Hitting Hard

Sustenic

An action plan for hard to decarbonise housing

This project is funded by the UK Government through the UK Community Renewal Fund. The UK Community Renewal Fund is a UK Government programme for 2021/22. This aims to support people and communities most in need across the UK to pilot programmes and new approaches to prepare for the UK
Shared Prosperity Fund. It invests in skills, community and place, local business, and supporting people into employment. For more information, visit https://www.gov.uk/government/publications/uk-community-renewal-fund-prospectus

UK Government

Prepared for Scarborough Borough Council and Richmondshire District Council by Sustenic Ltd.

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Introduction

Scarborough Borough Council (SBC) and Richmondshire District Council (RDC) have commissioned the Hitting Hard project to provide research on approaches to low carbon heating transition options for hard to decarbonise homes and prepare an action plan for SBC and RDC to aid the decarbonisation of these homes. This work is part of the wider Delivering a Carbon-Negative Energy System in North Yorkshire work programme funded by the Community Renewal Fund. The project has also been supported by the North York Moors National Park Authority, the Yorkshire Dales National Park Authority, and the York and North Yorkshire Local Enterprise Partnership.

The intention is for the Hitting Hard project to support efforts to tailor future work programmes to achieve maximum possible carbon emission reductions at sites least able to achieve the reductions without additional support.

In addition to this high level aim, the project aims to outline prioritised retrofit activities, locations, funding options, and community engagements, and identify actions that need to be taken in partnership with National Park Authorities.

The intention with this action plan is not to reinvent the wheel, rather it draws on and references existing good practice in retrofit, bringing together sources of information and practical guidance that can benefit the councils as they address the hard to decarbonise stock.

The action plan seeks to provide information to the councils in the following areas:

- Retrofit activities
  - Which measures should be getting installed?
  - Which shouldn't be?
  - What are the barriers to retrofit?
  - How can these be overcome?
  - How can the National Parks be engaged with to maximise progress?
- Locations
  - Where are measures needed?
  - In what numbers?
  - Where might restrictions apply due to location?
- Funding options
  - What are the likely costs of retrofit in the property types of interest?
  - What funding sources are available or might be available?
- Community engagements
  - How can installation numbers be maximised through engagement with the local community?

The plan is structured in three phases which relate to the nature and timing of the recommended activities. These are summarised below:

Phase 1 – Planning	Creating a framework for delivery. Establishing a baseline and setting out preliminary recommendations for the next phase
Phase 2 – Design	Activities required by the councils to create a master plan that is appropriate to the local situation, ensuring that data is enhanced at the local level and fit for the required purposes
Phase 3 – Implementation	Taking the master plan through to delivery, including the continuous monitoring and updating to keep the plan current.

Table 1 - Phases of the action plan

Phase 1 Planning

Context

Background

The UK government legislated in 2019 to reduce the UK's emissions of greenhouse gases to 'net zero' by 2050.

The North Yorkshire region has the ambition to be carbon neutral by 2034 and carbon negative by 2040.

Both Scarborough Borough Council and Richmondshire District Council have declared a climate emergency.

The York and North Yorkshire Local Enterprise Partnership (YNYLEP) have produced the *Routemap to Carbon Negative*[1]. Within this routemap, aspirations have been set for activity in heat and buildings.

- Retrofit homes to at least an EPC C rating - 180,000 by 2030 and 250,000 by 2038.
- Retrofit public buildings to at least an EPC C rating or above by 2027.
- Large-scale deployment of heat pumps – 130,000-200,000 will be required by 2030, and 200,000-270,000 by 2038.
- Deploy district heating to 10% of buildings by 2030 and over 18% of buildings by 2038.
- Install H_2 boilers in between 13%-40% buildings by 2038 (dependent on gas grid deployment)
- Eliminate oil boiler use by 2030.
- Deploy rooftop solar photovoltaics (PV, solar panels) on 70,000 homes by 2030 and 101,000 by 2038.
- Deploy biobased construction materials in 2,000 new homes by 2030, and 14,000 new homes by 2038.

To illustrate the scale of the ambition, the table below shows the number of measures required, per year, per week and per day, for some of the most relevant items.

	Targets		Per year		Per week		Per day	
	2030	2038	2030	2038	2030	2038	2030	2038
Retrofit to band C	180,000	250,000	22,500	15,625	433	300	62	43
Heat pump*	165,000	235,000	20,625	14,688	397	282	57	40
PV	70,000	100,000	8,750	6,250	168	120	24	17

* Average of low and high ambition figures

Table 2 - Routemap to Carbon Negative ambitions for Y&NY

Definitions

What is net zero?

Net zero housing can be defined as housing with all reasonable fabric measures installed as well as renewable generation and energy storage plus a low carbon heating system. "All reasonable fabric measures" is defined here as either the maximal fabric first approach of addressing all fabric elements to get the dwelling low carbon heat ready, or the minimal approach of doing only the basic fabric measures (typically roof insulation, windows and draft-proofing). The councils will need to develop their own views about which of these approaches, or some variant of them, is best suited to their situation.

[1] https://www.ynylep.com/routemap

What is low carbon heat ready?

This is the point at which a dwelling is capable of operating with a low carbon heat system, such as a heat pump, however there is no clear-cut threshold at which this becomes the case.

It is perhaps more helpful to think about a point at which the dwelling would not cost significantly more to heat with a low carbon heat source. Research[2] suggests that heat pumps could be cheaper than gas boilers if designed and installed well, achieving a seasonal coefficient of performance (SCOP) of at least 3.0 (depending on relative prices of gas and electricity). If replacing oil boilers, as will often be the case in off-gas areas, the crossover point will come even sooner. This may mean that homes can be considered low carbon heat ready without the need to maximise the fabric performance first; something that may have previously acted as a barrier.

Several metrics are used. Two such examples are the SEAI Heat Loss Indicator (HLI) threshold for heat pump grant eligibility of 2.0-2.3 $W/m^2/K$ and the guidance in the BEIS Social Housing Decarbonisation Fund (SHDF) of achieving a space heat demand of 90 $kWh/m^2/yr$. These are both measures of fabric efficiency. It is difficult to equate these to a specific standard, such as a SAP rating or a running cost, however it tends to be that achieving these levels of performance would typically require the installation of all fabric measures recommended on an EPC. A recent report (RAP, 2022[3]) has reviewed SEAI's use of HLI = 2.0-2.3 $W/m^2/K$ and has suggested that the threshold could be relaxed.

What is hard to decarbonise?

The Committee on Climate Change has used the description, "Homes for which the decarbonisation costs will be higher, the barriers harder to overcome, or the solutions more complex."

There is a desire to ensure that Scarborough and Richmondshire residents in these types of dwellings are not disadvantaged as systems and programmes focus on the 'low hanging fruit'. Scarborough has highlighted Victorian terraces as requiring particular attention and Richmondshire identified stone built properties.

Figure 1 - Typical Victorian terrace street scene

Figure 2 - Typical older, stone built property

[2] [Analysis: Running costs of heat pumps versus gas boilers - Regulatory Assistance Project (raponline.org)]
[3] [Good COP/Bad COP: Balancing fabric efficiency, flow temperatures and heat pumps - Regulatory Assistance Project (raponline.org)]

Current picture

Stock characteristics

The energy performance of the dwellings in the two areas can be described using EPC data. The Open EPC dataset provides summary information for every registered EPC in England and Wales (where the property owner has not opted out). Roughly 63% of dwellings in Scarborough and Richmondshire have an EPC. OS AddressBase was used to determine the number and distribution of those dwellings without an EPC and small area data on dwelling characteristics used to replicate EPC data from dwellings within the same small area and stereotypes, without replacement, ensuring the known distributions within the EPC for similar dwellings is retained, while adjusting for the bias in the EPC dataset. This provides a dataset with an energy rating for every dwelling in the area.

The table below shows the archetypes of interest in the context of the wider housing stock in Scarborough and Richmondshire. It shows the different focus of the two councils; Victorian terraces in Scarborough and stone built properties in Richmondshire. The categories have been colour coded according to the criteria below:

Highlighted in red (Scarborough): All pre-1930 housing is regarded as being of interest in Scarborough as it is often difficult to distinguish between genuinely Victorian dwellings and Edwardian and they present similar challenges. For this reason we include them in our key target group (as the data ranges available from EPCs are pre-1900 and 1900-1929).

Highlighted in red (Richmondshire): All pre-1950 stone built housing in Richmondshire is assumed to be pre-second world war and likely to be of solid wall construction and therefore in the key target group.

Highlighted in amber: Dwellings identified as in one of the two target categories but not deemed to be the primary focus of that authority.

Highlighted in yellow: Dwellings where similar challenges for retrofit are likely to be encountered but neither authority is currently targeting them.

Highlighted in light green: Dwellings where retrofit is unlikely to be more challenging than the national average.

Highlighted in dark green: Dwellings where retrofit is likely to be most straightforward e.g. installation of low carbon heat source and generation (PV) and battery storage only.

The table provides statistics which confirm each authority's view of their stock but also further informs it. For example, Richmondshire's stone built stock mostly dates from before 1930 and detached properties are the most frequent type, probably associated with the rural location of these dwellings. Within each pre-1930 property typology only around 1 in 8 dwellings are not built of stone. The table shows that including 1930-1949 stone built in the hard to decarbonise group has little impact overall as very few properties built during this period used stone as building practices were already shifting to more modern construction techniques.

In Scarborough, the focus on Victorian terraces is borne out by the pre-1930 terraced totals which are dominated by non-stone dwellings, and are therefore likely to be brick-built. There are significant totals of semi-detached and detached dwellings from this period which will present similar and probably higher decarbonisation costs due to their greater external wall area requiring treatment. As with Richmondshire, very few stone built dwellings date from the 1930-1949 period confirming these are not a typology of concern.

Typology	Richmondshire				Scarborough			
	Stone		Not Stone		Stone		Not Stone	
	Count	Per Cent	Count	Per Cent	Count	Per Cent	Count	Per Cent
Pre 1930 Mid-terrace	1,060	4%	182	1%	820	1%	5,411	9%
Pre 1930 End-terrace	716	3%	132	1%	543	1%	1,319	2%
Pre 1930 Semi-detached	1,273	5%	311	1%	959	2%	1,754	3%
Pre 1930 Detached	1,934	8%	349	1%	1,570	3%	1,030	2%
Pre 1930 Flat	408	2%	64	0%	609	1%	7,910	13%
1930-1949 Mid-terrace	20	0%	286	1%	1	0%	1,217	2%
1930-1949 End-terrace	37	0%	315	1%	3	0%	734	1%
1930-1949 Semi-detached	41	0%	1,303	5%	20	0%	4,624	8%
1930-1949 Detached	51	0%	499	2%	43	0%	1,413	2%
1930-1949 Flat	15	0%	143	1%	4	0%	867	1%
1950-1995 Mid-terrace	37	0%	1,249	5%	32	0%	1,252	2%
1950-1995 End-terrace	36	0%	1,009	4%	13	0%	961	2%
1950-1995 Semi-detached	85	0%	3,293	14%	40	0%	7,493	13%
1950-1995 Detached	179	1%	2,807	12%	144	0%	5,622	9%
1950-1995 Flat	48	0%	706	3%	23	0%	3,140	5%
Post 1995	652	3%	4,960	20%	370	1%	9,539	16%
Sub Total	6,592	27%	17,608	73%	5,194	9%	54,286	91%
Park homes	2				22			
Total EPCs	24,202				59,502			

Table 3 - Count of dwellings in each age-type category

These dwellings can be identified geographically and mapped to show where the concentrations are in each area.

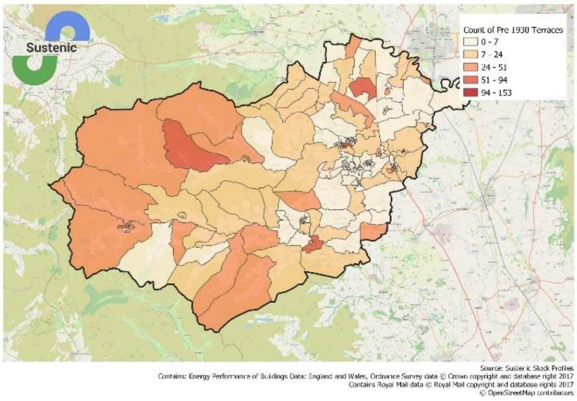


Figure 3 - Count of pre-1930 terraces in Richmondshire

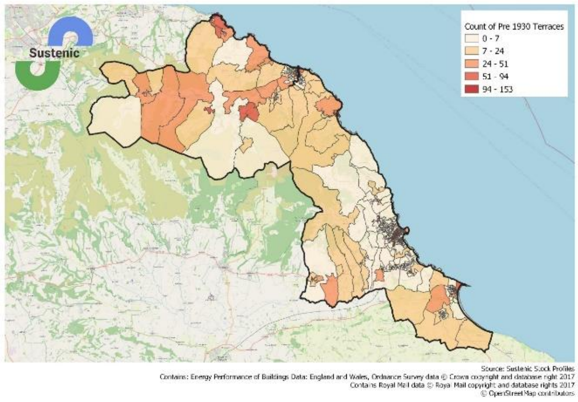


Figure 4 - Count of pre-1930s terraces in Scarborough

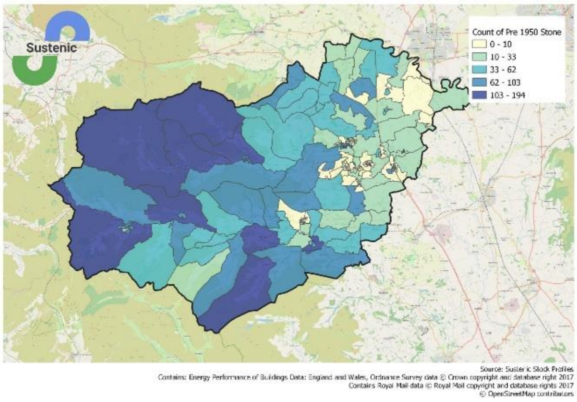


Figure 5 - Count of pre-1950 stone properties in Richmondshire

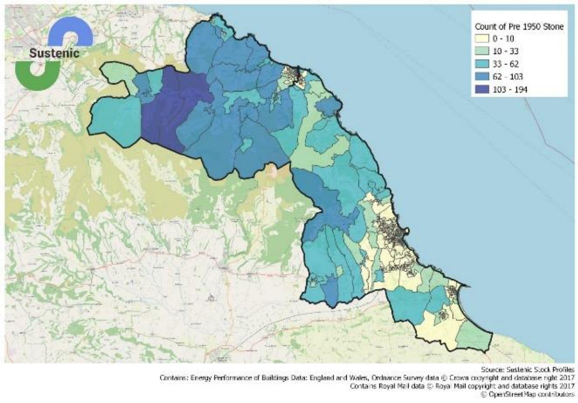


Figure 6 - Count of pre-1950 terraces in Scarborough

Energy performance

The graph below shows the percentage of dwellings in each EPC band for the two authorities, plus the figures for Yorkshire and the Humber, and England. It can be observed that there is a far lower percentage of dwellings in bands A to D in Scarborough and Richmondshire than can be seen regionally or nationally and correspondingly a higher percentage of dwellings in bands E, F and G. This is consistent with an older, more rural housing stock.

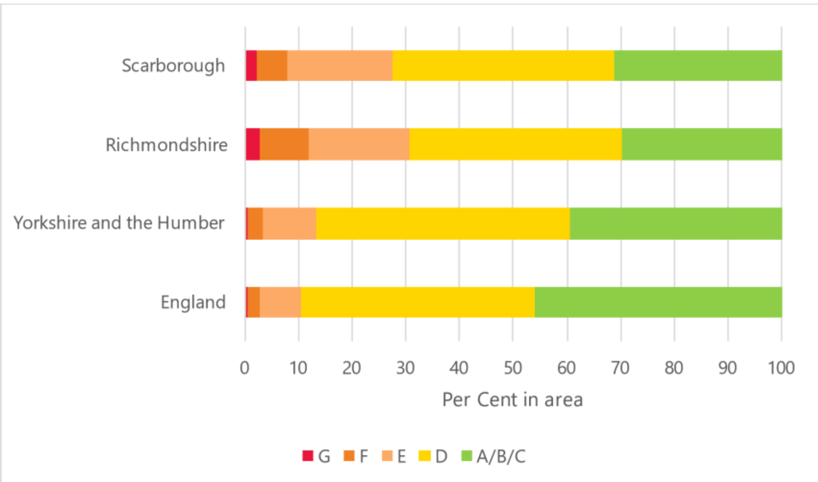


Figure 7 - Current distribution of EPC bands in SBC and RDC compared to the regional and national picture

Barriers to retrofit

Administrative

Restrictions may exist due to the planning system. Most types of energy efficiency work will be allowed under permitted development however restrictions may be greater in National Parks and Conservation Areas. Listed buildings are likely to be heavily restricted in terms of permitted alterations. The figures below show where the National Parks are located relative to the local authority boundaries and the table underneath shows the number of dwellings in each category in each council.

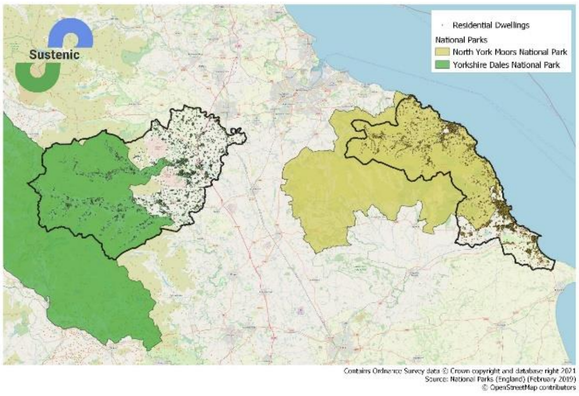


Figure 8 - Position of Scarborough and Richmondshire in relation to the National Parks

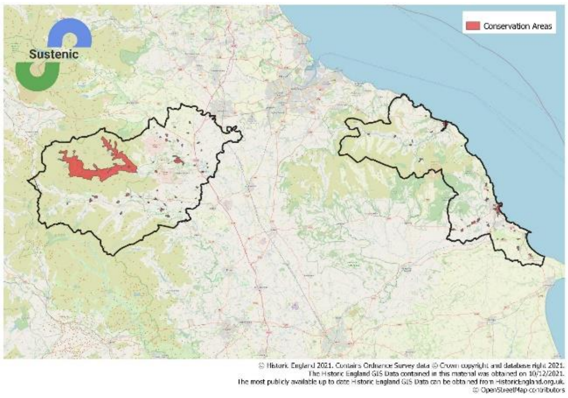


Figure 9 - Conservation areas

Local Authority	Local Planning Authority	Number of dwellings
Richmondshire District Council	Richmondshire District Council	4,176
	Yorkshire Dales National Park Authority	1,487
	Total	**5,663**
Scarborough Borough Council	Scarborough Borough Council	14,020
	North York Moors National Park Authority	1,785
	Total	**15,805**

Table 4 - Number of dwellings within each Local Planning Authority Conservation area

It is clear from discussions with planners that there is a potential tension between the desire for achieving net zero and the need to preserve the cultural heritage of the buildings and areas. The council officers responsible for retrofit will need to work closely with planners to find solutions that satisfy both those aims. Both parties will need to have a good understanding of the relevant issues that the other faces and look for solutions that can allow low carbon retrofit without negatively impacting on the heritage conservation of an area. In particular, clear guidance is required on PV, heat pumps and battery storage. EWI remains a difficult area, though the industry may be able to innovate to create solutions and finishes that are aesthetically sensitive to the cultural heritage. Hybrid insulation (insulating internally at the front and externally at the rear) is becoming a more commonly specified solution to restrictions on altering the external appearance of the front of a dwelling, where quite often, for Victorian terraces at least, there will not actually be that much exposed wall area due to the high proportion of windows. Internal insulation needs to be breathable to work in the context of the vapour open walls of traditional buildings.

Physical

The physical location of the dwelling constrains what can be done. For example, where dwellings face directly onto roads or paths there is the risk of oversailing when EWI is applied, whereby the wall effectively extends over land owned by another party, for example the Highways authority.

Traditionally, a connection to the gas network has been considered a barrier to retrofit because the cheapest form of heating is generally mains gas central heating. However, with the shift in focus to net zero as opposed to running costs, the lack of connection to a gas main is not so much of a barrier to improvement because mains gas central heating is not a long-term solution[4]. In fact, it can make the switch to low carbon heating such as a heat pump more attractive, because the running costs of systems such as oil fired boilers are generally higher (than mains gas central heating) and so the economics of a switch to low carbon heating are therefore more convincing. The table below indicates the number of dwellings on and off the gas network in each authority.

©2022 Google, Image capture: Jul 2018

Figure 10 - Example of dwellings with front face fronting onto a footpath (urban)

Dwellings	**Richmondshire**	**Scarborough**
Off the gas network	9,240	5,639
On the gas network	14,998	52,240
Total	24,238	59,786

Table 5 - Number of dwellings off/on the gas network by local authority

It could even be said that a mains gas connection presents a barrier to low carbon heating retrofit because it might be more difficult to convince those on relatively affordable mains gas central heating to make the switch to a low carbon heat source. For context the chart below shows the relative change in wholesale gas and electricity prices in the period from 1st February 2021 to 25th April 2022. This indicates that the two tend to track each other (particularly historically) but that the recent volatility in the energy markets has affected gas prices more acutely. Anecdotal evidence suggests that heating oil prices are affected at least as much as gas prices. As to how, or whether, a connection to the gas network presents a barrier to decarbonisation, it will still (generally) be the case that homes off the gas grid will be paying more to heat their homes and therefore a low carbon heating system is likely to make more sense financially. If gas and electricity retail prices are rebalanced (for example by attaching the cost of green policies to gas instead of electricity or moving them into general taxation as suggested by the CCC) then gas will look less attractive.

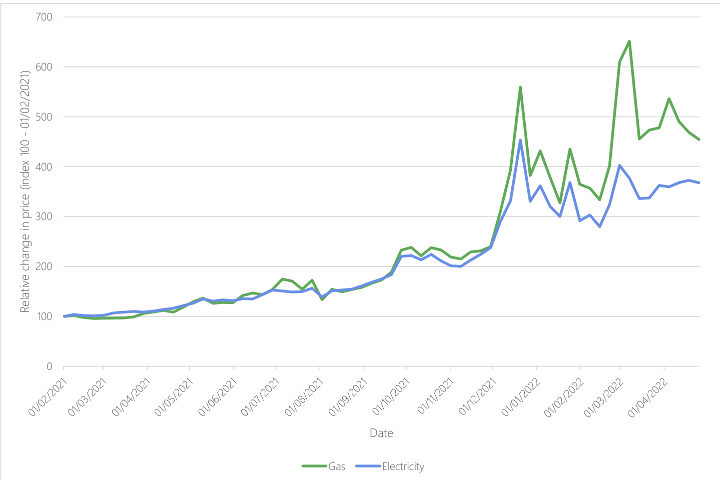


Figure 11 - Figure 27 - Relative change in wholesale gas and electricity prices (source: Ofgem)

[4] The possible use of the mains gas network to supply hydrogen to homes has been discussed however this is not currently proven to be a viable solution and further research is required.

Financial

Retrofit can require a large initial outlay which is a significant barrier to many householders. Other challenges also exist, such as the split-incentive issue for private landlords. Solutions to these financial barriers will be about making the investment in retrofit attractive to the homeowner considering measures. Some may want to retrofit their buildings for purely (or primarily) environmental reasons, but most will be looking for some financial benefit in the form of reduced bills.

Government policy will always have a role to play in overcoming financial barriers. This includes supporting home-owners directly to install measures (such as through grants), setting clear, long-term policies that provide certainty to the investment market and stimulating the financial sector to innovate in green investment products that can facilitate this kind of work (for example Green Investment Bonds).

Split incentives for landlords are a difficult issue to resolve. Current policy in this area is mostly in the form of the Minimum Energy Efficiency Standards (MEES) which forces landlords to achieve a certain EPC band rating (often viewed as a stick by landlords). It may be necessary to provide more of a carrot to landlords to ensure that they don't exit the private rented sector altogether.

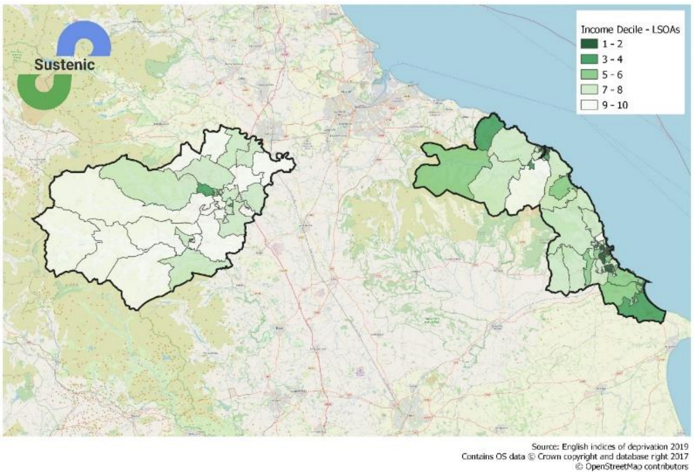


Figure 12 - Income Decile (where 1 is the most deprived 10% of LSOAs nationally)

Knowledge

Where something is not well understood, it is natural to be cautious in one's approach to it. This can be true of retrofit, especially when the available information may not be of high quality or contradictory. In these circumstances a barrier exists to retrofit work getting done. Solutions to knowledge barriers lie in more, and better, information provision. The consumer needs to be able to make informed choices about which retrofit options to select. Consumers may not understand the complex technical considerations, however basic advice can at least allow them to have informed conversations with contractors.

Social

Issues such as 'hassle factor', trust in professionals and life stage are classed here as social barriers. These social barriers are often related to a complex set of choices, decisions and emotions so there is no straightforward solution to overcome them. Generally speaking though, solutions that create as smooth a process as possible will be of most benefit to such households. For example, a grant funding scheme might assist with financial barriers, but a scheme with a very short duration or complicated application process will put people off engaging with it.

Technical

Technical barriers are generally obstacles that need to be overcome to get a building ready for retrofit. They are rarely insurmountable and it is a question of whether the cost and effort of removing the obstacles is worthwhile. Most enabling works required prior to retrofit are related to resolving condition issues that may undermine a retrofit installation if left untreated. For example, fixing cracks in the external finish of a wall before installing internal wall insulation. Were this not to be done, the risk of liquid moisture penetration impacting the insulation material would be too high. Maintenance works and repairs that are sensitive to the building's context can themselves improve the performance of the structure. There are products available on the market that seek to combine this approach with thermal performance enhancement, such as insulating lime mortars.

Potential performance

The EPC data includes information about the potential performance of dwellings. EPCs include a list of recommendations based on the characteristics of the dwelling as surveyed. The EPC shows what the performance of the dwelling would be were all of the recommended measures installed. This is referred to as the potential performance. The recommendations include all mainstream fabric measures, including solid wall insulation and floor insulation. It includes heating system upgrades however the most favoured option is a gas boiler (as this was generally accepted to be the cheapest way of heating a home to the required standard).

The chart shows that currently just under a third (31.2%) of dwellings in Scarborough have an EPC of band C or higher. In Richmondshire this figure is slightly lower (30%). If all EPC recommended measures were installed, the corresponding figures would be 84% for Scarborough and 85% for Richmondshire.

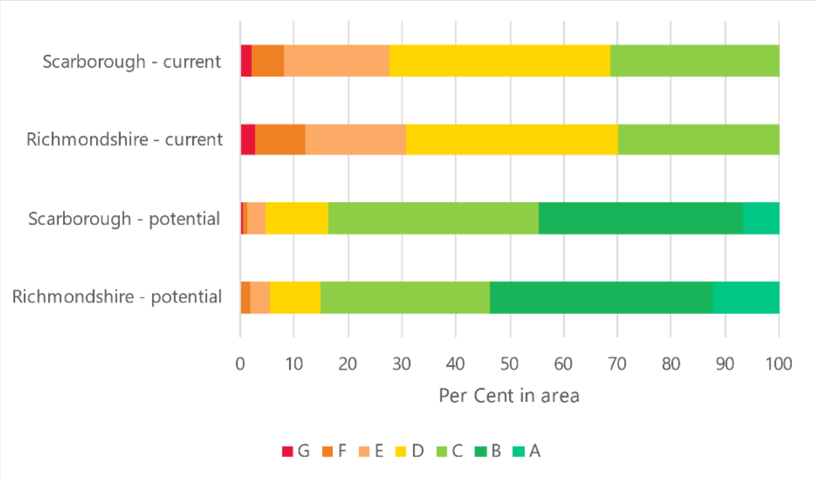


Figure 13 - Current and potential performance based on EPC improvements

The table below shows the number of each measure needed in each council area. The information is provided for the whole stock of the area and for the hard to decarbonise stock.

	Scarborough - all stock	Richmondshire - all stock	Scarborough - hard to decarb	Richmondshire - hard to decarb
Roof	25,564	8,212	7,098	2,887
Walls	29,253	10,353	10,675	5,421
Solid floor	14,846	11,966	5,062	4,395
Timber floor	25,474	5,338	5,482	937
Windows	13,480	4,330	4,717	2,715
PV + battery	41,837	20,714	8,637	5,488
Storage heaters	12,648	1,245	495	305
Heat pump	43,244	21,532	10,571	5,275

Table 6 - Number of measures needed in each area based on EPC data

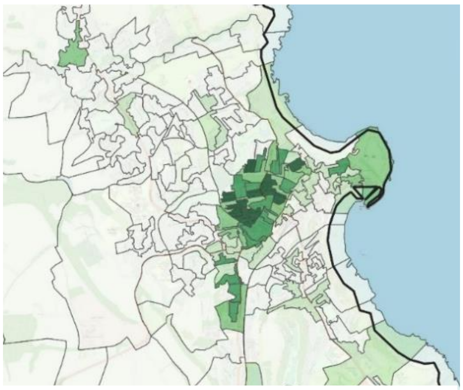


Figure 14 - Count of loft insulation requirement in pre 1930s terraces – Scarborough town

The EPC dataset can be used to map where the measures are required. This map uses loft insulation as an example of where the need is greatest in Scarborough town.

Improvement strategies

EPC data assumes all measures would be installed and therefore represents an artificially optimistic position given that this won't be possible in all cases. Best practice in retrofit has traditionally advocated a fabric-first approach, insulating and improving airtightness, then introducing a low-carbon heating system and finally incorporating appropriate renewable and battery storage technologies. Is this the best approach to achieving savings in older properties, given the costs and risks that can be associated with retrofitting hard to decarbonise buildings? It is important to avoid the mistakes of the past when installing measures, for example through the application of PAS 2035 principles.

What measures could be installed?

Focussing on measures of interest to the hard to decarbonise archetypes of interest to Hitting Hard.

External wall insulation

EWI would normally be considered first in the hierarchy of wall treatments (where cavity wall insulation is not appropriate) because it is less disruptive to install and it is generally easier to achieve improvements with lower risks. The archetypes of interest for Hitting Hard may not be able to have EWI installed, particularly on their front facades, but for rear facades it is likely to be the first option considered. Boundary issues may limit the number of cases that can accept this measure.

Internal wall insulation

The properties considered for this project may have features that preclude the use of EWI and therefore IWI should be considered. Rural stone properties with random or dressed stone, and Victorian terraces in conservation areas, are examples of where EWI cannot be installed, or at least, cannot be installed on the front façade. IWI may have a role to play here, particularly breathable wood-fibre solutions, however the risks associated with this measure would need to be understood and a comprehensive survey would need to be undertaken including the relevant modelling. Innovation may lead to new solutions such as a wet lime plaster containing aerogel being trialled by STBA.

Roof insulation

The materials used will normally be suitable for installation at either joist or rafter level however insulating at the rafters level is more challenging as it will usually require renewal of the internal finish.

As with any of the fabric elements, when thermal performance is improved, it becomes more important to pay attention to thermal bridges as heat will always looks for the easiest means of escape. In lofts, this will tend to manifest in two areas. The first is at the eaves. It can be difficult to insulate right up to (and partially over) the wall head while maintaining adequate ventilation to the loft space. Thermal imaging will often show this to be the case, such as in the image below. The second is at the loft hatch. This can be overlooked in loft retrofit because it is a small proportion of the overall area however it will lose a disproportionate amount of heat and moreover, it can lead to significant losses through drafts. A new, insulated loft hatch with built in draft proofing can be an effective solution for this.

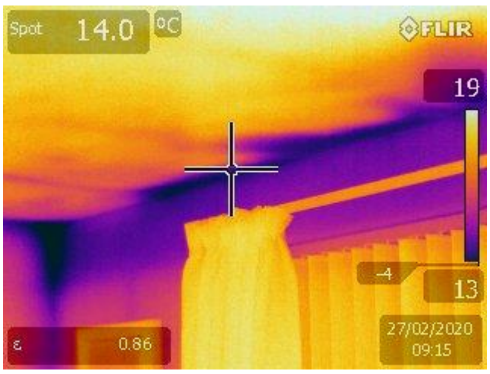


Figure 15 - Cold bridging due to inadequate insulation at eaves

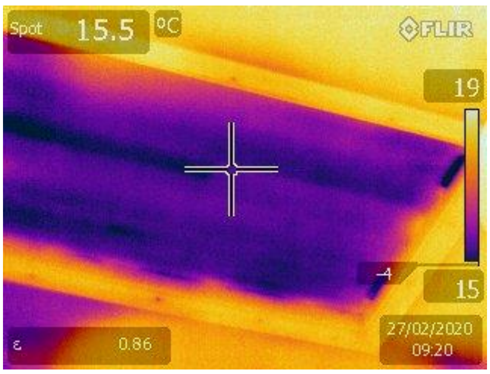


Figure 16 - Uninsulated loft hatch

Mineral wool provides the most cost-effective way to insulate the roof of a dwelling. Where there is a room in the roof with sloping ceilings, the use of rigid foam board is typical. Our hard to decarbonise archetypes are more likely to have partially vaulted ceilings, where the top floor is partially built into the roof space. Care should be taken not to create a thermal bridge at the sloping part of the ceiling.

Windows

Single glazed windows perform poorly in terms of direct heat transfer, with U-values of over 4.5 W/m^{2}K, but also tend to be draughty which affects thermal comfort. Typical U-values for UPVC double glazing units are in the range 1.0-1.5 W/m^{2}K. Triple glazing U-values can be as low as 0.7 W/m^{2}K. Where there are restrictions in place, timber framed units may be more appropriate. These can perform at least as well as UPVC equivalents though they may need more regular maintenance. A significant number of the properties of interest for this project will be in areas where there are restrictions on which windows can be installed. Where this is the case, heritage sensitive options should be pursued, with more standard options being used where possible, such as to the rear of the property.

Floors

The archetypes of interest are likely to have either suspended timber floors or solid earth floors due to their age. It is less likely that they will have cellars or otherwise good underfloor access so it is likely that in order to insulate, floor boards would have to be lifted. The level of disruption suggests that it is likely to be best considered when other work is undertaken, for example floor structure being replaced. Other trigger points might be the replacement of a kitchen.

Ventilation

A mechanical ventilation system is generally required in very airtight buildings in order to maintain indoor air quality. Where this includes heat recovery (MVHR) this can provide a very efficient means of maintaining a good indoor environment. This could be required for deeper levels of fabric retrofit.

Heating systems

Any central heating system should be designed to deliver low temperature heat via suitably sized radiators or underfloor heating (if the distribution system is water based). Upgrades to radiators may be needed to facilitate this. The system should be well controlled, including weather compensation to allow the system to modulate depending on external temperatures. It is also important that the system is properly designed. This should include a detailed heat loss calculation to ensure the system is sized correctly for the heat demand. The main options for net zero-aligned heating systems are heat pumps and high heat retention storage heaters and district heating where local circumstances are suited.

Previously, advice has suggested fabric efficiency should be brought up to a high standard before switching to a heat pump, however, there are examples of good performance being achieved in less well insulated properties. Shared ground loop communal ground source heat pumps are a novel approach which may be particularly suitable for small clusters of remote dwellings.

Hot water systems

Low carbon water heating relies on being able to store hot water and therefore a hot water cylinder is generally required. The trend towards combi boilers in recent years means that many homes will have lost the space and infrastructure (pipework, etc.) for a hot water cylinder. Heat batteries can provide similar functions in a smaller space. PV diverters allow excess solar energy to be used to heat hot water.

Renewables

This is primarily about the installation of PV on the roof of a dwelling and includes the addition of battery storage. As well as being low carbon, renewables reduce the amount of electricity required from the grid and therefore help reduce household bills. The main additional consideration for archetypes of interest are the planning constraints associated with conservation areas and listed buildings and possibly the space constraints for hot water tanks and battery storage.

The importance of good practices in retrofit

Done badly, retrofit can result in unintended consequences, often related to problems with moisture. Symptoms can range from increased condensation and mould growth to, in extreme cases, the failure of the wall structure. PAS 2035:2019, developed to address these issues, offers an end-to-end framework for the application of energy retrofit measures to existing buildings in the UK. It is required for some energy efficiency programmes such as ECO3 and while not mandatory for most aspects of retrofit, its principles are necessary to avoid problems. A number of common themes are found in literature:

- Take a whole-house, holistic approach.
- It is important to understand the **context** of the building. A comprehensive survey by a suitably skilled professional is vital to this.
- Plans should be tailored to, and **coherent** with, the context of that particular dwelling. There is no one size fits all solution.
- Ensure that the building is well maintained and that repairs have been completed prior to retrofit.
- Ensure that balance is maintained. Measures should be suited to the **capacity** of the building to accept changes. Some insulation (even if lower performing) is better than none.
- Where uncertainty remains, **caution** should be exercised.
- Quality is important, particularly in avoidance of thermal bridges.
- Engagement with residents is important.
- Understand the impact of measures (both positive and negative) with post-completion monitoring.
- Where failures have been observed, it is usually because one or more of the above principles has not been followed.

How much insulation is enough?

This is really a question of the point at which the dwelling can support the use of a low carbon heating system, such as a heat pump. Previous consensus has been that fabric efficiency must be maximised before installing such systems however there is growing evidence that these systems can be effective in homes with higher losses[5]. It is particularly important for traditional buildings that the structure is not compromised by the materials applied. Measures must fit the context of the building and it may be that a smaller amount of insulation, leading to a lesser improvement in fabric efficiency, may be the best option; not sacrificing the good for the sake of the perfect. It is still advisable to seek to increase fabric efficiency in the future when opportunities arise, for example during a refurbishment or when grant funding becomes available. In order for the heat pump to deliver its full potential, all aspects of the design and installation need to be done well. These include;

- Dwelling heat loss calculation (to establish heat pump power output)
- Distribution system design to ensure that low flow temperatures can be sustained
- Provision of hot water
- Configuration of pipework (including pipe diameters)
- Installation of the system to a high standard
- Specification and installation of effective control systems (including weather compensation)
- Commissioning of the system (including use of appropriate weather compensation curves), and
- Proper handover to customer including an understanding of optimal operation (e.g. always on heating with night set-back).

These factors will help to achieve higher performance as described by the seasonal coefficient of performance (SCOP). If the heat pump installation is performed to a high standard, it should be possible to achieve a SCOP of well over 3 which, depending on gas and electricity prices, should deliver a running cost that is no higher than for a gas boiler.

[5] For example, HeatpumpMonitor.org is crowd sourcing data from users of Open Energy Monitor.

Retrofit strategies in the archetype example dwellings

The EPC data has been used to illustrate the theoretical maximum of what could be achieved, however, it is recognised that this is unrealistic, and that in some circumstances it is possible to run a low carbon (low temperature) heating system using a Min-fabric approach. Energy modelling techniques can be used to run what-if scenarios to look at the impact of the different options available. SAP was used on the two archetype example dwellings to look at different improvement scenarios to show how the dwelling might perform relative to the baseline calculation. Note that SAP assumptions mean that the figures quoted for metrics such as running costs are unlikely to match reality as several dwelling and household specific factors are not taken into account in a SAP calculation, however the results do provide a good indication of the impact of measures. The version used for the modelling was SAP 2012. This is the version currently used in EPCs as the RdSAP specification is based on this. Some important net-zero technologies have not been considered here because of limitations to the modelling. For example, mechanical ventilation systems are not included, nor is battery storage.

The two archetype dwellings provide helpful examples of what might be the optimal package of measures for those types. It has shown that the more extensive retrofit approach (Max-fabric) can lead to deep carbon savings and will make the conditions more favourable for low temperature heating system operation, however, the basic fabric measures, plus PV and battery storage and a heat pump, can still deliver large carbon reductions. Once an initial package of measures is established, the next stage would be to look at barriers or conditions which might lead to alterations of the provisional plan. For example, is PV permitted in the National Park? Is there space for a hot water cylinder? If not, would a heat battery be more appropriate? What plans does the occupant have for refurbishment? For example, if they are thinking of getting a new kitchen installed, that could be a good opportunity to consider floor insulation. Once this process of refinement is complete, work can begin on designing and implementing the retrofit journey.

Modelling was undertaken to assess what upgrades would be needed to the distribution system to enable it to deliver heat at low flow temperatures which are required to achieve the highest performance levels in heat pumps (and condensing gas/oil boilers). It showed that even at a flow temperature of greater than 45°C, the majority of the radiators present would need to be upgraded. A flow temperature of 35°C would require all radiators to be upgraded and by a bigger margin, including upgrading to triple panel K3 radiators and the installation of additional radiators. The trade off here is that the seasonal coefficient of performance (SCOP) drops as the flow temperature increases. In the case of the Victorian terrace, the SCOP goes from over 5 at 35°C to around 3.5 at 55°C. This will mean higher running costs to maintain the standard of comfort.

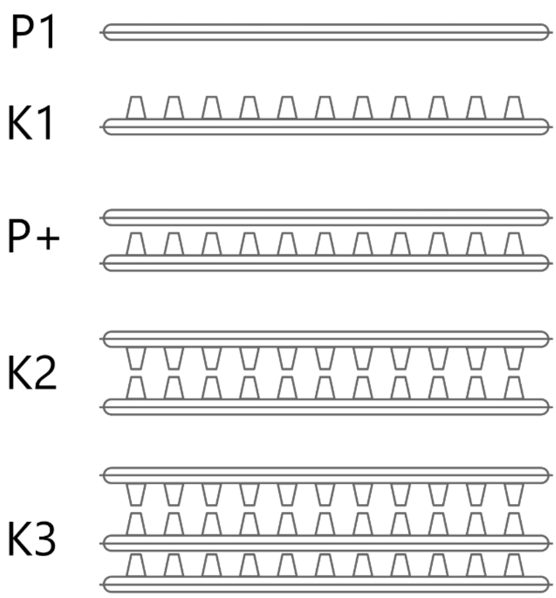


Figure 17 - Radiator type options

The different types of panel most commonly found are shown here. A K3 panel may mean that width and height dimensions don't need to be increased however the depth of the unit is in the region of 180 mm (it is essentially a K1 panel attached to a K2 panel) which may be unacceptable to residents.

The scenarios below include a low and high fabric approach (Ipm1 and Imp2), low and high(er) temperature heat pumps (HP35 and HP45) and PV.

Stone Cottage

Figure 18 - Older, stone cottage in Richmondshire

Figure 19 - Location context for stone cottage

	Base	Base + HP35	Base + HP45	Imp1	Imp1 + HP35	Imp1 + HP45	Imp1 + HP35 + PV	Imp1 + HP45 + PV	Imp2 + HP35 + PV
Space heat demand (kWh/m^2/yr)	190	190	190	176	176	176	176	176	75
Design heat loss (kW)	12.1	12.1	12.1	11.0	11.0	11.0	11.0	11.0	5.0
SAP rating	37	70	59	41	72	62	82	72	93
EPC band	F	C	D	E	C	D	B	C	A
Running costs (£/yr)	£1,717	£798	£1,083	£1,585	£741	£1,004	£469	£733	£193
Running costs at latest SAP prices (£/yr)	£1,547	£1,236	£1,678	£1,416	£1,147	£1,417	£727	£997	£300
CO_2 emissions (kg/yr)	8,451	3,140	4,263	7,824	2,915	3,951	1,847	2,883	761

Table 7 - Results of SAP modelling for stone cottage

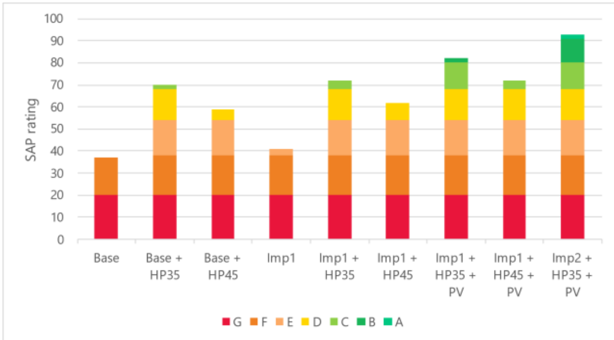


Figure 20 - SAP ratings and EPC bands under each scenario – stone cottage

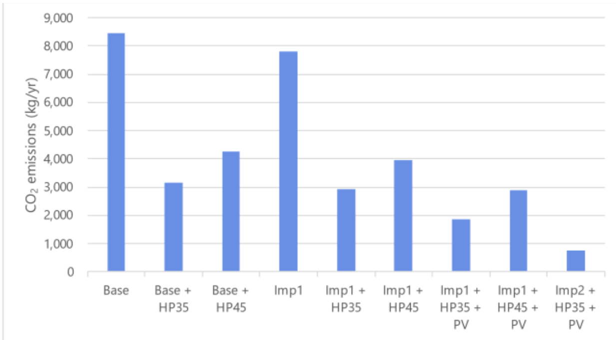
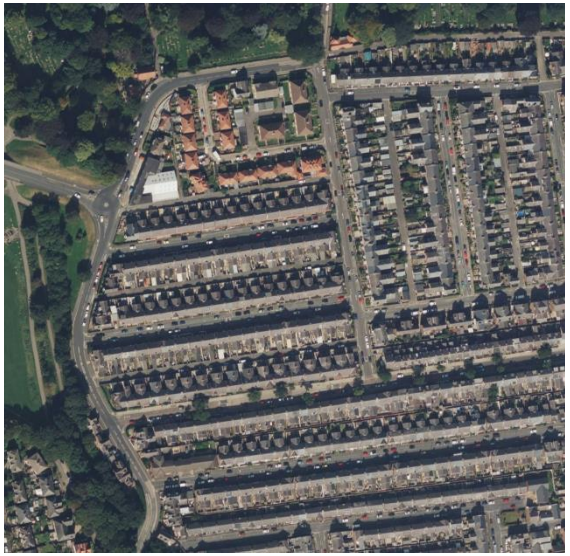


Figure 21 - Carbon dioxide emissions (SAP based) under each scenario – stone cottage

Victorian terrace

Figure 22 - Victorian terrace in Scarborough



Microsoft product screen shot(s) reprinted with permission

Figure 23 - Nature of area of example Victorian terrace

	Base	Base + HP35	Base + HP45	Imp1	Imp1 + HP35	Imp1 + HP45	Imp1 + HP35 + PV	Imp1 + HP45 + PV	Imp2 + HP35 + PV
Space heat demand (kWh/m^2/yr)	126	112	112	115	102	102	102	102	57
Design heat loss (kW)	6	6	6		5.4	5.4	5.4	5.4	3.3
SAP rating	68	79	73	71	80	75	93	88	97
EPC band	D	C	C	C	C	C	A	B	A
Running costs (£/yr)	£696	£469	£605	£636	£443	£541	£158	£256	£67
Running costs at latest SAP prices (£/yr)	£752	£727	£936	£677	£686	£838	£245	£397	£104
CO_2 emissions (kg/yr)	3,387	1,846	2,379	3,069	1,744	2,130	623	1,009	265

Table 8 - Results of SAP modelling for Victorian terrace

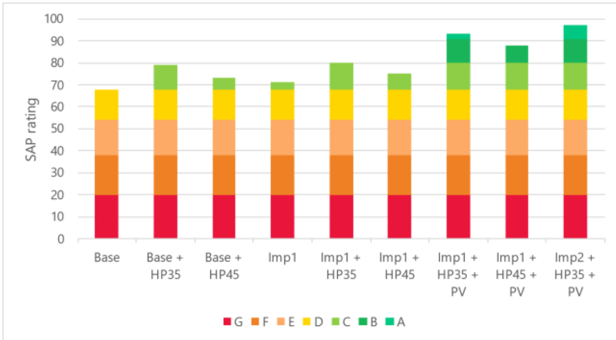


Figure 24 - SAP ratings and EPC bands under each scenario – Victorian terrace

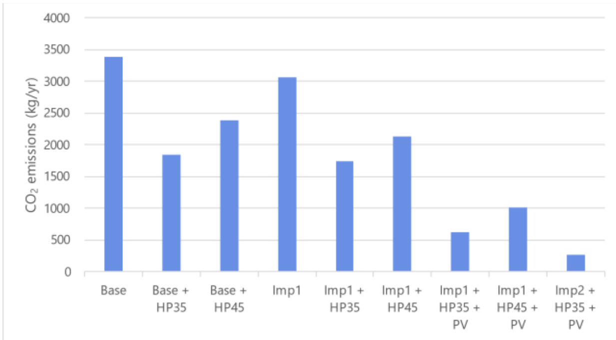


Figure 25 - Carbon dioxide emissions (SAP based) under each scenario - Victorian terrace

Delivering decarbonisation in housing

Internal systems and structures

The councils will need to ensure that they are setup to deliver what is required in terms of a strategic framework for retrofit, programmes and projects to take forward that delivery and in some cases, actual installation of measures (for example where the council owns its own housing stock). This should include senior management buy-in at Director level to ensure that the programme is well represented in the organisation and to council members. There also needs to be a clear structure and defined job roles within the council to ensure that all required tasks are sufficiently resourced.

Segmenting the hard to decarbonise housing stock

Action plans to decarbonise housing can be designed for implementation over a defined period of time, typically rolled out over many years, even decades. This process can be managed by developing appropriate housing stock segments to which energy efficiency measures can be applied at optimal points in time, taking account of the characteristics of the housing stock, as well as local policy priorities.

Initially the hard to decarbonise housing stock in SBC and RDC, defined as Victorian terrace and older, stone built properties, can be divided into three broad segments. Each of these segments can represent groups of properties of increasing technical difficulty and risk in relation to the installation of energy-efficiency improvement measures; these can be represented as green, amber and red segments.

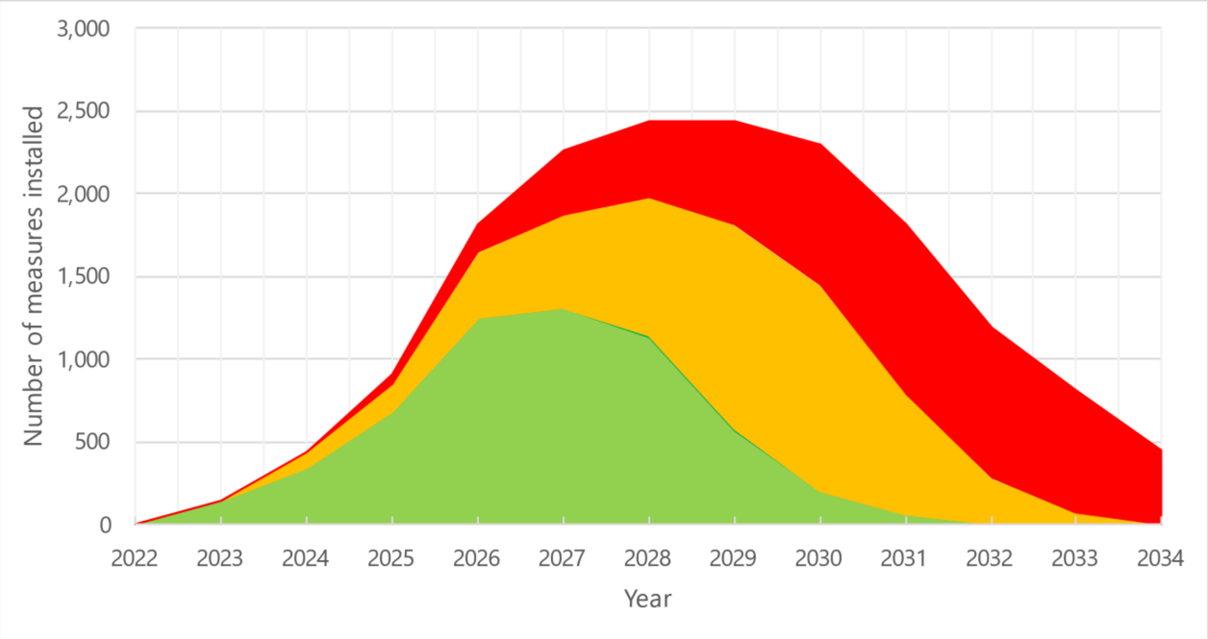


Figure 26 - An illustration of how energy efficiency improvements could be sequenced for housing stock segments

The condition of the target properties is an important identifier for the segmentation of the stock and subsequent sequencing of improvements works. This is because any existing property defects, particularly in relation to water penetration and the structure of the property, will need to be remedied ahead of completing most energy efficiency retrofits.

A sequenced programme of work can be developed such that the least cost and risk cases can be actioned first; this can enable the optimum number of properties to be improved during the first phase of works. Poor condition, more challenging and complex cases can be left for later stages, thus allowing time for improved technical solutions, resources, or other enabling mechanisms to become available. Any socio-economic priorities, such as fuel poverty, local deprivation issues can be factored into the above assessment once the technical prioritisation is complete.

Retrofit costs

A key aim of the Hitting Hard project was to establish how costs of retrofit in hard to decarbonise homes differ from a more modern property. A model has been developed, drawing upon available evidence, to assign costs to the common retrofit measures of interest. These costs can then be applied to the number of dwellings (or hard to decarbonise dwellings) to establish initial estimates of the funding required. An example of this is in the table below which shows the build-up of costs for a Victorian terrace such as the archetype example included in this report.

Step	Action	Notes	Worked example	Cost
1	Decide on measures required		Typical Package EWI/IWI 70:30/HTT loft/50:50 solid/timber floor	
2	Lookup cost of measures required by buildtype and size (SML)	Small Medium Large from lookup table	Medium mid-terrace	£10,164
3	Apply heritage uplift percentage	Apply low uplifts to measures 30% walls, 5% loft, 15% floor. Apply medium uplifts in conservation areas	Low uplifts applied	£12,607
4	Apply local labour cost uplift	Apply 29% uplift for current costs, 23% for future bid costs	29%	£16,264
5	Apply inflation uplift	Calculate uplift = current index/jun 2019 index	5.70%	£17,190
6	Economies of scale	Assume 0% in early stages	0.00%	£17,190
7	Apply condition contingencies uplift	Add 35% of cost of measures	£3,557	£20,748
8	Add scaffolding costs	Base cost £1475/£986	£1,033	£21,780
9	Add survey design and planning costs	£2,500 current/£1352 future bid	£2,500	£24,280
10	Apply inflation uplift to (preliminary) overheads and add	Calculate and apply uplift = current index/jun 2016 index x (prelim)overheads	11%	£24,660
11	Apply uplift for general overheads and profit	Apply 6.5%	6.50%	£26,263
12	Apply future inflation uplift	Spring 2022 8%, End 2024 add 16% (cumulative)	8%	£28,364

Table 9 - Cost model worked example

The Min-fabric approach removes the more difficult and costly measures (wall and floor insulation) and focuses on the basic fabric measures (roof and windows) plus PV, battery storage and low carbon heat. This results in a substantially lower average cost per home. The impact of this can be seen in the summary figures in the table below. These costs are before any adjustment for funding from grant schemes.

Current	Max-fabric		Min-fabric	
	Average cost per dwelling	Total cost for all H2D stock	Average cost per dwelling	Total cost for all H2D stock

Scarborough VT	£46,000	£312,000,000	£21,000	£143,000,000
Scarborough stone	£70,000	£320,000,000	£29,000	£132,000,000
Scarborough total	**£56,000**	**£633,000,000**	**£24,000**	**£275,000,000**
Richmondshire VT	£48,000	£15,000,000	£22,000	£7,000,000
Richmondshire stone	£80,000	£442,000,000	£32,000	£175,000,000
Richmondshire total	**£78,000**	**£457,000,000**	**£31,000**	**£182,000,000**

Table 10 - Summary average and total costs for Max-fabric and Min-fabric retrofit in each area

- More than half of the cost of the Max-fabric package is comprised of wall and floor insulation.
- Costs in Richmondshire are higher on average, likely due to the average size of the dwellings and the lower starting average energy efficiency, meaning more measures are needed per dwelling.
- Total costs of retrofitting the hard to decarbonise dwellings in both areas to the Max-fabric standard would exceed £1 billion. For the Min-fabric approach, the figure is just over £450 million.
- Assuming a linear spend profile, this would require an annual budget of around £90 million for the Max-fabric and £40 million for the Min-fabric.

Scaling the costs for an individual dwelling by the number of dwellings targeted for treatment by the Routemap to Carbon Negative can show the scale of funding required to achieve the aims in that document. The estimates below assume that hard to decarbonise homes would receive a similar number of measures proportionally to other dwelling types.

	Targets		Per year	
Scarborough	2030	2038	2030	2038
Retrofit to band C	£308,000,000	£427,000,000	£38,000,000	£27,000,000
Heat pump	£69,000,000	£98,000,000	£9,000,000	£6,000,000
PV	£23,000,000	£33,000,000	£3,000,000	£2,000,000
Richmondshire	2030	2038	2030	2038
Retrofit to band C	£188,000,000	£261,000,000	£24,000,000	£16,000,000
Heat pump	£29,000,000	£42,000,000	£4,000,000	£3,000,000
PV	£10,000,000	£14,000,000	£1,000,000	£1,000,000

Table 11 - Costs to deliver the ambition set out in the Routemap to carbon negative

It will be essential for the councils to maintain some form of price database that can enable realistic assumptions about the retrofit costs. This can be informed by ongoing programmes across the council.

Funding sources

The LAD and HUG schemes are targeted at lower income households. The threshold for this was originally set at £30,000 gross, before housing costs and where benefits are counted towards this figure. This has since gone up to £31,000. Based on the ONS data, it is reasonable to begin with an assumption that households in the lowest three or four income deciles would have a good chance of being eligible for support.

Using the EHS 2019 dataset, the proportion of households with an annual income below £31,000 within each tenure, dwelling type and super region were applied to the Sustenic Stock Profiles in Scarborough and Richmondshire. The results were then banded into quintiles to provide an indication across the two authorities of where clusters of households with an annual income below £31,000 may occur. Combining the Sustenic low-income indicator with EPC and gas connection data provides an indication of where eligible households may be for both GHG and HUG.

Funding schemes such as those mentioned here will be vital to making retrofit affordable to households that will otherwise be required to meet the capital cost. It will therefore be important for the councils to stay well informed about current and future schemes and to plan how they can be integrated with their programmes. An operating model where plans are in place and funding schemes support those plans, rather than plans being developed as a response to whatever funding schemes are available, will mean that best use can be made of the money available.

GHG-LAD

In Scarborough BC, eligibility is concentrated in the major towns of Scarborough and Whitby.

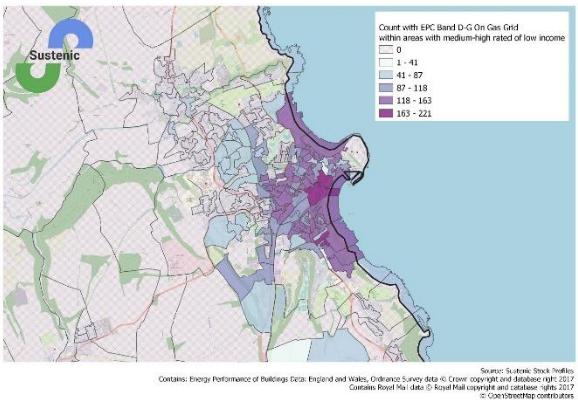


Figure 27 - Combined dwelling and income indicator for GHG LAD – Scarborough town

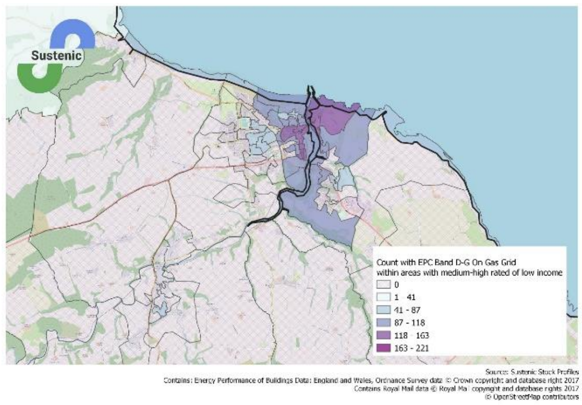


Figure 28 - Combined dwelling and income indicator for GHG LAD – Whitby

In Richmondshire, the low levels of gas-grid connectivity mean that eligibility is generally low and concentrated around Richmond.

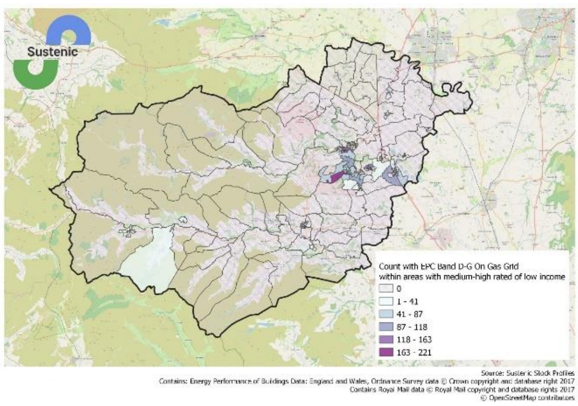


Figure 29 - Combined dwelling and income indicator for GHG LAD - Richmondshire

HUG

The Home Upgrade Grant is targeted at the private sector (owner occupiers and private renters) and is only for homes that are off the gas grid. HUG2 guidance promotes the fabric first approach and suggests that a target space heat demand of 90 kWh/m^2/yr should be used where reasonable and cost effective. It also includes requirements for the proportion of overall spend coming from different categories of measures, with windows only counting as a secondary measure. The Min-fabric approach described here should still be compatible provided it is consistent with PAS 2035 principles.

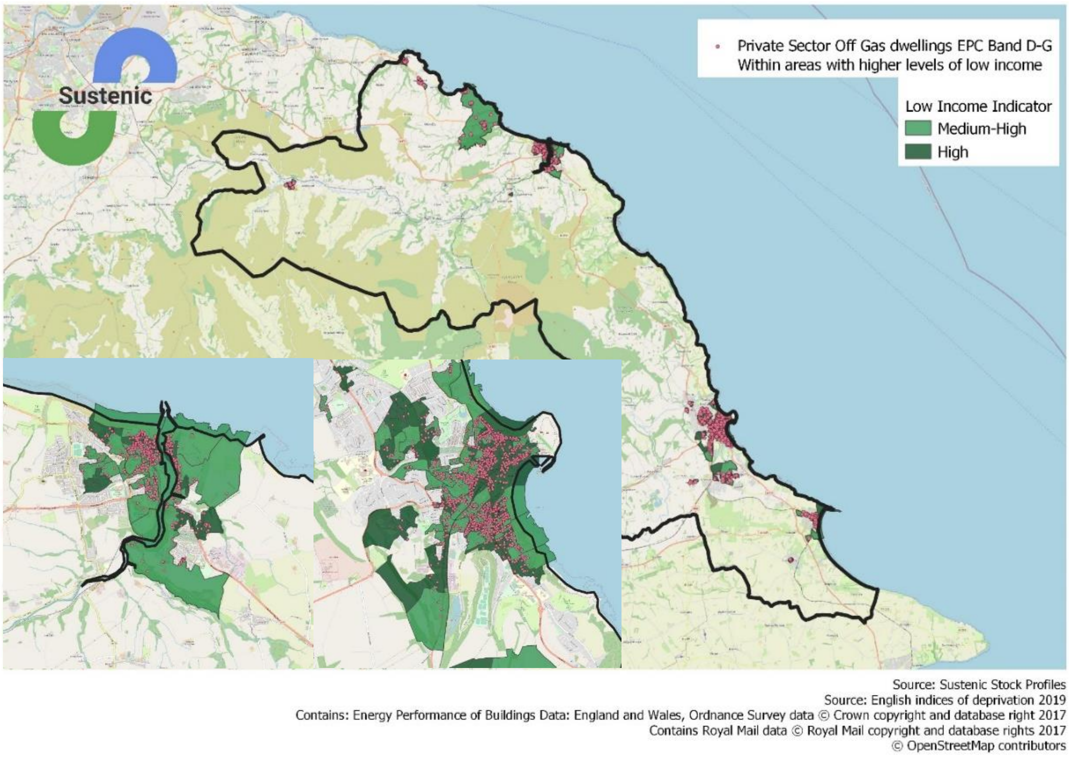


Figure 30 - Combined dwelling and income indicator for HUG 2 – Scarborough

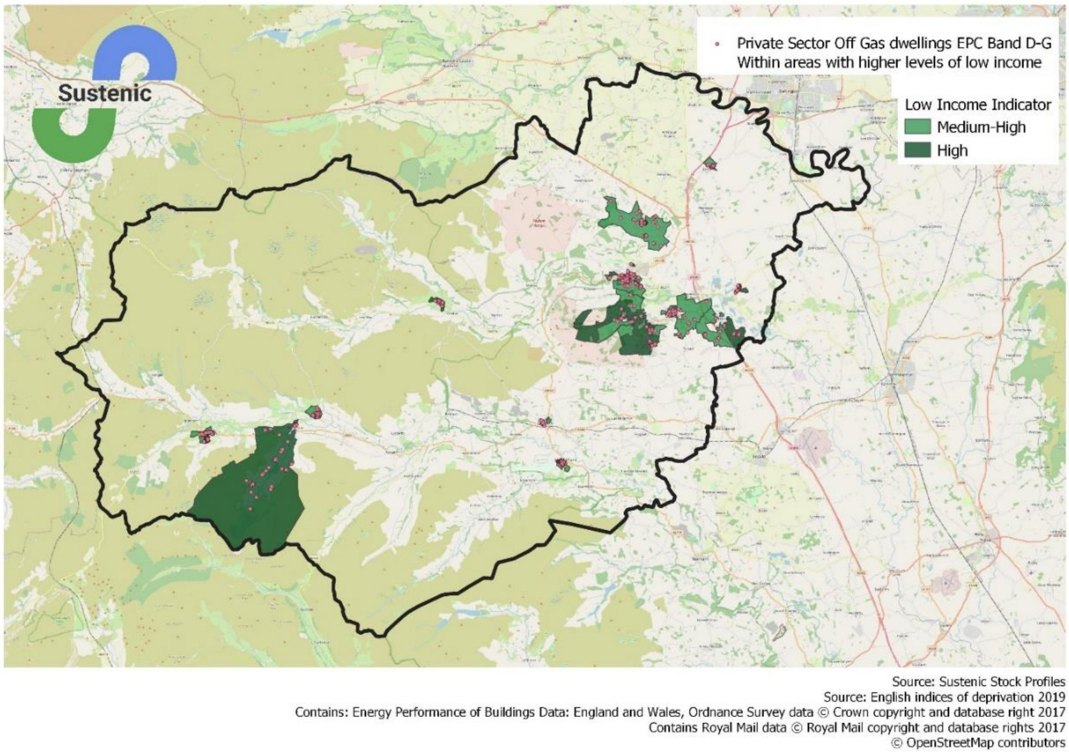


Figure 31 - Combined dwelling and income indicator for HUG - Richmondshire

Community engagement

In Scarborough, a community engagement exercise was conducted with funds secured through LAD2 to investigate the attitudes and perceived barriers of local inhabitants. Below are some examples of the comments given in the responses received.

"I am not convinced that heat pumps are suitable for this house all year round."

"I don't know if solar PV or thermal [would be] allowed in the national park."

"At our age we would be unable to recover any potential financial benefits."

"If it was at least 80-90% funded and a leading provider fitted them. Like when… loft insulation [was] for free for anyone, fully funded."

"It's a big problem these days to get reliable and competent tradesmen."

"I would need to know that my house would be as warm… as using my gas boiler."

The responses can be categorised into several themes.

- Tenure: The issues faced by owners are very different to tenants. Capital cost is not relevant for tenants but is important for landlords however the split incentive issue means that they will not benefit financially from installing measures.
- Lack of reliable information: Individuals are theoretically willing to install measures however they don't feel able to act because they do not have enough information to know which steps to take.
- Misconceptions and misinformation (myth busting): Several respondents said that they believed or had heard that heat pumps are not suitable for their house type or that they result in much higher energy costs. People need to hear about successful installs and even better, experience them for themselves, such as through the development of exemplars.
- Difficulty and disruption: Often referred to as "Hassle factor." This will be a barrier for many households, particularly where they may have additional needs such as disabilities.
- Mistrust of trades: The councils can seek to promote good tradespeople in a way that leads residents easily to the right place.
- Capital cost and return on investment: The role of the council will likely be to make sure that households are informed about funding and matched with the most appropriate sources.
- Planning barriers: The council should engage with planners from relevant planning authorities to seek solutions that meet the aims of emissions reduction and preservation of cultural heritage.

Phase 1 recommendations

Throughout Phase 1 of the action plan, the subjects covered have suggested actions that the councils should take to enable the activity required to meet their ambitions for the hard to decarbonise housing stock. These recommendations are summarised here.

1	Establish an agreed view of what net zero means for hard to decarbonise housing. This establishes the goal for which a plan can be formed.
2	Design and carry out targeted condition surveys to improve data held on the housing stock and enable an effective segmentation and prioritisation process.
3	Work with planners (including in the national parks) to ensure net zero objectives are balanced with heritage considerations.
4	Provide high quality advice that goes a step beyond what is currently available from central government.
5	Promote the development of skilled installers and seek to build capacity while maintaining quality through local training providers.
6	Ensure and facilitate good governance and good practice in retrofit. This incudes all phases of the retrofit process from initial survey, through to post-completion monitoring.
7	Don't reinvent the wheel when it comes to retrofit technical solutions. There is a wealth of material on retrofit of traditional buildings and many examples of how this has been done well.
8	Define packages of measures to suit a range of scenarios. These should be kept under review and updated regularly as the evidence base develops. Should include a high and low fabric approach.
9	Secure and sustain senior-level buy-in.
10	Define job roles and organisational structure within the council/s to execute the programme.
11	Integrate the costs model into council activity and update it with actual costs. Continually review costs to keep them as realistic as possible.
12	Move from a reactive model to a proactive one.
13	Create local exemplars. These are homes that are retrofitted by the councils in their areas, perhaps to varying standards, including heat pumps, that local residents can visit to experience retrofit in person.
14	Create a network of 'open houses' where people can see retrofit 'in the wild'. These would be homes that have been retrofitted by their owners and who are willing to open their doors to local people on certain days.
15	Develop a mechanism to promote good tradespeople. This ensures that more jobs are successful and customers have a better experience, creating a virtuous circle that should encourage more retrofit.

Phase 2
Design

Councils should extent and update the planning phase by following the 12 steps below:

Step 1: Review the planning stage

The first step in the design process is to implement initial preparatory activities. This includes a review of the planning phase and amending targets, policies and other elements as necessary.

Step 2: Review data, software and data analytical skills

Councils will need to undertake a review of their housing energy efficiency and stock condition data, software and analytical skills to ensure that they can make best use of the insights provided by data; a critical first step in the housing decarbonisation process.

Step 3: Develop and implement a data quality improvement plan

The gaps identified in step 2 are addressed here step 3 by creating a data quality improvement plan.

Step 4: Undertake householder and stakeholder engagement

Engage with householders at each step of the action plan and at the earliest opportunity. Households in all sectors will need to be educated about retrofit and encouraged to install measures.

Step 5: Plan, design and develop housing retrofit exemplars

Exemplar properties should be developed for use as demonstration tools for householder engagement and knowledge transfer, with more added over time to build up the evidence base. These exemplars can demonstrate how individual property types have been retrofitted to reduce carbon emissions.

Step 6: Develop local skills and supply chain

The ambitions set out in the Routemap to Carbon Negative report will need to be delivered by tradespeople that are sufficiently skilled, numerous and local. There is currently a gap in each of these areas that the councils should work to address in partnership with local stakeholders.

Step 7: Review and update barriers to retrofit take-up

Phase 1 of the action plan described the main barriers to retrofit currently faced in SBC and RDC. This list should be reviewed and updated to ensure the councils have a full understanding of the limitations that might be imposed on retrofit and how they might contribute to overcoming other barriers.

Step 8: Review and update energy efficiency improvement pathways

Use housing stock data to identify all technical energy efficiency improvement options to reduce energy use and carbon emissions.

Step 9: Review and update costs for energy efficiency improvements

The costs provided in the planning phase should be updated with all relevant new data in order to prepare funding cases and for engagement with suppliers.

Step 10: Identify and secure funding from external sources

Plan retrofit proactively, with external funding sources being worked into the programme. It is still vital that maximum use is made of external funding to make this programme successful. It is also important to ensure that requests for funding are realistic and can deliver the measures specified.

Step 11: Prioritise and sequence improvement work

Councils should act as enablers and coordinators for the installation of measures in hard to decarbonise properties. This should include high level oversight of the implementation of measures across local housing, including the monitoring of measures installed to help to track progress against targets.

Step 12: Review, extend and implement the key components for success

Achieving the decarbonisation goals for the hard to decarbonise stock will require best practice to be implemented in all processes and at all levels.

Phase 3 Implementation

This document provides a high level guide to users tasked with implementing the design phase. It is envisaged that the programme of work required to achieve the targets for the hard to decarbonise housing stock in SBC and RDC will include the delivery of many separate projects.

Hitting Hard phase 3 will implement the design phase, or programme plan, and will be enacted by councils. The programme plan is a live document and changes should be made where needed at any time, informed by incoming programme data reflecting progress against targets and any new resources or evolving challenges. It is anticipated that an extended time period *may* elapse between the completion of the design and implementation phases, resulting in the need to review and update the design phase.

In the majority of cases, councils should operate as enablers for the implementation of the Hitting Hard design phase to decarbonise (hard to decarbonise) housing in SBC and RDC; the primary exception being where they own and manage their own housing stock. This will involve a sector specific approach, breaking actions down by tenure to facilitate the tailored assessment and application of efforts.

There are six primary steps involved in implementing the design phase, including some planning that must occur before the implementation can begin. The following step-by-step set of actions is presented to follow in order to implement the design phase effectively for the hard to decarbonise housing stock in SBC and RDC:

- **Step 1: Review and confirm programme design phase (programme plan)**: Ensure that the plan meets the current expectations of management and stakeholders.
- **Step 2: Execute the plan**: The programme and project managers and team start work on the programme.
- **Step 3: Adjust the design phase (programme plan) as needed**: Monitor project progress, making changes as needed.
- **Step 4: Analyse data continuously**: Track key metrics to determine and report progress against targets.
- **Step 5: Gather feedback**: Helping to make continuous improvements and ensure the successful completion of future work.
- **Step 6: Reporting**: Provide details covering how programme delivery compared with the plan.