Martlesham Climate Action - Carbon Reduction Forum

Case Study 3 - Year 2 Update (November 2019 - November 2021)

Energy makeover for our house – Continued

David Faulkner 9 January 2022

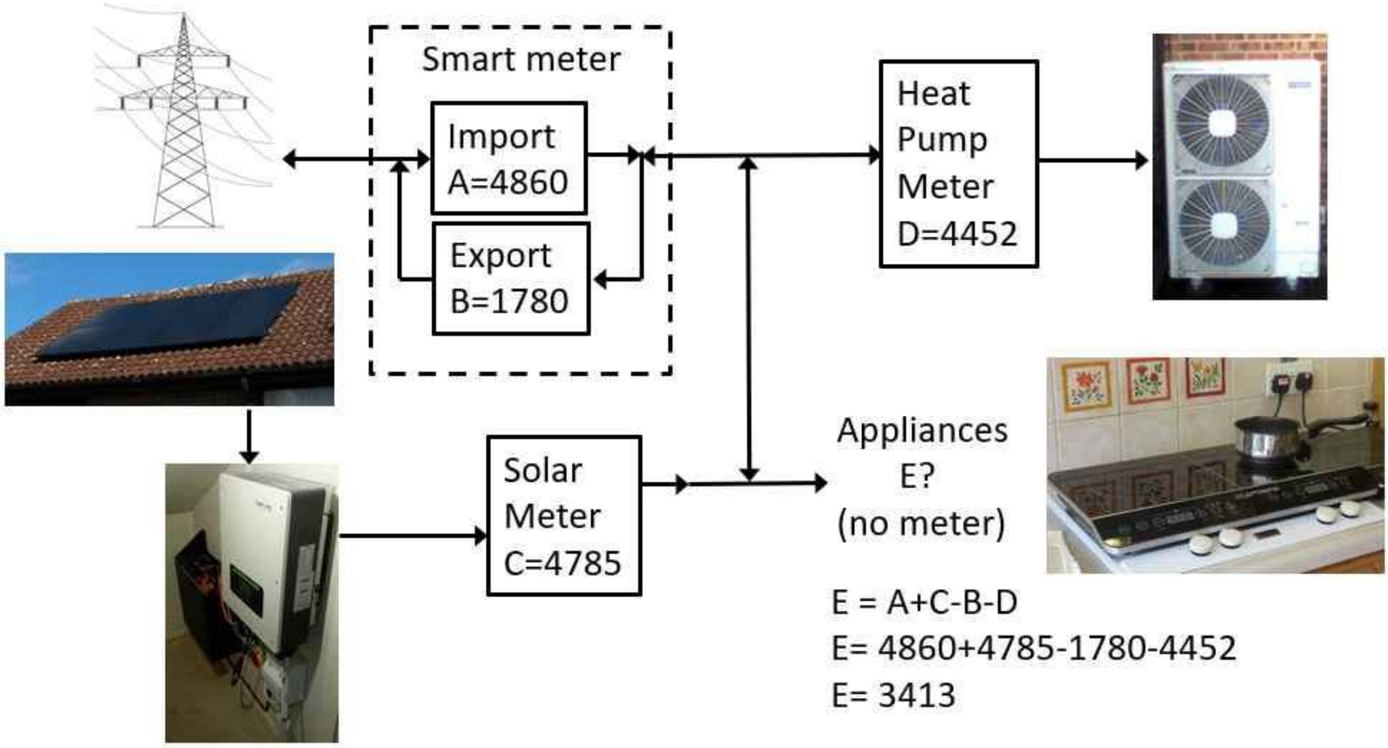
The aim of this report is to give a balanced view on how our home energy makeover has performed over the two years we have had it, by comparing the second year with the first. This report follows up on the one for the first year which gave more details of the changeover process.

Making the transition from a gas boiler to electric heat pump was a radical move for us. Several factors swayed us in that decision.

- Our gas boiler was nearly 40 years old and was likely to need replacing with a more efficient system
- The government was offering a considerable grant to help with the additional cost of a heat pump
- The electric heat pump chosen has an energy gain of more than four
- The electricity supply is constantly being improved year on year towards zero carbon by 2050
- The electricity to the house could be made less carbon intensive by installing solar panels and a house battery (no longer with government incentive)

Our energy makeover began in the summer 2019. The house is a 1980-built detached property with loft insulation and filled cavity walls. About 50% of the windows are double glazed. The boiler, which was removed, was the original non-condensing gas boiler sited in a ground floor utility cupboard with an asbestos-lined flue though the middle of the house to the rooftop. It had an input of 34.6-39.6kW and an output of 24.9-29.3kW. This was replaced by a 16kW Hitachi heat pump. This has two sections: an outdoor unit which provides sufficient warm water for the radiators when the outside temperature is above freezing and an additional cascaded indoor heat pump which starts up to raise the water temperature to around 46C at colder times. My estimate for the payback time for this system with help from the government grant was 15 years. The cost can be offset by the fact that the boiler would need replacing anyway, for example by a condensing gas boiler. We also had a 4kW solar system installed, including a battery with 4kWh of usable capacity. This had an estimated payback of 12 years assuming that the summer excess would be used to charge an electric car.

General Configuration of the new energy system (kWh/y for the year Nov 2019-Nov 2020)


Smart meter
Import
A=4860
Export
B=1780
Heat
Pump
Meter
D=4452
Solar
Meter
C=4785
Appliances
E?
(no meter)
E = A+C-B-D
E= 4860+4785-1780-4452
E= 3413

Results - showing the change from year 1 to year 2 on the bottom line

		Supply			Export	Demand		Results			electricity	gas	net
Year		Gas	Elect	solar	solar	heat pump	appliances	net Import	Cost	Standing	emission factc	emission fa	**CO2e**
Nov to Nov		kWh/y	kWh/y	kWh/y		kWh/y	kWh/y	kWh/y	£/y	Charge £	kgCO2e/kWh	kgCO2e/kWh	
2018-2019	**old**	18670	3224			0	3224	21894	1443	87	0.23314	0.18385	4190
2019-2020	**new**	426	3080	4785	1780	4452	3413	**3506**	633	129	0.23314	0.18385	796
Year1 change		-18244	-144	4785		4452	189	-18388	-810	42			**-3394**
2020-2021		12	4340	4593	1607	5427	3506	**4352**	647	146	0.21233	0.18438	926
year 2 change		-414	1260	-192		975	93	846	14	17			129

What were the key differences between year 1 and year 2?

The house energy import increased by 846kWh (24%) or 129 kgCO2e (16%) in 2021. This change could be accounted for as follows:

1. The heat pump consumed an additional 975 kWh, up 22%, in the second year. This could be attributed to a colder winter which was on average 0.59C cooler over the winter (Nov-March) months. The nearest publicly available figures I could find for the two years were recorded at Southend Airport.
https://www.wunderground.com/history/monthly/gb/southend-on-sea/EGMC/date/2021-2
However, thanks to help from Martlesham Climate Action, I was given access to data from a private weather station owned by a resident on the Heath. This showed that Winter 2020-2021 was **1.4C** cooler than winter 2019-2020 on Martlesham Heath. This helps to explain why we used more energy the second winter. This is like turning up the room thermostat by 1.4C.

2. The heat pump had a fault on 11 January 2021 when its automatic defrost control valve failed. It was limping along with frequent manual defrosting needed until it was fixed on 28th January which meant that its efficiency would have decreased over the period.

3. The solar energy generated was lower by 192 kWh (4%) in the second year. This could be attributed to the cooler year, hence less sunlight, which was on average 0.62C lower over the full year.

4. The appliance energy usage increased by 93kWh. This could be attributed to a gift of a small second-hand freezer in Sept 2020, the addition of electric induction hobs and charging visitors' electric vehicles (75kWh approx.).

5. The only reduction, -414kWh/y (76 kgCO2e), came from reduced gas usage because two electric induction hobs were added instead of using the gas hobs from April 2020.

6. The emission factors of the grid electricity for the UK decreased as more non-fossil fuel sources were added to energy production. DEFRA figures for UK electricity are shown.

Solar forecasting with Solcast

The solar array on our rooftop was uploaded to Solcast (with free forecasting for home systems). Forecasts were then recorded for every day during the preceding evening. The average error over April to September 2021 was 32% with no particular bias, plus or minus. During the months from October to 9th January 2022, the average error was 48%, mostly underestimates. The east-west solar array produced more power than forecast in the winter months so far (9th Jan 2022).

The purpose of forecasting was to allow the cost and energy savings to be better-tuned to the forecast. The house energy system can be tuned to the season and micro-managed 24 hours ahead. For example, if plenty of solar energy is forecast during the summer months, there is no need to charge the house battery at night. In the winter months the house battery is charged from the grid at night. In addition, in winter, the washing machine can be delayed or run overnight if the forecast for solar energy is small. Laundry can (usually) be planned to coincide with sunny days, so that the washing can be dried on the line outside, saving on the use of the tumble drier.

Load-shifting

We have been on the original 'Economy 7' tariff over decades. This operates between 24:00 and 7:00 GMT and was aimed at using spare nuclear capacity at night, for example in night storage heaters. Our heat pump is more efficient than a night storage heater but is not suitable for energy storage, except for heating the domestic hot water tank. During winter, it is running at a room thermostat setting temperature of 20C. During the summer it is switched off apart from short times around noon when it is then used to replenish the hot water tank. The standing load of the heat pump is 80W to keep the compressor oil at operating temperature. Hence the reason to turn it off when not required.

This tariff was carried over to Octopus energy in July 2019. Current charges are 20.21p per unit by day and 13.47p per unit by night. Load-shifting from day to night lowers cost and also lowers carbon intensity. During winter, the house battery and hot water tank have been replenished at night, and the dishwasher and washing machine have been mainly used at night.

How much carbon emission has load-shifting saved?

The annualised carbon emission figures from Defra for UK electricity reporting are 0.21233 kgCO2e in 2020 and 0.21016 kg CO2 in 2021.

The half-hourly carbon intensity figures for electricity in the East of England may be downloaded from https://carbonintensity.org.uk/

It is surprising to note that the carbon intensity varies considerably across the UK. These figures were averaged over the first week of January 2022. Here, in the East of England, the average was 0.117 kgCO2 whereas in the north of England, the overall figure was only 0.032kgCO2, so about a quarter, probably because more non-fossil fuel energy was available. Currently, both Sizewell reactors are online and generating 1.2GW.

Our smart meter readings for the two years, 7th Nov 2019 to 7th Nov 2021 (after the SMETS2 meter was installed), were 5481 kWh (night) and 5215kWh (day), so slightly more energy is used at night. All of the import load-shifting is carried out over the winter months, from day to night, when insufficient solar power is available.

As an example of the effect of load-shifting over a 24 hour period for our own energy system, the figures downloaded from Carbon Intensity were averaged over the first week of January 2022 and came out at 0.093 kgCO2 (night rate) and 0.125 kgCO2 (day rate). Therefore a 26% saving in emissions was possible by load-shifting from day to night.

The carbon saving due to load-shifting over the two-year period can be estimated by making the assumption that without load-shifting the load would be constant. The total energy used over the period was 10732 kWh. Without load-shifting the night units would have been 3130kWh. The additional load at night, the load shifted, was therefore 5481-3130 = 2350kWh. When multiplied by the difference in emission factors, this results in an additional saving of only 75kg carbon over two years or **37.5kg/year.** This is much less than I was expecting and is only 4% of the total emission for my household. Even so, it means that if 25 other homes were load-shifting then one of them could be regarded as carbon neutral.

What more can be done to reduce the carbon footprint of our energy system?

1. The addition of more battery storage would enable more solar energy to be stored. This would be useful in spring and autumn when the excess daytime solar energy could be stored and released overnight. It would also be useful in the winter for load-shifting, taking advantage of cheaper night rates. However, my calculations show that doubling the house battery capacity would not show a return on investment in 15 years, which is beyond the expected lifetime of a battery.

It would be even better for the environment if the battery resources could be embodied in an EV car battery. The Nissan Leaf is capable of both import and export to facilitate demand shifting. Trials were held using vehicle to grid chargers but I do not think my energy provider, Octopus, or any other UK energy company, has plans to market this option generally. A report on the outcome of trials says that the cost of installation of the special two-way chargers is too high https://www.current-news.co.uk/news/worlds-largest-domestic-v2g-trial-finds-hardware-costs-still-too-high-despite-significant-financial-rewards. This is a pity, as the battery is the largest cost (financial and in terms of embodied carbon) item in an EV and could serve the dual purpose of being a house battery when the car is not needed on the road. Vehicle to home (V2H) is another option which has not been taken up yet. A report on “The Role of Vehicle-to-X Technologies in a Net Zero Energy System” by BEIS, calling for evidence is here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1003871/role-of-vehicle-to-x-energy-technologies-in-net-zero-energy-system-cfe.pdf

2. The addition of an extra solar array was foreseen in 2019, but mainly to charge an electric car. An additional 2.4kW panel could be added for this. However, our mileage is still much lower than before Covid, at 3281 miles/year, compared with 12000-13000 per year beforehand. Making these two changes are no longer anticipated. If there were a local electric car-hire service nearby, that would be considered as a better environmental option.

3. Upgrading the insulation is also an option. The cavity walls are filled already and adding roof insulation is difficult as there is little or no loft space available. It would need to be paid for out of savings made on the £719 annual charge for electricity over the next 15 years.