AFFORDABLE WARMTH

NEXT STEPS FOR CLEAN HEAT IN SCOTLAND

WITH SUPPORT FROM THE MCS FOUNDATION & PEBBLE TRUST

MCS CHARITABLE FOUNDATION

The Pebble Trust

CONTENTS

Summary report by:
Fabrice Leveque
Climate & Energy Policy Manager
WWF Scotland

February 2023

Based on research by *Cambridge Architectural Research* and *CAG Consultants*

With thanks to the many contributions from members of Existing Homes Alliance Scotland and others.

FOREWORD

Our reliance on fossil fuel heating is driving up energy bills and worsening the climate crisis. Scotland can play to its strengths to tackle these challenges – harnessing our abundant renewable energy to electrify heating for a cleaner and brighter future. Significant investment is needed but worthwhile to protect households from unstable fossil fuel prices and to play our part in the fight against climate change.

Our homes account for 30% of Scotland's energy use and a significant part of our climate emissions. Their poor energy efficiency has left too many households struggling to heat cold and draughty homes as the price of fossil fuels has risen. The need to move to cleaner forms of heating has never been more urgent, and yet investment in better energy efficiency and low-carbon homes remains far below what's needed.

We commissioned new analysis to understand Scottish Government proposals to fix this investment gap. We explored the impact on households, and the climate, of proposed requirements to improve insulation and fit low-carbon heating systems in homes. The findings of that work, and the policy recommendations we developed using them, are summarised in this report.

It shows that energy efficiency, electric heat pumps and heat networks can help cut energy bills and lower carbon emissions. With energy prices likely to remain elevated, these solutions are our best strategy to minimise fuel poverty and tackle climate change at the same time.

Scotland is by no means going it alone and is following in the footsteps of other European nations in putting an end to fossil fuel heating. This report shows how policies to increase investment in cleaner heating can be designed to ensure a fair transition at the pace required of our climate change targets. There's no time to waste: we can capitalise on our abundant renewable resources to create warmer and healthier homes for everyone living in Scotland.

KEY FINDINGS

We commissioned external experts to evaluate the different options available to decarbonise home heating. Using their results, our assessment is that electric heat pumps, heat networks and energy efficiency should be at the core of Scotland's strategy.

HOW SHOULD WE DECARBONISE SCOTLAND'S HOMES?

Modelling of typical Scottish homes reveals that air source heat pumps are the lowest cost and most versatile electric solution.

Shared systems like heat networks and communal heating may provide greater flexibility where individual heat pumps systems are less suitable. And energy efficiency reduces household energy bills and makes heat pumps cheaper to run. These are mature technologies that can be rolled out now, help protect consumers from unstable fossil fuel prices and fuel poverty, deliver genuine emissions reductions without putting the decarbonisation of other sectors at risk.

We also commissioned analysis on the potential for **hydrogen heating** in Scotland. It found that if available at all**, deployment at scale is unlikely to be possible until the mid-2030s.** It is also likely to be much more expensive to run than natural gas heating. Using hydrogen for heating also creates wider risks: it could divert hydrogen supply from more critical uses in the economy such as heavy industry, heavy transport and peak power generation.

ELECTRIC HEAT PUMPS, HEAT NETWORKS AND ENERGY EFFICIENCY SHOULD BE SCOTLAND'S STRATEGY.

WHAT ARE THE BEST ELECTRIC HEATING SOLUTIONS?

We asked experts at Cambridge Architectural Research to explore the performance and costs of energy efficiency and electric heating across all of Scotland's housing stock. Performance was assessed using 'typical homes' and powerful energy modelling at hourly intervals across a year, using Scottish weather data, to give as accurate a picture as possible. They found that:

HEAT PUMPS WILL DRASTICALLY CUT HOMES' ANNUAL CARBON EMISSIONS,

Homes' annual carbon emissions by up to 90%. Scotland's electricity sector is already largely decarbonised, enabling heat pumps to be ultra-low carbon today.

HEAT PUMPS CAN BE FITTED IN ALMOST ALL TYPES OF SCOTTISH HOME, INCLUDING SMALLER, OLDER AND HERITAGE HOMES.

Potential challenges to installing heat pumps in homes were explored – such as limited internal space for a heat pump and/or hot water tank, and where planning rules may limit insulation in heritage homes. In both cases cost-effective alternatives such as air to air heat pumps (see results section for an explainer) and internal wall insulation were found.

HEAT NETWORKS MAY HAVE ADVANTAGES OVER INDIVIDUAL HEAT PUMPS IN FLATS AND TENEMENTS.

It is possible to install individual heat pumps in flats, but there are extra challenges to doing so that shared systems like heat networks and communal systems (potentially receiving heat from large heat pumps) could overcome. Information should be provided to households by the Scottish Government or local authorities on the potential for shared heating solutions in local areas by 2025.

WHAT ROLE FOR ENERGY EFFICIENCY?

The study provides an answer as to the 'optimal' level of energy efficiency when fitting a heat pump. Looking at costs over 15 years, a usually moderate investment in energy efficiency more than pays for itself, by lowering energy demand and helping heat pumps run more efficiently. Up to 80% of all homes would benefit from low-cost draught proofing, and half should improve insulation with moderate cost measures like loft and cavity wall insulation and double glazing. Average costs in these cases are £1,800 per home. Wall insulation is also very cost effective in the 12% of houses with solid walls. Average costs are £9,200 but these are recouped within 15 years.

Scottish Government proposals to set minimum energy standards for all homes will help ensure that energy bills are lower with heat pumps.

The Government has committed to reform energy performance certificates to make them fit for purpose for net-zero and we recommend that the minimum standards should be set as a maximum demand for space heating, set between 65-85 kWh per m2 per year. This is roughly three-quarters of typical energy for heating in Scottish homes now, and broadly equivalent to an Energy Performance Certificate (EPC) rating of 'C'. Some variation in the standard will also be needed to account for smaller and more modern dwellings. Solid wall insulation is recommended for houses, but given challenges with costs and visual impact, it could be made an optional measure for some properties. We also recommend that interim standards be set requiring draught proofing, loft insulation and better glazing in flats. As well as cutting energy and carbon, energy efficiency brings many other benefits including reduced risks of fuel poverty and reduced electricity demand at peak times.

ENERGY PRICES IN THIS REPORT

These findings are sensitive to energy prices. The prices used are broadly consistent with medium-term forecasts (at the time of writing) which suggest that prices will fall from a peak in late 2022 but remain higher than pre-crisis levels in the medium term. This provides a rough, albeit uncertain, indication of costs in 2025, when proposed Scottish Government regulations should enter force. The assumptions underpinning these results are set out in the 'energy prices' section.

WHAT WILL HEAT PUMPS COST?

It is estimated that heat pumps could lower energy bills in a majority of houses when regulations enter force in 2025.

Energy prices play a crucial part in this and at present are very uncertain – but policy changes by the UK Government could help ensure that heat pumps are cheaper. All the typical houses in the study starting with oil and electric storage heating, and just over half of those on gas, make savings. Where bills increase, these are modest and there are options to reduce them. Regulation could first target homes that can win immediate savings on energy bills – those with oil and old, non-condensing, gas boilers.

Recent UK Government policy changes are already making heat pumps cheaper to run, and further reforms could cut costs further.

The removal of UK Government policy costs from electricity bills has helped to reduce heat pump costs and was factored into these estimates. Electricity prices can be reduced further by reforming the electricity market to remove the influence of high gas prices, which have been the primary driver of electricity price rises since 2021.

Upfront heat pump costs are estimated to start at £4,500 with Government grant support, which should continue until costs reduce.

Some of these upfront costs are a one off due to the change of heating system and costs are likely to fall as supply chains expand and mature. Costs for the air source heat pumps begin at £12,000 (excluding Government grants) and so Scottish Government support (which presently starts from £7,500 per household) will continue to be crucial alongside regulation. Grants should be reduced over time as costs reduce.

ARE SCOTTISH GOVERNMENT PROPOSALS ENOUGH?

Regulations proposed by Scottish Government in the *Heat in Buildings Strategy* are a vital step to accelerate the roll out of energy efficiency and low carbon heating. They would require households to make energy efficiency and heating system upgrades at key points such as the purchase of a house or the replacement of a boiler. Regulations can drive demand, help costs to reduce and enable households to recoup their investment through higher house values. Using the modelling results, we evaluated the emissions impact of the proposals and found that they would miss our crucial 2030 climate target. Annual emissions from homes in 2030 could be over double (2.6 million tonnes) the Government's ambitions.

Closing this gap will require earlier deadlines for action through regulation and this should be done fairly, with households supported by Government. We estimate the total capital expenditure required to 2030 at between £23.5bn and £26.5bn – our proposals for regulation and funding would see half of this paid by Government and half paid by homeowners and landlords. As well as meeting climate targets, this scenario would likely see all fuel poor homes receive energy efficiency improvements, and a third heat pumps, helping lower their energy bills. Our scenario does not factor in the ability of supply chains to adapt and deliver at this scale and speed but their ability to do so will be aided by clear targets and the certainty of demand that regulation can provide. Public funding and other constraints will make delivery of the full set of proposals challenging. But it needs to be done if we're to have any chance of meeting climate targets and creating warm, high-quality housing on a par with European equivalents. We set out our recommendations below:

KEY RECOMMENDATIONS FOR SCOTTISH GOVERNMENT

1. Alongside regulation, help households with the upfront costs of required heating and energy efficiency measures

Fuel poor households should receive fully funded upgrades and upfront grants should be provided to others for heat pumps and energy efficiency improvements at current levels until costs reduce. Grant uplifts for rural homes should be maintained, and Scottish Government should investigate the need for an uplift for some smaller homes. Many households will need to borrow to pay for upgrades and Government can make this more affordable by extending current zero-interest loans and facilitating new private lending mechanisms such as green mortgages.

2.Increase ambition by requiring earlier action

Current Scottish Government proposals for regulation aren't enough to meet our climate targets. We need to accelerate action and recommend that this be done by:

- **Energy efficiency:** include flats in minimum standards and bring forward the deadline for all homes to meet minimum standards by 2030.
- **Earlier gas boiler phase-out:** prevent the purchase of houses with old (non-condensing) gas boilers from 2025, with all replacements of gas boilers (houses only) phased out from 2027.
- **Off-gas boiler phase out:** set a deadline for the replacement of all remaining coal, oil and LPG boilers (houses only) by 2033 (in addition to the proposed phase out of new replacements of such boilers from 2025).
- **Heat pumps in social housing:** set a target for social landlords to replace 30% of gas boilers by 2030.
- **Encourage early adopters:** continue grants and encourage households on gas to move to heat pumps before regulation requires it.
- **Heat networks:** provide information to households on the potential for shared heating solutions in their local area by 2025.

3. Hydrogen for heating should play a minimal role, if at all

Any support to further explore and develop this use of hydrogen should acknowledge the minimal role it is likely to play and must not distract or delay the roll-out of the established solutions we can deploy today: energy efficiency, electric heat pumps and low-carbon heat networks.

The Scottish Government has committed to publishing the next steps for its regulatory framework in 2023 – it is vital that this is done rapidly to give householders and industry clarity about the future and to prepare for the regulations taking effect from 2025. The investment required may be significant, but this will be dwarfed by the costs of failing to act on climate change.

Creating warm, liveable and climate friendly homes for people in Scotland is the right investment to make.

UK Government also has an important role to play. It must:

- **Confirm how policy costs will be removed from electricity bills on a permanent basis,** beyond the current approach via the Energy Price Guarantee.
- **Reform electricity markets to prevent high gas prices pushing up power prices.** The recently launched review of electricity market arrangements should consider existing proposals for rapid reforms as well as longer term changes that could reduce electricity prices.
- **Deliver proposals to expand heat pump deployment after 2024:** plans to regulate boiler manufacturers to provide a proportion of heat pump sales would likely apply across the UK and could help fund deployment in Scotland. The UK and Scottish Governments should collaborate to ensure that both sets of regulations work together.

ELECTRIC HEAT PUMPS, COMBINED WITH SOME INSULATION IMPROVEMENTS, ARE THE CHEAPEST WAY FOR MOST SCOTTISH HOMES TO ACHIEVE THE CRUCIAL CUTS IN CLIMATE EMISSIONS THAT WE MUST ACHIEVE BY 2030.

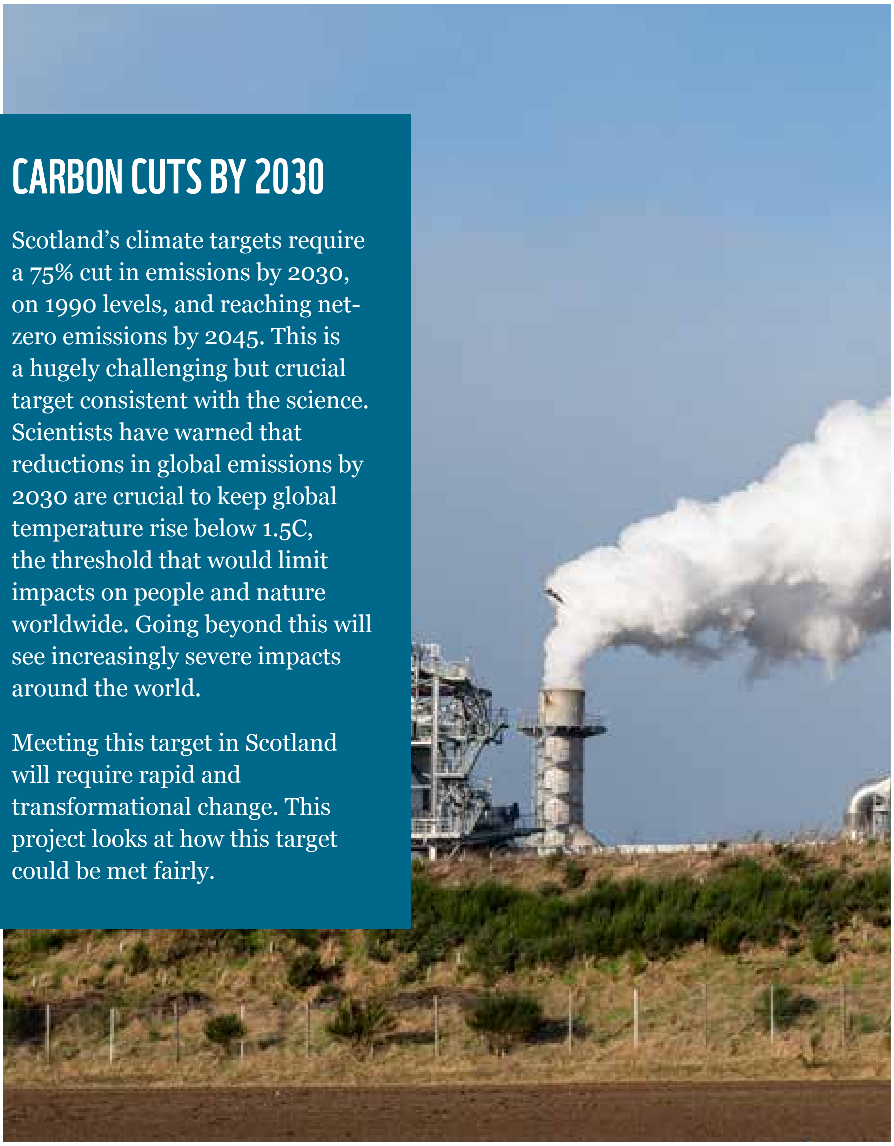
CLIMATE AND COST OF LIVING CRISIS

The gas and oil boilers in our homes contribute to climate change and as events since 2022 have shown, leave us exposed to unstable prices and rising fuel poverty. But we can tackle the climate crisis and the cost of living crisis at the same time. Low-carbon heating and energy efficiency can lower energy bills and end our reliance on fossil fuels

CARBON CUTS BY 2030

Scotland's climate targets require a 75% cut in emissions by 2030, on 1990 levels, and reaching net-zero emissions by 2045. This is a hugely challenging but crucial target consistent with the science. Scientists have warned that reductions in global emissions by 2030 are crucial to keep global temperature rise below 1.5C, the threshold that would limit impacts on people and nature worldwide. Going beyond this will see increasingly severe impacts around the world.

Meeting this target in Scotland will require rapid and transformational change. This project looks at how this target could be met fairly.



Credit © AdobeStock

We need to accelerate the pace of action: today only 11% of Scotland's 2.5 million homes have low carbon heating and around half are below recommended standards of energy efficiency. As energy prices have risen, this has contributed to the unprecedented rise in fuel poverty, which now affects around 35% of households. One in every four pounds spent heating a poorly insulated home is wasted through leaky roofs, walls windows and floors. As a result, climate emissions from housing have fallen only 2% since 2015.[1] To meet our targets we'll need to convert around a million homes to zero carbon heating by 2030, as part of global efforts to avoid the worst impacts of global warming.

ONE IN EVERY FOUR POUNDS SPENT HEATING A POORLY INSULATED HOME IS WASTED THROUGH LEAKY ROOFS, WALLS, WINDOWS AND FLOORS.

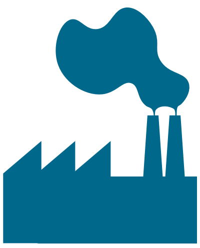
GOVERNMENT PROPOSALS

To increase investment in homes, the Scottish Government has proposed regulations that would require homeowners and landlords to fit energy efficiency and low carbon heating at specified points, such as the purchase of a house or replacement of a boiler. These proposals are a crucial step to secure the scale of investment that is needed, which cannot be funded by Government alone. Such regulations can drive private investment and will allow public funds to be prioritised. This is crucial, given the need for increased public investment to make the transition to cleaner heating fair, and at the pace required to meet our climate targets.

Whilst the last few years have seen a welcome increase in Scottish Government ambitions with publication of a 'Heat in Buildings Strategy' in 2021, we're yet to see this translate into the increased activity that is needed. In its 2022 report to the Scottish Parliament, the UK Climate Change Committee (UK CCC) noted Scottish Government's high ambition but cautioned that it 'does not have sufficient policies in place' to deliver these. Implementing these proposals is critical to addressing this. Time is of the essence – proposals have been in development for many years (see box) but clarity is now needed to enable households and industry to plan and invest.

THE RESEARCH

WWF Scotland commissioned this project to better understand the costs and practicalities of the Scottish Government's proposals and how they could best be designed to accelerate the transition to cleaner heating and make it affordable. We commissioned Cambridge Architectural Research (CAR) to provide in-depth modelling of Scotland's housing stock and low carbon solutions. They looked at which combination of options could decarbonise homes at lowest cost, and the upfront and energy bill impacts of doing so. Separately, we commissioned CAG Consultants to provide a review of the evidence regarding the potential to use hydrogen for heating homes. This report summarises the results of both pieces of research, and the policy recommendations we've developed using them.



EMISSIONS REDUCTIONS BY 2030 ARE CRUCIAL TO KEEP GLOBAL TEMPERATURE RISE BELOW 1.5C

A LONG ROAD TO GET HERE...

2007

An expert panel, chaired by Lynne Sullivan, is appointed by Scottish Government to recommend steps to improve the energy performance and reduce carbon emissions from new and existing buildings in Scotland.[2] WWF Scotland calls for Government programmes and regulation to drive greater investment in existing homes[3].

2009

Scotland's first Climate Change Act is passed.

2015

Scottish Government declares energy efficiency a National Infrastructure Priority, after sustained campaigning by a coalition of housing, health and environmental organisations[4].

2018

Scottish Government consults on the setting minimum standards of energy efficiency for all homes as part of a long-term programme to improve the housing stock.

2021

Heat in Buildings Strategy Published ahead of COP26 in Glasgow. A Heat Networks Act is passed into legislation, after many years of campaigning[5].

EVALUATING THE OPTIONS

WWF Scotland commissioned external experts to evaluate the different options available to decarbonise home heating. Using this research, our assessment is that electric **heat pumps, heat networks and energy efficiency** should be the core of Scotland's strategy. These are mature technologies that can be rolled out now, that can help protect consumers from unstable fossil fuel prices and fuel poverty, deliver genuine emissions reductions and won't put the decarbonisation of other sectors at risk.

THE OPTIONS

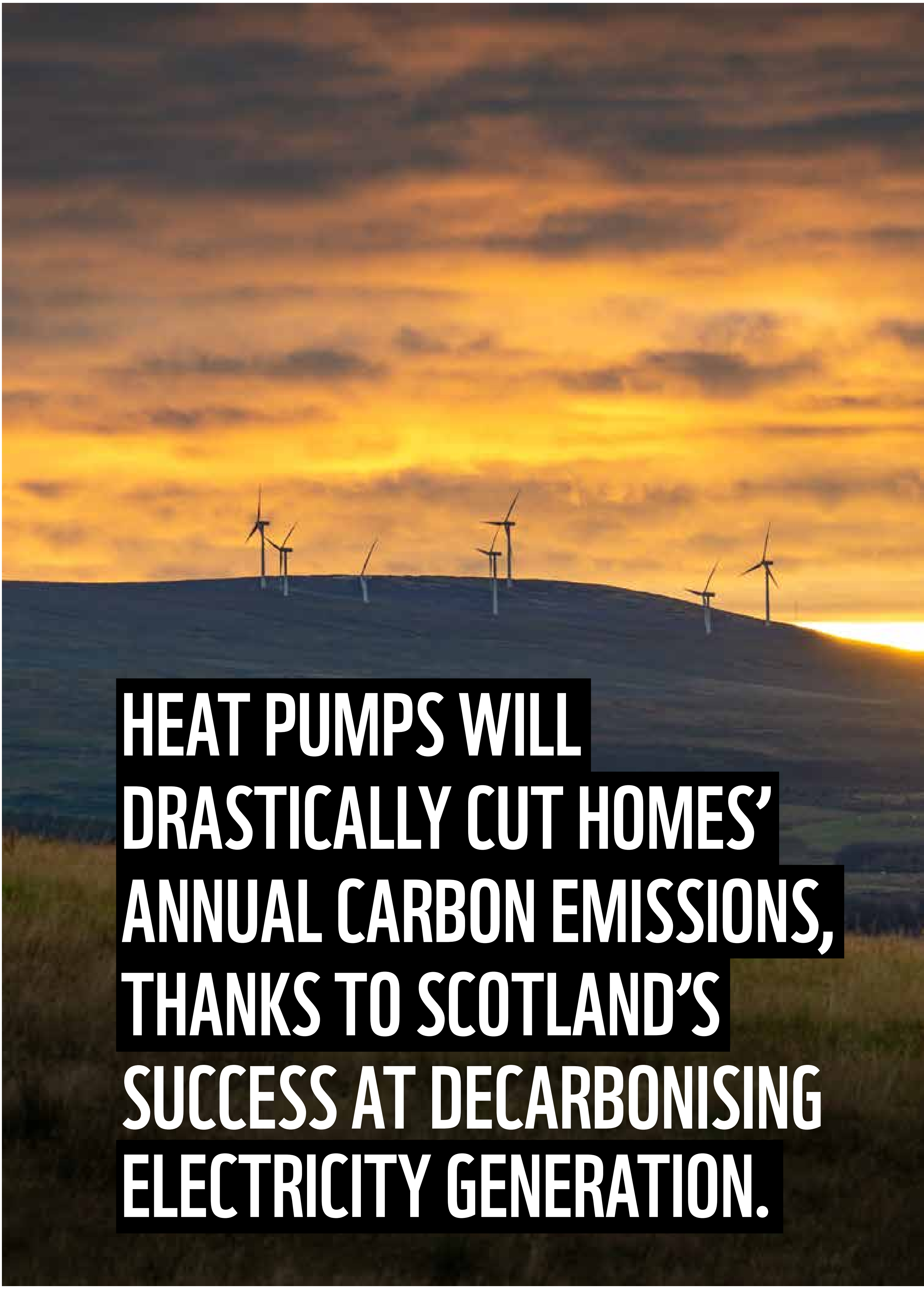
There are three groups of heating technology that could replace fossil fuel boilers: electric heating, boilers burning low-carbon hydrogen and bioenergy (biomass or biogas), alongside energy efficiency improvements to homes. Shared systems like heat networks are a further option to deliver heat to buildings less suited to the installation of individual systems, such as those located in densely packed centres of towns and cities and tenements or tower blocks. These systems pipe heat from any of the sources described above to multiple units within a large building (communal heating) or multiple buildings (a heat network).

OUR ASSESSMENT

We commissioned detailed modelling of typical Scottish homes to examine the electric heating options and energy efficiency to identify which are most suitable and cost effective. The modelling also looked at their suitability in flats and tenements, as an alternative to the use of heat networks. The results, which are outlined in the rest of this report, show that air source heat pumps are the lowest cost and most versatile option, with energy efficiency helping to reduce overall costs. The results for flats and tenements suggest that there are challenges of fitting individual systems in these types of dwellings - these could be mitigated by using shared systems. We also commissioned separate analysis of the evidence regarding the potential for hydrogen heating in Scotland, discussed below.

Bioenergy was not included in the modelling because home heating is not recommended as a major use of sustainable bioenergy. The UK Climate Change Committee recommends that its use in heating be minimised[6], given the importance of bioenergy and the resources used to make it for decarbonising other sectors of the economy. For example, bioenergy could be used in heavy industry, transport and aviation and input resources will also be in demand for construction, packaging and livestock feed. Moreover, bioenergy production must be carefully managed to ensure it delivers genuine emissions reductions and does not displace food production.

AIR SOURCE HEAT PUMPS ARE THE LOWEST COST AND MOST VERSATILE OPTION



HEAT PUMPS WILL DRASTICALLY CUT HOMES' ANNUAL CARBON EMISSIONS, THANKS TO SCOTLAND'S SUCCESS AT DECARBONISING ELECTRICITY GENERATION.

WHAT ABOUT HYDROGEN?

In future it may technically be possible to use boilers to burn low carbon hydrogen delivered through existing gas networks (with modification or replacement to make them suitable). Gas network companies and boiler manufacturers heavily promote hydrogen as an alternative to the mass-roll out of heat pumps as a way of capitalising on gas infrastructure already in place.

LITERATURE REVIEW

We commissioned external experts CAG consultants to evaluate the evidence on the potential for hydrogen heating in Scotland. Hydrogen heating has yet to be fully demonstrated or commercialised, and the evidence on its feasibility and costs remains limited. CAG explored three questions: the timescales over which it could become available for mass deployment, the potential impact on household costs and how infrastructure requirements may determine where it is developed. The full report can be accessed on our website here. The researchers found that:

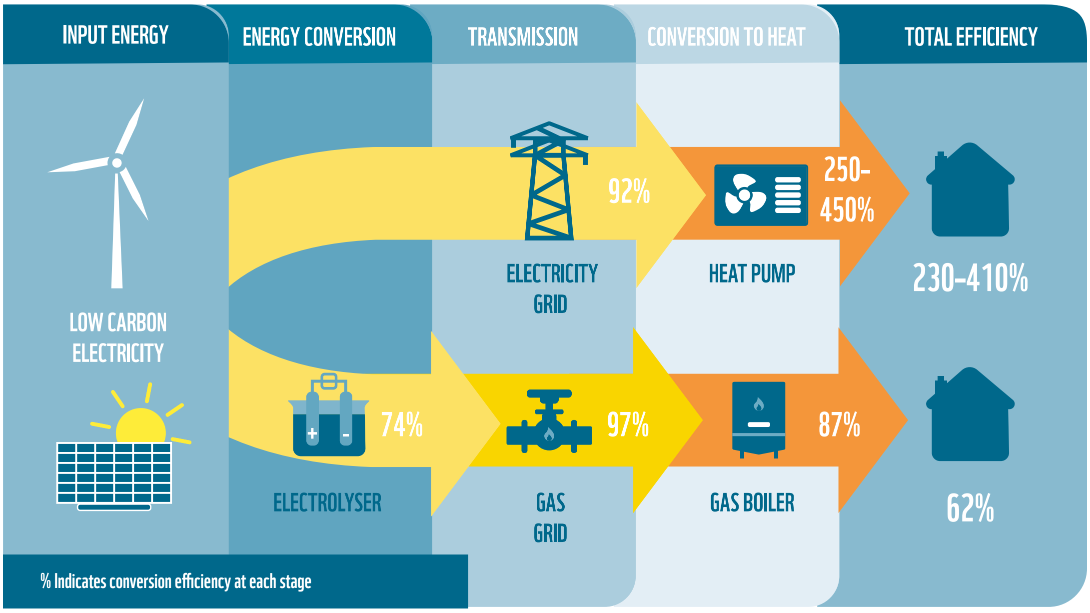
- **Hydrogen heating, (if ever available for mass deployment), would be unlikely to roll out widely until the mid-2030s:** this is due to key infrastructure and policy lead-times: making the safety, public acceptability and economic case through neighbourhood, village and town scale pilots; completion of hydrogen production, transportation and storage infrastructure; and time for 'hydrogen-ready' boilers to diffuse amongst the housing stock in appropriate areas. It will not therefore help meet crucial 2030 climate targets.

- **Running costs to households are likely to be high:** even with optimistic assumptions about cost reduction, it seems clear that energy bills for consumers using hydrogen will be significantly higher (estimated at two- or three-times (pre-crisis) gas prices). Any strategy that commits households to hydrogen heating at this early stage risks exacerbating fuel poverty. Households will also face other costs beyond the replacement of a boiler, including additional ventilation and safety testing in the home and replacement of other gas appliances (hobs, cookers) at the same time. Given the high likely cost of hydrogen, studies also indicate that it would be cost effective to bring all homes to a good level of energy efficiency.

- **Hydrogen could initially be available at or near industrial clusters:** conversion of large areas of the gas network will require large amounts of hydrogen, as well as transport and storage infrastructure. Many current projects and policy support are focussed on developing industrial uses of hydrogen, and it is therefore likely that infrastructure will develop at these sites earliest. In Scotland plans are most advanced at St Fergus, to blend up to 2% 'blue' hydrogen (made from fossil gas and requiring carbon capture and storage technology) into the gas network. There are longer-term plans to extend infrastructure to Aberdeen, but this is dependent on UK Government funding for which key projects were unsuccessful – these may not now become operational until 2030.

As well as those outlined above, there are wider risks facing the use of hydrogen heating:

FIGURE 1. RELATIVE EFFICIENCY OF HEATING: ELECTRICITY IN HEAT PUMPS VS ELECTROLYTIC HYDROGEN IN BOILERS (ADAPTED FROM THE UK CCC)



The diagram shows the indicative efficiency of using a given amount of zero-carbon electricity in delivering heat for buildings. Whilst in practice each of the efficiency numbers could vary, this would not be sufficient to change the conclusion that heat pumps provide a much more efficient solution for providing heat from zero-carbon electricity than use of electrolytic hydrogen in a boiler.

PRIORITISE LOW-CARBON HYDROGEN ELSEWHERE

Heating homes with hydrogen could create very significant demand that risks competition with more critical uses of hydrogen across the economy. These include heavy industry, heavy goods transport, electricity generation at times of peak demand and potentially aviation. The UK CCC has said that given likely costs and constraints on the production of low carbon hydrogen it is 'important for it to be focussed on the applications of highest value, where electrification is less feasible'[7].

INCREASED PRESSURE ON RESOURCES

In heating, hydrogen has a disadvantage in comparison to electric heat pumps due to the inefficiency of the process. Figure 1 shows how a system using heat pumps would generate two to four units of heat per unit of electricity consumed. A system using hydrogen boilers would generate just two-thirds of a unit of heat for each unit of electricity, due to inefficiencies in converting electricity into hydrogen and then into heat. This would require significantly more electricity generation capacity, with knock on impacts on land, sea and resource use.

WHAT SHOULD SCOTTISH GOVERNMENT DO?

Any Scottish Government policy support for the further exploration of hydrogen heating must not discourage investment by industry and households in more established solutions like heat pumps.

The vast majority of available evidence indicates that using hydrogen for heating carries significant risks to heat and wider decarbonisation[8] - it should therefore play no or a very limited role. Even a very limited role for hydrogen rests on the outcome of UK Government led village and town pilots, and decisions on the future of the gas grid. However, current policy support for hydrogen and mixed messaging risks discouraging investment by industry and homeowners in the established technologies that we have available now.

The Scottish Government continues to support plans for 'blending' hydrogen into the mains gas network (e.g. at St Fergus) but the UK CCC has warned[9] that this is not a key step for developing full hydrogen heating because going above a 20% mix will require substantial modifications to grid infrastructure.

Similarly, gas boilers with the ability to convert to hydrogen in future ('hydrogen ready boilers') could become available to buy within a few years. Consumers with these boilers could be given the impression that no further changes to their heating system are required. These boilers should not comply with regulations requiring an end to the use of fossil fuel heating. We welcome the position taken in the Draft Energy Strategy (January 2023) by the Scottish Government that it 'does not consider that hydrogen will play a central role in the overall decarbonisation of domestic heat' but caution that its continued support for some uses of hydrogen heating (e.g. blending, in small networks in remote towns) risks delaying and distracting from the deployment of more established solutions.

HOMES & ENERGY MODELLING

We commissioned experts Cambridge Architectural Research (CAR) to model typical existing Scottish homes and the housing stock, and the potential to fit electric heating and energy efficiency, to answer the following questions:

- What are the lowest cost solutions to decarbonise typical Scottish homes?
- What are the upfront and running costs and what emissions savings will be achieved?

The analysis was conducted in several stages. First, typical homes (archetypes) were created to represent the most common Scottish homes. Next, their 'baseline' energy use with gas and oil boilers and electric storage heaters was modelled, as was the performance of alternative electric heating solutions and energy efficiency. Finally, an optimisation process was used to determine the lowest overall cost solutions for each home. The following section summarises the approach – the full details can be found in the research report on our website.

HOMES MODELLING

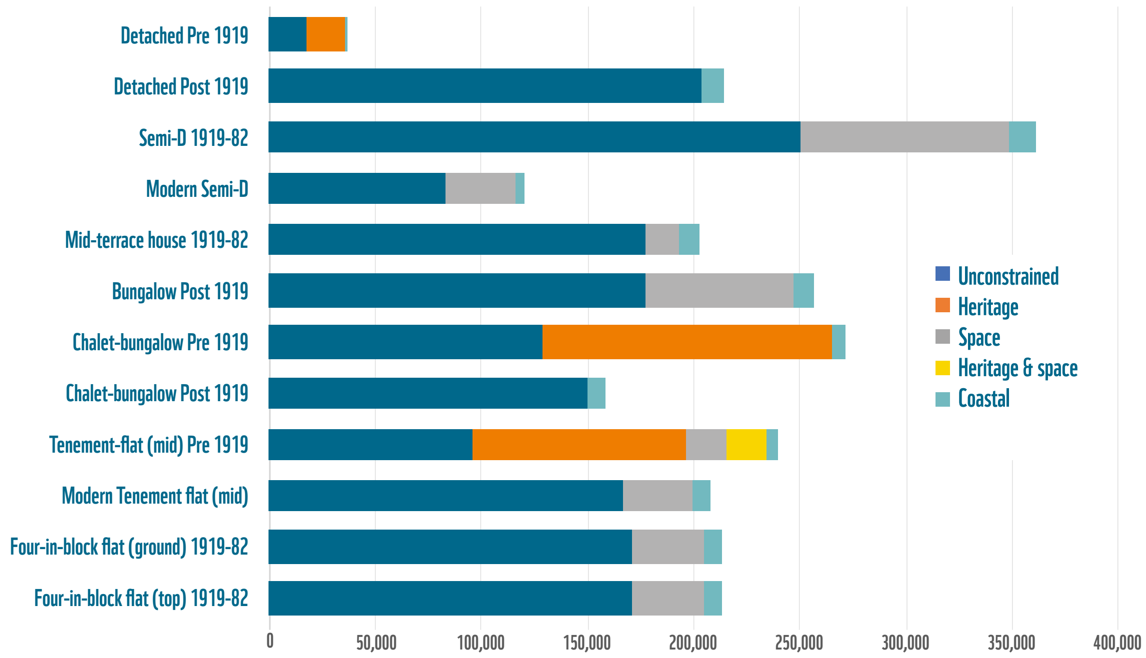
Twelve representative house types were developed for the model from data in the Scottish House Condition Survey (2019). The house types are set out in Table 1 and closely represent, in terms of geometry, 93% of the stock. This approach focusses on a relatively small number of house types to investigate in great detail the performance and options of each. The modelling is robust and in-depth, but the results are influenced by many assumptions such as the physical property of buildings, occupants' energy use, equipment performance and so on – full details can be found in the full report.

To work out total energy and carbon savings the typical homes were scaled to match Scotland's housing stock and data on total energy use. Total numbers of the homes in the model are set out in Table 1 and Figure 2. As well as proportional numbers of typical homes starting with gas, oil and electric heating an additional subset were modelled with 'constraints'.

TABLE 1. DESCRIPTION OF THE TWELVE 'TYPICAL HOMES' USED IN THE MODELLING

1. DETACHED PRE 1919 SOLID WALLS FLOOR AREA: 257M2 NUMBER: 37,000		**2. DETACHED 1919-82** CAVITY WALLS 158M2 214,000	
3. SEMI DETACHED 1919-82 CAVITY WALLS 102M2 361,000		**4. MODERN SEMI-D POST 1982** CAVITY WALLS 98M2 121,000	
5. MID-TERRACE HOUSE 1919-82 CAVITY WALLS 94M2 202,000		**6. BUNGALOW POST 1919** CAVITY WALLS 105 M2 256,000	
7. CHALET-BUNGALOW PRE 1919 SOLID WALLS 157M2 271,000		**8. CHALET-BUNGALOW POST 1919** CAVITY WALLS 137M2 158,000	
9. TENEMENT-FLAT (MID) PRE 1919 SOLID WALLS 82M2 240,000		**10. MODERN TENEMENT FLAT (MID)** CAVITY WALLS 69M2 208,000	
11. FOUR-IN-BLOCK FLAT (GROUND) 1919-82 CAVITY WALLS 70M2 213,000		**12. FOUR-IN-BLOCK FLAT (TOP) 1919-82** CAVITY WALLS 70M2 213,000	

FIGURE 2. NUMBERS OF TYPICAL HOMES AND CHARACTERISTICS



Note: the heritage and space constrained categories also contain some coastal homes

POTENTIAL CONSTRAINTS TO FITTING HEAT PUMPS

Three potential challenges to the installation of heat pumps were identified[10] and explored in the modelling by applying three constraints, below, to some of the typical homes (see figure 2 for totals). These constraints are:

Smaller homes that might struggle to fit internal heat pump equipment, a hot water tank (if not already present) and/or internal wall insulation. In these cases, only Air to Air heat pumps or storage radiators, and only internal insulation for solid walls can be selected. Where a hot water tank is not present, instant hot water heaters are selected. This risk is estimated to affect homes with an average room size below 18m2,[11] about 14% of the stock.

Heritage homes: current planning rules for heritage homes are not expected to greatly impact on the choice of heating system but do limit the use of external wall insulation on listed buildings or those in conservation areas. In these cases, the modelling can only select internal wall insulation. This affects some solid wall homes, around 10% of the stock.

Coastal environment: homes within five miles of the sea, which poses a higher corrosion risk to external heat pump equipment. The model adds £1000 to upfront costs for corrosion-resistant heat pumps. This affects 5% of homes.

OPTIONS ANALYSIS

The consultants used a powerful and adaptable model to calculate energy use in the typical homes before and after upgrades were applied. It is a full dynamic simulation model, carrying out calculations of air and surface temperatures at hourly intervals through the year, using heat pump performance data at different temperatures to provide a robust assessment.

Finally, energy efficiency and heating system upgrades were assessed together (there are a total of 7,200 combinations in the model) **to find the lowest overall cost solutions over 15 years** (the minimum lifetime expected of heat pumps[12]). Real-world data for heat pump installation costs in Scotland[13] was used and calculations also included energy, maintenance and replacement costs. All modelling work included checks on achieved thermal comfort – so that energy and carbon savings do not come as a result of under-heating or discomfort.

Ofgem caps for gas and electricity prices were used (at April 2022 values – see section seven for more detail). UK Government policy costs were removed from electricity prices to reflect commitments to do so. A discount rate of 3.5% a year (consistent with rates used by the UK's Governments) was applied to future costs to mimic consumer preference (which tends to value money now more than in the future). Upgrade options are set out in the box.

UPGRADE OPTIONS IN THE MODEL

BASELINE HEATING SYSTEMS

- Gas boiler
- Oil boiler
- Electric storage radiator

HEATING SYSTEMS

- Air source heat pump (low and high temperature)
- Air to air heat pump (see box in section 5)
- Modern electric storage radiator
- Direct electric (using infra-red panels, controlled using temperature)

ENERGY EFFICIENCY MEASURES

- Solid wall insulation (external or internal)
- Cavity wall insulation
- Loft top up (150mm to 300mm)
- High efficiency glazing
- Suspended timber floor insulation
- Draught proofing

ANCILLARIES

- Larger radiators
- New hot-water cylinder
- Wet central heating system (if not already present)
- Removal of radiators
- Instantaneous electric water heaters

OMITTED

- Ground source heat pump*
- Solar PV panels*
- Batteries: electric* or thermal (heat)

Biomass/biogas and hydrogen boilers were not included (see previous section for details). LPG boilers, solar thermal panels and heat batteries were not included to limit the scope of the modelling.

*Included in preliminary analysis

WHAT WASN'T INCLUDED?

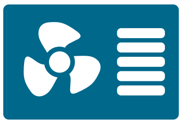
It is complex to model **heat networks and communal heating systems** and these were beyond the scope of the study. By including flats and tenements we were however able to assess their suitability for individual heating systems. **LPG boilers, solar thermal panels** and **heat batteries** were excluded for the same reason.

Ground source heat pumps were modelled, but they were never cost-optimal over 15 years because capital costs are much higher than heat pumps using air as the heat source. The efficiency of such systems is higher, so running costs are lower, because the ground temperature stays warmer than outdoor air in winter. This means that where the budget and site allow, they may be preferred in the real world.

Solar PV was also included in early modelling work and always selected, as high electricity prices meant that energy bill savings pay back the upfront capital costs within 15 years. However, it was removed from the project because, from a carbon reduction perspective and where household budgets are limited, funds should prioritise replacing heating systems and energy efficiency before investing in additional technology like solar PV. The early results show that where a homeowner can afford PV as well as heating and efficiency upgrades, it is beneficial to install it. Conversely, the early modelling work found that **electric batteries** were never economically viable over 15 years (partly because they need to be replaced after 10 years, so there are further capital costs downstream).

RESULTS: THE BEST SOLUTIONS

Detailed energy modelling was applied to the typical homes, followed by economic analysis to find the most cost-effective solutions.



HEAT PUMPS CAN BE FITTED IN ALL HOMES

The modelling found that heat pumps can be fitted in almost in almost all types of Scottish home, including smaller and heritage dwellings.

Air source heat pumps (ASHP) are the least-cost solution for homes starting with gas and oil boilers, with Air to Air heat pumps (see box below) the best solution for homes with electric storage heaters. Heat pumps drastically cut homes' annual carbon emissions – up to 90% when replacing oil and gas boilers and 45% for storage radiators. Annual carbon savings are much higher for fossil fuel boilers (6.8 and 2.5 tonnes per home for oil and gas) than electric storage radiators (0.3 tonnes) but there are significant fuel poverty benefits to moving homes away from this type of heating.

ENERGY EFFICIENCY HELPS MAKE HEAT PUMPS CHEAPER

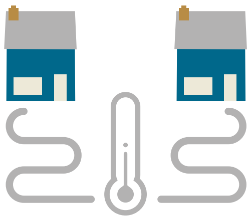
Scottish Government proposals to set minimum energy standards for all homes will help ensure that energy bills are lower with heat pumps and unlock other benefits.

The study found that many energy efficiency upgrades are cost effective – that is, they will pay for themselves within 15 years by reducing energy bills (by lowering a homes' heating demand and enabling heat pumps to operate more efficiently). The economic case for energy efficiency is enhanced by high energy prices since the pandemic and Russia's war on Ukraine. The recommended level of energy efficiency is broadly comparable to an Energy Performance Certificate rating (EPC) of 'C'. Energy efficiency also brings other benefits like reducing fuel poverty risks and potentially reducing the need for radiator upgrades.

SMALL HOUSES

There are space-saving solutions to help fit heat pumps in smaller houses.

Air source heat pumps require space for internal equipment and a hot water tank, and there is a risk that space for these may be limited in some smaller homes. The modelling found that in these cases, Air to Air heat pumps (see box below) and instant hot water heaters provide a cost effective and space-saving alternative. Although not part of this study, heat batteries also provide a smaller alternative to traditional hot water tanks[14]. Previous analysis suggests that internal space constraints could affect up to 14% of the stock. This could be an overestimate - a recent field trial for UK Government found internal space to be a limiting factor in only 2% of over a thousand UK homes surveyed for that project[15].



FLATS AND TENEMENTS

Heat networks may have advantages over individual heat pumps in flats and tenements.

The study findings suggest that some of the characteristics of flats – their size, energy use[16], space inside and out for equipment - can create challenges for and increase the costs of fitting individual heat pumps. Shared heating systems such as heat networks could overcome some of these challenges. Information should be provided to households (by the Scottish Government or local authority) on the potential for shared heating systems in the local area by 2025 (using information from Local Heat and Energy Efficiency Strategies). This will reduce the risks that flats fit individual heat pumps in blocks suitable for shared systems (these flats would then be unlikely to connect to that shared system, weakening the economic case for it) and conversely, to avoid delay to fitting individual systems in blocks that are unsuitable for shared systems.

AIR TO AIR HEAT PUMPS

These are similar to air Conditioning and widely used in commercial environments such as hotels. An external evaporator (with fan) is connected via refrigerant to internal heat distributors (blowers) that are wall mounted in each heated room. These are the only internal units, and so less space is required. No hot water is produced, so where a tank is not present alternative water heating is required – this can be provided by instant hot water heaters. These are small units that provide hot water on demand.

Using these results: these findings are meant as a guide to the practicalities and costs of decarbonising homes. They are very sensitive to an array of input assumptions regarding building geometry and fabric performance, occupants' energy use and assumed energy prices. Anyone using and interpreting these results should consult the full research report (available here) to understand these assumptions.

OLDER & HERITAGE HOUSES

It is possible and cost effective to fit heat pumps in older and heritage homes.

The study found that heat pumps can be fitted to the older typical homes that have solid walls and can achieve lower energy bills. In these homes it is most cost effective to install external wall insulation (EWI) alongside the heat pump - the energy savings pay back capital costs within 15 years. It is technically possible to fit heat pumps in these homes without insulating external walls provided other efficiency measures are in place (see below for detail), however energy bills are higher than with EWI. Around half of such dwellings are heritage homes that are either listed or in a conservation area. Planning rules for heritage homes are not likely to impact on the choice of heating system[17] but do limit use of external wall insulation. In these situations, internal wall insulation is a cost-effective alternative, except in rare cases[18].

RADIATOR UPGRADES

It may not always be necessary to change the radiators with a heat pump, particularly after improving energy efficiency.

None of the typical homes selected larger radiators - improved energy efficiency, and the size of existing radiators can reduce or avoid the need for upgrades.

Heat pumps work more efficiently at lower temperatures, heating radiators to between 35C and 55C. This is known as the ‘flow temperature’ and is the most important factor in determining how efficiently a heat pump operates. Different flow temperatures were tested in the modelling with an option to upgrade to larger radiators[19] (which are required to heat rooms at much lower flow temperatures).

However, these upgrades were not selected for the typical homes because lower flow temperatures were achieved (without compromising comfort) thanks to the size of the existing radiators[20], the energy efficiency upgrades and more constant operation of the heat pumps[21]. The energy bill savings from upgrading radiators did not pay back the upfront cost of the upgrades within 15 years and so weren’t selected. Larger radiators will lower energy bills over many decades of operation and householders may wish to take a longer view – installers should advise on the best course of action.

TABLE 2. BEST HEATING SOLUTIONS FOR THE TYPICAL HOMES (GAS/OIL)

	ARCHETYPE	HEATING SYSTEM	FLOW TEMPERATURE	BASELINE EMISSIONS (KGCO2E/Y)	UPGRADED ANNUAL EMISSIONS
1	DETACHED PRE 1919	ASHP 14 KW	40 °C	9,660	700
2	DETACHED POST 1919	ASHP 12 KW	45 °C	3,990	435
3	SEMI-D 1919-82	ASHP 10 KW	50 °C	2,860	370
4	MODERN SEMI-D	ASHP 8 KW	45 °C	2,085	300
5	MID-TERRACE HOUSE 1919-82	ASHP 8 KW	48 °C	2,495	350
6	BUNGALOW POST 1919	ASHP 10 KW	50 °C	3,440	400
7	CHALET-BUNGALOW PRE 1919	ASHP 14 KW	48 °C	6,310	555
8	CHALET-BUNGALOW POST 1919	ASHP 14 KW	50 °C	4,580	510
9	TENEMENT-FLAT (MID) PRE 1919	AIR TO AIR 12 KW*		3,190	360
10	MODERN TENEMENT FLAT (MID)	ASHP 4KW	55°C	1,190	250
11	FOUR-IN-BLOCK FLAT (GROUND) 1919-82	ASHP 6 KW	45 °C	2,255	320
12	FOUR-IN-BLOCK FLAT (TOP) 1919-82	ASHP 6 KW	48°C	1,670	320

The heating solutions for typical homes starting on gas or oil are the same. Carbon reduction figures are given here only for homes starting on gas

* The difference between this and a 10kW ASHP solution is very marginal – total costs over 15 years are £880 more for the ASHP. Owners are more likely choose this in preference over the air to air heat pump because it would be more disruptive to install this, requiring radiators to be removed and replaced by wall-mounted air blowers.

THE ROLE OF ENERGY EFFICIENCY

- A good standard of energy efficiency helps make heat pumps cheaper – broadly equivalent to an Energy Performance Certificate (EPC) rating of ‘C’.
- Up to 80% of homes could benefit from low-cost draught proofing and around 50% should improve insulation with moderate cost measure costing on average £1,800. Wall insulation is cost effective for houses with uninsulated solid walls (12% of homes) – costs are higher but are recouped within 15 years.
- Scottish Government proposals to set minimum standards of energy efficiency for all homes will make heat pumps more affordable and bring many wider benefits. Government should continue to financially support households to fit measures.
- Standards should be set as a maximum demand for space heating, of between 65-85 kWh per m2 per year. Solid wall insulation is recommended but could be made optional for some homes, with grants to encourage and support.

Improved energy efficiency reduces heat leakage from homes and can permanently reduce energy bills regardless of the heating system. The better a home can retain heat, the more efficiently a heat pump can operate (by enabling heating at lower flow temperatures) which will lower its running costs. The study assessed both the upfront and running costs over 15 years (the expected lifetime of a heat pump) for combinations of electric heating and energy efficiency measures and found that households would be better off bringing homes to a good level of energy efficiency before/at the same time as fitting a heat pump. For a moderate extra upfront cost homes have lower overall costs after 15 years than without these improvements. Most of the energy efficiency measures recommended are low or moderate cost and all will rapidly pay this back. This is despite relatively conservative assessment criteria: they were not selected if they took longer than 15 years to pay back, and a discount rate of 3.5% was applied to future costs (and bill savings).

MOST HOMES CAN REACH THE RECOMMENDED STANDARD OF ENERGY EFFICIENCY USING LOW OR MODERATE COST MEASURES

MODEST COST AND LOW DISRUPTION MEASURES

The recommended level of energy efficiency can be achieved in the majority of the typical homes by using low or moderate cost measures that can be installed without major disruption:

- Up to 80% of all homes could benefit from low-cost draught proofing at an average cost of £320[22].
- Around 50% should improve insulation with moderate cost measures like loft insulation (to 300mm), cavity wall insulation (including hard to treat) and double glazing.
- Average costs for homes adopting at least one of the above measures is around £1,800

The typical homes adopting measures see their annual energy demand reduced by 30% on average.

SOLID WALL HOMES

Around a quarter of all homes have uninsulated solid walls which can be insulated using either external wall insulation (EWI) or internal insulation (IWI). The study found that when fitting heat pumps to houses overall costs are lower with solid wall insulation, and costs are paid back within 15 years. However, it is expensive (average cost £9,200) and potentially disruptive. It is possible to fit heat pumps in the typical homes without it, provided other energy efficiency measures are in place. Running costs without it are still lower against oil and electric storage heating, and the same or slightly higher against gas. A larger heat pump is also required.

Around half of all solid-wall homes are classified as 'heritage' because they are listed or located in a conservation area, and planning may restrict the use of EWI. The study found that internal wall insulation is a cost-effective alternative in these situations, except in the very large (250m^2) detached house whose size increases cost significantly. Sometimes it may only be possible to insulate a few walls – e.g. at the rear of homes in conservation areas, but this would still bring benefits. The recommended standard of energy efficiency would require insulation of solid walls in most houses. It is desirable because it reduces homes' costs and carbon emissions, could enable them to capitalise on time of use tariffs (see box on p34) and brings wider benefits (e.g., reduced fuel poverty risk and demand on electricity networks). However, in light of the challenges that upfront costs, internal disruption (for IWI) and visual impact pose to public acceptance it could be made an optional measure for owner occupied properties. Homes that choose not to fit solid wall insulation will have lower upfront costs, but some will risk higher running costs after fitting a heat pump- households will need advice specific to their home. Government grant support should be provided to encourage uptake.

High-temperature ASHPs are sometimes proposed as an alternative to major energy efficiency (and/or radiator improvements). These were modelled but not selected because they lead to higher overall costs. This is because the typical houses with solid walls are able to run low temperature heat pumps at efficient flow temperatures, even without external wall insulation.

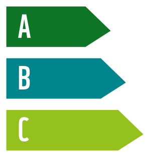
MINIMUM ENERGY EFFICIENCY STANDARDS

Scottish Government proposals to set minimum standards of energy efficiency for all homes will make heat pumps cheaper and bring many wider benefits.

Many energy efficiency improvements were found to be very cost effective from a householder perspective. Energy efficiency brings wider benefits too: it can cut carbon emissions before heating systems are replaced, reduces risks of fuel poverty and the costs to the NHS of illnesses like heart and respiratory disorders that are aggravated by people living in cold homes. It can also reduce the impact on electricity networks of heat pumps at periods of peak demand and can help households capitalise on time use tariffs by enabling more flexible heating.

The standard should be set as a maximum demand for space heating in kWh per m2 per year

After upgrades, the typical homes have an Energy Performance Certificate (EPC) rating of at least 'C'. However, in recognition that current EPC metrics are not suited to encouraging the adoption of low carbon heating the Scottish Government has committed to introducing revised metrics - the study recommends annual space heating demand as more appropriate. Post-upgrades, **most of the typical homes end up with a space heating demand of 65-85 kWh per m2 per**



STANDARDS SHOULD SET A MAXIMUM DEMAND FOR SPACE HEATING IN HOMES, IN KWH PER M2 PER YEAR

UP TO 80% OF HOMES COULD BENEFIT FROM A LOW-COST DRAUGHT PROOFING

year (as set out in table 3) roughly three-quarters of typical energy for heating in Scottish homes now. We recommend that this be the basis of revised standards, enforced through updated Energy Performance Certificates. Some variation in the standard will be needed to account for the size and age of dwellings - smaller and more modern homes can often achieve a lower heating demand. Houses will require solid wall insulation to meet this standard, but this could be made optional for owner occupied homes. The deadline for all houses to meet this standard should be brought forward to 2030 (from 2033).

Set an interim standard of energy efficiency for flats to reach by 2030.

The Scottish Government has proposed a combined energy efficiency and heat standard for flats (mixed tenure, tenement and mixed-use buildings) to reach by 2045, in recognition of the challenges of coordinating shared works between multiple owners (e.g. for external wall insulation and heating systems).

However, the study found significant potential for cost effective energy efficiency upgrades that can be carried out by individual flat owners (draught proofing, loft insulation, better glazing). We therefore recommend setting an interim energy efficiency standard for flats to meet by 2030, at a level that does not require the installation of solid wall insulation.[23] Setting this standard will encourage early action – households are keen to understand what they can do to reduce energy and carbon emissions now.

UPGRADES AND SUPPORT

Figure 3 gives a simplified indication of how costs to meet the standard may be spread between households. The Scottish Government currently provides grant funding to reduce the upfront costs of energy efficiency upgrades and we recommend that this continues once minimum standards are introduced (see p42 for more detail). We recommend that the rural uplift to grants be maintained, because costs for these homes are higher than average. Installation costs are also likely to be higher in remote areas of the highlands and islands.

Table 3 shows the most common energy efficiency upgrades adopted by the typical homes in the study, alongside their starting level of energy efficiency. Where two upgrade measures are listed (e.g. roof insulation or cavity wall) this indicates broadly equal numbers of homes (in the modelling) starting without and requiring the addition of either of these measures

FIGURE 3. INDICATIVE NUMBER OF HOMES BY ENERGY EFFICIENCY COST

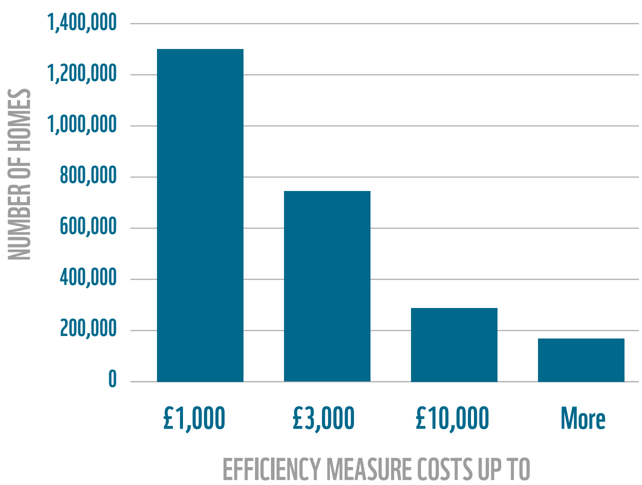


TABLE 3. MOST COMMON ENERGY EFFICIENCY IMPROVEMENTS FOR THE TYPICAL HOME

	ARCHETYPE	BASELINE ENERGY EFFICIENCY MEASURES	ENERGY EFFICIENCY UPGRADES	COST	SPACE HEATING DEMAND (KWH/M²/ YEAR)
1	DETACHED PRE 1919	ROOF INSULATION, DOUBLE GLAZING	EXTERNAL WALL INSULATION; DRAUGHT PROOFING;	£15,130	75
2	DETACHED POST 1919	CAVITY WALL INSULATION; DOUBLE GLAZING, FLOOR INSULATION	ROOF INSULATION AND TOP-UP; DRAUGHT PROOFING	£2,420	65
3	SEMI-D 1919-82	CAVITY WALL OR ROOF INSULATION; DOUBLE GLAZING	CAVITY WALL OR ROOF INSULATION; DRAUGHT PROOFING	£1,065	83
4	MODERN SEMI-D	CAVITY WALL INSULATION; FLOOR INSULATION	ROOF INSULATION TOP-UP	£470	50
5	MID-TERRACE HOUSE 1919-82	CAVITY WALL OR ROOF INSULATION; DOUBLE GLAZING	CAVITY WALL OR ROOF INSULATION; DRAUGHT PROOFING	£870	74
6	BUNGALOW POST 1919	CAVITY WALL INSULATION; DOUBLE GLAZING	ROOF INSULATION; DRAUGHT PROOFING	£1,550	84
7	CHALET-BUNGALOW PRE 1919	ROOF INSULATION; DOUBLE GLAZING	EXTERNAL WALL INSULATION; DRAUGHT PROOFING	9,040	100
8	CHALET-BUNGALOW POST 1919	CAVITY WALL INSULATION; ROOF INSULATION; DOUBLE GLAZING	DRAUGHT PROOFING	£430	99
9	TENEMENT-FLAT (MID) PRE 1919	DOUBLE GLAZING	DRAUGHT PROOFING	£290	117
10	MODERN TENEMENT FLAT (MID)	CAVITY WALL; FLOOR INSULATION; DOUBLE GLAZING; AIR TIGHTNESS	NONE	0	36
11	FOUR-IN-BLOCK FLAT (GROUND) 1919-82	CAVITY WALL INSULATION; DOUBLE GLAZING	DRAUGHT PROOFING	£270	77
12	FOUR-IN-BLOCK FLAT (TOP) 1919-82	CAVITY WALL OR ROOF INSULATION; DOUBLE GLAZING	CAVITY WALL OR ROOF INSULATION	£605	59

* 'Roof insulation' refers to homes with less than 150mm of insulation; 'roof top-up' refers to homes that have this level of insulation and require a smaller amount to reach the target level of 300mm.

HOW MUCH WILL HEAT PUMPS COST IN 2025?

ENERGY BILLS

- Heat pumps could lower energy bills in a majority of houses when regulations enter force in 2025.
- UK Government policy changes are already making heat pumps more competitive against gas boilers, and further reforms could enhance this.
- The results are highly sensitive to energy prices, but assumptions in the study are broadly consistent with medium term forecasts that could apply in 2025.
- Innovation in heat pumps and the return of time of use tariffs could further reduce costs in future.

MOST HOMES MAKE ENERGY BILL SAVINGS

Nearly two-thirds of the modelled stock of houses make energy bill savings.

Running costs were calculated for the typical homes using in-depth modelling at hourly intervals across a year, using Scottish climate data. It was found that all houses on oil and electric heating could have lower energy bills when moving to a heat pump in 2025 (with energy efficiency upgrades described in the previous section) and just over half of those currently with gas boilers.

Figure 4 illustrates energy bill changes for each house type[24] after adopting the recommended heating and energy efficiency measures.

Some houses on gas see modest increases – £80 on average. This is because they have high hot water demand and are relatively more modern and energy efficient and before upgrades already had the lowest energy bills. These factors also prevent the flats from making savings against gas; a further reason to explore the costs of shared heating systems in these dwellings first.

As well as the ratio of hot water demand, running costs are affected by heating patterns in the modelling – the study found it better to have a relatively high set-back temperature (18°C) over night or when residents are out, in order to meet comfort criteria quickly and efficiently. These homes are effectively heated for longer, raising energy costs. This can be compensated by lower upfront costs - for example a smaller heat pump or reduced need to replace radiators. Running costs could be further reduced by the steps outlined in the box below.

All fossil fuel boilers are assumed in the study to be of the efficient (condensing) variety[25] but around 20% of real-world boilers are older models – homes with these boilers will consume more energy than assumed here and will make larger savings when moving to a heat pump. These types of gas boilers could be targeted first by regulation.

FIGURE 4. ENERGY BILLS SAVINGS IN TYPICAL HOMES

	OIL	ELECTRIC	GAS
Detached Pre 1919	52%	35%	33%
Detached Post 1919	34%	36%	12%
Semi-D 1919-82	20%	26%	7%
Modern Semi-D	19%	31%	4%
Mid-terrace house 1919-82	20%	25%	4%
Bungalow Post 1919	29%	34%	6%
Chalet-bungalow Pre 1919	42%	29%	20%
Chalet-bungalow Post 1919	29%	34%	4%
Tenement-flat (mid) Pre 1919	25%	32%	2%
Modern Tenement flat (mid)	1%	0%	23%
Four-in-block flat (ground) 1919-82	19%	31%	5%
Four-in-block flat (top) 1919-82	8%	26%	13%
Average annual energy bill saving	£880	£870	£170

REDUCING HEAT PUMP RUNNING COSTS

Heat pump running costs could be further lowered by:

TIME OF USE TARIFFS

Time of Use Tariffs (TOU) reward consumers for using electricity at periods of low demand and avoiding use at periods of high demand. Prior to the spikes in energy prices in 2021/22 these tariffs could be used in conjunction with a heat pump to reduce overall running costs.[26] In well insulated homes the heat pump can be turned up before, and lowered during, peak pricing periods (typically 4 -7pm). At present, few Time of Use Tariffs are available, as many energy suppliers have temporarily removed them from the market in response to the current volatility of energy prices. However, Time of Use (TOU) Tariffs could well become more common as more homes are converted to cleaner electric heating (and transport) and the energy suppliers are likely to make them more attractive to help address periods of very high demand. Homes will need a good standard of energy efficiency to benefit – another reason for bringing homes to the standards outlined in this study.

SOLAR ENERGY

Solar thermal or photovoltaic (PV) panels can be fitted alongside a heat pump system to reduce running costs. Early modelling work for the study found solar PV to be cost effective for all house types, as high electricity prices meant that energy bill savings pay back the upfront capital costs within 15 years.[27] Solar thermal panels, which produce hot water, could also improve heat pump efficiency and lower running costs, particularly in homes with high hot water demand.

MORE ENERGY EFFICIENCY AND RADIATOR UPGRADES

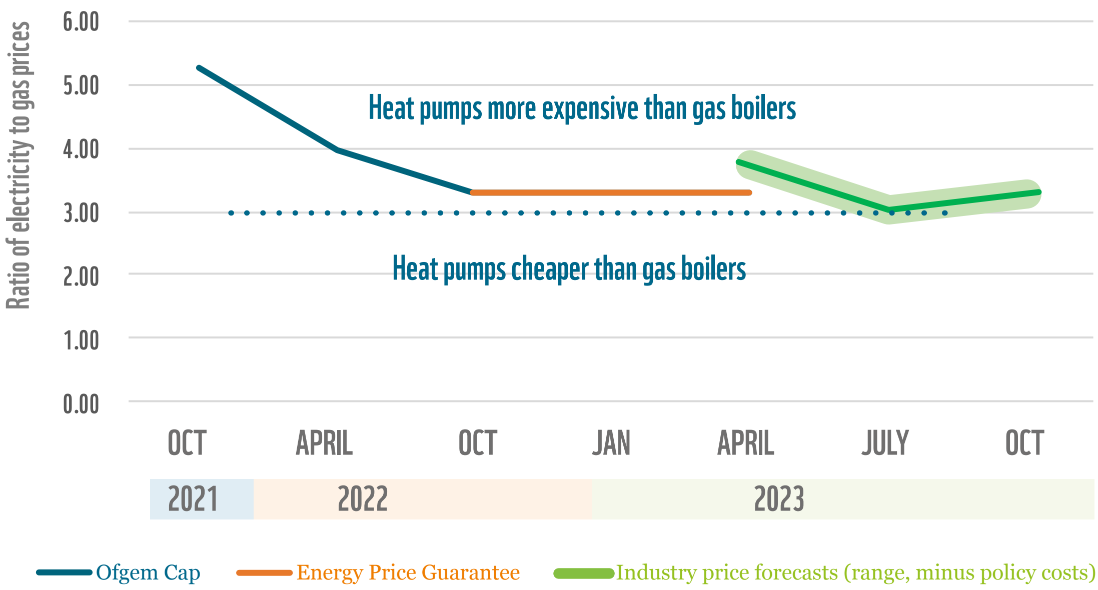
Homes could adopt further energy efficiency measures and/or larger radiators to reduce running cost. The study found that energy bills in the three typical houses that don't make savings when switching from a gas boiler can be reduced in this way. These improvements weren't selected however, as their upfront costs were greater than energy bill savings achieved over 15 years.

INNOVATION

Heat pump performance is also influenced by equipment design, and manufacturers are innovating the use of refrigerants, to both increase performance and sustainability. Products are already available with improved efficiencies.[28]

ENERGY PRICES

FIGURE 5. RATIO OF ELECTRICITY PRICES TO GAS PRICES



UK GOVERNMENT POLICY CAN REDUCE HEAT PUMP COSTS

The removal of UK Government policy costs from energy bills is a crucial step to make heat pumps cheaper to run than gas boilers.

These artificially inflate the cost of electricity relative to gas, pushing up heat pump running costs. Energy prices used in the study assume that these policy costs are removed. UK Government has committed to move these costs away from energy bills and this change was implemented through it's temporary Energy Price Guarantee (EPG) scheme,[29] which began in October 2022 to protect consumers from very high energy prices.

Figure 5 illustrates how heat pump running costs vs. gas have improved thanks to this policy change (and changes in energy prices). It shows the ratio of electricity to gas prices since 2021, and industry forecasts for 2023.[30] The dotted line illustrates the threshold (3:1) of electricity to gas prices broadly required for heat pumps to be cheaper than gas boilers. At or below this line, the efficiency of heat pumps operating with an efficiency of around 3 (the minimum for a correctly installed system[31]) counteracts the higher price of electricity, giving a lower cost per unit of heat generated than a gas boiler.(the ratio in the study was 3.2 to 1).

It is important that the UK Government set outs how this policy change will be made permanent beyond the EPG to bring clarity to future heat pump running costs.

MORE CAN BE DONE

The UK Government can further reduce electricity prices by reforming electricity markets to remove the influence of high gas prices.

These have been the primary driver of electricity price rises since 2021. It has launched a review of electricity market design to ensure it remains fit for purpose as the UK decarbonises. Although increasing amounts of the UK's electricity generation comes from low-carbon sources, the flexibility of gas power stations sees them set power prices in the day ahead market. Surging gas prices have increased their costs, pushing up the prices paid to all generators. One proposal[32] that is supported by industry could save household between £60 and £300 a year on electricity bills (note: these potential reductions were not factored into this study).

THE UK GOVERNMENT CAN FURTHER REDUCE ELECTRICITY PRICES

WHAT DO RECENT ENERGY PRICES MEAN FOR THESE RESULTS?

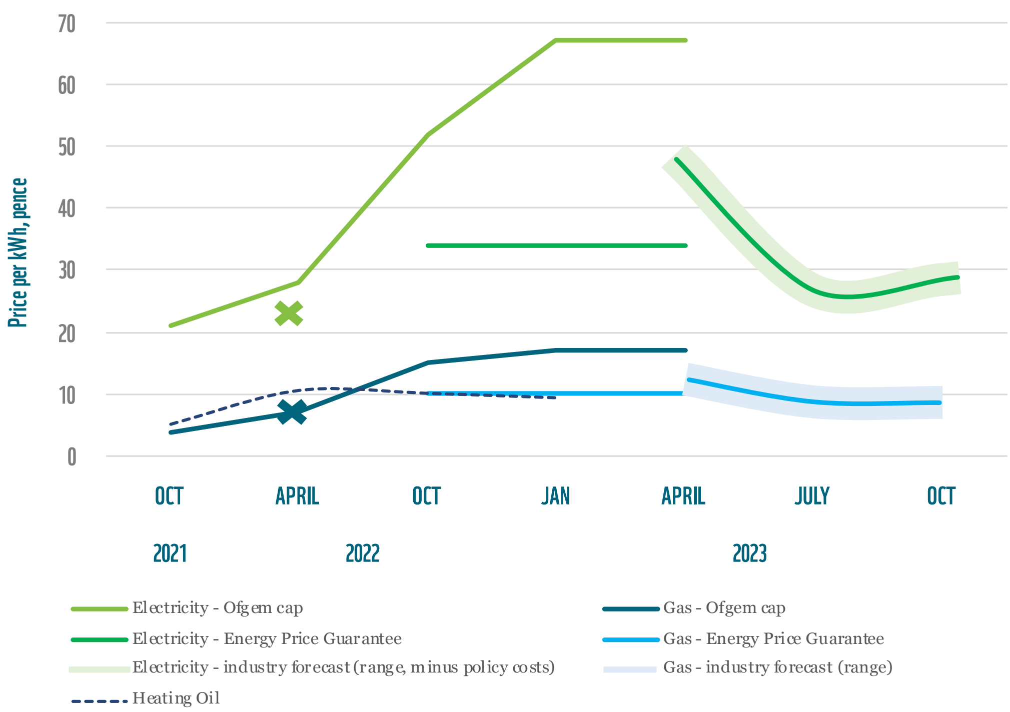
Energy prices used in the study are consistent with (current) forecasts that suggest prices will fall from the peak in early 2023 but remain above pre-crisis norms in the medium to long term.

The study used energy prices in April 2022, when prices had risen since the previous year by around 30%. Since then, prices have risen again, primarily because of Russia's war on Ukraine and reached record highs in late 2022.

Current industry forecasts expect energy prices to fall in 2023, but to remain above pre-crisis norms in the longer term[33], as Europe replaces Russian gas with more expensive alternatives. Figure 6 illustrates this story – comparing the energy prices used in this study (shown as crosses) with their actual levels since 2021, prices set by the UK Government's EPG and industry forecasts for 2023[34]. Despite reductions in 2023, these long term forecasts would still leave households with energy bills perhaps 50% more than norms before the crisis. Measures like a social tariff for energy will likely be needed to help low-income households in place of temporary Government measures, alongside the roll out of energy efficiency and heat pumps to minimise fuel poverty and tackle climate change at the same time.

Price rises since 2021 have made energy efficiency (especially more expensive measures like solid wall insulation) more economically attractive in our study compared to previous analyses. The higher prices seen in late 2022, should they persist, would make energy efficiency even more attractive.

FIGURE 6. ENERGY PRICES, RECENT TRENDS & FUTURE FORECASTS



UPFRONT COSTS

- Costs to fit an air source heat pump to the typical houses start at £4,500, including Scottish Government grants.
- Scottish Government should continue to provide support to households to help make heat pumps more affordable
- There is scope for capital costs to reduce by up to 27% by 2030 as supply chains scale up. Some of these costs are a one-off and subsequent heat pump replacements could be cheaper.

TABLE 4. CAPITAL COSTS FOR GAS/OIL HOMES

	TYPICAL HOME	HEATING SYSTEM	COST (£)
1	DETACHED PRE 1919	ASHP 14 KW	14,150
2	DETACHED POST 1919	ASHP 12 KW	13,060
3	SEMI-D 1919-82	ASHP 10 KW	14,300
4	MODERN SEMI-D	ASHP 8 KW	13,210
5	MID-TERRACE HOUSE 1919-82	ASHP 8 KW	13,210
6	BUNGALOW POST 1919	ASHP 10 KW	11,970
7	CHALET-BUNGALOW PRE 1919	ASHP 14 KW	14,150
8	CHALET-BUNGALOW POST 1919	ASHP14 KW	14,150
9	TENEMENT-FLAT (MID) PRE 1919	AIR TO AIR HP	14,630
10	MODERN TENEMENT FLAT (MID)	ASHP 4KW	11,290
11	FOUR-IN-BLOCK FLAT (GROUND) 1919-82	ASHP 6 KW	11,890
12	FOUR-IN-BLOCK FLAT (TOP) 1919-82	ASHP 6 KW	12,390

The study used cost data from 10,145 heat pump installations[35] in Scotland between 2019 and 2021, applied to the systems specified for the typical houses (with no constraints). The average installation cost to fit air source heat pumps are set out in table 4. The cost of the Air to Air systems, recommended for electrically heated homes or those with limited internal space, starts at £15,300.

The study costs do not include Scottish Government grants, which currently provide a discount up to £7,500[36] (£9,000 for rural homes). This is an important step to encourage early adoption and grow supply chains. Overall costs for the space constrained solutions are higher than for ASHP's and we recommend that Scottish Government explore the need for an uplift to grants for smaller homes. We recommend that grants be maintained beyond 2025 and the start of regulation – see our proposals in the next section.

WHAT WILL HEAT PUMP COSTS BE IN FUTURE?

Heat pump costs are expected to reduce in future. Already, at the time of publication some energy suppliers are offering heat pump installations in Scotland starting at £8,000[37] (before grants). Although heat pumps are a mature and proven technology worldwide, only a relatively small number of homes have installed them in Scotland – 21,000 to date.

As a result, current supply chains are small and increased demand could lead to cost reductions through learning and scale effects.

The study examined other literature which found that the upfront costs of heat pumps could by up to 27% by 2030, under the most optimistic scenario. At the upper end of these estimates, heat pump installation costs for typical houses would start at £8,750 in 2030.

ONE-OFF COSTS

The cost of subsequent heat pump replacements, after the initial conversion of a home, are likely to be much lower. This is because unlike simple like-for-like replacement of a boiler, there are additional plumbing and equipment costs when a heat pump is installed for the first time (the heat pump units comprise around 40% of the installation costs for the typical homes in Table 4). The full cost of these measures, including controls, buffer tanks and pipework are all included in these costs. These additional costs may be less when the heat pump comes to be replaced – say, in 15 to 20 years. New pipework and wiring should not be needed for the second and subsequent heat pump installations, and labour costs for installing should also be lower.

MAKING REGULATIONS WORK

- Regulations can drive demand, help industry reduce costs and enable households to recoup their investment through higher house values.
- Regulation should be accompanied by financial support from the Scottish Government: fully funded upgrades for fuel poor homes and upfront grants for others.
- Many households will need to borrow to pay for upgrades. Scottish Government can make this more affordable by lowering borrowing rates (e.g. existing zero interest loans) and facilitating new private lending mechanisms.

The Scottish Government has proposed regulaton (see box) to increase private investment by households. This is a vital mechanism and the surest way to drive demand, which in turn will enable industry to reduce costs. Our proposals build from analysis for Existing Homes Alliance Scotland on how to design and implement a successfult regulatory framework.[38]

Regulation will help ensure that house prices reflect the value of heating upgrades.

The total investment required to decarbonise Scotland's homes by 2045 is small in comparison to the total value of the stock (estimated at £390bn in 2021[39]) and the value transacted each year (£22.2 billion in 2020-21[40]). Recent analysis for WWF UK of housing sales data in England and Wales suggests that air source heat pumps have the potential to add between 1.7% and 3% to house values; in Scotland this could boost the average price of homes by £3,500 to £5,850.[41] Other recent survey data suggests that home buyers across the UK are increasingly seeking out more energy efficient properties and willing to pay a premium of up to 10% for them.[42]

Today, the value of upgrades is dependent on purchaser's preferences; regulation can help ensure that all purchasers seek (and reward) homes that meet standards.

Intervene at convenient times

Regulations can be designed to require action at times that are convenient, for example at the point of **property purchase, boiler replacement or major renovation**. Borrowing at point of sale (e.g. a mortgage) can include extra for upgrades with the potential for work to be carried out before new owners move in. Several European countries have already begun regulating heating systems at the point of replacement, an approach that gives households longer to prepare. Most boiler replacements take place before the end of a unit's life (e.g. in anticipation of breakdown) and in only 30% of cases has a boiler ceased operation altogether.[43] In these situations, temporary electric heating could be provided whilst a new system is fitted. Around a third of boilers are also changed as part of major renovations. Regulation can be **phased-in to target the homes with the highest cost/highest carbon heating systems** such as coal, oil and LPG, and less efficient (non-condensing) boilers.

SCOTTISH GOVERNMENT'S PROPOSED REGULATIONS

MINIMUM STANDARDS OF ENERGY EFFICIENCY

- Owner occupied and private rented houses to meet standard (equivalent to EPC C) from 2025 at point of sale/letting/major renovation. Private rented houses to meet standard by 2028 & owner-occupied by 2033 (i.e. those not bought/rented before that date).
- All social housing to reach EPC B by 2032 (standard under review for alignment with net zero).

REPLACEMENT OF FOSSIL FUEL HEATING SYSTEMS

- Requirements to install zero emissions heating systems in off-gas areas from 2025 and on-gas areas from 2030 (all tenures). Applied, as a minimum, when a boiler is replaced and/or point of sale/letting, major renovation. Backstop date of 2045 (or earlier) for all remaining boilers to be replaced.

MIXED TENURE AND MIXED-USE BUILDINGS (INCLUDING FLATS & TENEMENTS)

- Requirement to meet a combined energy efficiency and heating standard by 2040 – 45, earlier in some circumstances.

SUPPORTING HOUSEHOLDS

There are clear benefits to adopting heat pumps, but upfront costs are a challenge, and continued support from the Scottish Government will be vital. Advice will also be needed to help householders understand the changes required, and to find reliable advice on upgrades and installers. Our recommendations for financial support are as follows:

Fully funded upgrades for fuel poor homes:

Low-income and fuel poor households could face additional challenges in complying with regulations. The simplest and fairest way to support them is to provide fully funded installations delivered through existing Scottish Government fuel poverty schemes. These homes should be brought up to a higher standard of energy efficiency[44] to enhance energy bill savings – existing Scottish Government commitments to bring fuel poor (and social rented) homes up to the equivalent of an EPC 'B' should be maintained with deadlines brought forward to 2030. Eligibility criteria should be further widened to ensure that more households experiencing fuel poverty are able to get support.

WWF RECOMMENDATIONS FOR GRANT SUPPORT

We recommend that Scottish Government continue to offer grants to owner occupiers and landlords once regulations commence in 2025, including:

FULLY FUNDED ENERGY EFFICIENCY AND HEAT PUMP INSTALLATIONS FOR FUEL POOR HOUSEHOLDS

EXISTING £7,500 GRANT FOR HEAT PUMPS, CONTINGENT ON A HOME MEETING MINIMUM ENERGY STANDARDS

UP TO 60% GRANT FOR SOLID WALL INSULATION, UP TO A MAX. OF £7,500

CONTINUE THE £1,500 UPLIFT FOR RURAL HOMES APPLYING FOR A HEAT PUMP AND EFFICIENCY GRANT

GRANTS UP TO 75% OF THE COST OF ENERGY EFFICIENCY UPGRADES, TO A MAXIMUM OF £7,500

Government should also make Air to Air heat pumps eligible for grants and explore a grant uplift for smaller homes fitting heat pumps.

EXISTING SUPPORT TO HOUSEHOLDS FITTING ENERGY EFFICIENCY AND HEAT PUMPS SHOULD CONTINUE

Continue upfront grants: these are important to reduce costs, particularly for the first households affected by regulation before cost reductions occur - they should be rewarded for supporting early market development. Existing grants offered by the Scottish Government to homeowners fitting heat pumps and energy efficiency should continue at current levels until technology cost reductions allow support to be reduced. Some support to landlords in the social and private rented sectors will also require support.

Support households to borrow: up to 30% of households are likely to have adequate savings, with the remainder needing to borrow (having either small or no savings at all[45]). Extra borrowing will particularly impact middle income households that are not eligible for fuel poverty support. Scottish Government can support them by offering additional help to borrow and/or reducing interest rates, to reduce monthly borrowing repayments. It already provides zero interest loans to help households adopt heat pumps and energy efficiency – these schemes could be expanded, or funding could be combined with some of the private finance options outlined below.

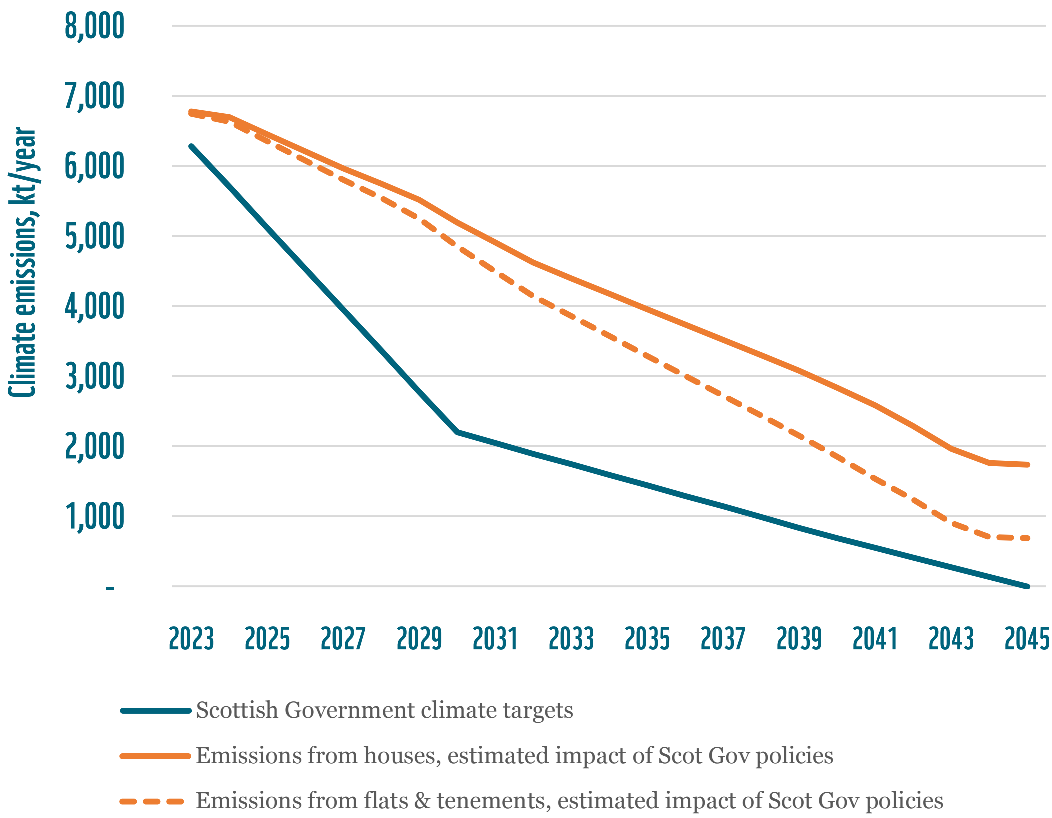
Private finance: banks and other lenders are increasingly lending at discounted rates for energy efficiency and green heating upgrades. Further reform of mortgage lending practices (to include actual energy bills in affordability assessments) could enable higher borrowing for efficient homes/ upgrades. New products are also being developed: equity release that would allow older households to borrow and 'property linked finance' that would alleviate household concerns about long pay-back periods. This would tie borrowing to a property and allow households that move before the loan is due to pass repayments on to subsequent owners (who will also reap the benefits of the upgrades). Scottish Government has convened a taskforce to explore these options but with regulation only a few years away it must set a clear and rapid pathway for bringing such products to market.

MEETING CLIMATE CHANGE TARGETS

- Proposals in the Scottish Government's Heat in Buildings Strategy will meet the 2045 net-zero climate target but annual emissions in 2030 would be over double the ambition set for homes. Reductions by 2030 are crucial to avoid the worst impacts of global warming.
- Acting with greater pace and fairness will require increased Scottish and UK Government funding and accelerated deadlines, particularly for energy efficiency upgrades in all homes and for the replacement of gas boilers in houses.
- Our proposals for regulations and funding would see over half the required capital investment to 2030 coming from public funds and the rest from homeowners and landlords.

Using the results of the modelling we estimate (see Figure 7) that although current Scottish Government policy proposals should decarbonise homes by 2045, emissions in 2030 could be over double (2.6 million tonnes) what is required to meet our targets, as set out in the 2020 Climate Change Plan Update (CCPu).

FIGURE 7. ESTIMATED EMISSIONS FROM HOUSING, SCOTTISH GOVERNMENT TARGETS & POLICY



Note: 2045 emissions are above zero due to residual power sector emissions in the modelling. Electricity supply is expected to fully decarbonise by 2045, resulting in zero emissions from electric heating.

HOW TO CLOSE THE GAP TO TARGETS?

Using the carbon and cost results of the homes modelling, we explored how Scottish Government proposals could be improved to meet the 2030 emissions target. Our recommendations for accelerating action are set out in table five. Our analysis and proposals assume that Scottish Government targets for heat network delivery in 2027 and 2030 are met, with 45% of this output connected to flats (via communal and district heating systems). Achieving this will require the rapid implementation of the Scottish Government's Heat Networks Act and 'zoning' of suitable areas by local authorities as part of 'Local Heat and Energy Efficiency Strategies' (LHEES). This information should be provided to households to explain the potential for such systems in their local area by 2025.

TABLE 5: WWF PROPOSALS TO ACCELERATE AMBITION

SCOT GOV PROPOSAL	WWF PROPOSALS
ENERGY EFFICIENCY – HOMES TO REACH EPC C* BY:	
Owner occupied houses at point of sale from 2025, and deadline for all homes to reach the standard by 2033	Earlier deadline of 2030
Private rented at new tenancy from 2025, all homes by 2028	No change
All social rented homes to reach EPC B* by 2032	Earlier deadline of 2030
Flats: combined energy efficiency and heat standard to be met by 2045	An interim energy efficiency standard for flats to reach by 2030
HEATING SYSTEMS	
Off-gas boilers: phase out new installations of coal, oil and LPG boilers from 2025 (houses); final deadline of 2045 or earlier for all remaining boilers to be replaced	Earlier deadline of 2033 for all remaining boilers to be replaced
Gas boilers: phase out need for gas boilers from 2030, final deadline of 2045 (houses)	• No home purchase (houses) with old (non-condensing) boiler from 2025
	• No new boiler replacements from 2027 (houses)
	• Target for social landlords to replace 30% of gas boiler stock by 2030
	• Grants & marketing to encourage early adopters to move from gas boilers early

* standards will be set using updated metrics for EPCs

The WWF proposals would see over half of all houses (1 million) and 45% of flats and tenements (385,000) fit low carbon heating systems by 2030. These proposals (and those for fuel poverty and grant support outlined in the previous section) are designed to show what's required to meet our climate change targets whilst supporting households, and particularly those on the lowest incomes. They would potentially see all fuel poor homes receiving energy efficiency improvements, and a third heat pumps, helping lower energy bills and protecting them from high fossil fuel prices, and could achieve a 68% emissions reduction by 2030 (on 2020 levels). We have not factored in the ability of supply chains to adapt and deliver at this scale and speed, but their ability to do so will be aided by clear targets and the certainty of demand that regulation can provide. Full details about the policy proposals and costings can be accessed here.

HOW MUCH INVESTMENT?

Our scenario of regulations and funding is designed to fairly meet climate targets for housing to 2030 and would require a total capital expenditure of between £23.5bn and £26.5bn.[46] Scottish (and UK) Government would provide over half of this funding, with the rest coming from homeowners and private and social landlords. Capital investment by the Scottish Government would need to increase to between £2bn and £3bn per year from 2025 to 2030, a very significant increase on current levels. Potential avenues for this uptick could include additional public funding from the UK Government, which will also need to increase investment if it is to meet its own climate targets and industry. The UK Government's proposed 'market-based mechanism' would require boiler manufacturers across the UK to sell an increasing proportion of heat pumps from 2024 - they may need to provide incentives to increase consumer uptake. Given funding and other constraints, we recognise that delivering the full set of proposals will be very challenging. But it needs to be done if we're to have any chance of meeting climate targets and creating warm, high-quality housing on a par with European equivalents.

NEXT STEPS?

The Scottish Government has committed to publishing the next steps for its regulatory framework in 2023 – it is vital that this is done rapidly to give householders and industry clarity about the future and to prepare for the regulations taking effect from 2025. The scale of the task ahead is challenging but investment now can reduce household's energy bills and help protect them from unstable fossil fuel prices, and fuel poverty. The investment is significant, but this will be dwarfed by the costs of failing to act on climate change. Creating warm, liveable and climate friendly homes for people in Scotland is the right investment to make.

SIGNIFICANT INVESTMENT IS NEEDED BUT THIS WILL BE DWARFED BY THE COSTS OF FAILING TO ACT ON CLIMATE CHANGE.

CASE STUDIES

So how do heat pumps perform in Scotland today? Around 21,000 homes in Scotland already have heat pumps and a review of the available evidence on their performance found nothing to suggest that they can't operate effectively in Scotland.

The performance of systems has improved between field trials, thanks to improving installer codes and standards[47]. Two recent installations are featured below, from Energy Saving Trust's 'Green Homes Network' and Osprey Housing Association.

DETACHED HOUSE (PRE-1982) ASHP REPLACING GAS BOILER

Philippa lives in a detached property in Stirling. Within the first year in her new home Philippa had upgraded the roof insulation, filled the cavity wall sections and fitted insulation under the ground floor. She says:

"We're really pleased to have been able to make such a significant step in reducing our carbon footprint"

She installed solar photovoltaic (PV) panels in 2015. In 2021 she installed a 7kW air source heat pump to replace her gas boiler, a hot water tank and upgraded radiators. She used a Scottish Government zero interest loan which included a cashback grant to pay for it and is very happy with how the system performs.

"We're really pleased to have been able to make such a significant step in reducing our carbon footprint"

SEMI-DETACHED HOUSE (POST 1982), ASHP REPLACING STORAGE RADIATORS

Martha lives in a semi-detached house in Burghead, Moray. In 2021 her landlord, Osprey Housing Association, decided to replace the electric storage radiators with air source heat pumps. She says:

"The new heating system has been great, the storage heating that we had in our home previously was very expensive to run and wasn't efficient. The new system is an instant heat and more affordable. The upheaval wasn't as bad as I thought and workmen who carried out the work were great, friendly and explained every step of the work being carried out."

Martha's home is about twenty years old, with insulated walls (timber frame construction) and double glazing. Before installing the heat pump the loft insulation was improved from 150mm to the recommended 300mm.

"The new heating system has been great, the storage heating that we had in our home previously was very expensive to run and wasn't efficient.

ENDNOTES

1 Scottish Government, 2022, Scottish Greenhouse Gas Statistics 2020

2 www.gov.scot/publications/a-low-carbon-strategy-scotland-sullivan-report/

3 http://assets.wwf.org.uk/downloads/carbon_homes_2.pdf

4 https://existinghomesalliancescotland.co.uk/wp-content/uploads/2015/05/EXHA_policybriefing_May2015.pdf

5 http://assets.wwf.org.uk/downloads/wwfscotland_election_manifesto_1.pdf

6 UK Climate Change Committee, 2020. The Sixth Carbon Budget

7 UK Climate Change Committee, 2020. The Sixth Carbon Budget

8 Rosenow, J (2022) 'Is heating homes with hydrogen all but a pipe dream? An evidence review' Joule 6 (10)

9 UK Committee on Climate Change, 2018, Hydrogen in a low-carbon economy

10 Element Energy (2020) Technical Feasibility of Low Carbon Heating in Domestic Buildings report for Scottish Government's Directorate for Energy and Climate Change.

11 Very small rooms, rooms with low ceilings, or without windows are excluded from this definition of 'habitable rooms'.

12 UK Climate Change Committee (2019) Net Zero Technical Report. London: CCC

13 Microgeneration Certification Scheme cost data for Scotland, 2019-2021, inflated to £2022. Unpublished.

14 Heat batteries store thermal energy in a more dense and compact form than hot water tanks.

15 Energy Systems Catapult, LCP Delta, Oxford Computer Consultants (2022) BEIS Electrification of Heat, Home Surveys & Install Report. Outside space for ASHP units was found to be a bigger challenge – 3% did not have any and 5% required noise dampening measures and planning permission (when a unit is close to neighbouring properties).

16 Hot water is a higher proportion of heating demand in smaller dwellings which need less space heating. Hot water needs higher temperatures which lowers heat pump efficiency (they are still more efficient than immersion heaters, however).

17 In some locations there may be some restrictions on where outdoor heat pump units can be placed, for example in listed dwellings.

18 Costs of internal wall insulation for the very large (250m2) detached home are higher due to a large number of rooms.

19 It is the surface area of a radiator that matters, and this can be increased by selecting a deeper unit that has an additional panel, but retains the same height and length

20 Heating engineers may have fitted larger than required radiators or sized these for a condensing gas boiler to function properly, which also requires lower flow temperatures and radiators of a similar size to those required for heat pumps.

21 Heat pumps work best when keeping a home at a constant temperature, rather than heating quickly (for example in the morning, when the heating has been off overnight). All of the typical homes adopt a 'setback temperature' (overnight and 'heating-off' thermostat setting) of 18°C (16°C being the alternative). More frequent operation isn't higher cost, because avoiding high heating demands (particularly in the cold early morning) allows lower flow temperatures which is more efficient and requires a smaller capacity heat pump.

22 Greater air tightness increases indoor condensation risks which can be managed by avoiding drying clothes indoors, putting lids on pots while cooking, opening windows when more ventilation is needed

23 Recognising the challenges of organising the fitting of EWI to a block with multiple owners. The study did not find it cost effective to fit solid wall insulation to pre 1919 tenements as the low ratio of external wall to floor area reduces the benefits, but the analysis did not consider potential savings from scale economies (e.g. shared scaffold costs). Solid wall insulation for these homes should be considered as part of assessments for shared systems or as part of wider apartment block renovation/common works programmes.

24 Results are for homes without space/heritage constraints – these results can be found in the full consultancy report

25 Operating at 85% efficiency, reflecting the reality of real-world performance

26 UK Government, 2021, Cost-Optimal Domestic Electrification (CODE), Research paper

27 Ultimately solar PV was removed from the project because most households would in practice struggle to afford additional capital costs on top of fabric and heating system upgrades, and also to maintain the project's focus on heating

28 RAP, 2022, Good COP/Bad COP: Balancing fabric efficiency, flow temperatures and heat pumps

29 www.gov.uk/government/news/government-announces-energy-price-guarantee-for-families-and-businesses-while-urgently-taking-action-to-reform-broken-energy-market

30 www.gov.uk/government/news/government-announces-energy-price-guarantee-for-families-and-businesses-while-urgently-taking-action-to-reform-broken-energy-market

31 The ASHPs in the typical houses in the study have a seasonal COP (coefficient of performance) of 2.9 to 3.5

32 UK Energy Research Centre, 2022, Can existing renewables and nuclear help keep prices down next winter? The case for a 'pot zero' CfD auction

33 www.baringa.com/en/insights-news/trending/the-challenge-of-european-gas-supply-in-2023/

34 https://www.cornwall-insight.com/winter-2023-24-price-cap-forecasts-fall-further-below-2022-23-epg-but-long-term-prospects-remain-uncertain/

35 Air and ground source heat pumps registered with the Microgeneration Certification Scheme, inflated to £2022. Note: costs also include radiator upgrades and exclude major energy efficiency works. Costs for Air to Air heat pumps were drawn from separate sources.

36 As of December 2022, with a £1,500 extra for rural properties

37 British Gas, Accessed 14.02.2023: www.britishgas.co.uk/home-services/boilers-and-heating/air-source-heat-pumps.html

38 Existing Homes Alliance Scotland, 2022, Owning the future: A framework of regulations for decarbonising owner-occupied homes in Scotland

39 Savills, 2021, 'UK housing value hits record £7.56 trillion high' Accessed 12.01.23

40 Registers of Scotland, 2022, 'Property market report 2021-22' accessed 12.01.23

41 WWF UK, 2022, Better Homes Cooler Planet. Sales data in Scotland was not included given differences in methodology. The average Scottish price house in Sept 2022 - £195,000 according to the UK Office for National Statistics

42 Santander, 2022, Buying into the Green Homes Revolution

43 UK Government, 2013, 'Homeowners' Willingness to Take Up More Efficient Heating Systems'. By Ipsos MORI and the Energy Saving Trust

44 For more detail, please see our Policy Briefing here: https://www.wwf.org.uk/parliamentary-briefings/scotland

45 Joseph Rowntree Foundation, 2022, Poverty in Scotland. Survey data, with 50% of households reporting little or no savings; 20% reporting savings of between £1,000 and £10,000; 15% reporting savings of £10,000 to £50,000 and 15% of over £50,000.

46 See policy briefing here: https://www.wwf.org.uk/parliamentary-briefings/scotland for full details of regulations, incentives and costings underpinning these figures

47 www.climatexchange.org.uk/media/5088/cxc-heat-pump-use-in-scotland-an-evidence-review-august-21.pdf

OUR MISSION IS TO CONSERVE NATURE AND REDUCE THE MOST PRESSING THREATS TO THE DIVERSITY OF LIFE ON EARTH.

WWF Scotland, The Tun, 4 Jackson's Entry, Holyrood Road, Edinburgh, EH8 8PJ Tel: 0131 659 9100

wwfscotland.org.uk

For a future where people and nature thrive | wwf.org.uk