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Reducing Domestic Energy Costs and Emissions

350PPM
Capitalist Solutions to Climate Change

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Introduction

Added together our homes directly generate about 20% of the UK's overall CO2 emissions, with the average home generating ~6 tonnes a year. In addition to this, our homes' energy supplies have their own significant carbon footprint, as well as costing us on average ~£1250 a year, according to the Money Advice Service.

In this report, we outline methods for cutting carbon emissions and energy costs in the home, the two being closely and happily related. Our aim is to cover the broad range of possible solutions, starting with those that - if not already implemented - should be considered first by all households. Some of these are free, cheap or have a short payback period. We then cover methods for households looking to go the extra mile; to greatly reduce emissions and energy costs. These methods involve producing and potentially storing renewable energy locally. At the expense of a larger capital outlay and slower payback period, these methods provide a more proactive route for households to fight climate change.

Contents

Background

To begin it is useful to know how energy is consumed in a typical UK property. This is illustrated in **Figure 1**. In **Figure 1** note that 80% of the energy is used for space (room) and water heating, making this the prime target for reducing costs and emissions. Related to this, for those properties that use gas heating this means that 80% of energy comes from gas, rather than electricity. It follows that although our grid-supplied electricity supply is decarbonising rapidly in the UK – as large-scale renewables proliferate - this is not the key consideration when limiting emissions in a gas-heated home. See grid carbon intensity.

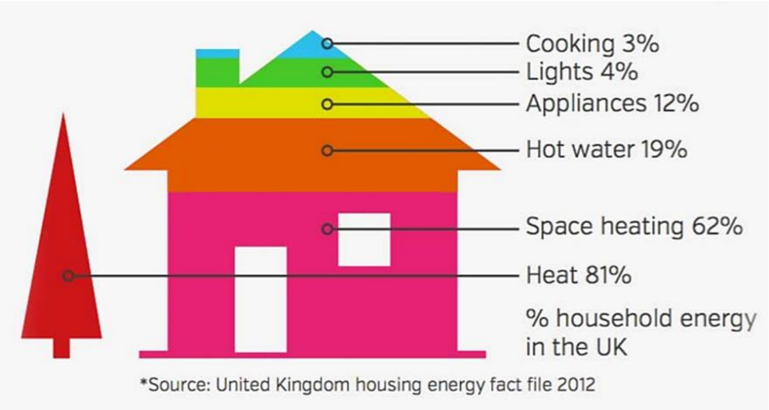


Figure 1 – How a typical household consumes energy. Source.

The total amount of energy a household consumes depends on several factors, some of which are not controllable, such as:

- The type and age of the home.
- Its size, particularly the external wall and window areas.
- Its location and associated climate.
- The occupancy.
- The lifestyle of the occupants. For example, are they at home all day, or out at work?

These place some limits on how much households can reduce energy consumption and related emissions. However, homeowners *can* change:

- How well insulated a home is. In this context it is helpful to know how a typical home gains and loses heat, see **Figure 2**. The key point is that most heat is lost through walls.
- The efficiency of the current heating system.
- The efficiency of electrical appliances and the lighting system.
- Their behaviour related to both heat and electricity consumption.

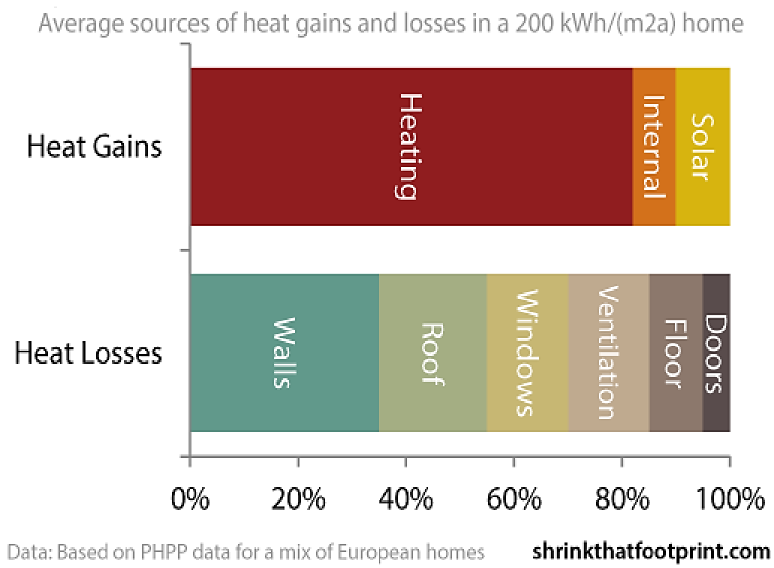


Figure 2 – How homes gain and lose heat. Source.

In addition, homeowners have the more radical option of redesigning their heat and electricity systems to produce low carbon energy locally. Adding energy storage can make this process more efficient.

Even without changing energy consumption at all, homeowners may still be able to reduce energy costs with minimal effort. We explore all these topics in this report.

To quantify the above discussion, **Figure 3**, right, shows the typical energy use for three types of gas-heated property. A range of electricity use from 2000-4600 kWh/year, and gas use from 8000-18000 kWh/year are shown.

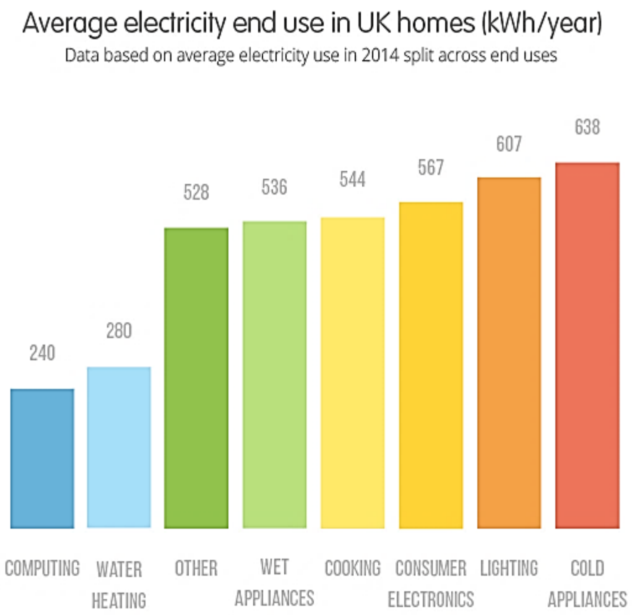


Figure 4 – Average household electricity use. Ignores any electricity use for space heating, electric car charging. Source.

Figure 4 then splits out the average electricity use by application. It may surprise you to see that cold appliances - fridges and freezers - consume the most electricity. Home electric vehicle charging is not included in **Figure 4**, but - depending on the miles driven - can easily consume many times more electricity than fridges or freezers.

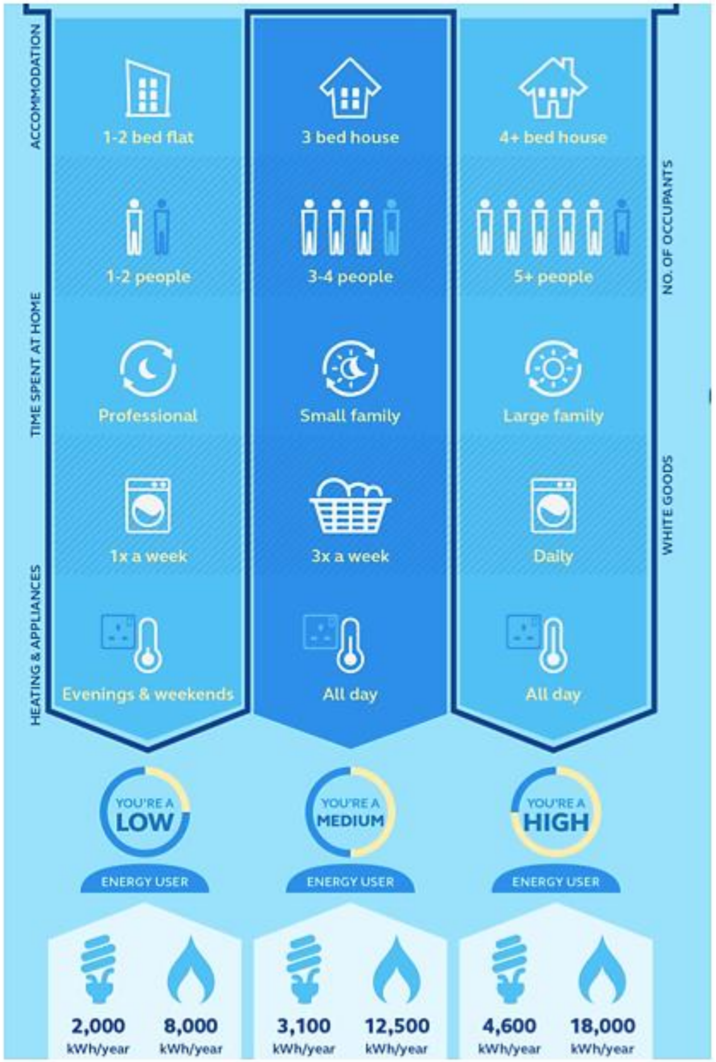


Figure 3 – Typical domestic energy use. Source.

Understanding Your Energy System

When considering ways to cut carbon emissions and energy costs, the natural starting point is a detailed understanding of a home's current energy system. There are two components to this – understanding the installed features and understanding the energy consumption and related costs.

Installed Features

The options available to improve a property's energy system depend on the features already installed. The main features to consider are:

- What type and depth of insulation, if any, is installed throughout a property? Is there any unwanted air flow from outside?
- What type of heating and hot water system(s) are installed? How are these controlled?
- How efficient are the lighting system and major electrical appliances, compared to what is available?
- Are any low carbon energy sources already installed? How are these connected and controlled?

If the answer to any of these questions is not known in detail, one place to look is a house's Energy Performance Certificate (EPC), if available. EPCs are most often created on the sale or renting out of a property; rented properties must meet minimum energy efficiency standards, certified by an EPC. EPCs are also required to qualify for the Renewable Heat Incentive (RHI), a government subsidy, introduced later. EPCs can be found online at https://www.epcregister.com/.

An EPC contains a variety of useful information including estimates for a home's current energy costs, energy efficiency and environmental impact. It also contains a summary of a home's 'energy performance related features', describing what is installed and how efficient these are. This summary will help answer the above questions but it may still be necessary to poke around a home to get complete answers.

Providing a kicking off point for further investigation, an EPC also gives an ordered list of potential energy performance improvements, along with cost and savings estimates. This list is fairly limited in the options it considers - compared to those that are available - and the suggested ordering ignores capital outlay and payback periods. A more detailed list of address-targeted suggestions can be found at the related website: https://www.simpleenergyadvice.org.uk/.

Consumption and Costs

To establish a baseline against which future improvements can be compared, and to provide insight into which improvements might be most beneficial, it is helpful to know how much energy is currently consumed, for what applications, and at what cost. The more granular this information the better.

An EPC provides only estimated current energy consumption and cost information; this can largely be ignored. Recent energy bills provide more useful data, but only after the fact and at the highest level. A conventional smart meter, if installed, such as the example one shown below, is most useful as it gives information in real-time. Learn more about smart meters. For those wanting to go into detail, devices are also available which automatically sense the activity of individual electrical appliances; for example, see sense.com.

Starter Methods

In this section we cover the basic cost and emissions saving methods that should be considered first by all households. We divide these into **quick wins**, which involve minimal effort/cost, and **basic home modifications**, which involve marginally more, but some are relatively cheap, or are economic no-brainers with a quick payback period.

Quick Wins

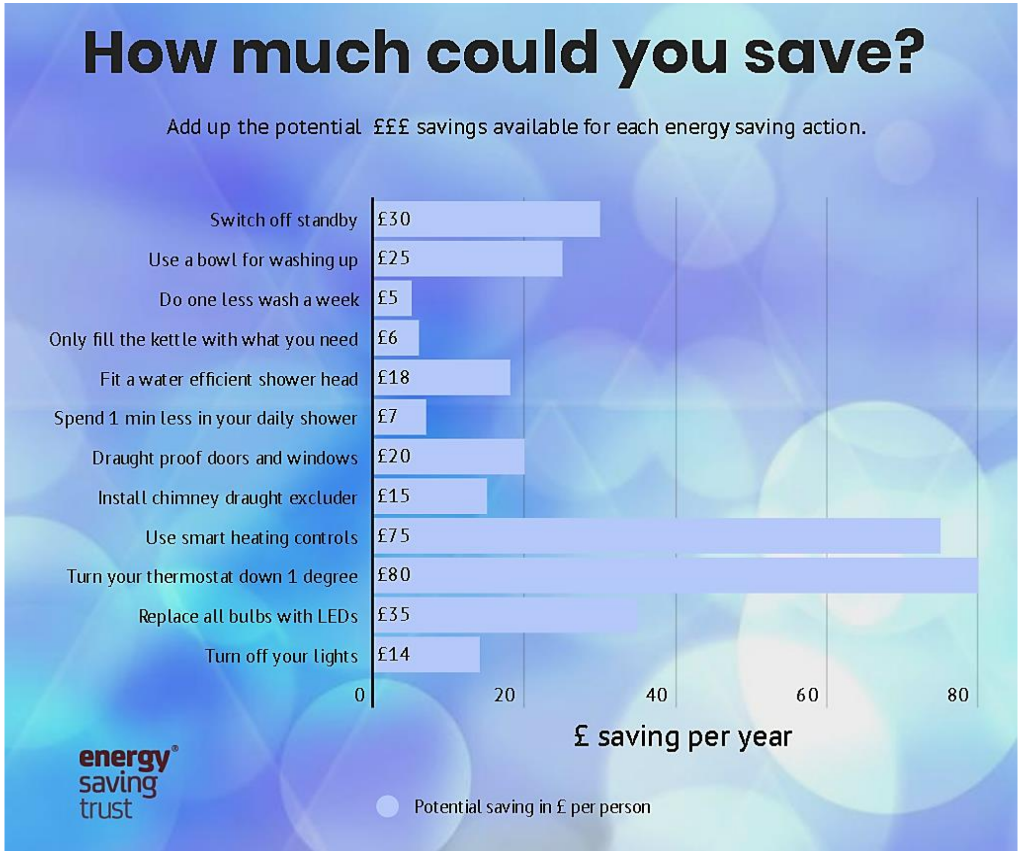
There are a number of simple changes that all of us can make to reduce energy consumption at home. Some of these are summarised in a graphic from the Energy Savings Trust, see right. More detail here. We say more about draught proofing, LEDs and smart heating controls later.

Switch Energy Supplier

Switching energy supplier, or tariff with the same energy supplier, and doing so as regularly as necessary, is potentially another straightforward way of saving money. Savings are claimed to be 'up to £479/year' according to one switching site. If you would rather save carbon emissions, consider switching to a green energy tariff (more detail on the next page).

There are numerous energy tariff comparison websites available for finding the best tariff, though many are not impartial. Try the citizens advice site, for example. Some websites offer automatic switching, for example Look After My Bills.

The way an energy bill is paid can also make a difference. On average, it is £100 cheaper per year to pay by monthly direct debit than paying by cash or cheque, according to the Energy Savings Trust.



Types of Energy Tariff

Standard variable rate - usually an energy supplier's default tariff. These do not have protection against price increases, are often not the cheapest available, but have no exit fees for leaving early.

Fixed rate - these fix the amount per unit energy for a certain period (~1-5 years) and may have exit fees for leaving early.

Dual fuel - gas and electricity from the same supplier. These will have a reduced rate but are not necessarily cheaper than getting gas and electricity from separate companies.

Green tariff - these match your usage with renewable electricity generation or green gas injection, or contribute towards environmental schemes on your behalf. Be warned - these may not be the cheapest and some 'green' tariffs are greener than others.

Time-of-use tariff - some electricity tariffs have rates that vary during the day. A common example is an 'overnight is cheaper' tariff such as Economy 7 or Economy 10. This may be beneficial for households with electric storage heaters, an electric car or energy storage.

Optimise Electric Vehicle Charging

For electric vehicle owners, charging the vehicle at home, rather than at a public charging point is a clear way of saving money. The cost of installing a dedicated home charging point, which charge faster than a standard wall socket, is subsidised up to £350 by the Electric Vehicle Homecharge Scheme.

Charging at home will increase electricity use substantially (up to 80%). To reduce the associated costs and emissions, there are two options:

- Switch to an electricity tariff specifically for electric vehicle owners, usually some combination of green and time-of-use tariff, for cheaper overnight charging using grid supplied electricity.
- Not exactly a quick win, but instead generate renewable electricity at home, for example by installing a photovoltaic (PV) and battery storage system. This is covered in more detail later.

Financial Support for Pensioners

Pensioners may be eligible for financial support for their energy bills. Find out more about the Winter Fuel Payment, Warm Home Discount and Cold Weather Payment. These are mostly paid automatically.

Basic Home Modifications

Measures to cut emissions and energy costs are most effective if built into the fabric of a home. In this section we list the simplest ways of modifying a home to firstly reduce heat and, in the next section, electricity consumption. Many of these modifications require professional installation, or are best done professionally, though we point out if something has DIY potential. It may be possible to save money by combining modifications with each other or other home improvements.

As with all home modifications, all building and planning regulations must be respected. In addition, modifications may have implications for home insurance cover. Seek advice if unsure.

For each modification, costs and savings estimates are taken from the Energy Savings Trust website, unless otherwise indicated. These apply to England only and may not be bang up-to-date. These should be taken as **order of magnitude estimates only**, not an exact cost estimate tailored to your home. That said, we highlight which modifications are likely to be economic no-brainers.

Reduce Heat Consumption

Reducing unnecessary heat consumption should be the priority for all homes. This is implemented by installing insulation, if necessary, and perhaps also updating the heating system. Alternatively, the heating system can be completely replaced with a low carbon alternative. This is covered separately later.

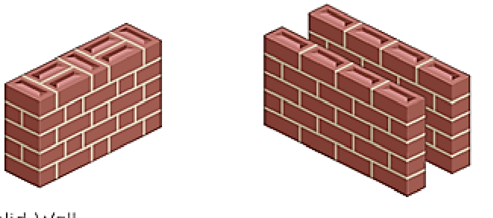
Note that it may be possible to get financial support for some insulation and heating system upgrades under the Energy Company Obligation (ECO), especially if receiving benefits. More on ECO.

Install Insulation

Installing missing insulation is priority one. In terms of stopping heat loss, it makes sense to insulate walls first, then the roof, windows and floors (see **Figure 2**). If you add in economic considerations, the picture is slightly less clear, though if relevant and missing or inadequate, likely **economic no-brainers** include the installation of **loft, cavity wall, and hot water tank and pipe insulation**. Payback time estimates for all insulation technologies are summarised at the end of this section.

Walls

About a third of all the heat lost in an uninsulated house escapes through the walls, so insulating them is key. In general, houses built from the 1990s onwards have wall insulation, but those built before may have none. Cavity walls, often found in houses built after the 1920s, are much easier and cheaper to insulate than solid walls, found in older houses. Find out how to determine which type of walls you have. Installing wall insulation is best left to professional installers, who typically include a 25-year guarantee with the price. Problems with damp should be solved before insulating walls. If done wrong, insulating walls can potentially create new damp problems.



Solid Wall
Typical in pre 1920 properties.
'Thick'-'thin' brick pattern.

Cavity Wall
Typical in modern homes.
Even brick pattern.

Cavity Walls (professional install)

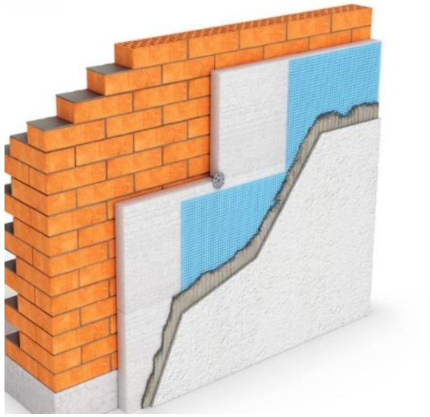
Installing cavity wall insulation involves drilling holes in the wall, then blowing or injecting insulating material into the cavity, usually mineral wool or polystyrene beads, then sealing up the holes.

For houses with uninsulated cavity walls and which are suitable for standard cavity wall insulation, this is an **economic no-brainer**. If a house has narrow or uneven cavities, is in an exposed site, or there is a risk of flooding, then it may be possible to fill the cavity with polyurethane foam. This is more expensive than standard cavity wall insulation but is a particularly effective insulator.

Cost estimate: £330-£725, depending on property type.
Savings estimate: £70-255/year, depending on property type.

Solid Walls (professional install)

Solid walls are traditionally insulated by strapping on thick layers of insulation either internally or externally. Internal insulation is cheaper, but disruptive to install and slightly reduces room sizes. External wall installation avoids these issues, and can improve the look and condition of a property's walls, but may not be suitable for listed properties or those in a conservation area.



With an order of magnitude greater install cost than cavity wall insulation, but with similar order of magnitude savings, solid wall installation is an investment for the long term rather than an economic no-brainer. As a thin, transparent and cheaper alternative to traditional solid wall insulation, consider nano-insulation instead. [Learn more here](#).

Cost estimate: £7,400 for external, £13,000 for internal (traditional insulation, typical semi-detached house). Nano-insulation is roughly 50% the cost of traditional external insulation.
Savings estimate: £120-435/year, depending on property type.

Roof and Loft (DIY/professional install)

A quarter of heat is lost through the roof of an uninsulated home. For a standard sloping roof, insulation can be added from below (internally), with different methods depending on the intended loft usage:

- For an unheated loft, the floor of the loft is insulated between and over the joists, usually using rolls of mineral wool insulation. For mineral wool a depth of 270 mm is recommended.
- For a heated loft, the roof is insulated between and over the rafters, usually using rigid insulation boards or spray foam.
- If the loft is a living space, then all the walls and ceilings between a heated room and an unheated space are insulated.

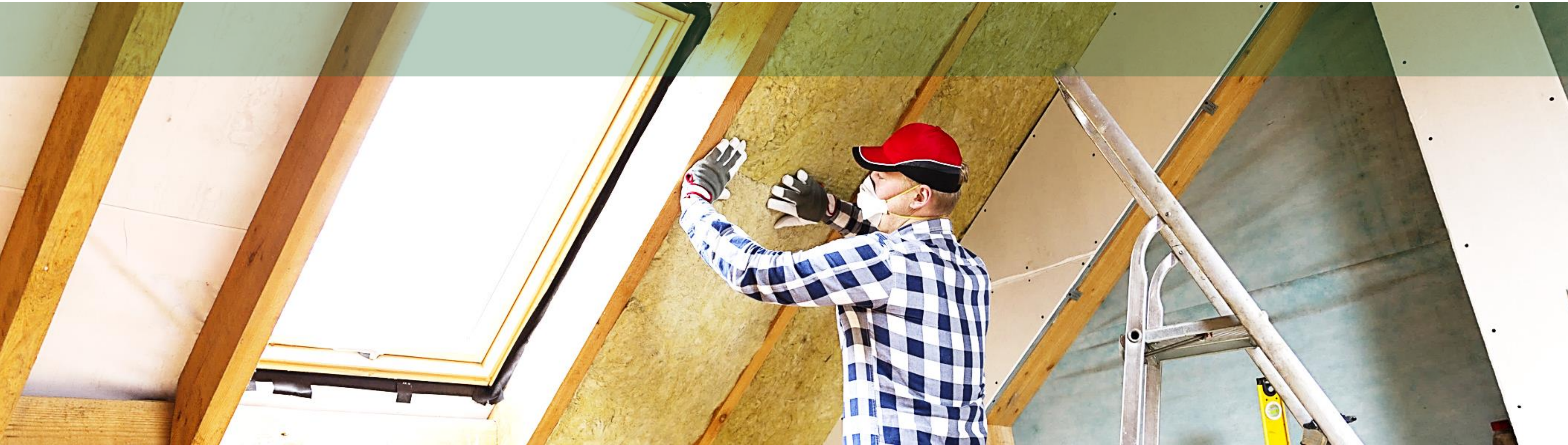
For a flat roof, insulation should preferably be insulated from above (externally).

If a loft is easy to access, does not have damp problems and is not a flat roof, then this is potentially DIY work, otherwise professional installation is likely required.

Given the low cost and minimal payback period, roof insulation is an **economic no-brainer** for most houses without any existing insulation. It is also recommended for houses with insufficient insulation. It can remain effective for at least 40 years.

Cost estimate: going from 0 to 270mm of loft insulation - £285-395, depending on property type; going from 120 to 270mm of loft insulation - £230-290.

Savings estimate: going from 0 to 270mm of loft insulation - £120-225/year, depending on property type; going from 120 to 270mm of loft insulation - £11-21/year.



Windows (DIY/professional install)

Despite windows losing less heat than walls and roofs, most homes already have some expensive form of double or triple glazing fitted. This is in part due to heavy promotion, although there are side benefits such as reduced noise and condensation build-up. For those homes with only single-glazed windows, insulation options include:

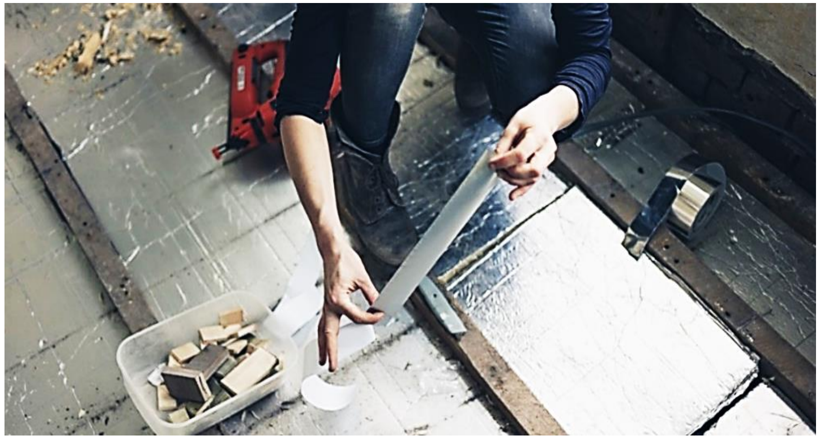
- Replacing windows (professional install). This will require planning permission for certain properties e.g. listed buildings, those in a conservation area. Even if windows can be replaced, they are not guaranteed to pay for themselves over their 20-year odd lifetime, given the high cost and low savings. The most efficient windows have a BFRC rating of A++, with the scale running from A++ to E.
- Adding secondary glazing to existing windows (professional install/DIY). DIY kits use polycarbonate or acrylic sheets and magnetic or clip-fit mounting systems. Professional secondary glazing provides custom build frames and glazing. Secondary glazing can be much cheaper and often not greatly less efficient than replacing windows.
- Using heavy curtains, sealed blinds or shutters.

Cost estimate: replacing all windows - costs will vary depending on the size of the property and windows, material used and choice of installer. Several thousands to low tens of thousands.

Savings estimate: replacing all single-glazed windows with A++ double glazed windows - £30-120/year, depending on property type.

Floors (DIY/professional install)

Relatively little heat is lost through floors compared to roofs, walls and windows. However, small improvements can be made by insulating the ground floor, and any floors above unheated spaces, such as garages. Unless DIYed, this is a high cost method relative to the potential savings.



With solid concrete floors, insulation can be added when replacing the floor – either above or below the concrete - or rigid insulation can be laid on top of an existing floor, thereby changing the floor height.

Suspended timber floors are potentially easier and cheaper to deal with. Insulation is fitted by lifting the floorboards and laying mineral wool insulation between the joists. Or, if there is a cellar or basement space below the floor, it may be possible to insulate the floor from below, without having to lift the floorboards.

Cost estimate: £520-1300, depending on the circumstances.

Savings estimate: £25-70/year, depending on property type.

Hot Water Tank, Pipes (DIY/professional install)

If missing or insufficient, insulating a hot water cylinder and the pipes between the hot water cylinder and boiler is an **economic no-brainer**. It is cheap, potentially easy to do, and has a very short payback period.

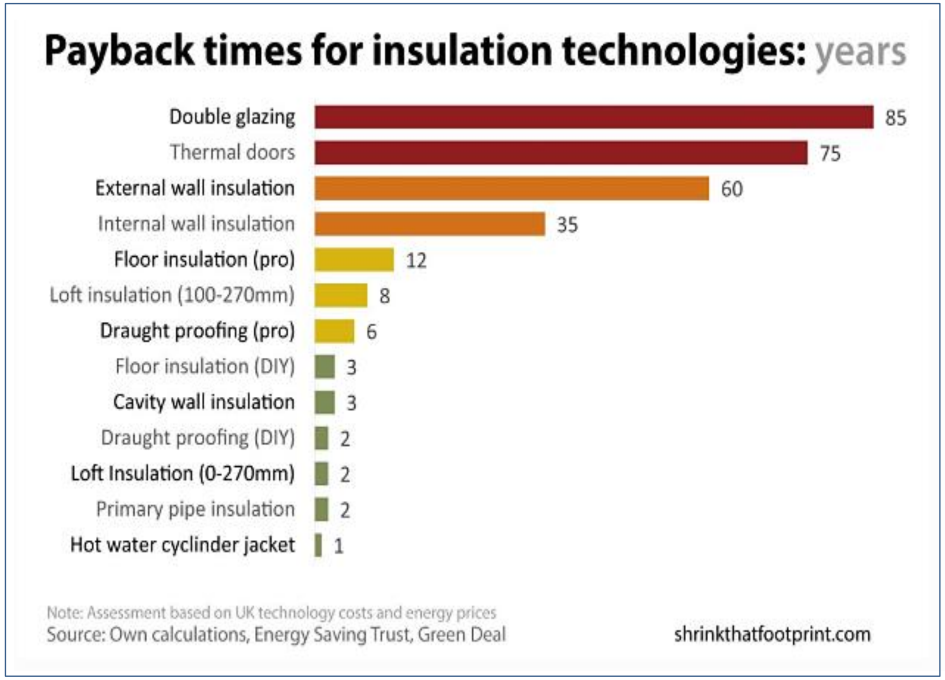
Cost estimate: DIY hot water tank installation on an uninsulated tank - ~£15; primary pipe insulation - ~£20.

Savings estimate: adding 80mm of insulation to uninsulated tank - £75-85/year; upgrading insulation from 25mm to 80mm - £17-19/year.

Draught Proofing (DIY/professional install)

Draught proofing is one of the cheapest and easiest methods for reducing heat consumption. It involves blocking up any unwanted gaps through which air can escape, such as in and around windows, doors, chimneys, floorboards, skirting boards, loft hatches and cracks in walls. Anyone half-way competent at DIY could attempt this, though it is important that intentional ventilation is not blocked in the process.

Cost estimate: ~£200 for whole house professionally done.
Savings estimate: £20/year for draught proofing windows and doors. £15/year for draught proofing chimney when not in use.



Update Heating System

As well as installing insulation as necessary, it may make sense to upgrade the existing heating system, or to replace it entirely.

For some background, homes in the UK typically have either a central heating system – a boiler and radiators, running on mains gas, LPG (tank gas), coal or wood - or they use electric heating, mostly commonly electric storage heating. Mains gas central heating is usually the cheapest and has the lowest carbon dioxide emissions, apart from wood. Electric storage heating is usually the most expensive, and it emits more carbon dioxide than most systems. It is also harder to control electric storage heaters than radiators, especially with older systems.

In this section we cover options for improving an existing central heating system without completely replacing it. Improvements for other types of system, such as electric storage heaters, are covered here.

If a property does not have central heating, has an old central heating system, or is not on mains gas, it may be worth considering completely replacing the heating system with a low carbon alternative - covered later - rather than implementing these improvements. Initial costs will be higher, but relative savings and emissions reductions should be higher too.

Get Connected to the Gas Network

If not connected to the gas network, it may be possible to get connected. Getting connected may or may not cut carbon emissions, depending on the current heating fuel, though energy cost savings could be considerable. Mains gas is roughly a third the price of LPG (tank gas), for example. More on getting a gas connection.

Cost estimate: depends on local factors, ballpark cost is £600 and up. Many thousands more if installing a gas central heating system too.

Savings estimate: £200-800/year, depending on current fuel.

Replace Old Boiler (professional install)

Modern boilers are considerably more efficient than older models, making replacement potentially worthwhile. Boilers are rated from A-G, with A most efficient. The less efficient the boiler, the stronger the argument in favour of replacing it.

Most old gas and oil boilers are regular boilers that have a separate hot water cylinder. When replacing a boiler, it is possible to either keep the hot water cylinder and just replace the boiler, or get rid of the hot water cylinder and install a combi boiler. Combi boilers generate hot water on demand. Which will be superior depends on:

- **Hot water usage** - large families using lots of hot water are likely to be better off with a regular boiler, whereas smaller households may be better off with a combi boiler.
- **Available space** - combi boilers do not need space for a hot water cylinder.
- **Compatibility with solar water heating** - many combi boilers are not compatible with solar water heating - covered later - or cannot use it so effectively.

Cost estimate: replacing gas boiler plus thermostatic radiator valves - £2,300; replacing oil boiler plus thermostatic radiator valves - £3100.

Savings estimate: for gas boiler replacement in a detached house estimated annual savings are £170 (old boiler: D rating), £190 (E rating), £220 (F rating), £315 (G rating); for oil boiler replacement savings are ~10-50% higher, depending on the old boiler rating.

Fit Better Controls (DIY/professional install)

Appropriate heating controls allow for the most efficient and convenient use of a heating system. A central heating system should ideally have - and is likely to already have most of - the following basic controls:

Programmer – sets the on and off time periods for heating and hot water.

Boiler thermostat – sets the temperature of the water that will be pumped from the boiler to the radiators.

Hot water thermostat – sets the temperature of the water in the hot water cylinder or coming from a combi boiler.

Room thermostat – prevents a home from getting warmer than necessary. This turns the heating on until the room reaches the set temperature, and then off until the temperature drops. Typically, there is one room thermostat in the entrance room of a property.

Thermostatic radiator valves – sets the heat output of each radiator, allowing different rooms to kept at different temperatures.

Fortunately, it is possible to upgrade or install some heating controls without replacing the boiler. This is a particularly good idea if the controls are over ~15 years old

Smart Heating Controls (DIY/professional install)

Efficiency and convenience may be improved further by adding 'smart' heating controls. These allow heating to be managed remotely from a computer, tablet or smart phone, and many incorporate other advanced features to control the heating in more sophisticated way. Some can learn from previous choices and make adjustments, while others use automation and optimisation features to help determine exactly when to turn the heating on. One clear advantage is that changes can be made remotely if plans change.

Smart heating controls may be included as part of a wider 'smart home' system. Common brands include Hive, Nest (Google) and Tado.

Whether smart controls will be appropriate for you and save you money will depend on your lifestyle, how you currently control your heating and whether you prefer using an app or traditional controls.

Cost estimate: smart heating controls - £100-300+, depending on functionality; professional installation adds to this cost. Compare smart heating controls here.

Savings estimate: manufacturers claim impressive savings and payback periods as short as a year, however, savings are not guaranteed and depend on several factors. See what Which? say about smart thermostats.

Other Central Heating Improvements

Replace hot water cylinder. Along with boiler design and heating controls, hot water cylinders have also undergone significant innovation in recent years. As one example, Mixergy offers a hot water cylinder they claim will save 5-20% off hot water bills. Hot water cylinders can also be replaced with heat batteries, discussed later.

Use chemical inhibitors. Corrosion deposits in an older central heating system can cause a substantial reduction in the effectiveness of the radiators, and the system as a whole. The build-up of scale in heating circuits and on boiler components can cause a reduction in efficiency too. Using an effective chemical inhibitor can decrease the corrosion rate and prevent the build-up of sludge and scale, thus preventing deterioration and helping to maintain efficiency.

Reduce Electricity Consumption

Modifying a home to reduce electricity consumption chiefly involves replacing inefficient electrical devices, either immediately, or when devices reach the end of their lives.

Lighting

Replacing traditional incandescent bulbs with energy efficient light bulbs is easy to do and an **economic no-brainer**.

There are two main types of energy efficient light bulbs to choose from: **Light Emitting Diodes** (LEDs) and **Compact Fluorescent Lamps** (CFLs). LEDs are more efficient than CFLs and will reach full brightness more quickly. If a very bright single bulb is required for a room, it will be easier to find a CFL to do this rather than an LED. Both will cost a bit more than traditional bulbs, but because they last a lot longer, they cost less overall. And this is on top of the electricity bill saving due to the efficiency gain.

When replacing incandescent bulbs, finding the right brightness can be a little challenging. Light output is measured in lumens (Lm). As a rough guide, about 1,200 to 1,300 Lm is needed to replace an old 100-watt bulb, and 630 to 700 Lm to replace a 60-watt bulb. 200 to 400 Lm will replace a halogen downlighter.

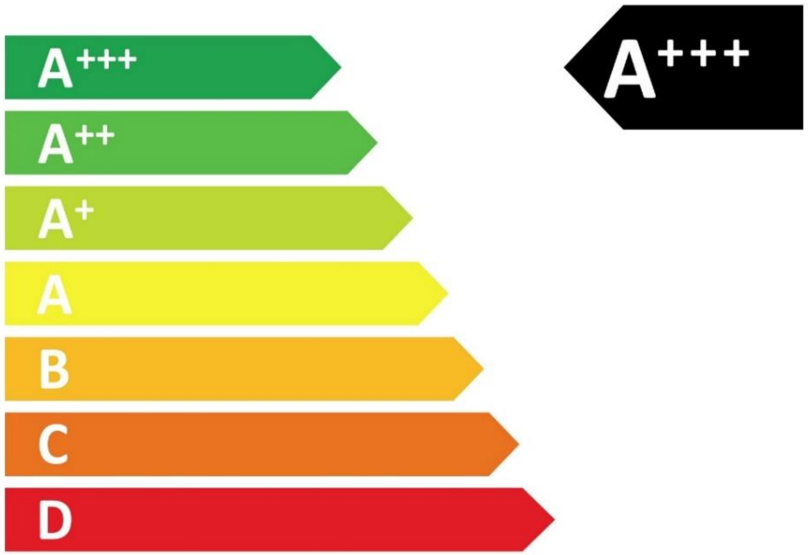
Other than switching light bulbs, electricity consumption can also be reduced by tweaking the lighting system itself. For example, how many lights are used and how they are switched. Automated switching is a particularly useful idea for certain lights such as external, bathroom, utility room or cupboard lights. This takes human sloppiness out of the equation.

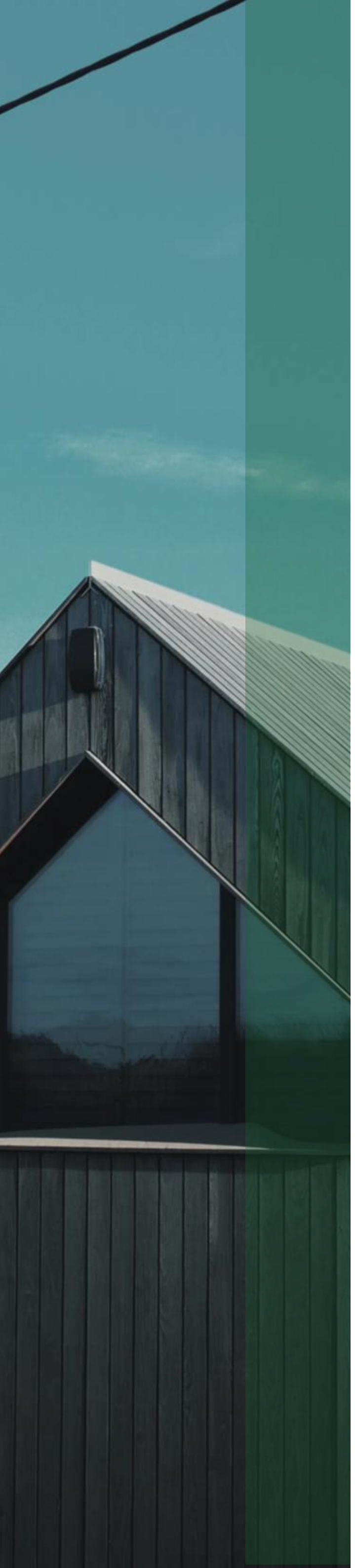
Savings estimate: replacing a traditional light bulb with an LED of the same brightness - up to £2/year; replacing all bulbs in a home with LED alternatives - ~£35/ year

Electrical Appliances

When buying new electrical appliances, electricity consumption can be minimised by choosing the product with the best energy rating – shown explicitly on an energy label as pictured below - at the required size, and no bigger than required. Things like fridges and freezers, which are on all the time, and high-power devices, such as ovens, kettles, electric showers, tumble driers, immersion and other electric heaters are the most important. [See list of household appliances by power usage.]

[Further information on energy efficiency considerations by type of appliance here.]





Advanced Methods

Having covered the methods that all households should consider first, we move on to methods for those looking to greatly reduce emissions and ongoing energy costs. These involve producing renewable heat or electricity and potentially storing energy too. These cost more to install and often have a slower payback period, though may make a property more attractive to potential buyers. **Certified professional installation is a requirement to obtain the available subsidy and export payments**. Heat is again the priority, given the larger energy usage involved.

Produce Renewable Heat

Traditional heating systems burn fossil fuels either locally or, if powered by non-green grid electricity, at the power station. Heat can instead be produced by local renewable methods, thus eliminating or reducing the fossil fuel burn.

Options for producing renewable heat utilise well established technologies and include the installation of a heat pump, biomass heating, solar water heating, or some combination. These generate heat in different ways and can play different roles: providing hot water, space heating, or both. Heat pumps are by far the most popular.

Biomass heating can supply all heating needs, in a direct one-for-one replacement for an existing system, with no loss of performance, but at the expense of having to deal with the wood fuel. Heat pumps can also provide all heating needs, and without fuel complications, but performance limitations mean they need to be used differently to achieve a similar outcome. In addition, certain properties and heat distribution systems are more suited to heat pump installation than others.

Solar water heating is an add-on to a heating system, rather than a complete replacement. It provides a fraction of hot water heating only, with the amount varying by season.

Renewable heat technologies are not cheap to install, but the government’s Renewable Heat Incentive (RHI) can improve the return on investment, see below. Savings on running costs, and therefore payback periods, depend on several factors, including the currently installed system and its fuel type…

If a property does not have central heating, has an old central heating system, or is not on mains gas, installing a renewable heat system is worth considering. On the other hand, if a house is on the gas network and has a relatively new heating system, switching to renewable heat may only be worth it if carbon emission reductions are highly valued. Updating the heating system, as outlined previously, or producing renewable electricity - covered later - may be better options.

Domestic Renewable Heat Incentive (RHI)

The domestic Renewable Heat Incentive (RHI) is a government subsidy providing quarterly cash payments over seven years for eligible renewable heating technologies installed in Great Britain. The RHI runs till 31/03/2022, although a replacement scheme has been signalled by government. Eligible systems include:

- Biomass boilers
- Biomass pellet stoves with integrated boilers providing space heating
- Ground to water heat pumps (including water source heat pumps)
- Air to water heat pumps
- Solar hot water panels (flat plate or evacuated tube only)

Air to air heat pumps, all log stoves, pellet stoves without back boilers and hybrid PVT (photovoltaic plus solar hot water) are not supported by the RHI. The technology and installer used must be certified under the Microgeneration Certification Scheme (MCS).

The subsidy amount depends on the technology installed, the latest tariffs available and, in some cases, metering; most commonly, RHI is paid based on the deemed heat used by a property, as evidenced by an Energy Performance Certificate, mentioned earlier. The April 2020 payments are:

Type	p/kWh
Solar Thermal	21.36
Ground Source Heat Pump	21.16
Air Source Heat Pump	10.85
Biomass	6.97

More on the RHI

Biomass Heating (professional install)

Biomass heating systems burn wood to provide warmth in a single room, or to power central heating and hot water boilers.

Biomass boilers can be used in place of standard fossil fuel boilers to heat radiators for a whole house, and to heat the hot water. Biomass heating employing a biomass boiler can therefore supply all heating needs in a direct one-for-one replacement for an existing system.

By contrast, **biomass stoves** are used to heat a single room, usually in conjunction with other heating systems, but may also have a back boiler to provide hot water.

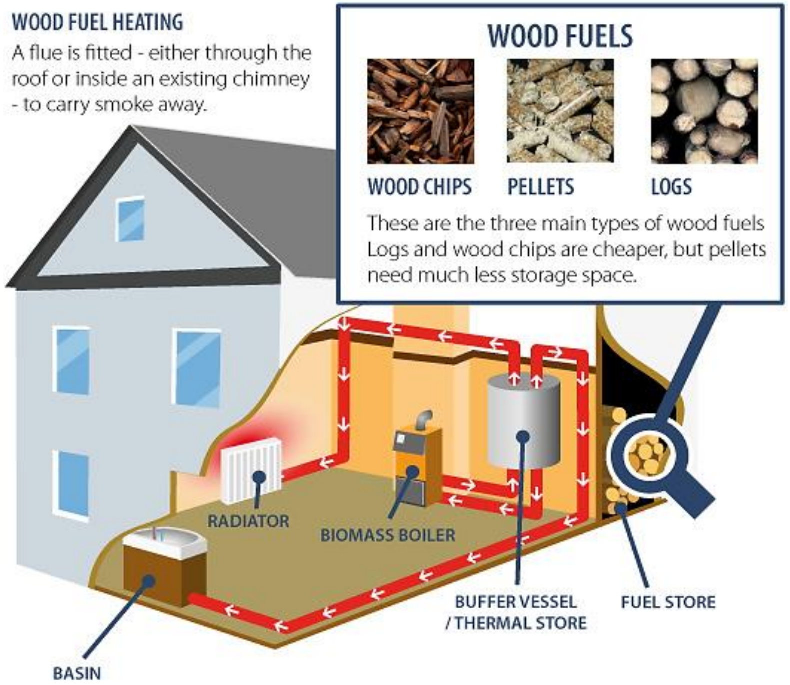
Biomass heating is considered low carbon as the wood absorbs carbon dioxide as it grows; this is simply released back to the atmosphere when burnt. There are carbon emissions caused by the cultivation, manufacture and transportation of the fuel, but as long as the fuel is sourced locally, these are much lower than the emissions from fossil fuels. The process is sustainable as long as new plants continue to grow in place of those used for fuel. Note that burning wood does release other pollutants (particulates, NOx & SOx).

Unlike heat pumps and solar water heating, where the fuel is either free, or readily available and fed directly into a house, fuel supply and input is more complicated for biomass heating. Three types of fuel are used:

Logs - log-burning stoves and boilers must be filled with wood by hand. A large supply of logs will be needed to heat a whole house, but they can be cheaper than pellets if there is a good local supply.

Pellets - pellets are much easier to use and much more controllable than logs. Pellet boilers can run automatically in much the same way that gas or oil boilers operate. Most pellet and chip burners use automatic fuel feeders which refill them at regular intervals.

Chips - used to heat larger buildings or groups of houses.



Maintenance varies by system, but boilers can be largely self-cleaning, meaning the only maintenance is occasional ash removal and an annual maintenance check. Regular sweeping of the chimney and flue pipe are also required. The typical life expectancy of a biomass boiler is around 18-20 years. Most boilers have a 2 to 5-year warranty.

Installation Prerequisites

- Space for the boiler - wood boilers are larger than gas or oil equivalents and space is necessary to store the fuel that is handy for deliveries as well as appropriate for feeding the boiler.
- Space for the flue - a flue is required which meets the regulations for wood-burning appliances. This could be a new insulated stainless-steel flue pipe or an existing chimney with added lining.
- A fuel supplier – RHI approved and preferably local.
- Check planning constraints.

Cost estimate: automatically fed pellet boiler £8000-£15,000, including all costs; manually fed log boiler systems can be cheaper; pellets in bulk delivery can be as cheap as £255/tonne, logs cheaper.

Savings estimate, $C0_2$: from 3.7 tonnes/year if replacing new gas boiler, to 14.3 tonnes/year if replacing coal.

Savings estimate, fuel bill: from -£798/year (costing more) if replacing new gas boiler, to £1205/year (saving money) if replacing old LPG boiler; should also save money versus electric storage and older oil boilers; coal, newer LPG, and older gas are marginal in terms of savings.

Savings estimate, RHI: £1320-1685/year.

Estimates assume 4 bedroom detached house. More detail.

Heat Pumps

A heat pump extracts heat from outside a property – from the ground, air or a water source – to provide space and water heating inside. Some can also provide cooling, though our focus in on heating.

Heat pumps operate on the same basic principles as fridges, and like fridges, run on electricity. Depending on the source of this electricity, heat pumps therefore may not be emission-free. However, they are multiple times more efficient at converting input energy into output heat than traditional electric heaters (and indeed gas boilers), meaning carbon emissions and ongoing costs will be much lower.

Unlike biomass heating, heat pumps do not offer a direct one-for-one replacement of an existing boiler-based system. This is because they provide lower temperature heat. This has various implications:

- A heat pump system takes longer to heat up and will therefore have to run for longer. This need not provide any noticeable difference to comfort.
- Heat pump systems are particularly suited for use with underfloor heating and warm air heating, rather than heating with radiators. Radiators can be used, but will be warm rather than hot, and will potentially have to be scaled up to provide the same level of heating.
- Heat pump systems can provide both heating and hot water if properly sized, but are less efficient at providing both. For air source heat pumps, efficiency can drop off in the winter.

To address the last bullet point, an electric emersion heater is often retained to supplement hot water provision. Alternatively, a heat pump can be combined with a fossil fuel boiler or, for lower emissions, solar water heating, introduced shortly. These hybrid systems may be suited to older properties where it is not possible to insulate to a high enough standard for heat pumps to be fully effective on their own.

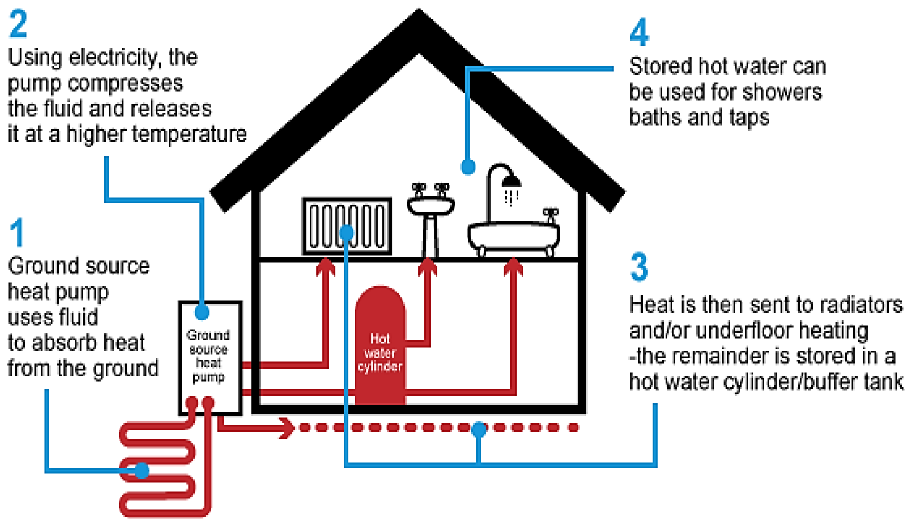
Potential cost and emission savings depend on the old system and the particular use of the heat pump – the heat distribution system, whether it is used to provide hot water and how the system is controlled. Savings will be greatest if switching from electric storage heaters or an older oil or LPG boiler.

A heat pump should operate for 20 years or more but do require regular scheduled maintenance (every 3-5 years by an expert). Heat pump systems typically come with an equipment warranty of 2-3 years (extendable) and workmanship warranty of up to 10 years.

The most common examples of heat pumps use a ground or air source; water source is similar to ground source and not covered here.

Ground Source Heat Pump (professional install)

Ground source heat pumps extract heat from the ground outside a property, see diagram below.



A mixture of water and antifreeze is circulated around a loop of pipe, called a ground loop, which is buried underground, either in a horizontal trench a few metres down, or a deeper bore hole. The latter is a much more expensive option but requires less space and benefits from higher ground temperatures. Heat from the ground is absorbed into the fluid, extracted in the heat pump – which is located inside the house - then passes into the heating system. As the ground stays at a fairly constant temperature under the surface, the heat pump can be used throughout the year with little efficiency loss. The ground loop can last 100+ years.

Installation Prerequisites

- Well insulated property.
- Space for the external ground loop – ground needs to be suitable for digging a deep borehole or shallow trench (for typical installation 2 trenches of 2m depth, 30cm width, 40-50m long, set 5m apart) and be accessible to digging machinery.
- Compatible heat distribution system – heat pumps operate best with underfloor and warm air heating; radiator systems may need larger radiators installed.

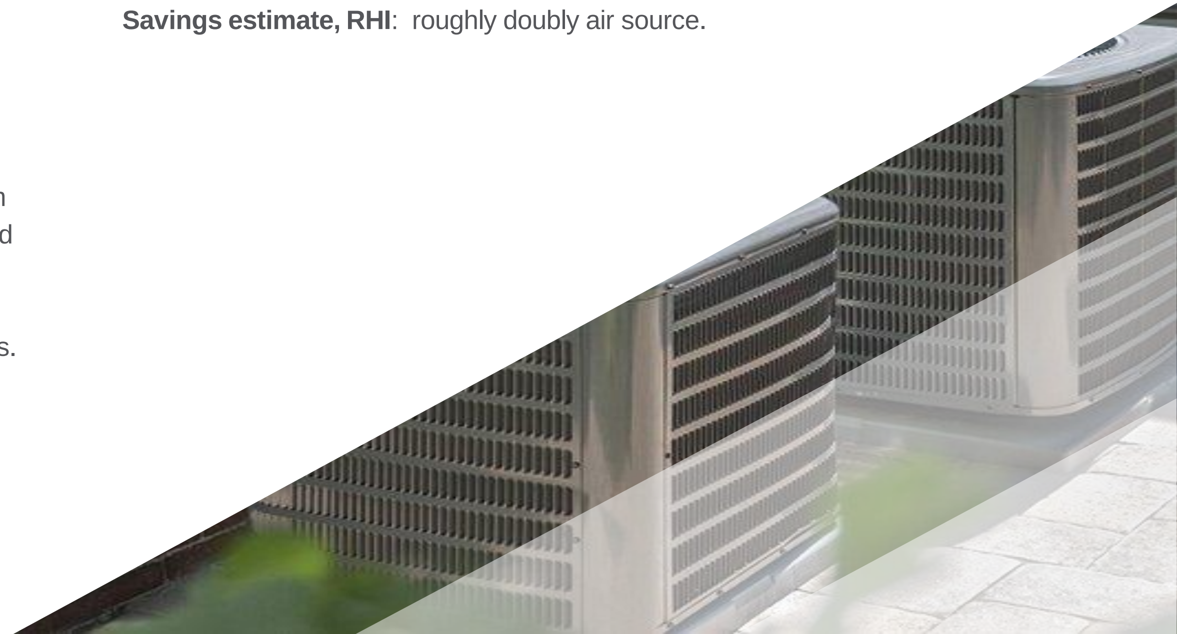
Cost estimate: £10,000-£18,000; upgrades to the heat distribution system may add to this; running costs will depend on several factors including the size of a home and how well insulated it is.

For savings estimates, please see notes below and compare with air source estimates on next page.

Savings estimate, CO_2: greater than air source.

Savings estimate, fuel bill: greater than air source.

Savings estimate, RHI: roughly doubly air source.



Air Source Heat Pump (professional install)

Air source heat pumps extract heat directly from the air outside a property. They work even when the air temperature is as low as -15° C, though efficiency does suffer at lower temperatures. The picture below is an example of the external unit. These do make some noise (40-60 decibels one metre away).

There are two types of air source heat pump systems:

Air-to-water systems are most common. These heat water, which is then circulated around the home via radiators or an underfloor heating system. These can also be used to provide hot water.

Air-to-air systems heat air which is then circulated by fan around the home. These are unlikely to provide hot water as well.

Only air-to-water systems are eligible for the RHI subsidy.

Air source heat pumps are much easier and cheaper to install than ground source heat pumps but are unsightly, noisy, and usually less energy efficient overall, with the efficiency variable and tied to the air temperature. The RHI subsidy for air source is roughly half that for ground source. That said, air source heat pumps are by far the most popular of all the renewable heat technologies. More on air source versus ground source heat pumps.

Installation Prerequisites

- Well insulated property.
- Space for the external unit - a place outside the property where a unit can be fitted to a wall or placed on the ground. It will need plenty of space around it to get a good air flow. A sunny wall is ideal.
- Compatible heat distribution system – heat pumps operate best with underfloor and warm air heating; radiator systems may need larger radiators installed.
- Check planning constraints.

Cost estimate: £6000-8000; upgrades to the heat distribution system may add to this; running costs will depend on several factors including the size of a home and how well insulated it is.

Savings estimate, CO_2: from 1,980 kg/year if replacing new gas boiler to 9,220 kg/year if replacing coal.

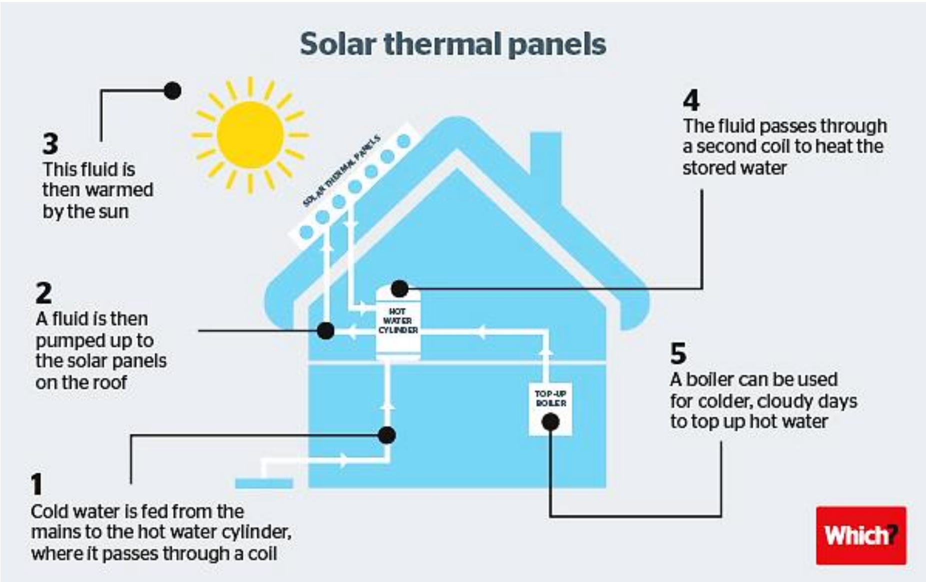
Savings estimate, fuel bill: £105-650/year (replacing gas boiler), £695-1315/year (electric storage heater), £285-1100/year (oil boiler), £565-1610 (LPG boiler); older devices are at the higher end of those ranges.

Savings estimate, RHI: £1341-1586/year.

Estimates assume 4 bedroom detached house. More detail.

Solar Water Heating (professional install)

Solar water heating, also known as 'solar thermal', uses heat from the sun to provide hot water. Without being hugely cheaper, this is a more limited system than those previously discussed, typically providing around 1/3rd of hot water needs and no space heating. A conventional boiler, immersion heater or heat pump (or combination) remains necessary to make the water hotter, as well as to provide space heating. These systems work all year round to some extent, even when cloudy, though it is necessary to further heat the water considerably more during winter months.



Solar water heating systems use solar panels, called collectors, usually fitted to the roof. There are two main types:

Evacuated tubes - a bank of glass tubes mounted on the roof tiles. Evacuated tube systems are more efficient than flat-plate versions, so are often smaller.

Flat plate collectors – flat panels which can be fixed on the roof tiles or integrated into the roof.

Other types of solar water heating are in the early stages of commercialisation, e.g. domestic Concentrated Solar Power (CSP) generators.

Solar water systems can last for 25-years+, though the pump (~£90) and anti-freeze (~£100) are likely to need replacing at least once. Pumps last for 10+ years. Most systems require little maintenance and come with a 5-year or 10-year warranty.

Installation Prerequisites

- Appropriate install space – typically 2-6 m^2 of roof space, ideally pitched at angle of 30 degrees from horizontal, facing East to West through South, South being ideal. Panels can also be fixed on a frame on a flat roof or hung from a wall.
- Compatible boiler - combi boilers, which do not use hot water cylinders, are usually not compatible.
- Space for a larger or extra hot water cylinder.
- Check planning constraints.

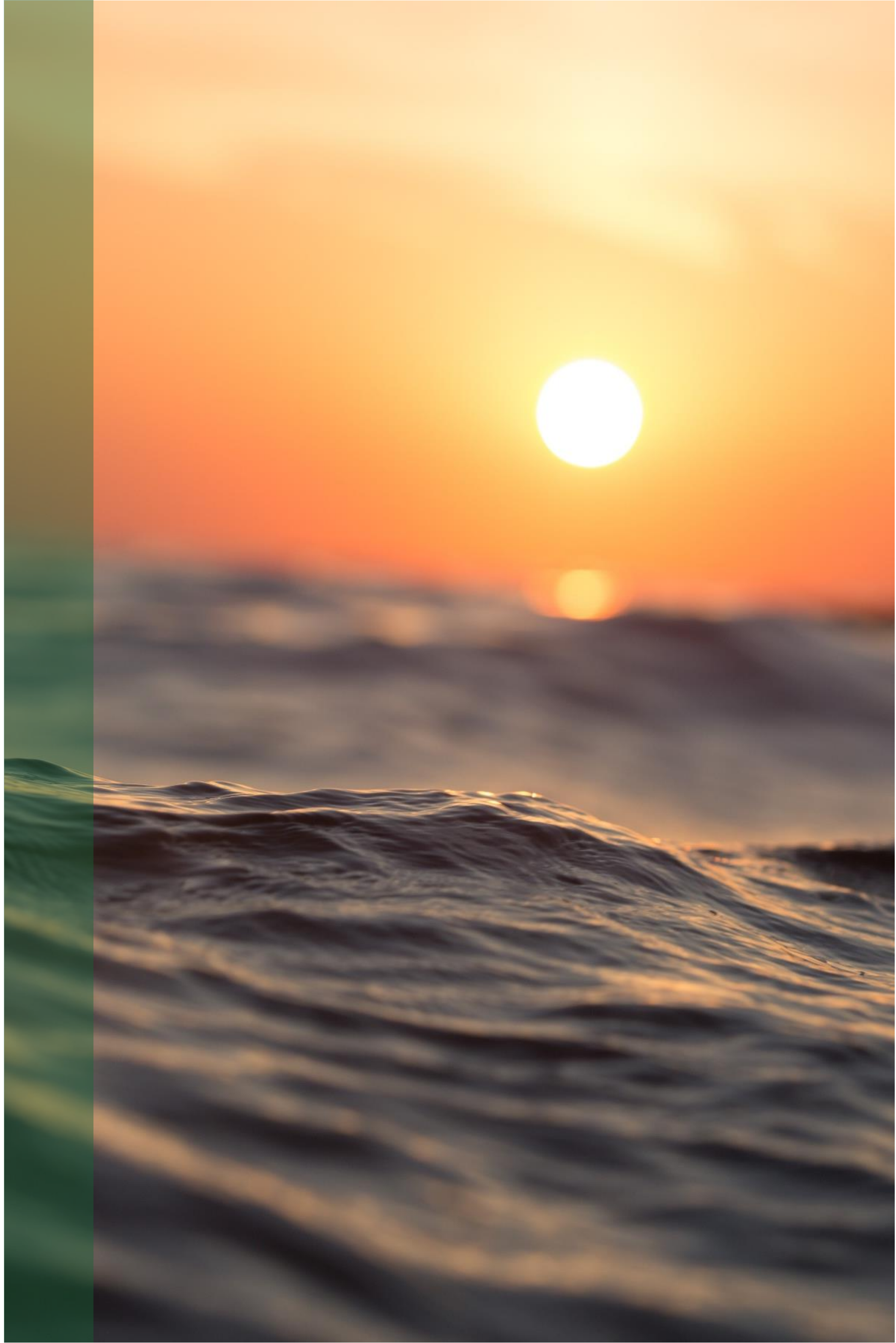
Cost estimate: £4000-£5000 for 3.6 m^2 system.

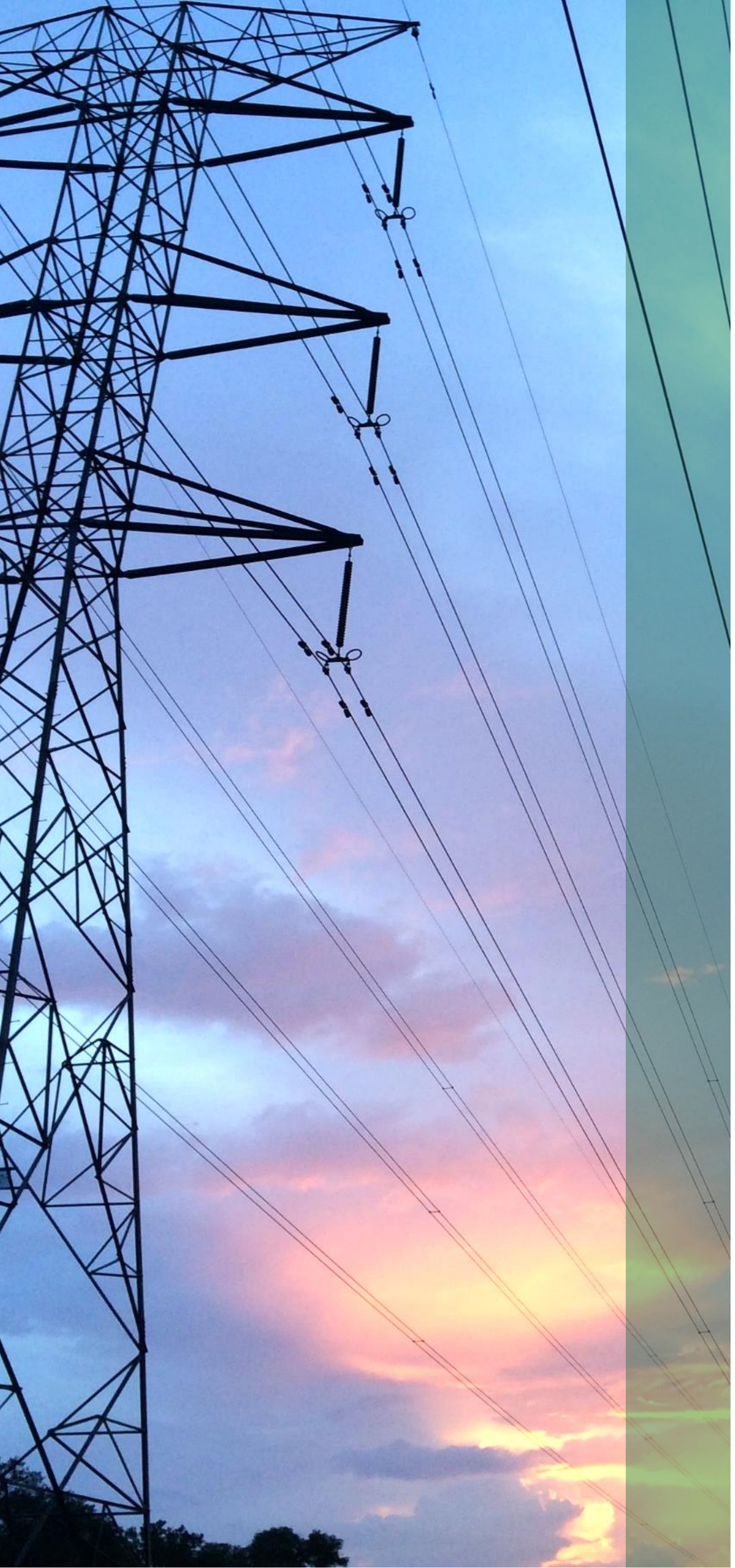
Savings estimate, CO_2: from 260 kg/year if replacing gas to 520 kg/year if replacing coal.

Savings estimate, fuel bill: £55/year (replacing gas), £70 (oil), £65 (coal), £65 (electricity), £95 (LPG).

Savings estimate, RHI: £205/year (2 person, 2 m^2 system), £360 (4 person, 4 m^2), £505/year (6 person, 6 m^2).

More detail





Generate Renewable Electricity

As well as or instead of producing renewable heat, generating renewable electricity is worth considering for some homes. Options include installing PV (photovoltaic), wind, hydro or micro-CHP (combined heat and power) systems. These can also be implemented as community energy projects, providing electricity for more than one property.

PV is by far the most widely applicable and widely adopted, even in the 'sunny' UK. The others are somewhat niche propositions, though micro-CHP is common in Japan, for example.

These technologies are not cheap, but costs are falling, particularly with PV. Although the generous feed-in tariff (FiT) subsidy has now ended, households can still receive payments for excess electricity exported to the grid via the Smart Export Guarantee (SEG), see below, thereby improving the economics. Ideally, though, electricity generated on-site should be used on-site (known as self-consumption). Self-consumption may be improved by installing energy storage, covered separately later.

Smart Export Guarantee (SEG)

The Smart Export Guarantee (SEG) is an obligation set by the government for licensed electricity suppliers in Great Britain to offer a tariff to small-scale low-carbon generators for electricity exported to the National Grid.

The SEG applies to the following technology types up to a capacity of 5MW, or up to 50kW for micro-CHP: PV, wind, micro-CHP, hydro and anaerobic digestion. The technology and installer used must be certified under the Microgeneration Certification Scheme (MCS) or equivalent. See Ofgem's SEG guidance.

Although energy suppliers have to offer a tariff, that does not mean they have to pay for the exported electricity. Some suppliers may only pay SEG for green electricity (not for energy that was imported from the grid, stored in a battery, then exported). Some may need you to be on their import tariff too. The best tariff currently available offers 5.6p/kWh. See list of SEG tariffs.

Photovoltaic (professional install)

PV (photovoltaic) systems covert the sun's energy into electricity. Like solar water heating, PV works all year round to some extent, though clouds reduce output and there is a considerable drop off in output in winter (up to ~80% less). PV systems provide no renewable power at night unless a battery system is also fitted; this is discussed further later.

Although PV systems can be standalone, most PV systems use panels that fit on top of an existing roof, see the picture below. Panels can be sunk into the roof at extra cost. Solar tiles, which replace ordinary roof tiles, are a novel alternative to panels. A system composed of solar tiles will typically cost about twice as much as an equivalent panel system, so are only likely to be used for reasons of aesthetics or planning.

The power of a PV system is quoted in kilowatts peak (kWp). This is the rate at which it generates electricity at peak performance in direct sunlight during the summer. In the South of England, a 4 kWp PV system can generate about 4,200 kWh/year; in Scotland, about 3,400 kWh/year. It is commonly assumed that 50% of electricity is self-consumed rather than exported to the grid. This percentage can be increased in various ways, such as by storing the electricity in a battery or converting to heat, and then storing this heat. Self-consumption will naturally be greater for occupants who are home all day, thus improving the economics for those households. In all cases, PV should provide a significant fraction of total household electricity, especially in summer. Larger systems will cost more but will increase savings so may be more cost-effective overall.

PV panels should last 25 years or more, but the invertor – the device that converts DC electricity from the panels to useable AC electricity – is likely to need replacing during this period (~£800). The panels themselves require little maintenance, other than cleaning and ensuring trees do not begin to overshadow them.

For more tailored advice on determining PV suitability, sizing, output, savings and payback period, various calculators can be found online.

Installation Prerequisites

- Suitable roof space – typically 15-25 m^2, ideally pitched at angle of 30 degrees from horizontal, facing East to West through South, South being ideal. Ideally there is no shading – from trees, chimneys, TV aerials, etc. - or only limited shading early or late in the day.
- Check planning and grid connection constraints.

Cost estimate: average 4 kWp system - ~£6200.

Savings estimate, CO_2: 4 kWp system - 1-1.3 tonnes/year, depending on location; further south, higher savings.

Savings estimate, fuel bill: London, 4 kWp system - £300-£390/year including SEG subsidy; range comes from amount of time occupants are home during the day; Scotland, 4 kWp system - £180-310/year including SEG subsidy. More detail.

Wind Turbine (professional install)

Wind turbines harness the power of the wind to generate electricity. Unlike PV, wind turbines are a niche product, lacking the widescale applicability or adoption. They typically require elevated and open sites, so are most suited to rural and coastal areas, especially where mains electricity is unavailable.

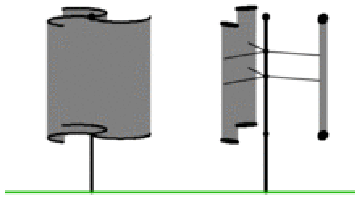
Domestic wind turbines range in size from 400 W to 15 kW+ - so from providing a small fraction of a home's instantaneous electricity needs to potentially all of it. By their nature they generate unpredictably throughout the day and night, and not necessarily when power is needed, so systems are often installed with batteries, especially off-grid.

As shown in the picture above, there are two main types of turbine:

Pole-mounted - these are free standing and are erected in a suitably exposed position, with a typical generation capacity of ~5-6 kW. A well-sited 6 kW turbine can generate 9000 kWh/year.

Building-mounted – these can be installed on the roof of suitable homes, are smaller and cheaper than pole mounted systems, but tend to be less efficient. Generation capacities range from 0.5 kW up to 2.5 kW.

Wind turbines are also classified into horizontal and vertical axis categories, the later promoted for use in urban areas. More here.



Examples of vertical axis turbines

A well-maintained turbine should last more than 20 years, but the invertor is likely to need replacing at some stage during this time (£1000-£2000 for large system), as are any batteries. Maintenance checks are necessary every few years (£100-£200 per year).

Installation Prerequisites

- An average wind speed of 5-6 m/s or more in an area free from turbulence caused by surrounding obstacles. Get a wind speed estimate for your location. A wind survey will determine suitability.
- Suitable space if installing pole-mounted turbine.
- Check planning and grid connection constraints.

Cost estimate: depends on size and mounting method; 2.5kW pole-mounted system £9,000-£19,000; 6 kW pole-mounted system £21,000-£30,000; average roof mounted system £2,000.

Savings estimate, CO_2: for well-sited 6 kW turbine, 3.4 tonnes/year.

Savings estimate, fuel bill: assuming total self-consumption of 9000 kWh/year generation, a well-sited 6 kW turbine could save ~£1300/year.

Hydro (professional install)

Even more site specific than wind turbines, hydro systems harness the power of moving water in streams or rivers to generate electricity. Most properties will simply not have access to a suitable resource even if there is a watercourse running nearby. The water must be able to provide enough of a 'push' to turn a turbine, and this push ideally needs to hold up during dry periods.

However, if suitable, hydro is one of the better ways of generating renewable electricity. Unlike wind and solar, hydro can generate reliably 24 hours a day, often generating more than the electricity need for a single household. Hydro is most attractive for off-grid properties, particularly if installation is less than the cost of getting connected to the grid.

Hydro is very reliable, long lasting (40-50 years) and with low maintenance costs.

Cost estimate: installation costs vary, largely depending on the location and equipment required for install.

Savings estimate: variable, depends on the amount of electricity generated; this is affected by the number of hours the turbine is able to run in a year, which in turn will depend on how often the level of the river is high enough to supply the system.

Hybrid Systems

Although we have considered the production of heat and electricity separately, there are systems which do both. This can be more efficient than generating them separately. Examples include:

Micro-CHP (combined heat and power) - these generate heat and power simultaneously from the same fuel, which is usually a fossil fuel but clean-burning hydrogen can also be used, if available. Learn more about hydrogen. The main output is heat, with some electricity generation at a typical ratio of about 6:1. A typical domestic system will generate up to 1kW of electricity once warmed up. There are two main types of micro-CHP - internal combustion engine CHP and fuel cells, the latter of which are widely used in Japan. More detail on micro-CHP.

Photovoltaic Thermal systems (PVT) – these generate both heat and electricity from the sun. These are not eligible for the RHI subsidy.

Store Energy

For those most concerned with reducing carbon emissions and ongoing energy costs, adding some form of energy storage to a renewable install is a logical step. This can be in the form of electrical storage, implemented with an electrical battery, or heat storage, implemented with a thermal store or heat battery.

Whether domestic energy storage makes economic sense is another matter entirely; this is a newish technology with high initial outlay and typical savings that are not widely reported. The ability to cut carbon emissions more deeply, and to increase energy independence, may offset straightforward economic considerations for some.

Installing energy storage is generally not a DIY task.

Electrical Storage

Electrical storage, implemented with batteries, can help optimise renewable electricity generation.

The main benefit of storing renewable electricity is the ability to time-shift it from when it is readily available – when it happens to be sunny or windy - to when it is most useful, the two often not matching. In theory, this helps maximise self-consumption, which in turn minimises the requirement to import higher cost and higher carbon electricity from the grid.

In addition to increasing self-consumption, batteries enable a household to potentially profit from an electricity tariff that has a time-of-use component. For example, on an Economy 7 tariff, energy could be imported cheaply overnight and used at otherwise expensive times of day.

Taking this concept one stage further, batteries may also be able to earn extra revenue by dynamically balancing the grid – matching local demand and supply - based on signals from an energy supplier or grid operator. This is not a common practice at this time but is likely to become increasingly important as the electricity system decarbonises and large-scale renewables penetration increases.

For off-grid properties, battery storage plus renewables can reduce reliance on an alternative fossil fuelled electricity generator. For off-grid renewables-only electricity supply, batteries are a critical component.

Suitability

Not all households will benefit significantly by installing batteries alongside renewables. Electrical storage can be expensive relative to very site specific savings. The two main factors affecting suitability are:

- The power output of the renewable generator.
- The amount of power consumed and at what times of day. Having a home charged electric vehicle can impact electricity use by ~80%.

For PV, broadly speaking, if occupants are out all day and have a larger system then batteries are more suitable. Having an electric vehicle that is charged at home overnight greatly improves the case.

Properties with PV and a divert device, which uses spare electricity from a renewable source to heat hot water, or with a heat battery, may see limited financial benefits from also installing electrical batteries. Homes with a wind turbine or hydro system may see greater financial benefits.

Types of Electrical Storage

There are several home battery systems currently on the market such as those from Tesla, Sonnen and Powervault. These come in the form of 1-2-metre-high rectangular boxes, which are usually installed inside on a wall or the floor, though some can go outside.

These systems use either lithium ion or lead acid batteries. For grid-connected homes, lithium ion is usually used, which although more expensive than lead acid has very roughly double the lifetime (10 years+).

Available storage capacities ranges from 1 kWh to 20 kWh, enough energy to boil your kettle from 10 to 200 times. Systems are often stackable if a larger capacity is required. Power outputs range from hundreds of watts to 5 kW or more. This determines what range of electrical appliances can be powered at one time from the battery.

Note that most systems for grid-connected properties **will not provide power during a power cut** (Tesla home gateway is an exception).

Batteries will degrade throughout their lifetime, meaning they store less energy as they get older (usually 20-30% less). They may have to be used in a restricted way to retain warranty provision.

At some time in the future, the batteries in electric vehicles may be used to store renewable power and to balance the grid, but this is currently still being trialled. Such use is likely to shorten battery lifetime.

More on batteries.

Cost estimate: £4,000 to £6,000 for a fully integrated 4 kWh system.

Savings estimate: variable, see example at end of this document about energy storage.

Heat Storage

Much like electrical storage can be used to optimise electrical systems, particularly those that include renewable electricity generation, heat storage can be used to optimise heating systems, particularly those that include renewable heat production. It is not quite this neat as electricity and heat can be converted into one another.

There are two main types of heat storage – thermal stores and heat batteries. These store the heat in different mediums.

Thermal Stores

Thermal stores are simply insulated tanks that store heat as hot water. Thermal stores can have a single heating input – from a boiler most likely - or multiple heat inputs, such as boiler, heat pump, solar water heating and/or immersion heater. Standard sized hot water cylinders (~120 litres) are the most common form of thermal stores, though much larger tanks are also available, if heat storage requirements are greater.

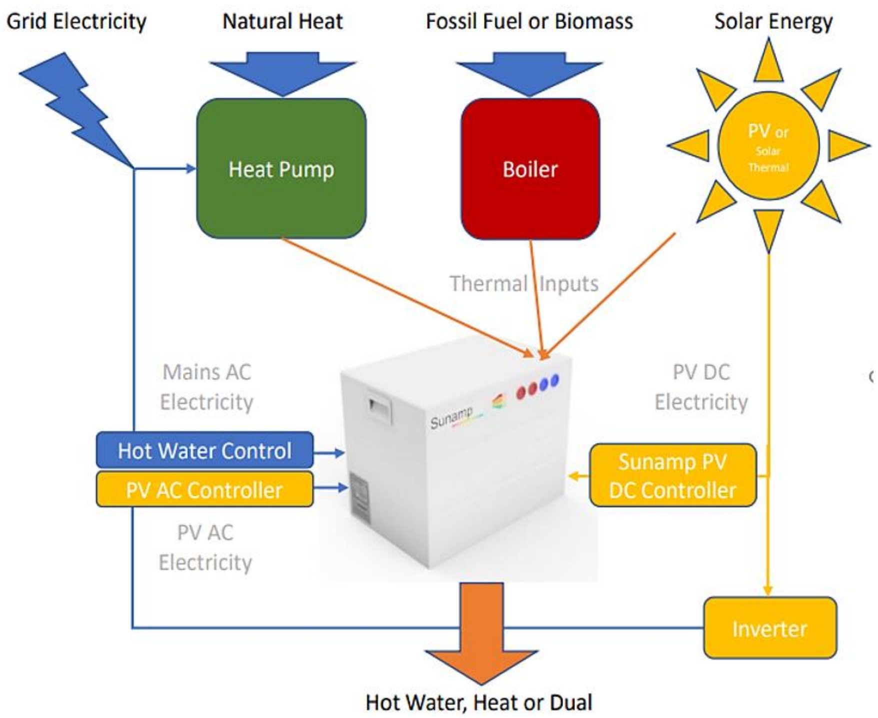
Cost estimate: large 500 litre thermal store - £2,500; installation costs up to £450.

Heat Batteries

Heat batteries are a novel technology that store heat in a phase change material. Spare heat or electricity is used to charge the phase change material inside the battery. When the heat is needed, the phase change material is converted to a liquid, releasing heat, which is used to provide rapid hot water or space heating. Heat batteries are smaller and lighter than thermal stores. They are used instead of thermal stores and any separate electric water heaters, or to enhance a combi boiler system.

Sunamp is the only supplier of heat batteries in the UK. Sunamp claim their heat batteries 'beat hot water cylinders and electric batteries on size, power and price.' Their batteries range from 3.5 kWh to 14 kWh, substituting for a hot water cylinder from 70 to 280 litres. Sunamp claim low maintenance, with a lifetime of over 50 years of average use, roughly 5 times longer than lithium ion batteries.

Cost estimate: 5 kWh heat battery - £1300 without installation or VAT.



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