# Energy and Environmental Report Castleland Renewal Area, Barry

# Stage 2


Report developed by the LCRI – LCBE – WP5

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In collaboration with:

## Contents

# Energy and Environmental Report for Vale of Glamorgan – Castleland Renewal Area, Barry

## Introduction

This report provides a guidance of the possible routes towards improving the energy efficiency of the existing housing stock in Castleland Renewal Area, Barry. A clustering analysis focused on domestic dwellings has been developed in order to maximise the available data, creating representative groups of the larger area.

Initial data has been collected and supplied by Warm Wales, thereafter complemented and expanded by the research team at the Welsh School of Architecture, where finally the information has been entered into the Energy and Environmental Prediction (EEP) model to create a database for Castleland. The analysis has been developed out of the collaborative work between Warm Wales and the Low Carbon Research Institute, at the Welsh School of Architecture (WSA), Cardiff University.

The area under analysis can be seen in Figure 1, located in Barry, Vale of Glamorgan, Wales. It covers a total of 1,248 houses, which are predominantly pre1919 dwellings.



***Figure 1.*** *Castleland Renewal Area.*
*The red shade indicates the area covered.*
***Inset*** *below shows the streets that are separated from the main area covered. They are also part of the renewal area.*

### Energy and Environmental Prediction model

The Energy and Environmental Prediction model (EEP) is a computer based modelling framework that quantifies energy use and associated emissions for cities, helping to design for low energy consumption, consequently reducing carbon dioxide ($CO_2$) and other emissions. EEP has been developed at Cardiff University since October 1994 with funding from the UK Engineering and Physical Sciences Research Council (EPSRC).

The EEP model has been used as an environmental auditing and decision making tool for local authorities. It is designed to be used by planners and others in pursuit of sustainable development. The EEP model is based on Geographical Information System (GIS) techniques and brings together a large database that can be acted upon. The model can predict the effects of future planning decisions from a whole city level down to a more local level.“The EEP model is created using built environment data associated with a region or city under investigation and can then be used to examine large to small areas enabling the user to pinpoint excessive energy use and associated carbon dioxide emission ‘hotspots’”.[1]

**Castleland Analysis Approach**

In order to provide guidance on reducing carbon emissions from Castleland’s housing stock, it was essential to identify the properties’ physical characteristics and current state of energy efficiency. The construction date and typology of dwellings are primary indicators of their fabric characteristics; therefore each dwelling within the renewal area was classified in terms of its age and typology. A sample of EPCs was used to further identify the range in energy efficiency performance within these classifications (i.e. improvements to the original fabric and the current heating system type and efficiency). By developing a detailed database for the sample area (i.e. about half of the properties) and using GIS, the data of all properties have been mapped and regions of particular interest pin-pointed. Moreover, alternative routes and associated costs of achieving lower carbon emissions have been laid out for the area using the database, SAP2009[2] recommendations of improvement and the SAP Sensitivity tool[3] which will be explained in detail in the methodology section.

<u>EU Context</u>

It is widely known that countries within the EU have a legal responsibility towards reducing GHG emissions. “The EU has committed to three targets for 2020. The first is to reduce emissions by 20% on 1990 levels. The second is to provide 20% of its total energy from renewable. The third is to increase energy efficiency by 20% from 2007 levels. EU leaders have also endorsed an 80-95% reduction in emissions by 2050”[4]. Although a low carbon roadmap has been produced to show how this target could be achieved throughout the EU, individual countries also have their own strategies to ensure that these fundamental targets are achieved.

<u>UK Context</u>

The UK is developing policies and economic strategies towards achieving such commitments. They aim to “reduce carbon emissions by at least 34% by 2020. Meeting that target will set the UK on the right path to meet the target of reducing greenhouse gas emissions by at least 80% by 2050”[5]

A few years into the implementation of strategies to achieve environmental goals, the government is looking to use their current records of achievements as a means to project

[1] JONES, P., PATTERSON, J and LANNON, S. 2007. Modelling the built environment at an urban scale – Energy and health impacts in relation to housing. Landscape and Urban Planning. 83, 39-49.
[2] The Government’s Standards Assessment Procedure for Energy Rating of Dwellings. 2009 edition. http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf
[3] SAP Sensitivity Tool. http://www.lowcarboncymru.org/interactive_tools.html
[4] Climate Change Legislation in the EU. Committee on Climate Change. http://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/european-union-legislation/
[5] Ofgem. Corporate Strategy and Plan 2011 – 2016. http://www.ofgem.gov.uk/About%20us/CorpPlan/Documents1/Corporate%20Strategy%20and%20Plan%202011%20-%202016.pdf

towards successful achievement of future Carbon Emissions reduction. Ambitious targets have been set, such as the previously mentioned 2050 target which also includes Wales which along with other devolved administrations, “currently accounts for around 20% of the UK’s total emissions”[4]

<u>Welsh Context</u>

Wales has aimed higher to achieve sustainability targets. It can be noted that the Welsh Government agrees that action must be taken immediately in order to achieve these ambitious goals and build up towards noticeable improvements. A short term goal of the Welsh Government has been to: “Reduce greenhouse gas emissions by 3% per year from 2011 in areas of devolved competence, against a baseline of average emissions between 2006-10”[6]. Furthermore, the Welsh target towards decreasing 2020 GHG emissions is more ambitious than the UK and European targets of 34% and 20% reduction respectively; Welsh Government is aiming to “achieve at least a 40% reduction in greenhouse gas emissions in Wales by 2020 against a 1990 baseline”[6].

The Climate Change Strategy for Wales Report offers a breakdown of the targets to be achieved by the different sectors, i.e. Transport, Residential, Business, Agriculture, Public sector and Water sector. The target for the residential sector is to reduce emissions “between 5.46 and 6.04 $MtCO_2e$ against a baseline of 7.48 $MtCO_2e$”[6] by 2020. They acknowledge the issues related to the existing building stock and their significance within the mentioned targets: “The existing stock of buildings in Wales is our greatest challenge because most of these buildings will still be with us in 15, 20 and even 50 years time and they have not been designed to either minimise their carbon footprint or to maximise their resilience to the impacts of climate change.”[6] A key priority within the Welsh Governments overall approach to climate change is to encourage “people to make improvements that enhance both these aspects”[6.] Moreover, three of the main actions established in the Climate Change Strategy for Wales Report[6] were to:

- Encourage installation of cost-effective energy efficiency measures in all households and adopting a ‘whole house’ approach
- Develop an area-based approach to domestic energy efficiency
- Target investment at those vulnerable to fuel poverty, and supporting community scale energy generation

Naturally, the Welsh strategy towards reducing GHG overlap with targets stated by the UK Committee on Climate Change, where the key areas for action in the residential sector include[6]:

- Improving energy efficiency and adopting a ‘whole house’ approach.
- Using efficient lights and appliances.
- Changing behaviour (for example turning off lights and appliances).
- Using more energy from renewable sources.
- Decarbonising electricity and heat supply.

The Welsh government clearly stated that they “will work closely with the UK Government to influence developments in this area.”[6] Therefore, as expected, the Welsh strategies to

[6] Climate Change Strategy for Wales Report. October 2010. Welsh Government. http://wales.gov.uk/topics/environmentcountryside/climatechange/publications/strategy/?lang=en

reduce GHG coincide with the targets stated by the UK Committee on Climate Change, such as playing an active role in the implementation of the Green Deal: "The UK Government's Green Deal is intended to provide policies and programmes to help reduce emission from heat and energy use across the UK. These policies will be important in helping reduce emissions from homes in Wales."[6] The Welsh Government is hoping to work closely with the UK Government to drive forward reductions in greenhouse gas emissions and influence important developments in this area.

This report aims to give evidence and guidance to the Vale of Glamorgan Local Authority on possible routes to achieve greater energy efficiency within the private housing stock. It is hoped that future action taken within the renewal area will have a positive impact on Castleland's households and will play a part in the achievements of Welsh Government, UK Government and the EU in reducing carbon emissions.

**Domestic Stock Profile**

A large sample has been taken from the Castleland renewal area. Data has been gathered for almost half of the dwellings in order to identify its current building quality and the potential of improvement. Data has been gathered for a total of **568 properties out of the 1,248**, which represents **45% of the whole site**. In order to corroborate that the sample is a close representation of the whole area, the dwelling typologies of the overall area has been compared to the typologies of the sample data. This comparison can be made by observing Figure 2 against Figure 3.

It can be seen that the data from the sample contains a good representative mix of buildings, which can be considered as a reliable indication of the whole area.

The 3 largest building classification groups in the area are:

**731 houses of the whole area classified as mid-terraced houses – Pre 1919**, which represent about 59% of the stock. The EPC sample size available for this group is: 352 houses (48% of this typology).

**142 houses of the whole area are classified as end-terraced and semi-detached houses – Pre 1919**, which represent about 11% of the stock. The EPC sample size available for this group is: 68 houses (48% of this typology).

**261 properties are classified as flats – Pre 1919**, which represent about 21% of the stock. The EPC sample size available for this group is: 106 properties (41% of this typology).

Further information on these percentages can be found in the table shown in the 'Methodology' section of this report (Table 1) as well as in Figures 2 and 3.

The following graphs show the size of the different typologies found in the area: Figure 2 representing the whole site and Figure 3 only the sample. It is highlighted that the predominant building age of the area is **pre 1919** and the most common building type is **mid-terraced houses.**

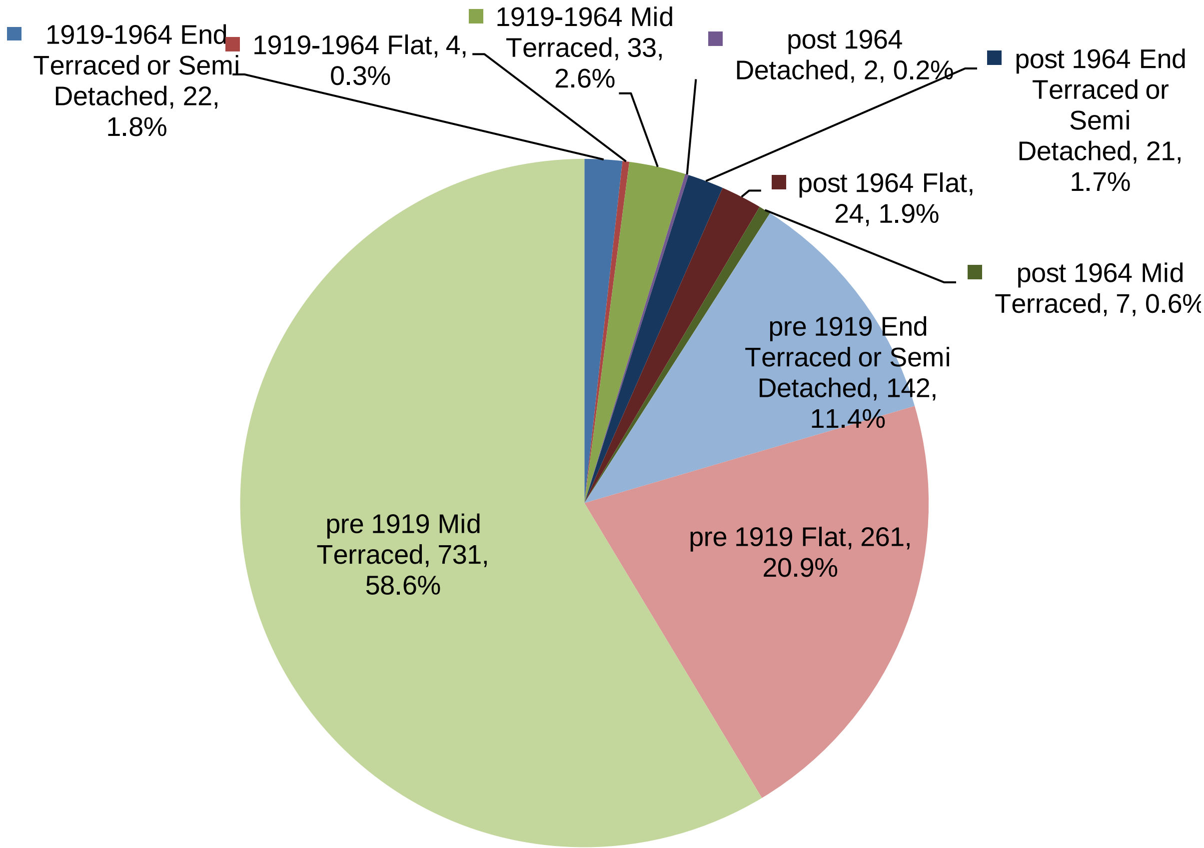


***Figure 2.*** *Typologies of residential buildings of the whole Castleland Renewal Area (1,248 houses). Data gathered and analysed using Digimap historical maps and up-to-date maps, street views, etc.*

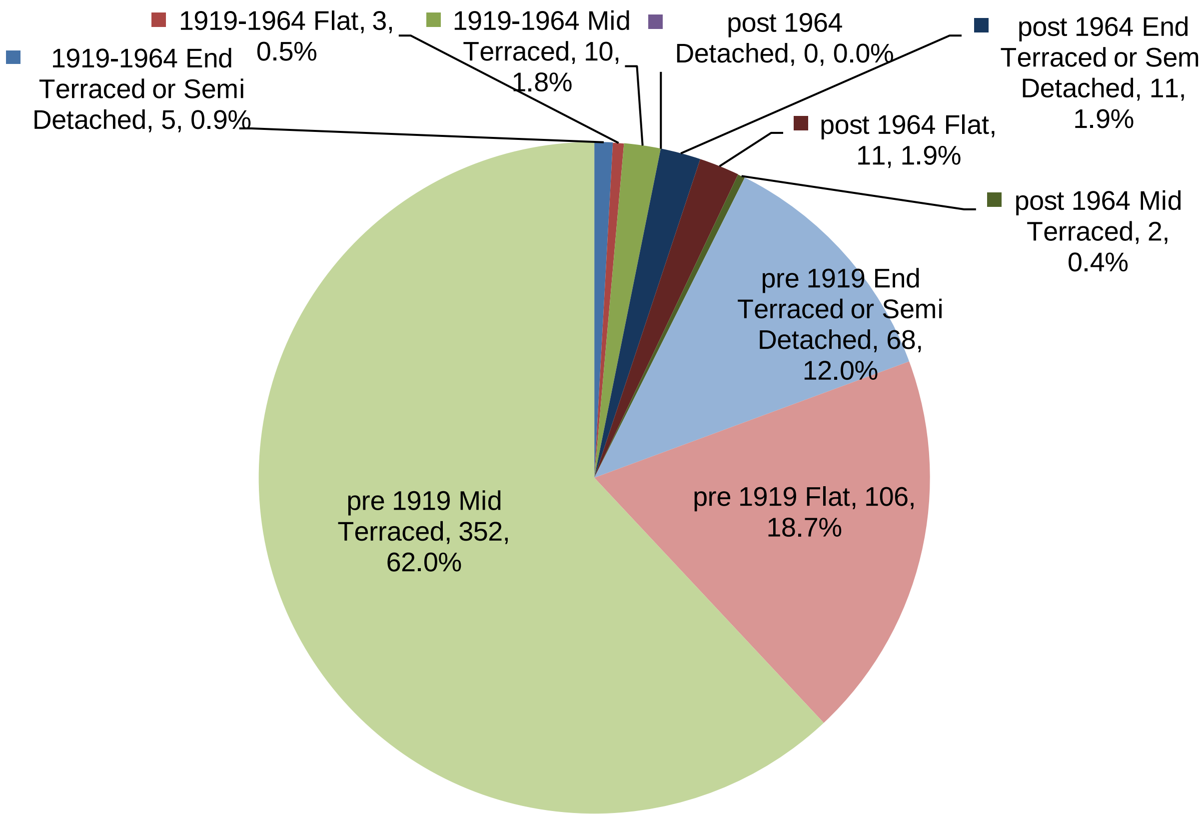


***Figure 3.*** *Typologies of residential buildings of sample (568 houses). Data obtained from EPCs and Digimap historical maps*

Figure 4 shows sample images of the mix of building typologies in the Castleland Renewal Area.

| | Mid-Terraced | End-Terraced / Semi-Detached | Flats |
|---|---|---|---|
| **Pre 1919** | **Pre 1919 MT**<br>731 (58.6%) | **Pre 1919 ET / SD**<br>142 (11.4%) | **Pre 1919 F**<br>261 (20.9%) |
| |  |  |  |
| **1919 – 1964** | **1919-1964 MT**<br>33 (2.6%) | **1919-1964 SD / ET**<br>22 (1.8%) | **1919-1964 F**<br>4 (0.3%) |
| |  |  |  |
| **Post 1964** | **Post 1964 MT**<br>7 (0.6%) | **Post 1964 SD / ET**<br>22 (1.8%) | **Post 1964 F**<br>24 (1.9%) |
| |  |  |  |

***Figure 4.****Sample buildings by age and type within the Castleland area*

**Energy and emissions**

A variety of data sources have been combined to develop this analysis, particularly the data available from Energy Performance Certificates (EPC)[7]. The data sources were used to identify and understand the range in energy efficiency performance within the property types found in the area.

SAP Distribution Compared to Local and National Values

The distribution of performance seen in Castleland follows a similar pattern to the local and national averages. This comparison can be seen in Figure 5 where the distribution of dwellings per rating band in the renewal area is viewed alongside Vale of Glamorgan (V.O.G) Council private sector house condition survey[8] and national values for Wales from the Living in Wales report[9]. It is to be noted that the data for V.O.G. and Wales were collected in 2008 while the data for Castleland is very recently gathered. The national housing stock is rapidly improving therefore care must be given not to mistake the improvement due to time as variation between areas. Saying this, there still seems to be a positive difference between Castleland and the wider areas probably owing to the recent work being carried out as part of the renewal project.

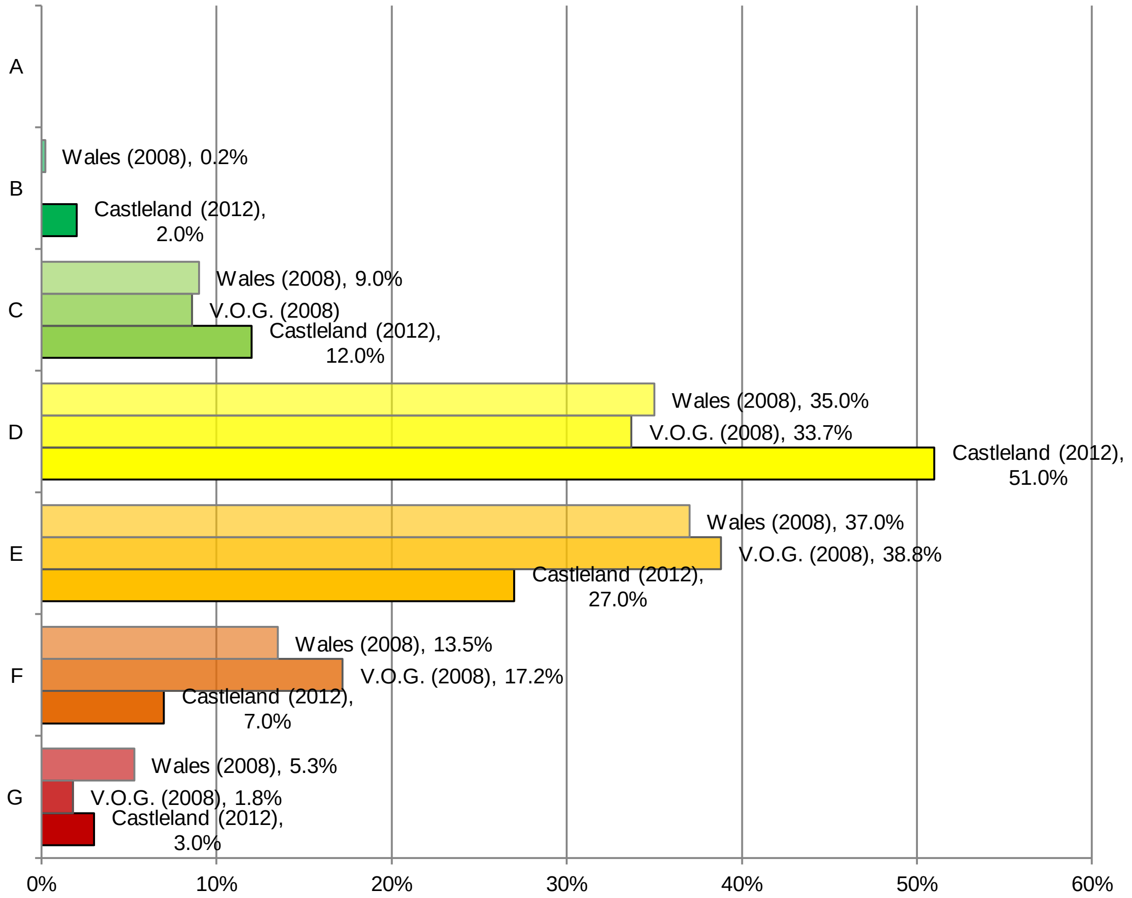


***Figure 5.*** *Comparing the distribution of dwellings per rating band (SAP2005) across Wales, the Vale of Glamorgan (V.O.G) and Castleland.*

[7] Energy Saving Trust Website. EPCs. http://www.energysavingtrust.org.uk/Insulation/Energy-performance-certificates

[8] Private Sector House Condition Survey 2009. Vale of Glamorgan Council. September 2009. Michael Howard Associates Ltd.

[9] Living in Wales 2008, Energy Efficiency of Dwellings. November 2010. Welsh Government. National Statistics

Fuel Poverty in Castleland and Wales

In contrast with patterns in SAP ratings, the percentage of households in fuel poverty within the Castleland area in 2001 was 21%*[10], which was above the Welsh national average of 14%*[10] in 2001. According to the British property Federation, "the current definition of fuel poverty is when a household needs to spend more than 10% of its income on fuel to maintain a satisfactory heating regime of 21°C for the main living area and 18°C for other occupied rooms during daytime areas"[11]. Fuel Poverty in Wales rose to 26%*[12] by 2008 and casted to include as much as 33.5%*[e13] of households by 2011. There is currently no up to date statistics on fuel poverty on a disaggregated level, but following the national trend, it would be expected that fuel poverty in Castleland would have also risen since 2001 in spite of recent work being carried out as part of the renewal project. Improving the Energy Efficiency of properties in Castleland would therefore contribute to the Welsh Government expectation of eradicating fuel poverty as far as reasonably practicable by 2020[6].

SAP Distribution of the Housing Stock

EPCs provide an energy efficiency rating based on the type of dwelling, its elements and fittings/systems. An EPC report provides a 'current' and a 'potential' rating of the energy efficiency of a property. Such energy efficiency is quantified using the Standard Assessment Procedure (SAP)[14] which is the methodology used by the Department of Energy & Climate Change (DECC) to assess and compare the energy and environmental performance of dwellings.

"SAP is the Governments 'Standard Assessment Procedure' for energy rating of dwellings. SAP provides a simple means of reliably estimating the energy efficiency performance of dwellings. SAP ratings are expressed on a scale of 1 to 100, the higher the number the better the rating."[14]

The current SAP rating found in the sample of EPCs gives an indication of the current state of the properties in Castleland. It can be seen in Figure 6 that properties' performance range from the worst possible (band G) up to a good standard (band C) with the majority of dwellings being poor to average in performance (D and E bands) in terms of energy efficiency.

[10] http://wales.gov.uk/topics/environmentcountryside/energy/fuelpoverty/fuelpovertymaps/?lang=en

[11] A British Property Federation guide to Energy Efficiency and the Private Rented Sector. January 2013. British Property Federation.

*Fuel poverty values are based on the full income definition of fuel poverty

[12] Living in Wales 2008: Fuel Poverty. November 2010. Welsh Government. National Statistics. http://cymru.gov.uk/topics/statistics/headlines/housing2010/1011261/?lang=en

[13] NEA Cymru. May 2012. Fuel Poverty Statistical Update

[14] Standard Assessment Procedure. January 2013. UK Government Website. Department of Energy and Climate Change. https://www.gov.uk/standard-assessment-procedure and http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf

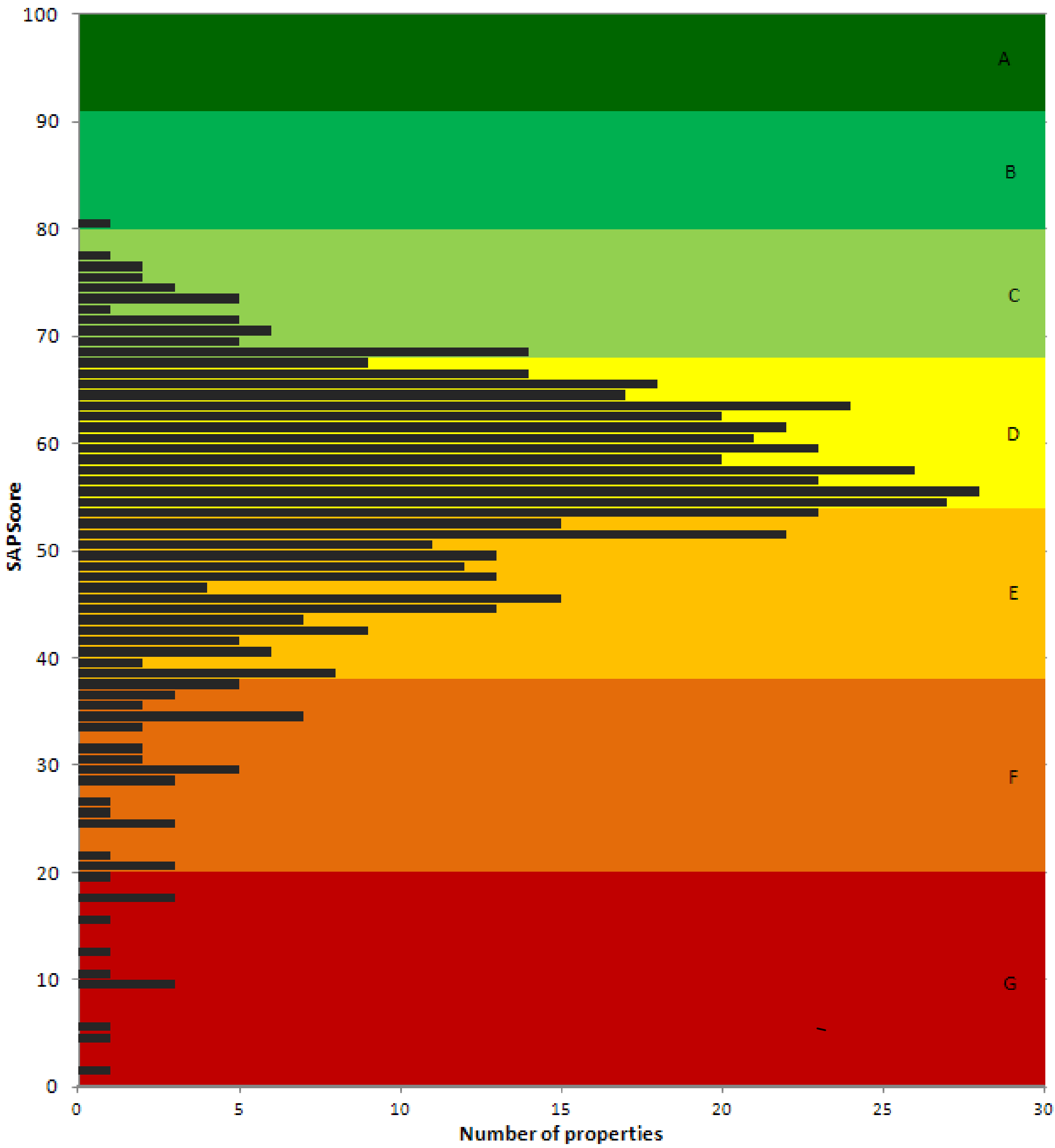


***Figure 6.****SAP distribution of the housing stock in Castleland*

<u>Current and Potential SAP ratings</u>

In Figure 7, the distribution of dwellings per SAP band can be further seen per postcode. This can be used to pinpoint areas which might need more attention. The height of the bar represents the amount of dwellings within each postcode therefore although a postcode might be dominated by poorly performing dwellings, it might only represent one or two properties.

Figures 5-7 provide a clear picture of the current state of properties in Castleland and the local and national context. As previously mentioned an EPC report provides a 'current' and a 'potential' rating of the energy efficiency of a property. While the 'current' SAP rating allows building up a database reflecting the actual state of properties, the 'potential' rating may be achieved if recommendations are followed towards improving various features within the properties.

This analysis uses this data to populate the information database, thereafter the SAP sensitivity tool[15] is used to analyse and assess the impact of various alternatives to achieve the upgrading of dwellings. More details about this tool are available in the SAP sensitivity tool section.

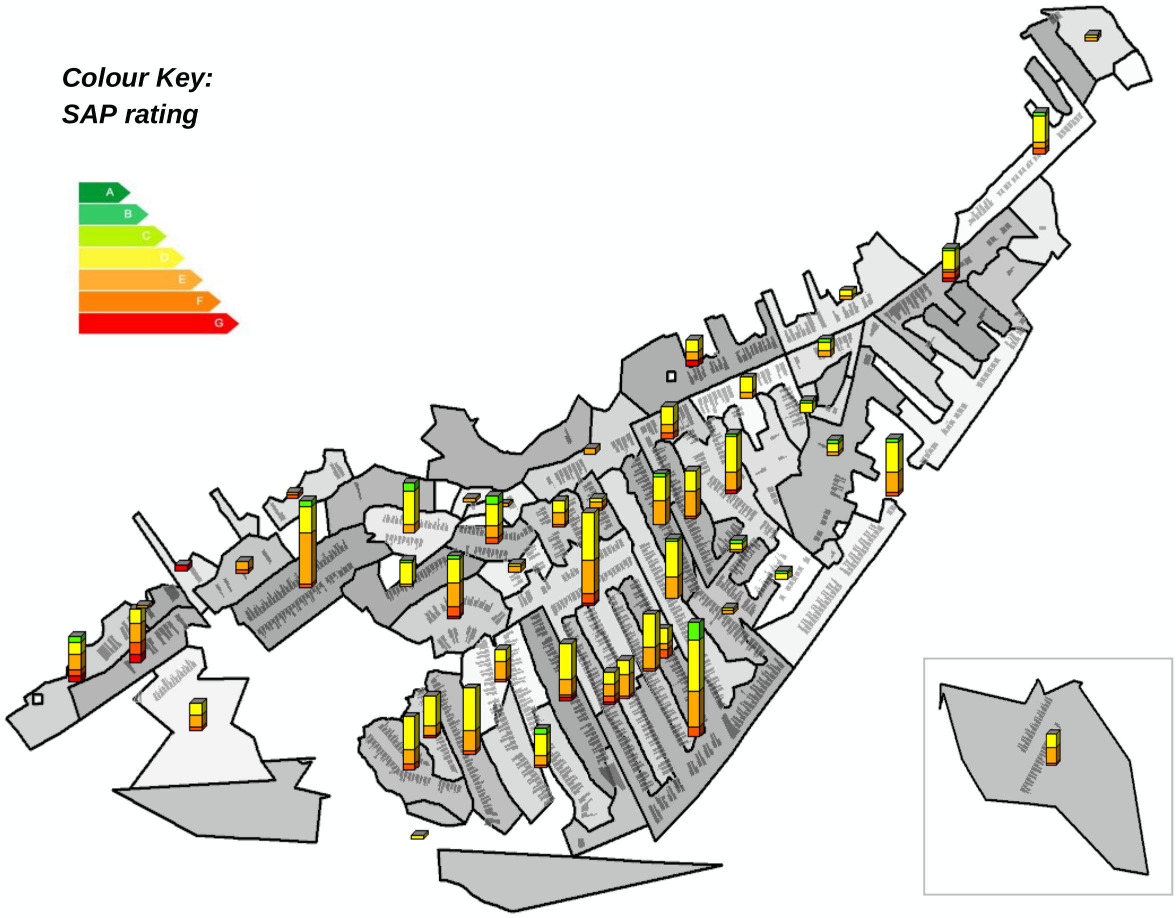


***Figure 7.***_SAP rating distribution by post code_

Figures 8 to 10 provide mapping of this data at a property level, the 3 map represent the various aspects that can be gathered directly from the EPC data: ‘current’ SAP rating, ‘potential’ and the difference in SAP points between ‘current’ and ‘potential’. The information drawn from the EPCs allowed us not just to pinpoint the worst/best energy performing properties with their current and potential SAP ratings, but also allowed us to identify which areas may have a greater potential after interventions and which areas may present greater challenges when aiming to retrofit towards specific targets.

15 SAP sensitivity tool. Delivering Low Carbon Buildings Cymru. http://www.lowcarboncymru.org.uk/interactive_tools.html

## Castleland Renewal Area

***Colour Key: SAP rating***

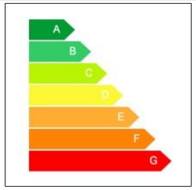


***Figure 8.*** *Map of 'current' SAP ratings of all available EPCs in the area*

## Castleland Renewal Area


***Figure 9.*** *Map of 'potential' SAP ratings of all available EPCs in the area*

## Castleland Renewal Area


***Figure 10.*** *Map of possible improvements in SAP ratings based on all available EPCs in the area*

## Housing Standards and Targets

The aim of this report is to suggest two possible routes toward upgrading the quality of the housing stock in Castleland Renewal Area. Based on relevant regulations and current policies, two main targets were selected in order to provide a reasonable action plan towards achieving certain goals to improve energy efficiency in Castleland. These targets provided a set of characteristics, which helped to establish a representative SAP rating to mark a given milestone towards increasing the quality and efficiency of dwellings. Thus, the two targets chosen for this report are:

1. **The 'Housing Health and Safety Rating System' (HHSRS) Target:**

   *The first and lower target established in this analysis is to achieve a SAP2009 rating of 62.5 for all properties in Castleland.*

   The HHSRS is the latest assessment system which is "structured around an evidence based risk assessment procedure (…) on which local authorities must base their decisions (…) from 6th April 2006."[16] There are a number of risks assessed under the HHSRS and the one closely related to SAP assessment is the 'excess cold' risk. "Excess cold can be caused by severe deficiencies in the thermal performance of a building."[17] Therefore, SAP assessments can provide support towards establishing the level of 'excess cold' risk in a property.[18] Within the house condition report of the Vale of Glamorgan Council[18] the excess cold hazard was identified as one of the most occurring in the area, "Slightly less than 1 in 2 dwellings in the private sector (…) were affected by the threat of excess cold and are often associated with older harder to heat dwellings."[18]

   The HHSRS came to replace the Housing Fitness Standard[19], which "was a set of basic requirements that homes should meet in order to be considered as acceptable places to live."[20] It "was contained in section 604 of the 1985 Housing Act (as amended by the schedule 9 to the 1989 Local Government and Housing Act)."[21] The Fitness Standard was used by the Welsh Housing Quality Standard (WHQS), which was introduced in 2002.[20, 21] The WHQS established the minimum quality standards for dwellings in Wales set by the Welsh Government, initially developed as part of the

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[16] Housing Health and Safety Rating System. Enforcement Guidance. Housing Act 2004, Part 1: Housing Conditions. 2006. Office of the Deputy Prime Minister. Creating Sustainable Communities. London.https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7853/safetyratingsystem.pdf

[17] A British Property Federation guide to Energy Efficiency and the Private Rented Sector. January 2013. British Property Federation. http://www.bpf.org.uk/en/files/event_related_documents/Energy_Efficiency_and_the_Private_Rented_Sector.pdf

[18] Private Sector House Condition Survey 2009. Vale of Glamorgan Council. September 2009. Michael Howard Associates Ltd.

[19] Welsh Housing Quality Standard (WHQS) as at 31 March 2012. First Release. Statistics for Wales. Knowledge and Analytical Service. Welsh Government. http://wales.gov.uk/docs/statistics/2012/121015sdr1732012en.pdf

[20] Housing Health and Safety Rating System (HHSRS). Social Policy Section. Library House of Commons. November 2008.

[21] The Welsh Housing Quality Standard. Revised Guidance for Social Landlords on Interpretation and Achievement of the Welsh Housing Quality Standard. July 2008. Welsh Government. HouseMark Cymru.

national strategy: "Better Homes for People in Wales"[22]. Within the WHQS guidance from 2002[23] in the 'Good practice guidance' section it is stated that "Basic conditions that are expected in dwellings are contained in the housing *fitness standard*."[23] Therefore, it can be recognised that since the ***Fitness Standard* has been replaced by the HHSRS, then by definition the HHSRS plays an important role in the WQHS.** "The Housing Health and Safety Rating System (HHSRS) which assesses twenty nine categories of housing hazard and provides a rating for each hazard (…) does not provide a single rating for the dwelling as a whole (…).From 2004 onwards landlords were required to include HHSRS in their inspection process and stock condition surveys. Any element categorised with a HHSRS Category 1 Hazard would automatically result in the dwelling 'Failing' the WHQS."[19]

Hence, since the HHSRS "does not provide a single rating for the dwelling as a whole" as mentioned above, this report has taken the most specific and relevant target within its context; since the HHSRS influences the WHQS, and such standard suggests a minimum target towards improving Welsh dwellings, in this report a first basic target has been selected, to mark an initial milestone for energy improvement: "A minimum rating of 65 out of 100 must be achieved."[19] Such value is based on SAP2005, the equivalent SAP2009 rating would be **62.5** (Based on Table 15 of the official SAP 2009 document section 'Formulae and Tables'[24])

**2. The 2050 Target:**

> *The second and more ambitious target set for this analysis is to achieve a SAP2009 rating of 92 for all properties in Castleland.*

The 2050 target reflects the commitment of Britain under the 2008 UK Government's Climate Change Act to reduce $CO_2$ emissions by 80% by 2050.[25,17] This target is based on the 1990 $CO_2$ emissions[17]. There are a number of areas where the country can aim to reduce GHG emissions. Within this context "the government sees improvements to the existing property stock as a key opportunity area to make progress against its emissions saving targets. The government's December 2011 Carbon Plan highlighted that 25% of the UK's emissions come from domestic property and that reducing demand for energy is the cheapest way of cutting emissions."[17]

Therefore, the second and upper target in this analysis has been established based on this standard and it will be calculated building up on the first target the *HHSRS Target* (62.5 SAP2009 rating). The analysis will demonstrate how much further 62.5

[22] Progress in Delivering the Welsh Housing Quality Standard. January 2012. Wales Audit Office: http://www.wao.gov.uk/assets/englishdocuments/WHQS_English_web.pdf
[23] The Welsh Housing Quality Standards. Guidance for Local Authorities on the Assessment Process and Achievement of Standard. Welsh Government. April 2002.
[24] SAP 2009. The Government's Standard Assessment Procedure for Energy Rating of Dwellings. 2009 edition incorporating RdSAP 2009. Department of Energy and Climate Change. 2011. http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf
[25] Residential Carbon Reduction in Wales. 1st report of the Sustainability Committee's Inquiry into Carbon Reduction in Wales. National Assembly for Wales. March 2008. http://www.assemblywales.org/sc_carbon_reduction_household_final_report_published_version.pdf

rating would be required to actually achieve the 2050 Target (SAP2009 of 92). Dwellings with a rating of 92 SAP2009 or more would be classified as BAND A, which is the highest band of the property energy classification (in SAP), and would constitute about 80% reduction on GHG emissions.

## Methodology

The method used within this report is based upon the EEP model framework which combines information sources within a database that can highlight the potential improvements required to achieve energy efficiency targets. The work flow is shown in Figure 11.

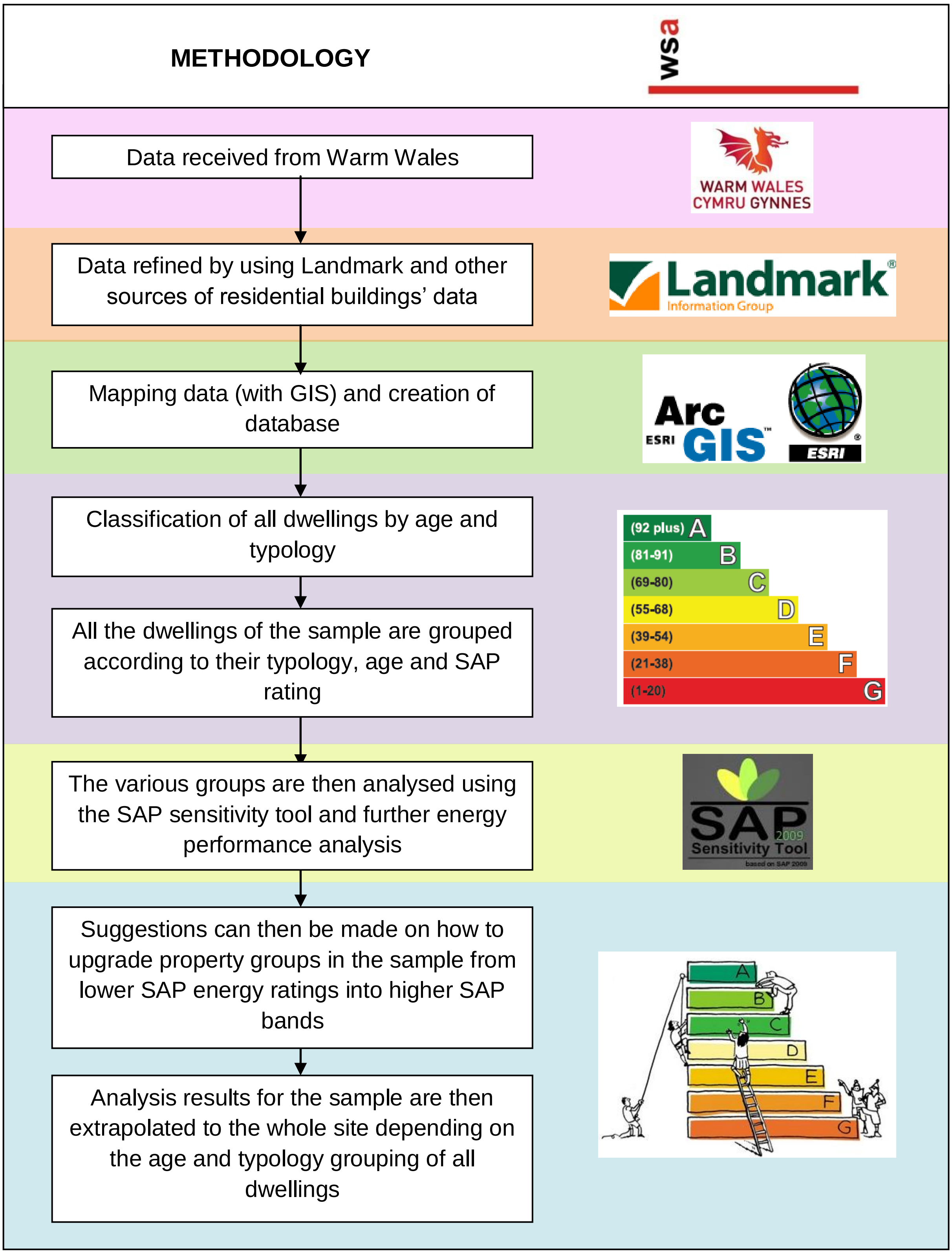



***Figure 11.*** *Flow diagram of the methodology of this analysis*

**Clustering**

In order to find possible routes to improve the energy efficiency of the existing housing stock, data was collected from all the available EPCs in the area (568 EPCs). Each EPC was identified by its typology and was further grouped in terms of its SAP rating (See Groups in Table 1). The data collected from the EPCs were recorded and analysed, helping to identify for each group the main characteristics of buildings affecting the energy performance (cluster analysis). Finally, allowing the identification of the recommended measures required for each cluster to achieve the *HHSRS* and *2050 targets*.

Table 1 below outlines the clusters (or groups) of properties created for this analysis based on their different characteristics and available sample sizes. The 3 main clusters identified in this table (highlighted in blue) will be analysed further in this report.

***Table 1.*** *Group classification of different typologies and available sample sizes*

| GROUPS | | Total of this property type on site | | Total EPCs available | | Number of EPCs in each SAP band | |
|---|---|---|---|---|---|---|---|
| | | No. of properties | % | No. of properties | % | | |
| **1- Mid-Terraced** | | | | | | | |
| **Pre 1919** |  | 731 | 58.6% | 352 | 48.2% | G/F<br>E<br>D<br>C | 18<br>124<br>200<br>10 |
| **1919 - 1964** |  | 33 | 2.6% | 10 | 30% | G/F<br>E<br>D<br>C | 1<br>1<br>6<br>2 |
| **Post 1964** |  | 7 | 0.6% | 2 | 28.6% | C/D | 2 |
| **2- End-Terraced / Semi-Detached** | | | | | | | |
| **Pre 1919** |  | 142 | 11.4% | 68 | 47.9% | G/F<br>E<br>D<br>C | 16<br>30<br>21<br>1 |
| **1919- 1964** |  | 22 | 1.8% | 5 | 22.7% | D/E | 5 |
| **post 1964** |  | 22 | 1.7% | 11 | 50% | G/F<br>E<br>D<br>C | 1<br>2<br>7<br>1 |
| **3- Flats** | | | | | | | |
| **Pre 1919** |  | 261 | 20.9% | 106 | 40.6% | G/F<br>E<br>D<br>C | 25<br>35<br>39<br>7 |
| **1919- 1964** |  | 4 | 1.8% | 3 | 75% | D/E | 3 |
| **post 1964** |  | 24 | 1.9% | 11 | 45.8% | C/D | 7 |

**SAP sensitivity tool**

The *SAP Sensitivity Tool 2009* (*SST2009*) is a software package developed by CRiBE (Centre for Research in the Built Environment). This tool has been used in this analysis to further consider the impact of the possible interventions required to improve the energy efficiency of each identified group. This process would allow keeping track of the various improvement paths taken in this assessment; the established process aimed to bring dwellings in Castleland to achieve the set targets*: the HHSRS target* and the *2050 target*. This has been possible after a thorough statistical analysis based on the main identified clusters, establishing thereafter prototype properties based on the most representative characteristics of dwellings belonging to a specific SAP rating band, for each of the 3 main clusters. By having these specific values, extrapolation could then be performed for each group, since the actual number of properties was available. These figures provided initial grounds to estimate the total number of measures needed in the area and to approximate the costs of achieving the two standards.


***Figure 12.*** *SAP tool website* *http://www.lowcarboncymru.org/interactive_tools.html*

The SAP sensitivity tool has been created at the Welsh School of Architecture, as part of the project 'Delivering Low Carbon Buildings Cymru', as one of the main outcomes of CRiBE. The main grounds to develop this software was to create a tool to help parties interested in the analysis of the energy performance of the built environment to understand its Welsh contexts, its history, legislation and the impact and role of the SAP rating system in the UK.

The tool possesses a built-in data base for *New and Existing Buildings*; furthermore it has several features that allow the identification of dwellings' energy rating, helping to provide an assessment of the interventions that would be more appropriate to specific types of houses. As it can be seen in Figure 13, the property can be closely classified in terms of real characteristics (i.e. Location; Typology: Mid-terrace, Detached, Semi-D and Flat; amongst many more options available at the top and on the left hand-side of the interface of the tool.)

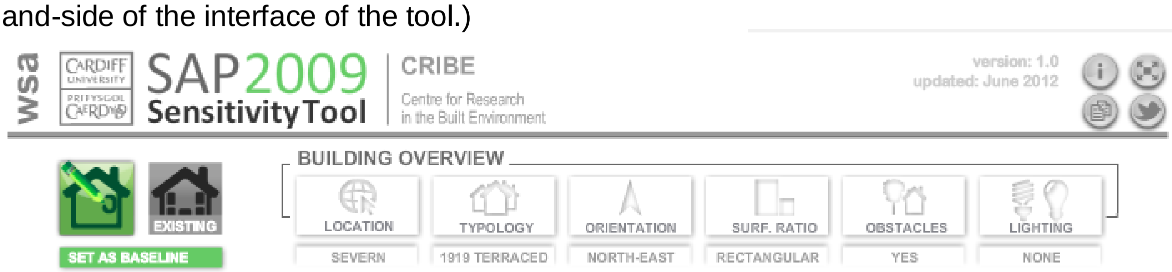



***Figure 13.*** *Some of the options available in the in the SAP sensitivity tool to select specific characteristic of the property.*

The tool has a series of 'sliders' that allow the user to establish specific values of the various elements related to the fabric and systems of the building to a close range, as it can be seen in Figure 14.

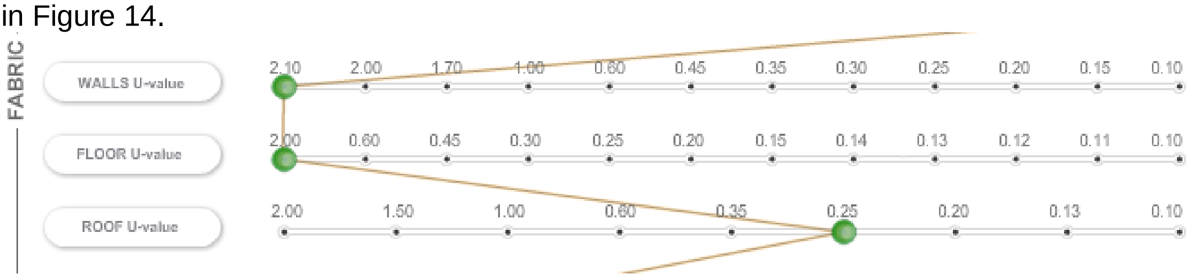



***Figure 14.*** *SAP sensitivity tool sliders*

While changes in fabric and systems are made to the building, the SAP sensitivity tool provides an interactive final SAP score, this score (or SAP rating) can be simultaneously compared to a set baseline (Figure 15). Therefore, this tool allows the user to compare the impact of specific improvements on the SAP rating of a property.

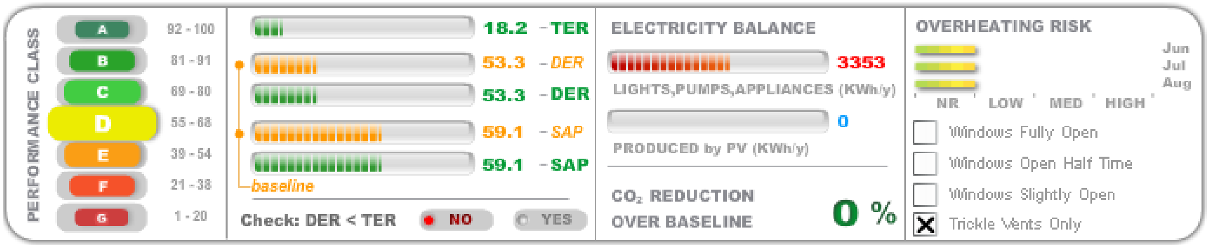



***Figure 15.*** *SAP sensitivity tool: display of the SAP score in results bar*

<u>Accounting for $CO_2$ improvement</u>

A further issue that adds value to this analysis is the capability of also allowing the simultaneous estimation of the $CO_2$ savings attached to the energy efficient improvements. This measure of improvement will be introduced along with SAP rating scores and associated costs of improvements in the results section.

**Establishing the Characteristics of Groups**

Available EPCs were used to identify the main characteristics of buildings that influence their energy performance. Average values were calculated for data such as the total floor area of dwellings and the percentage of efficient lighting. For other features such as main wall type, the mode (most frequently occurring) was chosen as typical. The method for determining typical energy performance related characteristics can be seen in Table 2. These were based on the summary of home energy performance related features from the EPCs. An example can be seen in Table 3.

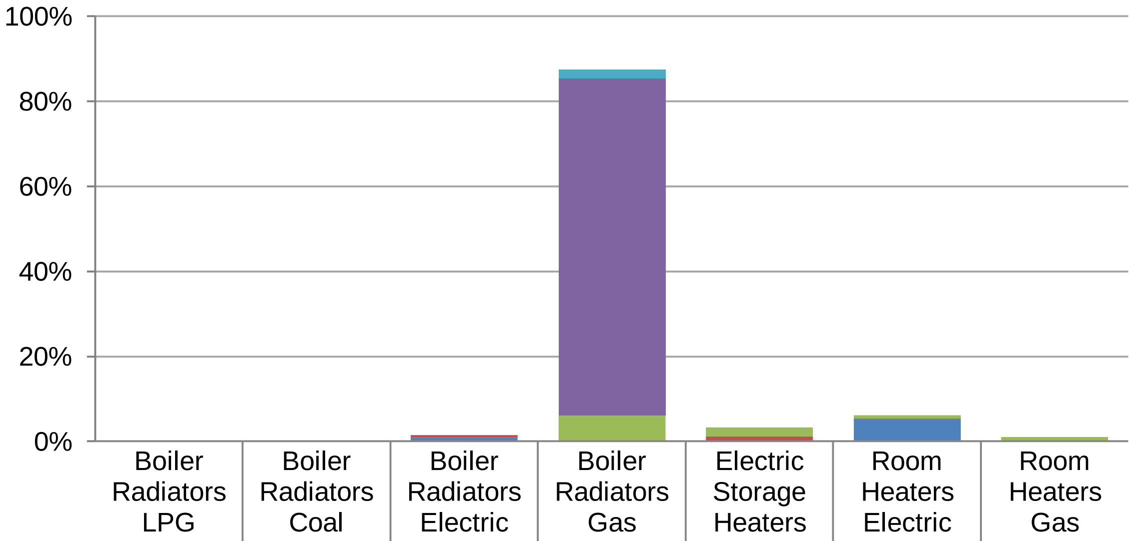
***Table 2.*** *Method of determining typical energy performance related characteristics*

| Average | Mode |
|---|---|
| Initial SAP rating | Primary wall type |
| Floor area of dwelling | Primary roof rating |
| % efficient lighting | Floor Insulated (yes/no) |
| | Double glazing coverage |
| | Primary heating fuel |
| | Primary heating system and system’s controls rating |
| | Secondary heating type |

***Table 3.** Table extracted from a sample EPC showing the description and energy efficiency rating of a home's energy* performance related features

| Summary of this home's energy performance related features | | |
|---|---|---|
| **Element** | **Description** | **Energy Efficiency** |
| Walls | Cavity wall, as built, partial insulation (assumed) | ★★★☆☆ |
| Roof | Pitched, 300+ mm loft insulation | ★★★★★ |
| Floor | Solid, no insulation (assumed) | – |
| Windows | Fully double glazed | ★★★☆☆ |
| Main heating | Boiler and radiators, mains gas | ★★★★☆ |
| Main heating controls | Programmer, room thermostat and TRVs | ★★★★☆ |
| Secondary heating | None | – |
| Hot water | From main system | ★★★★☆ |
| Lighting | Low energy lighting in 40% of fixed outlets | ★★★☆☆ |

Figure 16 shows an example of the distribution of existing heating system types and their ratings from all available EPCs. The rating system is based on the EPC's 'star rating system' (as can be seen in Table 3) where 1 star represents "very poor", 3 stars represent "average" and 5 stars represents "very good". This available data was then split further depending on the property type and rating band to give an idea of the characteristics of each sub-group (as can be seen in the results section).




| | Boiler Radiators LPG | Boiler Radiators Coal | Boiler Radiators Electric | Boiler Radiators Gas | Electric Storage Heaters | Room Heaters Electric | Room Heaters Gas |
|---|---|---|---|---|---|---|---|
| ***** | | | | 2.1% | | | |
| **** | | | | 79.2% | | | |
| *** | 0.2% | 0.2% | | 6.2% | 2.1% | 0.7% | 1.1% |
| ** | | | 0.5% | | 1.1% | 0.2% | |
| * | | | 0.9% | | 0.2% | 5.3% | |

***Figure 16.** Main heating system types and rating*

**Identifying the potential of groups**

The characteristics were then used to choose an EPC for each group that best represented its current and potential energy performance and hence a set of recommended measures that could be widely applied to that group.

Appendix T of the official SAP2009 document (recommendations for improvements 2012) gives the circumstances under which recommendations for improvements are made and are ordered by relevance. This gave a short list of frequently recommended improvements in the order that they would appear in EPCs. Some of the conditions were simplified in order to be comparable with values in the SAP sensitivity tool. Table 4 highlights the recommendations considered, values used in the official SAP2009 document and in the SAP sensitivity tool.

***Table 4.*** *Recommendations considered, values used in official SAP2009 document and in the SAP sensitivity tool*

| Measure | | Condition for improvement | Recommended Improvement |
|---|---|---|---|
| **Loft/roof Insulation** | | **<=150 mm insulation or U-value entered by assessor >=0.35**<br>(U-value >=0.35) | **250mm insulation**<br>(U value of 0.2) |
| **Wall** | **Cavity wall insulation** | **Wall U-value>0.6**<br>(U-value >0.6) | **Cavity filed wall (U-value dependant on age of wall)**<br>(U value 0.3) |
| | **Solid Wall Insulation** | **Wall U-value>0.6**<br>(U-value >0.6) | **Internal or external wall insulation with U-value of 0.3**<br>(U-value of 0.3) |
| **Floor Insulation** | | **Floor is as built (if built < 2006) Or U-value >0.5**<br>(U value >0.45) | **150mm of floor insulation**<br>(U value 0.25) |
| **Draught proofing** | | **Less than 100% draught proofing of windows and doors**<br>(poor or normal infiltration rate: approx. 10 m3/m2 air changes per hr or more) | **100% draught proofing**<br>(good practice infiltration rate: maximum of 5 m3/m2 air changes per hr) |
| **Low energy lighting** | | **Low energy lighting <100% of fixed outlets**<br>(Low energy lighting <100% of fixed outlets) | **Low energy lighting in all fixed outlets**<br>(Low energy lighting in all fixed outlets) |
| **Upgrade heating system** | | **Any component of system is below A rating**<br>(Age of system unknown) | **System that is A rated**<br>(Age of system 2006 to present) |
| **Solar water heating** | | **No solar thermal panel**<br>(No solar panel) | **3m2 Solar thermal panel**<br>(3m2 Solar) |
| **Double glazing** | | **Less than 80% of windows with multiple glazing**<br>(U value < 3) | **All single glazed windows replaced by double glazing with U-1.5 and G=0.63**<br>(U value 1.4) |
| **Photovoltaics** | | **No photovoltaics or less than 1kWp**<br>(No PV panels) | **Photovoltaics, 2.5kWp**<br>(2.5kWp PV panels) |
| **Values in Appendix T of SAP 2009 document**<br>(Values used in SAP sensitivity tool) | | | |

It can be observed in Table 4 that the retrofitting interventions proposed are focused on the “Fabric First” approach. For Castleland Renewal Area however the initial funding stage is focused on “Systems First” therefore the analysis will consider 2 different orders of interventions which can be seen in Table 5.

***Table 5.*** *Order of interventions: Fabric First and Systems First*

| Fabric First | Systems First |
|---|---|
| Roof | Heating |
| Wall | Lighting |
| Floor | Draught |
| Draught | Roof |
| Lighting | Wall |
| Heating | Floor |
| Solar | Windows |
| Windows | Solar |
| PV | PV |

A baseline for each group was created depending on the average current SAP rating and dwelling floor area of the sample. Then, if conditions for improvement shown in Table 4 were met, recommendations were applied in the order of relevance using the SAP sensitivity tool.

The improvement with each recommendation was recorded at each step. This made it possible to identify which measures were needed to achieve the *HHSRS target* and the *2050 target* for each of the groups.

**Aggregating the Results and Approximating Total Costs**

Both sets of recommendations were "applied" to all pre 1919 dwellings within the renewal area. As the sample represented the renewal area well in terms of typologies, the recommendations for groups were applied to the dwellings in the area per typology in line with the representation of the groups within that typology in the sample.

An average cost deduced from the sample EPCs was used to estimate the cost of separate measures. However, Warm Wales provided actual costs of wall insulation and upgrading of heating systems, therefore those figures were used instead of the EPC estimates. Table 6 outlines the costs used for each measure. The cost of achieving the two standards was calculated for a single dwelling in each group before calculating the total for all pre 1919 properties in the area.

***Table 6***. *Cost of measures*

| | ROOF | WALL | FLOOR | DRAUGHT | LIGHTING | HEATING | SOLAR | WINDOWS | PV |
|---|---|---|---|---|---|---|---|---|---|
| **All dwellings** | £250 | - | £530 | £100 | £50 | £2,300 | £4,800 | £4,900 | £8,750 |
| **Mid-Terraced** | - | £7,602 | - | - | - | - | - | - | - |
| **End-T / Semi-Det.** | - | £14,415 | - | - | - | - | - | - | - |
| **Flats** | - | £3,801 | - | - | - | - | - | - | - |

# Results

## Group 1 Results: Pre 1919 Mid-Terraced Houses

Pre 1919 mid-terraced houses account for nearly 60% of all dwellings in the renewal area. Just under half of these had available EPC data as can be seen in Figure 17. A small proportion (3%) of these EPCs had good energy performance related features and were C rated properties. 5% of the available EPCs were at the other end of the scale and had very poorly performing energy related features (F and G rated). The rest of these dwellings lied in the D and E bands and had poor to moderately rated features. A general overview of the features of each band can be seen in Table 7.

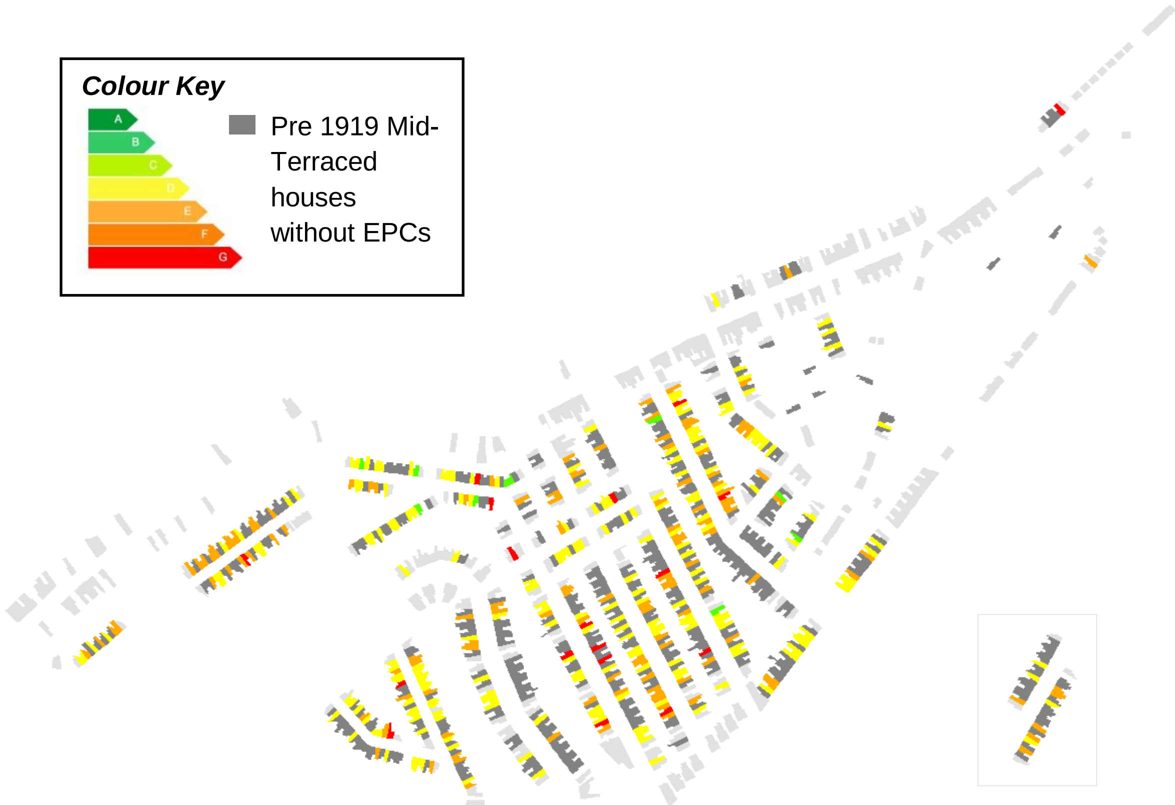



***Figure 17:*** *Mid-terraced houses and available EPCs*

***Table 7:*** *Typical Features of mid-terraced rating bands*

| | C (3%) | D (57%) | E (35%) | F/G (5%) |
|---|---|---|---|---|
| FLOOR AREA | 80m2 | 90m2 | 90m2 | 100m2 |
| WALLS | Externally/internally insulated solid | Un-insulated solid | Un-insulated solid | Un-insulated solid |
| ROOF | 200mm insulation | 50mm insulation | 25mm insulation | No insulation |
| FLOOR | Un-insulated solid or suspended | Un-insulated solid or suspended | Un-insulated solid or suspended | Un-insulated solid or suspended |
| WINDOWS | Full double glazing (few years old) | Full double glazing (few years old) | Full double glazing (few years old) | Little double glazing |
| HEATING | • Efficient gas boiler and radiators<br>• (2006 to present)<br>• Average controls<br>• No secondary heating | • Efficient gas boiler and radiators(2006 to present)<br>• Average controls<br>• No secondary heating | • Moderately efficient gas boiler and radiators (1996-2006)<br>• Average controls<br>• Gas room heaters as secondary heating | • Inefficient gas boiler and radiators (Pre 1996)<br>• Poor controls<br>• Gas or electric room heaters as secondary |
| EFFICIENT LIGHTING | 50% | 40% | 40% | 30% |
| DRAUGHT PROOF | Good | Normal | Poor | Poor |

SAP improvement and $CO_2$ emissions reduction of measures per band: Pre 1919 Mid-Terraced

The typical features identified in Table 7 were used to form 4 mid-terraced archetypes, each differing in its level of energy efficiency. The four representative dwellings were formed using the SAP sensitivity tool before the impact of energy efficiency measures on each was recorded. This analysis follows two progressive pathways of interventions: a fabric first approach (based on SAP2009 appendix T documentation) and an alternative which considers improving systems first. The impact of improvements for both approaches will be presented as the cumulative increase in SAP score with each successive measure needed for the 4 archetypes as well as the yearly $CO_2$ emissions (kg $CO_2$) at each step. The impact of individual measures was also recorded and will be displayed as the difference in SAP score before and after the measure is applied (assuming that measures are needed in all cases).

*Cumulative SAP improvement and $CO_2$ emissions reduction of applying measures*

Figure 18 shows the cumulative effect of measures when following a fabric first approach while Figure 19 shows the impact of successive improvements when applying the systems first method. It can be seen which improvements would be needed to achieve the *HHSRS target* (SAP above 62.5) and *2050 target* (SAP above 92) for each of the groups. Measures required for each group are highlighted by a solid line showing the improvement in rating and a dot representing the rating achieved after applying the measure and all preceding measures. The dotted lines represent measures that are not needed for that specific group and therefore have no influence on the improvement of the SAP rating. The bars in Figure 18 and 19 show the yearly $CO_2$ emissions (kg $CO_2$) for each band at each successive step.

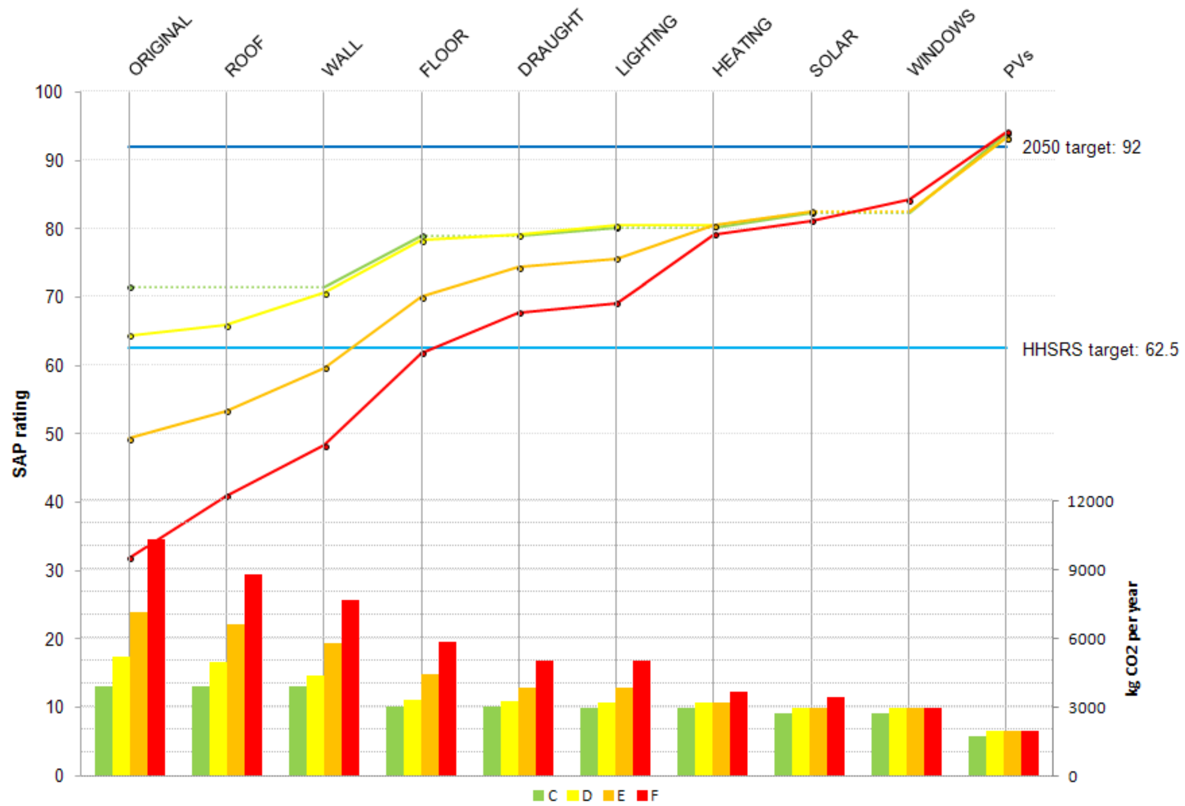



***Figure 18:*** *Fabric first: Cumulative SAP improvement of measures (Lines) and yearly $CO_2$ emissions (Bars) per band for pre 1919 mid-terraced houses*

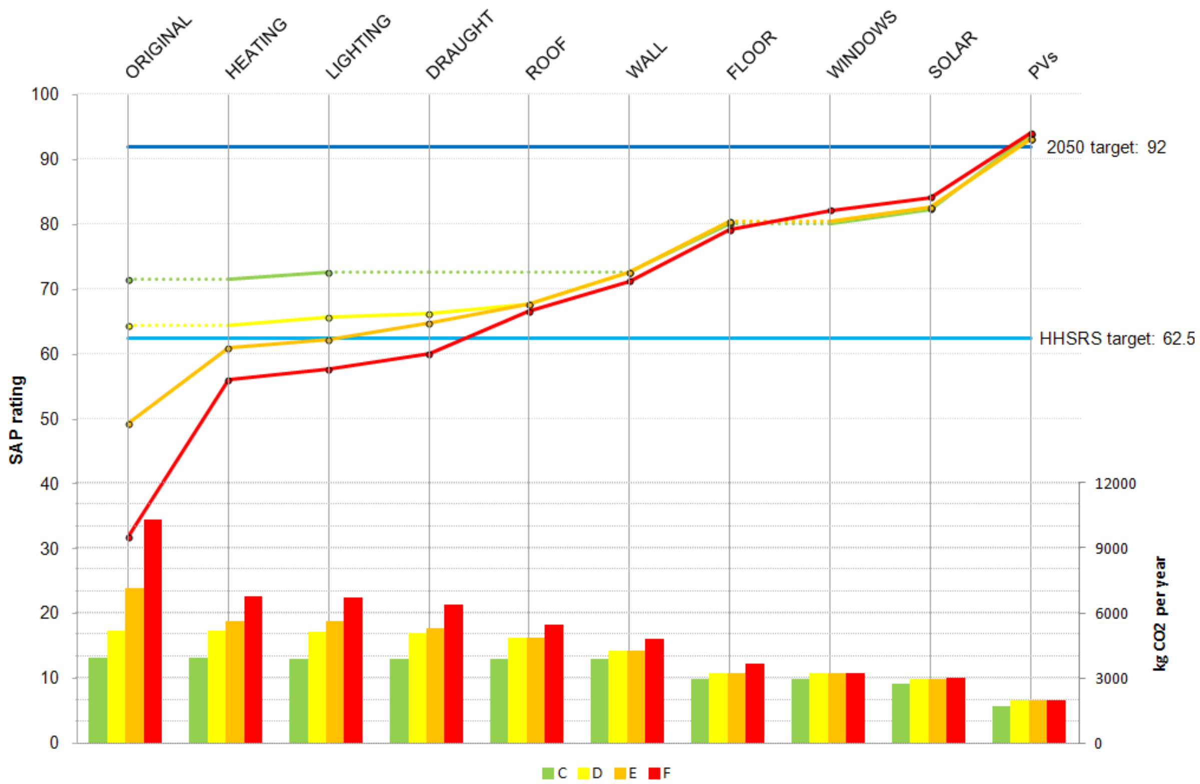
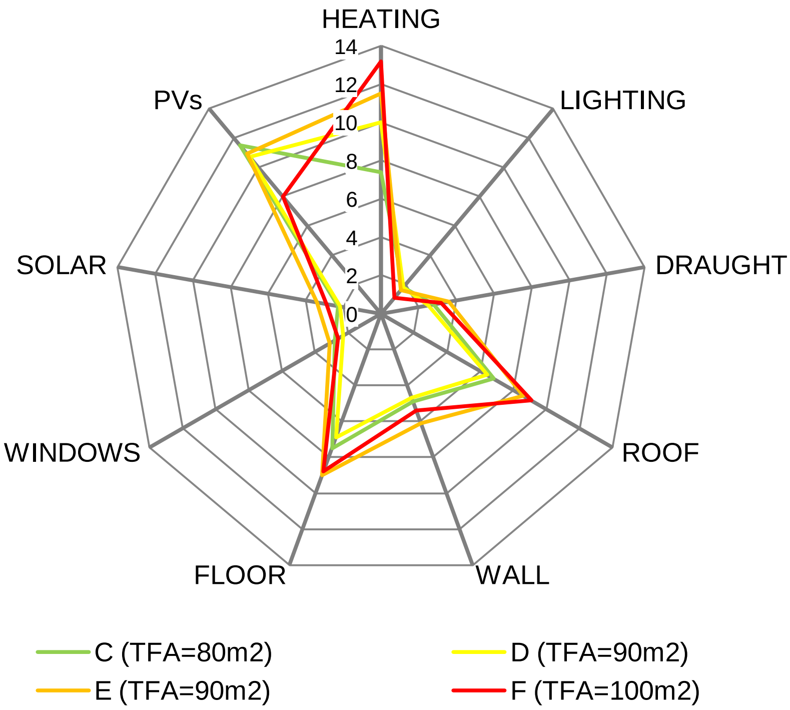



***Figure 19****: Systems first: Cumulative SAP improvement (Lines) and of measures and yearly $CO_2$ emissions (Bars) per band for pre 1919 mid-terraced houses*

*SAP improvement when applying individual measures*

Figure 20 shows the effect of individual measures on each of the representative dwellings and assumes that all measures are needed in all cases. It shows the impact of individual measures as the difference in SAP score before and after a measure is applied. All other characteristics of the bands are kept as in Table 7 except for the feature in question. The element under analysis is assumed to be improved from an inefficient state to an efficient one (see right of Figure 20 for assumptions used).




| | | |
|---|---|---|
| Moderately efficient gas boiler 1996-2006 | -> | Efficient gas boiler 2006 to present |
| 0% efficient lighting | -> | 100% efficient lighting |
| Poor draught proofing | -> | Good draught proofing |
| No roof, wall or floor insulation | -> | 200mm roof insulation, solid wall insulation, floor insulation |
| Single glazing | -> | 2012 standard double glazing |
| No solar thermal | -> | 3m2 solar thermal |
| No PVs | -> | 2.5kWp PVs |

***Figure 20.*** *SAP improvement of individual measures for typical pre 1919 mid-terraced houses of band and stated floor area*

Cumulative cost and SAP improvement of measures per band: Pre 1919 Mid-Terraced

In Figure 21 and 22, the relative cost of measures for single dwellings is compared to the improvement gained in terms of SAP rating score for both approaches. It is to be noted that the dotted lines represent measures that are not needed for that certain group and therefore the cost would not need to be applied. This is highlighted in the bars above the graph which indicate the recommendations and costs applied to rating groups as well as the total costs of all measures. Note that the costs provided in the bars above the graph are the overall cost of the properties of different bands to achieve the *2050 target*. i.e. a C rated pre 1919 mid-terraced house would cost approximately £14,130 to achieve the *2050 target*. This same typology graded as F or G in the SAP rating may cost twice as much, approximately £29,282. The figures are based on the estimated values described in this report.

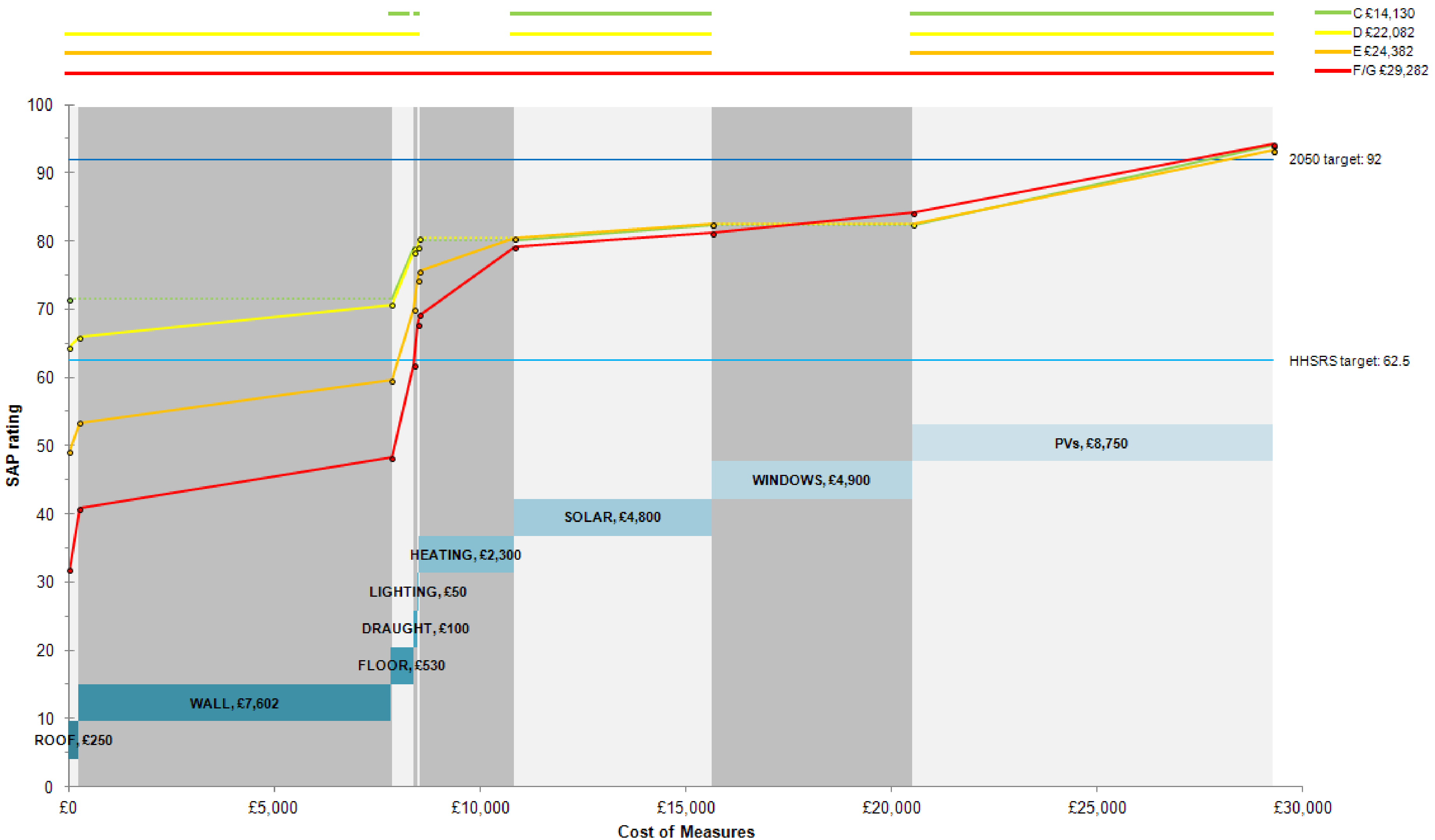



***Figure 21:*** *Fabric First: Cumulative cost and SAP improvement of measures per band for pre 1919 mid-terraced houses*

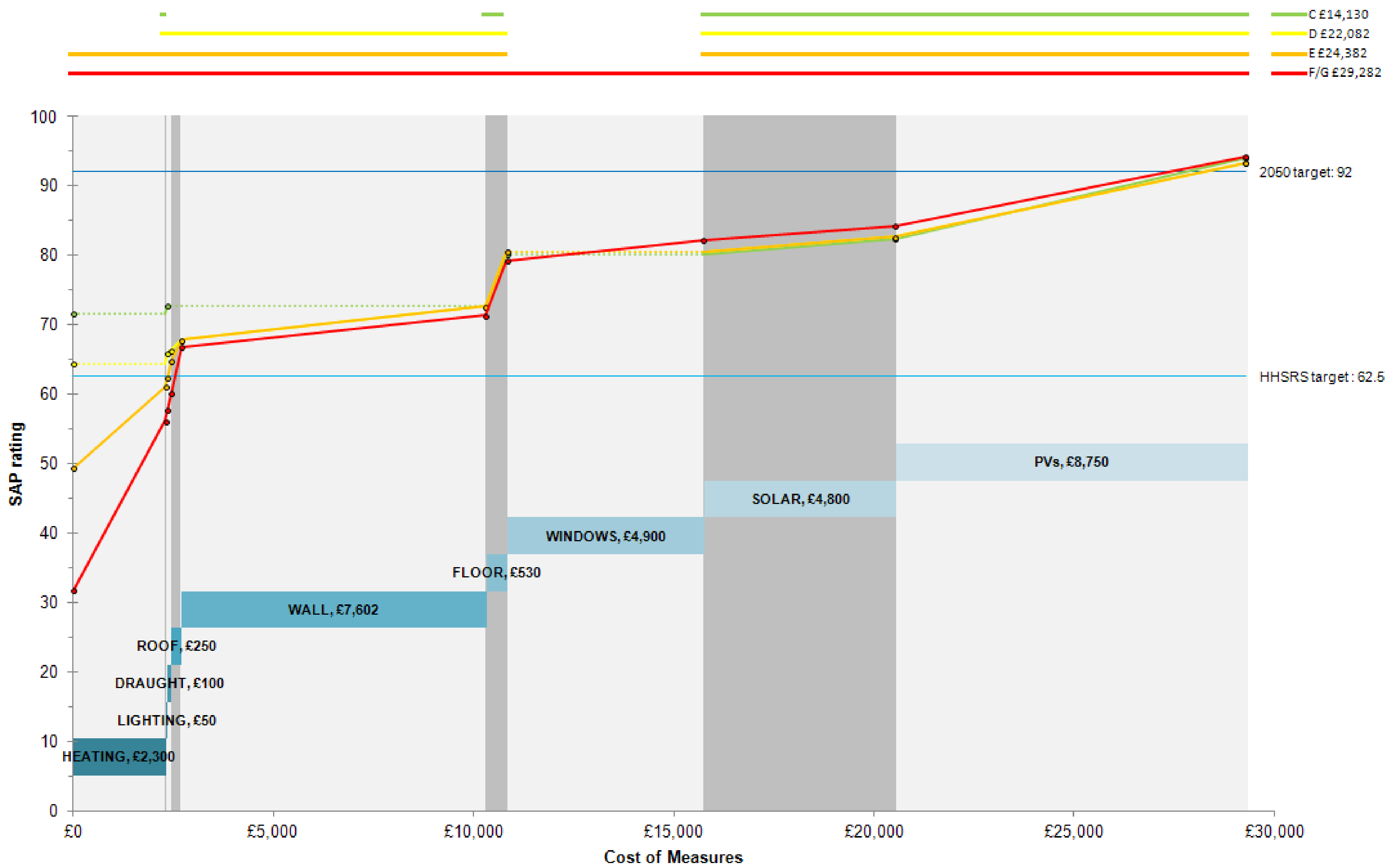



***Figure 22:*** *Systems First: Cumulative cost and SAP improvement of measures per band for pre 1919 mid-terraced houses*

### Group 2 Results: Pre 1919 End-Terraced/Semi-Detached Houses

Pre 1919 end-terraced and semi-detached houses account for over 10% of all dwellings in the renewal area. Just under half of these had available EPC data as can be seen in Figure 23. A very small proportion (1.5%) of these EPCs had good energy performance related features and were C rated properties. There was a higher proportion of poorly performing properties than there was in mid-terraced houses. 23.5% of the EPCs were F and G rated and had very poorly performing energy related features. The rest of these dwellings were within the D and E bands and had poor to moderately rated features. A general overview of the features of each band can be seen in Table 8.

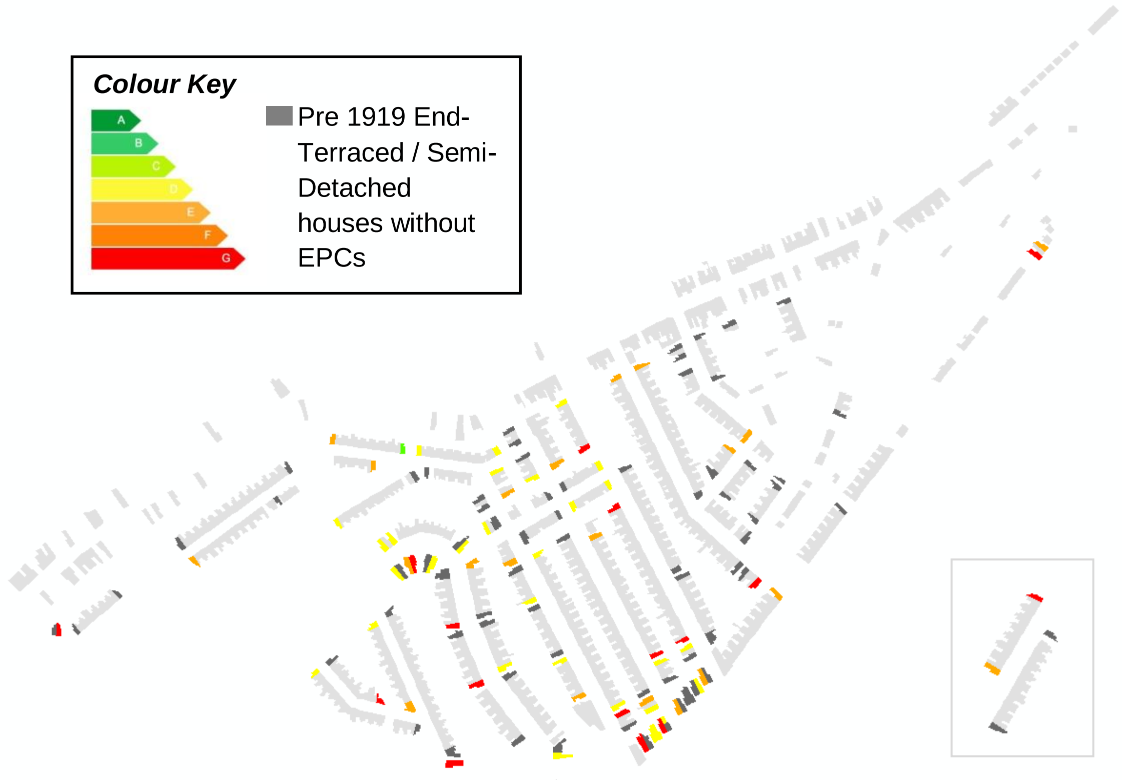



***Figure 23:*** *End-terraced/semi-detached houses and available EPCs*

***Table 8:*** *Typical features of end-terraced/semi-detached rating bands*

| | C (1.5%) | D (31%) | E (44%) | F/G (23.5%) |
|---|---|---|---|---|
| FLOOR AREA | 90m2 | 100m2 | 110m2 | 120m2 |
| WALLS | Externally /internally insulated solid | Un-insulated solid | Un-insulated solid | Un-insulated solid |
| ROOF | 200mm insulation | 200mm insulation | 50mm insulation | No insulation |
| FLOOR | Un-insulated solid or suspended | Un-insulated solid or suspended | Un-insulated solid or suspended | Un-insulated solid or suspended |
| WINDOWS | Full double glazing (few years old) | Full double glazing (few years old) | Full double glazing (few years old) | Little double glazing |
| HEATING | • Efficient gas boiler and radiators (2006 to present)<br>• Average controls<br>• No secondary heating | • Efficient gas boiler and radiators (2006 to present)<br>• Average controls<br>• No secondary heating | • Moderately efficient gas boiler and radiators (1996-2006)<br>• Average controls<br>• Gas or Electric room heaters as secondary heating | • Moderately efficient gas boiler and radiators (1996-2006)<br>• Poor controls<br>• Gas or electric room heaters as secondary |
| EFFICIENT LIGHTING | 60% | 50% | 50% | 40% |
| DRAUGHT PROOFING | Good | Normal | Poor | Poor |

SAP improvement and $CO_2$ emissions reduction of measures per band: Pre 1919 end-terraced and semi-detached

Similar to Group 1, the most representative properties were chosen for the analysis for the different SAP bands within Group 2. The improvement with each recommendation was recorded using the SAP sensitivity tool for both approaches (fabric first and systems first). The impact of the different interventions are analysed cumulatively and individually.

*Cumulative SAP improvement and $CO_2$ emissions reduction of applying measures*

Comparable to Figures 18-19 and 20 shown in the analysis for Group 1, Figures 24-25 and 26 illustrate the cumulative and non-cumulative results of the analysis for properties in Group 2. Figures 24 and 25 show the improvement of recommendations needed to achieve the *HHSRS* (SAP above 62.5) and the *2050 target* (SAP above 92) for each of the bands while a bar graph displays the reduction in yearly $CO_2$ emissions (kg $CO_2$) at each successive step. Measures required for each band are highlighted by a solid line showing the improvement in rating and a dot representing the rating achieved after applying the measure and all preceding measures. The dotted lines represent measures that are not needed for that specific group and therefore have no influence on the improvement of the SAP rating.

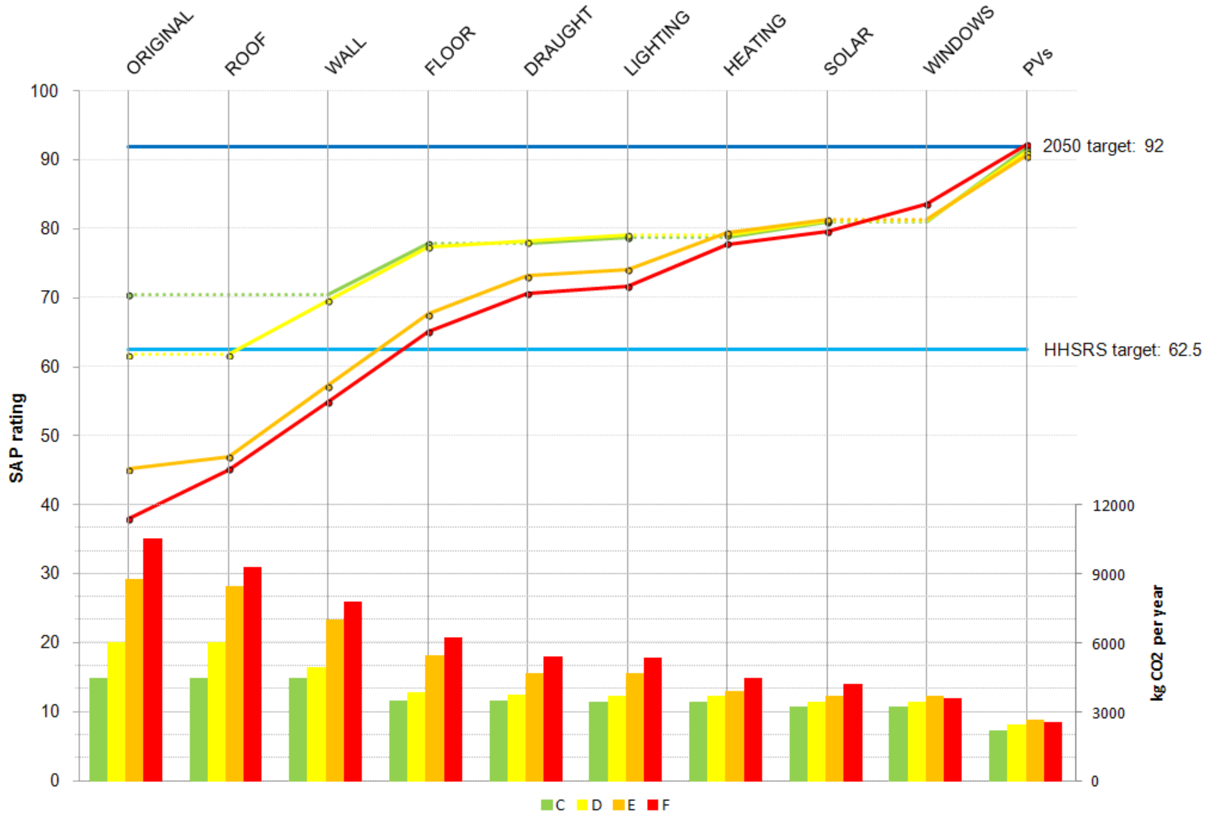



***Figure 24:*** *Fabric first: Cumulative SAP improvement of measures (Lines) and yearly $CO_2$ emissions (Bars) per band for pre 1919 mid-terraced houses*

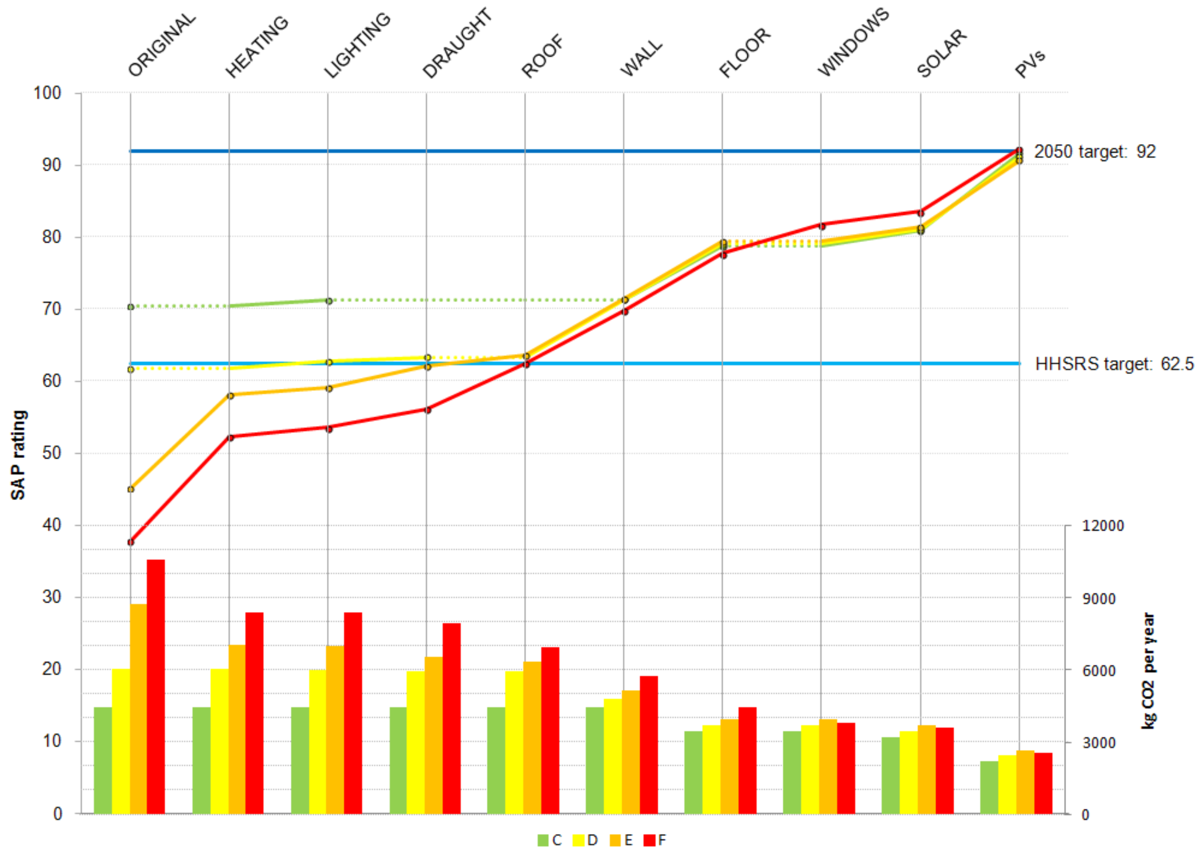
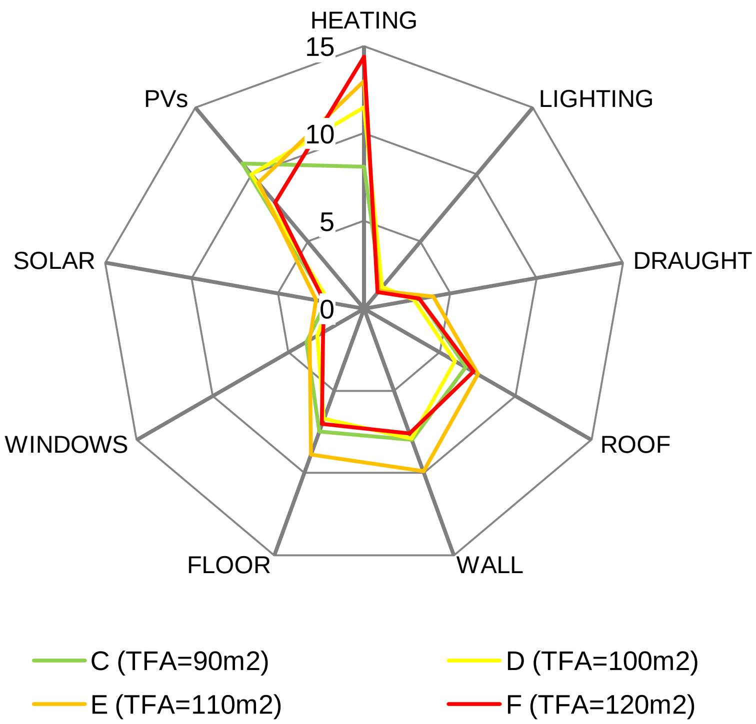



***Figure 25:*** *Systems first: Cumulative SAP improvement (Lines) of measures and yearly $CO_2$ emissions (Bars) per band for pre 1919 mid-terraced houses*

*SAP improvement when applying individual measures*

Figure 26 shows the effect of individual measures on each of the representative dwellings and assumes that all measures are needed in all cases. It shows the impact of individual measures as the difference in SAP score before and after a measure is applied. All other characteristics of the bands are kept as in Table 8 except for the feature in question. The element under analysis is assumed to be improved from an inefficient state to an efficient one (see right of Figure 26 for assumptions used).




| | | |
|---|---|---|
| Moderately efficient gas boiler 1996-2006 | -> | Efficient gas boiler 2006 to present |
| 0% efficient lighting | -> | 100% efficient lighting |
| Poor draught proofing | -> | Good draught proofing |
| No roof, wall or floor insulation | -> | 200mm roof insulation, solid wall insulation, floor insulation |
| Single glazing | -> | 2012 standard double glazing |
| No solar thermal | -> | 3m2 solar thermal |
| No PVs | -> | 2.5kWp PVs |

***Figure 26:*** *SAP improvement of individual measures for typical pre 1919 semi detached / end-terraced houses of band and stated floor area*

Cumulative cost and SAP improvement of measures per band: Pre 1919 end-terraced and semi-detached

For Group 2, Figures 27 and 28 depicts the relative cost of measures compared to the improvement gained in terms of SAP rating score per band following the fabric first and systems first approach respectively. It is to be noted that the dotted lines represent measures that are not needed for that certain group and therefore the cost would not need to be applied. This is highlighted in the bars above the graph which indicate which recommendations and costs apply to rating groups as well as the total costs of all measures. Note that the costs provided in the bars above the graph are the overall costs for properties of different bands to achieve the *2050 target*. I.e. a C rated pre 1919 end-terraced/semi-detached house would cost approximately £14,130 to achieve the 2050 target. The same typology graded as F or G in the SAP rating may cost 2.5 times as much, approximately £36,095. The figures are based on the estimate values described in this report.

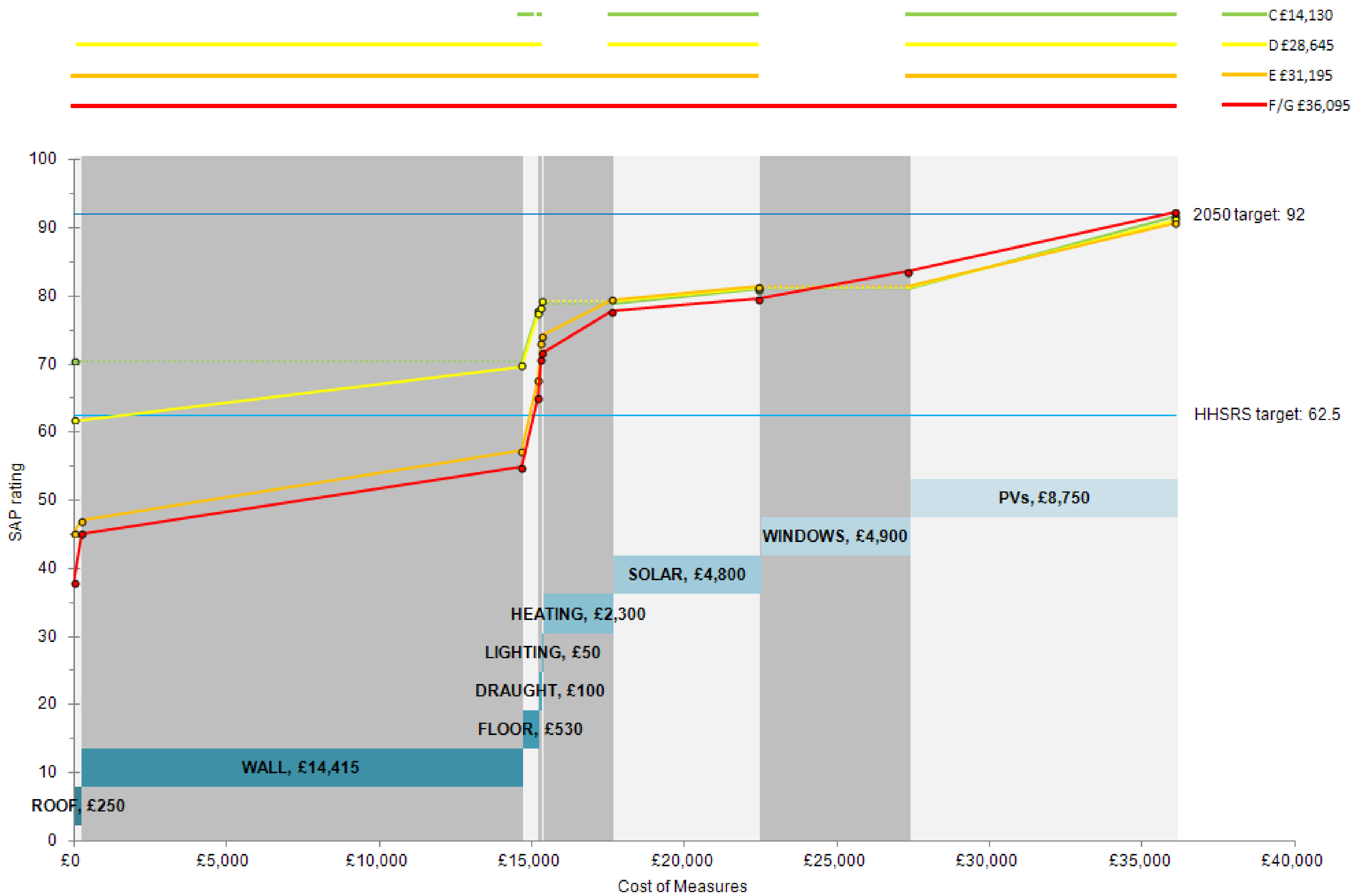



***Figure 27:*** *Fabric First: Cumulative cost and SAP improvement of measures per band for pre 1919 end-terraced and semi-detached houses*

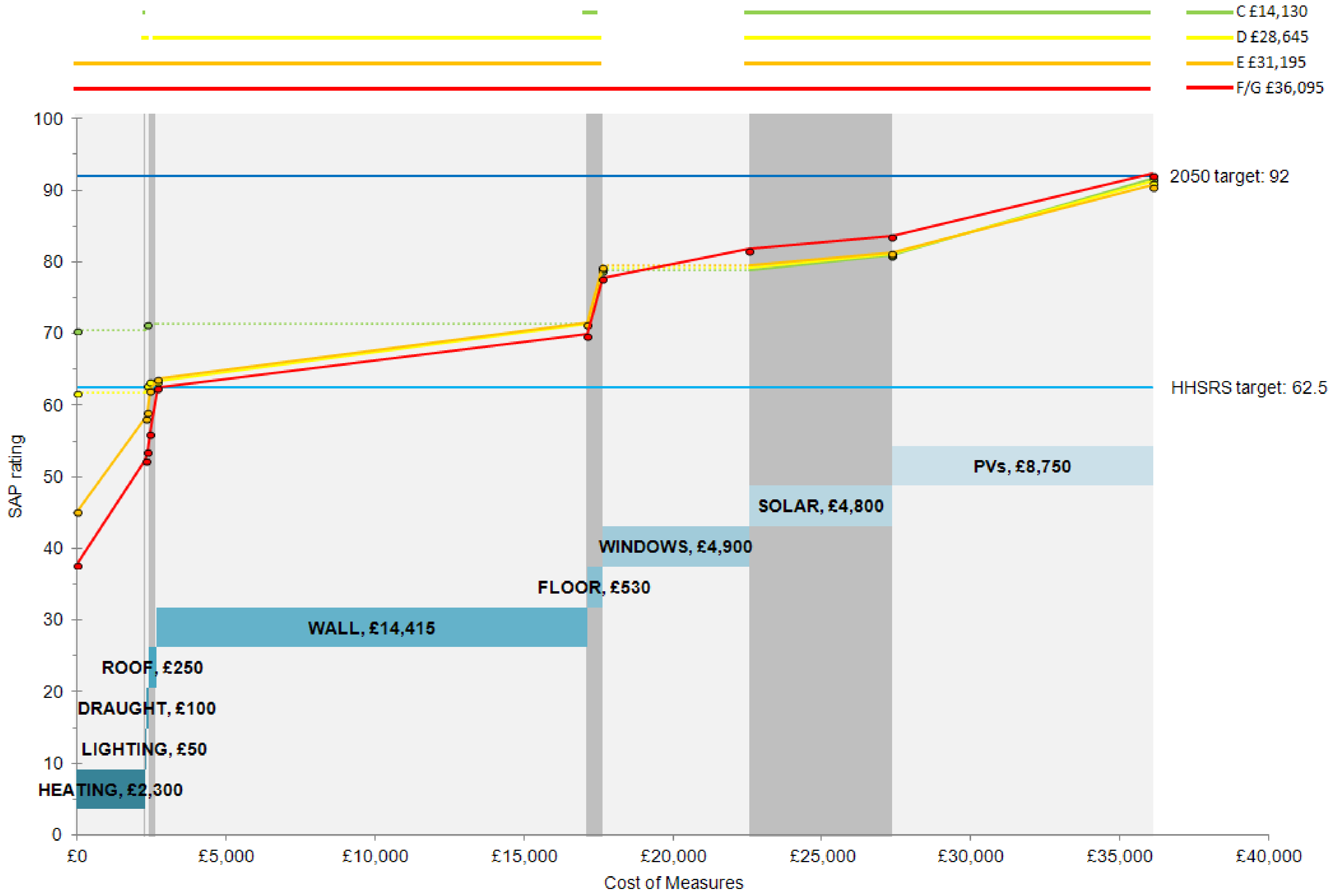



***Figure 28:*** *Systems First: Cumulative cost and SAP improvement of measures per band for pre 1919 end-terraced and semi-detached houses*

## Group 3 Results: Pre 1919 Flats

Pre 1919 flats account for 21% of all dwellings in the renewal area. 40% of these had available EPC data as can be seen in Figure 29. 70% of these flats' EPCs were within the D and E bands and had poor to moderately rated features. The other 30% were mostly poorly performing flats in the F and G bands with a small proportion of dwellings having good energy related features, rated within the C band. A general overview of the features of each band can be seen in Table 9.

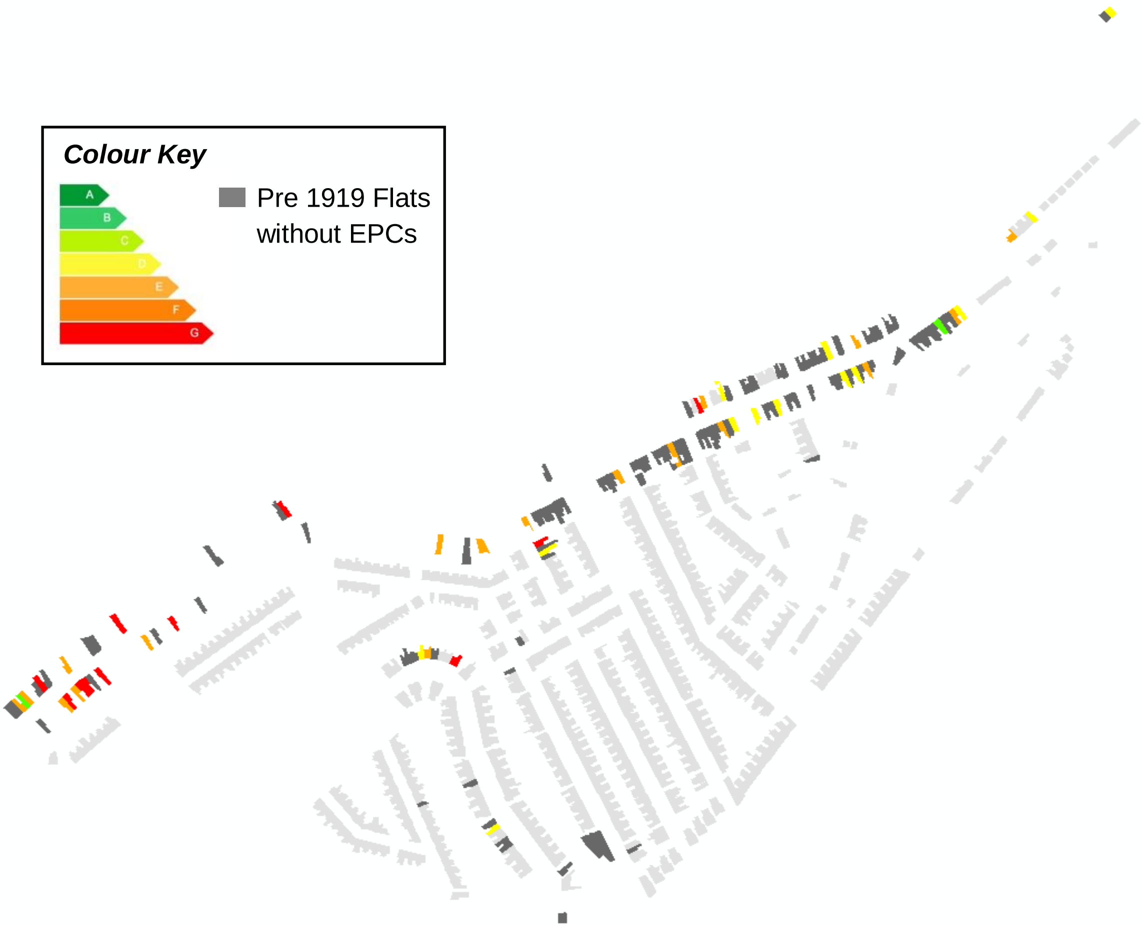



***Figure 29:*** *Flats and available EPCs*

The vast majority of these pre 1919 flats were not purposely built as flats. As a result, they comprise of a variety of characteristics, not necessarily common to the whole group. Flats can be classified as: basement, ground, mid or top floor flats as well as maisonettes. By considering these different classifications as well as other varying features, the thermal behaviour of the properties can vary quite significantly within this group. To avoid overcomplicating the analysis, the focus was placed on the most common type of flat found in this area: top floor flat (commonly situated above shops on Holton Road as can be seen in Figure 29).

Due to this simplification, care must be taken if undertaking individual interventions in pre 1919 flats as not all the recommendations stated here will be applicable for all cases within these groups.

***Table 9:*** *Typical features of flats per rating bands*

| | C (6.5%) | D (37%) | E (33%) | F/G (23.5%) |
|---|---|---|---|---|
| FLOOR AREA | 50m2 | 50m2 | 70m2 | 50m2 |
| WALLS | Externally /internally insulated solid | Un-insulated solid | Un-insulated solid | Un-insulated solid |
| ROOF | 200mm insulation | 25mm insulation | 12mm insulation | No insulation |
| FLOOR | - | - | - | - |
| WINDOWS | Full double glazing (few years old) | Full double glazing (few years old) | Full double glazing (few years old) | Little double glazing |
| HEATING | • Efficient gas boiler and radiators (2006 to present)<br>• Average controls<br>• No secondary heating | • Efficient gas boiler and radiators (2006 to present)<br>• Average controls<br>• No secondary heating | • Moderately efficient gas boiler and radiators (1996-2006)<br>• Average controls<br>• No secondary heating | • Inefficient gas boiler and radiators (pre 1996)<br>• Poor controls<br>• Electric room heaters as secondary |
| EFFICIENT LIGHTING | 60% | 50% | 50% | 40% |
| DRAUGHT PROOFING | Good | Normal | Poor | Poor |

SAP improvement and $CO_2$ emissions reduction of measures per band: Pre 1919 flats

Similar to Groups 1 and 2, representative properties were analysed for the four SAP bands of pre 1919 flats. Based on the fabric first and systems first approaches, the SAP sensitivity tool was used to record the improvement gained from interventions in terms of SAP score and yearly $CO_2$ emissions (kg $CO_2$). As well as recording the improvements cumulatively, results were also recorded individually for each needed measure for the four baseline properties as can be seen in Figure 32.

*Cumulative SAP improvement and $CO_2$ emissions reduction of applying measures*

The increase in SAP score with each successive measure can be seen in Figure 30 for the fabric first approach and in Figure 31 for the systems first approach. As in Figures 24 and 25 for Group 2, required measures are highlighted by solid lines and dots to represent the rating achieved after applying the measure and all preceding measures. The dotted lines represent measures that are not needed for that specific group and therefore have no influence on the improvement of the SAP rating. The bar graphs in Figures 30 and 31 display the reduction in yearly $CO_2$ emissions (kg $CO_2$) at each successive step.

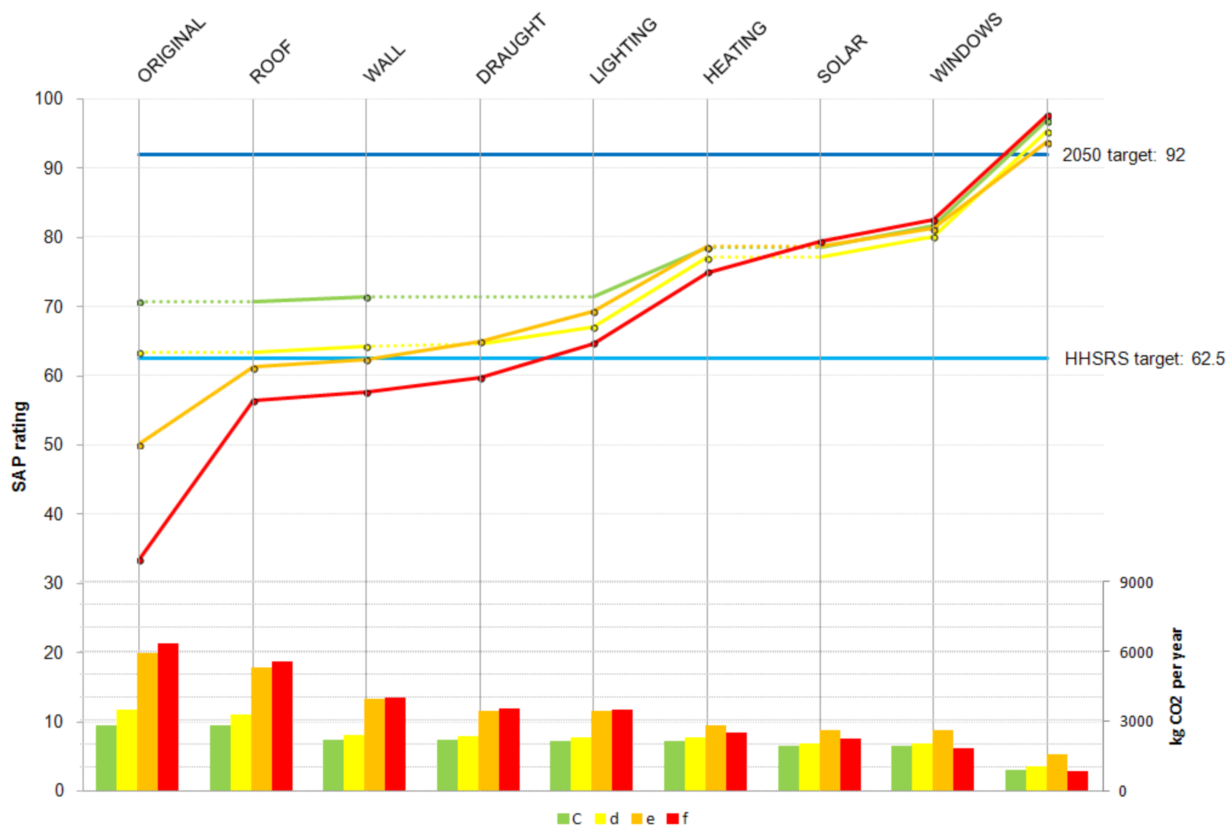



***Figure 30**: Fabric first: Cumulative SAP improvement of measures (Lines) and yearly $CO_2$ emissions (Bars) per band for pre 1919 flats*

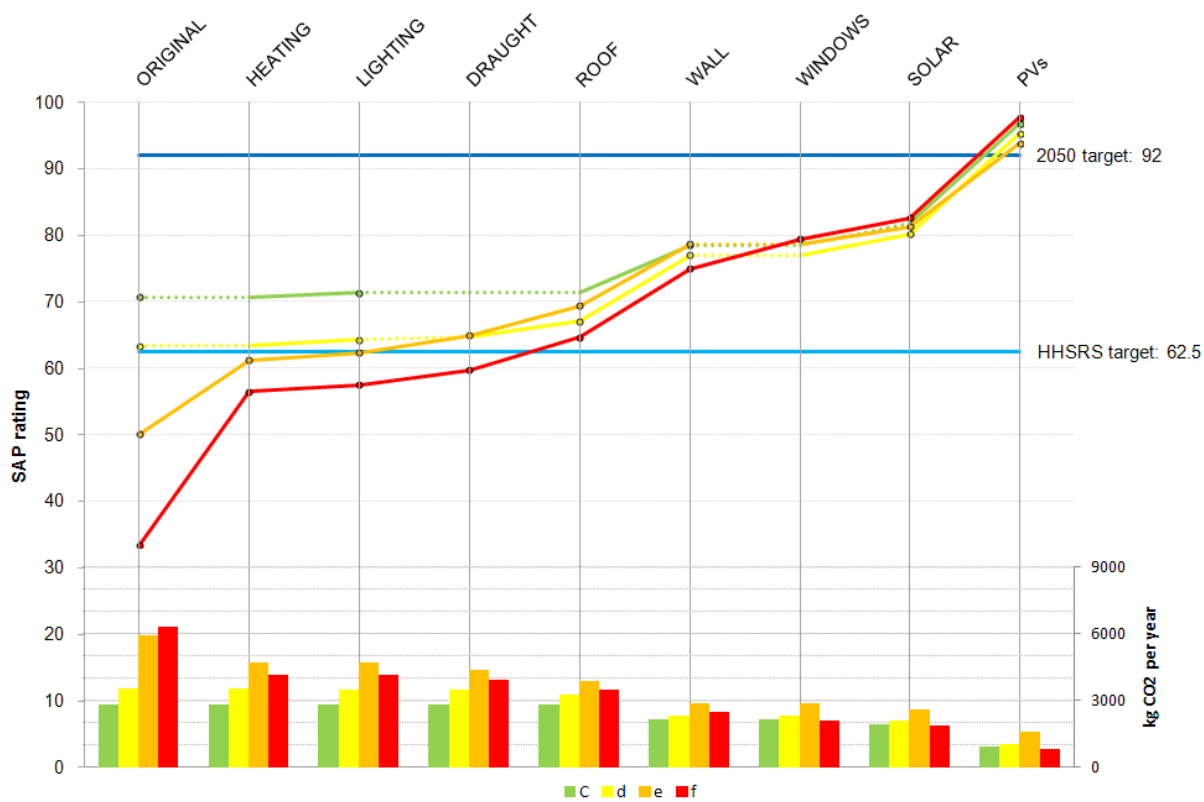
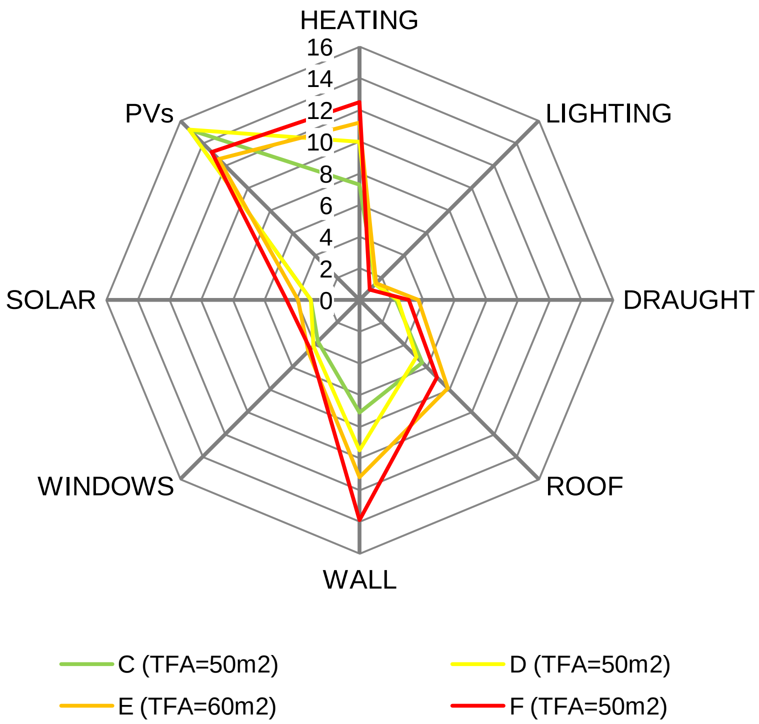



***Figure 31:** Systems first: Cumulative SAP improvement of measures (Lines) and yearly $CO_2$ emissions (Bars) per band for pre 1919 flats*

SAP improvement when applying individual measures

Figure 32 shows the effect of individual measures on each of the representative dwellings and assumes that all measures are needed in all cases. It shows the impact of individual measures as the difference in SAP score before and after a measure is applied. All other characteristics of the bands are kept as in Table 9 except for the feature in question. The element under analysis is assumed to be improved from an inefficient state to an efficient one (see right of Figure 32 for assumptions used).




| | | |
|---|---|---|
| Moderately efficient gas boiler 1996-2006 | -> | Efficient gas boiler 2006 to present |
| 0% efficient lighting | -> | 100% efficient lighting |
| Poor draught proofing | -> | Good draught proofing |
| No roof or wall insulation | -> | 200mm roof insulation, solid wall insulation |
| Single glazing | -> | 2012 standard double glazing |
| No solar thermal | -> | 3m2 solar thermal |
| No PVs | -> | 2.5kWp PVs |

***Figure 32:*** *SAP improvement of individual measures for typical flats of band and stated floor area*

Cumulative cost and SAP improvement of measures per band: Pre 1919 flats

In Figures 33 and 34, the relative cost of measures for single dwellings is compared to the improvement gained in terms of SAP rating score for pre 1919 flats per rating band. It is to be noted that the dotted lines represent measures that are not needed for that certain group and therefore the cost would not need to be applied. This is highlighted in the bars above the graph which indicate which recommendations and costs apply to rating groups as well as the total costs of all measures. These costs are equivalent to the cost of achieving the *2050 target* for an individual flat of that band. i.e. for an F or G rated pre 1919 flat it is estimated that all relevant measures would need to be applied and would cost approximately £24,951. It can also be seen that only roof, wall, draught and lighting measures would be needed for an F or G rated flat to reach the *HHSRS target* following the fabric first approach while only heating, lighting, draught and roof would be needed if the systems first approach was used. Detailed costs of reaching *HHSRS* and *2050 targets* for individual properties can be seen in the Total Costs section.

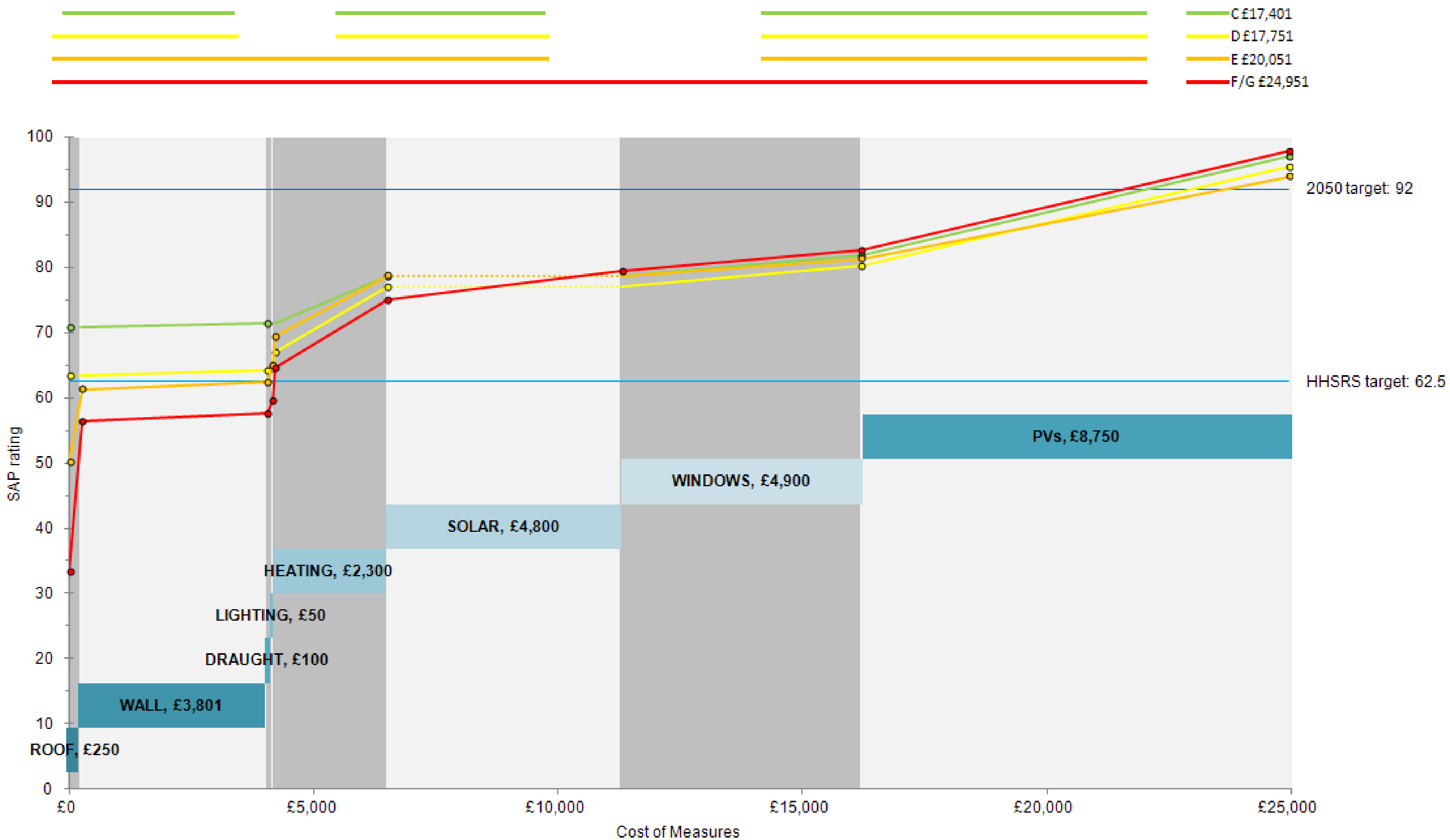



***Figure 33:*** *Fabric First: Cumulative cost and SAP improvement of measures per band d for pre 1919 flats*

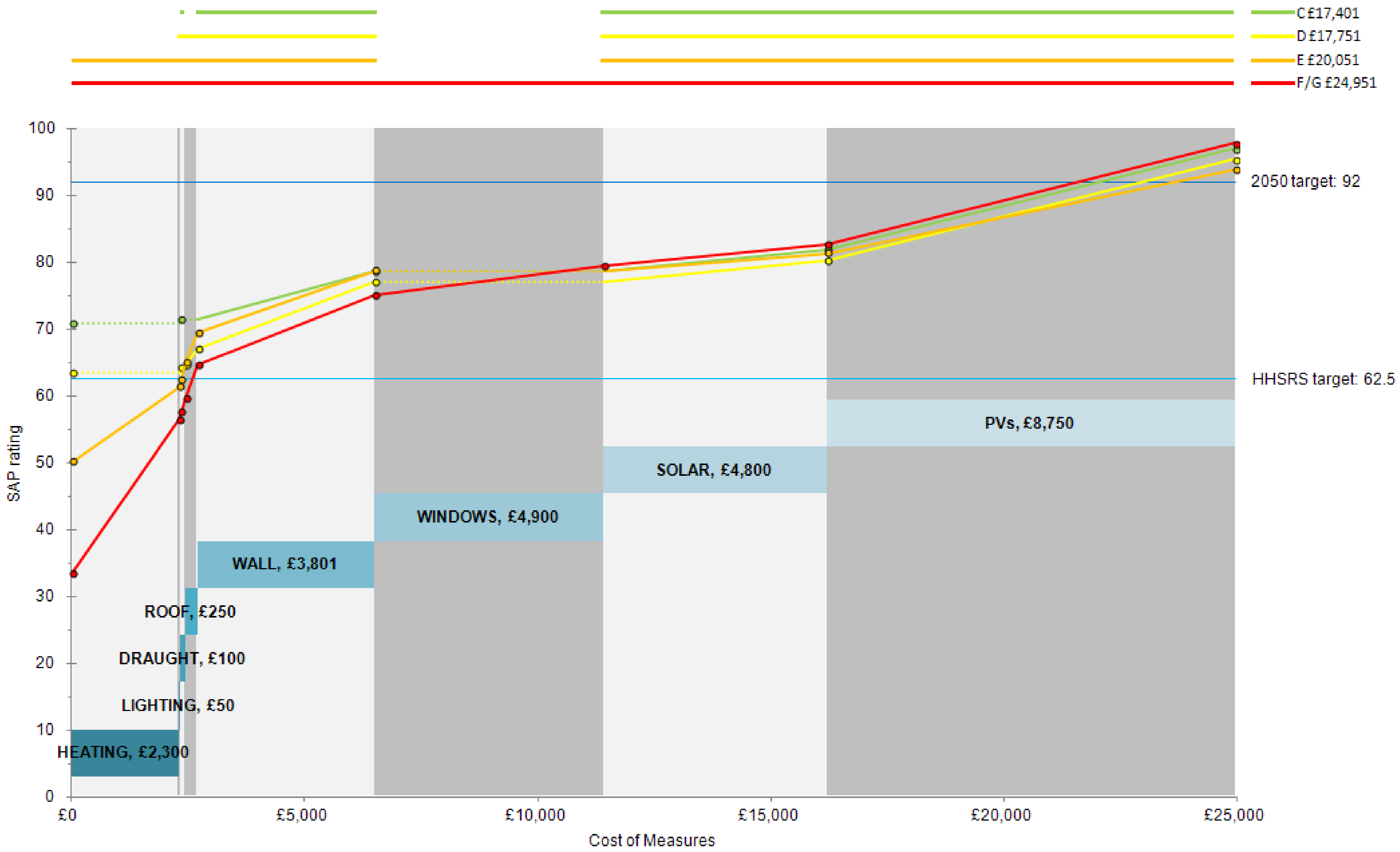



***Figure 34:*** *Systems First: Cumulative cost and SAP improvement of measures per band d for pre 1919 flats*

**Total costs and $CO_2$ emissions reduction**

To maximise the usability of these results, the total costs of achieving both targets for all pre 1919 properties is calculated initially per house type and then per measure. In addition, the yearly reduction in $CO_2$ emissions for each house type is calculated for the two targets following both approaches.

Cost and $CO_2$ reduction in achieving HHSRS and 2050 target per house type

The following three Tables (10,11 and 12) outline the cost of measures needed to reach the targets for each of the 12 identified groups as well as the associated reduction in $CO_2$ emissions. The totals of achieving both targets is calculated for all pre 1919 dwellings in the area and the total cost and yearly reduction in $CO_2$ emissions is shown at the bottom of each table. A breakdown of the figures involved is also displayed to allow flexibility in the application of these results. Measures and costs outlined in Table 12 are relevant to both approaches and are not in any particular order.

***Table 10**. HHSRS Target: Fabric First*

| | Band | Measure | Cost of Measure | Cost per property (yearly $CO_2$ reduction per property) | No. of prop. | Cost per band (yearly $CO_2$ reduction per band) | Cost per type (yearly $CO_2$ reduction per type) |
|---|---|---|---|---|---|---|---|
| **PRE 1919 MID-TERRACED** | **C** | - | - | - | **21** | - | **£2,476,390** (890,400 Kg) |
| | **D** | - | - | - | **415** | - | |
| | **E** | Roof | £250 | **£8,382** (2,697 Kg) | **258** | **£2,162,556** (695,865 Kg) | |
| | | Wall | £7,602 | | | | |
| | | Floor | £530 | | | | |
| | **F/G** | Roof | £250 | **£8,482** (5,258 Kg) | 37 | **£313,834** (194,535 Kg) | |
| | | Wall | £7,602 | | | | |
| | | Floor | £530 | | | | |
| | | Draught | £100 | | | | |
| **PRE 1919 SEMI DETACHED / END-TERRACED** | **C** | - | - | - | **2** | - | **£2,092,980** (398,241 Kg) |
| | **D** | Wall | £14,415 | **£14,415** (1,113 Kg) | 44 | **£634,260** (48,959 Kg) | |
| | **E** | Roof | £250 | **£15,195** (3,272 Kg) | 63 | **£957,285** (206,130 Kg) | |
| | | Wall | £14,415 | | | | |
| | | Floor | £530 | | | | |
| | **F/G** | Roof | £250 | **£15,195** (4,338 Kg) | 33 | **£501,435** (143,152 Kg) | |
| | | Wall | £14,415 | | | | |
| | | Floor | £530 | | | | |
| **PRE 1919 FLATS** | **C** | - | - | - | **17** | - | **£608,848** (345,583 Kg) |
| | **D** | - | - | - | **96** | - | |
| | **E** | Roof | £250 | **£4,051** (1,993 Kg) | 86 | **£348,386** (171,441 Kg) | |
| | | Wall | £3,801 | | | | |
| | **F/G** | Roof | £250 | **£4,201** (2,809 Kg) | 62 | **£260,462** (174,143 Kg) | |
| | | Wall | £3,801 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |

| | |
|---|---|
| **Total cost for all pre 1919 dwellings in area:** | **£5,178,218** |
| Total yearly $CO_2$ emissions reduction for all pre 1919 dwellings in the area: | **1,634,224 Kg** |

***Table 11.*** *HHSRS Target: Systems First*

| | Band | Measure | Cost of Measure | Cost per property (yearly $CO_2$ reduction per property) | Number of properties | Cost per band (yearly $CO_2$ reduction per band) | Cost per type (yearly $CO_2$ reduction per type) |
|---|---|---|---|---|---|---|---|
| **PRE 1919 MID-TERRACED** | **C** | - | - | **-** | **21** | **-** | **£706,200** (579,604 Kg) |
| | **D** | - | - | **-** | **415** | **-** | |
| | **E** | Heating | £2,300 | **£2,350** (1,549 Kg) | **258** | **£606,300** (399,705 Kg) | |
| | | Lighting | £50 | | | | |
| | **F/G** | Heating | £2,300 | **£2,700** (4,862 Kg) | **37** | **£99,900** (179,898 Kg) | |
| | | Lighting | £50 | | | | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |
| **PRE 1919 SEMI DETACHED / END-TERRACED** | **C** | - | - | **-** | **2** | **-** | **£261,400** (274,185 Kg) |
| | **D** | Lighting | £50 | **£50** (27 Kg) | **44** | **£2,200** (1,192 Kg) | |
| | **E** | Heating | £2,300 | **£2,700** (2,434 Kg) | **63** | **£170,100** (153,361 Kg) | |
| | | Lighting | £50 | | | | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |
| | **F/G** | Heating | £2,300 | **£2,700** (3,625 Kg) | **33** | **£89,100** (119,633 Kg) | |
| | | Lighting | £50 | | | | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |
| **PRE 1919 FLATS** | **C** | - | - | **-** | **17** | **-** | **£369,500** (287,002 Kg) |
| | **D** | - | - | **-** | **96** | **-** | |
| | **E** | Heating | £2,300 | **£2,350** (1,271 Kg) | **86** | **£202,100** (109,265 Kg) | |
| | | Lighting | £50 | | | | |
| | **F/G** | Heating | £2,300 | **£2,700** (2,867 Kg) | **62** | **£167,400** (177,737 Kg) | |
| | | Lighting | £50 | | | | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |

**Total cost for all pre 1919 dwellings in area:** **£1,337,100**

Total yearly $CO_2$ emissions reduction for all pre 1919 dwellings in the area: **1,140,791 Kg**

***Table 12.*** *2050 Target: Both Approaches*

| | Band | Measure | Cost of Measure | Cost per property (yearly $CO_2$ reduction per property) | Number of properties | Cost per band (yearly $CO_2$ reduction per band) | Cost per type (yearly $CO_2$ reduction per type) |
|---|---|---|---|---|---|---|---|
| PRE 1919 MID-TERRACED | **C** | Lighting | £50 | **£14,130** (2,201Kg) | **21** | **£296,730** (46,211 Kg) | **£16,834,750** (3,034,795 Kg) |
| | | Floor | £530 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **D** | Lighting | £50 | **£22,082** (3,228 Kg) | **415** | **£9,164,030** (1,339,649 Kg) | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |
| | | Wall | £7,602 | | | | |
| | | Floor | £530 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **E** | Heating | £2,300 | **£24,382** (5,196 Kg) | **258** | **£6,290,556** (1,340,645 Kg) | |
| | | Lighting | £50 | | | | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |
| | | Wall | £7,602 | | | | |
| | | Floor | £530 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **F/G** | Heating | £2,300 | **£29,282** (8,332 Kg) | **37** | **£1,083,434** (308,290 Kg) | |
| | | Lighting | £50 | | | | |
| | | Draught | £100 | | | | |
| | | Roof | £250 | | | | |
| | | Wall | £7,602 | | | | |
| | | Floor | £530 | | | | |
| | | Windows | £4,900 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |

| | Band | Measure | Cost of Measure | Cost per property (yearly $CO_2$ reduction per property) | Number of properties | Cost per band (yearly $CO_2$ reduction per band) | Cost per type (yearly $CO_2$ reduction per type) |
|---|---|---|---|---|---|---|---|
| PRE 1919 SEMI DETACHED / END-TERRACED | **C** | Floor | £530 | **£14,130** (2,266 Kg) | **2** | **£28,260** (4,531 Kg) | **£4,445,060** (810,841 Kg) |
| | | Lighting | £50 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **D** | Wall | £14,415 | **£28,645** (3,601 Kg) | **44** | **£1,260,380** (158,433 Kg) | |
| | | Floor | £530 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **E** | Roof | £250 | **£31,195** (6,092 Kg) | **63** | **£1,965,285** (383,793 Kg) | |
| | | Wall | £14,415 | | | | |
| | | Floor | £530 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |
| | | Heating | £2,300 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **F/G** | Roof | £250 | **£36,095** (8,003 Kg) | **33** | **£1,191,135** (264,084 Kg) | |
| | | Wall | £14,415 | | | | |
| | | Floor | £530 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |
| | | Heating | £2,300 | | | | |
| | | Solar | £4,800 | | | | |
| | | Windows | £4,900 | | | | |
| | | PVs | £8,750 | | | | |

| | Band | Measure | Cost of Measure | Cost per property (yearly $CO_2$ reduction per property) | Number of properties | Cost per band (yearly $CO_2$ reduction per band) | Cost per type (yearly $CO_2$ reduction per type) |
|---|---|---|---|---|---|---|---|
| PRE 1919 FLATS | **C** | Wall | £3,801 | **£17,401** (1,939 Kg) | **17** | **£295,817** (32,958 Kg) | **£5,271,261** (987,092 Kg) |
| | | Lighting | £50 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **D** | Roof | £250 | **£17,751** (2,471 Kg) | **96** | **£1,704,096** (237,254 Kg) | |
| | | Wall | £3,801 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **E** | Roof | £250 | **£20,051** (4,368 Kg) | **86** | **£1,724,386** (375,618 Kg) | |
| | | Wall | £3,801 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |
| | | Heating | £2,300 | | | | |
| | | Solar | £4,800 | | | | |
| | | PVs | £8,750 | | | | |
| | **F/G** | Roof | £250 | **£24,951** (5,504 Kg) | **62** | **£1,546,962** (341,262 Kg) | |
| | | Wall | £3,801 | | | | |
| | | Draught | £100 | | | | |
| | | Lighting | £50 | | | | |
| | | Heating | £2,300 | | | | |
| | | Solar | £4,800 | | | | |
| | | Windows | £4,900 | | | | |
| | | PVs | £8,750 | | | | |

**Total cost for all pre 1919 dwellings in area:** **£26,551,071**

Total yearly $CO_2$ emissions reduction for all pre 1919 dwellings in the area: 4,832,729 Kg

Cost of achieving both targets for all pre 1919 dwellings in Castleland per measure

Table 13, Figures 35 and 36 provide a breakdown of the total costs involved in achieving the HHSRS target and 2050 target per measure. The number in brackets in Table 13 and Figures 35 and 36 indicate the number of dwellings related to the cost. In addition to the costs associated with reaching targets, the 2050 target can give an indication of the costs involved in applying a measure to all dwellings in need i.e. if there was a desire to ensure that all pre 1919 properties in the renewal area had efficient heating systems, it would cost approximately £1,239,700 to replace all older systems.

***Table 13:*** *Total costs of achieving targets per measure*

| Measures | HHSRS Target: Fabric First | HHSRS Target: Systems First | 2050 Target: Both Approaches |
|---:|---:|---:|---:|
| **Draught** | (99 dwellings) £9,900 | (195 dwellings) £19,500 | (1,094 dwellings) £109,400 |
| **Floor** | (391 dwellings) £207,230 | - | (873 dwellings) £462,690 |
| **Heating** | - | (539 dwellings) £1,239,700 | (539 dwellings) £1,239,700 |
| **Lighting** | (62 dwellings) £3,100 | (583 dwellings) £29,150 | (1,134 dwellings) £56,700 |
| **PVs** | - | - | (1,134 dwellings) £9,922,500 |
| **Roof** | (539 dwellings) £134,750 | (199 dwellings) £48,750 | (1,050 dwellings) £262,500 |
| **Solar** | - | - | (1,134 dwellings) £5,443,200 |
| **Wall** | (583 dwellings) £4,823,238 | - | (1,111 dwellings) £8,407,581 |
| **Windows** | - | - | (132 dwellings) £646,800 |
| **TOTAL** | **£5,178,218** | **£1,337,100** | **£26,551,071** |

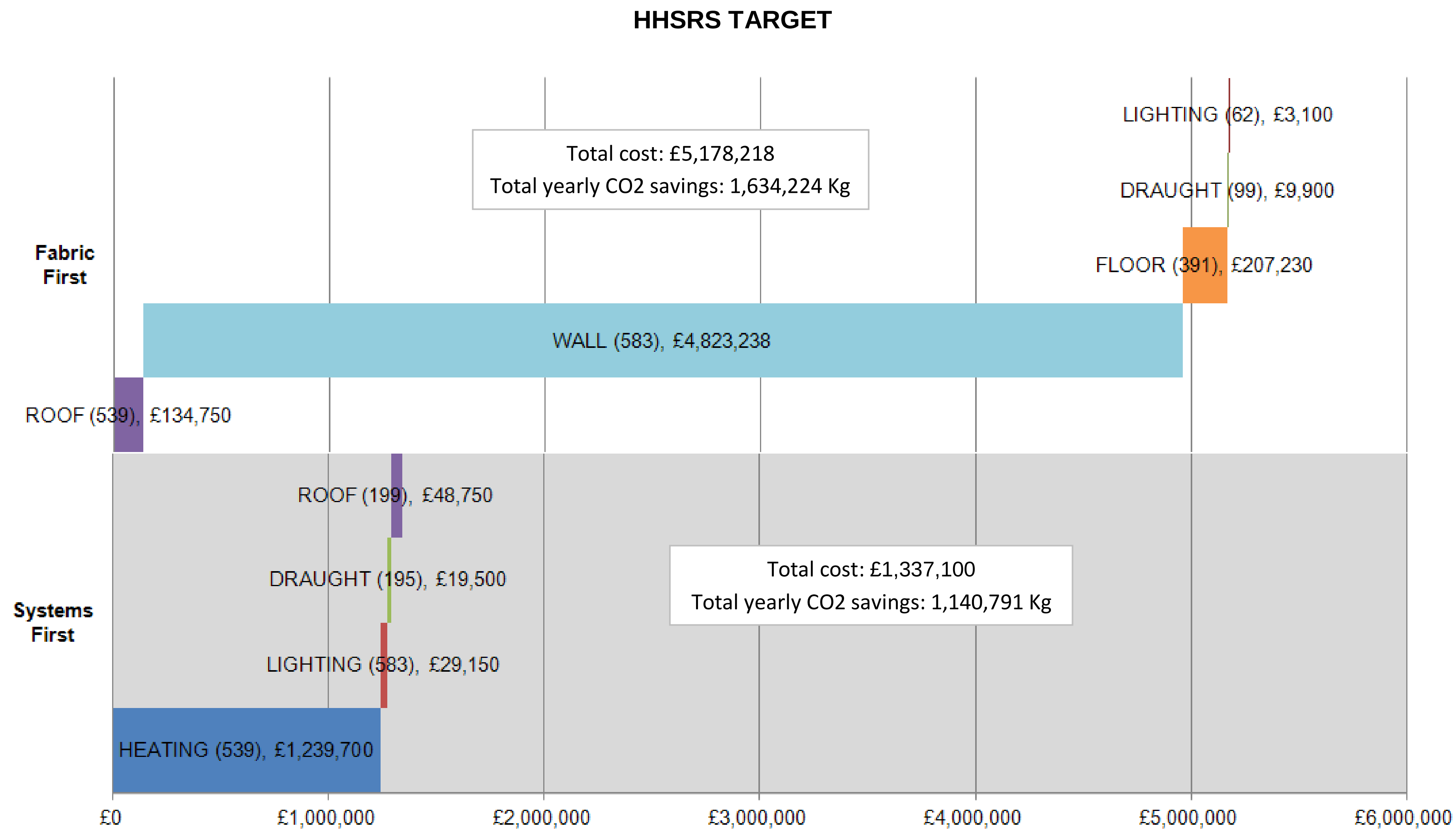



***Figure 35:*** *Total costs of reaching HHSRS target for all pre 1919 dwellings in the renewal area (1,134 out of 1,248 dwellings)*

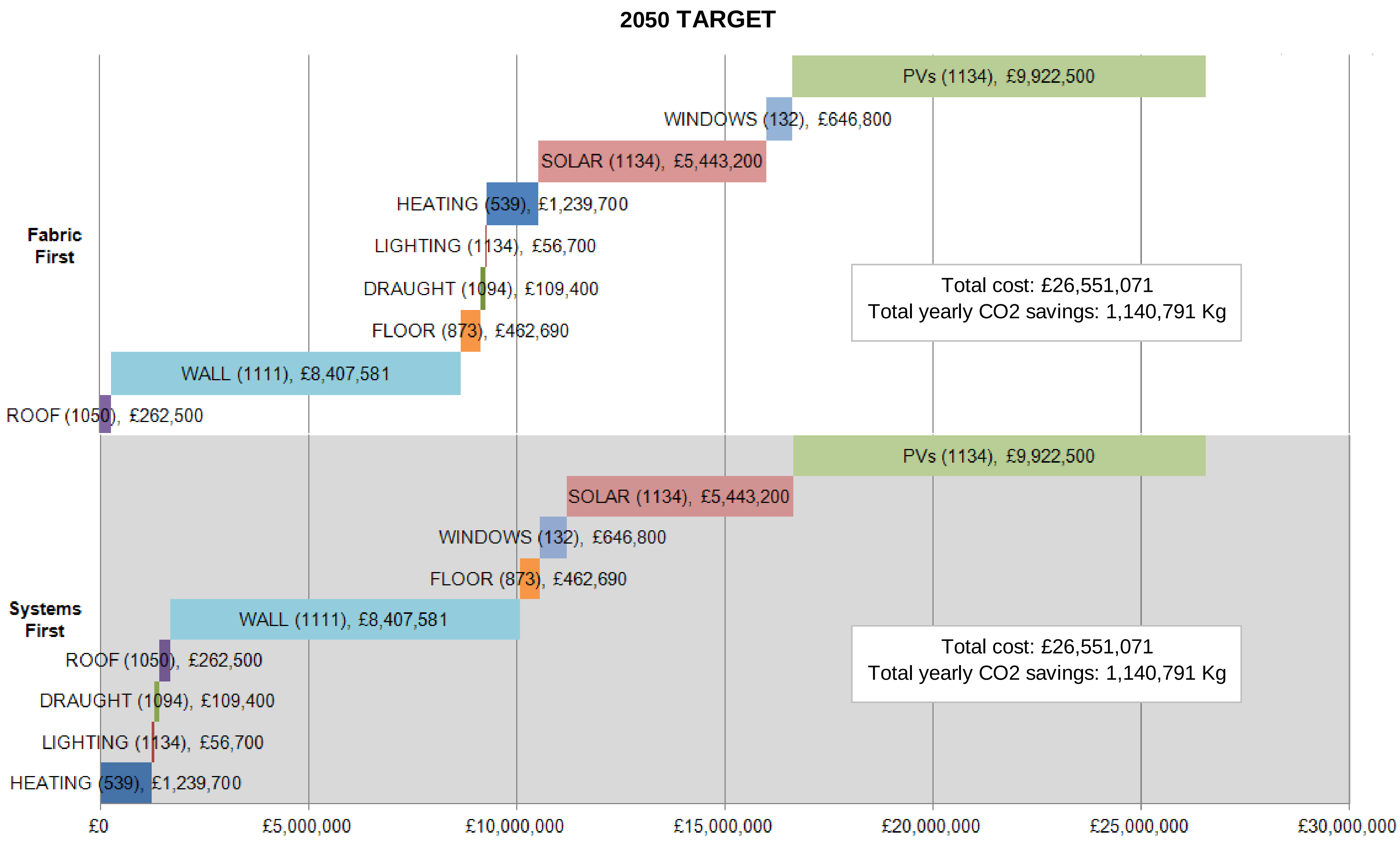



***Figure 36:*** *Total costs of reaching 2050 target for all pre 1919 dwellings in the renewal area (1,134 out of 1,248 dwellings)*

## Discussion

The results presented in this report reflect the significant impact of retrofitting interventions on the various building typologies. It is evident from Figures 35 and 36 that by using a fabric first or systems first approach, Castleland Renewal Area has the potential to achieve *The HHSRS Target* for all analysed properties in the area. However, to achieve the *2050 target,* the evidence shows that there is a need not just to improve the building fabric or systems, but also to integrate renewable energy technologies. This latter target has the potential to entail a considerable amount of investment, however if well planned, the economic viability may be increased by tackling areas with the greatest potential for energy efficiency improvement (See Figures 7 and 10), which could have shorter payback periods than other areas.

Evidently, Castleland is a large area, in order to successfully and effectively retrofit the whole site, planned investment can save money and effort. A retrofitting project of this size should be carried out in a number of stages. As mentioned in the previous paragraph, the most efficient way to develop a progressive intervention in an urban area may be to start with the properties that promise the shortest payback period. However, due to the sheer number of properties, it may be more sensible to undertake retrofitting in ‘bulk’, that is, by selecting areas where similar interventions would be required. A number of dwellings could be developed simultaneously, potentially reducing the installation and material costs. The analysis developed in this report provides evidence of the effects of interventions on various types of properties along with their estimated costs. This information could be used in planning alternatives of retrofitting route maps for such large areas.

## Summary

### Summary of Method

- The analysis was based on data collected for just under half of all dwellings in the area
- It was concentrated on pre 1919 dwellings which accounted for 90% of the stock
- A ‘clustering analysis’ method was used, categorising properties into groups and sub-groups
- Pre 1919 dwellings were split into three typologies: mid-terraced houses, end-terraced/semi-detached houses and flats (mainly converted houses into flats)
- Data available for the three typologies were then split further into 4 SAP rating bands to represent different levels of energy efficiency
- 12 representative dwellings were created using the SAP sensitivity tool based on statistical data relating to the energy efficiency properties of the 12 identified subgroups
- In line with SAP appendix T’s recommended measures for improvement, two approaches were followed to improve the representative dwellings to reach the HHSRS and 2050 target (again using the SAP Sensitivity Tool)
- Using the results from these representative dwellings, the associated costs of achieving targets were extrapolated to all pre 1919 dwellings in the area

### Summary of results

The cost of retrofitting pre 1919 dwellings differed depending on the typology and SAP rating band. The approximate retrofitting cost of individual dwellings per typology and band is as follows:

***Table 14.****Summary of costs per typology and band for individual dwellings*

| **HHSRS: Fabric First** | | | |
|---|---|---|---|
| Band | Mid-terrace | EndT/SemiD | Flats |
| **C** | £0 | £0 | £0 |
| **D** | £0 | £634,260 | £0 |
| **E** | £2,162,556 | £957,285 | £348,386 |
| **F/G** | £313,834 | £501,435 | £260,462 |
| **Total:** | **£2,476,390** | **£2,092,980** | **£608,848** |

| **HHSRS: Systems First** | | | |
|---|---|---|---|
| Band | Mid-terrace | EndT/SemiD | Flats |
| **C** | £0 | £0 | £0 |
| **D** | £0 | £2,200 | £0 |
| **E** | £606,300 | £170,100 | £202,100 |
| **F/G** | £99,900 | £89,100 | £167,400 |
| **Total:** | **£706,200** | **£261,400** | **£369,500** |

| **2050: Both Approaches** | | | |
|---|---|---|---|
| Band | Mid-terrace | EndT/SemiD | Flats |
| **C** | £296,730 | £28,260 | £295,817 |
| **D** | £9,164,030 | £1,260,380 | £1,704,096 |
| **E** | £6,290,556 | £1,965,285 | £1,724,386 |
| **F/G** | £1,083,434 | £1,191,135 | £1,546,962 |
| **Total:** | **£16,834,750** | **£4,445,060** | **£5,271,261** |

The overall costs and carbon savings of all pre 1919 dwellings are divided into the three groups as follows:

**To achieve the *HHSRS* following the fabric first approach, the costs and carbon savings are:**

- Pre 1919 mid-terraced houses: £2,476,390 and 890,400 Kg $CO_2$ saved per year
- Pre 1919 end-terraced/semi-detached houses: £2,092,980 and 398,241 Kg $CO_2$ saved per year
- Pre 1919 flats: £608,848 and 345,583 Kg $CO_2$ saved per year

**To achieve the *HHSRS* following the systems first approach, the costs and carbon savings are:**

- Pre 1919 mid-terraced houses: £706,200 and 579,604 Kg $CO_2$ saved per year
- Pre 1919 end-terraced/semi-detached houses: £261,400 and 274,185 Kg $CO_2$ saved per year
- Pre 1919 flats: £369,500 and 287,002 Kg $CO_2$ saved per year

**To achieve the *2050 target,* the costs and carbon savings are:**

- Pre 1919 mid-terraced houses: £16,834,750 and 3,034,795 Kg $CO_2$ saved per year
- Pre 1919 end-terraced/semi-detached houses: £4,445,060 and 810,841 Kg $CO_2$ saved per year
- Pre 1919 flats: £5,271,261 and 987,092 Kg $CO_2$ saved per year

To retrofit all pre 1919 dwellings in the whole area up to *HHSRS* following the fabric first and systems first approaches would have an approximate cost of £5,178,218 and £1,337,100 respectively. The associated yearly carbon savings would be 1,634,224 Kg of $CO_2$ per year if following the fabric first approach and 1,140,791 Kg of $CO_2$ per year if the systems first approach was followed. Furthermore, to achieve the *2050 target* would cost approximately £26,551,071 and would give a carbon saving of approximately 4,832,729 Kg of $CO_2$ per year (See Tables 10-13).

Work Package5: *Urban Scale Supply and Demand*
Low Carbon Built Environment
Low Carbon Research Institute
Cardiff University

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http://lcbe.cardiff.ac.uk/work-packages/urban-scale-demand-and-supply/