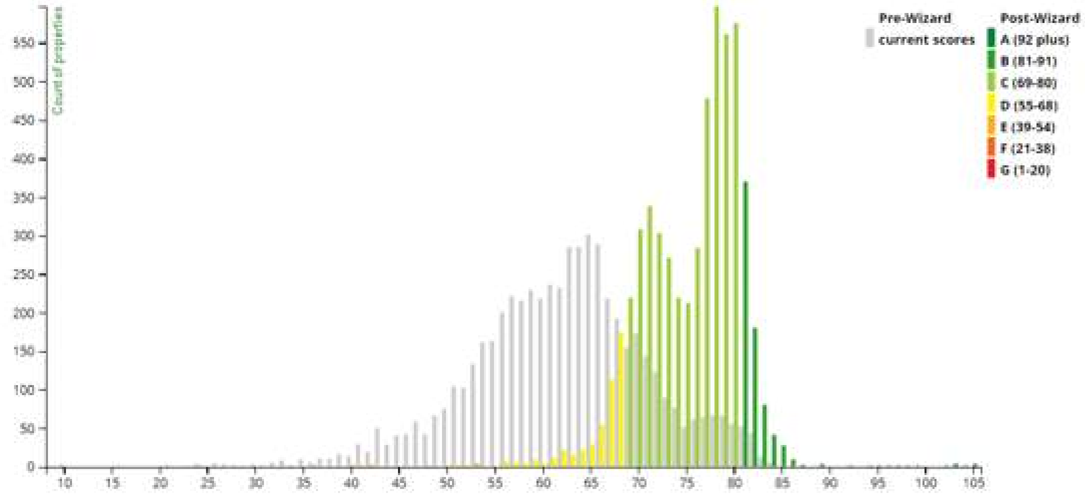
London Retrofit Action Plan | 4 | 65 kWh/m² heating demand + Net Zero Carbon

		£157 Million
Average Investment		**£28,200**
Mean SAP	**86 B**	
Mean 2038 tCO2		**0.084**
Mean kWh per m2:		**24**

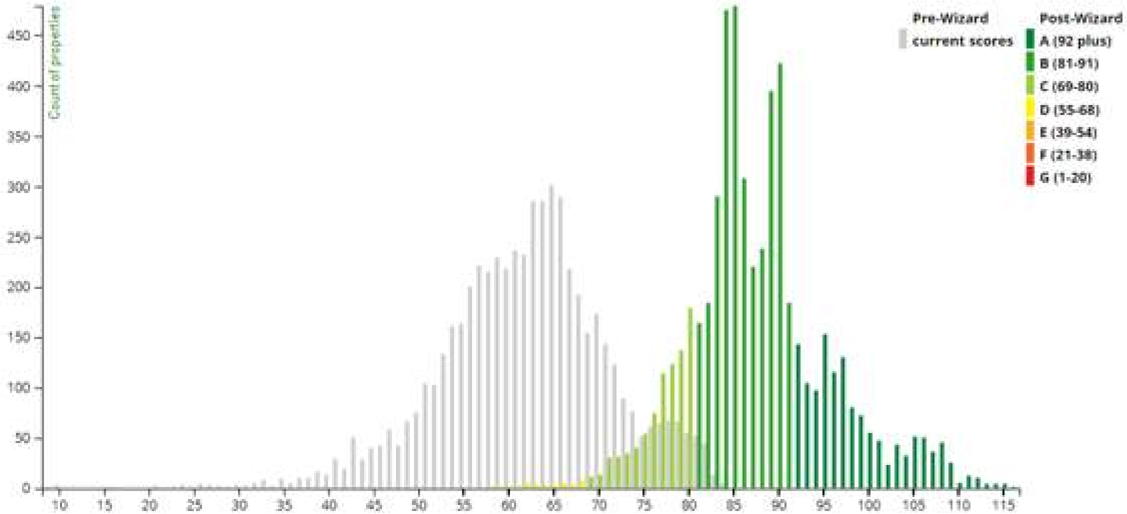


London Retrofit Action Plan | 5 | 35 kWh/m^2 heating demand + Flats 0.75 tCO_2, Bungalows 1, Houses 1.5

		£164 Million
Average Investment		**£29,900**
Mean SAP	**76 C**	
Mean 2038 tCO2		**0.363**
Mean kWh per m2:		**58**



		£208 Million
Average Investment		£37,400
Mean SAP	88 B	
Mean 2038 tCO2		0.07
Mean kWh per m2:		20



Summary

	Fabric Intervention	tCO_2 Target	Average Investment	Average CO_2	Resulting SAP
1	95 kWh/m²	1-1.5	£17K	0.369	75 C
3	65 kWh/m²	1-1.5	£23K	0.229	74 C
5	35 kWh/m²	1-1.5	£30K	0.363	76 C
2	95 kWh/m²	0	£23K	0.105	84 B
4	65 kWh/m²	0	£28K	0.084	86 B
6	35 kWh/m²	0	£37K	0.070	88 B

London Retrofit Action Plan | 7, 8 , 9, 10

I've split the 5% of Waltham Forest into 10 random equal groups. These have then been treated differently under 3 new scenarios, with the existing no. 4 scenario as the ultimate one. Each scenario has the properties treated in 3 different tranches as below:

Tranche 1: X% aiming for SAP 75 no heat pumps, no solid wall insulation, no community heating system changes

Tranche 2: Y% aiming for 65 kWh/m2 heating demand (middle scenario)

Tranche 3: Z% aiming for 65kWh/m2 heating demand and then Net Zero (no gas)

Later scenarios have progressively more of the fabric and then the 'fabric and net zero' tranches applied. No. 4 has all properties in Tranche 3 and none in the other.

The idea is that the 7,8,9 scenarios form various levels of success on the road to the final Net Zero scenario, whilst also allowing for heat pump supply chains to be built up.

The interest result is that all 3 scenarios result in an average SAP B

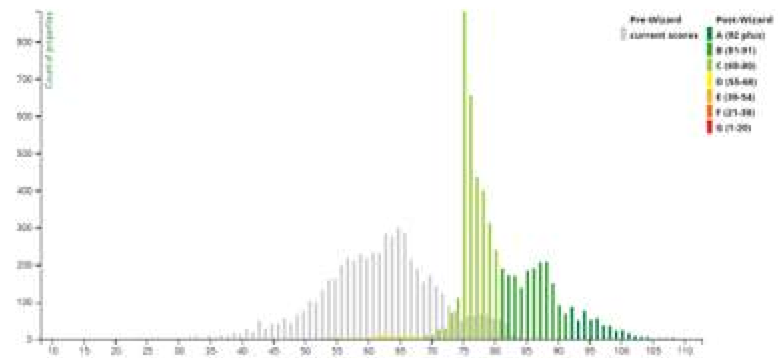
London Retrofit Action Plan | 7 | 80% Small improvements, 10% Fabric, 10% Fabric + Net Zero

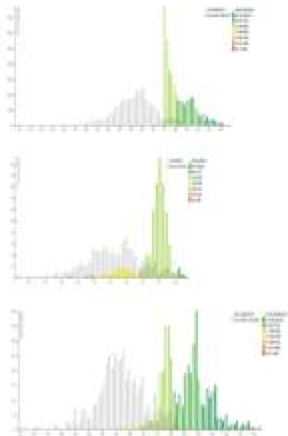
Tranche 1: 80% aiming for SAP 75 no heat pumps, no solid wall insulation, no community heating changes

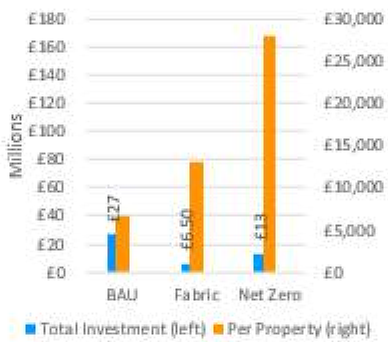
Tranche 2: 10% aiming for 65 kWh/m² heating demand (middle scenario)

Tranche 3: 10% aiming for 65kWh/m² heating demand and then Net Zero (no gas)

		£47 Million [£27M : £6.5M : £13M]
Average Investment		**£9,300 [£6,700 : £13,100 : £28,000]**
Mean SAP	**81 B**	
Mean 2038 tCO2		**1.97**
Mean kWh per m2:		**114**







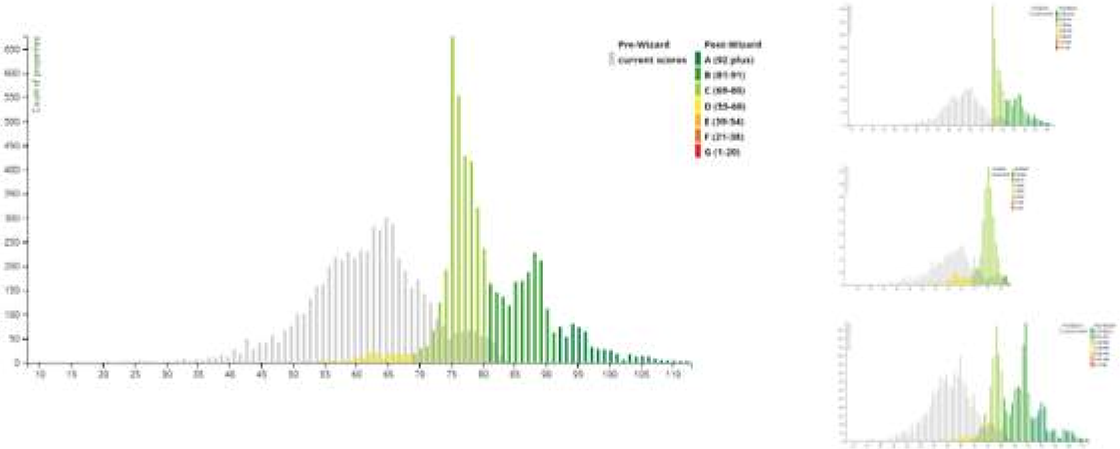
London Retrofit Action Plan | 8 | 50% Small improvements, 20% Fabric, 30% Fabric + Net Zero

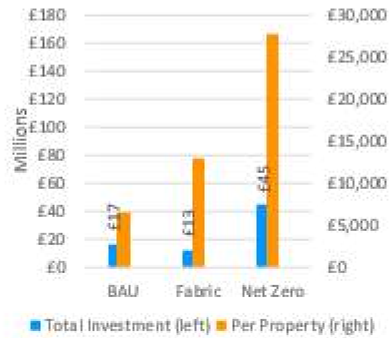
Tranche 1: 50% aiming for SAP 75 no heat pumps, no solid wall insulation, no community heating changes

Tranche 2: 20% aiming for 65kWh/m² heating demand only

Tranche 3: 30% aiming for 65kWh/m² heating demand and then Net Zero (no gas)

		£75 Million [£17M : £13M : £45M]
Average Investment		**£14,600 [£6,700 : £13,100 : £27,700]**
Mean SAP	**81 B**	
Mean 2038 tCO2		**1.45**
Mean kWh per m2:		**92**





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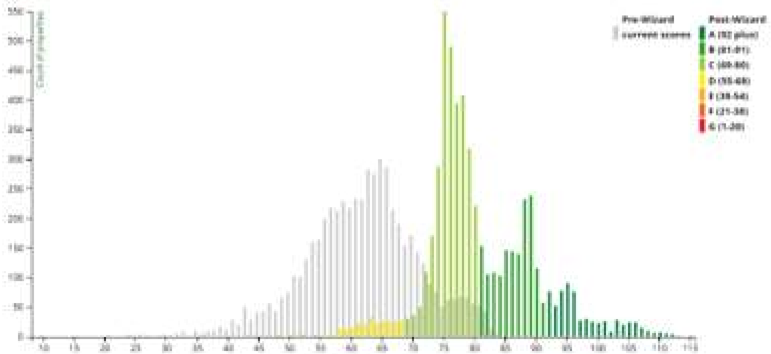
London Retrofit Action Plan | 9 | 20% BAU, 30% Fabric, 50% Net Zero

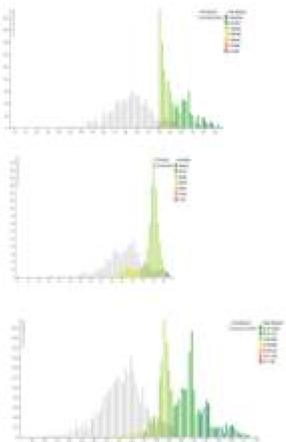
Tranche 1: 20% aiming for SAP 75 no heat pumps, no solid wall insulation, no community heating changes

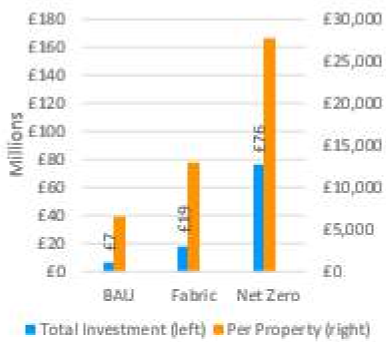
Tranche 2: 30% aiming for 65 kWh/m² heating demand

Tranche 3: 50% aiming for 65kWh/m² heating demand and then Net Zero (no gas)

		£102 Million [£6.6M : £19M : £76M]
Average Investment		**£19,500 [£6,500 : £13,100 : £27,700]**
Mean SAP	**81 B**	
Mean 2038 tCO2		**0.99**
Mean kWh per m2:		**72**







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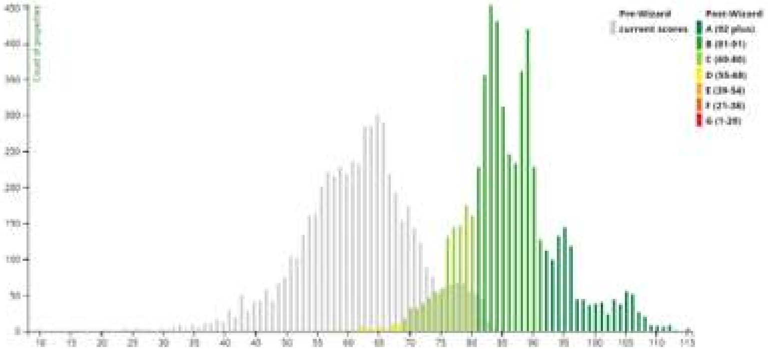
London Retrofit Action Plan | 10 | 0% BAU, 0% Fabric, 100% Net Zero (Similar as Scenario 4 previously)

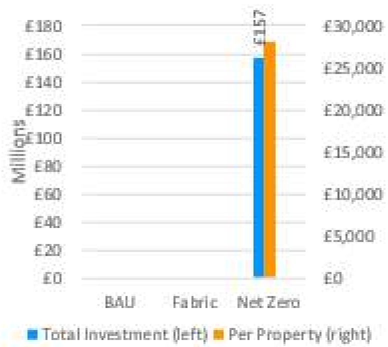
Tranche 1: 0% aiming for SAP 75 no heat pumps, no solid wall insulation, no community heating changes

Tranche 2: 0% aiming for 65 kWh/m² heating demand (middle scenario)

Tranche 3: 100% aiming for 65kWh/m² heating demand and then Net Zero (no gas)

		£157 Million
Average Investment		**£28,200**
Mean SAP	**86 B**	
Mean 2038 tCO2		**0.08**
Mean kWh per m2:		**24**





Etude ELEMENTA RAFT parity projects

For the Net Zero scenario we recommend targeting:

a) A **medium space heating demand of 65 kWh/m²/yr** on average in order to improve energy efficiency.

b) Net Zero emissions in order to identify what would be required and by when)

c) An EPC B (average across all properties)

-

Energy efficiency	Heat decarbonisation and solar PVs	Energy costs
Space heating demand	Carbon emissions (long term, e.g. 2038)	EPC (or SAP score)
95 kWh/m²/yr (average)	Flats 1 tCO_2 Bungalows 1.5 tCO_2 Houses 2 tCO_2	EPC C (average for all properties)
65 kWh/m²/yr (average)	Flats 0.75 tCO_2 Bungalows 1 tCO_2 Houses 1.5 tCO_2	EPC B (average for all properties)
35 kWh/m²/yr (average)	Net Zero Carbon	EPC B (minimum for all properties)

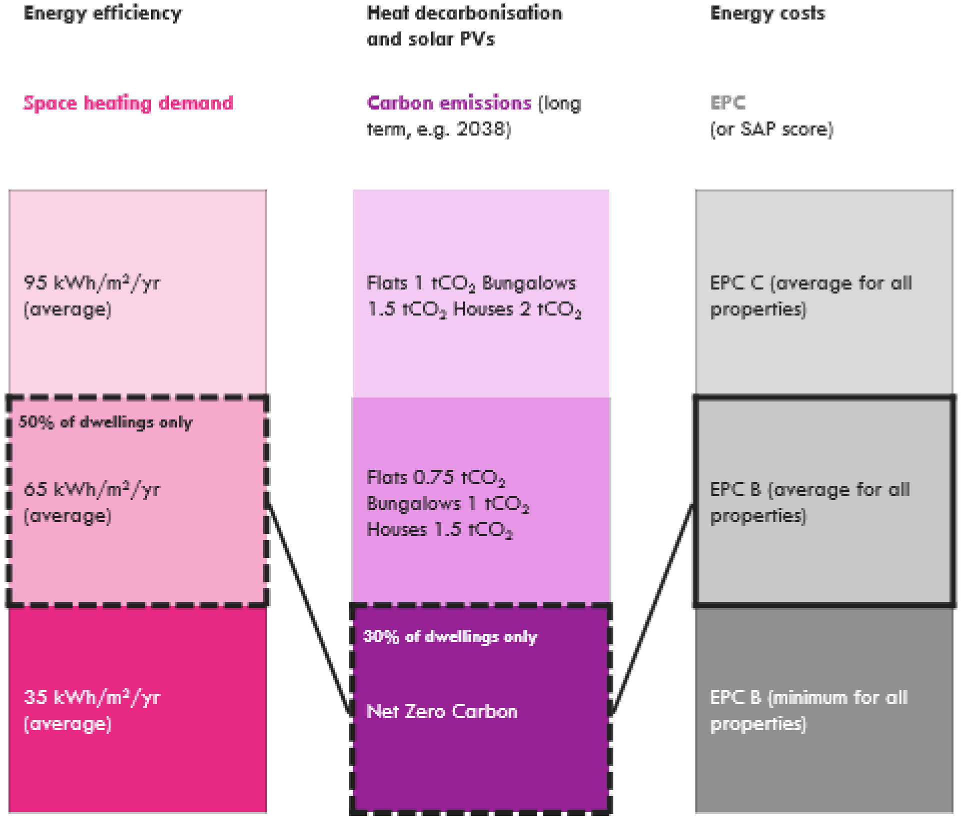
For the interim/less ambitious **scenario** we recommend targeting:

a) A **medium space heating demand of 65 kWh/m²/yr** on average in order to improve energy efficiency ONLY FOR 50% OF DWELLINGS

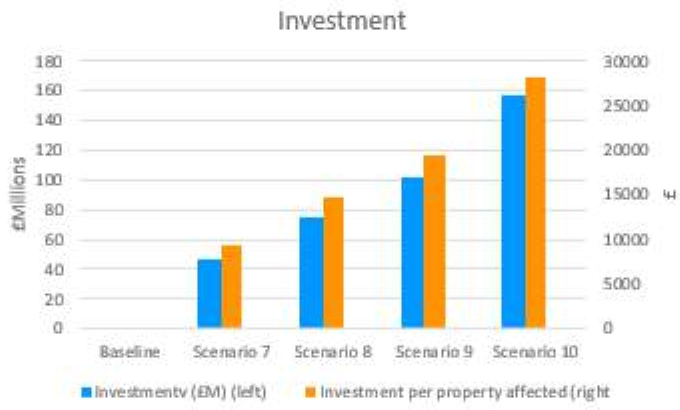
b) **Net Zero emissions** ONLY ON 30% OF DWELLINGS

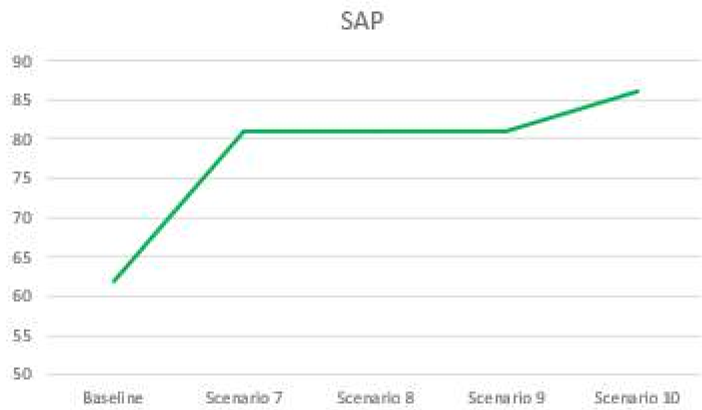
c) Minor improvements to the remaining 50% of dwellings

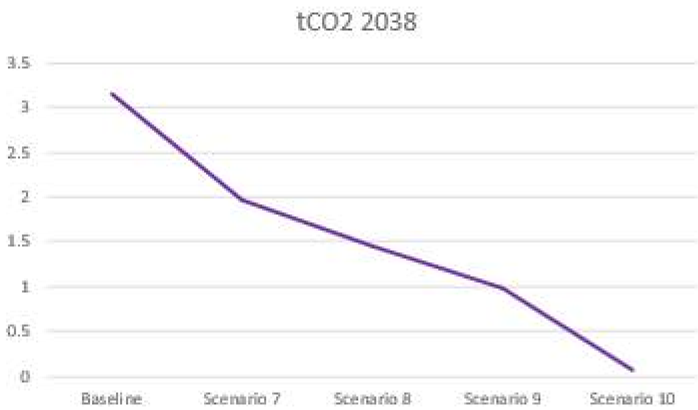
d) An **EPC B** (average across all properties)

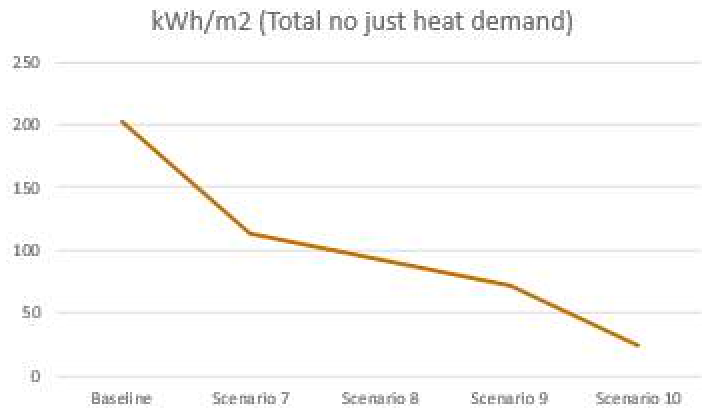


London Retrofit Action Plan |









Appendix | PROs and CONs of the other metrics

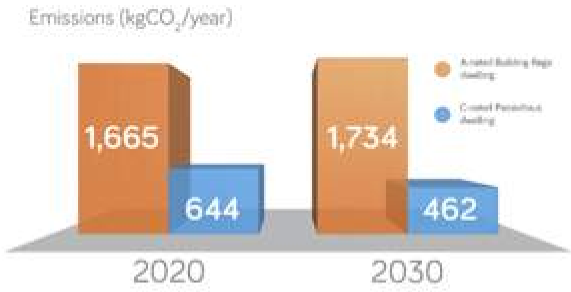
Metric	PROs	CONs
Space heating demand [kWh/m²/yr]	• Best metric for building fabric efficiency • Unaffected by heating system • Unaffected by carbon factor • Less subject to variation due to occupancy, behaviour, etc. • Good indicator for fuel poverty • Pretty easy to set consistent targets • A good proxy for build quality • Wide range between good and bad • Puts the spotlight on the biggest opportunity for energy efficiency	• Challenging to measure in use • Not a metric for heating system (and therefore heat decarbonisation) • Calculation method subject to debate
Carbon (long term) [$kgCO_2/m^2$]	• Alignment between strategic objective and indicator • A good indicator for heating decarbonisation	• Challenging to measure in use • Heavily reliant on carbon factor (and consensus required on set to use) • Heavily reliant on heating system (system can be played) • Does not include embodied carbon
Total energy use (gas – electricity) [kWh/m²/yr]	• Can be measured post-retrofit and compared to target • Reasonable indicator for fuel poverty (with caution) • It does not exclude any energy use (e.g. it includes hot water use) • Reasonable indicator for heat decarbonisation • Makes the balance between energy use and renewable energy generation more transparent • Growing industry consensus for it to become the key metric	• Not necessarily a good indicator of fabric efficiency (could be misleading) • Subject to effect of heating system • Not straightforward to estimate for heat networks

Why the use of an EPC metric can be misleading

These examples illustrate how the use of an energy cost metric (EPC band or SAP score) can be misleading.

It is a particular issue for addressing one of the key challenges associated with the climate emergency: the decarbonisation of heat. One of the most important challenges for Zero Carbon London is to phase out the use of gas boilers gradually, starting as quickly as we can.

If we use a metric which does not encourage that (e.g. EPC band, SAP score, space heating demand), it is crucial that the proportion of gas boilers is monitored with the aim of it reducing steadily.



Dwelling	EPC Rating	Emission Rate with 2020 SAP Figures ($kgCO_2$/year)	Emission Rate with 2030 Projections ($kgCO_2$/year)
Single storey 100m² with gas heating and hot water. Building Regulations fabric standards. 2.5kWp of PV.	A(93)	1665	1734
Two storey 100m² with electric heating and hot water. Passivhaus fabric standards. No PV.	C(80)	644	462

	EPC Band	Overall Energy Demand (kWh/year)
Baseline	D (58)	24,249
Energy Efficiency Measures	C (69)	16,468
Add ASHP	D (60)	7,425

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