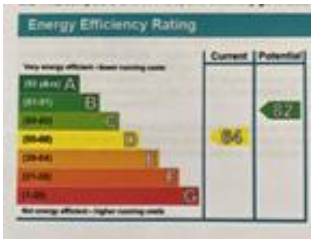
Part 1. Our journey towards low carbon living.

The building

An 80's three bedroom bungalow with early style double glazing, cavity wall insulation, gas condensing combi boiler, open coal effect gas fire and 200mm of loft insulation. 2019 Energy Performance rating D.



Concerned by the rather poor energy performance of our new home and wanting to make it more energy efficient, cheaper to run and responsible for fewer carbon emissions we embarked on a two year programme of retrofitting.

Our first target was to change the electricity supplier from one that sourced generation mostly from gas and oil fired power stations to a 100% renewable supply. Having already purchased a small electric car our next target was to generate some of our own electricity so we could charge the car battery from sunshine. 12 ground mounted PV panels with a maximum output of 3.4 kW were installed after having gained the necessary planning permissions. These are linked to a smart car charger. Once the house electrical needs are satisfied, surplus electricity goes to the car battery and when that is fully charged, any surplus is exported into the grid. Over a two year period we have found that during the summer the car was often running on sunshine!

With all lighting changed to LED units and most white goods rated at A+ or above we found that annual electricity consumption was around. 2,000kW, even accounting for car battery charging, with over 1,000 kW annually exported back into the grid, for which we receive a small payment. Car annual mileage is around 5,000 miles. There is also an electric oven.

The early double-glazed units were draughty with many cold spots around the edges of the frames. These were replaced with triple glazing and particular attention paid as they were fitted to ensure there were no voids or missing cavity insulation around the edges.

Our next target was loft insulation. Though a nominal 200mm it had been much trodden down by electricians working in the loft. This was topped up to 300mm and some missing pipe insulation replaced. Elsewhere in the house, exposed cold and hot water pipes were insulated. (Incidentally insulating the hot pipes has greatly reduced cold run off times as heat is better retained in the pipes.) A simple mechanical two on, two off timer on the gas boiler and a basic room stat were replaced with a "smart" programmable timer / stat which calculates and adjusts the required start up and shut down times according to the weather. The open gas fire was removed and replaced with an inset wood burning stove. Each radiator was fitted with a thermostatic valve (RTV) and including a gas hob the gas consumption is approx 12500kWh per annum.

The concrete floors are uninsulated. As carpets are replaced a thicker special thermal underlay is specified. These floors are now definitely warmer.

Curtains have thermal linings and are length adjusted so they just tuck down behind radiators, which have foil reflectors behind to reflect heat back into the rooms.

When updating the bathroom, the bath was removed and a shower installed. The vacated space was used to create an airing cupboard heated by a low wattage thermostatically controlled oil filled tubular heater. There is a second shower in the small en-suite.

The house warms up quickly when the heating comes on and retains heat well. Even in the middle of winter, overnight temperature drop between 21.30 – 06.00 has never been more than 4 degree.

Six months on.

Rainwater.

Soon after moving in we discovered the guttering was leaking at the joints and tended to overflow during heavy rain (which is more becoming more frequent with climate change.) It was replaced with a deeper design to better cope with these greater volumes of water. 4 water butts were installed and these generally provide enough rainwater for garden needs through the summer and also give us rainwater via buckets to flush the toilets, (supplemented by saving any saved cold run off from the hot taps.) Both toilets have a dual flush cistern but these are hardly used. Water consumption is generally now just 4 cubic meters a month.

The garden.

The garden was mostly ornamental shrubs. Several small raised vegetable beds were created which provide seasonal salad and green vegetables. All vegetable kitchen waste is composted as are grass cuttings, garden cuttings and fallen leaves. Two dwarf root stock apple trees and a greenhouse have added to the productive side of the garden. Bee friendly flowering plants were introduced and a wild flower area created.

Our Achilles heel is our gas consumption from the gas hob and central heating. Carbon cutting journeys take time and we are researching the possibility of replacing the gas heating with an air source heat pump.

Unfortunately we have no energy consumption figures prior to the retrofit work beginning.

Secondary emissions.

Carbon emissions for energy consumption are relatively easy to measure. More difficult are the emissions created by lifestyle, (our secondary emissions.) What are the carbon emissions of the food and other consumer items we buy, the plane flights we may take, the mobile phone calls, the plastic washing up brush etc? A book by Mike Berners-Lee *How bad are bananas* can be a useful source of information regarding these types of emissions. In it he has calculated the carbon footprint for almost everything. Our food, clothes, consumer goods and different modes of transport, even building materials etc. etc. They can all be measured. Reducing these is another carbon cutting journey. These types of emissions are very difficult to reduce to gross zero unless we lived on a desert island, with a plant based diet and absolutely no imports. To reduce these emissions we have to look at offsetting to achieve a net emissions existence whilst at the same time making choices as to what we buy in order to reduce them as much as possible. This is a whole new and continuous journey.

Shropshire is aiming to reach net zero carbon by 2030! This will be hard to achieve and will need the support of every resident in the county!

October 2020

Annual energy consumption totals

	12/18 - 11/19	12/19 -11/20
Green Electricity Import	1785kW	1708kW
Green Electricity Generation	2919kW	2938kW
Green Electricity Export	2097kW	2268kW
Green Electricity consumption	2607kW	2378kW
5% Green Gas consumption	12049 kWh	13078 kWh
Water usage	40 $_3$M	47 $_3$M
Kiln dried logs	1. 3 $_3$M	1. 3 $_3$M

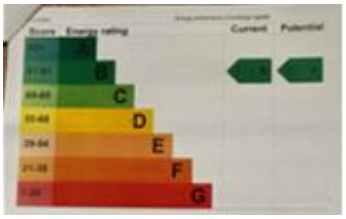
At the end of two years of planned retrofitting a new EPC has been done. The energy performance has improved from a D (64) to a B (87). To reach an A rating we would have to fully insulate the concrete floors, add solar hot water (which with a combi boiler and no hot water tank is unlikely to work) and ditch the gas boiler!

Part 2. Ditching the gas boiler.

Having completed most of our bungalow retro fit (so we thought) and increased the EPC from D to a top end B, we decided to think further and replace the gas boiler with an air source heat pump (ASHP).

Planning to apply for a Green Homes Voucher grant and topping it up with The Renewable Heat Incentive Scheme which will over several year cover most of the cost, three quotes were requested from installers with MSC certification and Trust Mark approval.

Some research on the subject led us to understand that homes with a poor EPC were unlikely to be suitable for ASHP heating as their heat loss would be too great. We also knew micro bore pipes could sometimes cause issues with lower water flow rates. We decided not tell the invited installers what our EPC was.



We were surprised to find considerable differences in specification. All three recommend a 9kW heat pump. One said it would definitely not be necessary to upgrade radiators at all, (this one also provided us later with a ten-year-old EPC showing the pre retro fitting rating). One said try for a winter and upgrade some double radiators if it proved the house was not warm enough, (this installer also wanted to replace all micro bore pipework). The third said from the outset that we would need to double living room and bedroom radiators (the recent dining room extension had better insulation and they felt should be adequately heated). They also said the micro bore piping was a technical design challenge they could confidently overcome with two circulation pumps. Excluding the additional cost of some new radiators the three quotes were roughly the same. The

third installer, noting we had 12 PV panels also suggested we divert surplus electricity from the PV before export to the immersion heater, rather than always using the heat pump to heat hot water. We went with this idea and subsequently found even in winter on a sunny day, surplus PV generation was topping up the hot water.

There were also differences re where the outside unit would be placed. The first installer suggested placing it out of sight against the back of the house on a draughty north facing wall with a long pipe and cabling run to the hot water tank. The others suggested at the south facing front of the house, closest to the hot tank; the tank was new as the old gas system was a combi boiler with no hot water tank. I raised the question of noise disturbance and both of these installers said noise would not be an issue as the unit was many metres from neighbours.

We opted for the third installer and subsequently during a spell of sub-zero temperatures they were proved to be correct over the need to upgrade many of the radiators.

The work took a total of seven days, (five for the plumbing and two for the electrical work). Installation was on time and communication with the company was good. The system took a few days to settle down, purging some trapped air on one occasion (we had been shown how to do this) and an unexpected fault code closing the system down which was quickly resolved over the phone.

ASHP's take a bit of getting used to. Especially with micro bore pipework causing lower flow rates to the radiators, they take longer to get rooms up to temperature, so time clock settings needed to be adjusted. To get the maximum heat out of living room radiators we have found it helps to turn down the RTV's a little in lesser used rooms though the system can cope even with daytime temperatures of minus 5 C. Doing this reduces the heat demand on the ASHP and during sub-zero temperatures reduces the electrical consumption which incidentally seem to be around 3.5Kw though the unit is working hard.

There is some noise from the former gas boiler cupboard where the two pumps, the two heat exchangers and hot tank are. This is in the centre of the bungalow but we don't find it intrusive (the picture was taken before all pipes were insulated). The outside unit produces 64 decibels at one metre distance and 54 decibels to passing pedestrians who are twelve metres away, (little more than quiet conversation). Even with a front bedroom window open we are not disturbed by noise from the ASHP unit when running at night time and are never aware of it from inside during the day. To reduce the visible impact of the outside unit the garden will be slightly rearranged with some new plantings suitably distanced so as not to impede air circulation.

Electrical consumption will certainly be higher, especially in the winter. On sunny days the surplus generation from the PV which goes first to the house, next to the immersion heater, thirdly to the electric car charger if required and finally to export may prove enough to keep the hot water topped up most of the time in the superbly insulated hot tank (set at 48 degrees C).

Having a smart meter allows us to change our green supplier to one with a variable rate tariff, to take advantage of low prices during parts of the day. We also plan to change the fixed room thermostat / time clock to a smart wireless one which will work via the internet in conjunction with the variable rate tariffs to help reduce electricity bills.

Would we recommend an Air Source Heat Pump? Most certainly BUT only in a well-insulated property and with a competent installer who conducts a thorough heat requirement and technical survey first.

February 2021

Part 3. Living with our Heat Pump… A year on.

The Eddi PV controller has proved very successful, diverting output from the PV array to the immersion heater. Even on cloudy days in summer hot water temperatures are more than adequate and the heat pump hardly ever needs to switch on. The order the PV output is used has been changed to a) house, b) car charging when required, c) immersion heater when required and then export. The fixed smart thermostat, (designed for the old gas boiler) proved to be an unsatisfactory companion to the air source heat pump and a Homely system installed. It learns how long the house takes to heat up and cool down. It then looks at internet weather forecasts and electricity prices to make sure the house is heated at the cheapest times to meet desired temperatures. It will overheat the house a couple of hours before expensive tariff periods by up to 2 degrees, the temperatures gradually dropping to those normally set. The heat sensor is wireless and kept in the living room but is moved if the log burning stove is lit. Should the internet or iPad, through which Homely is controlled, fail, the system remembers settings and times of the past 24 hours until services are restored. Homely can be controlled remotely so the heating etc. can be switched on or off away from home. Monthly energy records are being kept so running costs and emissions can be compared against the gas boiler in due course. We changed our energy supply to Octopus Energy Agile tariff once the Homely system was installed. Tariff rates vary every half hour and are known 24 hours in advance. Dishwasher, washing machine and electric car charging time clocks are now used much more to take advantage of lower price periods. During sunny days our PV output is generally sufficient for all our electricity needs other than the electric oven, (the gas hob has for the time been retained). We are however exporting less. By knowing in advance what the variable tariff costs are (shown via a smart phone App) we are, when we can, more likely to avoid peak consumption times and therefore highest prices. With a variable rate supply, it is very noticeable that during cloudy and windless periods, tariff costs are high. This is offset by winter prices (when there is more wind) which can even be negative during periods of excess generation. Then we are actually paid to use electricity!

The system has now been in for a complete year and the energy figures below tell their own story!

Have we finished the journey? As far as home energy efficiency and reducing emissions is concerned, possibly. Insulation in the concrete floor may be a journey too far. As far as electricity consumption costs and responding to greater demands at peak times on the national grid are

concerned, possibly not. Home battery storage or car to grid battery connections will possibly be the last piece in the jigsaw.

Reducing personal emissions, well that's another journey which is ongoing …

Consumption Figures Average before* and after** Heat Pump installation.

	Before	After
Electricity Import average	1733kW*	5576kW**
Electricity Export	2182*	1071kW**
Electricity consumption	2492*	7370**
Gas consumption	12584kW*	260**

Electricity consumption Energy is up by 4878kW but gas down by 12342kW.

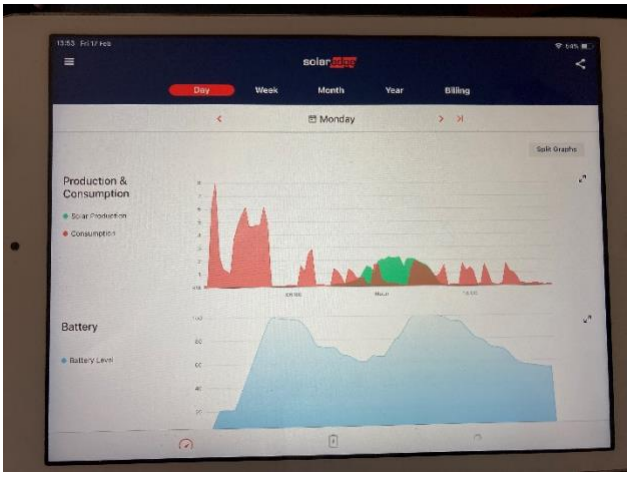
PS During the summer of 2021, there was less North Sea wind generation and the Octopus Agile tariff proved less agile – most times at the maximum price so we have changed to a variable day /night tariff, giving us 4 hours of lower price electricity between 00.30 – 04.30. It is straightforward to change the tariff setting in the homely system so we can change back in due course.

07/04/22

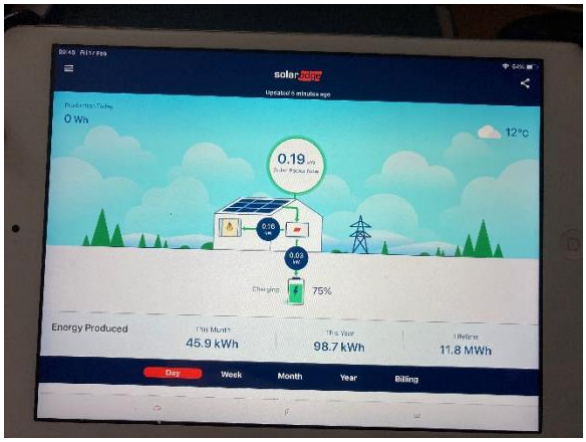
Part 4. Adding a storage battery to the set up.

With an average annual export of over 1,000kW, for which we received less that 10p per kW under the Renewables Obligation Scheme, we decided to complete our retrofit low carbon journey with the installation of a 10 kW storage battery. We opted for the new Solar Edge 10kW DC battery which not only matched our Solar Edge Inverter but could be charged from both the grid and our PV array. But first a few words about domestic battery storage.

Sizing the battery to match potential PV generation is important, and it normally needs to have a capacity of approximately 1—2 times the capacity of the PV array eg a 4 kW array needs a battery of between 4 kW and 8 kW so it can be fully charged each day. High demand devices such as cooker, ASHP's and immersion heaters will quickly drain a battery so if possible it is better to run some of these during the day with energy from the PV, leaving the battery to power low consumption items such as lights, fridge's etc in the evenings. Alternatively run as many high demand items, including electric car charging during off peak times. Through the use of time clocks. The Solar Edge battery can be charged not only from excess DC generation from our solar panels, but also overnight with off peak AC electricity so that, especially in the winter, the daytime demands of the ASHP could be run from the stored cheap rate electricity. In the summer months when there is often surplus DC generation from the P.V. this is stored directly into the battery and so very little incoming electricity is required to top it up to 100% overnight. If a DC battery system has a disadvantage it is that during a power cut the whole system shuts down and is not able to supply the house. An AC battery can continue to supply the house but needs a special relay to isolate the home battery from the grid in the event of a power cut, otherwise it could discharge back to the grid and endanger those working on grid repairs. AC battery systems are however less efficient.



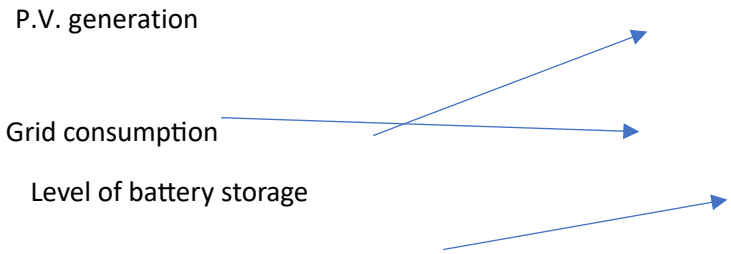
From ordering it took several months for the manufacturers to supply the battery and then on installation it was found that this new to the market battery did not exactly match our Solar Edge Inverter, now several years old. An updated piece of circuity was ordered and again another three months elapsed until it was available. Set up was not quite straight forward. Initially the battery wouldn't charge overnight BUT this was simply remedied remotely by the installer. Because we have a MyEnergy smart PV controller this also needed updated software to recognise the batteries existence. This was again done remotely as the whole system is internet connected.



The battery has now been running for two winter months with low PV output into the system. Most days the overnight off peak charge is exhausted by 20.00 due to the energy demands of our ASHP, but for one gloriously sunny day the PV produced enough surplus energy to keep the battery topped up to 50% even by the end of the heating day, (see image 1) opposite.

The Eddi Diverter now works in the following order: PV to House, then Battery , EV car charger, Immersion heater and finally Export. As each is satisfied, Eddi moves the surplus generation on to the next stage if required. It is unlikely we will export much, if any PV generation in the future.

The Solar Edge App shows real time PV output, consumption and level of battery charge as well as historical data.



Apart from the worst of the winter weather when the ASHP draws heavily from our stored electricity, the battery enables us to run the house almost entirely on "free" PV generated electricity or stored low tariff import. We now use very little day time and more expensive imported electricity. We will also make fewer demands on the grid at peak times.

Occasionally we will draw heavily from the grid if, during our off-peak time of 00.30—04.30 we charge the battery, run the dishwasher and washing machine and charge our electric car all at the same time. If everyone in the road were to do the same simultaneously, I do wonder how well the local grid would cope!!

We recently took part in a remote switching trial with our smart car charger. Its output was adjusted remotely to see how such heavy demands on the local grid could be adjusted if the grid risked being overburdened. Perhaps this might become necessary in the future as more homes have electric cars and heat pumps.

April 2022

PPS The energy crisis caused by the Ukraine War has resulted in the Octopus Agile Tariff continuing to be expensive so we have stayed with Octopus Go (a Four hour off peak tariff from 24.30 – 04.30 each night).

August 2023

Energy Running Totals from January 2023

Electricity Import		**Elecricity Export**		**Gas**		**Heat Meter**		**Generation**		**Water**	
Date	kWh	Date	kWh	Date	kWh	Date	kWh	Date	kWh	Date	Cubic M
07.01.23	947	07.01.23	17	07.01.23	18	07.01.23	673	07.01.23	431	07.01.23	3
11.02.23	510	11.02.23	8	11.02.23	16	11.02.23	721	11.02.23	286	11.02.23	5
07.03.23	520	07.03.23	1	07.03.23	22	07.03.23	430	07.03.23	426	07.03.23	3
09.04.23.	399	09.04.23.	20	09.04.23.	14	09.04.23.	260	09.04.23.	387	09.04.23.	3
07.05.23.	150	07.05.23.	25	07.05.23.	20	07.05.23.	47	07.05.23.	605	07.05.23.	7
11.06.23.	100	11.06.23.	219	11.06.23.	12	11.06.23.	0	11.06.23.	426	11.06.23.	3
07.07.23	168	07.07.23	66	07.07.23	22	07.07.23	16	07.07.23	276	07.07.23	3
07.08.23	185	07.08.23	556	07.08.23	20	07.08.23	12	07.08.23	394	07.08.23	4
08.09.23		08.09.23		08.07.23		08.07.23		08.07.23		08.07.23	
TOTAL	2979	TOTAL	912	TOTAL	144	TOTAL	2159	TOTAL	3231	TOTAL	31