Martlesham Climate Action - Carbon Reduction Forum

Case Study 3 by Dr David Faulkner

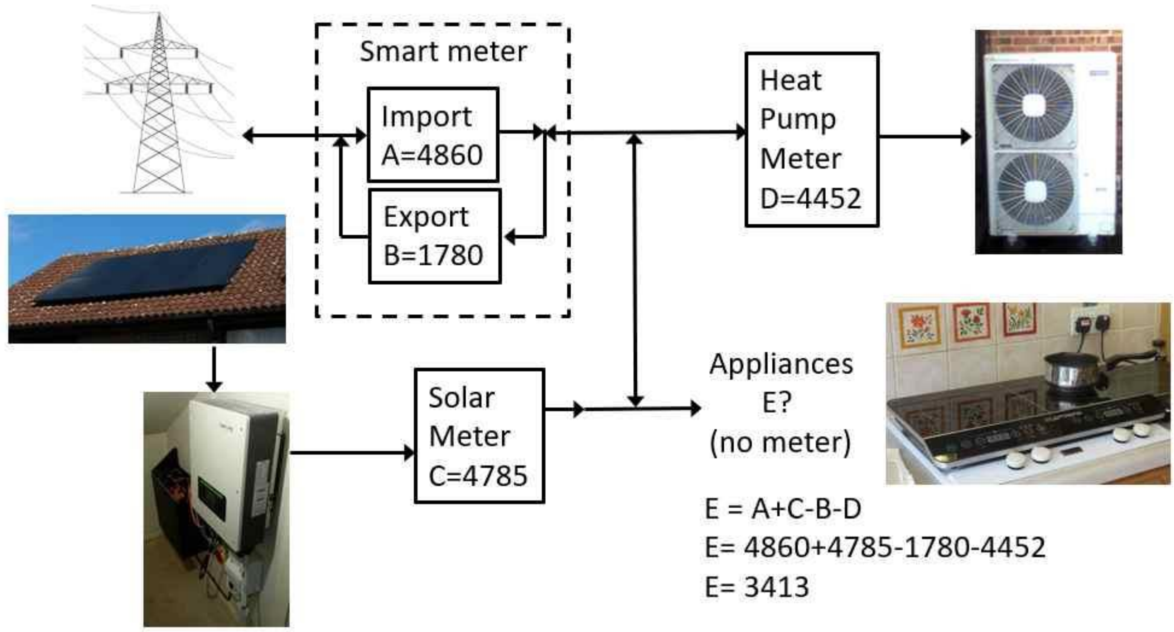
Energy makeover for our house

We have lived in our house on Martlesham Heath since Christmas 1980 when it was new. It is detached and had an initial floor space of 164m^2 . It was extended by 55m^2 in 1999 bringing the total to 219 m^2. In normal use, now there are only two of us at home, we heat only 105 m^2 directly; extra rooms are heated as required when we have visitors.

The house insulation was carried out according to the building regulations of the day with the later addition of cavity wall insulation. There is 10cm glass wool in the roof spaces.

Our energy makeover began in the summer 2019 with a view to significantly reducing our **carbon footprints**. We still had the original gas boiler (non-condensing) in a ground floor utility cupboard with an asbestos-lined flue up 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.

General Configuration of the new energy system (kWh/y)



The heat pump proposition

In July 2019 we were offered the opportunity to convert the heating system to an air-to-water heat pump. These typically have a coefficient of performance (CoP) in the range 2-4. This is the heat energy output divided by the electric energy input. The one we chose claimed to be world-beating for air-to-water systems with a CoP of 4.5.

Adding more insulation is normally the first step for a house energy makeover. If this is doubled (double the R factor) then the heating energy would halve. This would involve adding new insulation around the exterior walls, adding floor insulation, doubling the roof insulation and adding better insulated doors and windows. This work is extensive, costly and best carried out on an empty house and we are not planning a move.

In our case, going straight for a much more efficient heating system seemed to be the better choice, at least on paper. The heat pump would quadruple the energy efficiency whilst doubling the insulation would only halve the energy consumption. Ideally both would be done to reduce the overall energy to one eighth. Even so, the electricity grid is set to be carbon zero by 2050 and has already halved in the last 10 years.

In terms of costs, the boiler replacement heat pump was expensive at an estimated £15.5k but there is a renewable heat incentive (RHI) of up to £9.1k paid over 7 years. In contrast, doubling the insulation would cost upwards of £30k and would take up to a year to complete. (Check out the Green Homes Grant which may provide an up-front payment out of the total RHI payment).

A condition of the grant is that I do not use additional sources of heating. The gas boiler was removed and I was told by the installers that I would not have qualified if it remained as a secondary source of heat. Each year I am reminded to login and make a declaration that the system is still working and that I have not been using supplementary heating.

Condensing gas boilers are cheaper, and gas is about one quarter of the cost of electricity, but these systems **will never** be carbon zero during their lifetime, so they need to go ASAP. We made the decision to switch to electric heating on the basis that (a) the running costs would approximately balance out the high cost of electricity (4x gas) with a CoP of around 4; and (b) the National Grid has an increasingly green mix of fuels. (If the UN gets its way, the emitter should pay for the clean-up via a carbon emission tax. If that were to happen gas prices could rise to be close to or more than electricity).

The chosen heat pump has two heat exchangers. The outdoor unit does most of the work raising the water temperature by up to 40C. The indoor heat exchanger operates when the required water temperature is higher such as on cold days and for heating the hot water tank to 45C. The indoor unit can add another 40C. Having the two-stage heat exchanger meant that the existing radiators could be reused.

In practice, the system seems to perform better than expected. We now have more rooms heated and there is less draught. Much of this could be attributed to inefficiencies in the old gas boiler system such as heat lost up the flue and via draughts.

The installation

An energy performance certificate (EPC) inspection was carried out first at the request of the installers. The report shows a 'before' rating of 56 (yellow band D) and the 'after potential' of 77 (green band C). Air source heat pumps have recently listed on EPC as an Alternative Measure (dated 16 July 2019). It is not clear that my house energy rating would get a higher rating on the EPC if carried out now. The system has been slow to recognise their advantages. See https://www.yorkshireenergysystems.co.uk/epcandheatpumps/

The work took three days. This involved removal of the old system, including the gas boiler in the utility cupboard, the hot water tank and header tank in the airing cupboard. Thermostatic control valves were installed on most radiators, except the ones serving as 'ballast' to ensure there was always some load on the heat pump.

Commissioning

The system has a wall-mounted thermostat/controller. It takes some time, on-and-off, to learn how to programme it according to time of day and season. This is similar to learning how to run a smart phone. It automatically adjusts the outdoor pump speed according to the temperature required and the outside air temperature. On warm days, the system ticks over very quietly drawing less than 1kW. On full power one or both units make more noise. The indoor unit noise is about the same as the old gas boiler. The outdoor unit noise on full power matches that of the ambient traffic noise at 6 metres. Normally the balance point is at 3 metres although much of the time it is off.

There is an optional wireless thermostat. This did not work for the first 8 months but a phone call to the manufacturer solved it after an hour of reprogramming at the wall control unit.

Solar System

As we do not have a south facing roof, we did not install a solar system 10 years ago when very profitable feed-in tariffs were available. Since then, studies have shown that an east/west solar farm can generate more power per hectare than a south facing one (https://www.pv-tech.org/editors-blog/five-key-considerations-for-east-west-solar-design). This is because more panels can be fitted in the same area. However, if the number of panels is to be minimised, then a south facing system has a 12% advantage.

I compared a 4kW system facing south versus two x 2kW arrays facing east/west, all at 25 and 30 degrees to match the slopes of our roof using PVWatts. The difference was 20%. Despite this, I could expect to break-even in about 15 years assuming we use the excess summer energy to charge an electric vehicle (EV) during the summer months.

As things have turned out we have not bought an EV because of Covid restrictions on social life but we are getting agile export from Octopus Energy after having had a smart meter fitted and commissioned (long story).

A 4kW battery was included to maximise the available solar energy by smoothing out an intermittent supply during part cloudy days and allow load shifting to cover the hours of darkness in the summer and load shift on night rate in winter.

The system was installed in less than a day in Sept 2019

System Costs

Heat pump system		
	RWH-6.0VNFE	Indoor unit Yutaki S80 16kW 230/1
	RAS-6WHVNPE	Outdoor unit Tutaki S/SC/S80 R410A 16kW 230/1
	PC-ARFHE	Wired thermostat/controller
	ATW-RTU-05	Wireless thermostat
	Associated fitting	e.g. 13 thermostatic radiator valves, magna clean, installation work
	Centre Store	150lt unvented hot water tank (water temp adopted 45C)
Sub total cost	£14,757.29	
VAT	£737.71	
UK Government grant	-£9,100	paid quarterly over 7 years
Total cost	£6,395.00	
Solar system		
	LR6 60PB	16x Longi (305W) Solar Panels
	HYD 3600	Hybrid Invertor
	US2000	2 x Pylontech rechargable batteries
	i-boost	hot water immersion controller from solar system (not used)
Total cost	£8,100	including fitting
Grand total cost	**£14,495.00**	

Results

		Supply			Export	Demand		Results			
Year		Gas	Elect	solar	solar	heat pump	appliances	net Import	Cost	Standing	CO2e
Nov to Nov		kWh/y	kWh/y	kWh/y		kWh/y	kWh/y	kWh/y	£/y	Charge £	kg
2018-2019	**old**	18670	3224			0	3224	21894	1443	87	4571
2019-2020	**new**	426	3080	4785	1780	4452	3413	**3506**	719	129	1161
Year1 change		-18244	-144	4785		4452	189	-18388	-724	42	-3410

I was able to read annual energy figures in November, one year after the smart (SMETS2) meter was installed as shown in Figure 1 and in the table above.

The carbon saving of **3410kg** is based upon the national average emission for the grid rather than the Octopus energy figure of 100% renewable. I used the simple online calculator at http://www.carbon-calculator.org.uk/.

A bigger carbon saving may be estimated by taking account of the demand shifting made possible by the solar system and battery. See https://gridwatch.co.uk/. The emission coefficient of the grid is low at night in the winter and high in the day when the demand is high. My estimate is an additional carbon saving of 164kg bringing the total to **3574kg** for the year. This is 22% of our original carbon emission (CO2e).

Today, 4th Dec. 2020 at 07:50, we had our first dusting of snow. The outside temperature is 1C. The water circulating temperature to the radiators is 40C and the room temperature is 20.5C. The heat pump is drawing 2.17kW.

In terms of the metric of kWh/m2/yr, for the energy performance of a building, the original figure was 209 kWh/m2/yr (for 105m2 of heated space) falling to an apparent 33 kWh/m2/yr. 'Apparent' because this includes the energy gain of the heat pump and solar panels. **This is only 16% or 1/6th of the original figure.** To obtain such an improvement by insulation alone would be a monumental task. This is best attempted with new-build using passive house principles. For more details see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853067/energy-consumption-new-domestic-buildings-2015-2017-england-wales.pdf

Only in the last year have heat pumps been mentioned on the EPC as a possible improvement. My assessment did mention one.

Lessons Learned

The solar panels delivered 27% more energy than originally predicted via PVWatt and the associated Hemsby model over a year.

The excess was supposed to go into an electric car over the summer but this project was postponed.

The heat pump appears to better than expected with an apparent CoP of around 4.2 even though more rooms are being heated. This was calculated by dividing the energy used by the old gas boiler by the energy used by the heat pump. There are fewer draughts now that the gas boiler is gone, the rooftop flue has been removed, and the air intake vents are now closed and insulated.

The residual gas use for the hob and oven has been nearly eliminated by switching to two free-standing induction hobs for cooking and maximising the use of microwave combination ovens.

Only 81% of the 4.8kWh from the battery is available as its discharge is stopped at 19% to maintain battery life.

The heat pump has a standing load of 80W. This is noticeable in the summer when the system is only needed for about 30 minutes a day to top up the temperature of the hot water tank. Hitachi told me that the oil in the pump needs to be heated to 40C an hour before it operates to ensure efficiency and longevity. The heat pump has therefore been switched on manually at 12:00 and off again at 1:30.

A maintenance contract of £150 per annum was started after one year with the installer which includes one inspection per year and one possible maintenance visit.

Possible next steps

Addition of more house battery storage, or EV car battery (e.g. Nissan Leaf) which is capable of import and export via Octopus Energy taking advantage of demand shifting.

Addition of a time switch to allow more efficient use of the heat pump for hot water during the summer.

Addition of insulation, but this would need to be paid for out of savings made on the £719 annual charge for electricity over the next 15 years.

Conclusion of Recommendations

I hope this case study has opened your mind to the possibility of reducing both your day-to-day energy costs, making a significant reduction in your house carbon emissions and increasing the comfort of your home. Our reduction of **3574kg** is a significant saving on our personal carbon footprints; and the cost saving of £724 per year would break even after 20 years without allowing for alternative investment strategies and energy price inflation. Had we actually taken on the electric car as planned, more of the solar energy would have been used to our advantage and the payback would have been sooner. The evidence I have given also notes the disadvantages such as upfront costs and noise.

The RHI grant and efficiency of the heat pump clinched my decision to switch to electric heating. After one year we have no desire to switch back to gas heating again.

If you have only one or two spaces to heat you may wish to invest in an air-to-air heat pump system such as those found in hotel rooms. This has the advantage of enabling cooling as well as heating. Look for another case study on Martlesham Community Action to learn more about this (https://martleshamclimateaction.onesuffolk.net/).