SUSTAINABLE ENERGY ASSOCIATION

A Technology-Agnostic Approach to

Heat and Buildings Policy

2023

Foreword | Lord Best

President of the Sustainable Energy Association

As the UK sails into 2023, the scale and the necessity for tackling the net-zero challenge grows ever greater. The transition to a future no-longer dependent on fossil fuels coincides with the ongoing war in Ukraine and its subsequent fuel poverty implications, an ongoing UK recession as well as security and cost-of-living crises.

The Sustainable Energy Association (SEA) and its key partner organisations are collaborating to support the Government's push for net-zero and low-carbon heating. The Chancellor reinforced the Government's commitment in the 2022 Autumn Statement. And the SEA welcomes the renewed 2030 ambition to reduce energy consumption by 15%, with funding of £6 billion along with the establishment of an Energy Efficiency Taskforce to deliver overdue reductions in energy demand.

Earlier SEA reports have advocated a 'fabric-first' approach to decarbonising buildings: this starts with optimising the building fabric to the technologies used for delivering sustainable buildings, not least with better insulation. The latest SEA report moves on, beyond the fabric, to the heating systems, smart controls and other technological approaches. Its underlying theme is that we should take a technology-agnostic approach, rather than relying on a very small number of options.

This broader approach chimes with the recommendations in the Government-commissioned report—Mission Zero: Independent Review of Net-Zero—from former Energy Minister, Chris Skidmore, MP. The review provides a clear assessment of how net-zero policy can go further and faster, how it can deliver pro-business, economy-wide growth. I was delighted that the SEA was invited to feed into this highly relevant exercise.

This SEA report argues that it will be necessary to consider a wider diversity of technologies, with the need for clarity and long-term certainty for industry. Thus, while heat pumps have a key role to play, so do solar panels, on-site microgeneration and other solutions. This broader, more flexible approach needs to combine with giving the industry more long-term certainty, including clear dates for phasing out fossil fuel boilers, better measurement and recording of information on building performances, and more.

I commend this report and the continuing role of the SEA and its partners in informing and influencing national policy in pursuing this vital agenda.

Richard Best

Executive Summary

The UK's pathway to Net Zero 2050 is occluded by the monumental challenge that is decarbonising buildings and the way they are heated. The UK's building stock is antiquated, tailored to serve a population from a time when more inefficient means of heating were commonplace. Consequently, these buildings are thermally inefficient; with those living and working within them facing the ramifications of draughty, cold, expensive and unhealthy indoor environments. The societal costs of which are estimated to be in the region of £18.5 billion per year.

Moreover, this report comes at a trying time for the UK. Post-COVID rebound has manifested in tight supply chains; Russia's invasion of Ukraine and geopolitical manipulations have skyrocketed global gas prices and supply; the UK is battling a recession, cost-of-living and energy crisis; among other pressures and exacerbations. And, although the UK Government is supporting businesses, the vulnerable, low-income, and fuel-poor with tens of billions of pounds to pay the bills, investments into energy efficiency and low-carbon technologies for buildings have not seen equal support. Long-term financial savings, healthier, more comfortable buildings, and a decarbonised building stock can only be achieved with significant investment into installing energy efficiency and low-carbon technologies for decarbonising heat (LCTs). The vast scope of technologies this will include ranges from electrified solutions, such as all types of heat pumps, direct electric heating, infrared heating, mechanical ventilation with heat recovery, solar PV, and electric battery storage, to smart thermal storage, smart controls, solar thermal systems, low-carbon fuels and more.

The SEA advocates for a fabric-first approach to decarbonising buildings — optimising the building fabric to co-ordinate technologies for delivering their intended result as the first port of call. This report, however, is focused on the next stages of transitioning buildings, beyond the fabric, which includes the heating system, onsite microgeneration, flexibility and smart controls, and other aspects and technologies.

The Government's strategy for decarbonising heat in buildings includes a target for installing 600,000 heat pumps a year by 2028. Hydronic heat pumps, alongside other steps to electrify buildings, powered entirely by low-/zero-carbon renewable electricity generation by 2035, is planned to abate the bulk of carbon emissions from buildings.

Heat pumps are an absolutely vital technology for achieving net-zero buildings. The UK cannot afford to inappropriately install and mar the public perception of heat pumps, nor delay installing them in buildings where appropriate. Their tremendous energy performance, reliable results, scalability, and relative popularity and success in other countries means they represent a core solution for low/zero-carbon buildings. However, hydronic heat pumps are but one measure in a sea of LCTs that will play a role in decarbonising heat in buildings. An assessment of the risks and unintended consequences inherent in the Government's current approach are outlined from page 19.

The UK's building stock is massively diverse, and nearly every building is unique. And to address this heterogeneity in building, the solutions employed must equal its assorted nature. Technology agnosticism, or appropriateness, in this case, is defined as the requirement for policy to preserve optionality to deliver the best technologies for the right outcomes in order to decarbonise heat in buildings (Page15).

This technology agnostic approach puts greater policy focus on the targeting of best outcomes in the UK's transition to Net Zero. This is an opportunity for capitalising on the most favourable outcomes for the nation and getting it right from the outset. These outcomes are chiefly guided by the three main drivers of reducing cost, abating carbon and enhancing health and wellbeing. Once aiming at these desired outcomes, the approach takes into account the particularities, situation, and construction of an individual building, consumer preferences, and more, and supports the installation of the most appropriate suite of measures that are tailored for the circumstance. Examples can be drawn from other countries who have implemented policies that engender more of a technologically agnostic approach.

The benefits of the Government taking a technology-agnostic approach within policies for heat and buildings are wide reaching and desirable for the UK.

Accelerated Route to Net-Zero Buildings (Page 24):

“Technology agnosticism will target and channel investments made into LCTs for decarbonising the UK building stock to Net Zero at an accelerated rate and maximise the benefits of healthy and cost-effective buildings.”

Flexible and Smart Building Energy Systems (Page 42):

“A technology-agnostic approach puts more emphasis on the installation of smart and flexible technologies that unlock grids and homes of the future and reduce costs associated with operating buildings and transitioning to Net Zero.”

Effective Consumer Education and Engagement (Page 53):

“Taking a more technologically appropriate approach to what, where, and how LCTs are proffered and installed in buildings, will benefit this mammoth transition by marrying up consumer desires with a solution and engaging people in undertaking the necessary changes.”

High Quality Skills and Clear Local and National Planning (Page 59):

“A more technology-agnostic approach will benefit the transition with the deployment of solutions at a local level, primarily driven through its requirement for bottom-up, evidence-based, building-level decision making that targets specific outcomes over a specific technology.” And, “…has the benefit advantage of delivering the most outcome-effective route to Net Zero within a local area.” And, “...has the benefit of stimulating more supply chains for a greater variety of technologies, which, in turn, will drive and accelerate the deployment of technologies and skills at a local level.”

Stimulating Manufacturing, Supply Chains and Innovation (Page 64):

“…as the investment landscape takes a more concrete form, with clear pathways for industry to supply demand, then manufacturing capabilities, product investment, and supply chain diversity and resilience will grow, benefitting the UK’s low-carbon economy.” And, “If government policies were to increase the variety of technologies installed and take a more evidence-led approach to decarbonising heat, then huge benefits would be reaped for the innovation process, paving the route to market for new solutions.” We have also included economic analyses to provide evidence of the benefits for taking a more technology-agnostic approach. (Page 28,50,56).

Finally, we concluded and recommended on the next page that if the Government are to achieve the Net-Zero target and are driven to capitalise on the best outcomes from this opportunity, then ensuring policies are evidence led, data driven, and technology agnostic is a better route to Net Zero.

This report was made possible thanks to the help and expertise of key partner organisations, our membership and individuals from across the sector (Page viii).

Conclusion

This report comes at a time when key decisions needed for abating carbon emissions from heating the UK's building stock are well overdue. Considering the mammoth task that this transition represents, both speed and appropriateness must be employed to achieve the Net-Zero target in time and capitalise on the best outcomes for UK PLC, consumers and the Government.

As detailed throughout this report, the SEA has put forward that more evidence-led, multi-measure, technology-agnostic decision making for decarbonising heat in buildings is associated with realising these best outcomes and a host of benefits across the nation. It is also of particular significance and benefit considering the current crises that the UK is enduring. This approach engenders policies that can both support both vulnerable consumers and businesses, whilst decarbonising, by applying LCTs more appropriately considering the circumstances, requirements and desired outcomes.

This approach also puts more emphasis on first establishing what these desired outcomes are for the circumstance, the particularities of an individual situation or building and the priorities of the consumer or business. Once this baseline has been covered, the approach necessitates that the best mix of technologies are then applied and in the right order, specifically targeting these outcomes. Most existing policies utilise a top-down approach to specifying technologies, whereas a technology-agnostic approach takes more of a bottom-up, data-driven focus. All buildings, either existing or new build, will significantly benefit from tailored measure selections to match the building at a property level.

Firstly, by its very nature, this approach is beneficial for health and well being and the best value pathway to Net-Zero buildings. Focusing on lowering cost and carbon emissions, and enhancing wellbeing, whilst applying the most appropriate measures to a building to achieve this, will achieve Net Zero the soonest and with the best outcomes. For example, this approach will avoid the financial and carbon costs associated with incorrectly specifying measures in existing or new buildings, which will have to be removed/re-specified in the future.

Secondly, more technologically agnostic policies will provide a huge benefit for installing flexible and smart technologies in buildings that necessitate buildings and an energy grid of the future. Unlocking Net Zero will fall heavily on using low-/zero-carbon energy in response to demand, price, and carbon intensity, alongside shifting consumption or generation in time or location. The solutions that will enable smart and flexible energy systems in buildings are well deployed under a more technologically agnostic policy framework as these outcomes are of principal importance for attaining Net Zero, giving consumers and businesses ownership of their energy, and offering the best value, lowest carbon energy.

Thirdly, consumer education and engagement in the transition to Net Zero will benefit by taking a more appropriate approach to the way LCTs are deployed. This is partly because this approach puts a greater onus on the rollout of quality, tailored consumer advice that captures consumer interests and engages them in the transition. With the installation of measures more suited to the individual and the situation, the result will be more likely to breed confidence and trust in consumers. This will lead to fewer instances of distress purchases, (which lead to an unnecessary retention of the same fossil-fuel system); higher opinions and better buy-in of LCTs and their role in buildings; and a greater potential for consumers and businesses to invest in LCTs and undertake preparatory works and installations before made necessary by a heating system failure.

Fourthly, technology-agnostic policies will reap the benefits of delivering LCTs most appropriately through local, regional and national planning. Local delivery and planning are the most effective ways to deploy the most appropriate technologies, as individual areas are better aware of their plans for decarbonising to net-zero carbon emissions, their regional assets, and consumer and business requirements. And as a result, it will likely best capture the necessary skills required to install and drive the Net-Zero transition. It focuses on local skills, where they will be required the most and in what volume; alongside how best to attract new talent and up- and re-skill existing trades.

Fifthly, and finally, this approach is best suited for: growing a more holistic manufacturing base and service offering; creating a progressive industry for unlocking innovative measures and solutions; and stronger, more resilient supply chains for delivering LCTs for the transition to Net Zero. This is beneficial for diversifying the technology offering to consumers and businesses, spreading the risk of delivery or material/componentry shortages across a wider array of varied solutions. It also has the benefit of boosting the UK's potential to grow its economy by exporting low-carbon products and services for decarbonising buildings to a global market of decarbonising economies. Additionally, there are wider benefits for energy security and independence. As the market for a diverse offering of LCTs and fuel vectors grows, so does individual ownership and generation of energy, and protection from geopolitical turbulence.

Subsequently, the SEA advocates that UK Government policies for decarbonising heat and buildings are made more technology agnostic, evidence led, data driven and multi measure. Achieving the best outcomes in the transition to Net Zero is of paramount importance. Delivering better, healthier buildings for a better, healthier future; providing the best value for consumers and businesses; and decarbonising the UK's building stock, are the primary drivers for delivering this approach. And creating a policy framework that realises the potential of Net Zero and empowers consumers and businesses to decarbonise in a way that creates the best outcomes for them, is the goal for government policy in this area.

Partners

A special thanks goes to the many trade associations, organisations, members, and individuals who have helped to scope, construct, edit and proofread this paper.

Supporting Organisations

Active Building Centre (ABC)

Mitsubishi Electric

The Association for Renewable Energy and Clean Technologies (REA)

Building Research Establishment (BRE)

Naked Energy

Showersave

Electrical Contractors' Association (ECA)

NAPIT

Solar Energy UK (SEUK)

Herschel Infrared

National Energy Foundation (NEF)

Sovereign

IRT Surveys

NIBE

Thermal Storage UK (TSUK)

Microgeneration Certification Scheme (MCS)

Oil Firing Technical Association (OFTEC)

Windhager

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Introduction

The UK's 2050 Net-Zero target was one of the first of its kind to be enshrined in law: bringing with it the requirement for wholesale change to every conceivable aspect of the nation. One such element of this change lies in addressing the building stock, which is the UK's second greatest source of carbon emissions. Around 30% of all direct and indirect UK carbon emissions are produced from its near 31 million buildings[1]. Just shy of 80% of these emissions are generated from heating these buildings (Figure 2)[2].

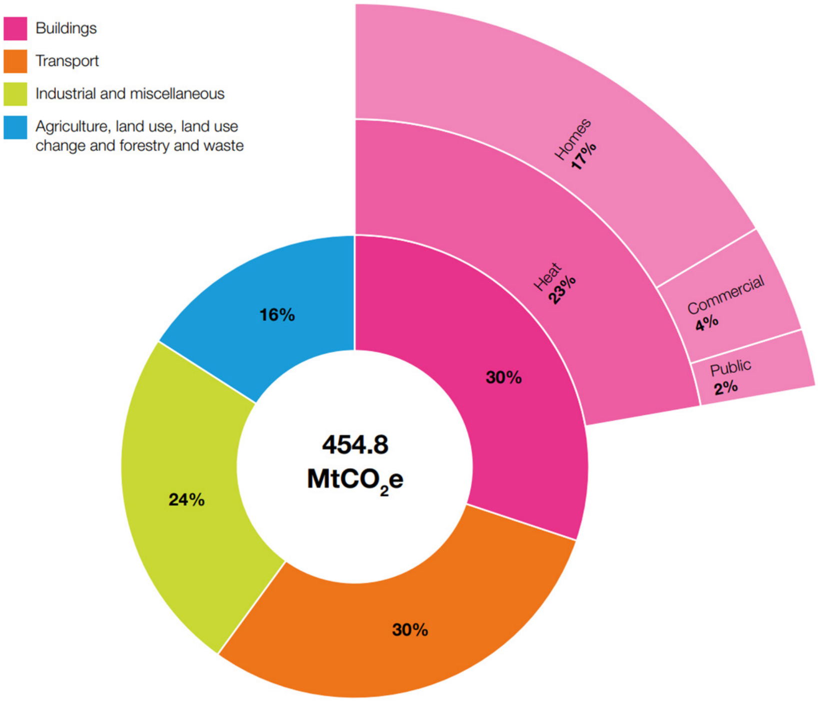


Figure 1: Direct emissions by source, UK, 2019, as a proportion of the total emissions (454.8 mega tonnes of CO$_2$ equivalent)[3].

Simultaneously, the UK's building stock is infamous for its antiquated qualities, older construction and outdated energy efficiencies. UK homes and buildings were built either for the purposes of industry and manufacturing, or for the evacuation of smoke from fires, as opposed to retaining warmth. Today, and in transitioning into a low-carbon society, modern heating technologies have moved on from coal and wood fires, and subsequently, the requirements for buildings and the technologies within them has changed. In 2021, over 55% of homes in the UK were rated EPC Band D to G[4] (Figure 2) and equally as many without an existing or valid EPC lodgement[5]. The knock-on effects of such poor-efficiency housing stock are myriad, not least on living conditions and public health of vulnerable citizens; which are estimated to cost the NHS £1.4 billion per year in first-year treatment costs alone (Figure 3)[6].

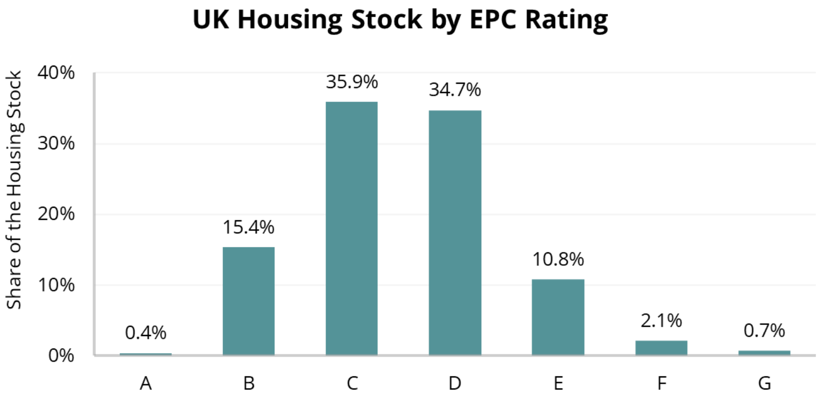


Figure 2: EPC rating distribution as a proportion of UK housing stock, 2022[7].

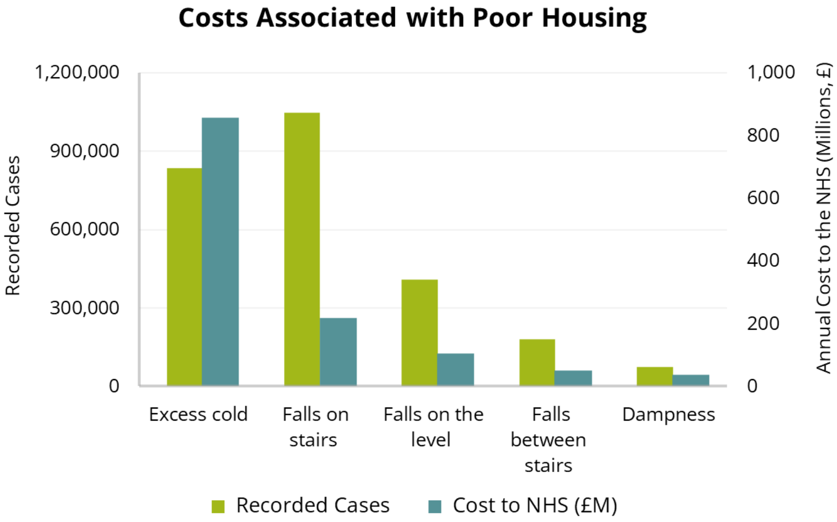


Figure 3: Costs associated with poor housing in the UK, 2021[8].

Furthermore, 85% of UK homes today are connected to the fossil gas grid, meaning that the UK must work hard to transition away from natural gas and towards a decarbonised electricity supply in order to eliminate carbon emissions from its buildings. Whilst, in equal measure, ensuring buildings are energy efficient, warm and healthy.

As detailed in our 2022 report, *What Next for Heat & Buildings Policy?*, a litany of voids remain in Government policy for this key area, post publication of the *Heat and Buildings Strategy*[9] and associated policies and strategies. These policy gaps span across the sector and act as serious barriers to decarbonising heating and energy in buildings.
These gaps consist of:

- A lack of consideration for the 60% of existing homes which are owner occupied and not fuel poor, to retrofit with energy efficiency and Low Carbon Technologies for decarbonising heat (LCTs).
- Scant support for building awareness and practical advice on energy efficiency, LCTs and retrofit for consumers.
- Technical training support and re-/up-skilling for installers is not being delivered on through policy at the scale required.
- No long-term, joined-up, consistent, or effective policy and regulation is supported by government across Parliamentary cycles and elections. These give confidence to the industry and supply chains through security of investment and assurance of direction.
- Lacklustre policy delivery of outcomes-based, multi-measure, whole-house, technology-agnostic approaches to heat and buildings decarbonisation.
- Blockers to innovation, as explored in our report, *Helpful Information and Tips for Manufacturers and Innovators on Gaining Access to Government Energy Efficiency Schemes.*

Geopolitical Headwinds

The challenge of the 'energy trilemma' — meaning affordability and access to energy, national energy security and environmental sustainability — has, of recent times, deepened in severity and magnitude. This is due to the need for faster, deeper, and wider decarbonisation efforts; remediation of the energy crisis, risking energy supplies and inflating wholesale costs; and subsequent tackling of the cost-of-living crisis to ensure energy equity and a 'just transition'. A host of recent events have exacerbated the energy crisis, including post-COVID rebound supply chain shortages; Russia's invasion of Ukraine and its impacts on global gas supply and prices; the UK's relatively small natural gas stores and capacity to import; and the UK's decline into a recession; alongside other challenges. This has resulted in exorbitant and spiralling wholesale energy costs (Figure 4).

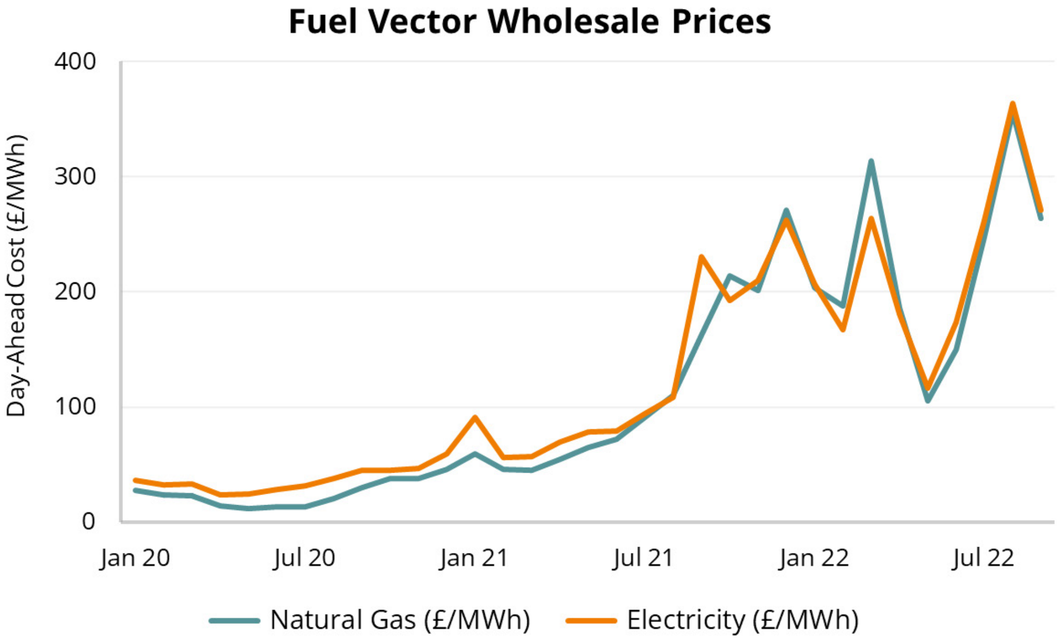


Figure 4: Electricity and natural gas day-ahead prices, monthly average[10].

The triple threat that these crises are presenting, have plunged the UK into the worst energy bill crisis in 50 years[11]. And have forced an estimated six–and–a–half million homes into fuel poverty with April 2022's price cap — estimated to be up to ten million homes with a price cap of £4,200[12]. The Government's planned spending for financially supporting UK citizens, is in excess of £55 billion; this is primarily through the Energy Bill Support Scheme, Energy Bill Relief Scheme, Energy Price Guarantee, Household Support Fund and Council Tax Rebate. However, these are inefficient, short-term methods for providing financial savings.

The inordinate spending to support the public and businesses may suffice as a temporary relief package for UK energy bills — or not, as analysis by Carbon Brief suggests[13] — but it does not guarantee long-term savings, as little additional investment has been directed into improving the energy performance of buildings[14] [15] [16]. Further still, annual heating bills for the ~85% of UK homes with gas boilers, have seen rapid and continual inflation across 2022, in line with rising wholesale fuel prices (Figure 4), and are expected to remain higher than historic norms into 2023 and 2024[17]. Further measures should be introduced to support energy efficiency and incentivise the most cost- and carbon-effective measures to reduce energy bills, whilst supporting health and wellbeing.

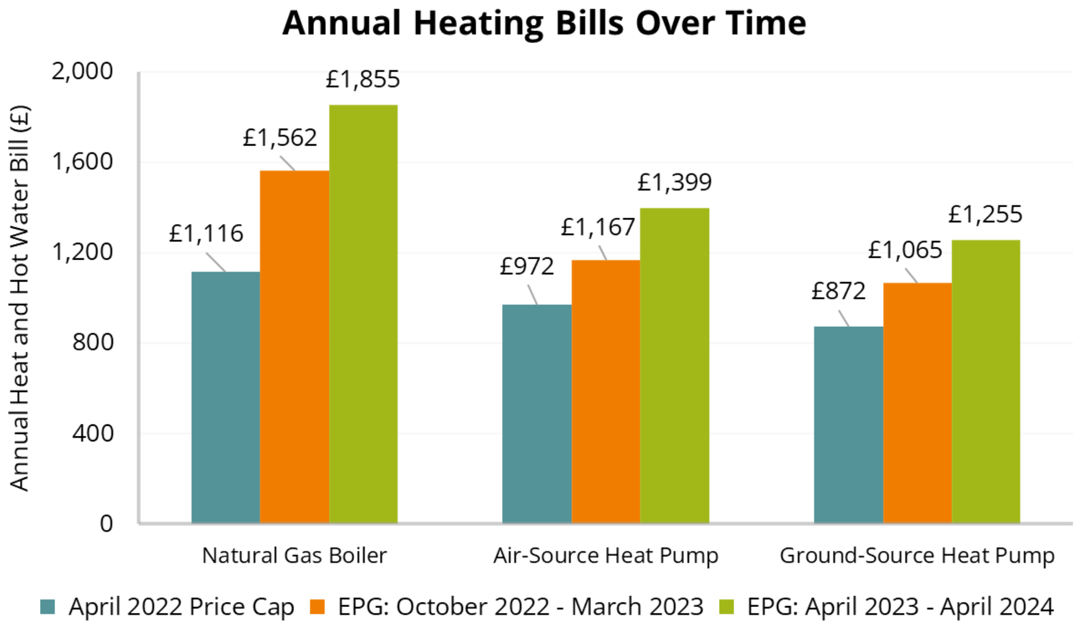


Figure 5: Comparative heating bills for a natural gas boiler, air-source heat pump, and ground-source heat pump, using national domestic property energy demand averages. This is modelled over the April 2022 price cap, Energy Price Guarantee (EPG) from October 22 to March 23 and EPG from April 23 to April 24.

The money invested in these bill-cutting and energy-price-cap-freezing policies are, ultimately, spent on paying off energy bills, which, assuming energy prices will remain volatile and inflated for many years, will only result in the current situation of high prices for those most vulnerable, consumers, and businesses when the support and cap freeze is lifted. Current policy does not focus on longer-term issues, nor materialise in direct investments for a building or homeowner itself, which would increase energy efficiencies and reduce energy demands through upgrading and optimising building fabric, installing LCTs and microgeneration capacity. These, the SEA believes, are the most cost-effective routes for not just cutting energy bills in the long term, but have myriad benefits for the route to net-zero buildings, flexibility and smart systems, consumer engagement and education, skills and local and national growth, and manufacturing, supply chains and innovation.

Contextually, the demand for delivering energy efficiency, low-carbon heating, and other low-carbon solutions through policy, has seldom been so pressing. It comes at a time when 58% of the population believe they will struggle to pay their bills this winter, with 76% of the opinion that the Government is not doing enough to support vulnerable households this winter[18]. Likewise, 37% of SMEs in the UK have declared they are facing difficulty paying energy bills, even in receipt of government support—this is equivalent to just over 2,000,000 SME's—and 4% stated they will not be able to pay their energy bills at all (around 220,000 SME's)[19].

Further still, 65% of non-domestic consumers reported reduced profit margins as a result of energy price rises[20]. The UK is required to create living and working spaces that are net-zero carbon emissions, energy efficient, cost-effective to run and own, warm, and healthy; whilst eradicating fuel poverty, encouraging investment, increasing productivity and wellbeing through healthy indoor environments, and more. During the cost-of-living crisis, these requirements and the journey to fulfilling them, are in jeopardy, but now is the time to make these investments that can remediate the deleterious effects these crises are inflicting on society and the economy; alongside making tangible progress towards these immovable targets.

Solutions for Remediating Short, Medium and Long-term Pressures

Government policy and regulation needs to be strengthened to create a long-term strategy for cutting energy bills. Moreover, policy and regulation directed at addressing energy security should not lose sight of the UK Government's objectives for the environment and climate. BEIS and other government departments must work to ensure that such policies are consistent with the *Net Zero Strategy*[21] and *Heat and Buildings Strategy*[22].

This means, continual motions must be made towards addressing a variety of aspects of the UK's building stock, which, the Climate Change Committee (CCC) estimates, will, alongside increasing low-carbon power capacity, require the greatest investment upscaling as part of their Balanced Pathway (Figure 6)[23]. Of which, the SEA believes can and should run compatibly with greater energy security, fewer carbon emissions, improved energy efficiency and lower energy bills, healthier indoor and outdoor environments, and living and working spaces that are fit for the future.

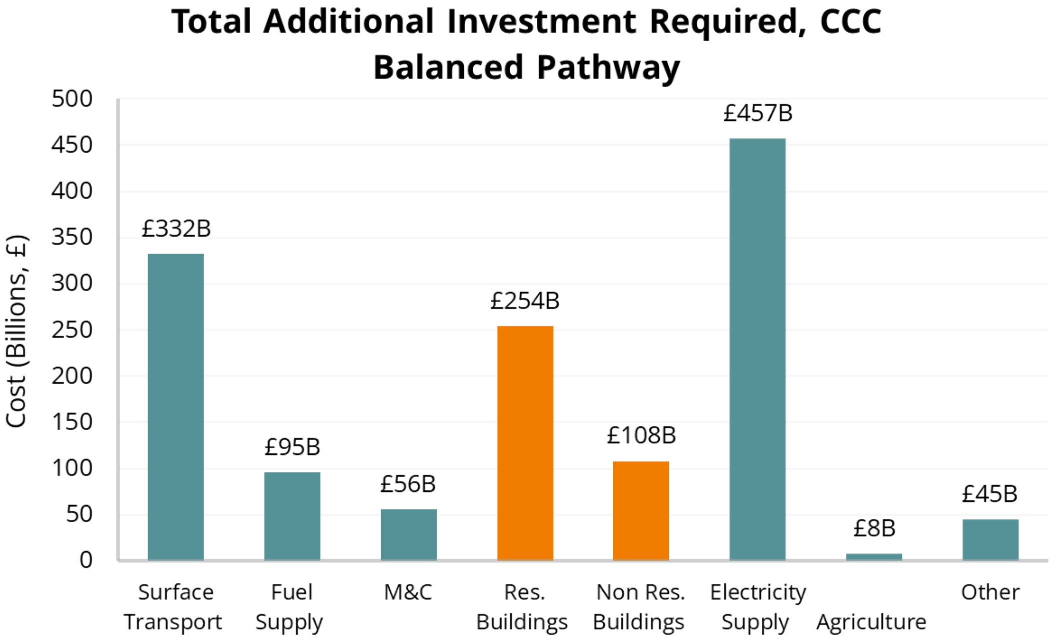


Figure 6: Summation of additional investment required (up to 2050), CCC Balanced Pathway[24].

As universal methodologies for tackling the UK's building stock, 'fabric-first', 'whole-house/building', and 'multi-measure/technology-agnostic' approaches should be prioritised for undertaking any works on, or when constructing new buildings. The SEA fully supports a fabric-first delivery, as part of a whole-building approach; our stance and positioning on fabric first can be read in Appendix 1. However, this report is focused on the next stages of transitioning buildings to Net Zero, which includes the heating system, onsite microgeneration, flexibility and smart controls, and other building aspects and technologies.

Whole-Building Approach

A whole-building approach, intrinsically linked to a fabric first and multi-measure approach, splices together many elements of a property that, previously, may have been viewed and upgraded/retrofitted separately, such as any historical alterations or renovations done throughout a building's lifetime. As a result of this disjointed approach, many measures and features may end up working counter-productively, or producing undesirable, unintended consequences, not just for energy efficiency, but for the general characteristics of the indoor environment.

For example, typically isolated improvements made to a dwelling include, blocking off a chimney stack or replacing wooden window and door frames with PVC or PU products, minimising draughts and heat loss, which may, in some cases, reduce ventilation and cause a build-up of moisture and produce damp and mould[25]. Another example is in the instance of upgrading or changing a gas boiler for a more efficient model or different heating technology. Especially, when planning to upgrade the energy efficiency of the building, it is important to take a whole-building approach to ensure the new system is sized correctly. This could consist of upgrading the fabric and the heating system together, or by planning in upgrades to the heating, ventilation, etc., as part of a whole-building, fabric-first retrofit. Gas combination boilers in the UK are usually oversized due to the disparity between higher water-heating demands and lower space-heating demands. The efficiency penalty from oversizing can be in the region of 9%, highlighting the importance of staging measures effectively to work in conjunction with one another[26]. This is also necessary for preventing further piecemeal retrofit works having to be carried out, resulting in additional cost, disturbance and carbon emissions.

Policies, such as ECO+ (Energy Company Obligation Plus)[27] and others that push for single-measure installations — bringing down capital costs and enabling a phased, incremental approach to retrofit — may play an important role in the pace of carbon reduction, but should be carefully considered to ensure that the measures supported do not cause unintended consequences and are planned as part of a wider package of measures.

A whole-building approach in construction or retrofit/upgrade, follows a structured approach. Examples of such approaches include the Publicly Available Specification (PAS) 2035, the Passivhaus Standard, the EnerPHit Standard (for retrofit), and Energiesprong. Such methods and standards ensure that measures complement each other. They not only enable the management of mould and moisture, air quality, damp, and ventilation, but readies the energy efficiency and energy management system of a property for installing LCTs; the next step in preparing the UK's building stock for a low/net-zero-carbon future, after maximising energy efficiency. Moreover, we can infer from analyses and models that once energy efficiency improvements have been maximised, there will still be sizable residual energy demands required to be decarbonised[28].

Electrification

This crucial next step in the process of developing net-zero buildings will take us from a currently exposed, gas-fuelled, high-carbon, high-cost society, to one of relative energy independence, net-zero carbon, good health and lower costs. The Government's prioritised route to decarbonised heat is through electrification — hence the high total investment costs (£457bn) modelled for electricity supply through the CCC Balanced Pathway (Figure 6). The electrification of heat is a vital technological journey that will see buildings become increasingly independent from fossil fuels, grow the renewable energy generation market to decarbonise the electricity grid, and unlock smart and flexible energy grids that improve the way energy is stored and used.

There are many technologies available that will make the electrification of buildings cost and carbon effective, accessible and beneficial to achieving the right outcomes for buildings. Heat pump technologies are a highly effective and core solution for electrifying and decarbonising the UK's building stock; chiefly due to their high performance efficiency, reliable results, scalability, and relative popularity and efficacy in other countries. Their key role in new buildings, buildings not connected to the gas grid, and through heat networks/district heating, will help to unlock the gradual transition to a net-zero-emissions built environment. The technology is comprised of hydronic heat pumps (like Air-Source Heat Pumps (ASHP's), Ground-/Water-Source Heat Pumps (G/WSHPs)), air-to-air heat pumps (AAHP), exhaust-air heat pumps (EAHP), hybrid heat pumps and others.

It is important to grow the market for all heat pump types and systems, alongside other key electrification technologies and enabling solutions, such as electric storage heaters, electric resistance heating, electric boilers, solar PV, solar thermal, hybrid photovoltaic/thermal (PVT), infrared (IR) panels, Mechanical Ventilation with Heat Recovery (MVHR), smart thermal storage, smart electrical storage, Waste-Water Heat Recovery (WWHR) and many others.

A necessary step to reaching the Net-Zero ambition through electrification is by ramping up large-scale and small-scale renewable electricity generation and flexible storage. Low-/zero-carbon electricity generation, using on- and off-shore wind and solar, tidal energy, nuclear, hydroelectric, bioenergy, etc., is the underpinning factor, on top of which many other processes and technologies for decarbonising the built environment are dependent. Technologies, such as electrified technologies in buildings (heat pumps, electric resistance heating, electric storage heating, etc.) and electrically driven processes for generating low-carbon fuels/biofuels (biomass pelletisation, hydrogen electrolysis, etc.).

Once electricity generation is made low-carbon by 2035—which the CCC model will consist of displacing unabated fossil gas usage with low-carbon alternatives and scaling up zero-carbon generation[29]—the bulk of UK energy carbon emissions will have been abated (~10 gCO_2/kWh; average 2021 emissions were 210 gCO_2/kWh).

At that point, electrified buildings will be low/zero-carbon energy and will be a primary decarbonised solution for heat in buildings, and as many buildings as practicable should electrify as soon as possible. This can be coupled with the wide-spread installation of on-site renewable energy generation technologies, such as solar PV, wind, etc., enabling self-generation to reduce energy demand and cost, and allow for the sale of energy back to the grid.

The suite of electrified technologies available caters to a wide range of building types and uses. Where non-domestic or industrial properties may not economically or technically suit a full wet central heating system — driven by electrical means (heat pump, electric boiler, etc.) — other technologies, such as IR, electric storage and electric resistance heating, alongside smart and flexible storage, may be more appropriate for heating single spaces.

However, electrification may not be most suitable for decarbonising space and water heating in all UK buildings and will need to be supported by other solutions. These include renewable generation solutions, like solar thermal and anaerobic digestion; and low-carbon fuel vectors, such as biomass (as used in boilers or Combined Heat and Power (CHP) units), hydrogen produced from renewable sources, Hydrotreated Vegetable Oil (HVO), bio–Liquid Petroleum Gas (bioLPG), renewable Dimethyl Ether (rDME), biomethane, etc.

Especially, when taking into account the variety of different use cases within buildings and the fact that many may have continuous and high heating demands, such as hospitals, industrial buildings and leisure centres. Local-area-based planning may also further create demand and lower the cost to consumers for these low-carbon fuels, as domestic and non-domestic buildings within specific industrial clusters or on district heating networks may benefit from using the potentially cheaper and more available technologies and fuels in their local area.

What Is ‘Technology Agnosticism’

The route to a Net-Zero 2050 will require a diverse array of policy, regulatory, and legislative action within the heat and buildings space to drive wide-spread uptake of the many varied forms of low-carbon and renewable space and water heating technologies for decarbonising UK buildings. **“Technology agnosticism, or appropriateness, is the requirement for policy to preserve optionality to deliver the best technologies for the right outcomes in order to decarbonise heat in buildings.”** The employed solutions and technologies that will deliver a Net-Zero future for the country’s buildings are manifold: hence, the important role policy plays in engendering a technology-agnostic, multi-measure approach to heat in buildings.

In formulating policy on heat and buildings that addresses the aforementioned concerns/barriers with the current state and future direction of buildings, the Government should ensure that the most optimal route is taken to achieve the best outcomes, with a view to achieving Net Zero at the best value for the consumer. These desirable outcomes and reaching Net Zero are defined and guided by a multiplicity of factors, but chiefly within the boundaries of three main drivers:

1. Increase the energy efficiency of buildings and reduce the level of heating (and cooling) required (cost reduction).
2. Decarbonise buildings to net zero by 2050 (carbon reduction).
3. Optimise the comfort, health, and wellbeing of occupants via enhanced indoor environments (enhanced wellbeing).

The policy approach to addressing the nation’s building stock in these three principal areas must, critically, be able to take into account the diverse and heterogenous outcomes and requirements that each individual property presents upon inspection and the preferences of consumers. Putting consumers at the heart of the transition is a mainstay to ensure the right decisions are made for buildings to serve the people living and working within them, and that the public are made aware of the challenges we face in achieving these goals.

No two buildings are the same. Models for approximating the proportions of decarbonised heat in buildings that LCT’s will represent, fluctuate heavily, and are contingent on a great many variables and potential eventualities with technological and situational developments. The CCC’s carbon budgets for buildings are highly comprehensive estimations of these proportions, and the particular pathways for decarbonising heat in buildings in different scenarios[30]. As per Element Energy’s commissioned research for the CCC’s *Sixth Carbon Budget*[31], we can observe, in Figure 7 and 8, the scales of utilisation for each individual technology vary substantially depending on the scenario. However, there is a particular focus on heat pump delivery.

To the best of our current understanding, we cannot know which scenario predicts the needs and requirements of the UK's building stock for decarbonisation, and therefore, cannot know the degree to which a single technology will represent a given proportion of heat decarbonisation.

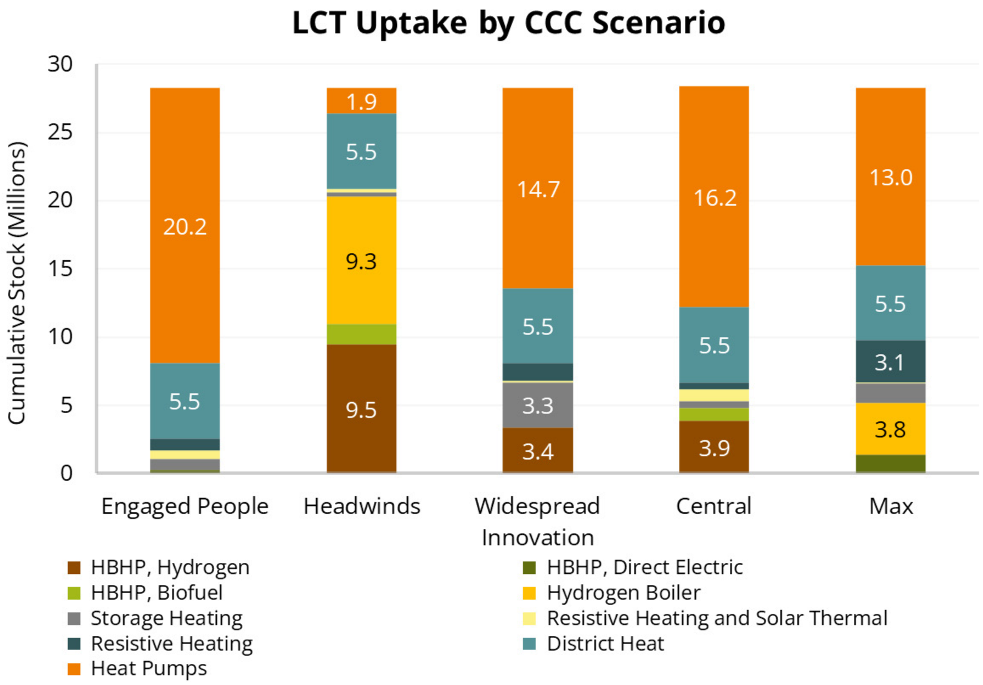


Figure 7: A breakdown of low-carbon heating technology uptakes by CCC scenario — illustrating the end-state technology blends at Net Zero. Adapted from the CCC's Sixth Carbon Budget and associated commissioned research, conducted by Element Energy[32]. HBHP (Hybrid Heat Pump).

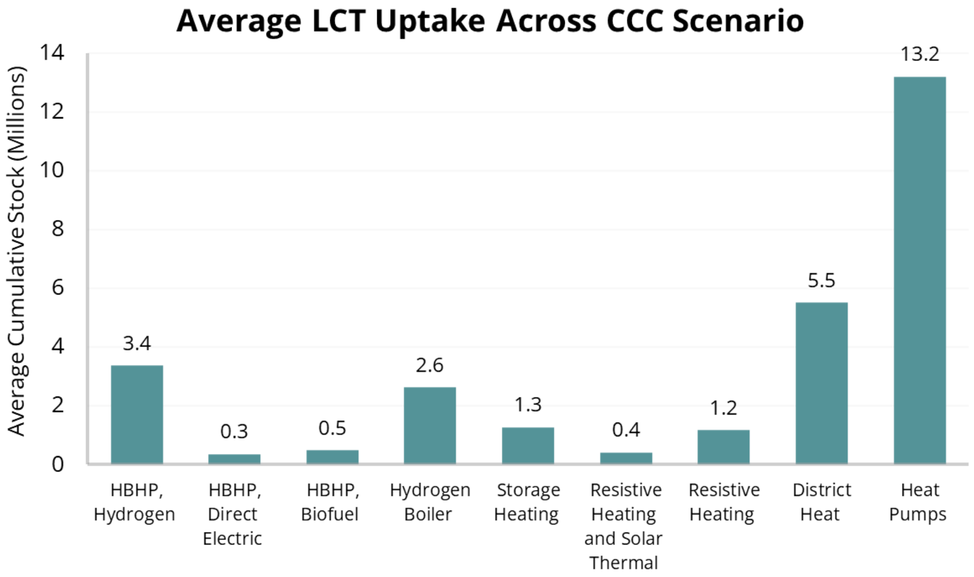


Figure 8: Average (mean) of LCT uptakes, across all CCC Decarbonisation Pathways[33]. HBHP (Hybrid Heat Pump). HBHP (Hybrid Heat Pump).

Moreover, similar models generated by equally reputable organisations will also differ significantly. The International Energy Agency's (IEAs) September 2022 report: Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030[34], predicts that 290 million new solar thermal systems will need to be installed in northern and southern climes in the 2020's alone to reach the Net-Zero 2050 target[35, 36]. The CCC's modelling for solar thermal system deployment falls very short in comparison, and therefore, policies put in place to deliver these LCTs will likely reflect this model.

Rather than bind policy to a fixed position, based on estimates for LCT uptake volumes, policy should instead, be open to a wider assortment of technologies and innovations that may be used in combination with one other, to suit a building and its context most applicably. And a technology-agnostic or appropriate approach follows this same logic, that we must preserve optionality to deliver the best technologies for the right outcomes in order to decarbonise heat in buildings. Further, it requires that not only the scope of technologies for consideration be wider, but the integration and interoperability of these measures be capitalised upon. How measures interact and best complement one another, will be key to producing the best cost, carbon, and health and wellbeing outcomes for buildings that unlock smarter energy systems of the future.

This framework should neutrally incentivise and guide the correct, most appropriate assortment of solutions to be delivered in a given property, taking into full consideration the individual needs of its occupant, the building circumstance, and its construction, to drive a choice, outcomes, or needs-based approach to policy making and the installation of LCTs. Importantly, this should operate within the context that cost and carbon should be reduced, and occupant wellbeing enhanced. These stipulations are fundamental to a more technologically appropriate policy's success. And underpinning such an approach, is the necessity for decisions taken and models made of buildings to be data-driven; utilising the power of digital frameworks to guide the pathway to achieving the specified desired outcomes.

Selecting the right assortment of LCTs for heat or electricity generation on a site, must be factored in holistically, and may require consideration of (other than cost, carbon, and health and wellbeing):

- the viability of renewable energy generation (solar PV, solar thermal, wind, etc.) — dependant on geographical location, microclimate, exposure, appropriate south facing roof space, available generation area, orientation, shading, usable surface area to building volume ratio, aesthetics, etc.;
- the availability of a water source (stream, river, lake, canal, etc.) for hydro generation (source water velocity, reliability of flows, etc.) or a heat pump (source temperature, peak temperature required, the specific heating system used, etc.);
- constraints on planning permission, environmental/historical protections, and other planning-related considerations;
- predicted/modelled energy consumption, and use profile of the building;
- building type, construction, thermal efficiency, airtightness, ventilation, etc.;
- client/consumer requirements — system preferences, expectations, and priorities; and
- maintenance requirements.

The quality and performance of measures supported, alongside the ability to set appropriate financial levels of support for eligible LCTs, will depend on how specifications are defined. There will be a need to set a strict definition of low carbon, and of the measures that may be most cost-effective in a given circumstance. For example, for the former point, the SEA has advocated for a 'carbon intensity standard' that would give a definitive meaning to low carbon; as discussed in our report, *Off Grid, Off Carbon: Regulating the Decarbonisation of Heat in Homes off the Gas Grid.*

A carbon intensity standard would set a projection for reaching net-zero carbon emissions from heating by 2050, forcing newly installed heating systems to produce at or below a level of carbon emissions per kWh of energy produced, as set by the standard (Figure 9). An interim period, from the commencement of the standard, until a decision is made on the phasing out of fossil fuels from buildings — ideally around 2030 — would allow for supply chain capacities to ramp up and deliver LCTs at the required scale, whilst being given clear market signals by the Government.

Ensuring the quality and performance of the measures delivered is also of paramount importance to ensuring the best outcomes are achieved, alongside a good public reception of the transition to decarbonised buildings. Putting in place tools to manage the cost of measures in use, monitoring and measuring installation efficiencies, should be integrated into policies driving decarbonisation in buildings. In-use performance metrics will deliver more cost-effective measure implementation, as well as monitor the suitability and running efficiencies of technologies post installation, as the designed efficiencies are measured against the system as installed. Furthermore, value-for-money delivery of solutions through government policies can be unlocked by performance-measuring tools, as technologies can be tested in-situ to guarantee their suitability given the unique situation and construction of a building.

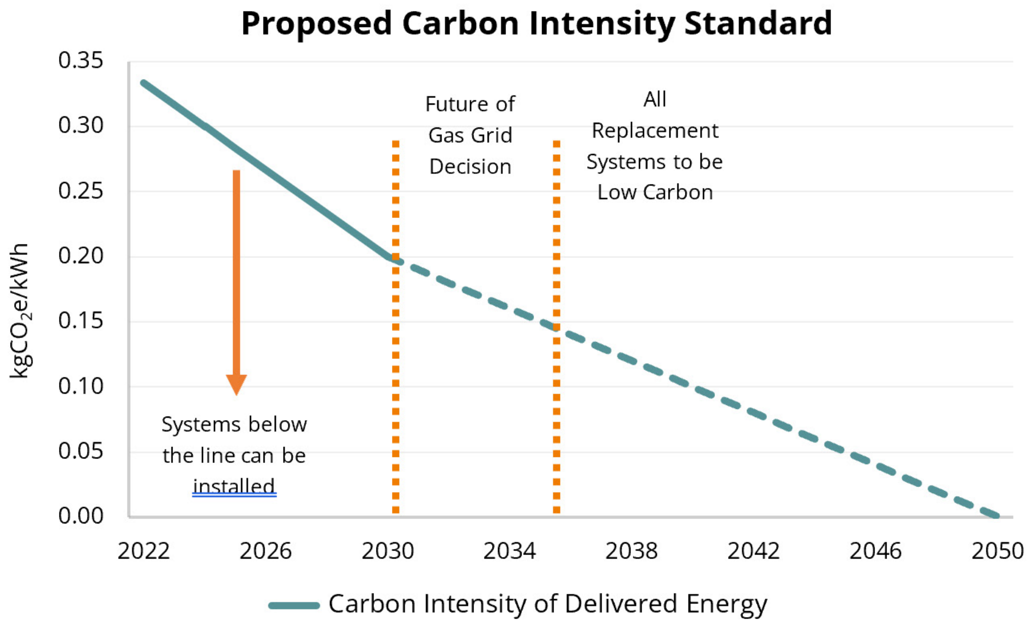


Figure 9: Proposed function of a carbon intensity standard for low-carbon heating as per a technology-agnostic policy approach to heat in buildings[37].

Unintended Consequences Through Current Government Policy

The unique mix of measures required to deliver the desired outcomes for a building and its inhabitants cannot entirely be delivered and specified using a top-down approach. A technology-appropriate methodology requires more of the decision-making impetus to be generated at a property or local level, feeding information upwards as to the most suitable measures required for a single or area-based case. Therefore, policy must also be driven by what the consumer expects when undertaking works to improve their property; this includes the cost and carbon intensity of heating and living/working in the building, and the comfort and health of the internal environment; which will be fundamentally unique at an individual property level. Correspondingly, a greater diversity of LCTs need to be supported by government policy in order to drive the uptake of the most suitable measures where needed and most efficacious.

A prescriptive policy regime, especially a single-measure, non-diverse, and therefore, risky, framework, will affect single-minded, tunnel-visioned and isolated thinking. This will lead, inevitably, towards unsatisfied outcomes, stifled innovation, and unintended consequences for buildings and their occupants, as the most appropriate measures are not considered, nor the ideal sequencing for their installation, nor their interactions with one other when installed.

The Government's current prioritisation of electrification through hydronic heat pump technologies, ASHPs chiefly, risks this same isolated, prescriptive, single-solution policy support. In their attempts to radically grow the heat pump market, the Government must show equal levels of proactivity and support across other technology types that will deliver decarbonised buildings. This approach risks both marginalising other markets and solutions within the electrification or low-carbon fuels industry, as well as new innovative measures entering the market that will help to achieve the Net-Zero target. Further, resulting damage could be done to the heat pump market if installations made are not suitable for the building in question.

Even with limited policy support, like the Boiler Upgrade Scheme (BUS)[38], market interventions — like the Market-based Mechanism for Low-carbon Heat[39], and targets, like the 600,000 heat pump installations by 2028[40] that solely support heat pumps as a primary technology for decarbonising heat—careful attention must be paid to how heat pumps are manufactured and installed (as well as addressing other challenges and barriers to their uptake). As the market scales, a 'quantity over quality' market, or 'race to the bottom' effect could occur, whereby, obligations and incentives for heat pump sales or installations are attempted to be met at the lowest cost possible.

Quality standards for all heat pumps manufactured and installed — like the Microgeneration Certification Scheme (MCS) (required for the BUS, but otherwise voluntary), or minimum performance standards, through UK Energy-related Products (ErP) framework[41] — should be required, and potentially legislated through the Building Regulations, to deliver the highest quality, best performing, and most efficient product for consumers, where deemed the most applicable technology. Not adequately protecting the quality and performance of installed products is one of the greatest risks this technology faces, as poor consumer experiences and marred public perception, will irreparably hamstring the heat pump market, and severely hamper the UK's ability to decarbonise heat in buildings; noting the considerable importance all heat pump technologies will serve in decarbonising heat and buildings.

In the first year of the BUS, from May 2022, the current run-rate and delivery is expected to cost less than the £150 million allocated to it for the financial year 2022/23. Combined with the 96% ASHP delivery from the scheme so far (May to September 2022), any potential underspend should be diverted to increasing the range of technologies supported, such as solar PV or thermal systems, smart thermal storage, and other highly beneficial complementary and ancillary measures.

Moreover, a symptom of the current hydronic–heat–pump–focused policy trajectory is manifesting in the exclusion and market shrinkage of other LCTs beyond reasonable levels. The policy, legislative, and target-setting focus on heat pumps, whilst a good strategy for growing the heat pump market to meet future demand, is significantly marginalising other products—including those which have received funding and policy support within the last decade. Many of these technologies are not well supported (IR heating, Mechanical Ventilation with Heat Recovery (MVHR), some heat pump technologies (AAHPs, EAHPs), hybrid heating systems, gaseous and liquid biofuels, etc.), or are now being phased out of policies and targets (solar thermal, biomass, etc.).

Another example is the government not taking a technology-agnostic approach to the treatment of Energy Saving Materials (ESMs) for zero-rated VAT. While it is welcome that the VAT charged on heat pumps and solar PV is now 0% until 2027, the tax regime is now inconsistent across LCTs. For instance, thermal storage installed with (or ancillary to) a heat pump is zero-rated, while thermal storage installed on its own incurs VAT at 20%. This inconsistent VAT treatment also applies to solar panels (which incur 0%) and batteries (which are zero-rated if installed with solar but incur 20% VAT if installed on their own).

This demonstrates how ancillary and complementary technologies for decarbonising heat and buildings, like solar PV, battery and thermal storage solutions, etc., are also seeing limited Government support. **These restrictions are harming the markets for other LCTs by reducing the number of installation opportunities where they could provide benefit; eroding confidence among the installer-base, exacerbating the skills shortage for particular technologies; creating challenging environments for innovative technologies to gain market traction; and lengthening the journey to Net Zero.**

The Domestic Renewable Heat Incentive (DRHI), a government-backed funding pot that enabled owner occupiers and private and social landlords to install low-carbon heating systems, exemplified the market's diminishing optionality as the focused shifted onto the rollout of ASHPs and GSHPs for domestic retrofit. In Figure 10, one can observe a marked decline in applications—ergo, public interest—directed towards solar thermal and biomass systems in the DRHI (comprising ~50% of the applications made in 2014). This was primarily caused by a cut in the supporting tariffs for these technologies.

In 2022, when scheme applications concluded, 4% of DRHI applications were made for solar thermal and biomass systems. Furthermore, voucher applications made through the BUS between May and December 2022, were represented by 96% ASHPs and 1% biomass (solar thermal has been made illegible under the BUS).

With significant predicted underspend for the first year of the BUS' deployment window, leftover allocated funding should be directed towards improving the BUS to increase optionality. For example, this funding could go to expanding the technology offering to include solar thermal systems, smart thermal storage, and others, extending the caps for particular supported technologies, and lengthening the final 2026 deadline to give longer-term clarity on funding.

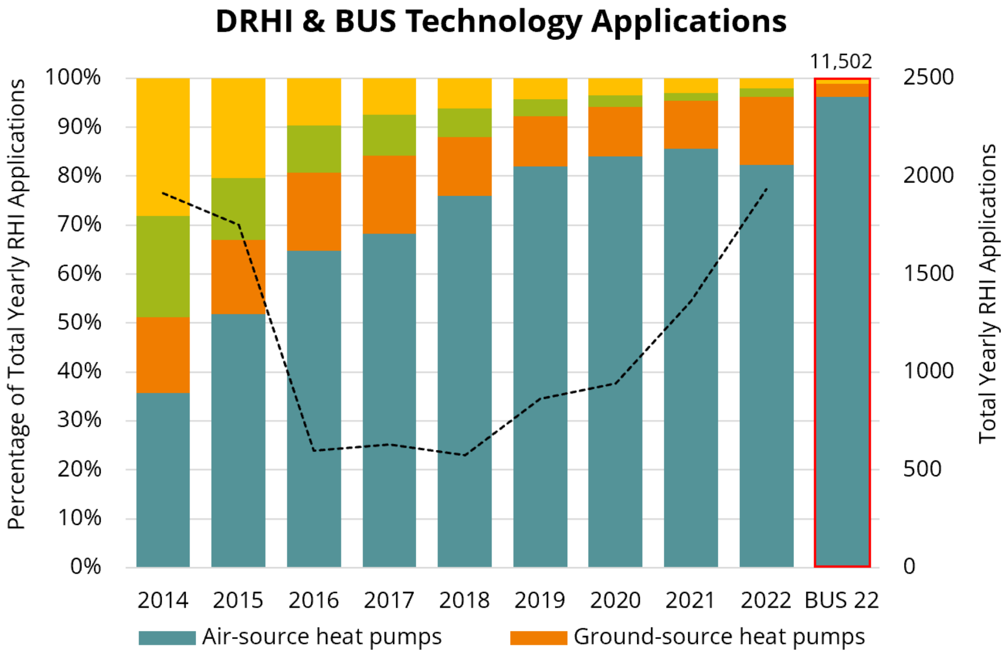


Figure 10: Number of domestic DRHI full applications by technology, per year, Great Britain, April 2014 to September 2022. The DRHI closed to new applicants at midnight, on 31st March 2021[42]. And the number of Boiler Upgrade Scheme (BUS) voucher applications by technology, England and Wales, May 2022 to December 2022 — as highlighted in red. The total number of applications for the BUS, received in the aforementioned period, is highlighted above the column[43,44]. Shared ground loop ground-source heat pumps were not included in the graph due to low numbers (8 applications in total).

Government policy also primarily focuses on the application of LCTs to domestic premises', missing an element of scale and use-case agnosticism. Much of the policy landscape tackles smaller family homes and leased properties, covering part of the policy landscape. On the other hand, heating non-domestic buildings (commercial, industrial, etc.) constitutes around 20% of carbon emissions from all building–heat–related emissions[45]. If the UK is to decarbonise these buildings and achieve the best outcomes, then policy support needs to adequately reflect the level of decarbonisation required, which is tailored to the unique requirements and circumstances of industrial and commercial buildings — the extent to which heat pumps will be able to adequately do so without considering a multi-measure approach or using other LCTs, is moot[46].

Other technologies and fuels on the market, such as solar thermal, biomass, bioliquids/gases, hybrids, plasma generation, hydrogen, etc., may be more suitable for the types of high energy demands, process temperatures and larger scales that non-domestic properties can present[47]. Typically, space heating, alongside high process-heat-related demands and the need for an industrial chemical feedstock, are serviced by fossil fuels. Process heating is typically high temperature, and low-carbon heating technologies, like hydronic heat pumps, are usually set to operate at lower temperatures. This is why a more technologically agnostic policy framework should enable the most suitable technologies to be installed that can service the high-temperature demands of specific industries and buildings. Hydrogen fuels are an appropriate solution in particular instances and driving down the costs of producing hydrogen through electrolysers, or offsetting through carbon capture and storage, will ensure that generation pathways through natural gas exclusively are phased out.

The Non-domestic Renewable Heat Incentive (NDRHI) was one of the few policies purposed for decarbonising the non-domestic sector in Great Britain. Providing funding for equipment installed post-2009, and up until 31st March 2021, the NDRHI was the last remaining non-domestic financial incentive for decarbonising heat that the Government offered—now there are no mainstream incentives. (The Industrial Energy Transformation Fund (IETF) is the closest policy to the NDRHI but is on a much smaller scale: £220m between 2021 and 2025, with the NDRHI having a combined committed spend of £1.79bn for FY21/22 and FY22/23[48,49].) A mix of measures were supported through the scheme (see Figure 11), which supported installing technologies for decarbonising heating in non-domestic buildings.

The proportions of these technologies have waxed and waned according to political, market, economic, and other factors over the scheme's lifetime, but has generated interest, uptake and revenue for a variety of technology providers. As is the case with the DRHI, a shift towards greater heat pump deployment throughout the NDRHI's duration can be observed. For the first half of the scheme's lifetime (2011 to 2017), ASHPs and GSHPs were represented in an average 5% of applications; however, in the latter half (2018 to 2022), these technologies reflected, on average, 42% of applications made. Simlarly to the DRHI, these fluctualtions in technology applications were primarily driven by more or less favourable tariffs for individual technologies.

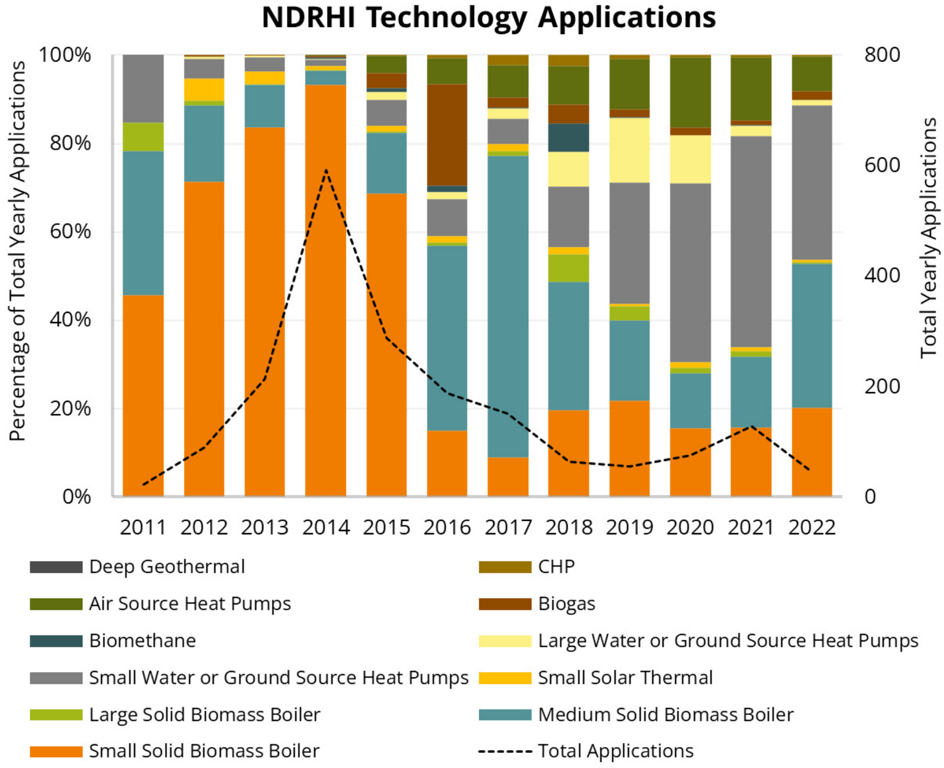


Figure 11: Number of non-domestic RHI full applications by technology, per year, Great Britain, November 2011 to September 2022. The NDRHI closed to new applicants at midnight, on 31st March 2021 — applications were still processed past this date due to application re-submissions, cancellations, rejections, or amendments[50].

For example, solar thermal technology is a widespread, validated, and effective solution for decarbonising buildings. To refer back to the IEA's Net-Zero approximations for technology uptake in buildings, models predict nearly half a billion solar thermal systems will need to be installed this decade across all global climates[51]. This scale of rollout is not reflected in the current policies governing UK building decarbonisation.

A better reflection of solar thermal installations can be observed through the Green Homes Grant (GHG) voucher scheme (Figure 12). Solar thermal was the most commonly installed renewable heating system. 14% opted for solar thermal, 8% for ASHP, and less than 1% for GSHP. This shows that when consumers are given more free choice, taking into account the differing policy design of the GHG versus the RHI, different technologies emerge, and consumer choice will likely be more diverse. Therefore, until policy is truly technology agnostic, policy design will have the tendency to warp what technologies are installed in buildings based on the incentives of the policy, rather than what is most appropriate.

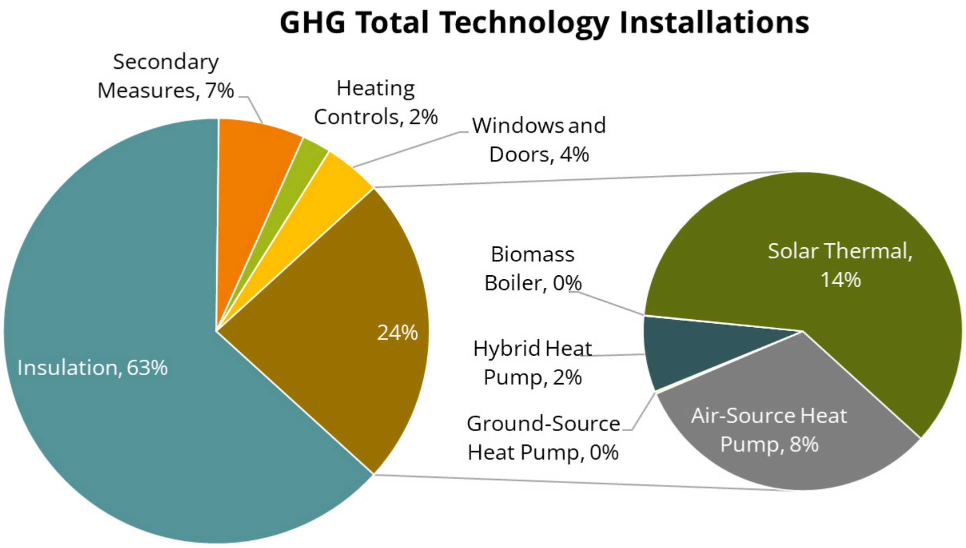


Figure 12: Green Homes Grant (GHG) voucher scheme total lifetime installations[52]. Applications for the scheme ran from 30 September, 2020, to 31 March, 2021.

The advantages of taking a more technology-agnostic approach to heat and buildings policy will enable many of the aforementioned risks to be mitigated and drive us rapidly onwards towards addressing the UK's buildings, creating healthier places for us to live and work and achieving climate and societal goals.

The Benefits of a More Agnostic Approach

Transitioning to low-carbon heating in buildings presents many opportunities for the UK. Supporting buildings to take up LCTs for decarbonising heat, and phasing out volatile and mutable fossil fuels, will boost five key areas pertaining to:

- Accelerated Route to Net-Zero Buildings.
- Flexible and Smart Building Energy Systems.
- Effective Consumer Education and Engagement.
- High Quality Skills and Clear Local and National Planning.
- Stimulating Manufacturing, Supply Chains and Innovation.

Developing these core areas through taking a more appropriate approach to how LCTs are applied to buildings, will benefit the UK in the short, medium and long term. This approach, being focused on what, where, and when specific technologies are needed to generate the required outcomes, will more rapidly deliver the desired targets, goals and results in the five key areas.

In the following sections, we will dissect the key value drivers that a more technology-agnostic approach could help to unlock and assess why this approach is an improvement on the current trajectory of government policy.

Accelerated Route to Net-Zero Buildings

A technology-agnostic policy approach prioritises achieving the desired outcomes for buildings. These outcomes have become ever-more important considering the current crises that the UK faces. A more appropriate application of LCTs in buildings can play a major role in deriving and assessing the most cost-effective route for consumers and wider society; the lifetime or whole-life carbon emissions of the chosen route to Net Zero; and the implications of this pathway and the measures chosen on the health of indoor and outdoor environment and wellbeing of those who live and work within it.

This will target and channel investments made into LCTs for decarbonising the UK building stock to Net Zero at an accelerated rate and maximise the benefits of healthy and cost-effective buildings.

This route to Net-Zero buildings necessitates the unlocking and recruitment of better data collection of building stock performances and conditions. The application of the most appropriate technologies is reliant on accurate, data-driven decision making and planning buildings' routes to Net Zero. These decisions and pathways are predicated on truly reflective whole-building assessments and models that capture the complexity inherent in all UK buildings. This complexity can also be built into a complex profile or Building Renovation Passport (BRP) for each property (or unit and block, in the case of flats and apartments).

BRP's are a live, digital database that functions as the central nexus for all individual building information (or units within a development) and is maintained across a building's lifespan. This passport of building history contains information on all works done (renovations, extensions, materials, etc.), and any relevant information (EPC's, smart meter data, ownership details and governance, Land Registry details, driving rain exposure, etc.) that the property has accrued up until that point. The passport can also update as changes are made to the building or dynamic data inputs require (in-use performance, environmental or weather conditions, etc.). BRP's can plot out a comprehensive, whole-house plan for decarbonising a building, calculating the order and costs associated with implementing energy efficiency and all LCT's an individual property would need to get to realise the desired outcomes (Net Zero, decreased running costs, increased comfort, consumer requirements, etc.).

For example, many models are based on the comprehensive and progressive Green Finance Institute's *Building Renovation Passports: Creating the pathway to zero carbon homes*[53] framework, but many other forms exist. The Welsh Government are engaged in several initiatives, one that sits within their Optimised Retrofit Programme (ORP)[54]. Social landlords are required to undertake whole stock assessments, modelling their property's affordable warmth rating and carbon emissions, and target energy pathways, setting out all retrofit measures required to be installed to achieve the target levels of affordable warmth and decarbonisation. In addition to this, landlords can choose how they conduct whole-home assessments and what platform for BRPs are used, and what monitoring is used to gauge in-use performance (environmental sensors).

The benefits of taking a technology-agnostic approach can be brought about through this more data-driven approach. There are existing frameworks and examples used across the UK for assessing buildings in a more comprehensive way that draws out the best solutions based on the required outcomes. From a fabric-first viewpoint, PAS 2035/2030:2019[55] and 2038:2021[56], developed by the British Standards Institute (BSI) and others, are industry best practice frameworks for minimising unintended consequences through retrofitting domestic and non-domestic buildings respectively, with energy efficiency and LCTs. For more complex retrofits, Medium-term Improvement Plans (MTIP's) are used to plan out works and measures across time, considering the cost and carbon reduction and increase in comfort at each phase of installation. There also exists PAS 2080:2016[57], which standardises the requirements for carbon management in construction and infrastructure more widely.

Many other advanced frameworks and standards can also be employed that generate digital models and simulations of buildings for better interrogation of the required measures. These models can also be modified to best target specific outcomes that need to be achieved in the construction or upgrading of buildings; tailoring what LCTs need to be used that best follow the desired pathway. For example, standards such as the Chartered Institution of Building Services Engineers' (CIBSE's) Technical Memoranda (TM)[58] are guiding documents covering all manner of building design and operational elements. TM's range from considerations for health and wellbeing in building services; building logbook creation; carbon management; and all aspects of building design and operational performances. TMs, like TM54[59] (Evaluating operational energy use at the design stage), link into other advanced data-driven decision-making frameworks, such as Dynamic Simulation Modelling (DSM).

This type of modelling, alongside Simplified Building Energy Modelling (SBEM), Building Information Modelling (BIM), digital shadows, and many more, produce highly complex and accurate digital constructs of buildings that model thermodynamic, energy and environmental performances. For example, University College London's (UCL's) Energy Institute carry out work through their Building Stock Lab[60] to produce 3D models, dynamic simulations, and more, of the UK's building stock. Their existing London Building Stock Model[61] is a London-wide interactive model that helps and advises councils and administrations with identifying fuel poverty, targeting regulations, helping enforcement of standards, and aiding businesses and households with cutting energy bills and carbon emissions through energy efficiency programmes. The model is planned to be expanded to all of England and Wales in late 2022.

IRT Surveys

Background

Having surveyed over 350,000 homes and 2,000 commercial buildings since its inception in 2002, IRT is uniquely placed to help clients identify simple leaks, evaluate a commercial property portfolio for refurbishment, or assess a housing portfolio for energy performance for a social landlord.

Methodology

IRT's DREam software and unique quantified thermal images, leads the way when it comes to optimising retrofits and putting data at the heart of decision making for decarbonising buildings.

DREam is an automated, cloud-powered Software-as-a-Service toolset that uses algorithms to create solution-agnostic, data-driven roadmaps to Net Zero. DREam highlights the most appropriate measures for installation, based on the desired outcomes and requirements, and suggests the optimal order and timing to retrofit, leveraging grant funding whilst mitigating risk.

DREam augments existing data sets of building performance such as EPC, client, and customer data, to create a cleansed, augmented, more accurate, and sanity-checked dataset. In isolation, DREam is a powerful "sat-nav" to Net Zero tool; but it becomes even more powerful and accurate when combined with IRT's in-situ thermal imaging surveys within their DREam software. Creating comprehensive digital building stock models integrated with performance metrics.

After ascertaining problems or insufficiencies in building performances, the next steps for planning optimised solutions and renovation pathways can be made. Retrofits can be quickly geographically planned, helping to visualise area-based distributions and programmes of work. This can also be linked to funding opportunities and financial support.

Benefits And Examples

DREam enables rapid uploading and assimilation of complex, and even incomplete and inaccurate data sets, onto its cloud-based platform. And by using thermal imaging surveys, time and money can be saved in planning retrofits that result in veritable, unbiased, and accurate energy-efficiency improvements that would otherwise not be possible. DREam can make suggestions for the best pathways to improving building energy performance and which buildings require the most improvement first, with clear plans and results at each stage. These pathways can be interrogated and adjusted based on where budget spending is a priority.

When bidding for government funding schemes, such as SHDF, LAD, HUG and ECO, IRT's platform and services can help clients (local council or authority, housing association, etc.) to secure this funding. For example, IRT engaged with Aberdeen City Council (ACC) on a consortium bid for SHDF funding in 2020. Over 22,000 properties were imported into DREam, comprised of cottages, flats, multi-story blocks and sheltered complexes. Five, 500 home clusters were defined, each evaluated to ensure they met the SHDF and consortium's requirements, with one cluster chosen as a primary area of focus. Thermal images were taken of all properties within the cluster, further augmenting the original data set and refining renovation pathways. Of the final 250 properties targeted, 100 tenants agreed to take part in a full fabric-first, whole-house retrofit, engaging in in-depth thermal testing (u-value sensors, air pressure testing and retrofit assessment and co-ordination (PAS 2035)).

IRT and their services were instrumental in enabling ACC to secure £5.5 million in SHDF funding for 100 homes. These homes will see energy usage more than halved to ~50kWh/m^2, as well as their energy bills, and installation of PV arrays for onsite microgeneration; all through the £55,000 per property grant that IRT enabled.

Every building presents much complexity and many unique requirements when planning for new construction or upgrading existing stock. The tools for modelling this complexity and producing outputs that enable buildings to reach their desired outcomes, run in parallel with and facilitate more technology-agnostic policies. Consequently, the UK's journey to Net Zero, capitalising on the many other benefits associated with constructing and upgrading buildings in the right way, will be tailored to individual circumstances and planned for in a highly accurate fashion.

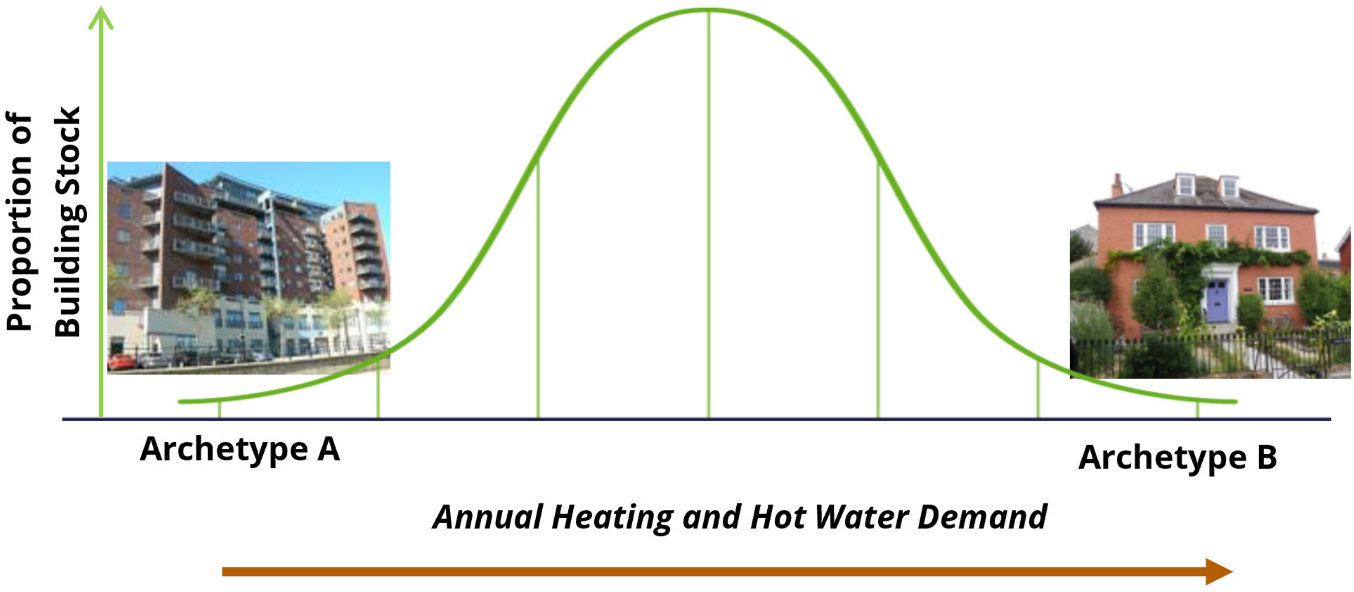
Archetype Analysis

One of the key arguments for a technology-agnostic approach is the added applicability and compatibility with the wide spectrum of the UK housing stock.

Generally speaking, houses more suitable for low-flow temperature heating systems, work better with heat pump installations. However, some of the largest, and most difficult to insulate properties can present challenges for efficient heat pump installation, often requiring significant, disruptive or costly renovation measures.

At the other end of the spectrum, some of the smallest properties may have heat demands low enough to be reliably serviced by direct electric (storage/resistive heaters, infrared panels, or underfloor heating, for example). In addition to this, some of the smallest properties may find the added space requirements of heat pump technologies, such as water cylinders, and the unit itself, to be impractical.

To illustrate these challenges, we have analysed two hypothetical archetypes, existing at the extreme ends of the housing stock (when arranged by annual heat demand). It is important to reiterate, we expect the majority of homes to be well-serviced by various heat pump technologies — those on the fringes must not be left behind by a narrow policy approach to heat decarbonisation. Our archetypes, A and B, are explained in their respective sections.

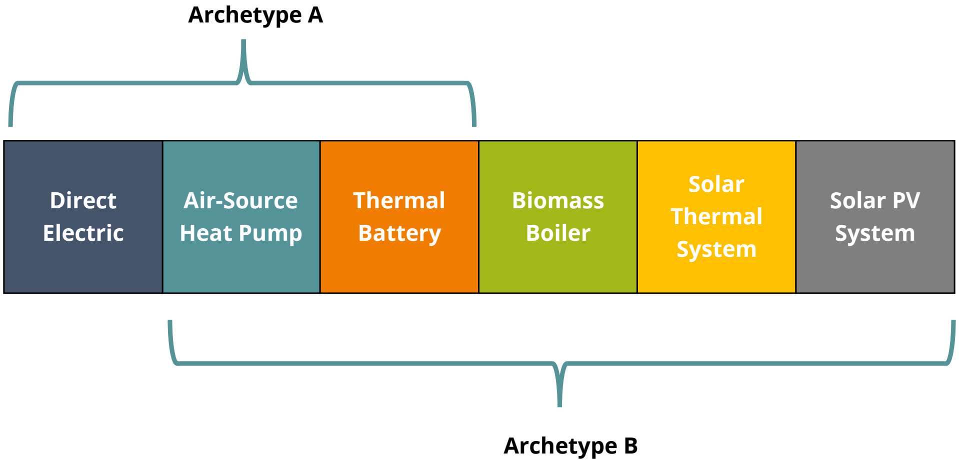


In the following analysis, we consider different forms of metric for evaluation:

- **Annualised NPV:** A standard net-present value calculation, divided by the lifetime of the system.
- **Consumer Annualised NPV:** The same method featured in the standard NPV calculation, but using a higher discount rate, more reflective of consumers' shorter-term preference for money shown.
- **Bill Savings:** A simpler measurement, which indicates the difference in annual bills consumers can expect from each measurement – versus the default configuration of a natural gas boiler.
- **Marginal Abatement Cost:** A metric for evaluating the cost of decarbonising a tonne of CO2-equivalent material. Those with no values represent measurements which return a profit and therefore, have no abatement cost.

It is incredibly important to highlight that the two archetypes below are not exact calculations of an entire section of the housing stock, but rather, illustrations to highlight how the picture around the decarbonisation of heat changes, as you move across the spectrum of heating demand and requirements.

We evaluate the performance of the following measures:



The limited range of analysis for Archetype A is explained by the physical limitations of the housing type. Both solar thermal and PV systems would ultimately require an area of roof space. For biomass boilers, the assumption can be made that the vast majority of multi-family homes (such as flats), are based in (intrinsically) high population density areas, where restrictions on the technology exist.

The limited range of analysis for Archetype A is explained by the physical limitations of the housing type. Both solar thermal and PV systems would ultimately require an area of roof space. For biomass boilers, the assumption can be made that the vast majority of multi-family homes (such as flats), are based in (intrinsically) high population density areas, where restrictions on the technology exist.

All results and assumptions can be found in full in the methodology, Appendix 4.

Archetype A

The first archetype we analysed considers a property with one of the lowest annual fuel demands. These properties generally tend to form part of larger multi-family home buildings (flats and apartments). Furthermore, as the Office for National Statistics (ONS) highlights, those buildings built most recently have some of the lowest energy demands[62]. Flats tend to make up around 20% of the UK housing stock, with nearly 25% of the housing stock built post-1980[63].

House Size (m^2)	**69**
Year of Construction	**2004 - 2009**
Annual Heat and Hot Water Demand (kWh)	**3,010**
Heat Pump Size (kW)	**3**
Resultant Efficiency (sCOP)	**3.06**

For further information, please see the methodology section following the main body of the report.

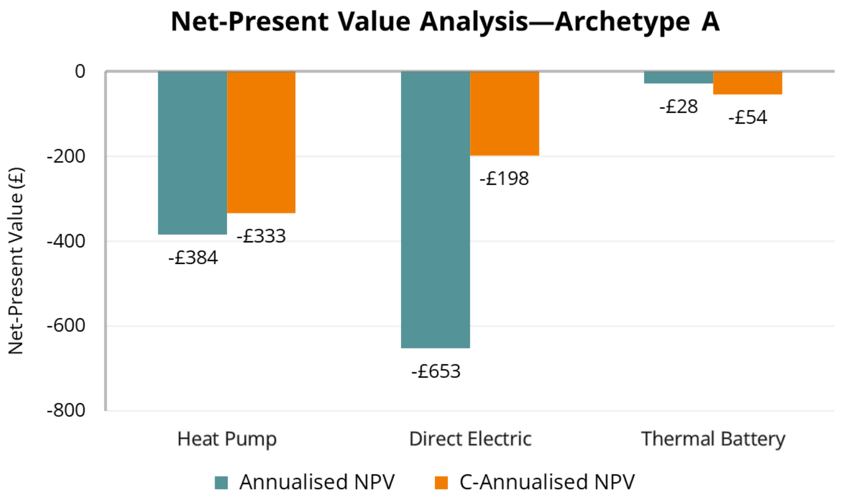


Figure 13: Net-present value analysis for Archetype A.

As seen in Figure 13, the heat pump outperforms direct electric in a standard net-present value analysis. When introducing a consumer-focused discount rate, direct electric comes out on top (C-Annualised NPV). This is to be expected, given the much larger up-front cost, a prominent barrier for consumer purchasing decisions (values found in the relevant appendices). The thermal battery proves the best option (purely in NPV terms).

For annual fuel bill savings, the heat pump results in only a slight increase in bills, whilst direct electric proves a costlier method of decarbonised heating.

Finally, the marginal abatement cost demonstrates a similar story (Figure 14) — the thermal battery proves a relatively cheap and affordable way to save on annual bills and reduce the carbon output of a home. Heat pumps prove a cheaper method of decarbonisation, with direct electric rounding off the three other measures.

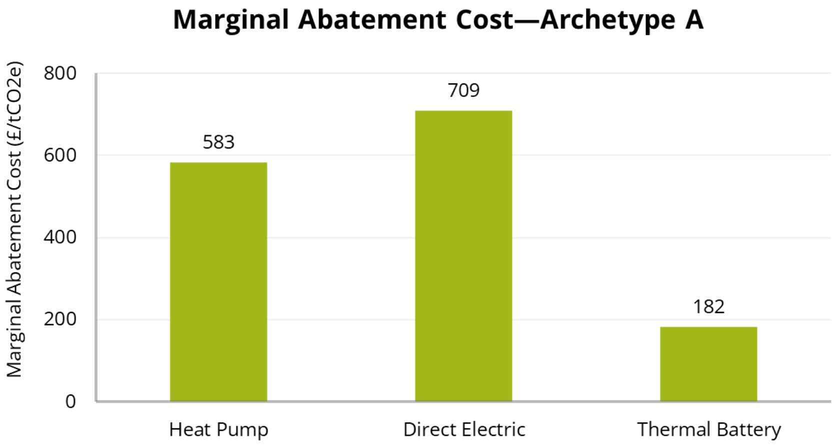


Figure 14: Marginal abatement cost results for measures installed in Archetype A.

Archetype B

Our second archetype looks at an example of properties with the largest heating and hot water demand. These properties generally tend to be the oldest in the housing stock, often existing off the gas grid. Just under 20% of homes in the UK were built before 1919, with at least 80% of these having solid walls (a total of 16% of the UK housing stock)[64]. As pointed out by the ONS, age has the greatest influence on a property's energy efficiency[65].

House Size (m^2)	**198**
Year of Construction	**< 1918**
Annual Heat and Hot Water Demand (kWh)	**28,156**
Heat Pump Size (kW)	**16**
Resultant Efficiency (sCOP)	**2.80**

For further information, please see the methodology section following the main body of the report.

Moving on to the results, we can see firstly that there is a much wider range of applicable measures for consideration — this analysis is by no means exhaustive. Firstly, it is worth discussing the heat pump result. Whilst heat pumps can run at sCOPs of up to 4.00[66] without deep, expensive retrofit, our modelled heat pump reaches an annual average efficiency of around 2.80. This is primarily dictated by the poor level of thermal insulation in the household — this, in turn, gives the values seen in Figure 15:

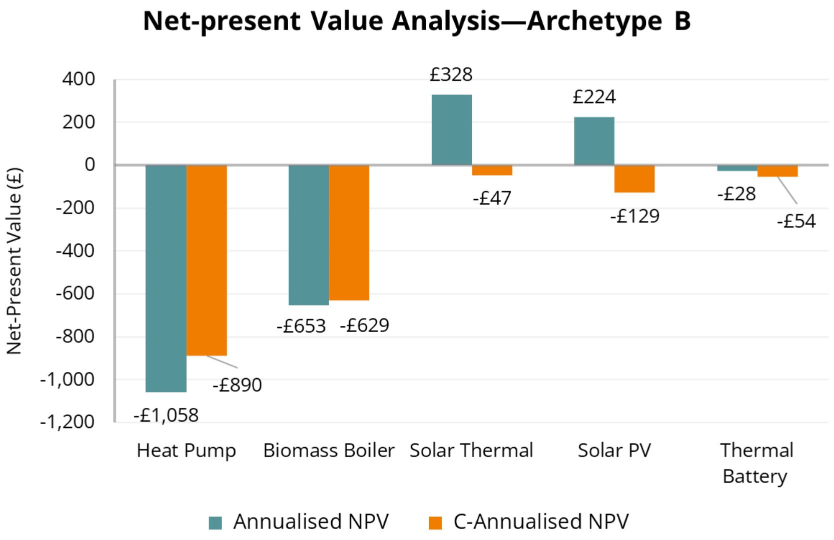


Figure 15: Net-present value analysis for Archetype B.

By contrast, the biomass boiler—which suffers far less in absolute and proportional terms when working at the higher-flow temperatures seen in our archetype—presents a far more cost-effective investment for heating system decarbonisation. The solar offerings present even more reasonable investments and are the only measures to offer positive overall NPV results.

The solar PV system delivers huge annual savings (£1,060) at the specified size—although, it is worth noting that these results are predicated on a flat feed-in-tariff (or Smart Export Guarantee) rate of 15 pence/kWh[67]. This has the potential to go down (or up) over the lifetime of the system, and this uncertainty cannot be expressed in the scope of these measurements but will factor into consumer investment decisions. Solar thermal performs well, saving £737 a year. Advancements in the field of hybrid PVT collectors offer an interesting combination that could be financially attractive to homeowners (see technology examples in final section)[68].

Importantly, when considering marginal abatement costs (Figure 16), the solar thermal, and PV systems both exhibit negative marginal abatement costs, at which point the measurement becomes nonsensical[69]. In short, the returns are good enough that there is no cost (but rather a profit) to abating carbon.

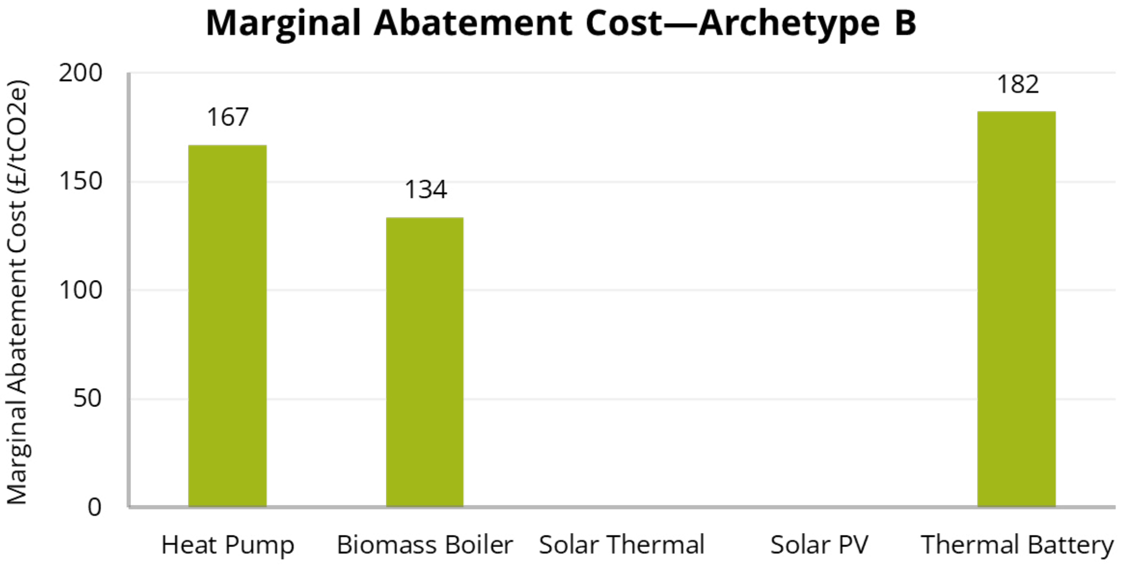


Figure 16: Marginal abatement cost results for measures installed in Archetype.

Inappropriate Installation Pathways

Not modelling building pathways and the most applicable measures for those pathways, alongside a top-down, single-measure approach to decarbonising buildings, is likely to substantially increase the risks of inappropriately installed measures. Anecdotal evidence given through our membership, points to some existing government policies creating inappropriate measure installations. For example, the BUS's stringent eligibility criteria for biomass boilers. In the cases of some living in fringe properties (misclassification of off-gas grid, rural properties, as on-gas grid, urban, according to the mapping software used in the BUS[70]), and for self-build properties, has resulted in ineligibility for a biomass boiler (which may have been more suitable). The only measure subsequently supported, was a heat pump, and for some of these properties, this would not have been an appropriate or practical technology to install. The poor measure optionality resulted in some consumers remaining on or installing a gas-fired or oil boiler system—the opposite intention of a scheme like the BUS. These risks can be mitigated by employing a more technology-agnostic approach, as evidenced through the two separate pathways below.

Pathway A:

2022: Inappropriately installed heat pump

2027: Household reverts to a natural gas system

2042: Biomass boiler system installed + replaced **in 2062**

Pathway B:

2022: Correctly installed biomass system

2042: Biomass boiler replaced

2062: Biomass boiler replaced

When we examine the pure financial costs of each pathway, we can see that the costs of an inappropriately installed system (in 2022), are relatively minimal, particularly over the span of around 50 years (Figure 17). However, when we look at a shorter view, up to 2030, the cost of an inappropriately installed system can burden households with an additional £4,220 worth of cost over the next 7-8 years (Figure 18).

The picture becomes even more stark when evaluating the additional carbon emitted as a result of the installation of an unsuitable technology in Pathway A (Figure 19). The 15 years' worth of natural gas emissions prove immense, particularly when compared against the performance of LCTs. Between now and 2070, the incorrectly installed system can result in an additional £8,000 worth of carbon emitted for our archetype household.

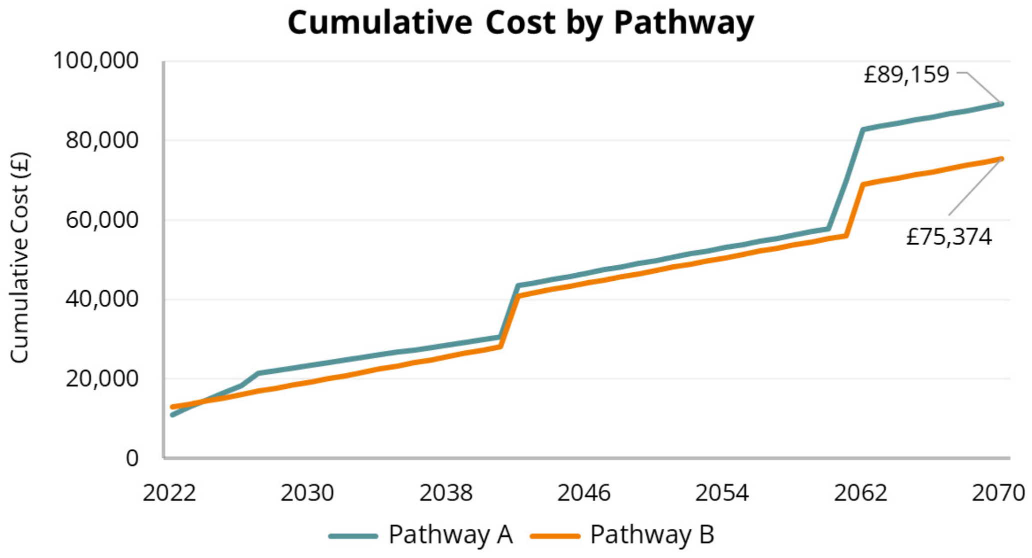


Figure 17: Cumulative cost of each proposed pathway, financial costs.

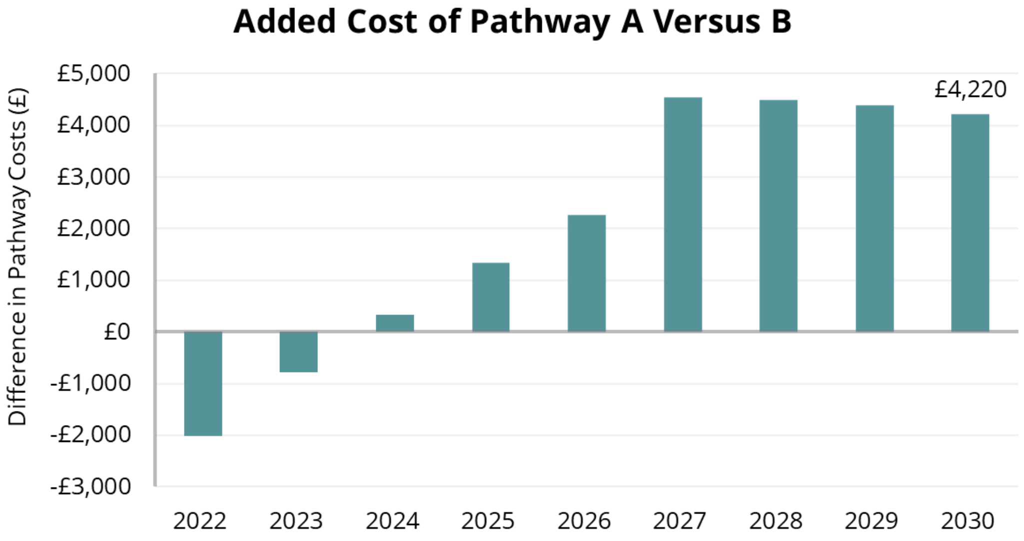


Figure 18: Delta of costs between Pathways A and B, up to 2030.

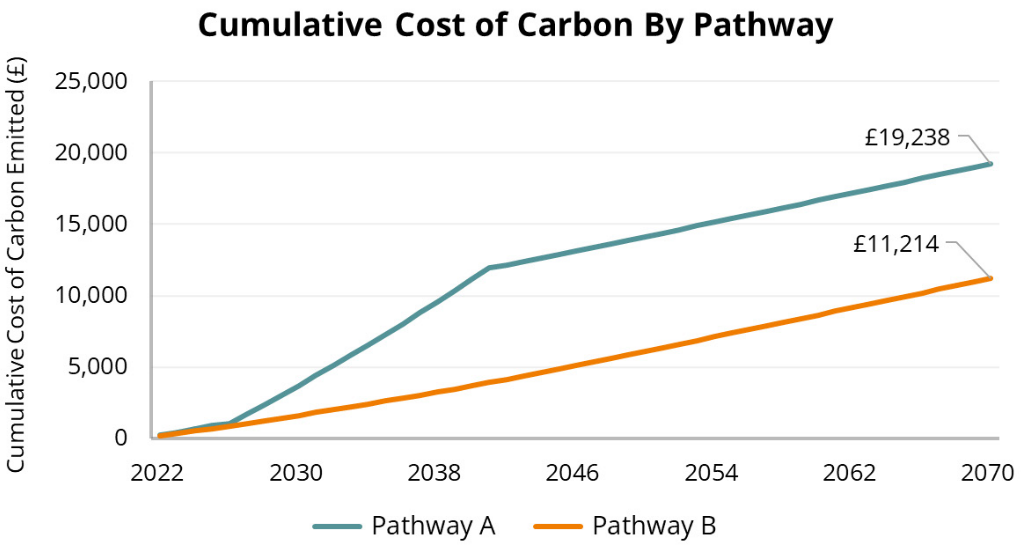


Figure 19: Cumulative cost of carbon between each pathway.

Combining the views seen in Figures 17 and 19, allows for us to see the total cost of the incorrectly installed system, with the financial and carbon costs included:

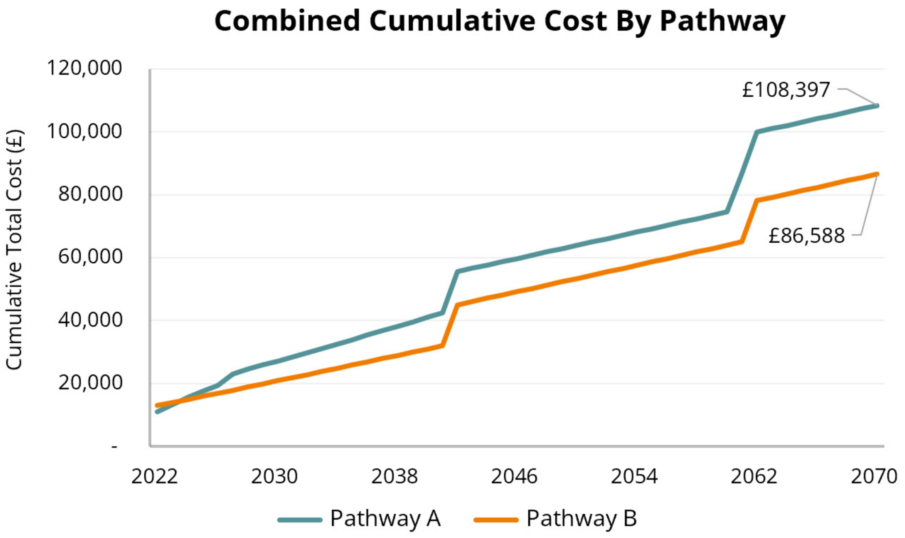


Figure 20: Combined (financial and carbon) cumulative cost by pathway.

To extrapolate these results to a macro-perspective, consider that, over the next five years, around 760,000 rural households will require a retrofit of their system. By using hypothetical incidence rates (how many of those households may experience the journey illustrated in Pathway A, rather than B) we can look at the sorts of costs experienced (Figure 21):

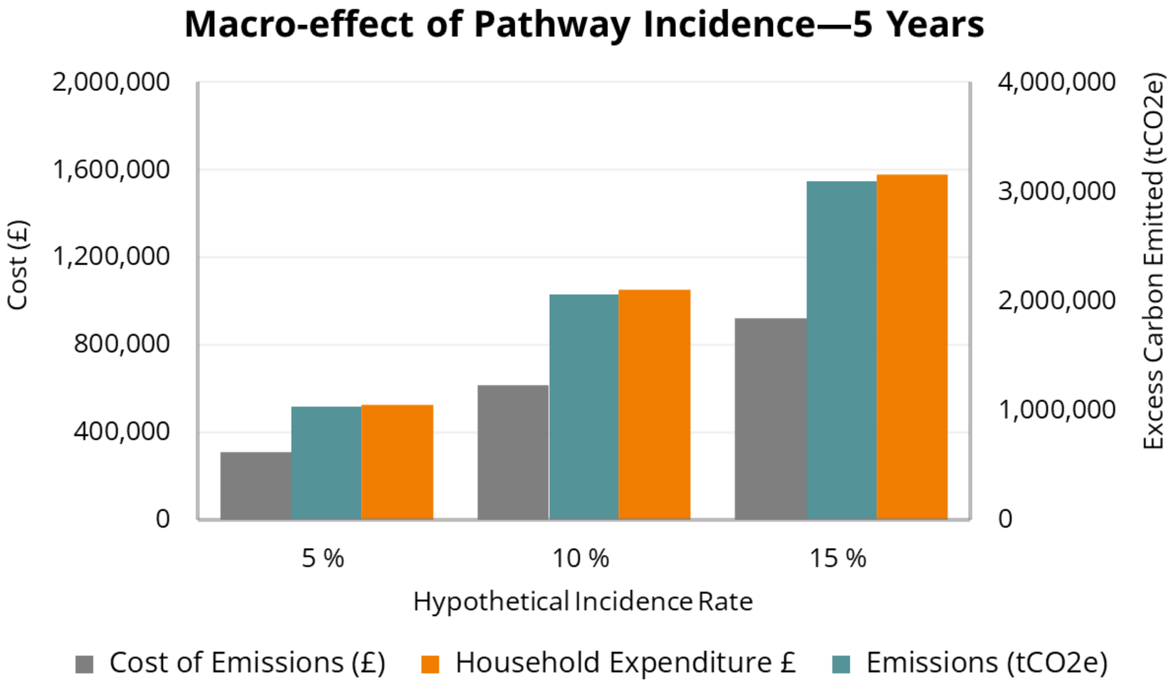


Figure 21: Extrapolated results from single household analysis. Based on the estimated number of rural households expected to replace their heating systems over the next five years and hypothetical incidence rates and 5%, 10%, and 15% respectively.

A conservative estimate for the incidence of Pathway A, rather than B, results in a million tonnes of cumulative excess carbon emissions, at a cost of £300,000. For the households involved, this would result in a total cost of £1 million.

It is important to caveat the above analysis. These incidence rates are hypothetical probabilities of a hypothetical installation pathway. In reality, these could be wildly different; both for better and for worse. Additionally, it is entirely feasible that similar poor-installation pathways exist for those in urban environments, with similar costs (at both the carbon and financial level).

The purpose of the results is simply to illustrate the scale of impact that technology agnosticism can help to alleviate by applying the most appropriate solutions to the building.

Comparative Policy Examples

As explored throughout this report, the Governments offering of policies for decarbonising heat and buildings can often be complex, short term, disjointed and technologically restrictive and compartmentalised. Policy failures, such as the Green Deal and the GHG voucher scheme, should be seen as opportunities for learning and betterment of current policy offerings. The general landscape of policies in this space varies dramatically by geographical region, devolved or local area, socio-economic status, building type/use, technology supported, status as an innovative, pilot or main-stream funding, funding mechanism (grant, voucher, loan, levy, etc.).

The ideal of a more technologically appropriate policy landscape should simplify the offering, and give clarity and certainty to manufacturers, the industry, and consumers as to the breadth of solutions and measures supported by the Government. This would de-risk private investment into this space and enable co-investment, as clear, long-term market signals will bind and strengthen supply chains and delivery mechanisms for decarbonising the UK's buildings.

The SEA has been supporting the Construction Leadership Council (CLC) in developing a *National Retrofit Strategy*[71] (NRS). If the Government used the approach set out in the NRS, then top-down policy support would be amalgamated into a more succinct and streamlined offering for consumers and businesses, activating enablers for decarbonising buildings that are currently hard to leverage with the current approach (Figure 22). It would also place a strong emphasis on delivering measures at a local level, bringing together actors at a local level, and linking in local supply chains and skills with the consumers and businesses looking to decarbonise their buildings.

1 Leadership and Communications

An umbrella to tie diverse local programmes into a coherent whole: A Retrofit Delivery Authority akin to the stature of the Olympics Delivery Authority is needed to oversee and lead strategy delivery, ensuring that all stakeholders, in particular locally-based delivery consortia, are fully enfranchised and that standards are high.

2 Supported transition and a research and innovation culture

Provide a safe development environment for new entrants and existing organisations so that they grow to meet the new demands as well as extending in capability.

3 Performance Standards

Ensuring homes perform as promised.

4 Finance and Grants

Financial support and fiscal incentives in a variety of ways to suit the variety of ownership models.

5 Training and Accreditation

Building up an army of professionals and trades that can do the work fully and well. This involve developing the skills of the existing workforce and recruiting and training new entrants.

6 Materials and Equipment

Scaling up the supply of materials and equipment in line with demanding quality standards.

7 Creating Customer Demand

A comprehensive approach to giving every homeowner a vision of what their home needs, the belief that it is needed and a route to achieving the change.

8 Compliance and Quality regime

Creating an industry culture that ensures all jobs are done to high, enforced standards.

Figure 22: Delivery system of the National Retrofit Strategy. Source from NRS V2[72]*.*

Example From Germany

The German Government’s consumer and business offerings are significantly different and more progressive than the UK’s methods. Learnings can be taken from their policy landscape to improve the UK’s policies for decarbonising heat and buildings. Through these schemes and others, Germany’s residential sector achieved a 53% reduction in GHG emissions (per m^2) from 1990 to 2018 and a 34% in final energy consumption (per m^2) over the same period[73].

The nexus of resources, advice, and funding is centrally distributed and maintained by the German Government’s Federal Office of Economics and Export Control (BAFA)[73], which sits within the Federal Ministry for Economic Affairs and Climate Protection (BMWK)[75]. This is also supported and operated by the German KfW development bank (Credit Institute for Reconstruction). The scheme, Federal Subsidy for Efficient Buildings (BEG)[76, 77], is a central funding pot for incentivising greater energy efficiencies and the use of renewable energies in all new and existing domestic[78] and non-domestic[79] German buildings. The funding, restructured in 2022, is also aimed at removing the relatively high German dependence on gas and oil fuels, following the war in Ukraine, alongside saving consumers and businesses money in the long term (and increasing property value) through more efficient buildings, and improving living and working comfort of the indoor environment.

BEG is a fully consolidated funding programme, taking consumers and businesses through the entire journey of decarbonising their building(s). The scheme is linked with the independent and centralised consumer advice centre, Verbraucherzentrale Energieberatung (Centre for Consumer Energy Advice)[80]; which plays one of the largest roles in supporting consumers and businesses on all matters relating to energy (energy saving, thermal insulation, modern heating technologies, renewable energy/ microgeneration, etc.). This is chiefly carried out through their energy consultants/experts and 900 nation-wide physical counselling centres. Their online service also contains many resources: information pages, Q&As, FAQs, a magazine, consultation and advice service, help desk, and regular, open, free lectures on topics across the energy space.

The consumer energy advice centre offers consultations and whole-building assessments for free or a fee of around EUR 30 (they are free for low-income households). The advice is linked with BEG funding, which offers several funding options to householders or businesses to cover any consultative costs accrued for renovations or new construction[81,82]. These whole-building assessments will evaluate the construction and building form, thermal properties, fabric, heating system suitability, solar heat and solar PV check, etc., to ascertain the most applicable technologies for renovating buildings with.

There are then a slew of generous grants, levies, repayment and interest subsidies, tax credits, and low-interest loans available for carrying out various works. The individual residential building funding cap is EUR 600,000, and the individual non-domestic building cap is EUR 10 million through specific routes. Additional monies are granted for following certain best practices, using innovative measures, and for signing up to Germany’s roll out of BRPs (or Individual Renovation Roadmap)[83,84]. The inclusion of a BRP in works carried out as part of BEG funding will be entitled to an additional 5% on top of the funding offered.

Renovations or new construction is typically carried out using the KfW-Effizienzhaus standard for new[85] or existing buildings[86]. The standard targets progressive levels of efficiency, and funding amounts are linked to each level of the standard. For example, Effizienzhaus Level 85, 70, 55, and 40, with 40 being the most thermally efficient (primary energy demand of 40% and transmission heat loss of 55%). The generous funding, alongside the ambitious levels for retrofitting and decarbonising, allows for many different measures and solution types[87,88,99].

Example From The Netherlands

The UK's Public Sector Decarbonisation Scheme (PSDS), currently in Phase 3[90], is a £1.4 billion funding scheme, providing grants to public sector organisations to decarbonise heat and install energy efficiency measures. This includes central government departments, educational institutions, local authorities and NHS trusts. The range of low-carbon heating measures eligible under the scheme is wide, and is combined with the requirements for considering a whole-building approach as part of the application[91].

Although there is no maximum grant funding cap for individual bids, the PSDS applications must meet a cost of carbon cap of £325 per tonne CO_2 over the project's lifetime. This is based on full project CAPEX (capital expenditure). This mechanism for funding applications enables flexibility in design, as multiple measures can be tailored to suit the building's decarbonisation needs.

However, the use of CAPEX exclusively in the grant funding calculation creates a bias towards the technologies that reduce the upfront capital costs of projects. For example, when comparing solar thermal technologies, commonly used across Europe, with heat pumps, the former requires a higher CAPEX (per tonne CO_2). But looking at lifetime OPEX (operational expenditure), solar thermal systems save money on bills once installed. Heat pumps have a positive OPEX as bills are typically higher after substituting a gas boiler, particularly in comparison to solar thermal. Therefore, if only considering CAPEX, there is a skew towards installing one technology when, in reality, technologies that may be best for a building are not selected. The policy should consider both lifetime carbon emissions as well as lifetime costs, so as to save public bodies money on their operational costs over the project's entire lifetime.

On the other hand, the Dutch SDE++ (Stimulation of Sustainable Energy Production and Climate Transition) scheme[92] takes a much more appropriate approach to CAPEX/OPEX funding calculations than the PSDS does. It is similarly aimed at rolling out technologies at a large-scale for renewable energy production or decarbonising infrastructure[93] for companies and organisations that operate in industry, the built environment, electricity generation, transport, etc. — the Dutch Government is disallowed.

SDE++ is a EUR 13 billion, 15-year operational subsidy that has run since 2010 and is planned to end in 2026 — if the Netherlands is not on track for Net Zero then it will be extended into the 2030's. The subsidy funds the difference between the cost of the installations (reducing CO_2 or generating renewable energy over its lifetime) and the revenue generated — `CAPEX and OPEX. Further, there are 87 types of technologies supported: most renewable or low-carbon technologies.

SDE++ uses a reverse bidding programme that works by setting a conventional fossil-fuel heating system (cost per kWh over its lifetime) as a baseline. Businesses then apply for funding with an associated lifetime kWh cost of carbon abated for their project. The investment entity will grant funding to projects with the lowest lifetime kWh costs of carbon abated first (EUR 60, EUR 80, EUR 120, EUR 200 per tonne CO_2); considering both the OPEX and CAPEX to weigh up the importance of these most appropriately to the financial situation. The result of this is the most carbon- and cost-effective projects are given funding first until the budget is spent, and the most applicable technologies are installed based on their lifetime costs and carbon emissions.

Finally, the SDE++ employs a base price for phasing out certain measures if electricity prices rise above this price. For example, with PV installations, if electricity prices rise above the base price (e.g., 19 cents/kWh), then the subsidy is not awarded for that period; stopping people or businesses from financially benefitting from high energy prices. The money is instead put back into the Government's general budget which can be used for supporting those in fuel poverty.

Flexible and Smart Building Energy Systems

To unlock a Net Zero future for buildings and the electricity grid, the UK must fully integrate smart and flexible systems. **A technology-agnostic approach puts more emphasis on the installation of smart and flexible technologies that unlock grids and homes of the future and reduce costs associated with operating buildings and transitioning to Net Zero.** Smart, is defined as a device capable of responding in real time to communication signals, using digital technologies, to deliver a service. Flexible, is defined as the ability for the consumption or generation of energy to be shifted in time or location.

This ambition is captured within the Government's 2021 Smart Systems and Flexibility Plan[94]. Achieving this will integrate low-carbon/net-zero power, heat, and transport technologies with buildings to create a future energy system capable of supporting the Net Zero transition. Supply and demand can be balanced, and network constraints and capabilities can be managed and enhanced to ensure expenditure on grid reinforcements, upgrades and infrastructure are reduced.

Inherent in this ambition, is the requirement for policy to be more open to the technologies being installed. Specifically, pushing for the installation of solutions and the many complementary and ancillary measures that will enable smart and flexible use of energy in buildings. Wide-scale electrification will be a huge challenge for the electricity grid. This pathway will require significant grid reinforcement investment — up to £50 billion on distribution networks by 2035, according to a Vivid Econometrics report commissioned by the CCC[95]. However, utilising hybrid pathways and a greater diversity of technologies than hydronic heat pumps alone can reduce distribution and reinforcement costs significantly and impact the cost of electricity less.

And, as explored in Thermal Storage UK's report, Flexibility for low carbon electric heating[96], if policy becomes more agnostic and encourages and values smart and flexible products then:

- Investment required for supply-side flexibility capacity will be reduced.
- Smart and flexible technologies rollout could result in £55.4 million to £106.2 million in savings from unrequired supply-side generation capacity.
- The need for electricity distribution reinforcements is minimised.
- Smart and flexible resources (energy storage, demand-side response, etc.) can reduce reinforcement investments by 10% (£10 billion by 2035)[97], or £10 billion to £16 billion per year in other models[98].
- Electricity network constraints and renewables curtailment will be decreased.
- Renewables curtailment reached an all-time high in 2020/21; costing consumers £806 million and electricity systems operators £141 million in 2021 alone[99].
- Modelling of future energy scenarios by the National Grid ESO reveals that with high levels of wind capacity in the mid-2030's, the levels of curtailment could surpass 80 TWh (22% of annual UK electricity demand in the same year), costing upwards of £2 billion per year[100].

There are many solutions that will enable flexible and smart use of energy in buildings. A focus on unlocking their installation through policy is a primary focus and benefit of more technologically agnostic thinking, helping to deliver on the Governments 2021 Smart Systems and Flexibility plan.

Energy Storage

Energy storage technologies are one key element for smart and flexible use of energy by shifting energy demands from peak times, when the cost is typically highest, to off-peak times. Electro-chemical batteries, such as those using lithium, are the most common technology for storing electricity and shifting demands. Typically, they store electricity as chemical energy. They can be charged up using grid energy and on-site renewables (solar panels, wind, etc.), and discharged as and when required. The market for batteries is widening, with products like libbi, by myEnergi[101], Powervault[102], or Tesla's Powerwall[103], and the advent of cheaper second-hand EV car batteries entering the market, driving down the cost of this technology.

Further, with the market for Electric Vehicles (EV's) growing rapidly in the UK, many consumers and businesses will already have access to large, rechargeable and dischargeable batteries. These will, in future, be able to interface with buildings and act as a source of flexible energy storage, and companies and the Government are still gathering evidence on consumer's willingness to use their vehicles in this way[104]. Finally, UK Research and Innovation (UKRI) funding for battery storage technologies will further create positive ripples through the battery industry for support and innovation and drive down costs[105].

Electrical energy storage systems have been increasingly installed at the same time as solar PV and in response to high energy prices. This activity is unregulated, and inclusion in the Building Regulations is not yet explicit. Standards are still emerging for the determination of demand and sizing (in many cases installations have not been economically viable), competence, performance and safety. The BEIS-funded BSI standard, PAS 63100 (domestic energy storage systems), is still under development, and the MCS scheme for installation, MIS 3012 (battery storage systems), is relatively new, while no product approval schemes are yet in place. Quality of product and their installation is vital if these products are to succeed and benefit the consumer.

There are also thermal batteries and stores that act to convert electricity into thermal energy, rather than as typical batteries do as chemical energy. Thermal stores have the major advantage of providing heat flexibility to the grid while producing comfort for the building, alongside benefits for the electricity grid and renewable energy generation (Figure 23). Historically, Hot Water Cylinders (HWC) have stored thermal energy, using hot water as a storage medium.

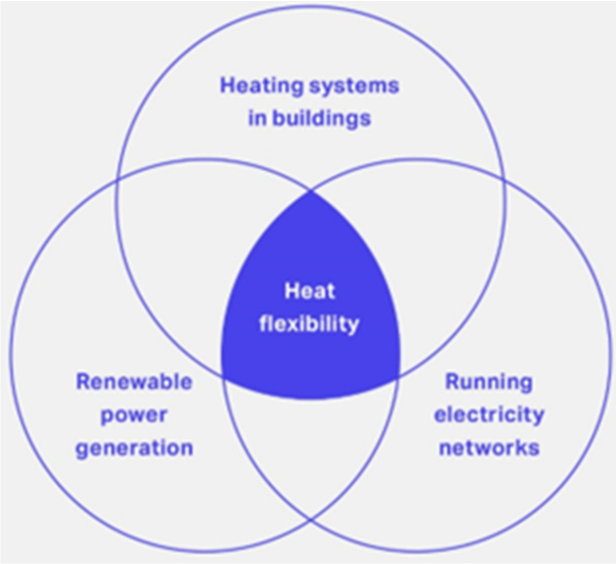


Figure 23: The role of heat flexibility in managing building heating systems, running efficient electricity networks and maximising renewable power generation[106].

For example, HWCs, as part of a central heating system, can store energy flexibly. HWC's can be charged up during off-peak hours to meet next-day demand, be it through an immersion heater, heat pump, solar PV or thermal, biomass boiler, or otherwise, and used across the day without drawing constant power from the grid. There are smart HWCs that amalgamate technologies for flexibility and smart use into one product, such as Mixergy products[107].

Smart thermal stores are coming to market from a range of innovative British companies. Other thermal storage technologies on the market include dry-core storage and phase-change batteries. These smart thermal stores can make the most of renewable electricity, provide flexibility to the grid (keeping grid reinforcement costs down) and keep homes comfortable and warm.

For example, Sunamp's Thermino thermal battery unit stores energy in a highly insulated core of phase-change material (PCM)[108]. This material, Plentigrade P58, can store up to four times more energy than an equivalent volume of water, and acts as a high-density store of heating and cooling water in a building. Sunamp's thermal batteries can be charged with any means of low-carbon energy-generating technology, including heat pumps and direct electric inputs (solar PV).

As with smart HWCs, thermal storage solutions can also incorporate smarter controls, such as tepeo's Zero Emission Boiler (ZEB)[109]. The ZEB combines a dry core thermal storage, capable of charging from solar PV, with smart controls, and charges using grid electricity during the cheapest and greenest times of the day. The stored thermal energy can then be used to heat spaces and water for domestic purposes as a regular gas combi boiler would.

Demand-Side Response and Flexibility

Unlocking the potential flexibility of energy storage technologies is done through smart demand-side response and suitable enabling measures. A primary technology for enabling this level of smart and flexible energy use in buildings, is the smart meter. Smart meters, alongside heat meters, will open energy customers up to a range of offers and options for managing their energy demands and costs.

Smart meters, alongside half-hourly settlement that reflects more accurate costs and carbon intensities of delivered energy, will allow consumers to sign up for time-of-use (TOU) and export tariffs. TOU tariffs work by offering customers two-or-more unit rates for electricity across any twenty-four-hour period. These tariffs may be simple and static (e.g. like Economy 7 or Economy 10 tariffs) or complex and dynamic (e.g., varying according to the price of electricity on the grid on a particular day).

During hours of peak demand (currently during the mornings and early evenings), unit prices for electricity may be much higher. But during off-peak hours (during the night), the unit price will fall to a much cheaper rate. During which, smart and flexible technologies will consume as much electricity as possible to service the next day's demands, using the cheapest electricity. For example, Octopus Energy's Agile Octopus tariff will benefit customers who are able to their shift energy demands into off-peak times or periods of cheaper/greener electricity[110].

Combined with tepeo's ZEB, for example, this will create an energy market where consumers and businesses can take advantage of TOU tariffs and unlock cleaner and cheaper energy. This approach of combining TOU tariffs and flexible products is expected to be more reliable for the electricity system to plan than relying on, for example, pre-heating buildings.

Moreover, TOU tariffs can be combined with tariffs for exporting electricity. Generous export tariffs, like Octopus Energy's Outgoing Octopus tariff (15p/kWh)[111], alongside the Agile Octopus tariff, could better incentivise consumers and businesses to install microgeneration technologies, like solar PV. Surplus electricity generated through on-site technologies can be sold back to the grid at a rate higher than the electricity paid for during off-peak hours.

Furthermore, this acts as a precursor to enabling active, energy-positive buildings. In these instances, buildings are turned from passive consumers into active contributors. Active buildings support energy networks by intelligently integrating LCTs for space and water heating, power and transport[112]. Please see the following example from Active Building Centre (ABC), typifying this approach and the benefits that can be reaped from enabling active buildings.

The Active Building Centre (ABC)

Background

Active Building Centre (ABC) are focused on innovation, research, and advice that is helping the built environment sector accelerate its journey to Net Zero. They create active buildings that are comfortable, low carbon, and low cost, which integrate with the local energy infrastructure, contributing to the energy network of the future.

Methodology

ABC take an agnostic, data-driven, approach to creating active buildings[113]. The journey to delivering such buildings runs through the stages of: design and pre-planning, pre-construction, on-site, handover, occupant and monitoring. Throughout, many standards, guidelines, and frameworks are drawn from to deliver buildings that meet their comfort, carbon and cost outcomes.

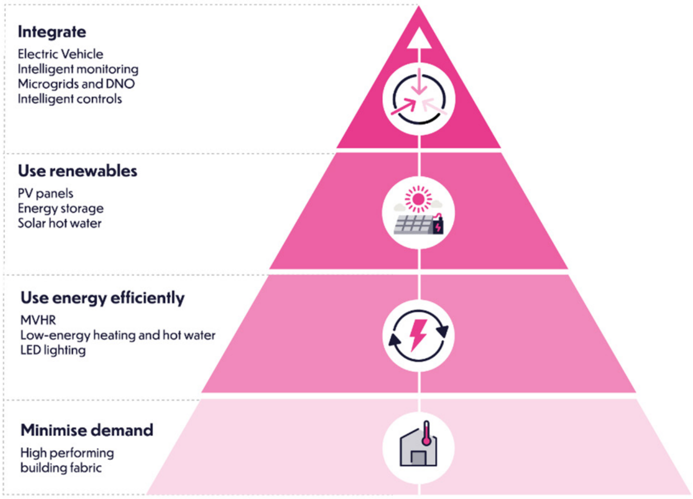
Comfort: WELL Building Standard, ASHRAE, Building Regulation Parts (O, F, etc.), CIBSE TM 52, TM 59, TM 68, and Guide A, Passivhaus (Passive House Planning Package (PHPP)), Society of Light and Lighting (SSL), BS 8233, BS 40101, BREEAM, Home Quality Mark, LEED and Soft Landings Framework.

Carbon: Green Construction Board, RICS whole-life carbon, LETI, UKGBC Net Zero Whole Life Carbon Roadmap, Greater London Authority's (GLA's) whole-life carbon, RIBA 2030 Climate Challenge, BSI PAS 2080, Institute of Structural Engineers (iStructE), BS EN 15978, BS EN 15804 and CIBSE TM 65.

Cost: BS ISO 15686-5, Standardised Method of Life Cycle Costing for Construction Procurement in the UK, BS 8544, Building Services Research and Information Association (BSRIA) and Energiesprong.

The ABC have also published their Blueprint, which is a collective contribution to help industry, society and government. It draws together theory and practical examples from the ABC team's work on the ABC's approach to achieving Net Zero and transforming construction.

The ABC's integrated active buildings energy hierarchy.



Their approach is predicated on the traditional energy hierarchy of reduce demand, use energy efficienctly and use renewable energy. However, it has been expanded on and enhanced to suit policy makers and organisations across the UK and guide an integrated, active buildings approach:

Benefits

The transformational attributes of active buildings enable energy system symbiosis. All buildings have space heating and cooling, ventilation, hot-water and equipment demands, which must be met by the building energy system. Active buildings smartly manage these demands and have energy generation and storage technologies that are integrated within the energy system, intelligently managed, and controllable; this maximises the comfort, cost, and carbon benefits for the building and community, whilst supporting the user experience and their preferences.

Integrated energy systems will unlock more advanced, self-sufficient and intelligent, energy systems, which will remove the need for traditional and costly network reinforcement, especially as the UK moves towards an increasingly electrified future.

Active Building Centre: Trent Basin

Building on ABC's approach to active buildings, Nottingham's Trent Basin takes this a step further to create 'active communities'. These entail having better connected active buildings within an area that can coordinate and share energy assets.

The principles of individual active buildings, with their ability to modulate energy demand, import and export energy to the electricity grid, generation on-site renewable energy, etc., can be scaled up to incorporate more buildings. This will allow for surplus energy from an entire community to be traded internally, on a micro-grid level, and externally, to the national grid, reducing individual building energy bills and gaining grid independence.

Trent Basin's 'Behind-the-Meter' study brings together many companies, key industry players, and academics to deliver a new community energy scheme model —with ABC committing £485k of funding investment. Around 350 energy-efficient, low-carbon homes are being constructed as part of the whole development, with 80 being connected to the community energy scheme.

Technologies included in the project include solar PV panels mounted on properties and across the community, as well as the UK's only urban solar farm; the largest communal battery in Europe to store the generated renewable energy; residential EV chargers; a smart energy management system with connectivity on a home-by-home basis; and more.

Trent Basin Energy Services Company (ESCO) was set up to run the project and sell the energy generated on site back to the National Grid. ESCO is co-owned by the residents, allowing for the profits to be socialised with the community. Further, using novel consumer monitoring and smart data dashboards, residents can get oversight of the impacts of their behaviours on energy usage, money and carbon emissions. With the community working together to maximise the use of on-site, self-generated energy, the residents will be less reliant on the national electricity grid as decarbonisation and energy bill savings are made independent of the grid.

Safety of installation is also of primary importance when utilising a number of different electrical technologies in homes, such as like solar PV, battery storage, electric vehicle charging and electrical heating like heat pumps. Our member, NAPIT, stresses the significance of using a competent electrician to co-install a system, as it will ensure that key touch points in the electrical infrastructure are suitably accounted for and upgraded.

Alongside key competencies, controls, linked to smart meters, are a useful tool for managing the diverse electrical demands that a building may see when incorporating measures. These smart controls can allow for high-energy loads to be operated at a reduced output, or for similar high-energy loads prevented from operating at their peak simultaneously.

Analysis: Flexibility

When discussing flexibility, it can be thought of as happening (or not), at two separate, but interlinked levels. Put simply, flexibility in the term of heating systems, or heat flexibility, refers to the ability to rely on separate sources of heat, simultaneously, or in conjunction. For example, heat pumps can load shift using the thermal mass of the building they're heating, pre-heating homes, or having access to a thermal storage medium, such as a hot water tank or phase-change materials.

Also, a hybrid heat pump system usually consists of a standard hydronic heat pump, alongside a more traditional combustion-based system, such as a gas-fired or biomass boiler. At the individual (or micro) level, flexibility allows consumers to vary the usage of each part of their system — this could be either to make use of time-variant pricing in fuels (for example, many electricity tariffs vary between a day and night billing period), or to reach a peak heat output, for use on the coldest days of the year.

Traditionally, tariffs for most electricity (and natural gas) are either at a fixed or peak/off-peak prices (referred to in the UK as Economy7 tariffs). Whilst hybrid systems would still have a role to play in these circumstances, the hypothetical benefit becomes far more apparent under an hourly, or half-hourly tariff. For example, Octopus Energy's Agile Octopus half-hourly tariff (see Figure 24).

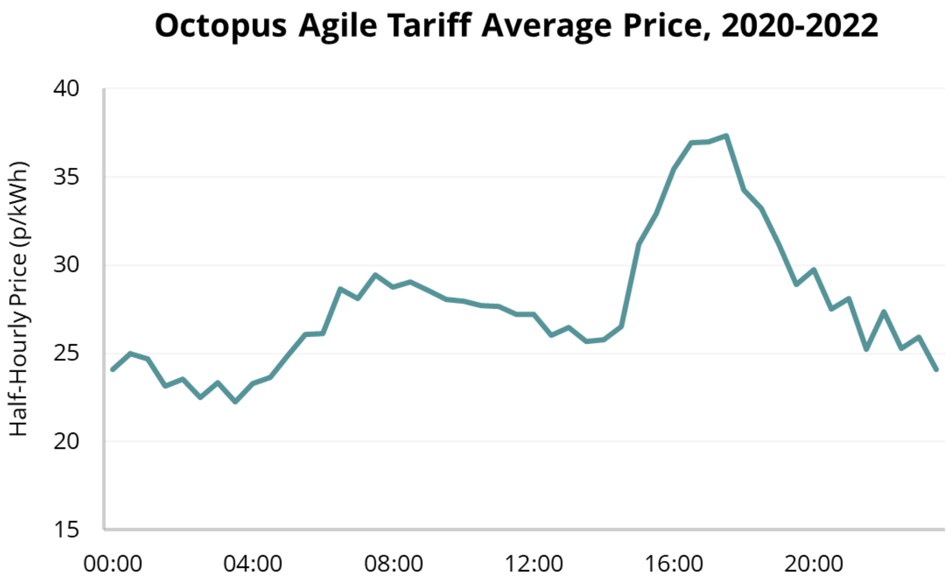


Figure 24: Octopus Agile Tariff, averaged from 01/12/20 to 01/12/22[115] .

Let us then consider a hypothetical system, an average household, utilising a hybrid heat pump system—an ASHP in conjunction with a biomass boiler. To simplify this, we assume both units are capable of meeting peak heat demand independently. Furthermore, we also assume a flat efficiency for the heat pump, regardless of the time, or energy required for output.Traditionally, tariffs for most electricity (and natural gas) are either at a fixed or peak/off-peak prices (referred to in the UK as Economy7 tariffs). Whilst hybrid systems would still have a role to play in these circumstances, the hypothetical benefit becomes far more apparent under an hourly, or half-hourly tariff. For example, Octopus Energy's Agile Octopus half-hourly tariff (see Figure 24).

	AIR-SOURCE HEAT PUMP	BIOMASS BOILER
EFFICIENCY	3.50[116]	0.90
PENCE PER KWH (INPUT)	Above	7.90[117]

This allows us to construct a graph of effective heat per cost, over the twenty-four-hour period.

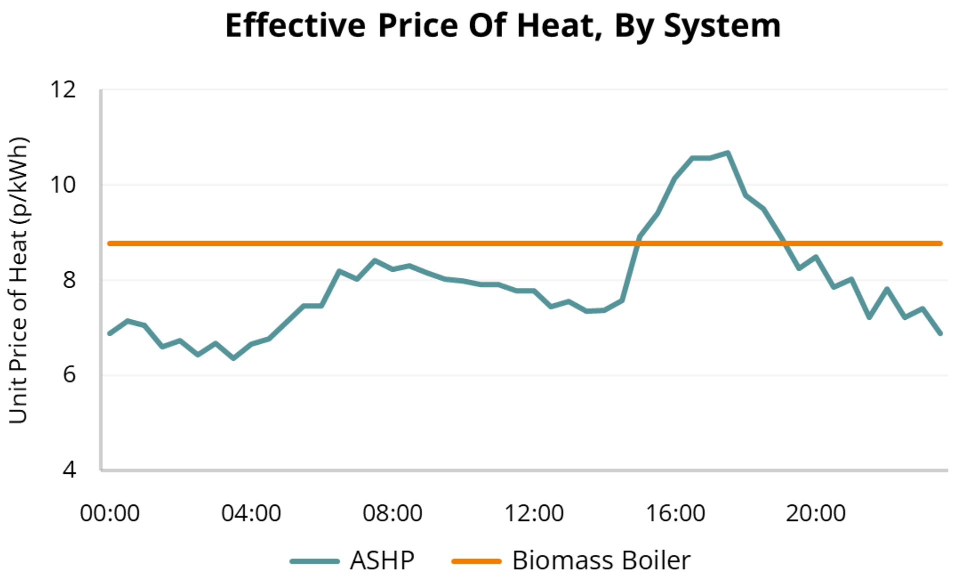


Figure 25: A comparison of the average effective price of heat by system.

As seen in Figure 25, the price for heat generation via the ASHP fluctuates with the time-of-use tariff from Octopus, whilst the biomass boiler does not. The period (roughly) from 16:00 to 19:00, shows a point at which it would be cheaper to run the biomass boiler, rather than the ASHP. Whilst this may appear to represent a small proportion of the twenty-four-hour period, it is worth considering the actual heat demand of a typical household (Figure 26).

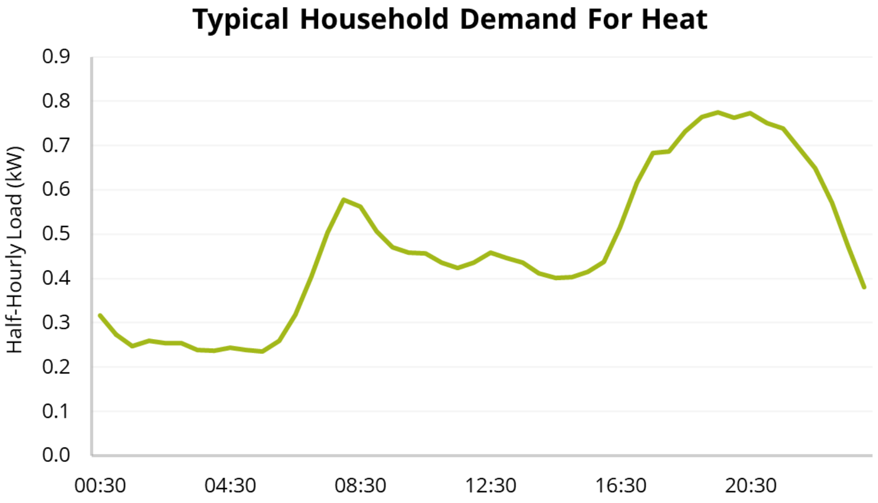


Figure 26: Example hourly demand for heat for a typical household[118].

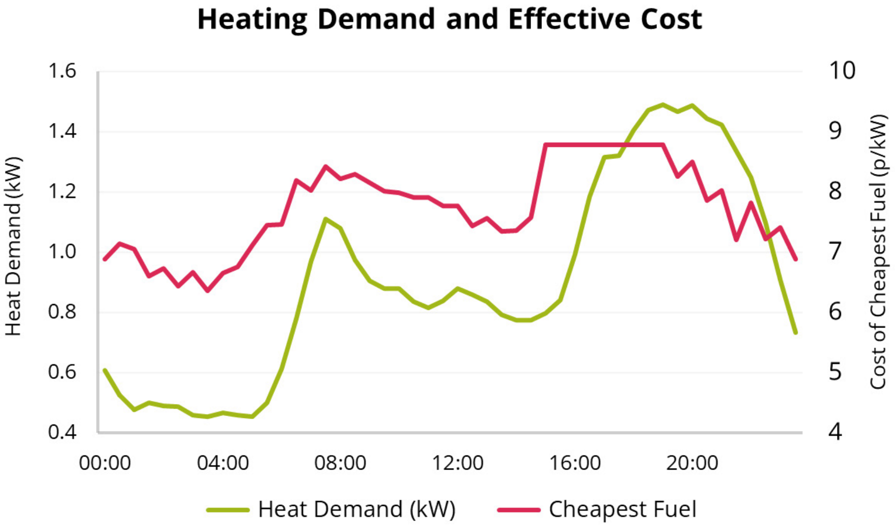


Figure 27: Overlay of Figures 25 and 26, with the cheapest fuel type selected.

When combining the average household heat demand with the cost of the cheapest fuel over a twenty-four hour period (Figure 27), we can observe how a hybrid system can benefit the consumer with bill savings. Aggregate these savings over the course of a year, and utilisation of a hybrid system could help to reduce heating bills as the system can prioritise the most cost-effective mode/fuel with which to meet the heating demand. Alongside this, the plethora of qualitative and functional benefits that hybrid systems can bring give the consumer a valuable option to consider for decarbonising their building(s).

Effective Consumer Education And Engagement

One of the greatest challenges that the UK faces with the transition to Net Zero is educating, engaging and driving consumers and businesses to take action. **Taking a more technologically appropriate approach to what, where, and how LCTs are proffered and installed in buildings, will benefit this mammoth transition by marrying up consumer desires with a solution and engaging people in undertaking the necessary changes**.

Consumer research indicated that 85% of consumers are in agreement that climate change is one of the most important issues to tackle in the UK, with 78% of consumers willing to make modifications to their homes in action for climate change mitigation[119]. Moreover, 84% of consumers agree that low-carbon heating and energy efficiency measures will need to be adopted, but only 35% have or are planning to do so in the next ten years[120]. The barriers to increasing this percentage of active consumers are chiefly cited as due to the level of consumer behaviour change required, poor demand stimulation, installation and running costs, the hassle of works, and other factors—as also discussed in the SEA's joint report with Placeshapers and Tpas, *Net Zero, Technology and Tenants.*

However, consumers are not wedded to oil and gas technologies and fuels[121]. The only priority for consumers and businesses is a warm, reliable and affordable heating system—the policy for decarbonising heating systems should reflect these priorities. The awareness of the suitability and applicability of replacement options is so low amongst consumers that, when asked, most technologies are seen as suitable replacements. Although, only 14% of consumers asked would have a heat pump installed as their next heating system—36% were wholly unsure[122]. This is driven predominantly by a lack of awareness of technologies and the high associated cost; alongside required behavioural change and the preparatory and parallel works needed.

As explored in a World Wildlife Fund (WWF) report, Better Homes, Cooler Planet[123], the evidence for the benefits of installing LCT's for cutting carbon emissions, reducing energy bills, and adding market value to homes, is well established. Engaging consumers in the decarbonisation of heat, and the benefits of installing the right technologies in buildings will help to transition the UK to Net Zero proactively, rather than reactively (such as in a distress purchase situation).

A large proportion, 57%, of off-gas grid oil and gas boiler installations are made as distress purchases[124]; further explored in our report, *Off Grid, Off Carbon*. Distress purchases are typically re-installations of existing technologies, replacing the unit the consumer is comfortable with, and knows works; rather than full consideration for a low-carbon option. The time involved in assessing the applicability of low-carbon alternatives, choosing a system, sizing and designing the system, installing the system, and potentially making a funding application, all during the winter period, is a large barrier to the transition. For the consumer, it is much cheaper, easier, and simpler to install a like-for-like replacement, and usually at a lower cost than low-carbon solutions.

Solving this issue will require consumer engagement and education. Pre-emptive steps must be taken to embed the ideas of transitioning to low-carbon technologies. This sits alongside any preparatory processes, like regulating for banning sales or installations of fossil-fuel boilers or assessing the building stock in high fidelity. This, linked with digital services, like a BRP, will give a clearer indication of what might need changing, when, and at what expense, in each building. Although quotes may have a margin of error, and product lines may be unavailable, these actions may act as a stimulus to consumers to prepare to transition to LCTs.

A further vital element is providing adequate financial support for the uptake of specific technologies. The advent and worsening of current crises have exacerbated the pre-existing challenge of financial barriers to LCT installations. Government support needs to remove the prohibitive costs associated with decarbonising homes, as high upfront and ongoing costs will block consumer engagement efforts. As part of a study by Nesta[125], 25% of consumers surveyed would pay the full up-front price of a heat pump (assumed £10,000 to £12,000). Yet, reducing the cost of a heat pump to £2,000 to £3,999 would incentivise 44% of those surveyed to make the transition. Furthermore, consumers can be encouraged to transition with other financial incentives, such as rewards for removing carbon emissions from the grid. This includes low-carbon heating, such as heat pumps and smart thermal storage, and microgeneration (taking into account TOU and smart export tariffs).

Alongside this, a large-scale rollout of quality consumer advice is needed. Country-wide, tailored, locally delivered advice will stimulate more demand for LCT's among homeowners and businesses. This core service will join up consumers, at any point in their Net Zero journey, with installers, advice, funding and more. Key to quality consumer advice services, is their impartiality and scope of measures. If the advice is to cover all of UK buildings—all houses, social properties, apartments, commercial properties, industrial buildings, both on and off grid, etc.—then allowing for the most appropriate measures to be communicated through the service, at the most cost-, carbon- and comfort-effective level, is central to its efficacy.

Gaining the trust of consumers and giving confidence in the measures and properties supported, will give clarity to the consumer journey and renovation pathways to Net Zero. This will be a role for the Government, advice agencies and housing providers. Good work is already underway with engaging consumers, such as through the Home Energy Scotland advice service, funded by the Scottish Government, and run by Energy Saving Trust[126]. This cross-cutting advice service incorporates energy-saving advice, and keeping warm in your home, with funding opportunities, renewable energy installations, greener travel and water waste advice. The scope of measures incorporated into the advice service, alongside the associated funding, allows for a diverse and holistic renovation pathway for consumers (many fabric/energy efficiency measures, linked with different renewable generation, energy storage, smart controlled and low-carbon heating technologies).

A member of the SEA, Sovereign Housing Association take a people-centric approach to decarbonising their homes.

Sovereign Housing Association

Background

Sovereign are one of the largest Housing Associations in England; providing good quality, affordable and sustainable homes and places across the south of England. Sovereign's strategic asset management and investment strategy looks to regenerate, retrofit and de-carbonise its 60,000 existing homes as well as deliver 2000+ new homes annually and is underpinned by their Home and Place standard 127 ; a design and investment framework that represents a holistic approach to sustainability with a central focus on four core themes of, the customer, home, place and sustainability.

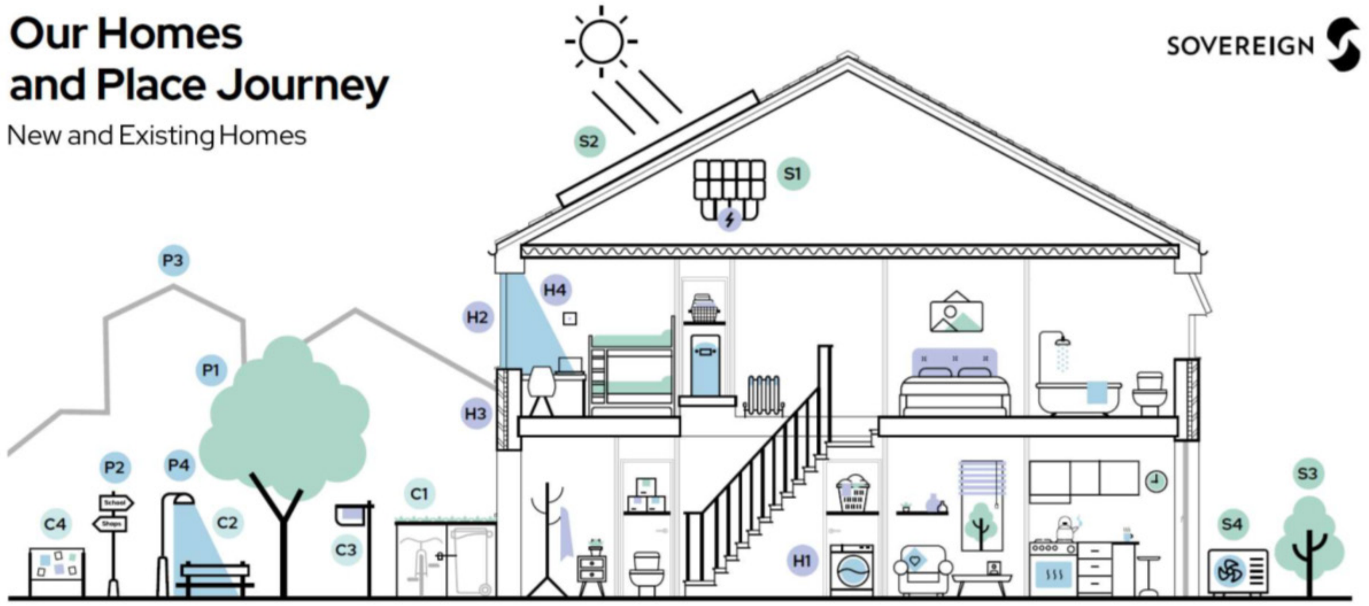
Methodology

The Home and Place standard is a qualitative and quantitative design guide and contains an assessment tool-kit – co-created with customers – that prioritises health, well-being, affordability benefits for customers as well as mapping a digital pathway to net zero.

Using the assessment tool-kit Sovereign scored and graded 46,000 of their 60,000 existing homes against the Home and Place standard to determine the quality of this portfolio and to inform strategic investment decisions on whether to regenerate, retro-fit or replace existing homes. Similarly the standard is used to assess qualitative and performance outcomes all new home and land acquisition decisions.

Our Homes and Place Journey

New and Existing Homes



Customers

- C1 Encourage long-term health and wellbeing
- C2 Be safe, secure and inclusive
- C3 Provide an excellent customer experience
- C4 Foster pride in homes and communities

Homes

- H1 Usable and adaptable
- H2 Enjoyable to live in
- H3 Cost effective
- H4 Digitally connected

Place

- P1 Have character and delight
- P2 Be well-integrated
- P3 Be inclusive
- P4 Be safe

Sustainable future

- S1 Be comfortable for the future
- S2 Have a simple approach to moving towards zero carbon
- S3 Promote a healthy environment
- S4 Empower customers through technology

With existing homes representing the largest contributor to Sovereign's carbon footprint and the need to create a new measureable data-driven methodology and real-time energy performance baseline, Sovereign teamed up with Sero Homes 128 to survey, carbon and energy-model existing homes to create a property specific Pathway - following a fabric-first whole-house approach to retrofit - but tailored to each individual property, considering its own unique circumstances, condition. This digital approach defines what specific interventions are needs and when and what the outcomes will be, linking to the familiar performance metrics of utility bills, carbon emissions, EPC, SAP, energy useage, heat demand, heat loss parameters, amongst others.

Benefits And Examples

Data gleaned from the property Pathway net zero software can then be integrated into consumer-facing apps and software; allowing for tenant engagement and awareness-building of their energy use, generation and costs. Empowering consumers to take ownership of their energy and educating them on the intricacies of the home energy system, will lead to a populous who use energy with greater due care and attention, and it is hoped will garner customer and community support for retrofitting homes in a way that expediates delivery and reduces customer energy bills while enhancing health and wellbeing and reducing carbon emissions.

2023/2024 will be a busy period for Sovereign having submitted a bid for 1,000 homes in the SHDF Wave 2.1 Funding round and in parallel undertaking 7 pilot projects totalling c.250 homes, all following a whole-house, fabric-first, 'digital retrofit' methodology while at the same time meeting the Home and Place standard. These projects, reliant on smart home technology, sensors and performance-in-use measurement, will explore a diverse array of technologies ranging from, ASHP, PV and Battery, GSHP, EAHP, HTHP and radiant heat. In doing so, these projects will inform thinking and should unlock tangible benefits for customers through lower utility costs; minimised fuel poverty/stress, comfortable, healthy and positive buildings and places, reduced carbon emissions, more engaged consumers; and banked-learning that can then be fed into wider portfolio analysis setting a pathway to net zero.

The final analysis will consider the home as a 'Smart Energy Hub' This project will explore and test how energy demand can be aggregated, and flexible, demand-shifted, locally stored energy can be unlocked to create integrated, community-driven energy systems that interact intelligently with the grid—not just for the benefit of a single area, but the whole nation.

A technology-agnostic approach puts greater emphasis on the assessment of measure applicability, based on the stipulations of individual building circumstances. This approach is beneficial as solutions will be tailored to consumers and the building, working most appropriately for its existing state and any planned future work. This level of engagement will be taken forward ideally with the integration of more effective building assessments with BRPs, training installers to engage effectively with consumers and businesses, and high-quality, tailored consumer advice services to stimulate demand.

After policies within the heat and buildings space are altered to include a wider diversity of solutions, building assessments with BRPs will be a key delivery mechanism for engaging consumers. Tailored plans that take into consideration the desires of consumers and what work they may want to carry out on their property, will allow for more effective application and phasing of measures. For example, if a new kitchen, office space, extension, redecoration, or renovation of a property is being planned, then a BRP should be able to account for these building-level alterations, staging measures across time and applying the most suitable solutions as a result of these changes, to better suit the consumer's needs.

Long-term, consumer-focused policies and frameworks, like BRPs, have the potential to increase the speed of transition to low-carbon/net-zero buildings. In our analysis below, we explore this potential to increase consumer satisfaction, garner support and buy-in for the long term, and achieve a speedier transition.

Analysis: Behavioural

"Behavioural economics has become one of the most successful social sciences when it comes to influencing energy policy discourse. Moving beyond homo economicus as a way of understanding energy behaviours, it highlights how individuals can be subject to systematic bias, and may be 'benevolently nudged' towards policy goals…"[129].

One of the primary drivers and benefits of technology agnosticism as a pathway to the decarbonisation of heat, is its intrinsic interplay with behavioural economics; a form of engagement and understanding of house and business owner choices, with regards to heat consumption. Dr Chadwich and Dr Hale of UCL argue that one possible interpretation for both barriers and enablers for the decarbonisation of heat (specifically within the home, although it could feasibly apply to business owners too), is the COM-B model[130].

A drastically simplified, yet intuitively useful way of categorising the primary factors in human behaviour, the COM-B model states that behaviour is dictated by three aspects, capability, opportunity and motivation (Figure 28).

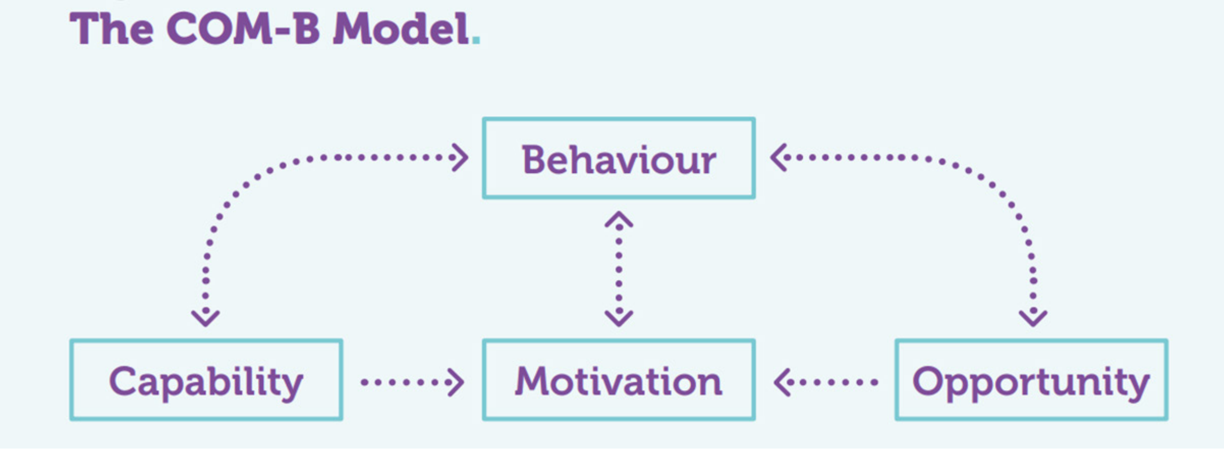


Figure 28: The COM-B Model[131].

A technologically agnostic approach to the decarbonisation of heat can benefit each of these parameters:

Capability – Ultimately refers to whether individuals have the knowledge, skills and ability to participate in a behaviour.

“Do I know and understand how to act out this behaviour?”

Opportunity: in the COM-B model, opportunity refers to external factors which make the execution of a behaviour possible. These can be broken down into physical and social aspects.

“Do my physical and social environments allow me to behave in a certain way?”

Motivation: Perhaps the most difficult to bring under the scientific lens, motivation refers to the internal processes which guide behaviours. These can again be broadly broken down into the reflective motivation (planning and evaluating), and automatic motivation (impulses and desires).

“Does this behaviour align with what I ultimately want to do?”

From this perspective, we can begin to structure how a technologically agnostic approach may ease the pathway towards decarbonisation of heat, by narrowing down the opportunities to facets of the COM-B model:

COM-B Aspect	Problem	Technology-Agnostic-Led Solution
Capability	Homeowners may struggle to understand how a heat pump system can heat their home reliably.	Alternative heating systems may provide more conventional experiences. Alternative technologies could help supplement the heat pump experience, or act as a substitute, e.g. secondary boiler system, electric boilers, or electric panel, storage or resistive heating.
Opportunity	Those living in rural areas may face prohibitive costs in achieving low-flow temperature heating.	As highlighted in our archetype analysis, older houses often face difficult pathways to low-flow temperature heating (e.g. due to solid wall construction). A more technologically appropriate approach allows for the usage of low-carbon-fuel-based solutions, useful in areas of low population density, and where air quality is less of a concern.
Motivation	Installation of LCTs can be a disruptive process. Distress purchases may limit the technologies installed as consumers want quick and easy replacement solutions.	A wider range of possible technologies ultimately means that consumers who are "disruption-averse" can pick an optimal decarbonisation pathway in light of this. A prescriptive and inhibitive approach may force consumers to delay decarbonisation until it is necessary by regulation. Incorporating good consumer advice, with better building assessments, building passports, data-driven decision making, and policy with a greater diversity of measures, will better motivate people to make the transition to Net Zero before a failure necessitates change.

High-Quality Skills and Clear Local and National Planning

Although Net-Zero policy sits chiefly at a national level, the delivery of Net Zero sits firmly at a local level. An overarching policy is needed from government to ensure the most optimal pathway to Net Zero is taken and set the pathway to achieving this target. However, as stated in the *Heat and Buildings Strategy*, "if national decisions are made without input from local actors, they will not adequately reflect the local landscape."[132] **A more technology-agnostic approach will benefit the transition with the deployment of solutions at a local level, primarily driven through its requirement for bottom-up, evidence-based, building-level decision making that targets specific outcomes over a specific technology.** The risks of setting top-down policy that disconnects the delivery arm of Net Zero (local) from the overall strategy and trajectory (central policy), could result in greater regional disparities and inequalities and increase costs for consumers.

The *Net Zero Strategy*, for example, committed to taking a "place-based approach to Net Zero, and working with local government to ensure that all local areas have the capability and capacity for Net-Zero delivery as we level up the country."[133] Devolving powers, responsibility, and money to the UK's devolved nations, 333 local authorities, eight combined authorities, 52 cities, local energy hubs, etc., will help to deliver Net Zero at a local level. Despite most local and combined authorities having declared a climate emergency[134], very few have a clear and effective route to delivering Net Zero, which is where overarching government policy can help to steer and guide delivery.

Planning

The benefits of taking a more evidence-based, data-driven, and technologically appropriate approach to decarbonising heat, has the advantage of delivering the most outcome-effective route to Net Zero within a local area. Policy at a central-government level should reflect the requirements for a diversity of solutions needed to suit the multifaceted UK building stock and unique requirements of individual areas of the UK. And if policy is to successfully empower local areas to deliver the most appropriate measures for their area, then central government may need to employ such frameworks as Local Area Energy Planning (LAEP).

LAEP, as defined by the Energy Systems Catapult (ESC), is a data-driven, whole-energy-systems approach that sets out the most effective route to decarbonisation for a local area, taking into consideration the technologies and services that are and may become available[135]. This addresses the applicability of: electricity, heat, and gas networks; future potential for hydrogen and low-carbon fuels; the fabric and energy systems of domestic and non-domestic buildings; and local energy generation, storage and flexibility. Taking an evidence-led, systems-based approach to LAEP involves whole-system engagement, modelling, and planning of the local energy system — the process has been mapped out in ESC guidance documentation[136].

Scotland are taking forward similar initiatives through their National Planning Framework (NPF), as Regional Spatial Strategies (RSS), Local Development Plans (LDPs) and Local Heat and Energy Efficiency Strategies (LHEES)[137,138]. Scotland has eighteen National Developments, which support the NPF and guide an overall strategy for planning future places in Scotland. RSS and LDPs are linked to National Developments, identifying and supporting these as necessary to their individual areas. As with heating and cooling decarbonisation, LDPs must take into account LHEES. LHEES are holistic and effective strategies for tacking energy efficiency and heat decarbonisation at a local level as they work through the following steps[139]:

Stage 1: An assessment of existing local and national strategies and data availability.

Stage 2: Authority-wide assessment of existing building stock's energy performance and heat supply.

Stage 3: Authority-wide setting of aggregate targets for heat demand reduction and decarbonisation of buildings.

Stage 4: Conduct a socio-economic assessment of potential energy efficiency and heat decarbonisation solutions.

Stage 5: Selection of areas/prioritisation of opportunities for energy efficiency and/or heat decarbonisation, leading to the designation of zones.

Stage 6: Costing and phasing of delivery programmes.

LAEP, LDPs, and LHEES, are advantageous frameworks for UK Government to mandate as it links in strategically a more technologically appropriate approach to heat decarbonisation. Data-driven, evidence-led policy making at a local level—unlocked through policy, legislation and devolved powers and financial support from central Government—can unlock the delivery of decarbonised energy systems and buildings. It can also further open up optionality to consumers and businesses, potentially creating more pathways to net-zero carbon emissions that are cost-effective and promote health and wellbeing.

Skills

The Government must ensure all forms of local planning frameworks are aligned with central government policy to guide the country as a whole to achieve the right outcomes. However, enabling each area to take ownership of delivering Net Zero, within boundaries, will allow for individual areas to go above and beyond central government's ability to deliver using a top-down approach. **A more technology-agnostic approach has the benefit of stimulating more supply chains for a greater variety of technologies, which, in turn, will drive and accelerate the deployment of technologies and skills at a local level.**

As previously mentioned, if the Government were to take forward an NRS, then even clearer market signals could be sent, alongside more effective delivery at a local level[140]. The NRS put particular emphasis on area-based approaches to generate capacity and create locally relevant, bottom-up retrofitting programmes. These local delivery programmes twin BRPs and local building/stock assessments with 'packages' of skills that reflect local housing stock requirements — activating enablers for decarbonising buildings and creating a local skills base for delivering in each area.

An NRS of £7 billion per year could sustain up to 1.2 million direct and 1.5 million indirect jobs by 2050. These retrofitting jobs also closely align with areas in the UK Government's Levelling Up Strategy[141]. This is because constituencies with the highest demand for installers are typically current or former industrial centres and coastal communities outside of London and the South East. An NRS enables the best use of talent, resources, technologies, and skills within a local area, whilst putting a focus on a local delivery structure that best suits the specific of that region.

An NRS and other local planning structures are needed as they will benefit the cavernous national skills shortage present in retrofit and construction for building decarbonisation. A profession in the sector offers a route to high-skill, high-wage, high-value jobs. Opinions need changing, routes into the sector need refining, and pathways to up- and re-skill need reforming. These planning structures can be integral to overcoming these challenges as once, at a pan-UK level, certain skill frameworks and competencies are embedded, a concerted effort can be made to plan out the specific requirements within each area.

For example, PAS 2035, as a standard for retrofitting homes, is a core approach that the SEA endorses, and one that needs further embedding into the UK retrofitting strategy. Retrofitting approaches that take into account individual building needs, such as PAS 2035 (domestic) and PAS 2038 (non-domestic) for more complex work, could help to unlock private-sector investment in delivering the skills needed for retrofit. Up-skilling and re-skilling existing trades, as well as attracting new talent into the industry will be better capitalised on with a clear and concise pathway to retrofit. This is an opportunity for growing the number of routes into the retrofit and construction sector or young people, as well as up- and re-skilling pathways for existing trades (apprenticeships, college courses, t-levels, training centres, skills academies, etc.).

However, to realise the full benefits of a technology-agnostic approach in the skills for delivering Net Zero, more holistic skills need to be trained[142]. There are skills needed for assessing energy efficiency and designing thermally efficient buildings: skills for surveying buildings; modelling performance and designing solutions; fitting and installing a variety of different solutions for increasing energy efficiency, air tightness, ventilation, etc.; project managing retrofits; managing different trades; and others.

There are also skills required for installing low-carbon technologies to decarbonise heat and the building more widely. This includes surveying the applicability of measures; specifying technologies and systems and their interoperability; installing the system itself, which may include skills like plumbing and electrics; training consumers in system operation; and more. The Microgeneration Certification Scheme (MCS) acts as the accreditation scheme for some low-carbon technology installations[143]. The competencies and installation standards stipulated by MCS are an effective protocol for protecting consumers, issuing a standardised installation approach for specific technologies, or groups of technologies, and helping to train contractors for individual technologies. Competency standards called Mandatory Technical Competencies (MTCs) are being developed for inclusion within the Building Regulations and work is ongoing to ensure these stipulate the same requirements as those under MCS. This should ensure that working outside MCS does not offer a route to bypass the agreed requirements.

Skills should be developed that tackle buildings as an energy system, with fewer siloed trades; like an energy system expert, or more holistic Retrofit Co-ordinator. These skills would incorporate more whole-house thinking, have greater digital capabilities, and consider a wider range of technologies that are likely to be most suitable for a building.

National Energy Foundation (NEF)

Background

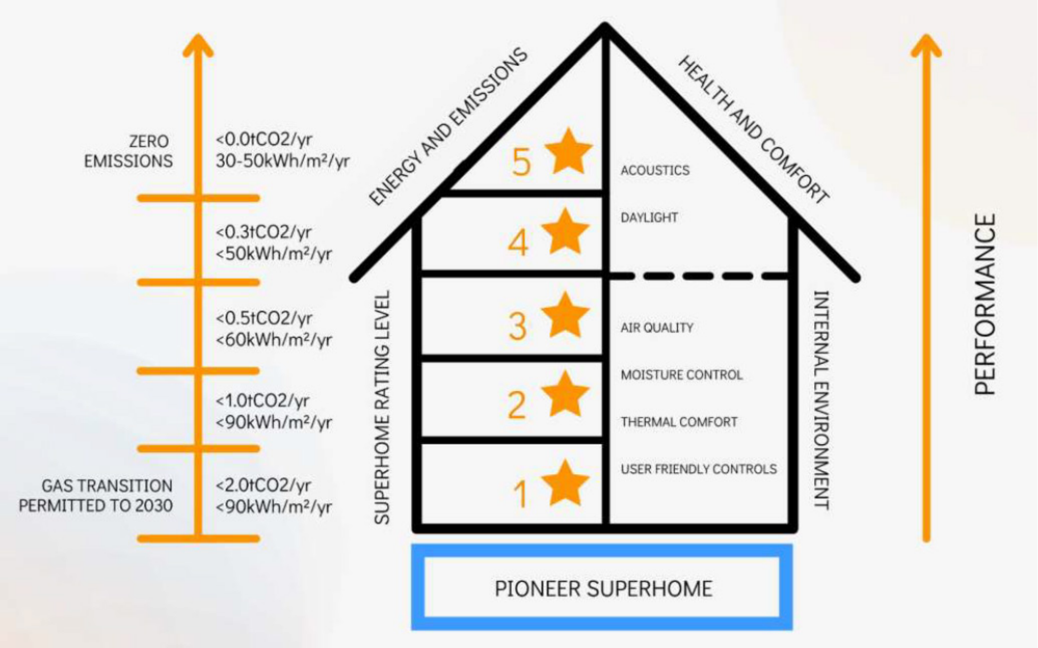
The NEF are an independent national charity, focused on increasing public awareness of the safe and efficient use of energy, and helping consumers to improve home energy efficiency and the affordability of heat. Their work on reducing fuel poverty, cutting household emissions and creating healthier communities, spans more than 30 years of innovative projects and community integration.

Methodology

The NEF's retrofit services are based on the creation of a Whole-House Retrofit Plan, or Medium-Term Improvement Plan (MTIP), as stipulated in PAS 2035. The NEF closely follow the PAS 2035 framework, enabling bespoke plans to be drawn up for every building, mapping a phased pathway to decarbonising, increasing energy efficiency and comfort, and lowering bills. To improve consumer engagement, terms used in the PAS 2035 process are simplified, and the entire process is joined up under specific NEF programmes; Whole House Plan (MTIP), Project Officer (Retrofit Co-ordinator), etc.

One such programme, is the NEF's SuperHomes Network[144]. SuperHomes is a group of individuals, organisations, installers, and assessors, interested in sharing experience and best practice, and championing going above and beyond in domestic retrofitting. The network is purposed with creating a greater number of energy-aware households, garnering support for lower-carbon, more energy-efficient, comfortable and healthy homes. Furthermore, two area-based community groups, Winchester Action on Climate Change and Petersfield Climate Action Network, are supported through SuperHomes, offering advice, financial support, and discounts to those undertaking a retrofit journey within these areas.

SuperHomes goes above and beyond the PAS 2035 MTIP, by monitoring and evaluating properties for 12 months post-installation. Properties are then assigned a rating, using their five-star rating scheme (see image [145]), as a way to benchmark retrofit achievement through cost, energy efficiency, carbon emissions and comfort.



NEF's Superhomes rating scheme.

Benefits

The SuperHomes rating scheme further opens up the complex and daunting topic of retrofitting to wider audiences and provides best-in-class examples of retrofitting homes in the right way. The network and rating system champions best practice and knowledge sharing on retrofit amongst communities, consumers, businesses, installers and organisations, and delivers the right outcomes for properties that undertake a SuperHomes-guided retrofit.

The process also simplifies the often-disjointed, and piecemeal approach to retrofitting (energy efficiency, airtightness, ventilation, low-carbon heat, microgeneration, monitoring) into a succinct, simplified, continual process, alongside year-long monitoring and assessment, to retrofit in a more technology-agnostic fashion. Ultimately, ascertaining the most appropriate pathways, and using the most applicable technologies, to achieve the right outcomes for homes under the SuperHomes scheme.

Stimulating Manufacturing, Supply Chains and Innovation

As explored in our *What Next for Heat & Buildings Policy?* report, the need for long-term policy, that breeds confidence and gives clarity to the sector, is the centrepiece for all policies, not least in the built environment.

The certainty that long-term policies bring is advantageous to unlocking private finance and encouraging UK businesses to invest in long-term infrastructure for manufacturing technologies, supply chains, training for installations and more. Simultaneously, oversight of strong government support for the medium to long term will breed greater demand for LCTs and encourage more consumers and businesses to transition to Net Zero. If policies are more evidence led and technologically agnostic, then the volume and diversity of products being installed will also increase significantly as they are applied most appropriately to buildings across the UK. **In turn, as the investment landscape takes a more concrete form, with clear pathways for industry to supply demand, then manufacturing capabilities, product investment, and supply chain diversity and resilience will grow, benefitting the UK's low-carbon economy.**

The primary focus in policy, targets, legislation and through financial support on accelerating hydronic heat pump deployment and manufacturing is highly beneficial to the expansion of the technology in the UK. However, as discussed in previous sections, solely focusing on installing this technology in most buildings will fail to capitalise on the plethora of benefits that lie in applying the most appropriate solutions to buildings in the journey to Net Zero. Taking advantage of a wider array of technologies will not only help to capitalise on these additional benefits, but it will allow for growth in the manufacturing, product, and supply chain investments across a multitude of different technologies. As a result, the capacity and capabilities for delivering the right mix of solutions for consumers and buildings will also be improved—delivering Net Zero whilst growing the domestic manufacturing base for LCTs.

Risk Mitigation

Diversifying the supply chain of LCT options will allow for risk mitigation and pinch points to be avoided. Incorporating a greater diversity of technologies for transitioning to Net Zero means a greater number of minerals, materials, constituent parts, and elements to LCTs that spreads the risk of particular shortages of these individual parts across a wider supply chain of technologies. If the decarbonisation of buildings was heavily reliant on one particular technology, and a period of relative shortage of a mineral or component occurs, then the whole journey to Net Zero slows and perceptions of technologies may falter. If, on the other hand, this same shortage occurs, but a varied spectrum of solutions are being rolled out to decarbonise buildings, then it is more likely that the journey to Net Zero will be less radically impacted and consumers/businesses will retain their momentum for decarbonising. For instance, many designs of smart thermal stores are based on readily available materials. The Sunamp Plentigrade P58 uses sodium acetate trihydrate.

There is also inherent risk associated with the success or failure of an individual technology when used in relative isolation. Heat pumps are a vital technology to achieve Net Zero, this is clear, but banking on their success alone, without completely watertight installations in all buildings, could result in a catastrophic risk to the UK's journey to decarbonised buildings. If enforcement and standards for heat pump installations are not tightly regulated for and carried out, then a period of high-volume, poor-quality installations could create a negative public perception of the technology. Any failed or unsatisfactory outcomes may mar the transition to Net Zero as a result of any lack of faith in the solution. The risks associated with deploying heat pumps as a primary technology—considering their inability to achieve all of the benefits that a more technologically appropriate policy approach would allow for—are better shared amongst a greater number of technologies that are better suited to the individual building (assuming other key processes for building decarbonisation are incorporated, like BRPs, better building assessments, more high-quality skills for installing LCTs, etc.).

Export Potential

The UK has significant potential for growing its manufacturing base and supply chain capacities for a variety of low-carbon products, services, skills, knowledge and expertise. This opportunity can be expanded to grow the UK's global influence in this space. All countries around the world will be transitioning into a low- to zero-carbon economy, and the UK can assist in this by exporting its products and services. Consequently, the economy for LCT and service exports can grow. The low-carbon economy has the potential to create £60 billion to £170 billion of export sales between 2015 and 2030, as evaluated by the CCC in 2017[146].

The table below, as included in the CCC's 2017 analysis, includes technologies that are currently deemed as a strength within the low-carbon economy. This covers many of the LCTs required for decarbonising heat in buildings in a more whole-building, technology-agnostic fashion, like solar PV, biofuels, smart controls, energy storage, etc. As the UK expands and shifts rapidly towards Net Zero, growing the markets for LCTs, then many more solutions are likely to take a leading role in the low-carbon economy and grow the potential for exporting these products and services.

Low-carbon economy sector	Potential to capture market share	Examples of current UK strengths
Energy efficiency products	Medium	Smart Grids, advanced building design, materials and manufacturing systems
Energy from waste and biomass	Low to Medium	Biofuels, waste recycling techniques, etc.
Low-carbon electricity	Medium	Off-shore wind, energy storage, solar PV, etc.
Low-carbon services	High	Finance, insurance, consultancy, etc.
Low-emission vehicles, infrastructure, fuel cells and energy storage	Medium to High	Power systems and transmissions, batteries, logistics, telematics, etc.
Other products and services	Medium to High	Membranes, catalysts, bioprocessing, etc.

Exporting a variety of LCTs and services to other countries gives opportunity and benefit for growing the UK's prosperity at an individual level. Creating jobs within certain areas of the UK that are associated with the manufacturing, processing, design, etc. of a variety of different LCTs and services, will allow citizens to prosper. Meaning more meaningful jobs, savings built, and disposable income accrued, and enable more consumers and businesses to contribute towards and invest in the transition to Net Zero. The number of technology and service offerings for decarbonising heat in buildings goes beyond hydronic heat pumps, and taking advantage of this suite of technologies, many of which are yet to have been innovated, will grow the number of meaningful jobs, and high skilled, prosperous citizens.

Policies, like ECO+[147], allow applicants to contribute more towards the installations of energy efficiency measures, on top of the grant offered. This could be replicated more commonly across the policy landscape as consumers grow their savings and disposable incomes from a stronger low-carbon sector, creating the potential for greater investment towards decarbonising buildings, above and beyond the Government's offerings.

However, care must be taken on the issue of a balance of payments when growing the capabilities of the low-carbon economy. The benefits of growing service and manufacturing offerings for a variety of LCTs for decarbonising heat has to create positive Gross Value Added (GVA) for the UK. Prosperity is only achieved if people are empowered to enter high-skill, high-wage, meaningful jobs, and grow their net worth. If, on the journey to Net Zero, the UK imports more technologies that are innovated and manufactured abroad, with the Government's financial incentives for installing them effectively funding businesses from other nations, then the balance of payments will create a negative GVA for the UK. The UK needs to protect and grow jobs in this sector. Therefore, taking a technology-agnostic approach can only be beneficial for prosperity if the UK makes a concerted effort to grow local, domestic jobs and services for these technologies.

For example, our members, Vaillant, are keen to develop a variety of technologies that can service the decarbonisation of buildings challenge. They believe in contributing to the challenge by manufacturing a range of technologies like heat pumps, hybrid systems, hydrogen gas boilers and smart controls. In 2022, Vaillant opened a new manufacturing line for their aroTHERM plus air-to-water heat pump[148]. Alongside their new scalable manufacturing line, Vaillant offers in-house vocational training courses to support the development of new low-carbon heating installers. This is done online, and through their six Centres of Excellence across the UK.

Many other examples exist of businesses in the UK investing in greater manufacturing capabilities for these LCTs. And with it, will come growth in the number of jobs and services that will see the UK exporting these technologies worldwide, and increase the speed of transition to Net Zero.

The UK Government has also invested £65 million through their Climate Investment Fund (CIF) Industry Transition Programme[149]. The funding will go towards expanding a global market in clean energy technologies, making them accessible and affordable for developing countries. Other similar innovation and clean tech investment funds exist under the £1bn umbrella Ayrton Fund[150]. These funds are driven by UK businesses, which will grow the UK's product and service offerings to a global market in LCTs for decarbonising buildings and energy systems.

Energy Security and Independence

As discussed previously, diversifying the offering of LCTs to the UK's buildings will play a core role in distributing the risk of delivery across a greater number of supply chains. However, this diversification of solutions and energy vectors has the additional benefit of enabling future energy security and energy independence.

Increasing electrification through all technologies—combined with smart and flexible assets, like energy storage, smart thermal storage and smart controls—alongside the use of low-carbon fuel vectors, will help to avoid critical points and pathways in the LCT value chain and wider energy system. This means shifting/flattening out the periods of peak demand, growing the amount of energy storage potential and microgeneration spreading national and international risks across a more diverse energy system. As a result, the amount of renewable energy curtailment will fall and national renewable energy generation can grow, servicing the population with cheaper domestically generated energy. This can be further bolstered through decoupling gas and electricity prices; ringfencing energy generated through national generation infrastructure. Furthermore, alongside a more resilient and efficient grid, this will give consumers and businesses more ownership over energy (generation and consumption) and protect them from geopolitical market instabilities (giving the best value for energy across the year).

Finally, the use of low-carbon fuel vectors as part of a decarbonised energy system and buildings can be made even more effective through a more diverse approach to LCT application. This would be chiefly due to particular feedstock pressures being alleviated as the energy system uses a number of different fuels and technologies. Several of which can be manufactured/grown in the UK, removing the risks of international shortages due to geopolitical events; such as the war in Ukraine impacting the supply of sustainable wood pellets for use in biomass boilers. The UK Government, as a result, consulted on suspending fuel quality requirements for biomass boilers installed through the RHI subsidy to prevent any potential shortages[151]. This poses significant risks not only for indoor and outdoor air quality, but also for losses in efficiency when burning unregulated, poor-quality fuel.

Oil Firing Technical Association (OFTEC)

Background

OFTEC is the leading not-for-profit trade organisation for heating and cooking industries in the UK and Republic of Ireland. Working with key industry stakeholders, local areas, and central and devolved governments, they provide technical standards and registration for technicians and businesses working in the industry.

For heating professionals across the UK, OFTEC run a competent person's scheme, offer PAS 2030, MCS, and Trustmark registration, among other services. OFTEC champion heat decarbonisation through a number of low-carbon heating alternatives. This includes liquid fuels, solid fuels, heat pumps, solar thermal systems, biomass heating and other electrical heating systems.

Methodology

Showcasing what an effective route to decarbonising hard-to-treat and off-gas-grid, rural properties can look like, OFTEC worked with the Northern Ireland Housing Executive in Omagh, Northern Ireland, to test the applicability of retrofitting hybrid heating systems. The EU-funded Rulet programme, in conjunction with the University of Ulster, assessed what appropriate measures could be employed to eliminate the risk of low-income households missing out on the opportunity to transition to low-carbon, clean and smart buildings. They were particularly concerned with providing a cost-effective route to Net Zero, whilst fitting the technology to the consumer and understanding their interaction with these new technologies.

The first step was to choose six EPC Band E to D homes to be upgraded to Band C. This was done through the installation of non-intrusive energy efficiency measures (<£10,000) to suitably insulate and prepare the properties for low-carbon heating systems. Further, three of the homes were heated using an oil boiler, which is particularly common in off-gas grid, rural areas. These homes were converted to a hybrid system comprised of a 6kW ASHP linked to an HVO-fuelled boiler system. HVO is an easy-to-implement, cost-effective, and like-for-like replacement option for converting existing oil boilers to a low-carbon alternative. The other three properties were transitioned using a range of technologies, including ASHP's and hybrids, electric immersion hybrids, solar PV and electrical batteries.

Benefits

These types of properties, and other energy inefficient and expensive to insulate buildings, are typically hard to treat. However, as a solution, in combination with other complementary and ancillary measures, HVO-fired boilers provided an effective option for decarbonising. The tenants of these HVO-hybrid off-gas grid, rural homes benefitted from the least amount of disruption and behavioural change, as the existing oil boiler required only a minor modification to run on HVO. Plus, the heating system function and its original controls were retained, keeping the same familiar set up that the consumer was used to.

HVO is a renewable liquid fuel derived from waste, such as cooking oil, animal fats, and processed vegetable oils; cutting emissions by 88% compared to traditional oil heating fuels, like kerosene. With some properties unable to transition to low-/zero-carbon without hugely expensive renovation works, the benefits HVO come into their own as a cost-effective, low-disruption technology for cutting emissions. In combination with other measures, such as solar PV, batteries, smart water tanks, etc., progress towards further decarbonisation and energy independence can be made.

Finally, as part of wider work to demonstrate the full potential of renewable liquid fuels, OFTEC has, with industry partners, successfully conducted a three-year HVO field trial across the UK. This involves around 150 off-gas grid domestic and non-domestic buildings.

Innovation

Our paper, *Helpful Information and Tips for Manufacturers and Innovators on Gaining Access to Government Energy Efficiency Schemes*, covers, in detail, the barriers and blockers in the current innovation process for the UK. New measures, or ones that are yet to have penetrated the UK market, have to demonstrate, at great difficulty, their benefits at scale, and subsequently, gain acceptance to the wider market. Current government policies sit alongside rules and regulations that protect consumers from measures that are either poorly installed or cause unintended consequences. However, these protections, despite their necessity, are a cause for concern and create barriers to innovative measures entering the market.

Key to supporting innovative product development, whilst managing consumer risk, is the ability to test products for performance and safety whilst allowing the formal process of full product development standards to evolve. Many product test houses will be able to provide bespoke testing, which will give the confidence of third-party assurance that manufacturer claims may lack.

If government policies were to increase the variety of technologies installed and take a more evidence-led approach to decarbonising heat, then huge benefits would be reaped for the innovation process, paving the route to market for new solutions. Innovative measures are the keystone to a more technology-agnostic approach. As the UK's manufacturing base and service offerings for technologies as part of the transition expand, so will the number of new measures that will contribute to accelerating the transition and providing the best value. Further, this includes measures that may be commonly used in other countries, but are yet to have entered the UK market, ergo, UK policies and schemes for funding LCT installations. It is these policies that can benefit from this more data-driven, free-market approach, as the assessment of buildings will uncover countless more opportunities for particular measures, or groups of measures, to meet specific demands and circumstances. Innovation will benefit from this renewed approach, as streamlined innovation processes will allow the most appropriate, proven technologies to be installed where they have the greatest impact, for the best value.

Technology Examples: Heat Pumps

For example, a member of the SEA, NIBE, have created several heat pump products that add to the diversity of measures that can decarbonise buildings. The NIBE F730 and F470 are two EAHP products that offer an all-in-one solution for space heating and hot water, as well as ventilation (Figure 29)[152]. These products will be the most effective solution for numerous buildings across the UK for various reasons. However, many government schemes that fund low-carbon heating measures preclude the installation of EAHPs — unblocking this innovation from installation through government schemes will benefit the transition to Net Zero as consumers and businesses will have access to a technology that may be the ideal solution for the circumstance.

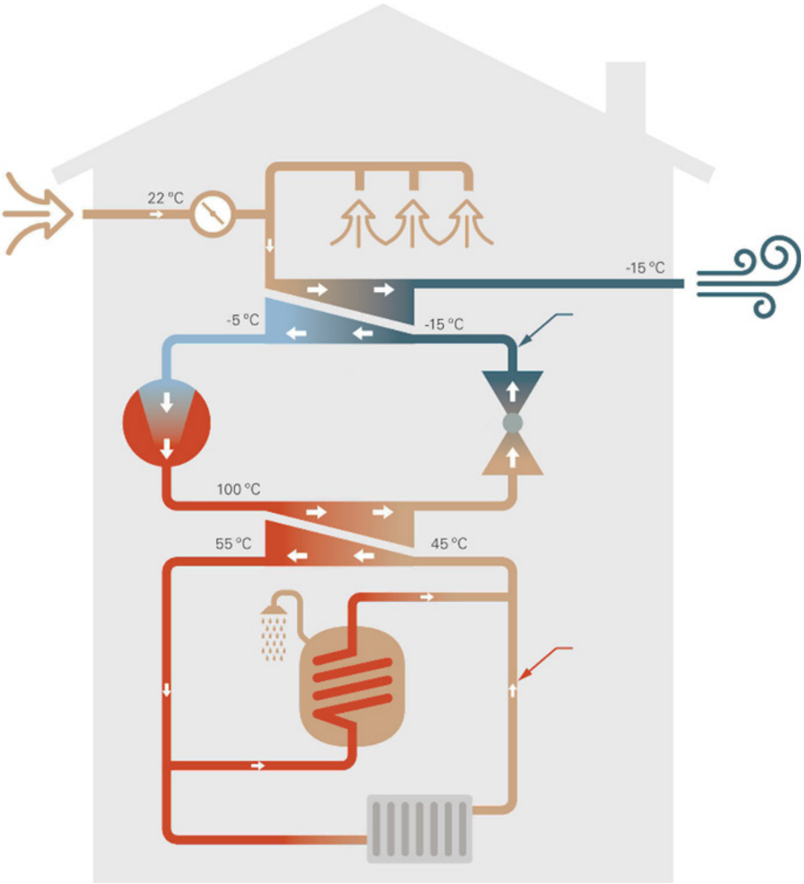


Figure 29: NIBE EAHP system. Example diagram depicts a typical EAHP system operation.

NIBE also offer a combination of PVT and solar PV products that go hand-in-hand with their ASHP or GSHP products153. A GSHP or Multi-source Heat Pump (MSHP), operates in conjunction with a PVT collector, which produces electricity and hot water, to boost the heat pump unit's efficiency (Figure 30). Among the benefits of removing the need for groundworks and increasing heat pump efficiency in line with GSHP levels, the solution may work most appropriately in a number of situations. Currently, however, due to their omission from government policy, consumers and businesses will not benefit from financial support and will have to pay the full price for installations and managing the install themselves.

Moreover, another member of the SEA, Daikin, offers an air-to-air heat pump solution for buildings[154]. AAHPs also offer a new option for decarbonising buildings, where other forms of heat pumps may not be the best value or most suitable technology depending on a variety of factors. Similarly to EAHPs, AAHPs offer exceptionally high-performance efficiencies, and are although they work most effectively in properties that have high energy efficiencies, such as Passivhauses, or other air-tight buildings, they are an effective technology in many EPC C- or D-rated buildings. As well as being easy to install, AAHPs are also very effective for heating and cooling smaller buildings, acting as a potentially ideal solution, in combination with other measures, for single rooms, or for a plethora of building archetypes, like apartments, smaller homes and park homes[155].

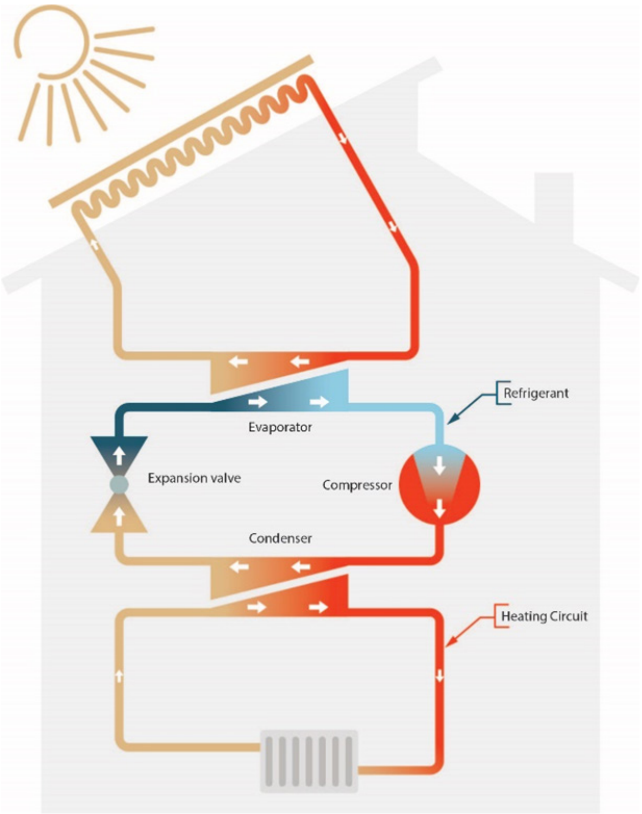


Figure 30: NIBE G/MSHP system. Example diagram depicts typical G/MSHP system operation.

Technology Examples: Solar Heat

Solar thermal systems provide zero-carbon heat, and solar PVT provides simultaneous renewable heat and electricity, both from the sun's energy. These technologies can be paired with heat pumps, electric, or infrared heating as part of a combined zero-gas heating solution; this reduces electricity consumption and the associated CO_2 emissions and costs. It can also be paired with existing gas-fired heating systems to reduce gas consumption in buildings where heat electrification is impractical or expensive.

For example, a member of the SEA, Naked Energy, has developed Virtu, a suite of innovative solar thermal and solar PVT collectors designed specifically for commercial, industrial and public buildings (C,I&P) with high heat demand (Figure 31). Virtu allows businesses to maximise the potential of their roof space by generating more energy per m^2 than any other solar technology. Naked Energy's high energy density solutions are capable of decarbonising heat affordably given its distributed nature and deliver up to four times the carbon savings per m^2 compared to conventional solar electricity/PV technology.

Naked Energy has deployed over 60 medium- and large-scale systems in 13 countries, with a strong focus on the UK. These systems provide zero carbon heat and electricity to apartment buildings, student residences, schools, hotels, public and private leisure centres, national libraries, army barracks and offices. Their products are manufactured in the UK (Essex), Italy and the United States.

Figure 31: Example of a Virtu solar PVT system in-situ, Naked Energy.

Solar thermal and solar PVT have been both included and excluded from government policies and support schemes in the past and present. When included as part of a technology-agnostic support scheme, such as the Green Homes Grant, solar thermal has had the highest uptake out of all renewable heating technologies. This shows that consumers and buildings have diverse requirements. Therefore, to drive fast paced decarbonisation of heat, building operators and homeowners should be empowered to make informed decisions by being offered technology-agnostic support. If the government promotes a bottom-up, instead of top-down, approach, technologies can compete on a level playing field.

Furthermore, solar thermal and solar PVT are increasingly cost effective on larger buildings in the C,I&P space, and in utility-scale solar heat networks with interseasonal thermal storage. These sectors should be supported to the same degree as individual homes.

Technology Examples: Electrical Heating

There are many new electrified technologies for heating buildings. Many of which may encounter significant blockage when trying to gain access to government energy efficiency and low-carbon heating schemes.

The Electrical Contractors' Association (ECA) pioneer the Leading the Charge initiative[156], featuring stories and case studies of organisations at the vanguard of electrifying and decarbonising the grid. As part of a series of podcasts, Jade Lewis, CEO of the SEA, spoke of the importance of a technology-agnostic approach to heating and buildings as part of a cross-sector collaboration to achieve Net Zero[157].

One such innovator, keen to contribute to decarbonising UK buildings, is The Electric Heating Company, and their electric boiler range. ECA highlighted their excellence in the space through their electric boilers and radiators, well suited to all building types. Their product range caters to a swathe of use cases, from larger buildings with wet underfloor central heating systems and space for HWCs, to small apartments with little room, save for compact cupboard space[158,159].

Applicable installations markets include:

- Domestic Properties
- Off-grid Properties with no access to Mains Gas
- Social Housing Contracts — Tower Blocks, Sheltered Housing Complexes, etc.
- Properties that currently rely on LPG or oil-fired central heating systems
- Conservatories and Sunrooms
- Portable Offices
- Holiday homes, Park Homes and Caravans
- Temporary Heating or Free-Standing Purposes

Technology Examples: Infrared Heating

IR heating is a capital-cost-effective technology that offers consumers and businesses an easy-to-install solution for heating walls, surfaces, and occupants, but not the air, as most other heating systems do. This can offer a more efficient mode of heating, and provides better thermal comfort without the energy demands required for heating the air within a building. Radiant heaters, like IR can be installed cheaply and easily as the cost of the unit, lack of pipework, radiators, etc., combined with the skills required to install, are relatively low in comparison to other heating systems. Furthermore, maintenance costs are zero. The infrared product manufacturer, and member of the SEA, Herschel Infrared, offer a range of IR heating solutions to suit many different situations and use cases (Figure 32).

Figure 32: Installations of Herschel infrared heating solutions. Image (left) depicts roof-mounted IR panels in a home. Image (right) shows a roof-mounted Halo IR product, as installed in a church.

Radiant heat also has the important benefit of increasing the health and wellbeing of the indoor environment. Firstly, as IR heat warms walls, and targets water molecules effectively, the presence of damp, condensation, and mould is reduced, creating a healthy, dry indoor living and working environment. Secondly, IR heat is non convective, like a traditional resistive or storage heater is, meaning it does not create currents and air flows around a room or building, with which dust, pollen and allergens can be transmitted.

IR works very effectively in energy-efficient buildings, and in conjunction with solar PV and thermal, and thermal/battery storage solutions to offset energy bills, like the Sunamp Thermino or Mixergy smart HWCs. By storing energy generated by solar systems (PV/thermal) in an electrical or thermal battery, discharging to 100% efficient IR heaters for space heating, and smart HWC's for water heating, efficient and low-/zero-carbon whole-house space and water heating solutions can be installed. The upfront capital costs for these whole-house heating solutions can be lower than other systems, like a full wet central heating system powered by a heat pumptttt. More of a budget can then be allocated to reducing heat losses and insulating the property, alongside the complementary and ancillary measures, like generating on-site energy, batteries, etc.

Alternatively, IR technologies as a part of a traditional wet heating system could allow for cost-effective, room-specific heating, better matching the consumer's preference or building requirements, and without having to make expensive and significant alterations to an existing or planned central heating system. IR heating installations can also be phased in over time to support the decarbonisation of a property and act as a cost-, carbon-, and comfort-effective way to provide space heating on a room-by-room basis. The great control over which each room and zone of a property can be temperature regulated means less energy is wasted to provide the same levels of heat and comfort, as well as maximising the running cost efficiency.

IR can also be used in many different property types, serving as a unique and effective technology for use in a variety of situations where a central heating system may not be most appropriate or heat adequately. However, effective running costs are typically higher than a well-installed, appropriately used heat pump per single kWh of electricity used, and flexibility and smart controls are a necessity to ensure its most cost-effective operation.

Despite IR heating not currently being included in many government policies, BEIS are analysing and testing the performance of this technology through a 2022 tender. The resulting literature and findings should help to showcase IR heating's value for decarbonising buildings and incorporate the technology within policy. Taking a more evidence-led approach to policymaking will benefit the innovation process by unlocking technologies like IR for consumers and businesses to use where best suited, decarbonising the building stock at an accelerated rate than with a single-measure approach.

Technology Examples: Waste-Water Heat Recovery (WWHR)

Showersave, an SEA member, manufactures WWHR solutions for recovering energy from waste water running to the drain. Though not a new technology, like IR heating, WWHR has been providing cost and carbon reduction to the buildings it is installed in. It is a highly effective complementary technology for decarbonising heat in buildings, working well with heating technologies like heat pumps, as waste heat is recovered and plumbed back into the pipework returning to the heat pump cylinder (Figure 33)[161].

This innovative technology, now recognised in SAP, was not recognised for several years, missing out on thousands of potential installations in new buildings or retrofits. Despite its huge success in being included as part of the Building Regulations for new buildings, government policy for retrofitting existing buildings still misses out on the opportunity for installation of this technology. WWHR is easily installed during a bathroom renovation, when the pipework, tiling, and walls are being removed and changed. At this time, WWHR solutions are ideal for being installed as work is already underway, but government policy is yet to capitalise on trigger points like this.

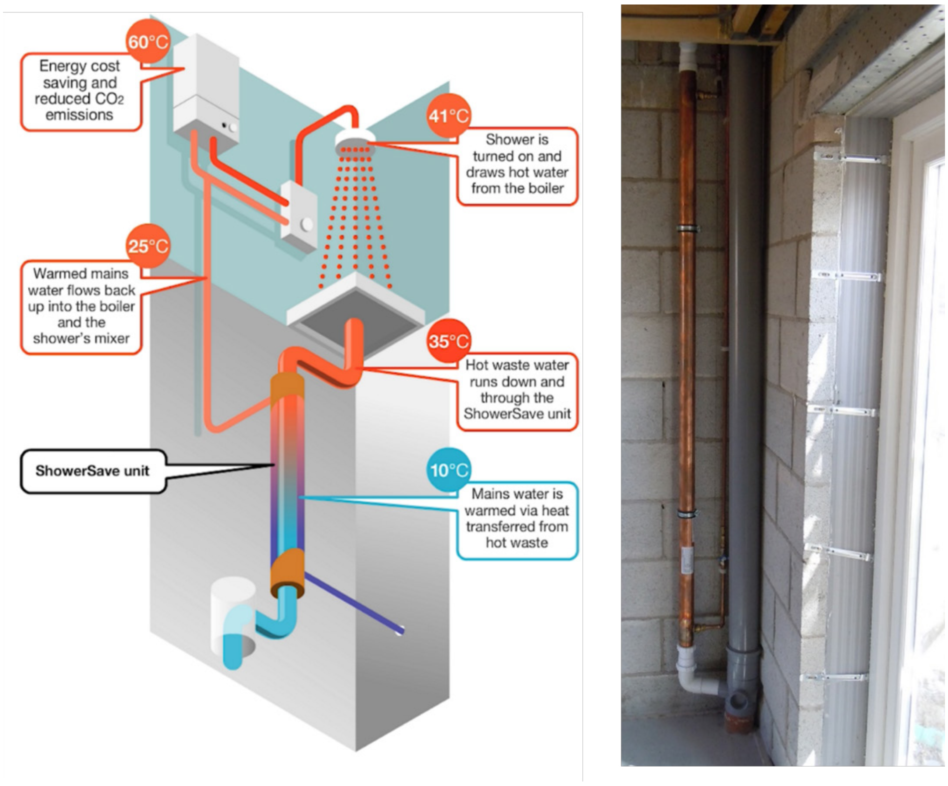


Figure 33: Diagrammatic example of the typical Showersave WWHR installation, alongside annotations of the key stages of its operation.

Appendices

Appendix 1: SEA Positioning on a Fabric-First Delivery

Fabric first, is defined as optimising the fabric performance of a building to ensure technologies deliver the intended outcomes for the building and its occupants: mitigating measure failure, planning the optimal solutions, integrating a holistic approach, and minimising the building performance gap. Integrating passive design principles and removing air leakage and heat loss from buildings is done through ensuring and planning for upgrades that take the fabric to its most practical extent — considering what extent is most cost effective and where appropriate and safe to do to. Optimising the building and fabric, through proper design and planning, will enable solutions for tackling other elements of the building to deliver their benefits most effectively. For example, the heating system, microgeneration, flexibility, and smart controls can be specifically designed in, as part of a fabric-first, whole-house approach, integrating with all other facets of the building.

Fabric first should be the first port of call, as not only do well optimised, comprehensively insulated, draught-proofed, and air-tight properties have vastly reduced energy demands, ergo, energy bills, but they will serve as comfortable, warm and healthy indoor environments for people to live, work and spend time within. The simplest and most effective way to reliably lower bills is to prevent energy from being wasted by inefficient buildings and increase investment in energy efficiency measures.

Moreover, all heating systems, and particularly some low-carbon heating systems, work most effectively, and heat most adequately, in buildings that are well insulated and energy efficient, and where they are designed to work effectively with all other elements. It is paramount to ensure that policies on buildings are interlinked with fabric-first approaches to safeguard and de-risk the transition to decarbonised buildings, as scheme failure could result in poor consumer experiences and low trust.

Investment in energy efficiency is strongly linked to productivity and long-term growth. Models suggest that by increasing average UK building energy efficiencies (D) to a higher level of insulation, such as EPC C or greater, aggregate savings of between £6 billion and £11 billion could be realised every year, or between £1,944 and £2,469 per household per year by 2030 (£4,486 to £5,697 from EPC Band F to C)[162,163,164]. In the financial year of 2011/2012 alone, the UK's energy efficiency market generated circa £18 billion of sales and sustained 136,000 jobs[165].

Estimations of the subsequent impact that the 2013, axing of "green c**p"[166] had on UK energy bills — during which, energy efficiency subsidies were reduced and the zero-carbon homes standard was scrapped — have materialised in around £2.5 billion of additional cost to households; £350 to £400 higher energy bills from October, accounting for the commencement of the price cap freeze; or £18 billion to Treasury and taxpayers through the two-year Energy Price Guarantee[167,168]. This is an additional cost on top of the losses accrued from not continuing sales in energy efficiency and growing green jobs in the sector, which is visualised in Figure 34.

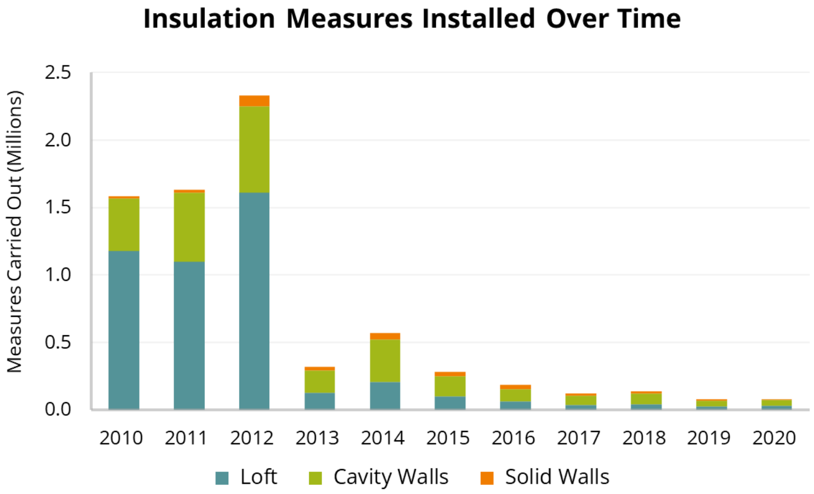


Figure 34: Government-funded Installation of Various Insulation Measures over Time[169].

Figure 35 also provides indicative projections for the progress made to date on installing loft, cavity wall, and solid wall insulation in domestic properties in England in line with the CCC's Balanced Pathway. If installations track along the projected lines, by 2030, there will be a shortfall of 4.7 million loft insulation measures and 1.7 million solid wall insulation measures. If the UK is to fulfil the Government's recent pledge of reducing energy consumption from buildings and industry by 15% by 2030 against 2021 levels[170], and follow the CCC's Balanced Pathway model, a much-hastened rollout of energy efficiency and performance measures will be required than at the current rate.

Importantly, despite the rationale behind these cuts and scrappages being to reduce consumer bills ahead of the 2015 general election, long-term decision-making and policies — substituting short-term cost reduction for long-term benefits — stands as a more favourable way to build policy. A fabric-first approach can bring about many of the aforementioned benefits and others, such as more rapidly reducing carbon emissions from heat in buildings and the grid in a cost-effective manner, alleviating grid demands, creating green jobs in retrofit design and delivery that support local economies and businesses, secure energy supplies and reduce reliance on energy imports, and much more[171].

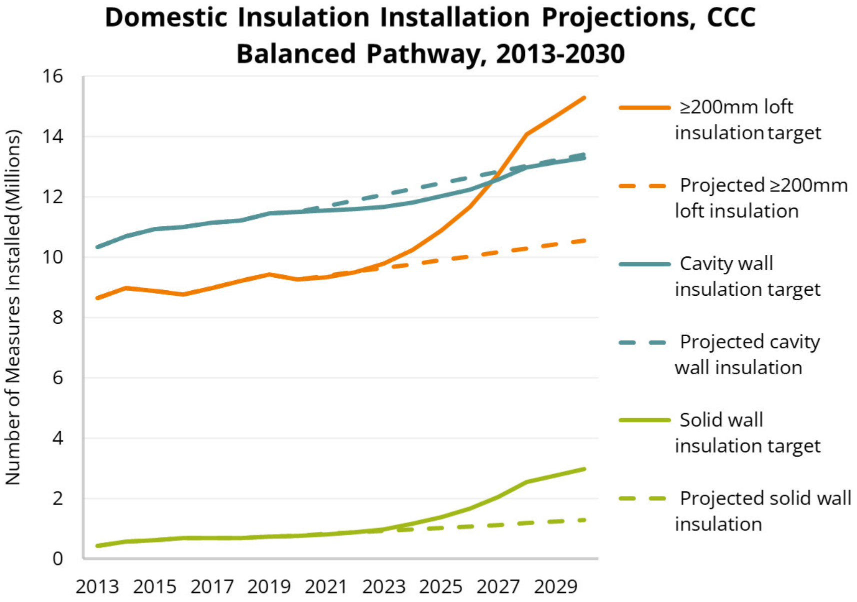


Figure 35: Cumulative projected versus target installed domestic insulation measures, England, using DLUHC's English Housing Survey and the CCC's Balanced Pathway respectively[172,173]. N.B. Actual insulation levels for 2008-2020 taken from English Housing Survey estimates, and projected installation rates are based on the average rates been between 2014 and 2019.

Appendix 2: Practical Challenges To Taking A Technology-Agnostic Approach

This paper has focused on the benefits that can be reaped from government policy taking this approach. However, we are aware that there are challenges inherent in practically delivering policies with more of a bottom-up impetus, and we have outlined some of these challenges below. We are keen to work with Government to find solutions for and help overcome these practical difficulties and deliver this approach to achieve a better Net-Zero 2050.

Data Frameworks

- Implementing this approach is only possible with an evolution or revolution of data frameworks for assessing buildings. Current frameworks, like EPCs and SAP/RdSAP (Reduced Data SAP), are a risk to recommending the best measures in the best combination for buildings. They are also incapable of distinguishing exceptional carbon performance from a standard EPC A.
- For example, SHDF requires the PAS 2035 process for installing technologies, but aims to retrofit to an EPC Band C. The interplay between these two frameworks, and the suitability of EPCs in general, is poor, leading to the potential for the wrong measures to be recommended or in an inappropriate order. PAS 2035 Medium-Term Improvement Plans (MTIPs), aiming at renovating to EPC C, have led to instances where external wall insulation, cavity wall insulation, new doors, new windows, ventilation, and a heat pump were specified, but no loft insulation as it had met EPC C with available funding. The knock-on effects of installations like this can potentially worsen properties and create entirely new issues and health hazards for occupants.

Biomass

- The quality of the fuel burned in biomass boilers is of particular importance for the performance efficiency and level of emissions from a boiler. Decisions, like those taken by BEIS on the RHI174, to suspend fuel quality requirements for biomass boilers pose significant risks for lowered boiler efficiencies and lower indoor and outdoor air quality. Particularly in areas with a high population density, poor air quality is associated with health-related issues and excess mortality.
- Similarly, a lack of enforcement has led to widespread installation of unauthorised wood burning stoves in smoke control zones. These can have high particulate emissions, and are damaging the reputation of quality biomass technologies[175].

Policy Complexity

- If communication pathways through to consumers are not made to be concise and effective, then there are risks associated with overloading consumers with superfluous and unnecessary technical or detailed information. Distilling pathways to Net Zero buildings, and the required alterations needed, into a succinct package of digestible information, or communicated effectively by a retrofit co-ordinator, is key for engaging and educating consumers.
- The pathway to Net Zero buildings is a complex mix of installing many different technologies in many different buildings and in many different ways. Making sure a tailored pathway for each building is communicated, that gives access to greater detail if desired, is a key part of this approach, and one that is yet to be perfected under current policy.

Skills

- As the number of technologies and complexity of different measures required to be installed grows, as does the requirement for effective installer competencies and training programmes.
- Overhauling the skills required for delivering Net-Zero buildings, incorporating a wider spectrum of skills, across a number of different technologies, and looking at a home as a whole system, is a necessary requirement for the Government’s current pathway to Net Zero, but especially so with a more technologically agnostic approach.

Commercial Interests

- In order to install and recommend the most appropriate measures in buildings, individual measure bias must be overcome. Installers of particular technologies must be able to avoid recommending the solution(s) they install if they are truly not appropriate for a building. Technology-agnostic policies will be competing with individual organisations pushing a particular technology.

Appendix 3: Benefits Of Taking A Technology-Agnostic Approach, Collaborator Roundtables

1. **Consumer satisfaction** of having a more diversified supply chain, rather than just single measures; alongside, **increased buy-in and support** from consumers on alternative solutions.
2. Ensuring a **fair solution** for consumers in a 'just transition'.
3. Increased **health and wellbeing** for property owners and householders.
4. Building a **diverse supply chain** and reducing constraints on individual technologies.
5. Having a **diversity of solutions** works better for the UK's **diverse housing stock conditions.**
6. **Unblocks barriers for innovation** as the increased optionality of solutions for buildings will develop innovation pathways for new technologies.
7. Enable buildings to become **energy-positive, active buildings** that materialise a host of additional benefits.
8. Provides the **lowest cost path to decarbonisation** (Government, consumers, etc.).
9. Becoming an **exporter of knowledge** on net zero, low-carbon technologies.
10. It **minimises unintended consequences.**
11. It enables the Government to **deliver its Net Zero targets faster** and more efficiently.
12. It delivers on the 2021 **smart system and flexibility plan**, and it **optimises systems,** which are **lower cost and more effective.**
13. **Building value will** increase (WWF report).
14. It will help further the **Levelling Up** agenda.
15. Increase the **volume of jobs created** as a result of the greater number of supply chains, manufacturing bases and technologies that will be supported.
16. They support good outcomes for:
    - affordability;
    - lower bills;
    - resilience;
    - air quality;
    - grid support; and
    - greater EV rollout.

Appendix 4: Analysis Methodology And Further Results

This appendix details the inputs, assumptions, and formulae used across the analyses found in the main body of the report, as well as those specific to each type of analysis.

Table 1: General inputs used across analyses.

Variable	Value and Unit	Source
Economic Inputs		
Discount Rate (Green Book)	3.5 %	HM Treasury
Discount Rate (Consumer Preference)	19 %	Haq, G. and Weiss, M. (2018)
Cost of Carbon	*Varies over time*	BEIS
Fuel Prices		
Natural Gas	10.30 (p/kWh) + Standing Charge at £102.20/year	BEIS
Electricity (2023) *	*Varies over time*	BEIS
Woody Biomass	6.25 (p/kWh)	SAP
Fuel Carbon Intensities		
Natural Gas	0.2023 (kgCO2e/kWh)	BEIS
Electricity (2023)	*Varies over time*	BEIS
Woody Biomass	0.0530 (kgCO2e/kWh)	SAP

**Electricity has been modelled to revert (via linear trend) to the prior predicted (by BEIS) prices within ten years. Ultimately, this is a simple assumption, but one that is important given the length over which some electric-dependent systems are modelled.*

Appendix 4.1 Archetype Analysis

Up-front costs of each system:

	Archetype A (Flat)		Archetype B (House)	
System	*Size*	*Cost (£)*	*Size*	*Cost (£)*
Natural Gas Boiler	7 kW	1,500	27 kW	2,000
Air-Source Heat Pump	3 kW	7,410	16 kW	17,140
Direct Electric Heating	8 kW (Equivalent)	1,000	N/A	N/A
Biomass Boiler	N/A	N/A	27 kW	16,006
Solar Thermal System	N/A	N/A	15 kW	6,000
Solar PV System	N/A	N/A	6 kW	11,256
Thermal Battery	10.5 kWh	2,190	10.5 kWh	2,190

- The sizing for the natural gas boiler, heat pump, and biomass boiler were all conducted using a proprietary model, which accounts for external temperatures, and the insulation values of the property.
- The solar thermal system had an upper limit of 15kW placed on its design, in order to keep sizes reasonable, and the system within range of external data sources surrounding cost and performance.
- The solar PV system was specified using the HOMER optimisation software, and is predicated on a flat 15 p/kWh feed-in-tariff rate (or Smart Export Guarantee).
- The same thermal battery was specified for both properties, in lieu of acceptable data sources.
- Direct electric costs are assumed at 5 radiators at £200 each — for a total of £1,000.
- Full building specifications can be found using the Tabula WebTool, using codes GB.ENG.AB.07.Gen.ReEx.001, and GB.ENG.SFH.01.Gen.ReEx.001 for archetypes A and B respectively.
- The up-front cost for the heat pump system includes £1,000 worth of radiators, and an appropriate figure of £3,000 of labour cost on the installation of those radiators. This has been done to achieve the MCS minimum sCOP of 2.80.

The performance metrics of each system:

	Archetype A (Flat)	**Archetype B (House)**
System	*Measure of Performance (Unit)*	*Measure of Performance (Unit)*
Natural Gas Boiler	0.87 (sCOP)	0.87 (sCOP)
Air-Source Heat Pump	3.06 (sCOP)	2.80 (sCOP)
Direct Electric Heating	1.00 (sCOP)	N/A
Biomass Boiler	N/A	0.90 (sCOP)
Solar Thermal System	N/A	7,000 (kWh/year) *Initial value*
Solar PV System	N/A	5,577 (kWh/year) *Initial Value*
Thermal Battery	940 (kWh saved per year)	940 (kWh saved per year)

- The solar PV system generates 5,577 kWh per year—a result derived from a combination of NASA insolation data and specialist PV modelling software.
- The same software indicates a household with average consumption behaviours can expect to directly consume 4,109 kWh per year, with the remainder being fed to the grid at a rate of 15 p/kWh.
- The solar thermal system generates 350 kWh per year, per m^2, with a figure of 0.75 kW per m^2 used to convert into a simple kWh per kW per year figure.
- The size of the system has been capped at 15kW, due to poor data availability of costs beyond this point. It therefore works in tandem with the natural gas boiler system counterfactual.
- Annual operation costs for both solar PV and thermal systems are set at 1.5%, whilst annual degradation rates are set at 0.5%.

Results in addition to the ones found in the main body of the report are presented below:

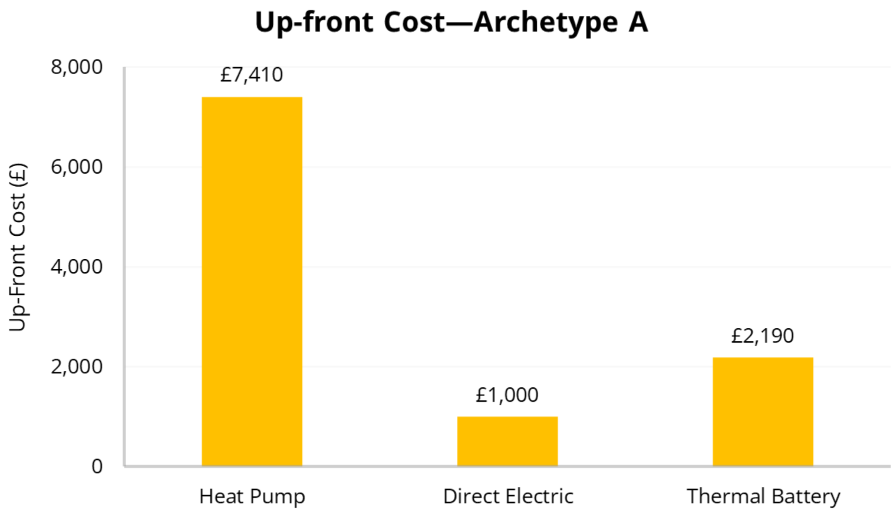


Figure 36: Up-front cost of measures considered in Archetype A.

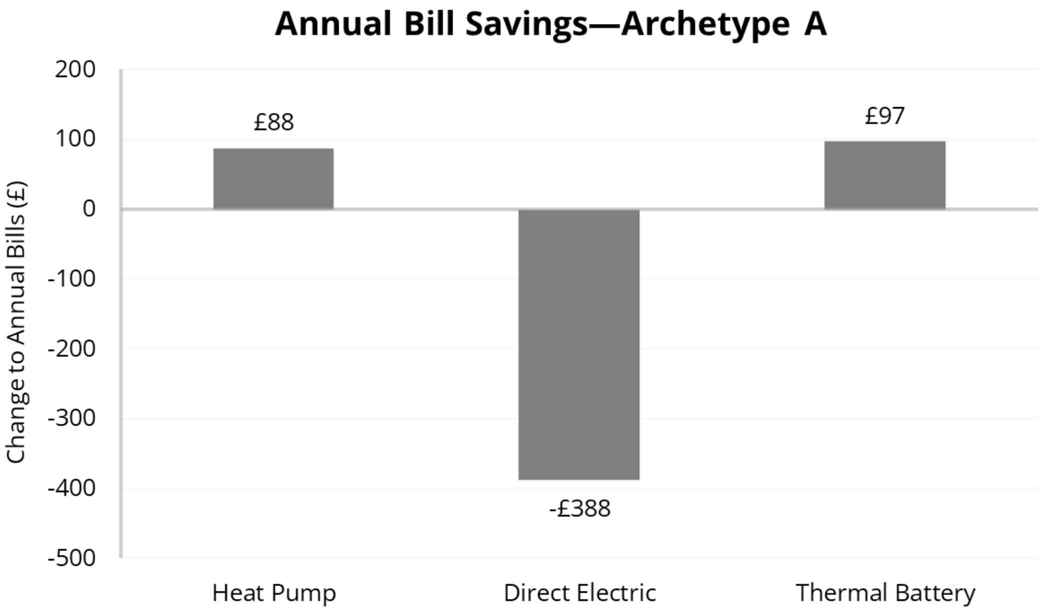


Figure 37: Annual bill savings of measures considered in Archetype A.

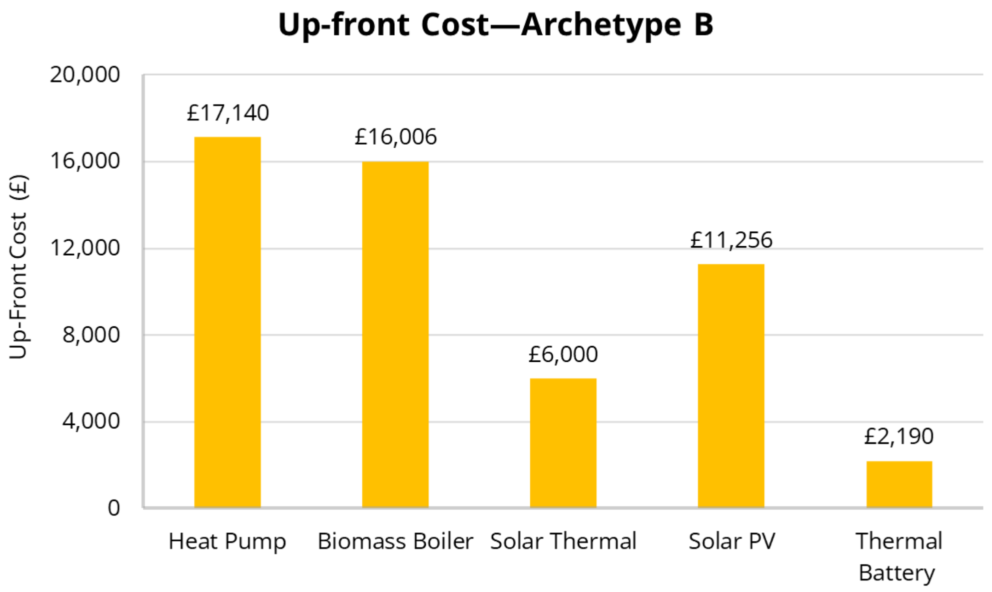


Figure 38: Up-front of measures considered in Archetype B.

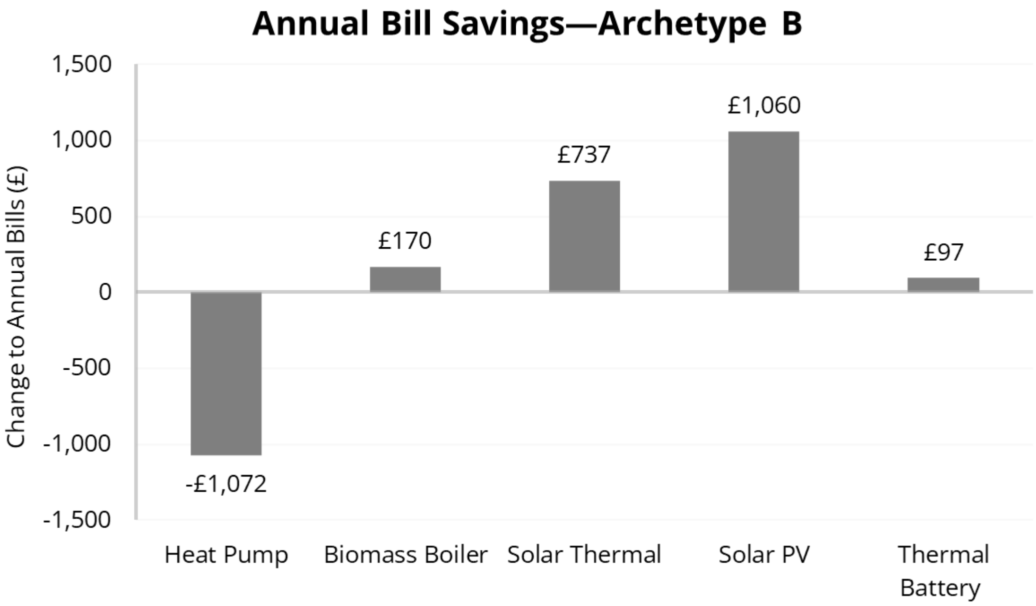


Figure 39: Annual bill savings of measures considered in Archetype B.

Appendix 4.2 Pathway Analysis

The work in this piece of analysis draws most of its inputs from the prior piece. The following table details the performance metrics of each system considered:

Measurement (Unit)	*Natural Gas Boiler*	*Incorrectly Installed Heat Pump*	*Biomass Boiler*
Size (kW)	10	8	10
Efficiency (sCOP)	0.87	1.83	0.90
System Cost (£)	1,700	8,710	12,061

- The incorrectly installed heat pump was incorrectly sized, and with a high flow temperature. The resultant calculation on efficiency was done using the proprietary model mentioned prior.
- Annual heating and hot water demand was set at 11,518 kWh, based on the housing archetype found on the Tabula WebTool, with code GB.ENG.TH.04.Gen.ReEx.001.
- The cost of carbon over time is provided by BEIS.
- The number of rural households requiring retrofit is derived from detailed in-depth analysis, which takes into account UK heat decarbonisation policy, and is sufficiently robust.

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