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BETTER HOME, COOLER PLANET

How low-carbon technologies can reduce bills and increase house value

SCOTTISHPOWER | WWF

Accelerating solutions together to fight cimate change

CONTENTS

BEAMA provided expert technical advice for this report, including on the costs and characteristics of low carbon technologies, as well as contributing funding. BEAMA is the UK trade association for manufacturers and providers of energy infrastructure technologies and systems.

FOREWORD

WWF and ScottishPower are working together to accelerate the UK's transition to net zero. We are championing low-carbon energy solutions and jointly calling for ambitious climate action from the UK Government, devolved government, regional government, and local authorities across all the nations of the UK.

We have embarked on a joint research project that investigates how installing low-carbon technologies, such as heat pumps, solar panels, battery storage and electric vehicle chargers, can add value to a home, cut carbon emissions and reduce energy bills. We hope this report will help to inform stakeholders about the benefits of low-carbon technologies and drive changes that will enable more people to access them and realise their benefits.

With WWF as the world's leading independent conservation organisation, and ScottishPower as the first major integrated energy company in the UK to generate 100% renewable electricity, we are uniquely placed to work together to find solutions ot the UK's biggest energy and environmental problems.

EXECUTIVE SUMMARY

There are clear benefits associated with delivering the UK's net zero target. Not only is it essential to tackling the climate emergency but transitioning to low-carbon sources of energy will improve the UK's energy security and independence. Approximately one fifth of the UK's carbon emissions currently come from our homes [i,ii] and, in order to achieve net zero, these emissions must be eliminated by 2050.

This will predominantly be achieved by improving the energy efficiency of existing buildings, decarbonising the electricity grid, and installing low-carbon technologies, such as heat pumps and solar panels, in homes across the country. The UK's buildings tend to be less energy efficient than those in neighbouring countries, meaning that we need to do more work in this area to decarbonise them [iii]. However, we also stand to reap greater benefit from these changes, including reduced energy bills and warmer, comfier homes, as well as the potential to boost our domestic supply chain and create new green jobs.

Many of the technologies needed to decarbonise homes will be familiar to households across the UK, but there is conflicting information available about their advantages and disadvantages, particularly from a financial perspective. This report explores the impact of installing various low-carbon technologies, such as heat pumps, solar panels, electric vehicle (EV) charge points and battery storage, on the sales value, energy bills, and carbon emissions of a home.

IMPACT ON SALES VALUE

The analysis shows that installing **an air-source heat pump could increase the sales value of a home by around £5,000-£8,000; solar panels could increase sales value by around £1,350 - £5,400; and an EV charge point could increase it by around £5,400 - £7,400. In combination, these technologies could increase the value of a home by, on average, around £10,000 [1].** Individual homes could see sales value increases in excess of this figure.

IMPACT ON ENERGY BILLS AND CARBON EMISSIONS

A combination of energy efficiency measures and low-carbon technologies have the potential to greatly impact home energy bills and carbon emissions. The results show that **energy costs can be 37.4% lower when heating a well-insulated home with a heat pump, compared to an energy inefficient home with an old gas boiler,** and 25.8% lower than heating an energy inefficient home with a modern gas boiler.

In a best-case scenario, **a home that is energy efficient and fitted with all the technologies discussed in this report can achieve energy bill savings of £1,634 per year when compared to an energy inefficient home with a modern gas boiler** (or up to £2,065 per year when including transport fuel savings). Meaningful savings of £1,509 per year (or £1,940 when including transport fuel savings) are still realised when comparing an energy efficient, low-carbon home to an energy efficient home with a modern gas boiler. Savings are even higher when compared to an energy inefficient home with an old gas boiler, reaching up to £1,878 (or £2,309 when including transport savings). In addition, **these upgrades can reduce a home's carbon emissions by over 95% over the lifetime of their installation.**

RECOMMENDATIONS TO INCREASE SAVINGS AND WIDEN ACCESS

While there is already a good financial case for installing low-carbon technologies, there are opportunities to further increase savings and improve household access more broadly, providing more opportunities and support to install these technologies. Action will be needed to shift to widespread adoption of all low-carbon technologies, but this is particularly important for heat pumps, where higher upfront costs are currently more likely to be a barrier to uptake. Grant support is therefore needed to drive early deployment, helping to deliver an upfront cost reduction in the technology over time, thereby improving the payback period for consumers.

1 All sales value increases do not include the cost of installation.

This report includes a number of policy recommendations for government with regard to improving public awareness of the benefits of low-carbon technologies and ways to reduce the upfront costs of technologies over time. The key policy recommendations are to:

SCALE UP GOVERNMENT SUPPORT FOR ENERGY EFFICIENCY UPGRADES, PARTICULARLY FOR LOWER-INCOME HOUSEHOLDS. Energy efficiency improvements can result in bill savings for all households and enable further savings to be realised from other technologies, particularly heat pumps.

FULFIL THE COMMITMENT IN THE HEAT AND BUILDINGS STRATEGY TO WORK ON RE-BALANCING POLICY COSTS ON ENERGY BILLS – These sit disproportionally on electricity bills, increasing running costs for electric heating.

SCALE UP THE BOILER UPGRADE SCHEME (BUS) OVER TIME (AND SIMILAR INCENTIVES IN SCOTLAND), INCLUDING EXTENDING THE BUS BEYOND 2025 to support more homeowners to decarbonise their heating, thereby driving the deployment needed to support reductions in upfront costs.

Support from both the public and private sector will be crucial in ensuring that a wide range of homeowners, landlords and housing associations can decarbonise their homes and access the benefits of low-carbon technologies, including reduced bills and carbon emissions, as well as higher home equity value. Whilst the Government will need to provide upfront financial support in the short-term, the long-term benefits in terms of lower bills, reduced emissions, and increased green energy security, as well as the wider economic benefits of jobs and growth, mean that this is an excellent value for money investment [iv, v].

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CHAPTER 1: INTRODUCTION

WHY DO WE NEED LOW-CARBON TECHNOLOGIES IN OUR HOMES?

The impacts of the climate emergency are being felt closer to home than ever before, for example through catastrophic flooding incidents, whilst households are currently experiencing the pressure of very high global gas prices in their domestic heating bills. The UK has a legal commitment to achieve net zero greenhouse gas emissions by 2050. Achieving this will not only help to protect us from the consequences of climate change; it will help to deliver a better future, based on green energy security, warmer homes, and a dynamic low-carbon economy with well-paid green jobs across the country [vi]. As the Government notes in its Energy Security Strategy, reducing our country's dependence on expensive, carbon-intensive gas can help to promote the UK's energy security and reduce energy bills.

Households across the country have a key role to play in delivering this greener future, as 15-20% of the UK's carbon emissions come from our homes [vii, viii], with a further 15% from cars [ix]. To achieve net zero, these emissions will need to be reduced to zero in less than 30 years. The world of energy is changing, and as the power sector decarbonises, adopting low-carbon technologies, like heat pumps and solar panels, will be essential to clean up our homes and our environment. Greening the UK's homes with energy efficiency upgrades and low-carbon technologies will speed up the transition away from fossil fuels, protecting UK households from volatile fossil fuel prices and saving them money in the longer-term.

IT IS CRUCIAL THAT WE UPGRADE THE UK'S EXISTING HOUSING STOCK THROUGH ENERGY EFFICIENCY IMPROVEMENTS AND BUILD ON THIS BY INSTALLING LOW-CARBON HEATING TECHNOLOGIES.

Most of the homes that will exist in the UK in 2050 have already been built. Requiring new homes to have low-carbon technologies installed as standard practice, therefore, is necessary to reach net zero, but not enough on its own. The UK has 28 million homes, the vast majority of which need some level of retrofit work to drive higher energy efficiency standards [x]. Low-income communities across the country – including many ethnic minority communities –are particularly affected by this, as they are more likely to live in poor quality homes with inadequate insulation [xi]. These low-income communities consistently experience some of the highest levels of fuel poverty in the UK and higher rates of illness as a result [xii]. Studies show that old and inefficient housing leads to thousands of early deaths per year and adds around £1.4 billion to annual NHS costs [xiii, xiv, xv].

Therefore, it is crucial that we upgrade the UK's existing housing stock through energy efficiency improvements and build on this by installing low-carbon heating technologies. A programme of upgrades would create warmer, comfier places to live, improve health outcomes, deliver energy bill savings, improve the value of homes [xvi], and support thousands of jobs [xvii]. UK citizens overwhelmingly support the net zero target - many would consider upgrading their home with low-carbon technologies and energy efficiency measures, but many are concerned about the cost or do not know where to start [xviii,xix].

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CHAPTER 2:
DECARBONISING THE UK'S HOMES

Most of the low-carbon technologies (henceforth referred to as 'LCTs', which includes energy efficiency measures) that we need to support the decarbonisation of homes already exist. These are technologies that emit zero or very low levels of carbon, including but not limited to, heat pumps, solar panels, electric vehicle charging points and batteries, all of which are explored in this report. While some of these technologies will be familiar to UK households, misconceptions often exist about their complexity and benefits.

A factor contributing to confusion regarding the benefits of LCTs is the limited amount of research exploring the financial benefits they can bring to homeowners. Where research has been conducted, sample sizes are often relatively small and data is often fragmented, making the research difficult to replicate. As a result, many homeowners are unaware of the potential financial benefits these technologies can bring, or how they can be installed in order to maximise the chance of savings. Clear information on the financial implications of installing these technologies is needed, given that policies designed to reduce emissions in buildings will increasingly require households to engage with them. Clear information on the financial impact is also important for the wider property sector, where estate agents and mortgage providers are likely to encounter increasing interest from consumers in low carbon and energy saving measures.

Research from Savills shows that homeowners are already showing more interest in the energy performance of properties and are willing to pay more for LCTs [xx]. However, without robust evidence, property surveyors and estate agents rarely account for the value of LCTs when assessing the value of a home, due to lack of an evidence base to support their professional judgement. Meanwhile, financial institutions currently offer a limited range of green products that allow homeowners to borrow money to install LCTs or improve the energy efficiency of their property. The Green Finance Institute argues that, while some lenders offer discounted interest rates for properties that have high levels of energy efficiency, an increase is needed in offerings that incentivise households to increase the energy efficiency of their properties [xxi].

Householders also require support and advice when decarbonising their homes, yet many do not know where to go to find reliable information. In this regard, there could be a role for a dedicated, government-backed energy advice and support service. Moreover, promoting high standards and training in the installation supply chain will be key, including ensuring that construction industry employees receive the necessary training to help consumers decarbonise their homes, and that installers comply with recognised accreditations schemes. Credible, verifiable, and independent sources of information must be used when discussing the benefits of LCTs with homeowners, particularly when proposing to install combinations of LCTs. Ensuring that the right advice is given in each individual circumstance will be vital to building trust and consumer demand.

Finally, while the costs of many LCTs have reduced over time, the upfront cost of installing some of these technologies remains a barrier for many homeowners, even when the longer-term benefits are clear. Support schemes are needed to address this issue, particularly for those on low incomes who are in, or at risk of, fuel poverty. Whilst in the private rented sector, there is a need to address the split incentives landscape, as landlords may have less of an incentive to install LCTs because the bill savings and comfort benefits often accrue to the tenant.

THE FINANCIAL BENEFITS OF LOW-CARBON TECHNOLOGIES, AND HOW TO INCREASE ACCESS TO THEM

Low-carbon technologies already offer financial benefits to households

This report provides a comprehensive analysis on the value of LCTs to households, based on analysis of over 5 million house sales and robust modelling by leading experts. It demonstrates how installing an appropriate combination of LCTs can improve the value of a home, reduce energy bills and reduce carbon emissions.

Chapter 3 of the report sets out key findings from the modelling, which consists of (i) equity value modelling (to assess the impact on home value) and (ii) running cost modelling (to assess the impact on energy bills).

The report also examines several possible LCT combinations that can help to decarbonise a home and the associated potential financial benefits through a number of case studies. These are summarised in Chapter 3, and the detailed case studies, which cover LCTs in isolation and in combination, are set out in the Annex.

IMPROVING THE FINANCIAL CASE FOR HOMEOWNERS AND MOVING TO WIDESPREAD DEPLOYMENT

Chapter 4 of the report includes a range of policy recommendations, based on the findings outlined in the first part of the report. While the results of the modelling are broadly positive in terms of the value that installing LCTs can bring, there are opportunities to improve the business case further and open up access to these technologies to a greater proportion of households.

Action is needed to facilitate the widespread deployment of all the technologies discussed in this report, although particularly for heat pumps, where high upfront costs are more likely to present a barrier to uptake. Upfront grant funding is needed to spur early deployment and thereby bring the upfront costs down over time, through learnings, innovation and economies of scale.

Additionally, while the equity model does not specifically assess the impact of energy efficiency measures, the results from the running cost model supports existing research in showing that the installation of energy efficiency measures can produce substantial savings[xxii]. Energy efficiency measures also help households to access greater savings from other technologies, such as heat pumps.

CHAPTER 3:
SUMMARY OF MODELLING AND KEY FINDINGS

This report suggests that installing an appropriate combination of LCTs could increase the value of a home by, on average, around £10,000 and reduce energy bills by up to £1,878 per year, or up to £2,309 per year when transport fuel costs are considered as well [2]. It could also reduce the carbon emissions from energy use of a home by over 95% over the lifetime of the technologies [3].

It is essential to note that the estimated reductions in energy bills and carbon emissions are best-case scenarios and based on assumptions-driven modelling. These estimates should be interpreted as illustrative of the savings that can be realised. The exact figures involved would vary if input assumptions were altered, although the direction and magnitude of the saving would be unlikely to change substantially, unless input assumptions were also altered substantially.

SUMMARY OF MODELLING

The findings outlined below were generated by two sets of modelling – equity value modelling to determine the impact of LCTs on the sales value of a home and running cost modelling to determine their impact on bills.

1. Equity Value Modelling

For the equity value modelling, a large dataset containing over 5.4 million English and Welsh house sales transactions [4], along with a dataset containing over one million installations of low-carbon technologies, has been analysed. As such, this one of the largest studies that has ever been conducted on the impact of LCTs on property prices.

Analysis revealed that installing heat pumps [5], electric vehicle (EV) charging points and solar panels has the potential to increase the sales value of households fitted with one or more of these technologies. The potential increase in sales value is proportional to the capital cost of installing the LCT for heat pumps and solar panels, while it is disproportionately higher than the cost of installation for EV charging points, as the table below illustrates. Not only this, but LCTs also have the potential to significantly reduce energy bills, as well as adding equity value.

	Average Installation Cost [6]	Average Equity Value on Sale [7]
Air Source Heat Pump	£10,980	£6,220 [8]
Solar Photovoltaic	£3,800	£3,840
EV Charge point	£1,000	£5,200

Table 1.
Average LCT Installation Cost Vs. Average Equity Value Uplift

A number of stakeholders in the property industry can play a major role in accelerating uptake of LCTs, enabling more homeowners to realise their benefits. We therefore provide a number of recommendations to several key stakeholder groups:

ESTATE AGENTS SHOULD:

Mention presence of LCTs in all property listings and viewings, highlighting their benefits which include increased equity value, lower bills and reduced energy usage. More details of their benefits can be found in the case studies later in this report.

PROPERTY LISTINGS WEBSITES SHOULD:

Ensure that all listings prominently feature information on the presence of LCTs, EPC ratings, and likely running costs, and provide best practice guidance to estate agents on ensuring LCTs are included in their listings and mentioned to property viewers.

Gather and share data on the installation of LCTs in homes, then use this data to update software (including Automated Valuation Models and Surveyor Comparator Tools) to better reflect the value of LCTs and highlight suitable comparable properties to surveyors.

PROPERTY SURVEYORS SHOULD:

Better account for and reflect the value of LCTs, based on the growing evidence that these measures can add value to homes and that consumers show increasing interest in procuring solutions [1]. Where data is lacking or tools do not reflect this value uplift, surveyors should engage with the relevant stakeholders to fill these gaps.

Make use of the RICS Home Survey Standard to analyse EPC reports and comment on how to improve the energy performance of a property on top of the recommendations outlined in the EPC.

MORTGAGE AND FINANCE PROVIDERS SHOULD:

Offer green mortgages and explore other innovative financial products to support and reward homeowners for upgrading their home by installing LCTs.

Update guidance for surveyors and valuers, in order to take account of the impact that LCTs can have on improving loan performance and payback, by reducing energy costs and increasing home value, where applicable.

Highlight the benefits of installing LCTs to customers when buying, selling, and re-mortgaging, including financial benefits, avoided regulatory risk, and co-benefits such as improved air quality.

1 All sales value increases do not include the cost of installation.
2 Bill levels used are reflective of changes to the energy price cap, which were implemented in April 2022, and the consequent impact on tariffs. Figures including transport fuel costs are inclusive of the annual cost saving derived from powering an electric vehicle with electricity, rather than a standard car with petrol.
3 By installing an appropriate combination of LCTs, a home could reduce its carbon emissions from energy use by 96.8% over the 30-year lifetime of the technologies, when compared to a poorly insulated home with an old gas boiler, or by 95.9% with compared to a poorly insulated home with a modern gas boiler. Further details can be found on p.40.
4 Postcode-level house price datasets for Scotland and Northern Ireland were not available on an aggregated basis, meaning that a hedonic regression analysis could not be performed for these two nations. While the Scottish housing market has somewhat different processes and rules to those in England and Wales, the increase in property value derived from installation of LCTs is expected to be broadly similar.
5 Unless explicitly stated, where this report mentions 'heat pumps', it refers to air-source heat pumps, rather than ground-source or other forms of heat pump.
6 Average install costs based on typical prices in 2021.
7 Please note that the equity value increase does not include the cost of installation.
8 This figure reflects the average equity value uplift for all heat pumps, both air source and ground source. This is because the number of heat pumps installed in the UK is still relatively small, so including both types of heat pump generated a more robust sample. It should be noted that a large majority of the sample were air source heat pumps.

Fitting the appropriate combination of LCTs could increase the value of a home by, on average, around £10,000, with individual homes potentially seeing value increases above or below this figure. The hedonic analysis of recorded sales transactions indicates that heat pumps add around £5,000-£8,000 (derived from a percentage estimate of 1.7-3%, multiplied by the average value of a home in England and Wales), solar PVs can add £1,350 - £5,400 (0.5-2%) and EV charging points can add around £5,400 - £7,400 (2-2.75%). While the sample analysed in this study did not allow us to observe price premiums paid for combined LCT packages directly, it seems plausible that these are additive and complementary, as these three technologies can support each other (for instance, EV charging points or heat pumps can be powered by domestic solar energy).

2. Running Cost Modelling

The running cost modelling demonstrates that investing in LCTs can reduce householders' energy bills [9,xxiii], in some cases significantly. When installed in the right circumstances and combinations, LCTs can both reduce energy bills and cut carbon emissions, benefiting people's pockets, as well as the planet. While the report focuses primarily on household LCTs, potential savings increase further when households switch from a petrol or diesel car to an electric vehicle. While charging an electric car will increase household electricity consumption, this will be much less expensive than the cost of running a car using petrol or diesel. In a best-case scenario, energy cost savings, which include not needing to buy petrol or diesel, could be as high as £2,309 per year.

A range of case studies based on the running cost modelling explore the impact LCTs can have on home energy bills, in isolation or in combination, as well as looking at the impact of switching energy tariff (e.g., to an electric vehicle tariff), and of government levelling the costs of electric and gas heating. The aim of the case studies is to help stakeholders, including financial institutions, property surveyors and homeowners, understand which combinations of LCTs tend to be most cost-effective, and the impact of different choices.

Local authorities and housing association will play a vital role in ensuring the benefits of LCTs are available to as many people as possible" (we don't need to specifically say we're making recommendations, that much should be clear). Would maybe do the same with the box on page 11.

HOUSING ASSOCIATIONS AND LOCAL AUTHORITIES SHOULD:

- Invest in installing LCTs at scale in their housing portfolios, supported by the government where necessary, such as under the Welsh Government's Optimised Retrofit programme [1]. Where possible, consider virtual energy services arrangements to share the benefits of local generation, which can help to reduce levels of fuel poverty.
- Inform applicants for domestic planning applications of the benefits that LCTs can provide, or direct them towards reliable advice services, such as the Energy Saving Trust.
- Local authorities, specifically, should facilitate a fair distribution of EV charging points in their localities, particularly in areas with limited off-street parking, working alongside Distribution Network Operators (DNOs) to ensure that grid capacity is optimally used to support installation of EV charge points and other LCTs.

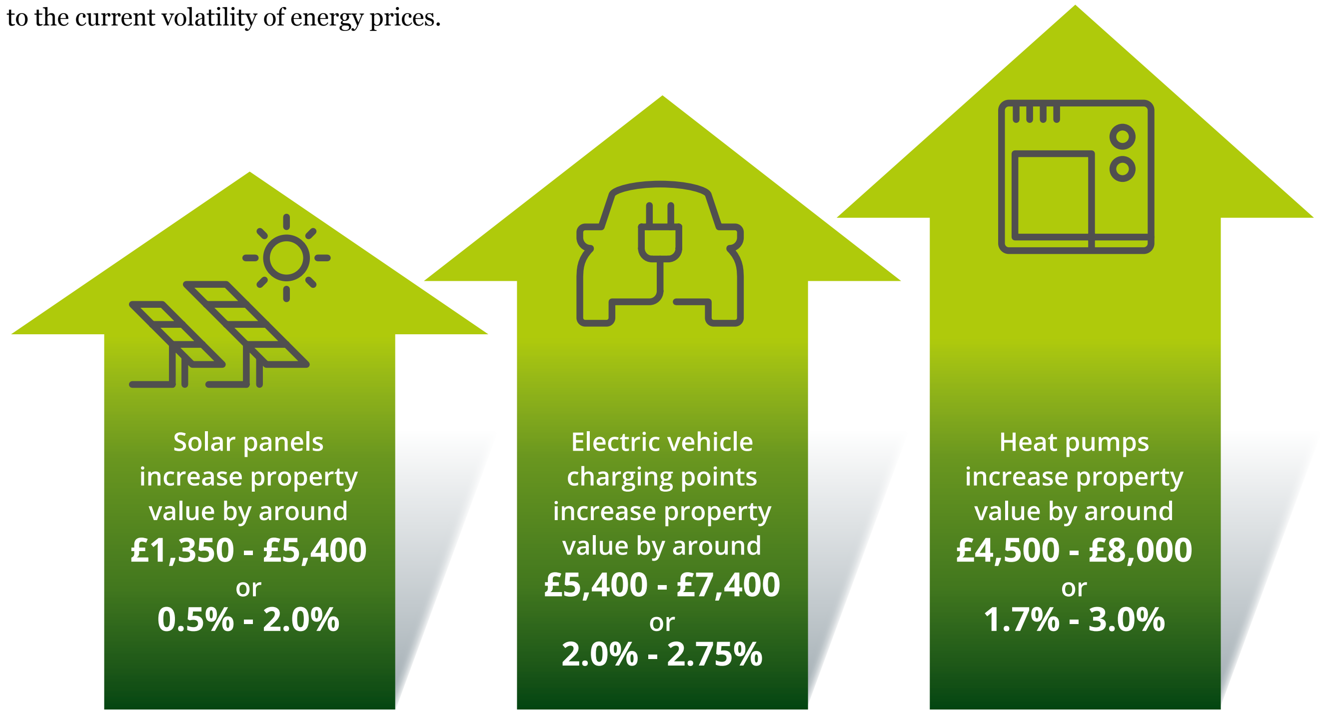
1 All sales value increases do not include the cost of installation.

9 The analysis of the impact of LCTs on energy bills assumes the consumer is on a standard variable tariff (SVT) set at the level of the energy price cap for the period beginning April 2022. The tariffs used are a Standard Variable Tariff and ScottishPower's EV Tariff, a Time of Use Tariff that, at the time of modelling (February 2022), was available to existing customers with a smart meter, and did not require them to own an EV. The energy price cap will be updated on 1 October 2022, and Ofgem will announce the new level in August 2022, however, Ofgem has already indicated that it anticipates a rise in the price cap. Depending on the final cap level and how it is set, this may further increase the savings associated with these technologies, in some cases significantly.

Time of Use Tariffs

Time of Use Tariffs reward homeowners for using electricity at certain times, often when there is an abundance of renewable electricity being generated. This can help to lessen the strain on the grid, ensure maximum usage of clean electricity and reduce bills. These tariffs are likely to become increasingly widespread and innovative in the future and could increase the benefits associated with smart operation of LCTs. 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.

It is also important to note that, as the modelling was undertaken in February 2022, it does not take into account the impact of the UK Government's announcement in the Spring Statement that VAT on energy savings materials and their installation will be reduced to 0% for five years. These changes will help to reduce the upfront cost barrier of installing LCTs, which will improve the payback periods referred to in this report.



SUMMARY OF CASE STUDIES

HEAT PUMPS

Heat pumps are a low-carbon technology that can be used to heat a home by transferring heat from a source outside (such as the air or the ground), inside. They are already popular in Scandinavia and other parts of Europe and are very efficient, with the potential to be four to five times more efficient than a standard gas boiler.

Energy efficiency can have a noticeable impact on heating costs, regardless of the technology used to heat a household (house). Research from the Energy Systems Catapult shows that heat pumps can be suitable for all types of homes, however, it is recommended that a good level of energy efficiency, for example loft and cavity wall insulation, is installed to reduce the demand for space heating and keep running costs down [xxiv].

The table below shows the running costs and carbon emissions of a well-insulated house with a heat pump, when compared to houses with an inefficient old gas boiler and an efficient modern gas boiler. It shows that heat pump running costs are currently lower than an old gas boiler, by £117 per year (approximately £10 per month) and are competitive with modern gas boilers (being only £56 more expensive per year, or approximately £5 per month).

Policy reforms can further improve the economic case for installing a heat pump by making them cheaper to run. Currently, policy costs fall disproportionately on electricity bills rather than gas bills; action to rebalance these policy costs would help to make heat pumps cheaper to run than modern gas boilers.

	Poorly Insulated House with Old Boiler	Well-Insulated House with Old Gas Boiler	Well-Insulated House with Modern Boiler	Well-Insulated House with Heat Pump
Annual Energy Costs (£/year)	2,416	1,629	1,456	1,512
Reduction in Annual Energy Costs (vs. poorly insulated house with old gas boiler)	n/a	32.6%	39.8%	37.4%
Annual Energy Costs (with legacy policy costs moved to government spending) (£/year)	2,265	1,478	1,305	1,290
Reduction in Lifetime Emissions Versus Poorly Insulated House with Old Gas Boiler	n/a	49.8%	60.7%	87.6%

See p. 25 and the technical report for further details.

ELECTRIC VEHICLE CHARGING

Electric vehicle charging points allow homeowners (with off-street parking options) to easily charge their car at home. The cost of charging an electric vehicle at home depends upon many factors, including the householder's electricity tariff, the type of electric vehicle being charged, and the length of time it is charged for. Across all of our scenarios, charging an electric vehicle is cheaper than paying to fill up a tank of petrol or diesel and has the potential to save a driver between £194 - £572 per year.

At the time of analysis [10] the cost of charging an electric vehicle from home was estimated as costing between £206 - £500 per year, but this has the potential to be reduced further if the house is equipped with solar panels and a battery, as energy generated from solar panels can be stored and used to charge the vehicle overnight. A household with an EV, which installs solar panels and a battery, could see their electric vehicle charging costs reduce by £334 - £385 per year according to this analysis, depending on the electricity tariff, charging patterns and home battery storage capacity. Larger capacity home batteries can store more energy, which can then be used at night to charge the EV without drawing on the grid.

The table below shows the impact of using solar PV and a battery to enable overnight charging for two models of EV.

Energy tariffs can make a big difference to the EV charging costs, and consumers should make sure to pick the tariff that is most suited to their lifestyle and needs.

	Nissan Leaf [11]	Tesla Model S	Tesla Model S
Charging Profile	Midnight to 5 a.m.	Midnight to 5 a.m.	Off-peak times only
Charge Cost Using a Standard Variable Tariff (£/yr) [12]	£206	£230	£500
Charge Cost Using a Standard Variable Tariff, Plus Battery and Solar Panels (£/yr)	£183 [13]	£0	£195

See p.29 and the technical report for further details.

10 February 2022.

11 No off-peak charging times are given in this table for a Nissan Leaf, as this model of car reaches full charge on the overnight charging cycle, from midnight to 5am, so does not require further charging. The Tesla Model S, by contrast, does not reach full charge on an overnight charging cycle. Therefore, an off-peak charging profile for this car has also been provided, to give indication of the yearly cost of fully charging the battery.

12 Prices calculated using a standard variable tariff of 28p/kWh.

13 The reduction in charging cost for a Nissan Leaf when using solar panels and a battery is less than the Tesla because the car battery and home storage battery for the Nissan Leaf scenario are smaller. As the home storage battery is smaller, it has little charge left after (electricity is used in) the house and, as a result, electricity is taken from the grid to charge the Nissan Leaf. A larger battery is not used in the Nissan Leaf scenario because an oversized battery will negatively impact the battery's efficiency and lifetime. In the Tesla scenario, the home storage battery is larger and therefore is more likely to have charge left over at the end of the day, which can be used to charge the EV.

SOLAR PV

The size of the solar panel system on a house, its orientation and where it is in the country will all make a difference to the potential bill savings from solar panels; for instance, a solar panel system facing southeast/southwest will generate more power than a solar panel system facing east/west.

A home that has a 4kWp solar panel array, and a 5.5p/kWh Smart Export Guarantee (SEG) tariff, could see a total financial benefit of £586 per year. The financial benefit is made up of the avoided cost of not using electricity from the grid, plus the money made by selling surplus energy back to the grid via the SEG tariff. The SEG tariff is the amount of money an energy supplier guarantees they will pay a household for any low-carbon electricity it exports back to the grid.

Energy bill savings are currently likely to be maximised by households increasing their use of the electricity generated from their solar panels, before selling the rest back to the grid. This financial benefit could also increase if the household uses an electric vehicle tariff, instead of a standard variable tariff, because the PV system helps to reduce use of electricity from the grid during times of higher daytime import tariffs, resulting in annual financial benefits rising to £786 per year. Installing solar panels could also prevent 22tCO_2 from being emitted into the atmosphere over their lifetime (i.e., 30 years).

If a home has solar panels and a battery (meaning that excess energy from the solar panels can be stored for use when needed), a household could see a financial benefit of £713 on a standard variable tariff and £1,186 on an electric vehicle tariff.

See p.31 and the technical report for further details.

A LOW-CARBON HOME

This case study looks at the best-case scenario for a well-insulated, low-carbon home equipped with all the technologies explored in this report, including energy efficiency measures. This considers the possible energy bills of the house with and without transport costs, to better account for the impact a vehicle will have on energy bills.

The annual running cost for a low-carbon home without an electric vehicle, could be as little as £240 per year, in an optimal scenario. In contrast, the annual running cost for an energy efficient home with a modern gas boiler is likely to be around £1,749. This would equate to an annual saving of £1,509 and a reduction in CO_2 emissions of 59 tonnes over a 30-year period.

When the cost of charging an electric vehicle is included, the annual energy bills for a low-carbon home could be closer to £507. In comparison, annual energy costs could be closer to £2,447 per year for an energy efficient home with a modern boiler and operating a petrol car, resulting in savings of £2,065 per year for the low-carbon home.

See p.36 and the technical report for further details.

KEY FINDINGS

- An analysis of over five million house sales shows that LCTs could increase the sales value of homes as follows:
  - Heat pumps can add around £5,000 - £8,000 (1.7-3.0%) to the value of the average home.
  - Solar PV can add around £1,350 - £5,400 (0.5-2.0%) to the value of the average home.
  - EV charging points can add around £5,400 - £7,400 (2.0-2.75%) to the value of the average home [14].
- Where LCTs are installed in combination, they can increase the value of a home by, on average, around £10,000, depending on the value of the home and its location and characteristics. Individual homes may see sales value increases above or below this figure.
- In a best-case scenario, a low-carbon home that is energy efficient and fitted with all the technologies discussed in this report, can deliver:
  - Energy bill savings of up to £1,878 per year when compared to an energy inefficient home with an old gas boiler [15] (or up to £2,309 per year including transport fuel savings, when switching from a petrol car to an EV).
  - Energy bill savings of up to £1,634 per year when compared to an energy inefficient home with a modern gas boiler [16] (or up to £2,065 per year including transport fuel savings, when switching from a petrol car to an EV).
  - Energy bill savings of up to £1,509 per year when compared to an energy efficient home with a modern gas boiler (or up to £1,940 per year including transport fuel savings, when switching from a petrol car or an EV).
- A low-carbon home that is energy efficient and fitted with the technologies discussed in this report can deliver lifetime carbon emissions savings for energy use of over 95%.
- Running an electric vehicle (EV) using electricity is much cheaper than running a car using petrol or diesel, with an average cost of 7-9p per mile, compared to 15-19p per mile for petrol and diesel. In the case studies, this difference delivers savings of £194 - £572 per year, depending on the charge time and type of EV. Savings could be higher than this, depending on miles driven and charging patterns.
- Investment in energy efficiency measures has a significant impact in reducing heat loss from homes, particularly older homes, thereby making use of heat pumps cost-effective. Installing heat pumps in poorly insulated homes without implementing energy efficiency measures first may increase energy bills. When installed correctly however, research suggests that all housing types are suitable for heat pumps [xxv].

14 Although the number of EV charge points modelled was statistically significant and the modelling is robust, knowledge of the relative cost of an EV charge point versus the value uplift in the data means that we have less confidence in the projected increase in sales value occurring consistently. It would be valuable for further studies to be conducted in this area to validate this result.

15 Defined as a 66% efficient gas boiler

16 Defined as an 89.4% efficient gas boiler

- Heating a well-insulated home using a heat pump could cost 37.4% less in energy bills than heating a poorly insulated home via an old gas boiler and 25.8% less than an energy inefficient home with a modern gas boiler, even before any potential action from government to address the unlevel landscape in terms of policy costs being placed on electricity bills rather than gas bills.
- Where homes previously heated using gas switch to a heat pump, lifetime carbon emissions could fall by over 80%.
- Solar PV panels are already extremely cost effective, and it is possible to have payback periods of less than ten years, even before other LCTs are added to a home.
- Adding a battery to a house with solar panels and a heat pump can increase the total financial benefit of the solar panels by allowing homeowners to use more of the solar energy generated to power the heat pump. Depending on the electricity tariff, this can offset higher energy import costs and provide significant energy savings over the life of the battery. In case study 3, adding a battery increases the total financial benefit of the solar panels by 32.2% on a Standard Variable Tariff or 37.0% on an EV tariff.
- Solar panels and a battery can offset a significant proportion of EV charging costs (~10% to >90%) depending on the battery control logic, the EV and EV charging times, the size of the battery and the electricity tariff being used to charge the EV. In the case studies below, this can lead to savings in EV charging costs of up to £385 per year on a Standard Variable Tariff and up to £334 per year on an EV Tariff.

POLICY COSTS

"Policy costs" are the cost of government environmental and social schemes which are funded through energy bills. They are currently placed disproportionately on electricity bills, which creates a distortion in favour of gas. This report further distinguishes between all such policy costs and "legacy" policy costs, which are the cost of closed schemes such as the Renewables Obligation and the small-scale Feed-in Tariff schemes. Moving these "legacy" policy costs away from consumer bills and into government spending could incentivise the uptake of clean heating technologies.

CHAPTER 4:
KEY POLICY RECOMMENDATIONS FOR PUBLIC POLICY MAKERS

In this chapter, we set out some key recommendations to further promote the decarbonisation of homes in the UK. A key dimension underpinning many of the proposals is the need to ensure a fair low-carbon transition, so that the benefits of decarbonising our homes and economy are shared throughout society.

STRENGTHENING INCENTIVES AND THE SUPPORT FRAMEWORK TO IMPROVE THE DELIVERY OF ENERGY EFFICIENCY AND HEAT DECARBONISATION MEASURES

ENERGY EFFICIENCY

- The UK Government should set out a clear trajectory for all homes in England and Wales to reach Energy Performance Certificate (EPC) Band C and, as part of this process, should consider increasing its ambition for an end date for all properties to reach this standard. In setting standards across different building types and tenures, it is essential that this is complemented by appropriate incentives and support, especially for those on low incomes and at risk of fuel poverty.
- The Scottish Government should implement the commitment that from 2025 all private housing must achieve minimum standards equivalent to EPC Band C at key trigger points, as well as considering an increase in its ambition for an end date for all properties to meet this standard. In setting standards across different building types and tenures, it is essential that this is complemented by appropriate incentives and support, especially for those on low incomes and at risk of fuel poverty.
- Building on the existing GB-wide ECO4 energy efficiency scheme focused on those at significant risk of fuel poverty, the UK Government should look to fund an additional 'ECO+' energy efficiency scheme, targeting a broader group of lower income households and helping them to make improvements to the fabric of their homes.
- Complementing this, the Scottish and Welsh Governments should keep under review progress under their own publicly funded energy efficiency support schemes with a view to scaling up this support over time to match their ambitious plans for delivering improvements to households across Scotland and Wales, respectively.

LOW-CARBON HEATING

- The UK Government should scale up the new Boiler Upgrade Scheme over time, including extending it beyond 2025, so as to promote the installation of low-carbon heating options such as heat pumps across England and Wales.
- Likewise, the Scottish Government should provide long term clarity on the future of incentives currently available through Home Energy Scotland to households wishing to install heat pumps and other low-carbon technologies.
- Increasing grant support for low-carbon heating options in this way - combined with the planned introduction of the obligation on boiler manufacturers to scale up the supply of heat pumps to households over time – should help to deliver significant reductions in the upfront costs of heat pumps in the years ahead, thereby promoting further take-up by households.
- The UK Government should take forward the commitment in the Heat and Buildings Strategy to re-balance policy costs placed on electric and gas heating bills to avoid the current distortion in favour of gas. This would help to reduce the running costs of clean technologies powered by electricity such as heat pumps [17].
  - One way in which this might be progressed is to move legacy policy costs relating to closed schemes (such as the Renewables Obligation, and the small-scale Feed-in Tariff scheme) away from consumer bills and into government spending [18] . This would help to re-balance costs between gas and electricity given that these legacy policy costs currently fall disproportionately on electricity bills rather than gas bills.

GREEN FINANCE

- The UK Government should consider introducing an Energy Saving Stamp Duty incentive [19] and other green financing incentives to better promote the uptake of energy efficiency and low-carbon heating measures by those better off households who might be able to fund such improvements.
- Building on the Chancellor's strategic steer to the UK Investment Bank (UKIB) earlier this year, the UK Government should ensure that the decarbonisation of homes and buildings is properly treated as one of UKIB's infrastructure priorities.
- As part of its ongoing work on green finance, the UK Government should look at ways for facilitating mortgage lenders to disclose the average EPC ratings of their portfolios so as to show progress over time; whilst avoiding any unintended consequences such as limiting the availability of mortgage finance in an unfair way.

INTRODUCING SMARTER REGULATION TO PROMOTE ENERGY EFFICIENCY IMPROVEMENTS AND LOW-CARBON HEATING

- As regards the private rented sector, both the UK and Scottish Governments should deliver on proposals to raise Minimum Energy Efficiency Standards for private rented homes to EPC Band C by 2025 for new tenancies and 2028 for all tenancies, as well as introducing incentives for landlords to meet them, including – for the UK Government – a renewed Landlords Energy Saving Allowance for landlords who exceed the Minimum Energy Efficiency Standard.
- The UK Government should set out a trajectory for social housing to meet EPC Band C by a clear end date this decade, as well as ensuring that funding for the Home Upgrade Grant and the Social Housing Decarbonisation Fund is sufficient to deliver timely progress with this. This must be matched by proper resourcing of local authorities and social housing providers to improve the condition of their housing stock and install low-carbon heating options.
- The Scottish Government should bring forward plans to implement the proposed phase out of new installations of coal, oil, and LPG boilers from 2025 and gas boilers from 2030.

17 Where reference is made to moving policy costs into government spending in this report, we assume that the specific approach outlined here is the one chosen.
18 A recent report from to Public First considered this option: Options for Energy Bill Reform - Public First
19 In Wales, this would involve reform of the land transaction tax, rather than of stamp duty, but the same type of reform could be applied.

TAKING STEPS TO IMPROVE CONSUMER ADVICE FOR HOUSEHOLDS

- The UK Government should deliver on its commitment in the Energy Security Strategy to set up a new comprehensive energy advice service on gov.uk to help consumers navigate improving the energy performance of their homes.
- As the Climate Change Committee recommends in its 2022 Progress Report [xxvi], an energy advice service should include an online platform including high-level trusted information and advice, a link to local providers who can undertake assessments of home energy performance, and bespoke support for households wishing to undertake more complex retrofits.
- The UK Government also needs to prioritise taking forward putting in place a system of additional support for householders through telephone support and specific, consistent local area advice for energy consumers.

IMPROVING DATA QUALITY AND VISIBILITY TO SUPPORT THE TRANSITION TO LOW-CARBON HEAT

- The UK Government should continue to deliver on the proposals in its EPC Action Plan to improve the accuracy and reliability of EPCs. This will be increasingly necessary in the context of energy performance targets outlined in the section above, but also to support deployment of low-carbon heat, and facilitate wider usage, for example in green finance offerings.
- Specifically, the UK Government should ensure that EPCs reflect reductions in the carbon intensity of electricity and are based on up-to-date heat pump performance data.
- The UK and Scottish Governments should look to phase in Building Renovation Plans based on consistent and interoperable data structures, in order to help property owners, assess how to retrofit their homes and consider the role of targeted support for property owners unable to afford a BRP.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CHAPTER 5:
CONCLUSION

This report shows that installing low-carbon technologies, including energy efficiency measures, can benefit people's pockets, as well as the planet. Not only can they improve the quality of life for homeowners and tenants, by making homes warmer and more comfortable places to live, but a combination of these measures could also:

1 INCREASE THE VALUE OF A HOME BY, ON AVERAGE, AROUND **£10,000**

2 REDUCE ENERGY BILLS BY UP TO **£1,878** PER YEAR, OR BY UP TO £2,309 PER YEAR WHEN INCLUDING TRANSPORT FUEL SAVINGS FROM SWITCHING TO AN EV FROM A PETROL CAR

3 REDUCE CARBON EMISSIONS FROM ENERGY USE BY OVER **95%**

This report illustrates that people living in a range of property types, with a range of different needs and lifestyles, should consider low-carbon technologies and energy efficiency upgrades in their home. However, for these technologies to expand beyond early adopters, government needs to use a suite of policy measures to incentivise their uptake, as highlighted in Chapter 4 above.

Government must recognise the need for near term support to tackle the upfront cost barrier associated with energy efficiency retrofits and the installation of many LCTs, alongside the introduction of smarter regulation to drive progress where appropriate. Despite the benefits in terms of reduced energy bills and increased equity value, many low-income homeowners will, in particular, be unable to participate in the low-carbon transition without this support.

Without a comprehensive and ambitious set of policies, progress in decarbonising the UK's households will be slow, hindering the UK's ability to achieve its legally binding net zero target [xxvii]. As the Climate Change Committee highlighted in its most recent Progress Report, delivering net zero requires major policy strengthening with a particular focus needed on promoting the decarbonisation of buildings [xxviii,xxix]. Moreover, delivering such improvements to the policy framework could deliver long-term benefits to households in terms of lower bills.

Estate agents and property surveyors can also play an important role in encouraging the rollout of LCTs by better incorporating their value into their modelling and communications. Finance providers, in turn, can introduce innovative products to support homeowners in installing LCTs, and the construction industry can focus on upskilling their staff to deliver a retrofit revolution.

Rolling out LCTs in homes across the country is essential to meeting our climate goals, cutting energy bills, and promoting green energy security in the long-term; whilst investing in the delivery of these technologies will support jobs and wider economic benefits across the country. In short, this report helps to set out how LCTs can benefit people's pockets, as well as the economy and the climate.

ANNEX:
FULL METHODOLOGY AND RESULTS

Two models were used to understand the potential financial benefits to homeowners of LCTs. The first model looks at the impact of the presence of LCTs on home equity value (i.e., sales price) using a hedonic regression analysis. The second model looks at the impact LCTs can have on energy bills, using a bespoke model which calculates the energy demand of different property types and examines the financial costs and benefits of installing one or more of these technologies.

The 'equity model' has been produced by Franz Fuerst from the Department of Land Economy at the University of Cambridge, and the 'running cost model' has been produced by Kirk Archibald from Think Three consultancy. Part A of this section describes the equity model and its results; whilst Part B explores the running cost model and its results, which are illustrated using a set of case studies.

PART A

EQUITY MODEL OVERVIEW

Property prices can be used to understand the value of different characteristics of a property; for instance, individuals may be willing to pay more for a home equipped with solar panels but wish to have a discount on a home near a major road junction. Hedonic regression analysis is used to measure the relative importance of these different variables on property price, independent of each other. It is a well-established method for investigating and disentangling variables and establishing the contribution each variable makes to the overall price of a product.

The datasets used for the hedonic regression in this study include:

- **House price data in England and Wales** [20] consisting of over five million data points from 2007 until the present day, capturing approximately 80% of all sales that occurred in this period.
- **Energy Performance Certificate (EPC) data in England and Wales** consisting of more than 10 million EPC records for UK homes from 2009 to the present day.
- **Microgeneration Certification Scheme (MCS) data on domestic LCTs** consisting of over one million records of solar panels and heat pumps, installed from 2007 to the present day. The dataset gives details of the number, type, size and location of small-scale renewable heat and power generation systems in the UK.
- **Office for Zero Emissions Vehicles (OZEV) data on domestic electric vehicle charging points** consisting of data relating to the location, investment, type of charger and vehicle make and model for over 200,000 electric vehicle charging points in the UK [21].

20 Postcode-level house price datasets for Scotland and Northern Ireland were not available on an aggregated basis, meaning that hedonic regression analysis could not be performed for these two countries. While the Scottish housing market has somewhat different processes and rules to those in England and Wales, the increase in property value derived from installation of LCTs is expected to be broadly similar.

21 Data on installations of domestic batteries is currently unavailable and therefore did not feature in the hedonic regression analysis.

The equity model integrated and analysed the above datasets to assess whether investments in LCTs are associated with higher sales prices. Previous, similar studies have relied on evidence from a relatively small number of houses. This study, however, resolves that problem by considering a vast database of several million sales transactions, effectively covering the entire English and Welsh housing market over the last decade. These housing transactions were matched with information on homes with LCT installations in the databases listed above. After the matching process was complete the resulting sample size consisted of 5.4 million valid data points. The sample contained homes across all typologies, sizes, and locations, meaning that it is highly representative and is one of the largest studies that has ever been conducted on the impact of renewable energy investments on property prices.

EQUITY MODEL RESULTS

Results from the hedonic regression show that there is a significant uplift in value for properties fitted with LCTs such as EV charging points, heat pumps and solar panels. The value uplift for each technology varies:

- Heat pumps increase property value by around £4,500-8,000 or 1.7% - 3.0%.
- Solar panels increase property value by around £1,350-5,400 or 0.5% - 2.0%.
- Electric vehicle charging points increase property value by around £5,400-7,400 or 2.0 -2.75% [22].

These value uplifts are significant and indicate that home buyers are prepared to pay more for properties that are fitted with LCTs. Furthermore, 93.6% of the variation in house price data can be explained by the model, meaning we can be confident that the results were not obtained by chance or due to other variables, such as upgrading a kitchen at the same time as installing an LCT. The value increase could rise even further in the future, particularly if proposals to phase out fossil fuel heating systems are introduced.

It should be noted that the value increase will vary by region, property type and year of installation. In fact, the results of the model indicate that the green premium on a property is larger in percentage terms for homeowners with lower priced properties. For instance, where the average house price is £150,000, a solar panel installation worth £5,000 adds 3.3% to the property's initial value, but this falls to 1% where the average price of a property is £500,000. A solar panel installation worth £5,000 adds 1.86% to the value of a house worth £268,349, which is the average UK house price [xxx].

For further details, please refer to the technical report containing details of the modelling, which is available on Think Three's website: Better Homes, Cooler Planet: Technical Report.

22 Although the number of EV charge points modelled was statistically significant, the projected increase in sales value appears high, and indeed exceeds installation costs, so requires further explanation and more fine-grained analysis.

PART B

RUNNING COST MODEL OVERVIEW

The Running Cost Model assesses the impact LCTs can have on annual home energy bills [23], by combining datasets that calculate the energy demands of different house types with information about the characteristics of different technologies.

The following LCTs can be included within the model, separately or in various combinations:

- **Energy efficiency measures**
- **Heat pumps**
- **Solar panels**
- **Energy storage batteries**
- **EV charge points**

It should be noted that some LCTs work best when installed alongside other technologies or energy efficiency measures. For example, it would not be advisable to install a heat pump in a property with very poor insulation, as this would potentially require a larger capacity heat pump to meet the higher heating demands, resulting in higher costs and inefficient use of the heat pump. Investment in energy efficiency improvements will reduce energy demands and facilitate efficient use of LCTs like heat pumps.

The minimum amount of information required for the model to function includes:

- **The first half of the property postcode**
- **House type (e.g., bungalow, terraced house, detached house etc. [24])**
- **Property age**
- **Household heating patterns (i.e., when is the heating on or off)**
- **Heating fuel**
- **Heating system**

Based on the above information, along with data on the LCTs being considered and the chosen energy tariff, the model generates an energy consumption profile for the home in question. This reflects the energy it needs to function, including for heating, hot water, lighting and charging electric vehicles, as well as any energy generated using solar panels.

The consumption profile is then used to calculate the impact of installing LCTs on energy consumption and bills, the installation and operating costs of the LCT, the savings made over the lifetime of the LCT, the return on investment, and the amount of years it would take for the investment to have paid back in full.

23 The Running Cost Model's findings apply across England, Scotland, and Wales. The structure of Northern Ireland's electricity market means the findings may not be fully generalisable to homes there.

24 While flats were included in the modelling, they are not one of the illustrative case studies. This is because the benefits case is more complicated, with considerations including landlord/tenant splits and the use of shared energy infrastructure, such as community solar panels. As this report focuses on the benefits to individual homeowners of LCTs, communal assets are out of scope and not directly comparable. Given the potential benefits of communal assets, as well as the importance of decarbonising flats, however, future research in this area would be extremely beneficial.

RUNNING COST MODEL CASE STUDIES

A range of case studies have been created to explore the impact LCTs such as heat pumps, electric vehicles, solar panels, and batteries can have on home energy bills. The case studies represent a range of outcomes depending upon several factors including, but not limited to, energy tariffs, energy efficiency, the capacity of a solar energy system, and the make of electric vehicle. The final case study explores a best-case scenario, as well as the impact of introducing different combinations of LCTs into a relatively energy efficient home.

Aside from these case studies, the running cost model was also used to create a range of scenarios, each of which dig deeper into:

- **The impact of changing energy tariffs**
- **The importance of an energy efficient home**
- **The impact of gradually adopting domestic LCTs**
- **The most cost-effective way to charge an electric car**
- **The most cost-effective way to install and use solar panels**
- **The most cost-effective and energy efficient way to charge a domestic battery**

Further details of these scenarios can be found in the related technical report, produced by Think Three.

Note: For all calculations in the report, an energy efficiency rating scale, adopted from the SAP model, has been used instead of EPC ratings, to infer the performance at each level. This is to avoid a common issue with EPC ratings, where systems that are fuelled using higher energy cost energy tend to result in poorer EPC ratings, despite potentially being closer and more efficient to use.

The energy efficiency rating scale used consists of intervals from one to six, with six indicating a new home constructed today with energy efficiency measures required to comply with building regulations. The table below shows what each rating signifies, while the figures within the description of each rating represent U-values, which indicate the insulation properties of a given feature; the lower the U-value, the better the performance.

Table 2.
Energy Efficiency Rating Scale

Energy Efficiency Rating	Summary	Description
EE0	A home that has had no energy efficiency improvements and has solid walls with single glazing, with a 66% efficient gas boiler unless specified otherwise.	Incumbent property constructed using the methods at the time and with little or no improvements to the energy efficiency of the dwelling since it was built.
EE1	Roof + Wall 0.5 + Double Glazing + Hot Water Cylinder.	Improvements to the insulation of the walls, roof and hot water cylinder jacket (in older properties), plus double glazing.
EE2	Roof + Wall 0.28 + Double Glazing + Hot Water Cylinder.	Further improvements to wall insulation and hot water cylinder jacket (in more recently constructed properties), plus double glazing.
EE3	Roof + Wall 0.28 + Double Glazing + Hot Water Cylinder + Wastewater Heat Recovery.	As EE2, plus wastewater heat recovery (this rating relates to gas heated dwellings only).
EE4	Roof + Wall 0.28 + Double Glazing + Hot Water Cylinder + Heat Pump.	As EE2, however from this rating heat pumps can be used in lieu of gas heating.
EE5	Roof + Wall 0.28 + Triple Glazing + Hot Water Cylinder + Wastewater Heat Recovery + Heat Pump.	As EE4, with triple glazing and wastewater heat recovery.
EE6	Current newbuild specification [xxxi] with heat pump of Seasonal Performance Factor 3.5-3.8.	Assumes current newbuild specifications for homes constructed to satisfy current building regulations.

CASE STUDY 1: HEAT PUMPS

Heat pumps transfer heat from an external source and use it to heat homes. Air source heat pumps, which are focused upon in this report, extract heat from the outside air, warm it up and transfer it indoors. A well-designed, good quality heat pump system can operate at an efficiency of 250% 400% (meaning that 2.5-4 kilowatt (kW) of heat is produced for every kW of electricity consumed), whereas a typical boiler operates at 65% - 92% efficiency. As such, heat pumps are more efficient than a standard gas boiler.

THE FOLLOWING CASE STUDY FOCUSES ON HEAT PUMP USAGE IN A TYPICAL UK HOME, WITH THE FOLLOWING CHARACTERISTICS:

- Region: UK average
- Typology: Semi-detached house
- Constructed: 1900 - 1966
- Floor area: $120m^2$

Energy Efficiency Ratings:

- Poorly insulated house: EE0
- Improved house: EE4
- Well-insulated house: EE5

Heating Efficiency:

- Old boiler: 66.0% efficient
- Modern boiler: 89.4%
- Heat pump Seasonal Performance Factors: 2.35 to 3.55

This case study shows the impact improved energy efficiency can have on the cost of heating a semi-detached house. It demonstrates that even minor energy efficiency improvements, alongside a heat pump, can reduce energy bills when compared to an equivalent house that uses gas heating. Even for a home with an old gas boiler, upgrading fabric efficiency can have a significant impact, reducing bills from £2,416 (in a poorly insulated home) to £1,629 (in a well-insulated home).

However, as with a gas boiler, it is important that a home has a minimum level of energy efficiency before installing a heat pump. If it does not, the property may struggle to achieve the desired indoor temperature because heat will be lost from the home faster than it can be delivered, and household energy bills will be more expensive as a result. Table 3 illustrates that, while the cost of powering an energy inefficient home with a heat pump will still be lower than powering the same home with an old boiler, it would be more expensive than doing so with a modern gas boiler.

By contrast, when a heat pump is installed in a well-insulated, energy efficient home, energy costs are 37.4% lower than heating an energy inefficient home with an old gas boiler, and 25.8% lower than heating an energy inefficient home with a modern gas boiler, as shown in Table 3. While it has already been established, by modelling from RAP, that an average house with a heat pump is cheaper to run than an average house with a gas boiler, with energy bills falling by £261 each year [xxxii]. This demonstrates that, with the right combination of energy efficiency measures and home heating habits, a heat pump can substantially lower energy bills and reduce lifetime carbon emissions by over 85%, as shown in Table 4. However, it can cost 3.8% more to heat a well-insulated home using a heat pump than a modern gas boiler, as a result of policy costs falling more heavily on electricity bills. This highlights the need for government to take action to level the cost of electricity and gas, incentivising clean heat and making it cheaper to use a heat pump in a well-insulated home.

When the energy market stabilises, more flexible energy tariffs are likely to become available again, enabling heat pumps to make use of cheaper periods of electricity and further reduce bills. The flexible use of heat pumps, such as pre-heating homes outside of peak electricity price periods, can play an important role in saving money.

Manufacturers should ensure that heat pumps come 'smart as standard', meaning that they possess the necessary communications, data, and metering capabilities to enable homeowners to operate them efficiently, saving money, energy, and carbon emissions. This also gives homeowners the option of providing energy flexibility services to the electricity grid, resulting in further bill savings. Distribution Network Operators (DNOs) should maximise the use of local flexibility markets across the UK, financially rewarding homeowners for the smart use of LCTs. This would reduce network costs, thereby increasing bill savings and accelerating the decarbonisation of the electricity grid.

Table 3.
Annual energy costs for a semi-detached house with different modes of heating and levels of insulation

Parameters	Metrics	Poorly Insulated House with Old Boiler	Poorly Insulated House with Modern Boiler	Poorly Insulated House with Heat Pump	Improved House with Modern Boiler	Improved House with Heat Pump	Well-Insulated House with Old Gas Boiler	Well-Insulated House with Modern Boiler	Well-Insulated House with Heat Pump
Energy Efficiency Standard	Energy Efficiency Rating	EE0	EE0	EE0	EE4	EE4	EE5	EE5	EE5
Annual Energy Costs	£/year	2,416	2,037	2,412	1,466	1,651	1,629	1,456	1,512
Reduction in Annual Energy Costs (vs. poorly insulated house with old gas boiler)	%	n/a	15.7%	0.2%	39.3%	31.7%	32.6%	39.8%	37.4%
Annual Energy Costs (with legacy policy costs moved to government spending)	£/year	2,265	1,886	2,073	1,315	1,411	1,478	1,305	1,290
Reduction in Annual Energy Costs with Legacy Policy Costs Moved (vs. poorly insulated house with old gas boiler, with legacy policy costs moved)	%	n/a	16.7%	8.5%	41.9%	37.7%	34.8%	42.4%	43.1%

Table 4.
Lifetime CO_2 emissions of a semi-detached house with different modes of heating and levels of insulation

Parameters	Metrics	Poorly Insulated House with Old Boiler	Poorly Insulated House with Modern Boiler	Poorly Insulated House with Heat Pump	Improved House with Modern Boiler	Improved House with Heat Pump	Well-Insulated House with Old Gas Boiler	Well-Insulated House with Modern Boiler	Well-Insulated House with Heat Pump
Energy Efficiency Standard	Energy Efficiency Rating	EE0	EE0	EE0	EE4	EE4	EE5	EE5	EE5
Lifetime CO2 Emissions (over 30 years)	tCO2	135.6	103.1	25.6	54.2	18.1	68.1	53.3	16.8
Reduction in Lifetime Emissions Versus Poorly Insulated House with Old Gas Boiler	%	n/a	24.0%	81.1%	60.0%	86.6%	49.8%	60.7%	87.6%

As noted in the Executive Summary, the purchase cost of heat pumps represents a barrier to some homeowners. The Scottish Government's 'Home Energy Scotland' scheme provides homeowners with the opportunity to receive a low-interest loan coupled with cashback if they install a low-carbon heating system, with further incentives available for some energy efficiency upgrades.

In England and Wales, the Boiler Upgrade Scheme provides a £5,000 grant to homeowners for upgrading their existing fossil fuel or electric heating system to an air source heat pump, or £6,000 for a ground source heat pump. Alongside the newly introduced 0% VAT rating, this means that the overall cost of the heat pumps (including initial capital cost and lifetime running cost savings) will achieve rough parity with a fossil fuel-based heating system. Expanding the scope of the Boiler Upgrade Scheme and extending it beyond 2025 would ensure that the overall cost of transitioning to a low-carbon heating system is less than that of retaining a fossil-fuel based heating system and help government to achieve its target of installing 600,000 heat pumps per year by 2028.

The capital cost of heat pumps is likely to fall as they become more widely adopted due to economies of scale, but targeted support to 'pump prime' the market is important as this stage. Financial support is likely to be needed in order for many homeowners to make the necessary energy efficiency upgrades and ensure that their heat pump can operate cost-effectively.

CASE STUDY 2: ELECTRIC VEHICLES

This case study explores the impacts and cost-effectiveness of switching to an electric vehicle (EV) from a petrol or diesel car. The influence that solar panels and home battery storage devices can have on the cost of running an EV is also explored, alongside different charging times and electricity tariffs. The purchase costs of the EV and the EV charging point are not part of the scope of this case study [25].

THIS CASE STUDY HAS THE FOLLOWING ASSUMPTIONS AND CHARACTERISTICS:

House Parameters:

- Region: UK average
- Typology: Semi-detached house
- Constructed: 1900 – 1966
- Energy Efficiency Rating: EE4 (improved house)
- Solar Panel Array (where specified): 4.0kWp; generating 4117.0kWh/year
- Solar Panel Orientation (where specified): Southeast/southwest
- Smart Export Guarantee Tariff (where specified): 5.5p/kWh
- Home Battery (where specified):
  - Moixa 4.8kWh (for Nissan Leaf)
  - Powervault 8.0kWH (for Polestar)
  - Tesla Powerwall 13.5 kWh (for Tesla Model S)

EVs Tested:

- Nissan Leaf: EV battery capacity of 37.0kWh; 241.4Wh per mile
- Polestar 2 Standard Range: EV battery capacity of 61.0kWh; 280.0Wh/mile
- Tesla Model S 100D: EV battery capacity of 90.0kWh; 305.0Wh per mile [26]

Charging Times Analysed:

- Midnight to 5 a.m. (5 hours)
- Midnight to 6:30 a.m. (6.5 hours)
- 10:30 p.m. to 6:30 a.m. (9 hours)
- Off-peak times only (10:30 p.m. – 7:30 a.m. and 11:30 a.m. – 3:30 p.m.; 14 hours)

Tariffs:

- Standard Variable Tariff: 28.0p/kWh [27]
- ScottishPower EV tariff: 13.1p/kWh (off-peak) and 40.9p/kWh (on-peak) [28]

25 The purchase costs of EVs, as a recent technology, are still relatively high. Policies to drive deployment, both direct, such as the proposed zero emissions vehicle mandate, and indirect, such as expanding the EV charging network, will be essential in enabling cost reduction and increasing their accessibility.

26 The differences between the batteries in the three EVs modelled mean that they have slightly different costs in pence per mile of driving – the Nissan costs 7p/mile, the Polestar costs 8p/mile, and the Tesla costs 9p/mile. This is factored into the calculations in the table below.

27 This is the electricity unit rate for the price cap period beginning 1 April 2022, for a customer on a direct debit tariff. The standing charge is not included in the calculations, given that all homeowners pay this as a fixed amount for their household electricity consumption, so it does not vary according to charging of an EV or not.

28 According to tariff prices available February 2022.

Charging Times and Costs

Table 5.
Comparison of Costs of Driving an EV vs. a Petrol or Diesel Car, Using Different Charging Patterns

	Nissan	Polestar	Polestar	Polestar	Tesla	Tesla	Tesla	Tesla
Charging Profile	Midnight to 5am	Midnight to 5am	Midnight to 6.30am	10.30pm to 6.30am	Midnight to 5am	Midnight to 6.30am	10.30pm to 6.30am	Off-peak times only
Charging energy consumed (kwh/yr)	734	821	1,068	1,210	821	1,068	1,478	1,785
Distance able to drive from this charge (miles/yr)	3,040	2,933	3,813	4,322	2,693	3,500	4,847	5,854
Charge cost using standard variable tariff (£/yr)	£206	£230	£299	£339	£230	£299	£414	£500
Cost of driving this distance using petrol (£/yr)[29]	£557	£537	£698	£791	£493	£641	£887	£1,072
Cost of driving this distance using diesel (£/yr)[30]	£479	£462	£601	£681	£424	£551	£763	£922
Fuel cost saving from driving an ev (£/yr)	£351 (petrol), £273 (diesel)	£307 (petrol), £232 (diesel)	£399 (petrol), £302 (diesel)	£453 (petrol), £342 (diesel)	£263 (petrol), £194 (diesel)	£342 (petrol), £252 (diesel)	£474 (petrol), £350 (diesel)	£572 (petrol), £422 (diesel)

Table 5 shows that electric vehicle charging costs can range from £206 - £500 per year on a Standard Variable Tariff, depending upon the type of EV and length of time its charged for. Across all scenarios, charging an EV is much cheaper than the equivalent fuel cost to drive a petrol or diesel car the same distance. In these scenarios, switching to an EV can enable fuel cost savings of £194 - £572 per year [31], depending on the charge time and type of EV.

29 Modelled as 18.3p/mile.
30 Modelled as 15.8p/mile.
31 36mpg petrol; 43mpg diesel; £6.59/gallon (petrol) and £6.77/gallon (diesel), according to prices in January 2022.

Table 6.
Impact on Charging Costs of Using an EV Tariff and/or Pairing EV Charging with Solar and Battery Combination

	Nissan	Polestar	Polestar	Polestar	Tesla	Tesla	Tesla	Tesla
Charging Profile	Midnight to 5am	Midnight to 5am	Midnight to 6.30am	10.30pm to 6.30am	Midnight to 5am	Midnight to 6.30am	10.30pm to 6.30am	Off-peak times only
Charge cost using a standard variable tariff (£/Yr)[32]	£206	£230	£299	£339	£230	£299	£414	£500
Charge cost using a standard variable tariff, plus battery and solar panels (£/Yr)	£183	£0	£7	£24	£0	£7	£29	£195
Charge cost using an ev Tariff[33] (£/yr)	£96	£107	£208	£308	£107	£208	£376	£553
Charge cost using an ev tariff, plus battery and Solar panels[34]	£85	£0	£10	£34	£0	£10	£42	£285

Charging costs can be reduced even further with solar panels and a battery. This is because energy that is generated by the solar panels during the day and not used can be stored by the battery and used at night to charge the EV. If this is the case, EV charging costs can be reduced by up to £385 on an SVT and up to £334 per year on an EV tariff, depending upon charge times and self-consumption rates.

Using a specialised EV tariff can significantly reduce bills in some circumstances, delivering further savings of almost £100 per year where solar panels and batteries are used. Specialised EV tariffs do not generate savings in all circumstances, particularly where EVs require longer charging times, meaning that they are being charged for significant periods outside of off-peak tariff times or other appliances in the home are being used heavily.

This shows that it will be important for consumers to select the right tariff based on their lifestyle, heating system and EV charging habits. As the energy retail market potentially stabilises in the medium term, it is likely that more competitive Time of Use Tariffs will once again become available, enabling better significant bill savings in a wider range of circumstances.

32 Prices calculated using a standard variable tariff of 28p/kWh.
33 Modelled as 7-8p/mile.
34 According to tariff prices available Spring 2022.

CASE STUDY 3: SOLAR PANELS

THIS CASE STUDY LOOKS AT THE VALUE OF SOLAR PANELS IN THE HOME. THE HOME IN THIS EXAMPLE HAS THE FOLLOWING CHARACTERISTICS:

- Region: UK average
- Typology: Semi-detached
- Constructed: 1900 – 1966
- Energy Efficiency Rating: EE4 (improved house)
- Energy Tariffs:
  - Gas: 7.0p/kWh
  - Electricity: 28.0p/kWh
  - Smart Export Guarantee: 3p/5.5p/11p/kWh (varies within case study)
- Solar Panel Array (where specified): 2/3/4kWp (varies within case study)
- Solar Panel Orientation (where specified): Southeast/southwest; south; east/west
- Battery (where specified): Moixa 4.8kWh
- Heating System (where specified): Air source heat pump

The size of the solar panel system on the house in this example varies from 2kWp – 4kWp. A larger solar panel system has the capacity to generate more electricity, which results in larger financial benefits [35]. These financial benefits increase by 4.4% when solar panels face southeast or southwest, rather than east or west, as this increases the amount of sun they are exposed to and therefore the amount of energy they can produce. By maximising the use of solar generation with optimal orientation, correct elevation and no shading, homeowners can minimise the amount of electricity they need to import from the grid and save money. Table 7 shows that, for a semi-detached house with an air source heat pump, having solar panels can result in savings of £443 to £666 per year, as less energy is used from the grid.

Table 7.
The Financial Benefits of Having Solar Panels in a Semi-Detached House with a Heat Pump

Solar Panel Power	2kWp	3kWp	4kWp	4kWp
Solar panel orientation	Southeast/ Southwest	Southeast/ Southwest	Southeast/ Southwest	East/ West
Savings from reducing energy imported from the grid (per year)	£410	£493	£547	£524
Income from selling solar energy to the grid for 5.5p/ kWh (per year)	£33	£73	£119	£97
Total financial benefit of solar panels (per year)	£443	£566	£666	£621
Annual energy costs	£1,006	£897	£805	£847

35 Total financial benefit is made up of the avoided costs of importing electricity from the grid, plus the money made by supplying electricity back to the grid.

Homeowners will currently derive the greatest financial benefit from solar panels by maximising the amount of energy they use from them – known as self-consumption – rather than selling it to the grid via the Smart Export Guarantee. Installing a battery with smart controls alongside solar panels can help to maximise self-consumption rates by storing energy generated by the solar panels for later use, such as charging an electric vehicle, heating a home via a heat pump, or using electrical appliances and lights.

Table 8 shows that, for a south-facing, semi-detached house with an air source heat pump, adding a battery increases the financial benefit of solar panels, mainly by enabling a 20% increase in self-consumption rates, which reduces energy bills.

Table 8:
The Impact of Adding a Battery to a House with Solar Panels and a Heat Pump

Note: All example homes in the table below are homes heated with a heat pump.

Technologies/Export Tariff	4kWp SEG 5.5p/kWh	4kWp SEG 11p/kWh
Total financial benefit - solar panel only, SVT[36]	£684	£812
Total financial benefit - Solar + battery, SVT	£904	£978
Increased financial benefit from addition of battery	32.2%	20.4%
Total financial benefit - solar panel only, EV tariff	£939	£1,068
Total financial benefit - solar + battery, EV tariff	£1,286	£1,360
Increased financial benefit from addition of battery	37.0%	27.3%

Table 9:
The Impact of Adding a Battery to a House with Solar Panels and a Gas Boiler

Technologies/Export Tariff	4kWp SEG 5.5p/kWh	4kWp SEG 11p/kWh
Total financial benefit - solar panel only, SVT[37]	£586	£738
Total financial benefit - Solar + battery, SVT	£713	£931
Increased financial benefit from addition of battery	21.7%	26.2%
Total financial benefit - solar panel only, EV tariff	£786	£938
Total financial benefit - solar + battery, EV tariff	£1,186	£1,276
Increased financial benefit from addition of battery	50.9%	36.0%

36 Financial benefits are slightly higher than in Table 7, even without batteries, as the solar panels in this example face south, not south-east/south-west.

37 Financial benefits are slightly higher than in Table 7, even without batteries, as the solar panels in this example face south, not south-east/south-west.

Smart batteries can be programmed to charge as much as possible using excess solar power and to only charge from the grid when energy costs are below a certain price. Where a Standard Variable Tariff of 28p/kWh is used, smart batteries take no charge from the grid, as this would cause annual energy costs to rise.

In the current market circumstances, where energy prices are elevated, the overall energy costs from using a Time of Use Tariff (in the table, labelled as 'EV tariff') are higher than a Standard Variable Tariff. This is despite the solar panels delivering increased financial benefit under the Time of Use Tariff by offsetting grid imports, because on-peak rates under this tariff are currently relatively high.

As the energy retail market potentially stabilised in the medium term and more competitive Time of Use Tariffs become available once again, smart batteries will be able to charge during periods where energy costs are low, for example overnight, and store the electricity for later use, resulting in further bill savings.

N.B. While the following two tables only include an energy efficiency upgrade in the final row, for ease of presentation, in reality this should often be the first step for many homeowners, before or alongside installation of a heat pump and other LCTs, in order to maximise bill savings. All rows without an energy efficiency upgrade in the table are because the house in question already has good enough energy efficiency and does not require an upgrade, not because it is not an important first step for many houses.

Table 10.
Upfront Cost, Financial Benefits, and Payback Periods of Different LCT Combinations with Solar Panels Under a Standard Variable Tariff

LCTs installed	Metric	4kWp SEG 5.5p/kWh	4kWp SEG 11p/kWh
Solar	**Upfront cost**	**£5,064**	
	Financial benefit (per year)	£586	£738
	Payback period (years)[38, 39]	14.7	11.5
Solar + Battery	**Upfront cost**	**£8,507**	
	Financial benefit (per year)	£713	£931
	Payback period (years)	15.3	13.9
Solar + Battery + Heat Pump	**Upfront cost**	**£14,493**	
	Financial benefit (per year)[40]	£904	£978
	Payback period (years)	18.5	17.4
Solar + Battery + Heat Pump + Energy Efficiency Upgrade	**Upfront cost**	**£27,158**	
	Financial benefit (per year)	£904	£978
	Payback period (years)	25.5	24.8

38 The length of time it takes for the ongoing financial benefits derived from an LCT to have outweighed the upfront and maintenance costs.

39 A number of assumptions have been made to calculate the payback periods and capture the way each technology performs over time, including energy, operation and maintenance costs, and the general costs of living (e.g., Retail Price Index). The payback calculations are typically made over a 30-year period, although this is adjusted to match the lifespan of the technology in question. The costs of energy are calculated using assumptions about price inflation and the amount of energy consumed. The cost of maintaining the technology accounts for the degradation of performance over time; for instance, the generation yield of solar PV systems typically degrades at approximately 0.4% per year. The savings attributed to the investment are offset against any ongoing costs. The payback period is calculated when the combined savings from the investments made exceed the initial cost of the energy efficiency improvements and/or LCTs. Some technologies result in higher savings and lower payback times. Offsetting higher energy costs can also result in lower payback times.

40 In this row and the following one, 'financial benefit' refers to the total financial benefits derived from the solar array within this mix of LCTs. Any savings from replacing a boiler with a heat pump, for example, are not included.

Table 11.
Upfront Cost, Financial Benefits, and Payback Periods of Different LCT Combinations with Solar Panels Under ScottishPower's EV Tariff

LCTs installed	Metric	4kWp SEG 5.5p/kWh	4kWp SEG 11p/kWh
Solar	**Upfront cost**	**£5,064**	
	Financial benefit (per year)	£786	£938
	Payback period (years)	12.4	9.9
Solar + Battery	**Upfront cost**	**£8,507**	
	Financial benefit (per year)	£1,186	£1,276
	Payback period (years)	12.3	11.2
Solar + Battery + Heat Pump	**Upfront cost**	**£14,493**	
	Financial benefit (per year)[41]	£1,286	£1,360
	Payback period (years)	13.7	13.0
Solar + Battery + Heat Pump + Energy Efficiency Upgrade	**Upfront cost**	**£27,158**	
	Financial benefit (per year)	£1,286	£1,360
	Payback period (years)	19.9	19.2

An export tariff, based on the Smart Export Guarantee (SEG), determines the amount of money you are paid for every unit of energy you sell back to the grid. A favourable export tariff helps reduce bills and decreases the payback period, which is the length of time it takes for the ongoing financial benefits of an LCT to have outweighed the cost of installing and maintaining it. The tables above show that securing an export tariff of 11p/kWh could reduce the payback period of solar panels, for example, to 11.5 years for a home on a Standard Variable Tariff. Adding a battery also shortens the time it takes for the investment to pay back, by maximising self-consumption and therefore financial savings.

In the table above, all LCTs have financial benefits over their 30-year lifetime that outweigh the cost of the initial investment. The payback calculations include both the upfront cost and maintenance cost of the LCTs. Where a full or partial replacement would be required for an LCT within the 30-year window, such as for a battery or a heat pump, this cost is also included.

Where a heat pump is included, it is assumed that it is bought using the £5,000 Boiler Upgrade Scheme grant to partially offset the upfront cost. If the price of heat pumps reduced, or the size of the grant were increased, this would further reduce the upfront cost for homeowners and shorten the payback period.

41 In this row and the following one, 'financial benefit' refers to total financial benefits derived from the solar array within this mix of LCTs. Savings from replacing a boiler with a heat pump, for example, are not included.


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CASE STUDY 4:
THE LOW-CARBON HOME

This case study illustrates a best-case scenario for introducing LCTs into a home, by optimising the use of technologies both in isolation and combination. The scenario is intended to help readers better understand which LCTs could be most suitable for their home and in what order they should be installed in.

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THE LOW-CARBON HOME IN THIS EXAMPLE HAS THE FOLLOWING CHARACTERISTICS:

- Region: Southern England (higher irradiation levels)
- Typology: Detached
- Constructed: 1996-2002
- Energy Efficiency Rating: EE4 (improved house)
- Standard Variable Tariff: 28.0p/kWh
- ScottishPower EV tariff: 13.1p/kWh (off-peak) and 40.9p/kWh (on-peak)[42]
- Export tariff: 5.5p and 11.0p/kWh[43]
- Solar Panel Power (where specified as included): 5.0kWp
- Solar Panel Orientation (where specified as included): South
- Battery (where specified as included): Powervault, 3.8kWh
- EV Charger (where specified as included): Polestar long range; 75.0kWh/7.36kW

Heating System Characteristics (where specified as included):

- Heating System: Air source heat pump
- Heat Pump Flow Temperature: 45.0˚C
- Heating Profile: Three-hour pre-heat
- Heat Pump Purchasing Cost Discount: Boiler Upgrade Scheme (£5,000)
- Policy Costs (where specified as altered): Legacy costs moved from energy bills to government spending

In this example, the energy inefficient home has an energy efficiency rating of EE0. The energy efficient home with modern boiler has improved insulation (EE4). The low-carbon home has the same level of improved insulation (EE4), allowing the heat pump to run at an efficient temperature, and the solar panels to cover all available roof space. The heating profile with a three-hour pre-heat is designed to complement use of a heat pump and a Time of Use Tariff structure. Both a Standard Variable Tariff (SVT) and the ScottishPower EV Tariff are modelled in the technical report, however the table below shows only energy costs under the SVT, to avoid complexity.

42 According to tariff prices available February 2022.

43 A number of suppliers offer a SEG of 5.5p/kWh. 11.0p/kWh represents the highest SEG rate currently available on the market (albeit with certain conditions attached to it).

Table 12.
The Annual Energy Costs of a Standard Home vs. a Low-Carbon Home on a Standard Variable Tariff

Description	Energy Costs (Exc. Transport)	Energy Costs (Inc. Transport[44])	Energy Costs (Exc. Transport) After Policy Costs Moved	Energy Costs (Inc. Transport[45]) After Policy Costs Moved
Energy Inefficient Home (EE0) with Old Boiler	£2,118	£2,816	£1,939	£2,637
Energy Inefficient Home (EE0) with Modern Boiler	£1,874	£2,572	£1,694	£2,392
Energy Efficient Home (EE4) with Modern Boiler	£1,749	£2,447	£1,570	£2,268
Low-Carbon Home (EE4) with Heat Pump, Solar Panels, Smart Battery (and EV where transport costs are included)	£240	£507	£150	£383

Table 13.
The Annual Energy Savings of a Standard Home vs. a Low-Carbon Home on a Standard Variable Tariff

Comparison	Low-Carbon Home Net Energy Savings (Exc. Transport)	Low-Carbon Home Net Energy Savings (Inc. Transport)	Low-Carbon Home Net Energy Savings (Exc. Transport) After Policy Costs Moved	Low-Carbon Home Net Energy Savings (Exc. Transport) After Policy Costs Moved
An Energy Inefficient Home with Old Boiler	88.7% (£1,878 saved)	82.0% (£2,309 saved)	92.3% (£1,789 saved)	85.5% (£2,254 saved)
An Energy Inefficient Home with Modern Boiler	87.2% (£1,634 saved)	80.3% (£2,065 saved)	91.1% (£1,544 saved)	84.0% (£2,009 saved)
An Energy Efficient Home with Modern Boiler	86.3% (£1,509 saved)	79.3% (£1,940 saved)	90.4% (£1,420 saved)	83.1% (£1,885 saved)

44 For the non-low-carbon homes, this is the cost of running a petrol car for a year (£698), while for the low-carbon home, this is the cost of charging an electric vehicle for a year for the same number of miles (£416).

45 For the non-low-carbon homes, this is the cost of running a petrol car for a year (£698), while for the low-carbon home, this is the cost of charging an electric vehicle for a year for the same number of miles (£416).

The table opposite compares the net energy costs of running a low-carbon detached home against three counterfactuals:

i A detached home with an old boiler and no energy efficiency improvements (EE0).

ii A detached home with a modern boiler and no energy efficiency improvements (EE0).

iii An energy efficient detached home with a modern boiler (EE4).

The table demonstrates that a low-carbon home can deliver energy bill savings of over £1,800 per year (excluding transport fuel costs) and over £2,300 per year (including transport fuel costs) against an energy inefficient home with an old gas boiler. Savings of over £1,600 (excluding transport fuel costs), or over £2,000 (including transport fuel costs), are possible compared to a standard home with no energy efficiency upgrades and a modern gas boiler. Even when compared to a modern energy efficient home with a gas boiler, savings of over £1,500 per year (excluding transport costs) and over £1,950 (including transport costs) can still occur.

While the upfront cost of adding all these LCTs is substantial, this is largely offset by the increase in home equity value, carbon reductions and decreases in bills. Nevertheless, action will still be needed from government and business to reduce capital costs and facilitate sustainable finance solutions to promote uptake, enabling more homeowners to attain these benefits, as discussed in the recommendations section.

It is unlikely that every home in the UK will be fitted with every LCT discussed in this report, at least in the short to medium-term. As such, different combinations of technologies have been explored and compared below. The examples in Graph 1 show that installation of various technology combinations can deliver lower net energy costs and lifetime carbon emissions. In addition to technologies that reduce the emissions associated with the home, EV charge points enable lifetime emissions to fall even further, by enabling the replacement of a high-carbon petrol or diesel car with an EV.

Moving renewable legacy costs from energy bills into government spending reduces household energy costs including transport for a low-carbon home by a further 20%, creating an even stronger case for the electrification of heat and transport across the UK.

Graph 1.
Household Energy Costs, Net Energy Costs, and Residual CO2 Emissions of Different Technology Combinations

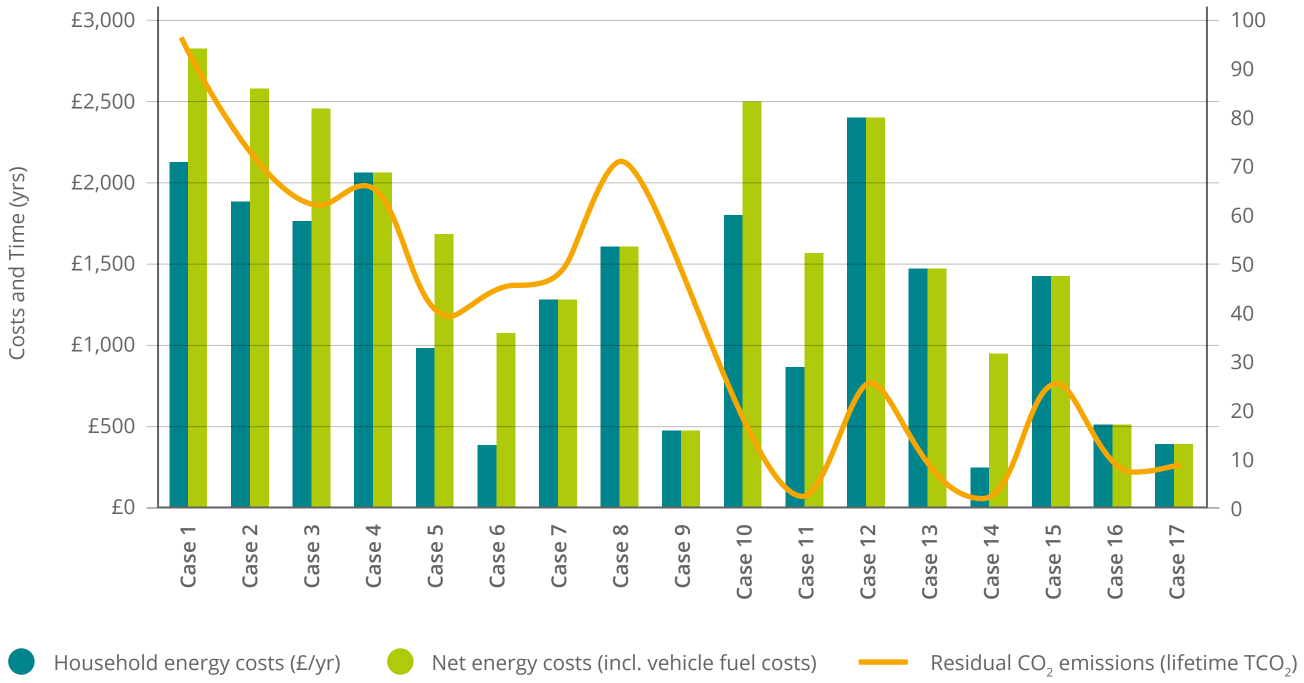

Table 14.
Key for Graph 1

Case No.	Heat & Hot Water Fuel	LCTs Installed and Energy Efficiency Standard	Upfront Cost (£)	Energy Costs (Exc. Vehicle Fuel Costs) (£/yr)	Energy Costs Saved (£/yr)	Energy Costs (Inc. Vehicle Fuel Costs) (£/yr)	Residual CO_2 Emissions (Lifetime tCO_2)
Case 1	Gas	Baseline Case (no EE improvement) + Old Gas Boiler	£0	£2,118	n/a	£2,816	94
Case 2	Gas	Baseline Case (no EE improvement) + Modern Gas Boiler	£0	£1,874	£245	£2,572	73
Case 3	Gas	Energy Efficiency Upgrade (EE4) + Modern Gas Boiler	£4,285	£1,749	£370	£2,447	62
Case 4	Gas	EE4 + Electric Vehicle	£5,285	£2,048	£71	£2,048	65
Case 5	Gas	EE4 + Solar Panels	£10,615	£978	£1,141	£1,676	40
Case 6	Gas	EE4 + Solar Panels + Battery	£16,497	£374	£1,744	£1,072	45
Case 7	Gas	EE4 + Electric Vehicle + Solar Panels	£11,615	£1,277	£842	£1,277	48
Case 8	Gas	EE4 + Electric Vehicle + Battery	£11,167	£1,599	£519	£1,599	71
Case 9	Gas	EE4 + Electric Vehicle + Solar Panels + Battery	£17,497	£459	£1,660	£459	48
Case 10	Electricity	EE4 + Heat Pump	£13,699	£1,794	£325	£2,492	17
Case 11	Electricity	EE4 + Heat Pump + Solar Panels	£20,029	£861	£1,257	£1,559	3
Case 12	Electricity	EE4 + Heat Pump + Electric Vehicle	£14,699	£2,392	-£273	£2,392	25
Case 13	Electricity	EE4 + Heat Pump + Electric Vehicle + Solar Panels	£21,029	£1,459	£660	£1,459	8
Case 14	Electricity	EE4 + Heat Pump + Solar Panels + Smart Battery	£29,713	£240	£1,879	£938	3
Case 15	Electricity	EE4 + Heat Pump + Electric Vehicle + Smart Battery	£24,383	£1,417	£701	£1,417	25
Case 16	Electricity	EE4 + Heat Pump + Electric Vehicle + Solar Panels + Smart Battery	£30,713	£507	£1,611	£507	8
Case 17	Electricity	EE4 + Heat Pump + Electric Vehicle + Solar Panels + Smart Battery (policy costs moved)	£30,713	£383	£1,735	£383	8

GLOSSARY

Battery storage – A type of rechargeable energy storage. Batteries can be used to store surplus power produced by a solar energy system for later use.

BRPs – Building Renovation Plans. Also known as Building Renovation Passports and Building Retrofit Passports are digital logbooks containing information about a property's construction, renovation, upgrades, and operational performance. They contain long-term renovation roadmaps, which identify opportunities for future home improvements and connections to contractors, service and finance providers.

CCC – Climate Change Committee. This an independent, statutory body that advises the UK and devolved governments and Parliaments on tackling climate change.

DNO – Distribution Network Operator. The operator of the electric power distribution system, which takes electricity from the high-voltage transmission network and delivers it to most end users, including homeowners. In Britain, there are 14 licensed DNOs, owned by six different groups, serving specific geographical regions.

Electrification – The use of electricity instead of gas or other fossil fuels to provide energy for heat and/or transport.

Energy Price Cap - Officially named the Default Tariff (Price) Cap, was introduced by the Government from 2019 to cap the price for consumers on default (including standard variable) tariffs (well over half of UK households). The tariff rates used in this report are the average price cap unit rates and standing charges for a customer paying by direct debit for the period 1st April to 30th September 2022. The rates are set by Ofgem.

Energy Saving Stamp Duty – Also known as Green Stamp Duty, is a proposed incentive to encourage the public to consider energy efficiency when buying a home. Under the proposal, those who either purchase an energy efficient home or improve the energy efficiency of a property within two years of purchase would pay a lower level of stamp duty.

EPC – Energy Performance Certificate. This is a statement of information about a property's energy use and costs. It is required whenever a property is built, sold, or rented. It provides an energy efficiency rating from A to G, where A is the most efficient.

EV – Electric vehicle. A car or van that uses an electric motor instead of a fossil-fuel internal combustion engine for propulsion.

The Grid – The interconnected network of cables and other equipment which transports electricity around the country.

Heat Pump – A heat pump is a device for transferring energy in the form of useful heat from one place to another. A heat pump is capable of transforming a large quantity of low grade, low temperature heat to (a smaller quantity) of higher-grade higher temperature heat which can be used for heating or providing hot water for your home

kW – Kilowatt. A measure of electric power.

kWh – Kilowatt hour. The provision of one kilowatt of electric power for an hour. A typical home in the UK uses around four kWh of electricity per day.

kWp – Kilowatt 'peak' power. A unit of measurement that describes the amount of energy a set of solar panels provides. A solar panel with a peak power of 4kWp will produce 4kWh when working at full capacity for one hour.

LCT – Low-carbon technology, such as a heat pump, solar panel, energy storage battery, electric vehicle charging point, or energy efficiency measure.

MCS – Microgeneration Certification Scheme. The quality assurance and standards body for residential renewable technologies in the UK.

MPG – Miles per gallon.

MW – Megawatt. A measure of electric power equivalent to 1,000 kilowatts.

MWh – Megawatt hour. The provision of one megawatt of electric power for an hour.

Net Zero - When the amount of greenhouse gas emissions to the atmosphere produced by human behaviour is balanced out by the removal of the equivalent volume of emissions from the atmosphere. Achieving net zero requires greatly reducing the amount of greenhouse gas emissions produced by human behaviour and offsetting any that remain, for instance, by planting trees.

NPV – Net Present Value. This is an investment metric which refers to the lifetime cost or benefit of an investment, accounting for the cost of borrowing money and other factors relating to how the value of money changes over time. An NPV above zero means that over its lifetime, an investment will provide a positive return and conversely where the NPV is negative, any returns derived do not recover the cost of the initial capital investment. For example, if a project has a total NPV of £4,000, the person or organisation which paid for the project will be £4,000 better off.

OZEV – Office for Zero Emission Vehicles.

PV – Photovoltaic. A type of solar energy system which converts light into electricity.

Running costs – The amount of money spent maintaining and running a property, business or vehicle.

SAP – Standard Assessment Procedure. This is the UK Government's method of measuring, assessing and comparing the overall energy performance of a home.

Seasonal Performance Factor – A unit of measurement for heat pump efficiency. The higher the value of the seasonal performance factor, the more efficient the heat pump is.

SCT - Surveyor Comparator Tool. This is a tool used by surveyors, which allows them to compare similar properties and support the valuation process.

SEG - Smart Export Guarantee. This is the amount of money someone is paid by an electricity supplier for exporting energy to the grid from a domestic solar panel system.

Smart Battery – In the context of this project and the logic used within the running cost model, a 'smart' battery is set-up to charge, discharge and store according to the following premises:

- The battery will receive charge from excess solar power, after the solar power has been used to offset electricity imported from the grid.
- The battery will only take charge from the grid when the cost of importing electricity from the grid is below a certain price.
- The battery will neither charge nor discharge (i.e., remain in a state of 'store') where the cost of importing electricity from the grid is below a certain price, when there is no excess PV generation, or where there is no consumption within the home. This price can be varied and is set at 20p/kWh in the scenarios.
- The battery will discharge to the house (or grid) at specific rates and times when there is available charge in the battery, there is demand for electricity from the house, and the cost of importing electricity from the grid exceeds a certain price.

TOUT – Time of use tariff. This is a retail electricity tariff where the price of electricity changes during the day. This means that residential properties can trade electricity, buying power when it is cheap (or generating it for free from a solar system), storing it in a battery, and selling it when it is more expensive.

UKIB – UK Infrastructure Bank.

Wastewater Heat Recovery – Extracts heat from water sent down the drain from a bath or shower, which is then used to heat incoming mains water. This reduces the amount of energy needed from the boiler to heat up water in the house.

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