CASE STUDY: MAKING A HOME CARBON ZERO IN 2020

I moved into this large 4-bed detached 1970's house in 2012 in a rural location, and over an 8-year period have made it almost carbon neutral. This was achieved mainly through the installation of solar PV panels, an air source heat pump, and a wood burner. Over that time carbon emissions have reduced by 98% and costs by 79%.

The following changes were made:

- Cavity wall's insulated and loft insulation topped up
- 8 solar PV panels installed (2.5 kWp)
- Replaced gas boiler with air source heat pump
- LED lighting throughout
- A+++/A++ appliances
- More efficient wood burner with catalytic converter
- Behavioural change: turning appliances off, wearing warm clothing, smart meter monitoring of usage patterns

There was nothing radical about the work and most of the costs were covered by government CERT, FIT and RHI subsidies. Net of subsidies the total capital outlay has been about £3,000. The reduction in energy usage saves about £1,300 each year in energy bills.

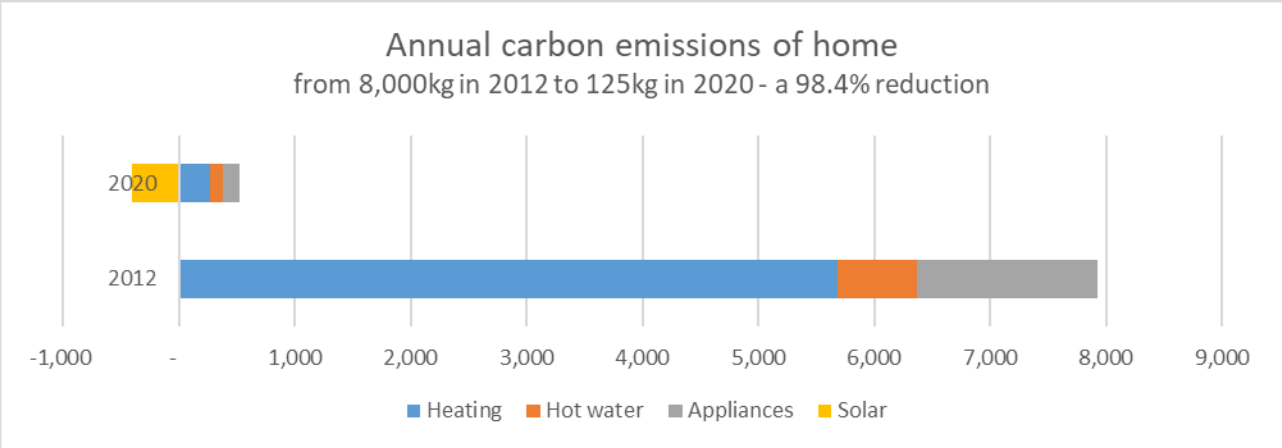
By 2035 most homes in the UK will need to become carbon neutral if we are going to meet the UK's climate change obligations. This will require us all to make similar changes to our homes, and in particular we will all have to replace our gas boilers with low carbon electric heating.

This case study attempts to prove that making a relatively ordinary home in the UK carbon neutral is achievable today.

The rest of this case study goes into the individual measures in detail, explaining the thought process behind each of the changes. Although the text often focuses on running costs, any reduction in running costs almost always implicitly means a reduction in carbon emissions. There is quite a lot of detailed information below, however reducing a home's carbon emissions can be spread out over a number of years, and if there is one take-way from this case study – the biggest saving was replacing the gas boiler with an air source heat pump.

CHANGE IN ANNUAL CARBON EMISSIONS OVER THE LAST 8 YEARS:

The chart below shows the carbon emissions in 2012 when I moved my home and that of today:



Carbon emissions have reduced from the 8,000kg predicted by my Energy Performance Certificate, and the home's emissions today using data from my energy bills/smart meter. The biggest change is with the heating – replacing the gas boiler with an air source heat pump and a wood burner. What is left of the home's carbon emissions are now almost exactly offset by the home's solar PV panels – although not necessarily at the same time of year!

For most homes the decarbonisation of the electricity grid (more wind turbines) will continue to help reduce the carbon emissions of your home into the future if you have an air source heat pump unlike a gas boiler.

Its difficult to attribute the impact of individual changes, as they overlap – for example turning the heating down reduces demand and therefore the impact of switching between a gas boiler and an air source heat pump. Approximately the impacts of the measures have been as follows:

Change	Impact - CO2 reduction kg
Cavity Wall + loft impact	800
Appliances + behaviour	600
Wood burner	1300
Behaviour change (lower temperatures, woolly jumper)	2100
Air source heat pump	5500
Solar PV	600

CAVITY WALL AND LOFT INSULATION

On moving into home in 2012 the first thing I did was to get cavity wall insulation installed and the loft insulation topped up from 50mm to 270mm.

I insisted that the cavity wall installer used carbon coated polystyrene (EPS) beads rather than the blown fibre insulation often offered – the costs aren't significantly different but the beads offer 20% better insulation, its less likely to slump and leave gaps over time, works better with narrow cavities (50mm for my home) and is less susceptible to damp.

30% of UK homes with cavity walls still aren't insulated, most are suitable unless in exposed wet and windy locations. Only 65% of homes currently have reasonable levels of loft insulation. Installing insulation can reduce heat losses by between 50% and 70%, is cheap and very cost effective.

At the time cavity wall insulation was free, but without subsidies it typically costs between £300 and £700. The 2020-21 government green grants scheme currently provides free installation.

I was lucky in that the home was already reasonably draught-proofed and didn't need further work; and in general draught-proofing of windows and doors only has a small 2% to 8% effect on energy losses. The one exception to this rule is exposed ground-floor floorboards which can have large heat losses and can be draughty.

METERING, LED LIGHTING AND A++/A+++ APPLIANCES

Choosing appliances

When I moved in in 2012 I had to buy a number of appliances, and when I did I ensured that they were energy efficient and in particular looked at the total cost of ownership – i.e. the purchase cost of the appliance plus its electricity consumption and maintenance costs. Purchasing (or replacing) energy efficient appliances which run all the time like fridges and freezers are the highest priority purchases.

An example was my decision on purchasing a freezer. Should I purchase a more expensive more efficient freezer:

Freezer Cost	Energy efficiency rating	Annual electricity consumption kWh	Electricity cost p/kWh	Life of appliance years	Running costs over life	Total cost over life (capital + running)	Saving
£300	A+	300	15	15	£675	£975	
£500	A+++	100	15	15	£225	£725	£250

The dilemma being do you spend an extra £200 on a more expensive freezer? If you look at the running costs the answer becomes obvious, the more expensive freezer is likely to save me £250 over its lifetime (breaking even after 7 years). The annual running costs of appliances are included in the appliance energy rating sticker which retailers are required under EU law to display, so it's easy to do similar calculations to the above for all appliances..

Other decisions I made on appliances:

- I deliberately don't own a tumble dyer but keep an eye on the weather and using a washing line. If I had to buy a tumble dryer, I would buy one with a heat pump which can reduce annual running costs from £95 per year to £35 per year over a traditional condenser type
- LED TV: mine is A+ rated, uses 30W when on, and is only 32" – larger TVs use more power

- Laptop – I use a laptop and a tablet rather than a desktop as they typically use 70% less electricity
- Hob – I have an induction hob, which is very energy efficient – it only heats the pan and food, unlike a gas hob which heats the surrounds as well, using an induction hob is about twice as efficient as gas and unlike gas doesn't cause local air pollution – you also don't need to run your extractor as high to extract the H2) which is a by-product of burning gas

In general if you have an older appliance which is rated A or below its probably worthwhile from a cost and carbon reduction perspective replacing it with an A++ rated appliance today rather than waiting for it to wear out.

LED lighting

LED lighting is the most efficient type of lighting and unless you don't turn lights on that often saves you electricity very quickly.

Type of light	Standard	Halogen	CFL (compact florescent (	LED
Equivalent wattage	60W	50W	11W	7W

My kitchen was a good example – in 2012 it had 12 50W halogen GU10 bulbs – which if turned on for 400 hours per year (2 hours per day, 200 days of the year) were consuming 240 kWh per year or £34/year. Replacing them with LEDs at a cost of £20 would save about £25 per year.

I installed LEDs in about 80% of sockets as soon as I moved in in 2012 and replaced the remainder over time when suitable replacements became available. Generally if you have dimmer switches you will need to change them at the same time, and also if you have MR16 type 12V downlighter bulbs you will either need to replace their transformers which are generally hidden in ceilings or rewire with GU10 bulbs which don't need transformers.

The Energy Saving Trust has a good article on LED lighting here: https://energysavingtrust.org.uk/sites/default/files/reports/EST%20Lighting%20Guide%20-%20the%20Right%20Light.pdf

METERING AND MEASURING CONSUMPTION

I used an appliance monitor to determine what individual existing appliances were using. Interesting results were that the remote-controlled garage opener, and the aerial power booster both were individually using more electricity on standby than my freezer. So, I removed the aerial booster and put the garage opener on a manual switch.

I also have a smart meter which I check occasionally to make sure my standby (overnight) consumption is staying as low as possible; it is also useful for significantly reducing electricity costs (see below under air source heat pump) my enabling a time of day tariff.

SOLAR PANELS

In 2016 I installed 8 solar PV panels (2.5 kWp) on my garage roof while Feed In Tariff subsidies were still available. They produce about 2,200 kWh electricity per year, which is almost exactly the home's annual electricity consumption from appliances, lighting, heating, and hot water, and hence why the home is now almost carbon neutral.

AIR SOURCE HEAT PUMP

The biggest impact on reducing the carbon emissions of my home was to replace the gas boiler with an air source heat pump. I use the heat pump in combination with a wood burner to keep the home warm. I generally wear a thick woolly jumper during the winter to reduce the heating required during the day – this is the most cost-effective energy saving measure you can take to reduce your carbon emissions. I use the wood burner to keep the lounge warm in the evening.

Air source heat pump's carbon emissions are currently about 4 times lower than gas:

	Efficiency	Carbon intensity of fuel g/kWh	Carbon intensity of heat[1] g/kWh	Times lower carbon efficiency than gas
Gas boiler	80%	210	263	
Air source heat pump (2020)	300%	200	67	3.9
Air source heat pump (2030)	300%	100	33	7.9

and with the decarbonisation of the national electricity grid (to 100g/kWh – more wind turbines) will be 8 times lower in carbon by 2030. This is because they their efficiency through extracting latent heat from the outside air at about 300% is much higher than a gas boiler's 80% efficiency.

There is a further, more detailed article on Transition Bath's website on my air source heat pump installation.

Costs are likely to be slightly lower for an air source heat pump (£540) compared with a gas boiler (£540):

	Heating and hot water requirements kWh	Efficiency	Fuel requirement (requirement / efficiency) kWh	Fuel cost p/kWh	Annual fuel cost	Standing charges	Total annual fuel costs
Gas boiler	10,000	80%	12,500	4	£500	£146	£646
Air source heat pump	10,000	300%	3,333	14	£467	£73	£540
Air source heat pump (Octopus time of use tariff)	10,000	300%	3,333	6.5	£217	£91	£308

And, under half the costs if you switch to a time of use tariff where you can benefit from lower electricity prices outside peak hours. I use an Octopus Go tariff, and my average electricity costs last year were 6.5p/kWh

[1] The carbon intensity of heat is simply the fuel carbon intensity divided by the efficiency e.g. for gas 210g/kWh / 80% = 263g/kWh.

compared with the average 14p/kWh for homes on more normal flat rate tariffs. To benefit from these cheaper tariff's, you need a smart meter installed.

The costs of installing an air source heat pump are roughly:

Property size	2 bed	3 bed	4 bed	Large 4 bed
Cost	£7,500	£8,500	£10,500	£12,000
RHI subsidy over 7 years	-£5,500	-£7,000	-£9,500	-£12,000
Net cost	£2,000	£1,500	£1,000	£0

Mine cost £12,000 (Mitsubishi EcoDan PUHZ 11.5 kWp) and I will receive about £12,000 in government Renewable Heat Incentive (RHI) subsidies over 7 years.

Comments:

- You will need space outside your home to install an outside unit – mine was installed behind the garage, and with 3 metres of pipes underground below a path to my home
- The gas boiler was removed – which potentially frees up space in your home
- You do however need a new hot water cylinder (its needs a larger heat exchanger), or if you don't have space for a cylinder then you will need to go for electric hot water taps and showers – which might exclude having a bath
- All radiators will need to roughly double in size because hot water from heat pumps is a lower temperature than gas boilers (45C versus 80C), in order that they produce the same heat output. Doubling in size might just require a deeper radiator with more panels and vanes, I installed some fan convector radiators – which were half the size of the original radiators downstairs and moved the larger downstairs radiators they replaced upstairs to save costs. Its important to ask an air source heat pump installer what 'flow temperature' they are expecting the system to work at – the lower the flow temperature (the larger the radiators), the more efficient the system will be, the lower your costs and carbon emissions will be – insist on something at 45C or below. If you have underfloor heating, then heat pumps can be very efficient – up to 500% if they run at 30C
- Once installed I had my gas meter removed for free, saving about £75 per year in standing charges
- I had an additional 'MMSP' monitoring package installed which provides me with internet access to control the pump and detailed consumption and heat output information – it cost an extra £800 but you get £1,600 in extra RHI subsidies over 7 years for installing one
- My home came with microbore which is potentially a problem as a heat pump needs to pump about twice as much water around the system as a gas boiler – my installer got around this by installing 2 pumps – one for upstairs and one for downstairs – which I wanted anyway as it allows me to have the heating on downstairs during the day and just run the heating in the bedrooms later in the evening, plus I needed a 100 litre buffer to compensate for the lack of water volume in the microbore
- Planning permission is generally not required as its permitted development, most are very quiet, mine is an 'ultra quiet' model which you can't hear unless standing within 1 metre of it. The permitted development rights suggest permission is not required in a conservation area or World Heritage Site – but you may want to phone your planning department first and if they say you do need it ask them to explain why it is not permitted development according to government regulations?
- It is possible to install an air source heat pump in an older solid walled building, it can be challenging in detached properties with large outside wall areas, but for example terraced properties should be more feasible

- I considered ground source heat pumps, but they are much more expensive, required a large garden, or a risky borehole and aren't that much more efficient but RHI payments are significantly higher

Don't worry if all the above seems a little complicated, your installer who must be MCS registered will deal with all the above for you before the system can be installed.

Further reading:

- The government RHI calculator: https://renewable-heat-calculator.service.gov.uk/ tells you how much RHI subsidy you will receive
- For this you will need an Energy Performance Certificate – which you can download here https://www.epcregister.com/reportSearchAddressByPostcode.html for your home if there is one or a similar home in the neighbourhood
- On the final page of the calculator, I suggest you change the 'Seasonal Performance Factor' – defaulted to 2.5 (250% efficient) – this changes depending on the efficiency of the heat pump and increases with lower flow temperature/larger radiators – mine is 3.8 at a flow temperature of 45C, this will increase your RHI payments; and as above installed a MMSP monitoring package increase RHI income by a further £1,600
- To find an MCS registered installer: https://www.simpleenergyadvice.org.uk/installer-search or the less user friendly MCS official website: https://mcscertified.com/find-an-installer/
- This manufacturers website which is quite helpful in explaining heat pumps: https://www.nu-heat.co.uk/renewables/heat-pumps/air-source-heat-pumps/

WOOD BURNER

Wood burners have the potential to be carbon neutral but cause air pollution. I have recently replaced the home's original wood burner with a more efficient burner with a catalyst.

There is some controversy about the carbon neutrality of wood burners depending on where the wood is sourced from and whether it is replaced. My wood is sourced very locally from fallen branches and trees and so should be fairly carbon neutral.

The new wood burner is 85% efficient and is DEFRA approved, and exceeds the EU Ecodesign 2022 requirements and is rated Ecoelite; its difficult to judge but I am seem to be consuming between 30% and 50% less wood than the previous wood burner, so a significant improvement in energy efficiency. I also had an external air kit installed, so the air (oxygen) for the burner is directly sourced from the outside of the house via a pipe to the subfloor, rather than pulling cold air into the house if it were sourced internally – this should improve the efficiency of the installation further,

In towns, air pollution from wood burners can be a problem. My home is rural, with the nearest home in the direction of the prevailing wind power 500 metres away but to make sure air pollution isn't a problem the new wood burner has a catalytic converter, which should reduce carbon monoxide, NOX and particulate emissions. In additional I make sure the wood I use is properly seasoned with a humidity below 20% - this aids clean burning, reduces air pollution and improves efficiency.

FURTHER WORK

There are two areas of further work I would like to do on the energy efficiency of the house:

- **Triple glazing:** the home's double glazing is quite old, about half is probably 30 year's old, and the remainder 18 year's old; with an efficiency, U value of about 2.4 $W/m^2/K$, triple glazing would be about 3 times more efficient with a U value of 0.8 $W/m^2/K$. However, at a cost of more than £20,000 it is unlikely to pay back the cost in energy saving, just make the home more comfortable
- **Underfloor insulation:** the house currently has no underfloor insulation, and about half of the ground floor is laminated and not carpeted so there is a reasonable heat loss. I have however put off a decision on doing this as I am looking at replacing the suspended floor with a solid floor consisting of insulation and a concrete slab with underfloor heating – which would be quite disruptive

External wall insulation was consideration, but the house has a rough Bath Stone rubble face, almost non-existent roof overhangs and sits in an AONB and the green belt where all the surrounding homes are of Bath Stone, so I felt the home was probably unsuitable for this type of insulation. However I have planning permission for a small extension where I will probably use a Deco Pierre render – which can be made to look like Bath rubble stone or a dressed Bath Stone finish, and could be applied to external insulation.

Philip Haile, November 2020