Evaluating solar PV with electric heating with North Devon Homes: electricity tariffs

Paul Rogers and Michael Hamer February 2025

Background - Who we are

National Energy Action (NEA), the fuel poverty charity, campaigns so everyone can afford to live in a warm, safe and healthy home. This is something denied to millions because of poor housing, low incomes, and high bills.

Working across England, Wales and Northern Ireland, everything we do aims to improve the lives of people in fuel poverty. We directly support people with energy and income maximisation advice, and we advocate on issues including improving the energy efficiency of our homes.

We do not work alone. Partnerships and collaboration have been at our heart for over 40 years, helping us drive better health and well-being outcomes for people struggling to heat their homes.

This evaluation was carried out by the Innovation and Technical Evaluation team at NEA:

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February 2025
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Acknowledgements

Funding for this project was provided by the Energy Industry Voluntary Redress Scheme.

With grateful thanks to our project partners:

John Evans, Planned Improvements Manager, North Devon Homes
David Jeffrey, Managing Director, RES Devon Ltd

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Executive Summary

Project Overview

The 'Evaluating solar PV with electric heating' project was a 2.5-year project which added solar PV installations to 18 properties with the following technologies:

- Air source heat pumps and batteries
- Air source heat pumps (ASHPs)
- Storage heaters and batteries
- Storage heaters and panel heaters
- Infrared heating panels and batteries
- Infrared heating panels

The evaluation of the project consists of four separate reports looking at:

- Wondrwall installations and infrared heating panels
- Mixergy cylinders with solar diverters
- A main report on the benefits of the solar PV systems
- Electricity tariffs and electric heating

This report looks at electricity tariffs which are suited to homes with different electric heating technologies. It also looks at consumption data from households on the project and assesses the benefits and costs with different tariffs.

Electricity tariffs for different technologies

Electricity tariffs for storage heaters

The storage heaters are designed so they fully charge within seven hours and can supply sufficient heat on the coldest days in winter. Typically, they use an Economy 7 tariff with seven hours of lower-cost off-peak electricity overnight at a time when electricity demand is lower.

Traditional storage heaters are often unpopular with residents due to the limited control of the heating output and the fact that they are often cold by the early evening when residents are home and want to be warm.

Tariffs such as Economy 10 have been used for storage heaters with off-peak times in the afternoon. These can allow the storage heater to recharge in the afternoon, so they are not cold in the evening. Few suppliers are currently offering such a tariff, and it may require a five terminal SMETS 2 smart meter or a specialist load control switch for the storage heaters. Octopus has introduced Snug Octopus which has attractive day and night tariff rates. It offers six hours of off-peak electricity overnight and a further hour in the afternoon at variable times. This requires a SMETS 2 meter with an auxiliary load control switch.

Electricity tariffs for heat pumps

Normally a household with a heat pump would be advised to be on a single-rate tariff. There are now specialist heat pump tariffs available. The first of these was Cosy Octopus and this is a three-rate tariff with the following times

- Cosy rate: 04:00-07:00, 13:00-16:00, 22:00-24:00
- Peak rate: 16:00-1900
- Day rate: 00:00-04:00, 07:00-13:00, 19:00-22:00

EDF introduced their heat pump tariff with off-peak rates at the same times as the morning and afternoon Cosy rates and a day-rate at other times with no peak rate.

To benefit from these tariffs a household could turn up the thermostat during off-peak times and turn it down during the peak-rate period. Alternatively, a battery could be used to charge during the off-peak times and discharge during the peak-rate period.

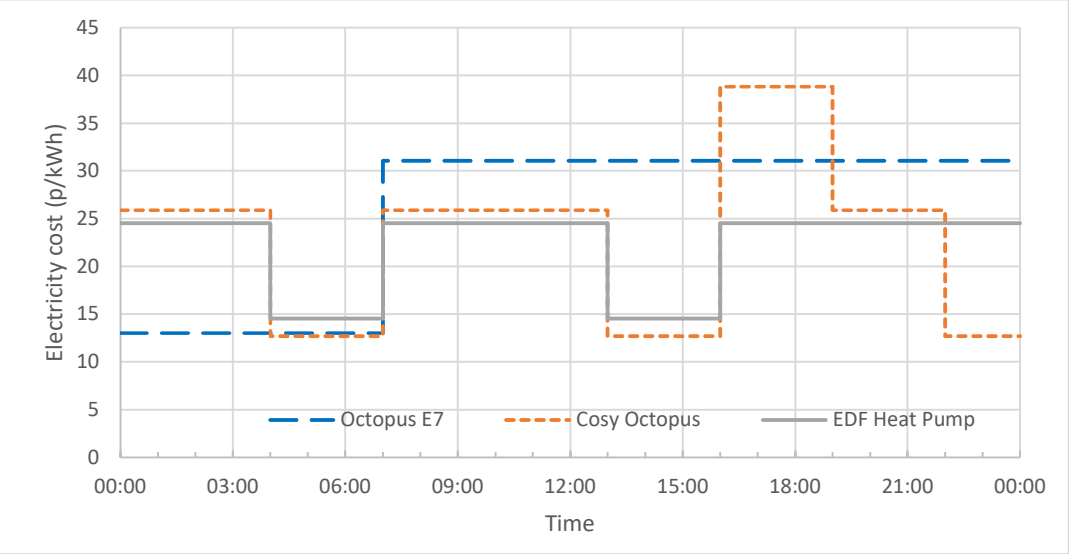

Figure ES1 Variation of the electricity tariff rate cost in South West England for Economy 7 and two heat pump tariffs in January 2025

Electricity tariffs for solar PV and batteries

Solar PV installations can receive a payment for electricity exported to the grid called the smart export guarantee (SEG). The SEG rate is not fixed but all SEG suppliers must offer a non-zero rate. The incentive is better suited to owner-occupiers, but Good Energy is running a pilot where they are aiming to make it more straightforward for landlords to claim the SEG.

Electricity tariffs designed for batteries are available. These may have about three hours of off-peak electricity overnight and three hours of peak-rate electricity from 16:00 to 19:00, with electricity at other times charged at a day-rate. A smart meter able to record half-hourly consumption is required.

The most complex time-of-use tariffs include Octopus Agile where the tariff rate varies each half-hour, and the rates are only available the day before. Some battery and heating systems are compatible with this via an API key. This tariff may be too complex for socially renting households.

Electricity tariffs for electric vehicles

Many electricity suppliers have introduced low-cost smart time-of-use electricity tariffs for charging electric vehicles. Usually, the tariff is restricted to households that have an electric vehicle.

These tariffs can offer fixed times for the off-peak rate. More sophisticated tariffs charge the vehicle at a time with lower demand on the electricity network and require a smart charger. The tariffs can offer between five and seven hours of off-peak electricity, with a day rate only slightly more expensive than for a single-rate tariff. The off-peak rate at the time of writing was between about 7p/kWh and 10p/kWh and was cheaper than the off-peak rate for Economy 7.

Electricity costs for different heating installations

The electricity consumption and costs with different tariffs were analysed for different installations on the project. The costs calculated did not include the standing charge for the electricity. The following tariff rates were used:

- Single-rate tariff – 24p/kWh
- Economy 7 tariff – 12.5p/kWh off-peak and 30p/kWh peak
- Cosy Octopus tariff – 12.7p/kWh Cosy rate, 25.9p/kWh day rate, 38.8p/kWh peak rate
- EDF Heat Pump tariff – 14.5p/kWh tracker rate, 24.5p/kWh day rate
- EDF Go Electric overnight – 9p/kWh off-peak, 25.3p/kWh peak rate

ASHPs with solar PV and battery storage

Seven of the households on the project originally had storage heaters. These were then replaced by a wet central heating system with an approximately 10kWh battery and a large domestic solar PV system was later added.

Household B-05 provided a good illustration of the savings, having consistent thermal comfort and occupancy over the project. The electricity consumption in 2020 with storage heaters was 10,951kWh with a modelled cost on Economy 7 of £2,088. After the ASHP and battery were fitted, the grid import decreased to 7,545kWh while providing improved thermal comfort with whole-house heating. The cost on Economy 7 fell over £800 to £1,247. After the addition of a 5.81kW

east-west solar PV system, there was a further reduction in grid import to 5,354kWh. The modelled electricity cost on Economy 7 decreased to £875.

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
B-05	NSH	1 Jan 20	31 Dec 20	10,951	62.4%	£2,628	£2,088
B-05	ASHP + Battery	1 Aug 22	31 Jul 23	7,545	77.0%	£1,811	£1,247
B-05	PV, ASHP + Battery	1 Jan 24	31 Dec 24	5,354	78.0%	£1,285	£875

Table ES2 Consumption and modelled electricity cost for household B-05

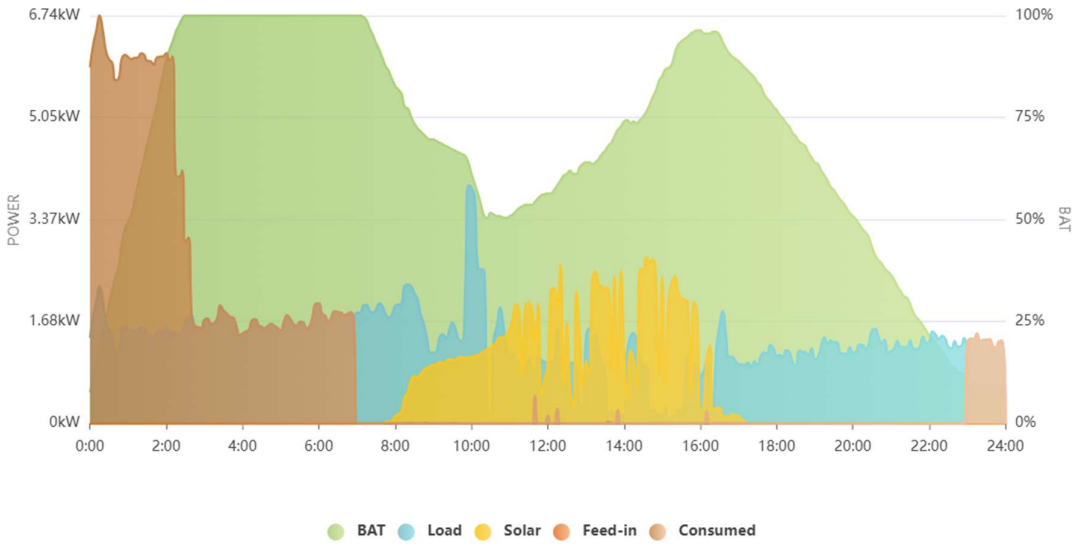

Figure ES3 Power Diagram from the Alpha ESS battery portal for Household B-05 on 12 Feb 2024 with an Economy 7 tariff

Figure ES3 shows a plot from the Alpha ESS battery portal for Household B-05 on a cold sunny day. There was grid consumption (in brown) overnight as the battery charged (in green). The heat pump was running consistently and started to be powered by the battery from 07:00 during the peak-rate period. There was solar PV generation (in yellow), and the battery was charged by the solar PV from about 11:00 until about 16:10. The battery was able to power the ASHP and home until 23:00. The household consumption was 36.3kWh but 12.3kWh of this was provided by the solar PV system. For comparison, the battery was fully discharged by 16:15 on a milder day a year before without the solar PV. The average daily grid import in February 2023 (without the solar PV system) was

30.9kWh and this fell to 25.8kWh in February 2024 after the solar PV system was installed.

Code	Technology	Start date	End date	Grid import (kWh)	Cost for single rate	Cost for E7	Cosy Octopus
B-02	NSH	29 Oct 20	27 Oct 21	9,505	£2,281	£1,694	-
B-02	ASHP + Battery	25 Nov 21	22 Nov 22	7,514	£1,803	£1,353	-
B-02	ASHP + PV Battery	1 Jan 24	31 Dec 24	3,939	£945	-	£561

Table ES4 Consumption and modelled electricity cost for household B-02

Household B-02 lived in a two-bedroom bungalow like B-05. During a period of about a year with storage heaters, the grid import was 9,505kWh. The modelled cost for Economy 7 was £1,694. After the ASHP and battery was installed, the grid consumption decreased by 20.9% to 7,514kWh. The percentage off-peak consumption was 68.5% with the battery and the modelled cost on Economy 7 was £1,353, which was £450 lower than on a single-rate tariff.

After the 5.81kW south facing solar PV system was installed, there was a further reduction in grid import by 47.6% to 3,939kWh. The household switched to the Cosy Octopus heat pump tariff in 2023. The modelled cost with the tariff rates for Cosy Octopus at the time of writing was £561. This was less than one third of the cost of heating with storage heaters on Economy 7.

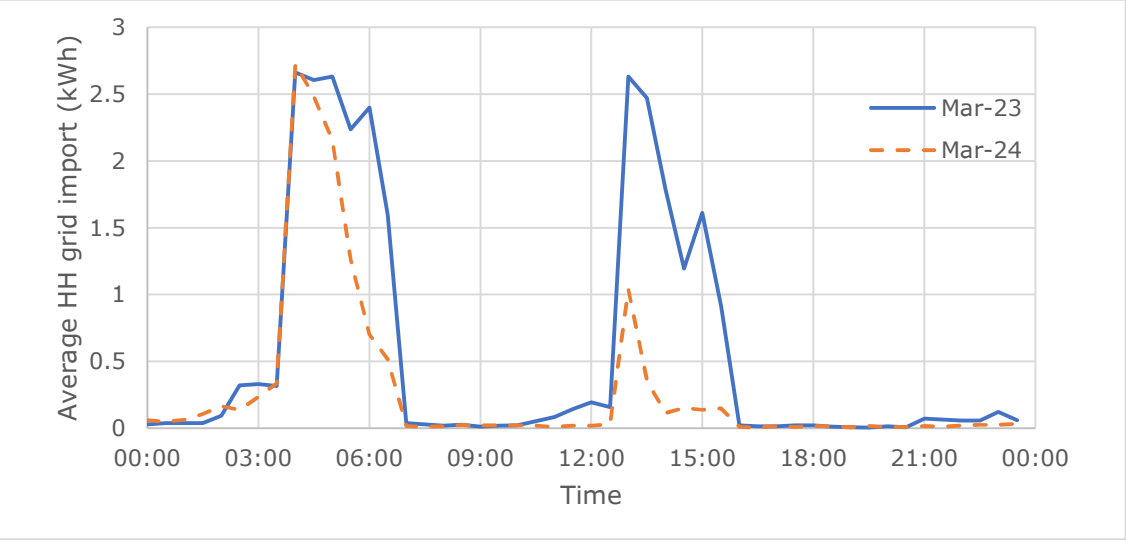

Figure ES5 Graph showing the average half-hourly grid import in March with and without solar PV for household B-02 on the Cosy Octopus tariff

Figure ES5 shows the average half-hourly grid import for B-02 in March 2023 (without the solar PV) and March 2024 (with the solar PV). The Alpha ESS battery was set to charge twice a day during the Cosy Octopus morning (04:00-07:00) and afternoon (13:00-16:00) off-peak periods. Most of the grid import was during the off-peak periods. The grid import was lower after the solar PV system was installed, with the savings greatest during the afternoon off-peak period. The average consumption during the afternoon off-peak period decreased by 81.6% from 10.6kWh to 1.95kWh.

Household B-01 was another bungalow with an ASHP and battery that had a 5.81kW south facing solar PV system installed. The grid import before the solar PV system was installed was 5,317kWh and the cost on Economy 7 was £862. The grid import decreased to 4,227kWh in 2024. The household started using an electric vehicle in February 2024 and this consumed 1,353kWh in the year. The solar PV system provided savings of 2,818kWh which more than compensated for the increased consumption due to the electric vehicle.

The modelled cost on Economy 7 for 2024 was £712. The household switched to the EDF Go Electric EV tariff at the end of August 2024. The modelled cost on this tariff for 2024 using half-hourly smart meter data was £616.

ASHPs and solar PV with Mixergy cylinders

Two households living in one-bedroom bungalows had existing Daikin ASHPs. Solar PV systems with Mixergy smart hot water cylinders with solar diverters were installed.

Household AC-03 had a 4.74kW PV system installed in June 2023 across an east-west roof. The Mixergy cylinder was installed in February 2024 but there were about three weeks with the CT clamp reversed and the diverter not working correctly.

The grid import over a pre-installation period of 364 days was 3,757kWh with a modelled cost on a single-rate tariff of £902. The grid import decreased to 2,314kWh in 2024 with 27% of the consumption during Economy 7 off-peak times. The cost on a single-rate tariff decreased by £347 to £555. The household would have paid more on Economy 7 at £585. Modelling was carried out to assess the costs with heat pump tariffs. In 2024, the cost on Cosy Octopus would have been £565 while it was £502 on the EDF heat pump tariff. Savings were greater on the EDF tariff as there was no behaviour change with the household shifting consumption away from the peak-rate period for Cosy Octopus.

The grid consumption for household AC-04 decreased from 4,750kWh to 2,452kWh after the installation. However, this was complicated by a change in occupancy and the bungalow also having external wall insulation fitted shortly before the solar PV system was operational. There were savings of 1,252kWh from the solar PV system in 2024. The electricity cost was £588 on a single rate

in 2024. This was lower than the £645 for Economy 7 due to a 21.1% off-peak consumption. Again, the electricity cost was cheaper on the EDF heat pump tariff than Cosy Octopus due to no shifting of demand away from the peak-rate period.

Storage heaters with solar PV and battery storage

The consumption of two households with storage heaters and Tesla Powerwall 2 batteries was analysed before and after solar PV installations. Mixergy cylinders were installed but the solar diverter did not operate correctly, probably due to interaction between the Mixergy cylinder and the battery.

Household T-03 had a high annual grid import using 14,232kWh in just over a year during the pre-installation period. 90.2% of the consumption was during the off-peak period. The modelled electricity cost on Economy 7 was £2,025, which was nearly £1,400 lower than it would have been on a single-rate tariff. The grid import was 11,978kWh in 2024 with 2,447kWh of the solar generation used in the home. The electricity cost on Economy 7 was £1,895. The percentage off-peak consumption decreased to 81% which reduced the level of savings. This may have been associated with the diverter for the Mixergy cylinder not working correctly and there being greater water heating during peak-rate times.

Household T-09 imported 10,025kWh during the pre-installation monitoring with 94.9% of the consumption off-peak. The modelled cost on Economy 7 was £1,343 which was over £1,000 lower than it would have been on a single-rate tariff. In 2024, after the solar PV installation, the grid import decreased to 6,550kWh. There were savings of 2,689kWh from solar generation used in the home. The electricity cost on Economy 7 was £868 with 95.7% of the consumption during off-peak times.

Storage heaters with solar PV and Mixergy cylinders

Two households with storage heaters and panel heaters had solar PV and Mixergy cylinders installed. The households made limited use of the storage heaters and had quite high supplementary heating use.

Household SH-02 had a 4.98kW solar PV system fitted across east-west roofs and a Mixergy cylinder installed in late January 2024. The solar diverter for the Mixergy cylinder was operational from mid-February.

In a pre-installation analysis period of just under a year, the grid import for SH-02 was 7,040kWh with 42.8% of the consumption off-peak. The cost on a single-rate tariff was £1,690 but was about £100 cheaper on Economy 7 at £1,585. The second analysis period was for a year and included about 11 months with the solar PV operational. The grid import decreased by 1,280kWh to 5,760kWh with 54.7% of the consumption off-peak. The modelled cost on a single-rate tariff was £1,382 and was £1,176 on Economy 7.

Household SH-01 had a smaller 3.89kWh south-facing solar PV system. This was commissioned in mid-March 2024 but was operational for less than nine months. The household was not using the Mixergy cylinder correctly until late June which meant there was more water heating during peak-rate times. In 2023, the grid import was 9,465kWh with 45.1% of this at off-peak times. The modelled electricity cost on a single-rate tariff was £2,272 while it was £180 cheaper on Economy 7 at £2,092.

In 2024, the grid import for SH-01 was 8,852kWh with 33.7% of the consumption at off-peak times. The electricity cost was £2,124 on a single-rate tariff and £2,133 on Economy 7. The cost on Economy 7 was higher than on the single rate due to the low percentage off-peak consumption. This also meant an increase in the modelled electricity cost compared to 2023 despite lower grid import. The lower solar PV generation and incorrect use of the Mixergy cylinder were factors in there being low savings in grid consumption and no savings in electricity cost.

Infrared heating panels with and without batteries

Two households had storage heaters replaced by a Wondrwall system including a 5.81kW solar PV system, 6kWh battery, infrared heating panels and Mixergy cylinder. These were compared with a household with existing infrared heating panels who had a 5.81kW solar PV system with a Mixergy cylinder installed. The Wondrwall households had existing external wall insulation while the other household had this fitted at the time of the solar PV.

Only Wondrwall household W-01 is discussed in this report as the other Wondrwall household rarely used the heating and had low room temperatures. Household W-01 had a grid import of 5,320kWh during a pre-installation period, with 87.4% of the consumption off-peak. However, this included two months during the winter when the house was unoccupied and the heating on lower. In 2024, after the Wondrwall installation, the grid consumption was 4,686kWh. The percentage off-peak consumption was 69.5% with overnight consumption due to battery charging, water heating and some space heating. Due to the reduction in grid consumption between the pre- and post-installation periods, the electricity cost on a single-rate tariff decreased from £1,277 to £1,125. There was an increase in cost on Economy 7 from £783 to £836 due to the decrease in percentage off-peak consumption. On a typical year with the resident not away for two months, the cost over the pre-installation period could have been higher than in 2024.

The grid import for household IC-01 in 2022 with infrared heating panels was 7,620kWh with only 12.1% of this at off-peak times. The electricity cost on a single-rate tariff was £1,829 but it was almost £300 more at £2,125 on Economy 7 due to the low percentage off-peak consumption. After the installation of the solar PV, Mixergy cylinder and external wall insulation, the grid import decreased to 5,136kWh with 1,971kWh of the solar generation used in the home. The

percentage off-peak consumption increased to 26.6% most likely due to regularly heating the Mixergy cylinder overnight and less daytime consumption due to the solar PV. The modelled cost on the single-rate tariff was £1,233 and the cost was £69 more on Economy 7 at £1,302.

The households with infrared heating panels could benefit from switching to a heat pump tariff with more than one off-peak period. The EDF heat pump tariff would better suit household IC-01 as they did not have a battery and were likely to have higher consumption during the peak-rate period of 16:00 to 19:00.

Conclusions and Recommendations

- Replacing storage heaters with ASHPs, batteries and a large domestic solar PV system can lead to a reduction in grid import of more than 50%
- Households with a 10kWh battery and ASHP used 60-80% of the grid consumption at off-peak times leading to large savings on Economy 7
- Greater savings were possible for ASHPs and batteries on the Cosy Octopus tariff with the battery charging twice a day during morning and afternoon off-peak periods
- Savings of over 1,000kWh were achieved by adding solar PV and a Mixergy cylinder to homes with an ASHP
- The installations with an ASHP and solar PV used 20-30% of consumption at off-peak times which meant Economy 7 was more expensive than a single-rate tariff, although the EDF Heat Pump tariff was cheaper still
- Households with storage heaters and a Tesla Powerwall 2 battery made savings of about 2,500kWh after adding a solar PV system, with 80-95% of the grid import at off-peak times
- Savings were more limited for households with storage heaters and panel heaters where solar PV and a Mixergy cylinder were installed, with one household saving about £400 while the other saw an increase of about £40 due to incorrect use of the Mixergy cylinder
- Infrared heating panels on a single-rate tariff were more expensive to run than storage heaters on Economy 7
- Adding solar PV and a battery to infrared heating panels lowered grid import compared to storage heaters while costs due to grid import could be similar to storage heaters; there was also grid export which could earn export tariff income
- The addition of solar PV, a Mixergy cylinder and external wall insulation for a household using infrared heating panels led to improved thermal comfort and a reduction in grid import of 2,484kWh with savings of 1,971kWh from the solar PV
- It is important that smart time-of-use tariffs for technologies will be available in the long-term, so households do not invest in technologies only to find their savings significantly reduced following a reduction in the range of tariffs offered

- Tariffs such as those for heat pumps should be made available to households with other technologies
- Battery systems should be able to charge more than twice a day

1. Project overview

1.1 Introduction

The 'Evaluating solar PV with electric heating' project was a 2.5-year project funded by the Energy Industry Voluntary Redress Scheme which was led by North Devon Homes (NDH) in partnership with National Energy Action (NEA). The project installed 18 solar PV systems along with 11 Mixergy smart hot water cylinders and two Wondrwall smart heating systems. The Wondrwall systems used infrared heating panels which were combined with solar PV, battery storage and two of the smart hot water cylinders.

The project added solar PV to properties with the following technologies:

- Air source heat pumps and batteries
- Air source heat pumps (ASHPs)
- Storage heaters and batteries
- Storage heaters and panel heaters
- Infrared heating panels and batteries
- Infrared heating panels

All but seven of the households with ASHPs also had Mixergy smart hot water cylinders installed which included a solar diverter to allow excess solar generation to heat the water for free.

The evaluation of the project consists of four separate reports looking at:

- Wondrwall installations and infrared heating panels
- Mixergy cylinders with solar diverters
- A main report on the benefits of the solar PV systems
- Electricity tariffs and electric heating

This report looks at electricity tariffs which are suited to homes with different electric heating technologies. It also looks at consumption data for households on the 'Evaluating solar PV with electric heating' project and assesses the benefits and costs with different tariffs.

1.2 Context

There is a desire to decarbonise home heating and move away from fossil fuels such as gas, oil and LPG. This will initially mean a shift to greater electric heating for off-gas grid homes and new-build homes. Over a longer period, many homes currently heated by gas are also likely to shift to electric heating.

Figure 1.1 illustrates how the demand for electricity varies across a winter day. It is typically lower overnight when most of the population sleeps. Wholesale electricity prices are lower due to the lower demand. Greatest demand normally occurs between about 16:00 and 19:00. Wholesale electricity prices can rise significantly and this peak in demand can be close to the network capacity on cold winter evenings.

There will be a need for greater electricity generation and upgrades to the electricity network to meet the demand from greater electric heating and charging of electric vehicles. Greater flexibility in electricity demand can reduce the investment required in generators and the electricity network. This can be encouraged with time-of-use electricity tariffs which encourage demand to shift away from periods of peak consumption. Smart meters which record electricity consumption every half-hour have allowed electricity suppliers to offer more advanced tariffs than just the traditional single-rate and Economy 7 tariffs.

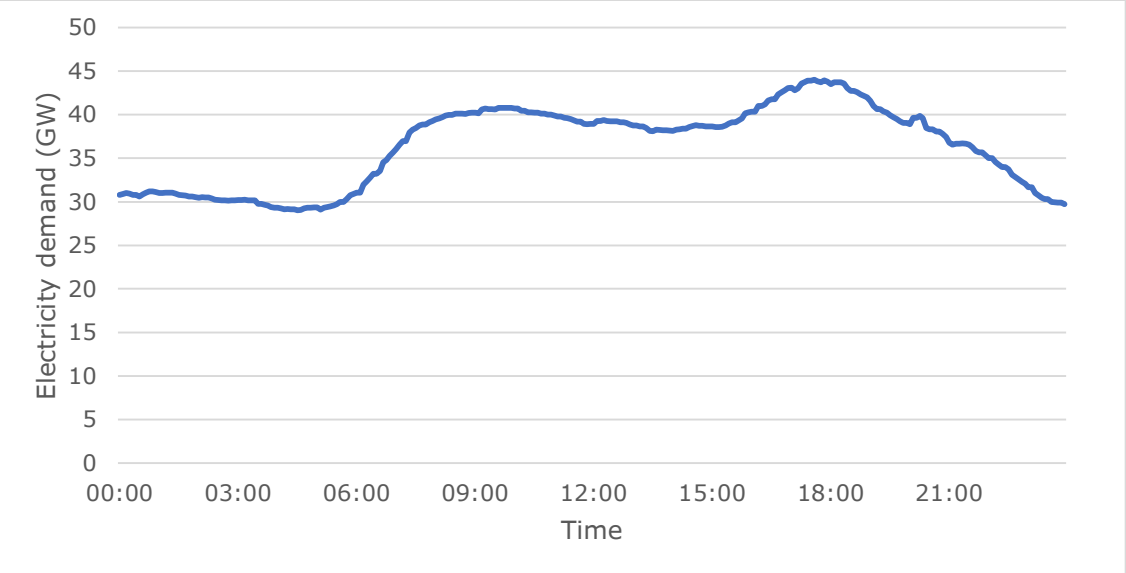

Figure 1.1 GB electricity demand on 15 Jan 2025[1]

The two main options for electric heating are on-demand heating such as a panel heater or heat pump and storage heaters which use cheaper tariffs and shift electricity demand.

[1] Data from Gridwatch, https://www.gridwatch.templar.co.uk/download.php (Accessed 14 Feb 2025)

1.3 Electricity tariffs for storage heaters

Low electricity demand overnight and generators such as nuclear power with limited flexibility led to the introduction of the Economy 7 tariff. This has seven hours of low-cost electricity, typically from 00:00 to 07:00. Electric storage heaters have been popular since the 1970s and heating elements are powered overnight with the heat stored in ceramic blocks and emitted during the day.

The storage heaters are designed so they fully charge within seven hours and can supply sufficient heat on the coldest days in winter. Normally there would be an electricity meter with two registers (two meter readings). The storage heaters and the off-peak immersion heater would be on a separate electrical circuit for the heating. The times the heaters were turned on and off could be determined by a Radio Teleswitch. The Radio Teleswitch service became fully operational in 1984 and is due to shut down at the end of June 2025.

Figure 1.2 Older dual rate mechanical Economy 7 meter with Radio Teleswitch

Traditional storage heaters are often unpopular with residents due to the limited control of the heating output and the fact that they are often cold by the early evening when residents are home and want to be warm.

The off-peak rate for Economy 7 can be less than half the rate during peak periods. A typical tariff at the time of writing was about 12.5p/kWh for off-peak electricity and about 30p/kWh for peak-rate electricity. A single-rate tariff was about 24p/kWh throughout the day. Storage heaters have the advantage of charging at a cheap rate. The heating cost for panel heaters is higher on a single-rate tariff, but there is a greater degree of control and so residents can potentially heat the home and selected rooms only when needed.

Alternative time-of-use tariffs to Economy 7 have also been available. In 2004, Economy 10 was introduced which had 10 hours of lower-cost, off-peak electricity. There were off-peak periods overnight, in the afternoon and in the evening with the exact times depending on the region of Great Britain. Typical off-peak times could be 00:00 to 05:00, 13:00 to 16:00 and 20:00 to 22:00.

The tariff rates for Economy 10 could be higher than for Economy 7 to reflect the greater number of hours of off-peak electricity.

Alternative legacy time-of-use tariffs have been more common in certain parts of the country. Heatwise, similar to Economy 10 was popular in the East Midlands. In Scotland there have been time-of-use tariffs with dynamic teleswitching which allowed the hours of off-peak electricity to vary depending on the weather.

An advantage of an Economy 10-type tariff is that it can allow storage heaters to charge more than once a day. This then ensures that the storage heaters are not cold in the evening and the household reliant of supplementary heating.

It is not possible for new customers to be switched to a traditional Economy 10 tariff. However, some energy suppliers are offering an Economy 10-type tariff with a smart meter.

Connected Response developed the HeatSage smart heating control which can control the times traditional storage heaters charge. The HeatSage control was installed in over 30 properties owned by North Devon Homes[2]. The technology has also been installed on a project in Glasgow with up to 10,000 homes[3].

Households on an Economy 10-type tariff can have the storage heaters charge more than once a day. The HeatSage system also provides weather compensation for the storage heaters. This uses a daily weather forecast and the hours the heater charges are varied according to the external temperature. The control is capable of operating with more advanced time-of-use tariffs and charge storage heaters at times of low wholesale electricity due to excess renewable generation.

Connected Response has also analysed the ideal times for a tariff for electric storage heaters and water heating[4]. They suggest primary heating times of 02:00-07:00 and 13:30-16:30 with secondary and tertiary times during other periods of lower demand on the network. Smart meters would allow the times of charging to be varied between households so that electricity demand is distributed more evenly, reducing the need for upgrading the electricity network.

Snug Octopus is a smart time-of-use tariff specifically for storage heaters. This provides six hours of off-peak electricity overnight (00:30-06:30) and a boost of one hour in the afternoon which helps to keep the storage heaters warm in the

[2] Rogers and Hamer (2025), Installation of the Connected Response HeatSage control for storage heaters with North Devon Homes (in press)
[3] Energy Action Scotland (2023), Connected Response Wheatley Homes Glasgow project, Energy Review Spring 2023 pp 18-19, https://connectedresponse.co.uk/latest-news/wheatley-homes-glasgows-trailblazing-project-to-install-heatsage-technology-in-10000-homes/ (Accessed 25 Feb 2025)
[4] Cameron and Wight (2025), Energy Spectrum, Issue 935, pp 24-25, Cornwall Insight

evening. The time of the afternoon charge will vary depending on the wholesale cost of electricity.

Snug Octopus requires the customer to have a SMETS2 smart meter with the heating managed by an auxiliary load control switch. A five terminal SMETS2 smart meter should be compatible. At the time of writing the tariff rates were cheaper than for Economy 7. The night rate was 9p/kWh and the day rate was 27.4p/kWh including VAT in the south west.

As well as time-of-use tariffs, some electricity suppliers are starting to offer type-of-use tariffs. In this case, the electricity for a particular technology such as an electric vehicle or heat pump is charged at a different rate to the other electricity consumption. There has been interest in developing a type-of-use tariff for storage heaters. The aim would be to provide a consistent level of thermal comfort but vary the times the storage heater charges based on the wholesale price of electricity.

Storage heaters are the most common form of heat storage with electric charging. However, new products are also being developed. One of these is the tepeo zero emission boiler (ZEB). This uses similar technology to storage heaters, with ceramic blocks heated by electric heating elements. The stored heat is used to heat water in a wet central heating system. The ZEB has an electrical input of 9kW and can fully charge to 40kWh within 4.5 hours. This means the ZEB is more flexible in the tariffs it can use.

The tepeo ZEB could operate on an electric vehicle (EV) tariff with five hours of low-cost, off-peak electricity[5] if the supplier would accept an application. Snug Octopus or a similar tariff could also be suitable if the supplier could provide suitable control. The device will operate with Octopus Agile and charge at the cheapest time for wholesale electricity. However, this tariff, with the electricity cost varying each half hour and each day may not suit many households.

1.4 Electricity tariffs for heat pumps

Normally a household with a heat pump would be advised to be on a single-rate tariff. For an efficient heat pump installation, you would expect about three units of heat to be produced for each unit of electricity consumed. So, for a single-rate electricity unit cost of 24p/kWh, the heating cost would be about 8p/kWh. A heat pump is likely to therefore have lower heating costs than storage heaters but is likely to be more expensive than gas.

Heat pumps are normally used in a different way to gas boilers. Manufacturers recommend the thermostat temperature does not change significantly through

[5] Energy tariffs, tepeo (2025), https://www.tepeo.com/energy-tariffs/ (Accessed 25 Feb 2025)

the day, to ensure a higher coefficient of performance (COP). The heat pump runs more efficiently while maintaining the room temperature rather than raising it to temperature. There is however a balance between consistent operation to improve efficiency and unnecessarily heating the home when you are out/away.

Heat pumps can use high levels of electricity during periods of high demand from 16:00 to 19:00 when the wholesale electricity price is higher. Energy suppliers have introduced tariffs specifically for households with heat pumps to encourage greater use during times of lower electricity demand.

Cosy Octopus was the first advanced smart time-of-use tariff for heat pumps. It originally had two low-cost, off-peak periods from 04:00 to 07:00 and 13:00 to 16:00. There was also a peak-rate period from 16:00 to 19:00 while at other times the tariff was at a standard day-rate. Later a third off-peak period was introduced from 22:00 to 24:00. E.ON Next has more recently introduced the Next Pumped tariff for heat pumps which has a similar structure to the original Cosy Octopus.

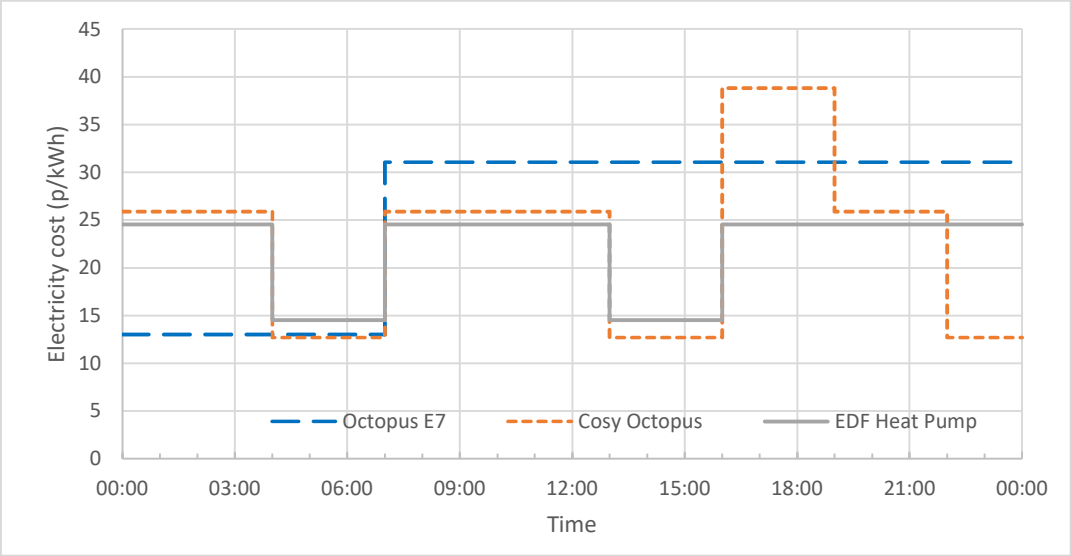

Figure 1.3 Variation in the electricity tariff rate cost through the day for Economy 7 and two heat pump tariffs in January 2025

EDF introduced a trial smart time-of-use heat pump tariff in 2024. There were off-peak periods from 04:00 to 07:00 and 13:00 to 16:00 with standard rate electricity at other times and no expensive peak-rate period.

At the time of writing, EDF also offered customers the opportunity for free electricity on a Sunday called the EDF Sunday Saver. Customers who could shift electricity usage away from peak hours of 16:00 to 19:00 were awarded free electricity the following Sunday. The number of hours of free electricity awarded was dependent on the amount of peak-rate usage shifted during the week.

To take advantage of these tariffs, households should aim to heat the home more during the off-peak periods. For example, the thermostat could be turned up from 04:00 to 07:00 to heat the home after a period with a setback temperature overnight. Likewise, the thermostat could be turned up from 13:00 to 16:00 to ensure the home is warm by 16:00. If the household is on the Cosy Octopus tariff, the thermostat could be turned down from 16:00 to 19:00 to limit electricity consumption during the peak rate period. Households could also make savings by cooking after 19:00 or using a slow cooker during the day.

These tariffs are even better suited to heat pumps with electrical battery storage. The battery can charge during the off-peak periods and discharge, powering the home during the peak and standard-rate periods. There is not the same need to turn down the thermostat temperature during peak-rate periods in order to reduce electricity consumption.

An earlier project with North Devon Homes replaced storage heaters with ASHPs and approximately 10kWh batteries[6]. The households remained on an Economy 7 tariff. The battery charged overnight and discharged from about 07:00, powering the heat pump and household appliances. Cost savings were made through shifting the electricity demand of the household from the day to the night as for storage heaters.

Figure 1.4 shows a Power Diagram from the Alpha ESS battery portal for household B-05 with an ASHP and battery and on Economy 7. The plot is from 21 Feb 2023, which was a fairly cold day with 9.7 Degree Days. There was electricity consumption from the grid (in brown) from 00:00 to 03:00 as the level of battery charge increased (in green). The battery started to discharge and power the home and ASHP from 07:00 (shown in blue). It was fully discharged just after 16:00 and subsequently electricity was imported from the grid (in brown). The total electricity consumption on the day was 26.3kWh with 18.2kWh of this at the off-peak rate (69.2%).

In colder weather with higher heating demand, the battery could fully discharge by 12:00 to 14:00, which meant the household was using a higher proportion of peak-rate electricity over the day.

[6] Rogers and Hamer (2023), Making Heat Cheaper, Smarter and Greener, https://www.nea.org.uk/wp-content/uploads/2023/06/CP1438-Boxergy-NDH-full-report-16-Jan-22.pdf (Accessed 14 Feb 2025)

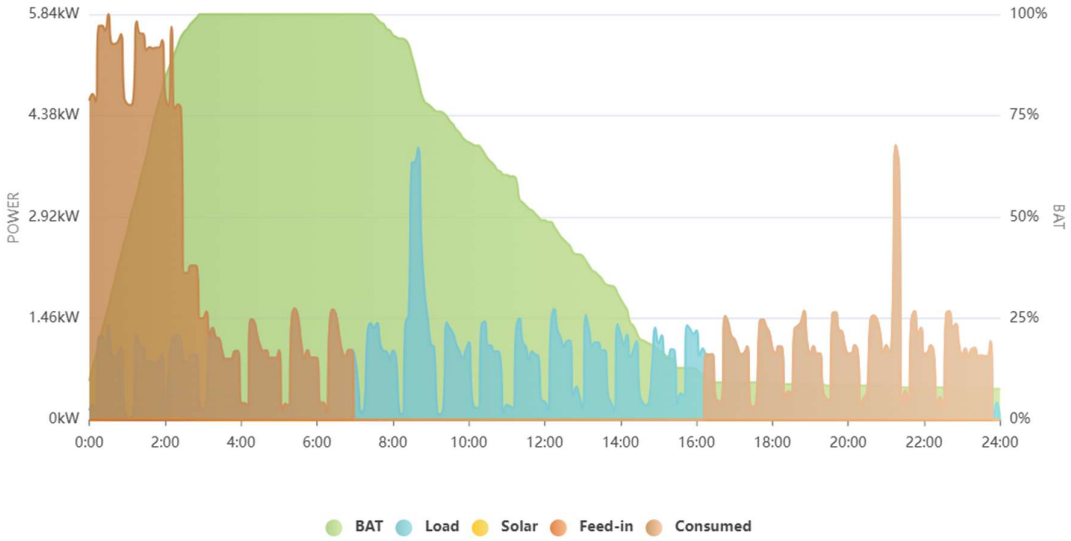

Figure 1.4 Power Diagram from the Alpha ESS battery portal for Household B-05 on 21 Feb 2023 with an Economy 7 tariff

Figure 1.5 Power Diagram from the Alpha ESS battery portal for Household B-02 on 21 Feb 2023 with the Cosy Octopus heat pump tariff

Figure 1.5 shows a Power Diagram for household B-02 on the same day. This household had switched from Economy 7 to Cosy Octopus and the battery charged twice in the day from 04:00 to 07:00 and 13:00 to 16:00. The household consumption on the day was 24.6kWh but the percentage off-peak consumption for B-02 was much higher at 98.8% and so reduced costs.

Similar shifts in consumption would be possible with both the EDF and E.ON Next heat pump tariffs which had the same overnight and early afternoon off-peak

periods. This would be particularly beneficial for the households with higher electricity demand or a smaller battery.

There has also been interest in type-of-use tariffs for heat pumps. An example was Heat Pump Plus from OVO. Here the electricity supplier charges the customer a low rate for electricity from the heat pump (e.g. 15p/kWh) with the rest of the electricity at a normal rate. Suppliers may limit this to heat pumps their partner has installed and to specific heat pump manufacturers. There will also be the need for online monitoring of the heat pump electricity consumption.

1.5 Electricity tariffs for solar PV and batteries

The UK government incentivised installation of solar PV between 2010 and 2019 with the feed-in tariff (FiT). Domestic solar PV systems received a payment for each unit of electricity generated and for the amount that was exported to the grid[7], which was estimated to be 50% of generation. Many social landlords installed solar PV during this period with the investment repaid by receiving FiT payments. As the price of solar PV installations fell and the number being installed rose, the UK government reduced the level of payments for the FiT and closed the scheme to new installations in March 2019.

More recently, the Smart Export Guarantee (SEG)[8] was introduced in Great Britain. This ensured that owners of solar PV systems were able to receive payment for electricity exported to the grid. This was particularly beneficial for systems installed since the close of the FiT scheme. Households need a smart meter that will record the electricity exported to the grid. Unlike the FiT, the rates for the SEG are not fixed but SEG suppliers must offer a non-zero rate. SEG tariffs can be at a fixed rate, or they can be variable, affected by the wholesale price. Different suppliers offer different SEG rates and tariff products.

In recent years, making an application for the SEG has often been complicated and it could take a long time for the application to be accepted. This incentive is better suited to owner-occupiers. There are complications with rented properties.

Should the application be in the name of the tenant, there would be a time-consuming administration process to switch the beneficiary should there be a change of tenant. Tenants in properties with solar PV systems funded by the Feed-in Tariff (FiT) do not receive the FiT payments for generation or export. There is an issue of equity and could cause controversy if one group of tenants receive payments from the Smart Export Guarantee and another group receives only free electricity from PV systems with the FiT. Landlords who may have fully

[7] Feed-in Tariff, Energy Saving Trust, https://energysavingtrust.org.uk/grants-and-loans/feed-in-tariff/ (Accessed 17 Feb 2025)
[8] Smart Export Guarantee, Energy Saving Trust, https://energysavingtrust.org.uk/advice/smart-export-guarantee/ (Accessed 17 Feb 2025)

or part-funded a PV installation may want the SEG payments to contribute towards maintenance or help fund new installations.

To date it has been difficult for a landlord to claim the Smart Export Guarantee while the tenant can be with any electricity supplier. Good Energy began a pilot in 2024 which allows landlords to claim the SEG from a portfolio of properties. Export data is collected from the household smart meter. Installations from the current project were part of this pilot and it was hoped the tariff would be fully launched later in 2025. It is likely this will pay around 7-8p/kWh.

Solar Energy UK publishes a list of SEG tariffs which is updated periodically[9]. SEG tariff rates can vary significantly. At the time of writing there were some tariffs which paid a fixed rate of over 20p/kWh for export. These tariffs usually required the household to have the installation carried out through the energy company and to have their electricity supply with the energy company. SEG tariffs rates where the household supply is also with the energy company could pay up to a fixed rate of 15p/kWh. Examples of this are Octopus Outgoing and Good Energy Solar Savings. The worst tariff rates are about 2-3p/kWh.

There are a few electricity tariffs specifically designed for battery storage. One of these is Octopus Flux which combines a tariff for import and export (SEG).

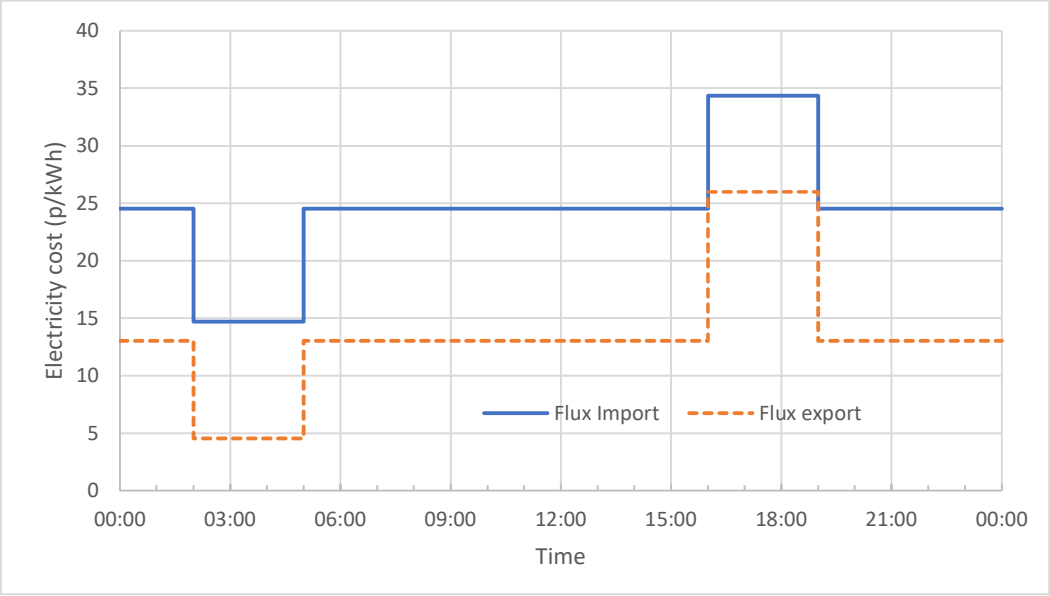

Figure 1.6 Tariff rates in SW England for Octopus Flux for import and export

There is a cheap off-peak period from 02:00 to 05:00 where a battery can charge. For most of the day the import rate is similar to a single-rate tariff but from 16:00 to 19:00, when there is high demand on the grid, there is an

[9] Smart Export Guarantee League Table, Solar Energy UK, https://solarenergyuk.org/resource/smart-export-guarantee/ (Accessed 17 Feb 2025)

increase in the tariff rate. The export rate follows the same pattern as for the import but at lower rates. This means that exporting electricity to the grid from 16:00 to 19:00 when demand is high receives a higher payment.

EDF had the Empower Tracker tariff with similarities to Octopus Flux. Here there was a discount of 10p/kWh overnight from 01:00-04:00 and a premium of 10p/kWh during the peak-rate period of 16:00-19:00.

OVO had a type-of-use tariff called Battery Boost at the time of writing where the battery could charge at 10p/kWh at times when the grid was at its greenest. In order to be eligible customers must receive both their electricity supply and SEG tariff from OVO. They must also have a battery (e.g. GivEnergy) which is compatible with their Kaluza platform. As with Heat Pump Plus, the Battery Boost is provided as a credit once data from the battery system is obtained at the end of the month.

The most sophisticated smart time-of-use tariffs are those such as Octopus Agile and Octopus Tracker. Here the electricity price varies every half hour, and you only know the price rates a day in advance. The prices are higher in the winter than the summer and there is a price peak between about 16:00 and 19:00. Plunge pricing can occur when there is excess renewable generation on the grid. This can lead to very low or even negative prices where you are paid to consume electricity. Octopus noted that unit prices for Octopus Agile fell below 2p/kWh on 163 occasions between July 2020 and July 2021. Prices have generally been higher since the Energy Crisis from 2021.

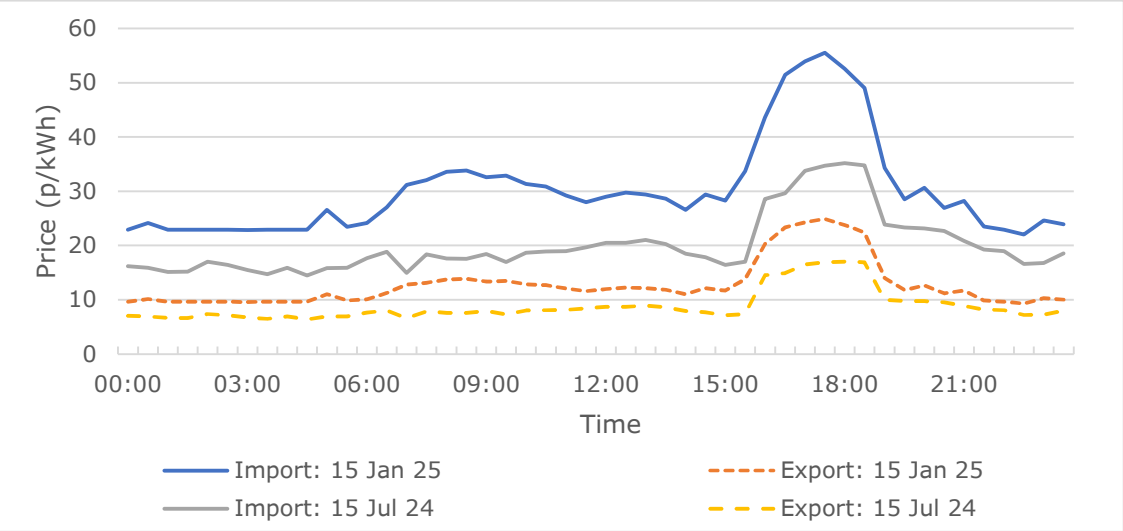

Figure 1.7 Octopus Agile tariff in SW England on 15 Jan 2025 and 15 Jul 2024

Tariffs like Octopus Agile require battery storage and use of the Agile API to programme devices to maximise benefits. NEA questionnaires have indicated that while socially renting households are happy with tariffs like Cosy Octopus,

tariffs like Octopus Agile are too complex for them. Octopus Agile is not ideal for households with electric heating as the costs are higher in winter when consumption is higher.

If the landlord is to receive the Smart Export Guarantee payment, the household will be unable to switch to a tariff such as Octopus Flux which combines with the SEG. In this case an alternative tariff type such as one for a heat pump is more suitable.

1.6 Electricity tariffs for electric vehicles

Many electricity suppliers have introduced low-cost, smart, time-of-use electricity tariffs for charging electric vehicles. Usually, the tariff is restricted to households that have an electric vehicle, although in the past households with other technologies could benefit from Octopus Go.

These tariffs can offer fixed times for the off-peak rate, with typically five hours of low-cost electricity. More sophisticated tariffs charge the vehicle at a time with lower demand and require a smart charger. This includes the OVO Charge Anytime type-of-use tariff and Intelligent Octopus Go which were both offering an off-peak rate of 7p/kWh.

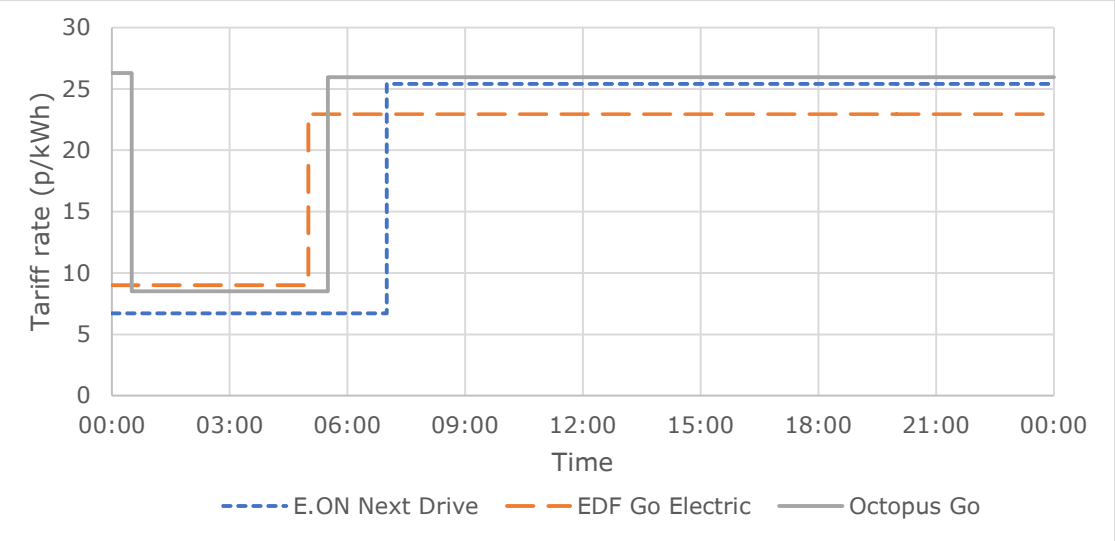

Figure 1.8 Electric Vehicle (EV) tariffs with fixed peak and off-peak times

Households with other technologies can benefit from an EV tariff if they also have an EV. For example, a household with a battery or an ASHP and a battery can charge the battery overnight on the off-peak tariff.

While EV tariffs provide sufficient off-peak hours for battery charging, they usually have too few off-peak hours for charging storage heaters. An exception to this is the E.ON Next Drive tariff with seven off-peak hours. Care must be

taken however to make sure that if charging other appliances and the EV that the maximum load for the house is not exceeded and the DNO fuse blown.

2. Electricity costs for different heating installations

2.1 Introduction

The following section looks at consumption data from the Evaluating Solar PV with electric heating project. It considers costs for different tariff types for households with different electrical heating technologies before and after solar PV was installed.

The technologies are:

- ASHPs with solar PV and battery
- ASHPs with solar PV and Mixergy cylinders
- Storage heaters with solar PV and battery
- Storage/panel heater with solar PV and Mixergy cylinder
- Infrared heating panels with solar PV with and without a battery

The tariff rates chosen for the assessment were close to those used by suppliers at the time of writing.

- Single-rate tariff – 24p/kWh
- Economy 7 tariff – 12.5p/kWh off-peak and 30p/kWh peak
- Cosy Octopus tariff – 12.7p/kWh Cosy rate, 25.9p/kWh day rate, 38.8p/kWh peak rate
- EDF Heat Pump tariff – 14.5p/kWh tracker rate, 24.5p/kWh day rate
- EDF Go Electric overnight – 9p/kWh off-peak, 25.3p/kWh peak rate

Note that variable rate tariffs are currently changing every three months. The prices discussed in the following sections are indicative and show the relative costs between types of tariffs.

2.2 ASHPs with solar PV and battery storage

Economy 7

There were seven households where night storage heaters (NSH) were replaced by a Vaillant aroTHERM plus ASHP with an approximately 10kWh battery in an earlier project[10]. These households subsequently had a large domestic solar PV system installed in the 'Evaluating Solar PV with Electric Heating Project'. Three of these households remained on an Economy 7 tariff throughout.

Table 2.1 shows consumption and modelled costs for these three households, with the costs modelled with the standardised tariff rates discussed earlier.

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
B-04	NSH	9 Jan 20	9 Jan 21	11,220	48.4%	£2,693	£2,415
B-04	ASHP + Battery	1 Aug 22	31 Jul 23	8,311	60.2%	£1,995	£1,617
B-04	PV, ASHP + Battery	1 Jan 24	31 Dec 24	3742	78.1%	£898	£611
B-05	NSH	1 Jan 20	31 Dec 20	10,951	62.4%	£2,628	£2,088
B-05	ASHP + Battery	1 Aug 22	31 Jul 23	7,545	77.0%	£1,811	£1,247
B-05	PV, ASHP + Battery	1 Jan 24	31 Dec 24	5,354	78.0%	£1,285	£875
B-06	NSH	2 Oct 20	1 Oct 21	8,126	70.5%	£1,950	£1,435
B-06	ASHP + Battery	1 Aug 22	31 Jul 23	9,015	61.7%	£2,164	£1,732
B-06	PV, ASHP + Battery	1 Jan 24	31 Dec 24	5,690	70.2%	£1,366	£1,008

Table 2.1 Consumption and modelled electricity cost for households on the Evaluating solar PV with electric heating project with different measures

[10] Rogers and Hamer (2023), Making heat cheaper, smarter and greener, https://www.nea.org.uk/wp-content/uploads/2023/06/CP1438-Boxergy-NDH-full-report-16-Jan-22.pdf (Accessed 18 Feb 2025)

Household B-04 had the highest costs in the pre-installation period with the electric storage heaters. The household disliked the storage heaters, only using the storage heaters in the hall and the bathroom while using an electric fire in the living room. This led to the relatively low percentage off-peak consumption of 48.4% for a household with storage heaters. Overall, there was high electricity consumption while also having poor thermal comfort. The modelled cost on Economy 7 was £2,415.

After the ASHP and battery were installed, the battery charged overnight on the off-peak tariff and supplied power to the home and the ASHP during the peak-rate period until it was discharged. The grid import fell by 2,909kWh to 8,311kWh after the ASHP was installed and the percentage off-peak consumption increased to 60.2%. The modelled cost on Economy 7 fell by nearly £800 to £1,617.

Following the addition of the solar PV, there was a large drop in consumption from 8,311 to 3,742kWh. This was partly due to behaviour change by the household with a drop of about 1,000kWh in the consumption of the ASHP. Savings from the solar PV between 1 Nov 2023 and 31 Oct 2024 were about 2,508kWh. Over 2024, the modelled electricity cost was £611 on Economy 7 based on smart meter readings.

Household B-05 had similarly high electricity consumption with the night storage heaters, using 10,951kWh in 2020. Due to greater use of the storage heaters and a higher percentage off-peak consumption, the cost on Economy 7 at £2,088 was over £300 lower than for B-04. After the ASHP and battery was installed, the grid import fell by 31% to 7,545kWh. Charging the battery overnight led to an increase in the off-peak consumption to 77% and the electricity cost fell over £800 to £1,247. The addition of the solar PV system led to a further reduction in grid import of over 2,000kWh to 5,354kWh. The modelled electricity cost on Economy 7 was £875 ignoring any standing charges.

Households B-04, B-05 and B-06 all lived in similar semi-detached bungalows. The grid consumption of B-06 over a 12-month period with storage heaters from 2 Oct 2020 was 8,126kWh. This was just over 3,000kWh less than for B-04. A major factor in the lower consumption of B-06 was likely to be the level of heating, with an average living room temperature of 14.7°C between 1 Nov 2020 and 1 May 2021.

After the storage heaters were replaced with the ASHP and battery, the consumption increased to 9,015kWh for the monitoring period of 1 Aug 2022 to 31 Jul 2023. This increase in consumption is likely to be primarily due to an increase in thermal comfort of the household. Between 1 Nov 2022 and 1 May 2022, the living room temperature was consistent over the winter with an average of 19.1°C. There have also been teething problems with this heat pump installation which could also be a factor in the higher household consumption.

After the solar PV system was installed, the grid consumption of household B-06 fell from 9,015kWh at a cost of £1,732 on Economy 7 to 5,690kWh with a modelled Economy 7 cost of £1,008. The thermal comfort for the household was maintained during the period from 1 Nov 2023 to 1 May 2024 with an average temperature of 19.3°C in the living room.

Figure 2.2 shows a power diagram from the Alpha ESS battery portal for household B-05 on 12 Feb 2024. This graph from after the installation of the solar PV can be compared to figure 1.4 about a year earlier without the solar PV.

It was a cold day on 12 Feb 2024 with 10.9 Degree Days[11]. The ASHP was running consistently throughout the day. In contrast, on 21 Feb 2023, the ASHP had regular consumption cycles of about 40 minutes, and the temperature was somewhat milder with 9.7 Degree Days. The grid consumption recorded by the portal was 25.2kWh on 21 Feb 2023 with the battery fully discharged by 16:15. In contrast, on 12 Feb 2024, the household consumption was 36.3kWh but the solar PV system generated 12.3kWh. This was all consumed powering the home and charging the battery, leading to a lower grid import than on 21 Feb 2023. The generation from the solar panels recharged the battery from about 11:00 and the battery did not begin discharging again until about 16:10. This meant that the household was able to power the ASHP and home appliances from the solar PV and battery until 23:00 instead of 16:15 the year before without the solar PV. Over the day 93.7% of the grid consumption was at the off-peak rate on this sunny day. This compares to 69.1% on 21 Feb 2023.

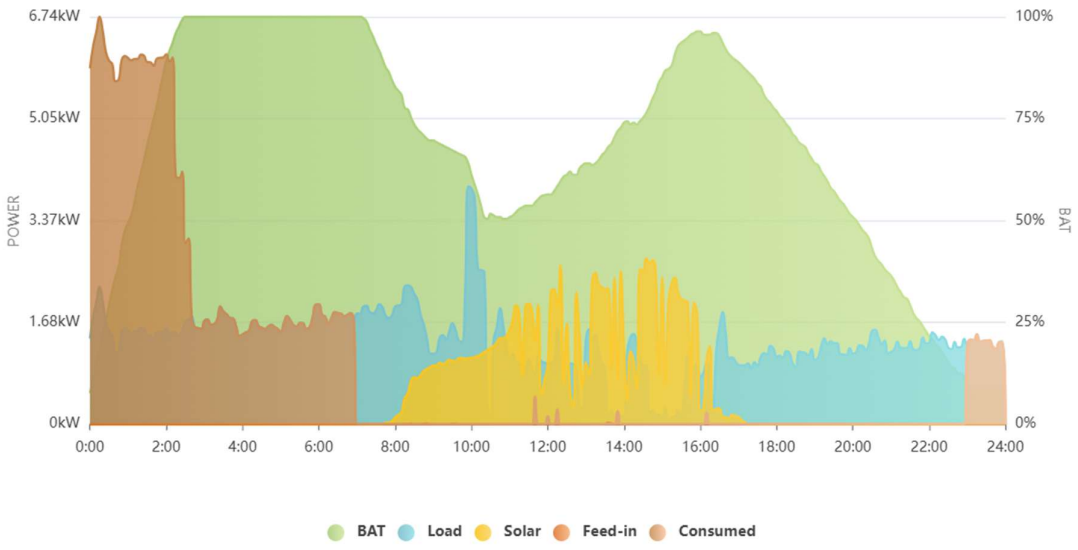

Figure 2.2 Power Diagram from the Alpha ESS battery portal for Household B-05 on 12 Feb 2024 with an Economy 7 tariff

[11] Dunkeswell Airport, Station ID 03840, Bizee Degree Days, Weather Data for Energy Saving, https://www.degreedays.net/ (Accessed 18 Feb 2025)

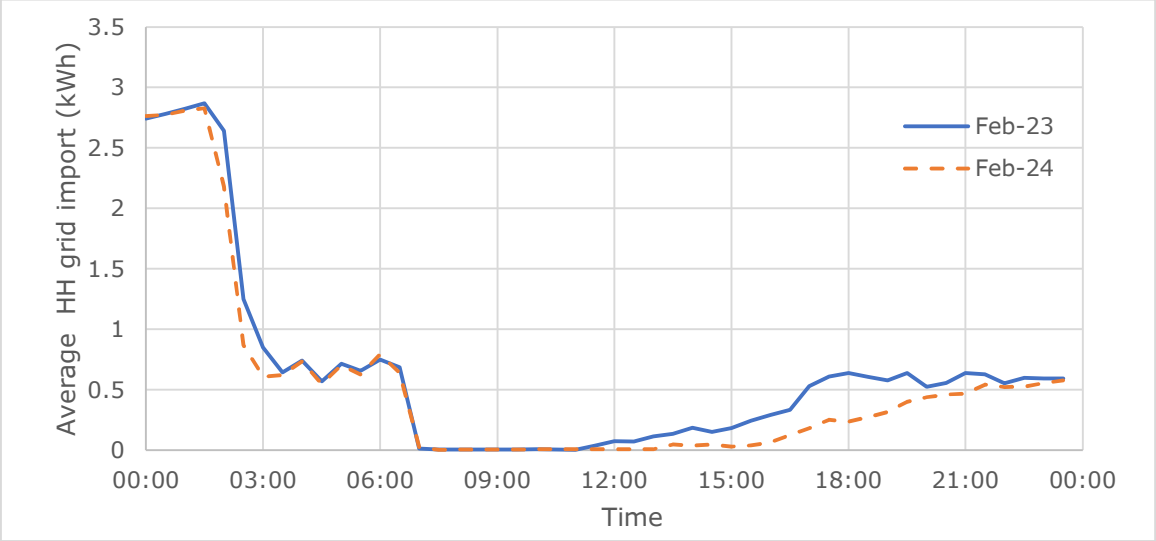

Figure 2.3 Graph showing the average half-hourly grid consumption in February with and without solar PV for household B-05 on Economy 7

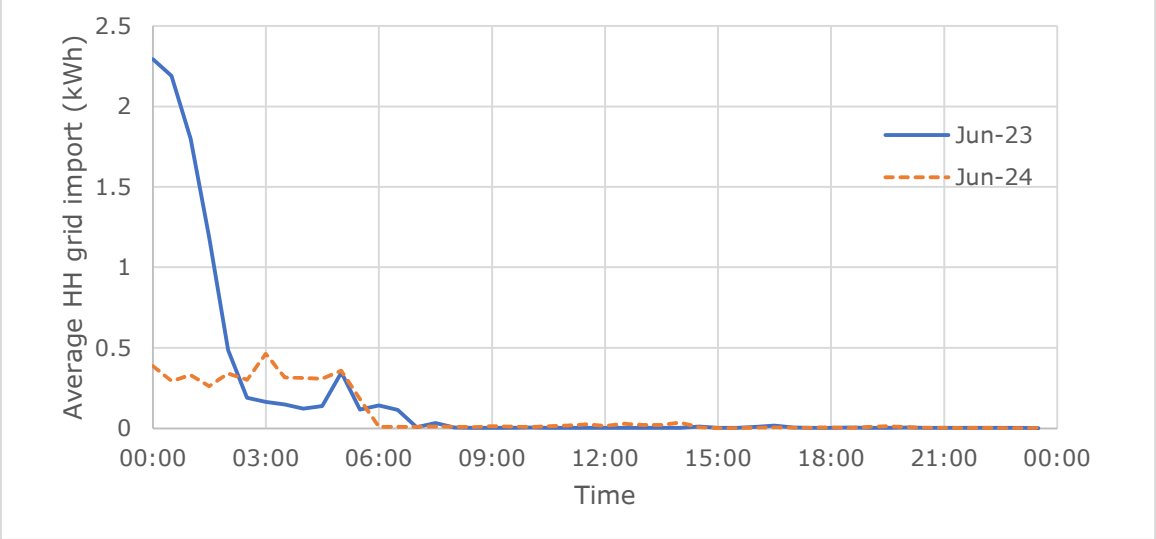

Figure 2.4 Graph showing the average half-hourly grid consumption in June with and without solar PV for household B-05 on Economy 7

Figure 2.3 was produced using half-hourly smart meter data and plots the average grid import for each half hour in February. During February 2023, the household had an ASHP and battery. By February 2024 a 5.81kW solar PV system had been installed, split across east-west roofs.

The average consumption from 00:00 to 00:30 was about 2.75kWh in both February 2023 and February 2024. The average consumption during the off-peak period before 07:00 was similar in both years but was slightly lower in 2024 between 02:00 and 03:30. Average grid import for both years was very low between 07:00 and about 12:00. After 12:00 the average consumption

started to rise in February 2023. This was due to the battery starting to fully discharge in the early afternoon on the coldest days. There was a day-rate peak in average half-hourly consumption of 0.636kWh at 18:00. The solar PV ensured the battery fully discharged later in the day in February 2024, with average half-hourly consumption only starting to significantly rise from after 16:00. Highest consumption during the peak-rate period was at 23:30.

The average daily grid import in February decreased by 16.6% from 30.9kWh in 2023 to 25.8kWh in 2024. Over the 16:00 to 19:00 period where demand on the grid is greatest, the average grid import was 3.01kWh in February 2023 and this decreased by 62.3% to 1.13kWh in February 2024

Figure 2.4 shows a similar plot with the average half-hourly grid import in June with and without the solar PV. The average daily grid import was much lower than in February, with 9.63kWh in June 2023 and 4.2kWh in June 2024. Most of this consumption was on the off-peak tariff between 00:00 and 07:00 with 98.0% of the consumption off-peak in June 2023 and 91.7% in June 2024.

The battery was set to fully charge overnight daily before the solar PV was installed. In June 2023, the battery was often able to fully power the home during the peak-rate period. On days of lower consumption, more of the battery charge was left over and less charging required the following night. This meant there was less overnight charging in June 2023 than in February 2023.

After the solar PV system was installed, the overnight charging of the Alpha ESS battery was manually adjusted on a seasonal basis by NEA. The overnight charging was set to 50% in summer. The lower overnight consumption in June 2024 is partly due to the battery charging to only 50% capacity as well as there being some spare charge left over from previous days. On some dull days or where there was higher household consumption, the battery might fully discharge due to the lower overnight charge. This explains the slightly higher peak-rate consumption and lower percentage off-peak consumption in June 2024 compared to June 2023. However, the average daily consumption in June 2024 was 56% lower than the previous year at 4.2kWh.

Heat pump electricity tariffs

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
B-02	NSH	29 Oct 20	27 Oct 21	9,505	69.6%	£2,281	£1,694
B-02	ASHP + Battery	25 Nov 21	22 Nov 22	7,514	68.5%	£1,803	£1,353
T-06	NSH + Battery	1 Aug 22	31 Jul 23	7,510	91.5%	£1,802	£1,050

Table 2.5 Consumption and modelled electricity cost for households on the Evaluating solar PV with electric heating project with different measures

Several of the households on the project were initially on Economy 7 tariffs but later switched to heat pump tariffs. Household B-02 originally had a mix of Dimplex Quantum and traditional storage heaters in a bungalow. Between 29 Oct 2020 and 27 Oct 2021, the electricity import was 9,505kWh, with 69.6% of this at off-peak times[12]. Using the modelled electricity tariffs, the cost on Economy 7 was £1,694.

In late November 2021, the storage heaters for B-02 were removed and a wet central heating system fitted for an ASHP with an approximately 10kWh battery. As for households B-04, B-05 and B-06, the battery charged overnight on the Economy 7 off-peak tariff and powered the ASHP and home during peak-rate periods. The grid import of 7,514kWh for the year with the ASHP and battery was 20.9% lower than the year with the storage heaters. There was also an improvement in thermal comfort. The percentage off-peak consumption from the battery charging and discharging was comparable to before at 68.5% but the cost of the Economy 7 electricity (excluding standing charge) fell by £341 to £1,353.

Household T-06 had traditional storage heaters downstairs and panel heaters upstairs in a 3-bedroom house. A Tesla Powerwall 2 battery was installed as part of an earlier project, charging on the off-peak tariff and providing low-cost electricity during peak-rate times[13]. The household had an open fire in the living room which was used daily for about six months a year. About £120-£150 per month was spent on coal and wood for the fire in the living room. The electricity

[12] Rogers and Hamer (2023), Making Heat Cheaper, Smarter and Greener, https://www.nea.org.uk/wp-content/uploads/2023/06/CP1438-Boxergy-NDH-full-report-16-Jan-22.pdf (Accessed 19 Feb 2025)
[13] Rogers and Hamer (2018), Tesla Powerwall 2 batteries charged using off-peak electricity, https://www.nea.org.uk/wp-content/uploads/2020/10/CP1139-TIF-REPORT_FINAL-25-04-19-v2.pdf (Accessed 19 Feb 2025)

consumption with the storage heaters was 7,510kWh between 1 Aug 2022 and 31 Jul 2023. If storage heaters are regularly used, the percentage off-peak consumption can be 60-70%. With the battery also charging overnight, this increased the off-peak consumption to 91.5%. The modelled annual cost of the electricity was £1,050 for the period.

Household B-02 had a south-facing 5.81kW solar PV system installed in August 2023. The storage heaters were replaced by an ASHP for household T-06 and a 4.57kW solar PV system was installed in September 2023. There was improved thermal comfort for household T-06 with the ASHP system and the residents used two radiators in the living room for heating instead of the open fire.

Both households switched from Economy 7 to the Cosy Octopus electricity tariff for heat pumps. Initially when Cosy Octopus was introduced, there were two low-cost periods with the Cosy rate but in 2024 a third period was added in the late evening. Table 2.6 shows the tariff times for Cosy Octopus and the EDF Heat Pump tariff. E.ON also had the Next Pumped tariff which had the same times as the original version of Cosy Octopus.

Tariff	Rates	Times
Cosy Octopus (original)	Peak rate Cosy rate Day rate	16:00-19:00 04:00-07:00, 13:00-16:00 Other times
Cosy Octopus (current)	Peak rate Cosy rate Day rate	16:00-19:00 04:00-07:00, 13:00-16:00, 22:00-00:00 Other times
EDF Heat Pump	Heat pump tracker Day rate	04:00-07:00, 13:00-16:00 Other times

Table 2.6 Times of the tariff rates for Cosy Octopus and EDF heat pump tariffs

Code	Technology	Start date	End date	Grid import (kWh)	Cost Old Cosy	Cost New Cosy	Cost EDF ASHP
B-02	ASHP + Battery	1 Mar 23	31 Jul 23	2,674	£363	£361	£404
B-02	ASHP + PV + Battery	1 Jan 24	31 Dec 24	3,939	£570	£561	£622
T-06	ASHP + PV + Battery	1 Jan 24	31 Dec 24	7,292	£1,101	£1,077	£1,181

Table 2.7 Consumption and modelled electricity cost for households with an ASHP and on a heat pump electricity tariff

Household B-02 switched to Cosy Octopus in February 2023 about six months before the solar PV system was installed. The grid import over the five-month analysis period from 1 Mar 2023 to 31 Jul 2023 was 2,674kWh. 94% of the consumption was on the original Cosy rate with a further 0.54% on the additional late night Cosy period. 4.9% of the consumption was at the standard rate and only 0.62% was at the peak rate.

Modelling the electricity cost for B-02 with the time periods for the two versions of Cosy Octopus showed the cost decreased from £363 to £361 for the newer version of the tariff with the third off-peak period. There was little extra benefit because only two grid charge and discharge periods could be set each day for the Alpha ESS battery. Also, there was little consumption during the third off-peak period as the household was often being supplied power by the battery. The cost under the EDF heat pump tariff was £43 more than with the newer version of Cosy Octopus. However, EDF had also been offering some free electricity on a Sunday which improved the savings with the EDF tariff.

The consumption was also analysed for B-02 over 2024 after the solar PV system was installed. The total grid import was 3,939kWh with savings in grid consumption of about 2,700kWh from the solar PV system. Over the year, 87.1% of the consumption was at the original Cosy rate with a further 1.76% on the additional late-night Cosy rate. There was 10.54% of the consumption at the standard rate and 0.6% at the peak rate.

The modelled annual electricity cost for B-02 was £570 for the original version of Cosy Octopus and £561 for the current version. Again, the EDF heat pump tariff cost was higher at £622. This was due to the higher tariff rate for off-peak electricity at the time of writing. There was a fall in the modelled annual electricity cost for B-02 from £1,328 with the ASHP and battery on Economy 7 to £561 with the ASHP, solar PV and battery on Cosy Octopus. Note that 2024 was a colder period with 2048.1 Degree Days compared to 1918.1 Degree Days during the initial analysis period with the ASHP and battery.

The grid consumption for household T-06 decreased from 7,510kWh with the storage heaters to 7,292kWh in 2024 with the solar PV and ASHP. There were savings of about 2,800kWh from the solar PV, so once this is also included, the household load for T-06 in 2024 had increased. The increase in household load was due to improved thermal comfort (average dining room temperature increasing by 4°C during the heating season) and the living room being heated by the ASHP rather than the open fire.

Out of the 7,292kWh consumption in 2024 for T-06, 83% was at the original Cosy rate with a further 2.5% at the additional Cosy off-peak rate. There was 13.2% at the standard rate and 1.25% at the peak rate. The Tesla battery was set to charge using the original Cosy Octopus times. There is potential to reduce

the standard rate consumption overnight if the third Cosy off-peak period was added to the charge/discharge schedule for the battery.

The modelled cost of the electricity in 2024 using the original Cosy Octopus times was £1,101 and this fell to £1,077 with the additional off-peak period. The cost with the EDF heat pump tariff was higher at £1,181 but this analysis did not consider periods of free electricity on a Sunday.

The modelled electricity cost for the year with the storage heaters on Economy 7 was slightly lower at £1,050. However, the overall electricity and heating cost would have been significantly higher than in 2024. This was due to the household also using the open fires, with wood and coal costing £120-£150 per month during the heating season.

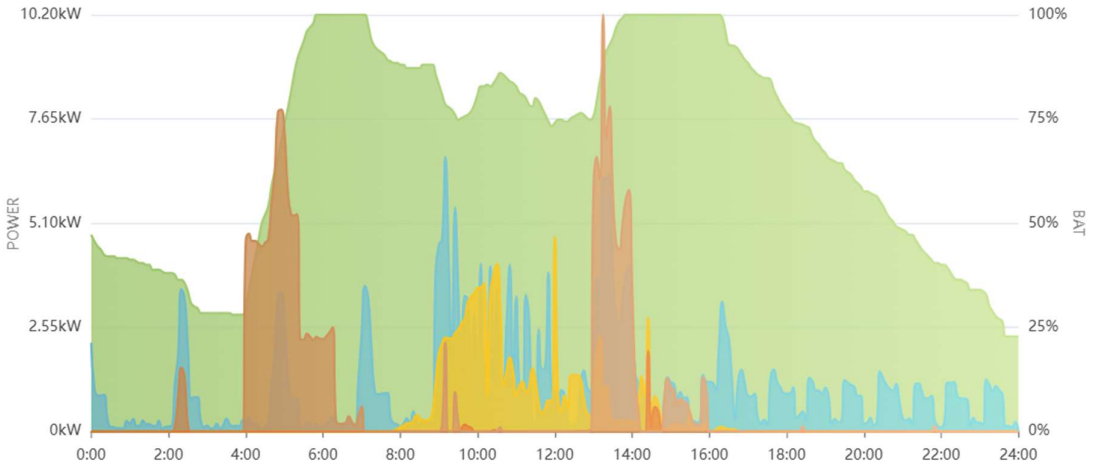

Figure 2.8 Power Diagram from the Alpha ESS battery portal for Household B-02 on 10 Feb 2024 with the Cosy Octopus heat pump tariff

Figure 2.8 shows a Power Diagram from the Alpha ESS battery portal for household B-02. This has similarities to figure 1.5 with household B-02 on the Cosy Octopus tariff for both dates. The main difference was the contribution of the solar PV system (shown in yellow) on 10 Feb 2024. The battery fully charged between 04:00 and 07:00 (grid import in brown) and from 13:00 to 16:00.

Generation from the solar panels helped power the home between about 08:00 and 16:00 and this included charging of the battery from 09:30 to 10:30. All the 9.8kWh generated by the solar panels was used in the home. This meant the grid consumption was reduced from 29kWh to 19.2kWh.

With the newer version of Cosy Octopus, on 10 Feb 2024, 93.6% of the consumption was at the Cosy rate, with 5.85% of the consumption at the day rate and 0.55% at the peak rate.

The percentage battery charge from the grid for the Alpha ESS battery currently needs to be set manually and NEA altered this during the project on a seasonal basis. In winter, the battery was set to charge 100% during each off-peak period. This was effective on 10 Feb 2024 with all the PV generation used in the home. On days such as 12 Feb 2024, with higher PV generation (22.6kWh) much of this was exported to the grid (15.6kWh). Alpha ESS needs to add a feature to the battery where the grid charging can be automated based on the predicted PV generation and household consumption. This feature is already available with the Tesla Powerwall 2.

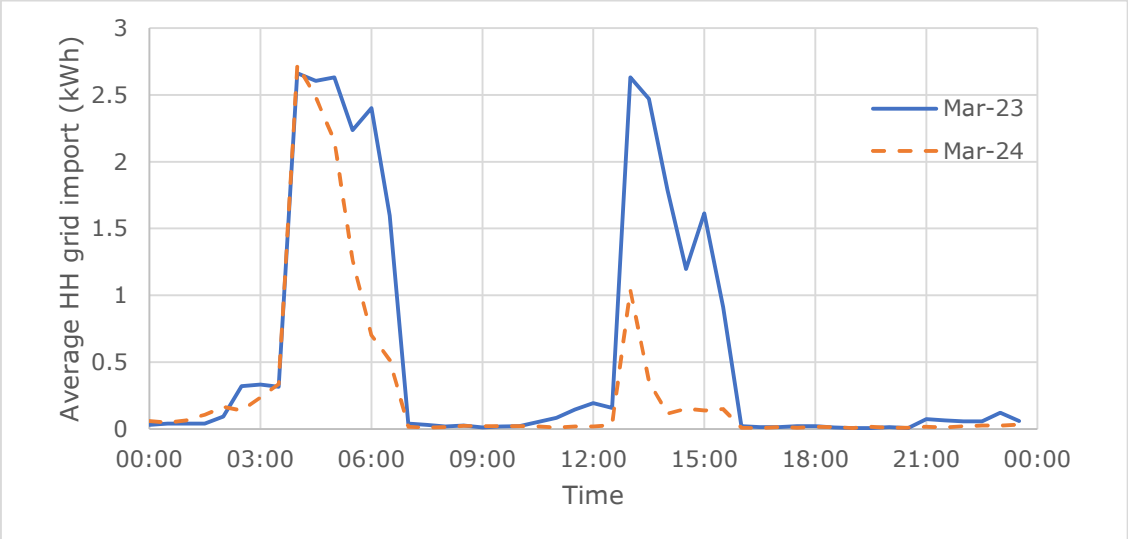

Figure 2.9 Graph showing the average half-hourly grid import in March with and without solar PV for household B-02 on the Cosy Octopus tariff

Half-hourly smart meter data was averaged over the month in March 2023 (without solar PV) and March 2024 (with solar PV) for household B-02. The average daily grid import in March 2023 was 27.3kWh with 90.6% of this consumption during the early morning and early afternoon Cosy off-peak rates. The average daily grid import in March 2024 was 13.4kWh which was 50.9% lower than the average for the previous year. There was a reduction in the average grid import during the early morning off-peak period from 14.1kWh to 9.84kWh. This was due to more days with the battery not being fully discharged overnight after the solar PV was installed. There was a more significant decrease in the average consumption during the early afternoon off-peak period with the consumption falling 81.6% from 10.6kWh to 1.95kWh.

A similar plot of average half-hourly electricity consumption is shown in figure 2.10 for June 2023 (without solar PV) and June 2024 (with solar PV) while on the Cosy Octopus tariff. The average daily consumption in June fell by 79.2% from 11.0kWh to 2.3kWh.

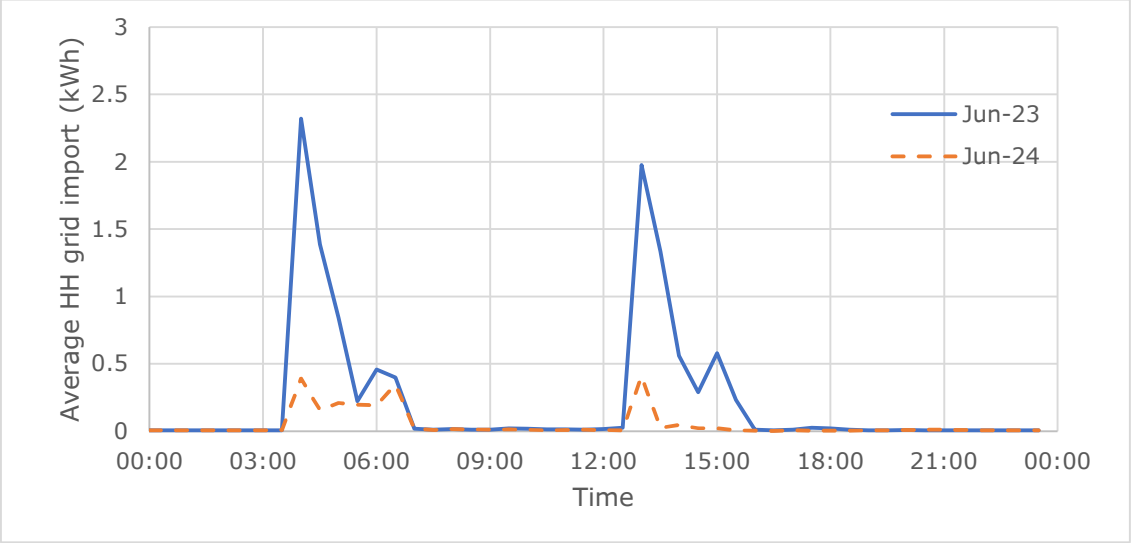

Figure 2.10 Graph showing the average half-hourly grid import in June with and without solar PV for household B-02 on the Cosy Octopus tariff

Most of the consumption was during the off-peak periods in the early morning and early afternoon. In June 2023, 96.6% of the consumption was during these off-peak periods with 88.2% in June 2024. The average consumption during the afternoon off-peak period was 4.97kWh in June 2023 and this fell to 0.53kWh in June 2024 due to charging of the battery by the solar PV during the morning and continued PV generation during the afternoon. Due to the solar PV, the battery was also more likely to have a higher charge level overnight and less charging of the battery in the early morning. The average consumption during the early morning off-peak period was 1.49kWh in June 2024 compared to 5.63kWh in June 2023.

Household B-03 lived in a 3-bedroom house. The space and water heating demand for the EPC was about 13,000kWh. The household switched from Economy 7 to the EDF heat pump tariff in November 2024. Table 2.11 shows the grid import in December 2024 and January 2025 was 2,512kWh. December and January are often months with the highest consumption for electric heating. During this period the electricity used by the ASHP was about 1,060kWh, with 80% of the heat pump consumption used for space heating.

Code	Technology	Start date	End date	Grid import (kWh)	Cost Old Cosy	Cost New Cosy	Cost EDF ASHP
B-03	ASHP + PV + Battery	1 Dec 24	31 Jan 25	2,512	£379	£374	£408

Table 2.11 Consumption and modelled electricity cost for household B-03 with an ASHP and on a heat pump electricity tariff

The modelled electricity cost based on the household grid import was £374 with the newer version of Cosy Octopus and £408 with the EDF heat pump tariff. EDF at the time of writing were also offering the benefit of some free electricity on a Sunday. The offer was based on households shifting their electricity use away from peak hours (16:00 to 19:00) during the week. This provided additional savings for households at a time with lower electricity demand.

Household B-03 showed significant behaviour change on a Sunday while this offer was available. The household washed and dried clothes on a Sunday and also made savings by batch cooking meals for later in the week. Figure 2.12 shows a plot of the average half-hourly grid consumption for household B-03 on Sundays in December compared to an average over the other six days of the week. The average grid import on a Sunday in December was 48.3kWh compared to 36.3kWh for the other days of the week.

The grid import during the off-peak periods from 04:00 to 07:00 and 13:00 to 16:00 was similar on Sundays and the other days. These peaks in grid import were primarily due to charging of the battery (figure 2.13 with battery charge in green) along with regular consumption from the heat pump (figure 2.14).

There was an increase in household consumption in the morning on Sundays. This led the battery to discharge earlier than usual with greater import from the grid after that. On 29 Dec 2024 the total grid import for the day was 54.3kWh. The battery had fully discharged by 9:20 in the morning and 19:45 in the evening. There was a peak in consumption at 09:00 due to use of the electric shower. The more sustained consumption in the middle of the day was likely to be due to washing/drying clothes and cooking

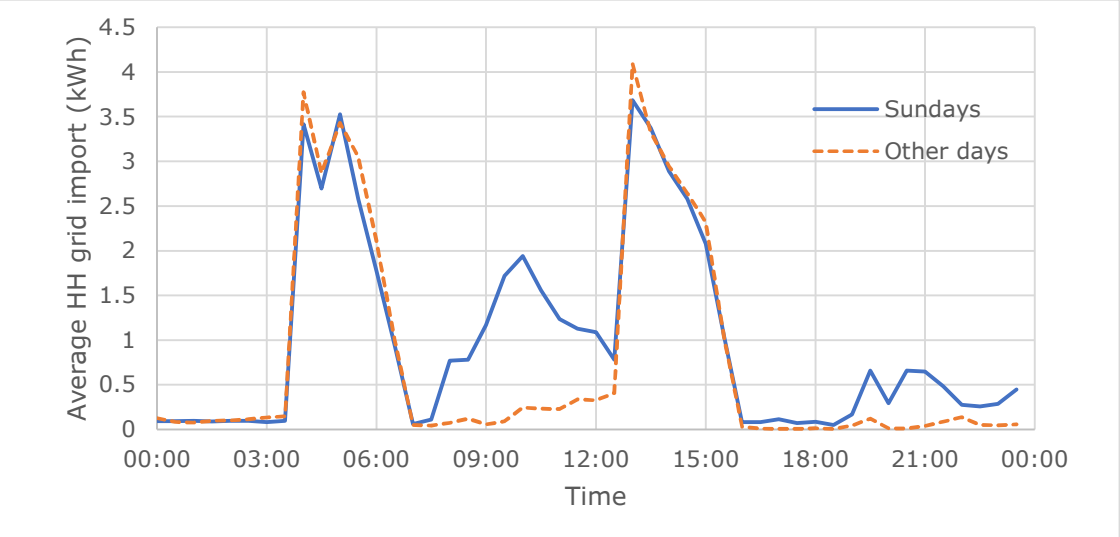

Figure 2.12 Graph showing the average half-hourly grid consumption on Sundays and other days for household B-03 in Dec 2024 on the EDF heat pump tariff

Figure 2.13 Power Diagram from the Alpha ESS battery portal for Household B-03 on Sunday 29 Dec 2024 with the EDF heat pump tariff

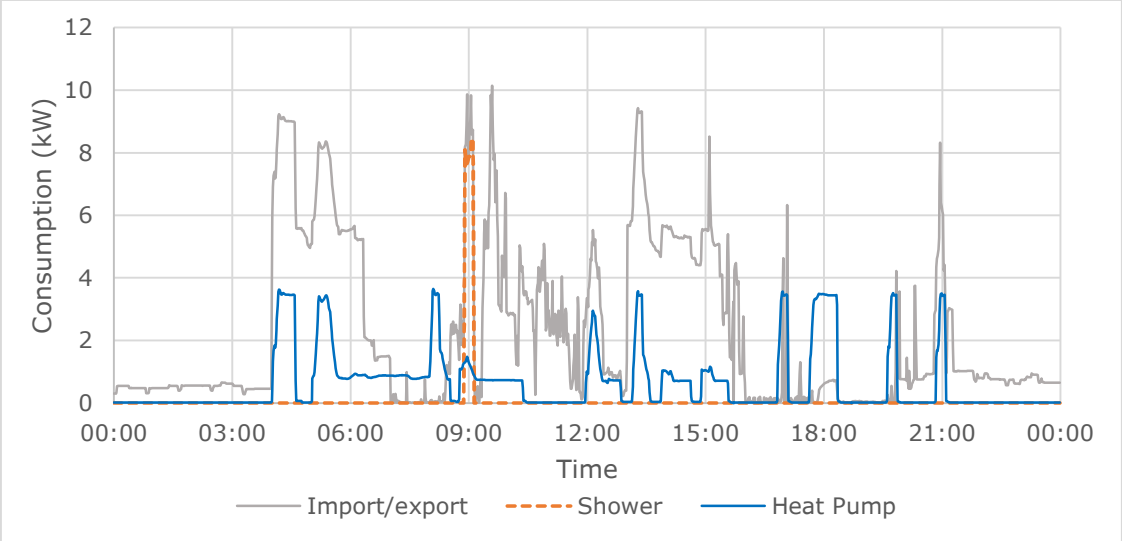

Figure 2.14 Electricity consumption of household B-03 on Sunday 29 Dec 2024 as measured by a Wibeee electricity monitor

Figure 2.14 is a plot of electricity consumption of household B-03 based on 1-minute data from a Wibeee electricity logger. The electric shower used 1.77kWh and the ASHP used 15.6kWh on 29 Dec 2024.

The household estimated they were saving about £10 a week due to periods of free electricity on a Sunday. EDF withdrew the free electricity offer from this household in mid-January 2025, perhaps because they had been losing money with this household. The household subsequently switched to Cosy Octopus.

Electric vehicle electricity tariffs

Household B-01 had an ASHP and 10kWh Alpha ESS battery fitted in an earlier project[14]. A 5.81kW solar PV system was installed in August 2023 as part of the current project. An installation fault was detected in November 2023, and this was resolved at the beginning of January 2024.

The household started to use an electric vehicle (EV) in February 2024 and switched tariff from Economy 7 to EDF Go Electric Overnight at the end of August 2024. Time-of-use EV tariffs have attractive off-peak tariffs, often for about five hours and a day rate only slightly higher than for a single-rate tariff. Unfortunately, at the time of writing, EV tariffs are restricted to households that have EVs and a charge point.

Code	Technology	Start date	End date	Grid import (kWh)	Cost Single rate	Cost E7	Cost EDF EV
B-01	ASHP + Battery	1 Aug 22	31 Jul 23	5,317	£1,276	£862	-
B-01	ASHP + PV + Battery	1 Jan 24	31 Dec 24	4,227	£1,014	£712	£616
B-01	ASHP + PV + Battery	1 Sep 24	31 Dec 24	1,729	£415	£291	£227

Table 2.15 Consumption and modelled electricity cost for household B-01 with an ASHP and battery on Economy 7 and an EV electricity tariff

The initial analysis period was from 1 Aug 2022 to 31 Jul 2023. The household had an ASHP and battery, with the battery charging overnight on Economy 7 off-peak electricity and discharging during peak rate periods. This helped power the home and the ASHP until the battery was discharged. The consumption during this period was 5,317kWh. The modelled cost on a single-rate tariff was £1,276 and was £862 on Economy 7.

The grid import fell by 1,090kWh to 4,227kWh in 2024 after the solar PV system was fully operational. Although the grid import fell, the household electricity consumption increased. There was additional household consumption of 1,353kWh in 2024 due to charging of the EV. The solar PV system generated 5,212kWh in 2024 and provided savings of 2,818kWh.

[14] Rogers and Hamer (2023), Making Heat Cheaper, Smarter and Greener, https://www.nea.org.uk/wp-content/uploads/2023/06/CP1438-Boxergy-NDH-full-report-16-Jan-22.pdf (Accessed 19 Feb 2025)

Electricity costs were modelled for 2024 using smart meter data. The cost on a single-rate tariff was £1,014 compared to £712 on Economy 7. Using EDF Go Electric Overnight tariff rates at the time of writing, the modelled electricity cost with five hours of off-peak electricity was £616. The household switched to EDF Go Electric at the end of August 2024 and the costs were remodelled for the period from 1 Sep 2024 to 31 Dec 2024. There was behaviour change from September with the household aiming to charge the EV overnight during the five hours of low-cost electricity. The grid import for the last three months of 2024 was 1,729kWh. The electricity cost on a single-rate tariff was £415. This fell to £291 on Economy 7 and was cheaper still on Go Electric at £227.

Figure 2.16 plots the average half-hourly grid import for household B-01 in June 2024 while on Economy 7 and in November 2024 while on the Go Electric tariff. The average daily consumption in November was 19.5kWh with 14.2kWh (72.9%) of this on the off-peak rate between midnight and 05:00. On average, the consumption rose after 16:30. This was due to the battery having fully discharged in the late afternoon on colder or less sunny days.

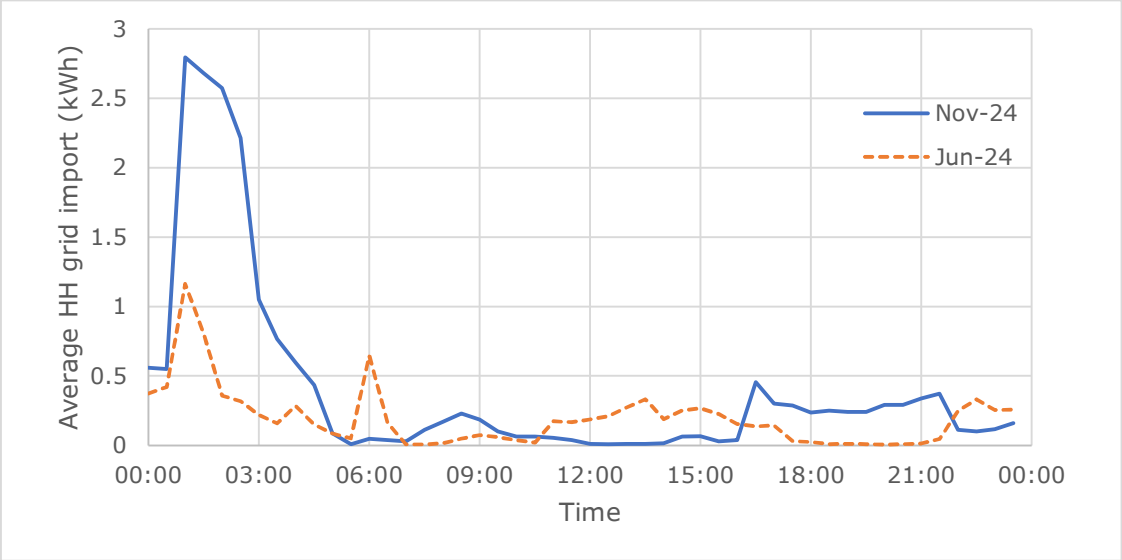

Figure 2.16 Graph showing the average half-hourly grid import for B-01 in June and November 2024 on Economy 7 and EDF Go Electric

The Alpha ESS battery charged overnight from 01:00. There was less overnight battery charging in June 2024 as the battery was set to charge to only 50% from the grid instead of 100% in November. Also, solar charging in June meant that the battery often still had more than 50% charge left at 01:00. On nights such as this, there was no grid charging overnight.

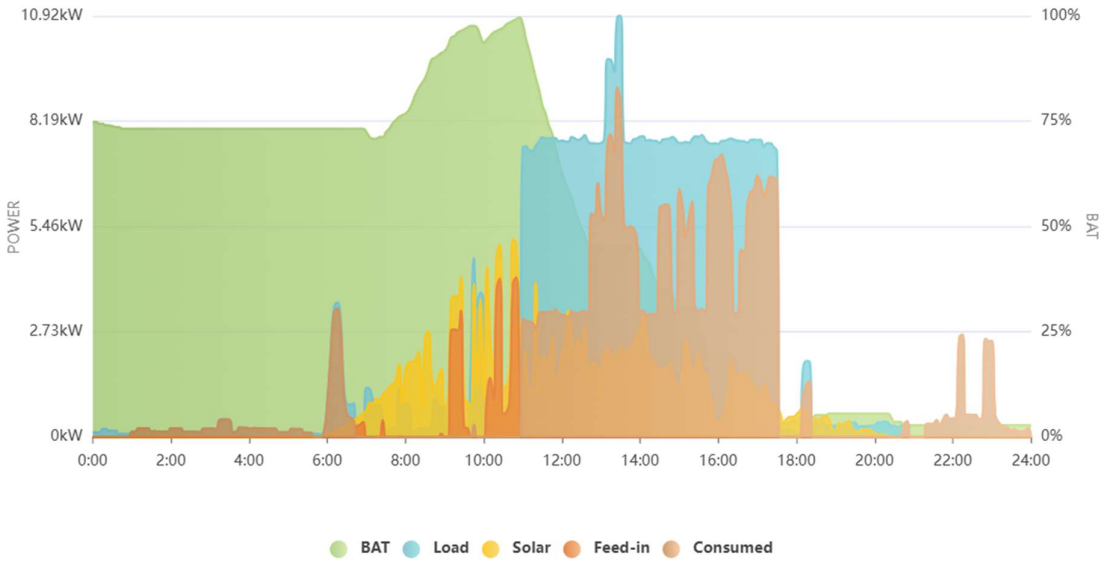

Figure 2.17 Power Diagram from the Alpha ESS battery portal for Household B-01 on 7 Jun 2024 on Economy 7 with EV charging in the middle of the day

Figure 2.17 shows a graph from the Alpha ESS battery portal on 7 Jun 2024. Here there was no overnight charging of the battery as the charge level was at about 73%, above the level of 50% for overnight charging in summer. There was a small peak in average grid import at 06:00 in June 2024. This was due to the ASHP starting to run before the battery began to discharge at 07:00.

With solar generation from about 06:00, the battery was fully charged by 10:55. The resident started charging the EV from 11:00 which was powered by a combination of the battery, solar PV generation and grid import. The resident finished charging the EV at 17:00. Over the time the EV was charging, the grid import was 32.1kWh out of a total of 37.3kWh in the day.

The rise in average half-hourly grid import in the middle of the day in June 2024 in figure 2.16 was due to the resident charging the EV in the middle of the day on around four days that month. Although this was during a peak rate period, some of the consumption was provided by the solar PV and battery. On 7 Jun 2024, there was 22.3kWh of solar generation with 18.7kWh of this used in the home. After switching to the Go Electric EV tariff, the resident typically charged the EV overnight on the off-peak tariff.

2.3 ASHPs with solar PV and Mixergy cylinders

Two households living in 1-bedroom bungalows had existing Daikin ASHPs on the 'Evaluating Solar PV with Electric Heating' project. They were part of an earlier study[15] as control properties C-03 and C-04. They had reference numbers AC-03 and AC-04 for the current project where solar PV was installed along with Mixergy smart hot water cylinders which had a solar diverter.

A 4.74kW solar PV system was installed on 8 Jun 2023 for household AC-03 with the panels split across an east-west roof. The Mixergy cylinder was operational from the end of February 2024 but had just over three weeks in 2024 where the CT-clamp was reversed, and the diverter was not working correctly.

Household AC-04 had a south-facing 4.15kW solar PV system installed in early October 2023. The system generated only about 100kWh less in 2024 than the system for AC-03. The Mixergy cylinder was also installed in late February. The CT clamp was not in the correct orientation for the diverter to heat the water from excess solar generation until late March 2024.There was also an installation issue which meant the Mixergy cylinder was only heated by the solar diverter and not the ASHP. This was not recognised and resolved until December 2024.

There were changes to the insulation for AC-04 during the project. The old cavity wall insulation was extracted; the cavity left to dry and new thermal bead insulation was installed during the winter of 2022-2023. By the time of the solar PV installation, external wall insulation had also been installed.

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
AC-03	ASHP	9 Mar 22	8 Mar 23	3,757	-	£902	-
AC-03	ASHP + PV Mixergy	1 Jan 24	31 Dec 24	2,314	27.0%	£555	£585
AC-04	ASHP	1 Aug 21	31 Jul 22	4,750	17.5%	£1,140	£1,280
AC-04	ASHP + PV Mixergy	1 Jan 24	31 Dec 24	2,452	21.1%	£588	£645

Table 2.18 Consumption and modelled electricity cost for households on the Evaluating solar PV with electric heating project with different measures

[15] Rogers and Hamer (2023), Making Heat Cheaper, Smarter and Greener, https://www.nea.org.uk/wp-content/uploads/2023/06/CP1438-Boxergy-NDH-full-report-16-Jan-22.pdf (Accessed 19 Feb 2025)

The electricity consumption of household AC-03 was already low before the new installations with a consumption of 3,757kWh. The household was on a single-rate tariff and no half-hourly electricity meter data was available for this period, so the cost on Economy 7 could not be assessed.

The grid import was 2,314kWh for AC-03 in 2024. This was 38.4% lower than the import of 3,757kWh in the pre-installation analysis period. The solar PV generation was 3,842kWh in 2024 with 1,628kWh of this used in the home. Most of the self-consumed solar generation was used by the Mixergy solar diverter with 1,089kWh used between 1 Mar 2024 and 31 Dec 2024. It is likely that most of the reduction in grid consumption was due to the solar PV installation.

The cost of the electricity on a single-rate tariff in the pre-installation analysis period was £902 for household AC-03. This fell to £555 in 2024. Using half-hourly consumption data, the cost on Economy 7 would have been higher at £585. The percentage off-peak consumption was 27%. This could have been raised to some extent as there was less consumption during the day due to the solar PV generation.

For household AC-04, during a pre-installation period of 1 Aug 2022 to 31 Jul 2023, the consumption was unusually high at 5,855kWh. This was due to the thermostat being kept consistently high because of the poor health of one of the residents during this period. A pre-installation period of 1 Aug 2021 to 31 Jul 2022 was used instead for this analysis with an import of 4,750kWh.

After the solar PV installation, the grid import decreased by 48.4% from the pre-installation analysis period to 2,452kWh in 2024. This large reduction in consumption was due to several factors. The solar PV generation in 2024 was 3,736kWh and 1,252kWh of this was used in the home reducing the grid import. There were also changes in insulation with improved cavity wall insulation and the addition of external wall insulation by 2024. There was also a reduction in occupancy by 2024 as well, with the number of residents falling from two to one and periods in late 2024 with the home unoccupied but with the heating on.

The percentage off-peak consumption for AC-04 was about 17.5% for the pre-installation monitoring period and this rose slightly to 21.1% after the installation. This rise in off-peak consumption could be due to the solar generation reducing the amount of consumption during the day but not the night. Although the household was on Economy 7, for the modelled tariffs, the costs were lower on the single-rate tariff due to the low percentage off-peak consumption. The modelled cost on a single rate fell from £1,140 to £588 while for Economy 7 it decreased from £1280 to £645.

Using half-hourly smart meter data, it was possible to model the electricity cost with the Cosy Octopus and EDF heat pump tariffs (table 2.19). It should be noted that since these households had not switched to one of these tariffs, there

was no behaviour change to shift consumption to off-peak periods and away from peak-rate periods. The households did not have a battery to charge or discharge at relevant times. They also did not alter the thermostat for the heating so that the heat pump ran more in off-peak times and less in peak-rate times. There was no shifting of cooking times away from peak-rate periods.

The grid import for household AC-03 in 2024 was 2,304kWh based on half-hourly data. This was 10kWh lower than from meter readings due to data loss with the half-hourly smart meter data. The modelled electricity cost for the recent version of Cosy Octopus with three off-peak periods was £565. This compares to £585 on Economy 7 and £555 on a single-rate tariff. The lowest electricity cost without behaviour change was with the EDF heat pump tariff. This had an annual electricity cost of £502 based on the tariff rate for South West England at the time of writing.

The same trends in costs were apparent for household AC-04. The electricity cost on Economy 7 was £1,280 in the pre-installation period and £645 in 2024. This was more expensive than with the three heat pump tariffs. The costs on the single-rate tariff were slightly lower than on Cosy Octopus. Again, the cost with the EDF heat pump tariff was the lowest.

Code	Technology	Start date	End date	Grid import (kWh)	Cost Old Cosy	Cost New Cosy	Cost EDF ASHP
AC-03	ASHP + PV Mixergy	1 Jan 24	31 Dec 24	2,304	£585	£565	£502
AC-04	ASHP	1 Aug 21	31 Jul 22	4,750	£1,239	£1,201	£1,065
AC-04	ASHP + PV Mixergy	1 Jan 24	31 Dec 24	2,452	£641	£616	£551

Table 2.19 Consumption and modelled electricity cost for households with ASHPs and no battery with different heat pump electricity tariffs

To maximise the cost savings with Cosy Octopus, it is important to change behaviour or use a battery to shift consumption away from peak-rate periods to off-peak periods. Household B-02 had a grid consumption of 3,939kWh in 2024 which was 60.6% higher than for AC-04. However, the modelled cost was only £561 on Cosy Octopus due to the battery helping shift 88.9% of the consumption to the low-cost Cosy rate. This illustrates the benefits of time-of-use tariffs for households where there can be a high percentage consumption during off-peak periods.

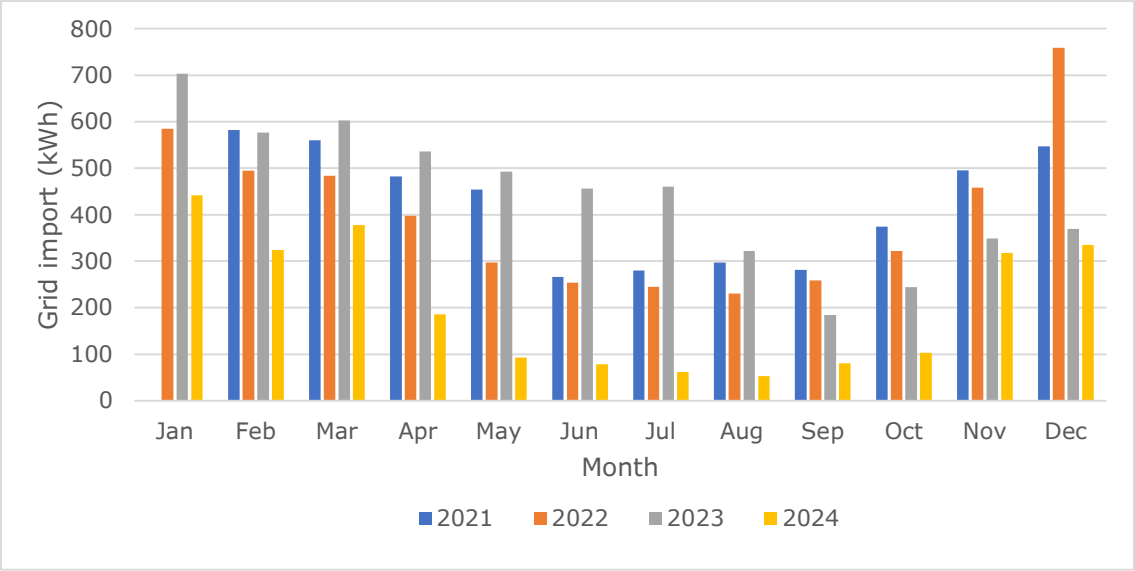

Figure 2.20 Graph of monthly grid import for household AC-04 with an ASHP

A plot of monthly grid import over four years is shown in figure 2.20 for household AC-04. As noted earlier, there was abnormally high consumption from Dec 2022 to Aug 2023 due to the health of one of the residents.

The solar PV system was operational from October 2023, and the external wall insulation had also been completed by that date. The impact of the solar PV system is particularly noticeable between April 2024 and October 2024. There were large reductions in the consumption for these months compared to previous years.

2.4 Storage heaters with solar PV and battery storage

Households T-03 and T-09 had Tesla Powerwall 2 batteries installed during an earlier project[16]. These were 3-bedroom homes with storage heaters and overnight water heating on Economy 7. Household T-03 had four residents and used large quantities of hot water while household T-09 had two residents.

[16] Rogers and Hamer (2018), Tesla Powerwall 2 battery charged using off-peak electricity, https://www.nea.org.uk/wp-content/uploads/2020/10/CP1139-TIF-REPORT_FINAL-25-04-19-v2.pdf (Accessed 20 Feb 2025)

A 4.74kW solar PV system was installed in mid-June 2023 across an east-west roof for household T-03. A south-facing 4.15kW solar PV system was installed for T-09 in late September 2023. Household T-09 also had the traditional storage heaters replaced by Dimplex Quantum high heat retention storage heaters soon after the solar PV installation. Both households had Mixergy cylinders installed in the first half of 2024 but there were interactions between the Mixergy cylinder and the Tesla battery, so the Mixergy solar diverter was of limited benefit.

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
T-03	NSH + battery	5 Apr 22	23 Apr 23	14,242	90.2%	£3,418	£2,025
T-03	NSH + PV + battery + Mixergy	1 Jan 24	31 Dec 24	11,978	81.0%	£2,875	£1,895
T-09	NSH + battery	1 Aug 22	31 Jul 23	10,025	94.9%	£2,406	£1,343
T-09	NSH + PV + battery + Mixergy	1 Jan 24	31 Dec 24	6,550	95.7%	£1,572	£868

Table 2.21 Consumption and modelled electricity cost for households on the Evaluating solar PV with electric heating project with different measures

Table 2.21 shows consumption and modelled electricity costs before and after the solar PV installations. The grid import for T-03 during a pre-installation monitoring period of just over a year was 14,242kWh. This was at a level that might be expected based on the Energy Performance Certificate (EPC) where the space and water heating demand was about 12,000kWh. Three storage heaters were typically used from October to April and there was a coal fire in the living room about three times a week in winter. The water heating demand was high with about three baths a week and 20 showers per week.

The percentage off-peak consumption for T-03 was 90.2% during the pre-installation period. This was higher than for most households on Economy 7 due to having both storage heaters and a 13.5kWh battery charging overnight. With such a high electricity consumption, the modelled cost during the pre-installation period was £3,418 on a single-rate tariff. It was much lower at £2,025 on Economy 7 due to the high percentage of off-peak consumption.

The grid import for T-03 was 11,978kWh in 2024. It should be noted that this was over 365 days instead of 383 days for the pre-installation period. Data from the Tesla app indicated the PV generation in 2024 was 3,759kWh with 2,447kWh of this used in the home. The percentage off-peak consumption fell from 90.2% to 81% in 2024. This may be partly because of the Mixergy cylinder. Due to interactions between the Tesla battery and the Mixergy solar diverter, the solar diverter was not able to use excess solar generation to heat water in the cylinder. With the high hot water use, there was regular heating of the cylinder by the immersion heater during peak-rate times.

The electricity cost for T-03 in 2024 on a modelled single-rate tariff was £2,875 while on Economy 7 it was £1,895. The Economy 7 cost was only £130 lower than during the pre-installation period with 383 days. The decrease in percentage off-peak consumption lowered the savings.

During a pre-installation period of 1 Aug 2022 to 31 Jul 2023, the grid consumption of household T-09 was 10,025kWh. For comparison, the space and water heating demand on the EPC was about 8,000kWh. In 2024, after the solar PV installation, the grid import fell by 3,475kWh to 6,550kWh. The solar PV generation over the year was 3,872kWh with 2,689kWh used in the home.

The percentage off-peak consumption remained very high and was 94.9% during the pre-installation period and 95.7% in 2024. This meant the modelled electricity cost on Economy 7 in 2024 was £704 lower than for a single-rate tariff. During the pre-installation period, the Economy 7 electricity cost was £1,295 and this decreased to £868 in 2024 after the solar PV was installed.

Figure 2.22 is a graph of monthly grid import over five years. Although there was variation in consumption between years, the monthly consumption decreased after the solar PV system was installed in late September 2023. The reduction is particularly apparent between December 2023 and September 2024. For the months March to September, the consumption in 2022 was 4,221kWh and this fell by 50.5% to 2,088kWh in 2024.

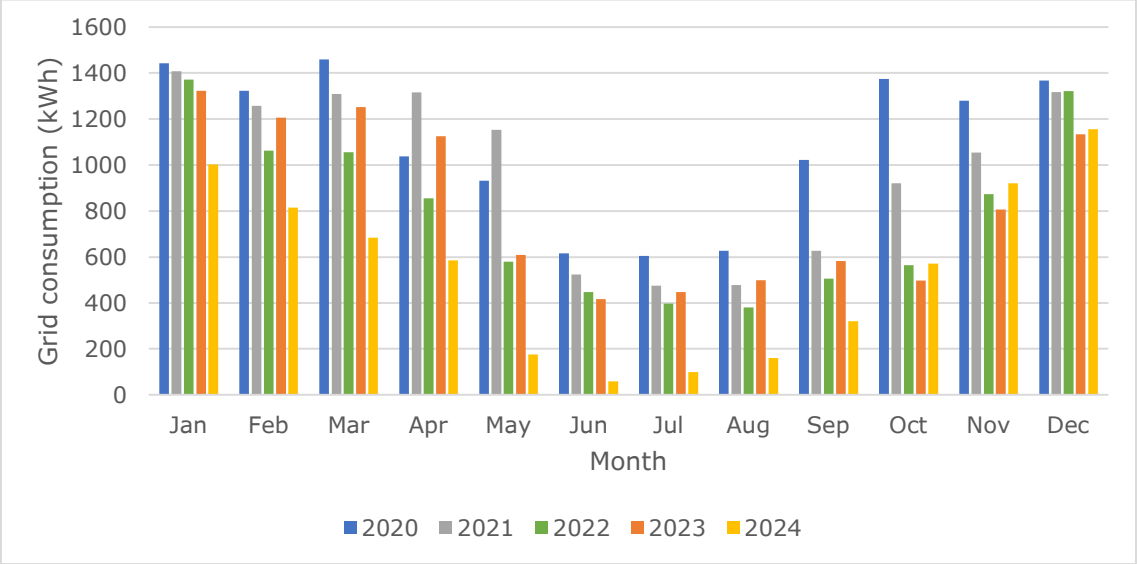

Figure 2.22 Graph of monthly grid import for household T-09 with storage heaters and a Tesla Powerwall 2 battery before and after installing solar PV

2.5 Storage heaters with solar PV and Mixergy cylinders

The consumption of two households with traditional storage heaters and panel heaters was analysed before and after a solar PV system was installed with a Mixergy cylinder and solar diverter. Household SH-01 lived in a 4-bedroom house. The space and water heating demand on the energy performance certificate (EPC) was about 9,200kWh. There were storage heaters downstairs but only the one in the hall was used. An electric fire was used to provide supplementary heating in the living room. The bedrooms had panel heaters.

Household SH-02 again had traditional storage heaters downstairs and panel heaters upstairs. They lived in a 3-bedroom property and the space and water heating demand on the EPC was about 8,600kWh. Only the living room storage heater was used downstairs during the winter with bursts of supplementary heating from an electric fire. The upstairs panel heaters were timed to come on between 04:00 and 06:00.

A 4.98kW solar PV system was installed for household SH-02 at the end of January 2024. The panels were split across the east-west roofs. The solar diverter for the Mixergy cylinder was operational from mid-February.

Household SH-01 had a smaller 3.89kW south-facing solar PV system. This was installed in mid-March 2024 but tripped for two weeks in March-April and one week in November 2024. The household was not controlling the Mixergy cylinder correctly until late June. This meant before that date, the cylinder when used had often been heating using peak-rate electricity. As a result, there was not a full year of consumption data with the solar PV, and the Mixergy cylinder for SH-01 had not been used as intended for two to three months.

Table 2.23 shows the grid consumption for households SH-01 and SH-02 along with modelled electricity costs on a single-rate tariff and Economy 7. The grid import for household SH-01 for a pre-installation period of a year was 9,465kWh, with 45.1% of the consumption on the off-peak tariff. This was quite low due to using a mix of a single storage heater and supplementary heating. The modelled electricity cost on a single-rate tariff was £2,272 and was £180 cheaper on Economy 7 at £2,092.

In 2024, the electricity consumption was 8,852kWh. Note that the solar PV system was operating for only about nine months of this period. The percentage off-peak consumption decreased from 45.1% to 33.7% in 2024. This may have been primarily due to incorrect use of the Mixergy cylinder for two to three months. During this period, the household turned the cylinder on and off with an isolator switch in the kitchen, thinking it was a boost button. This meant that the cylinder, when used, would often fully charge on peak-rate electricity.

The modelled cost for 2024 on a single-rate tariff was £2,124. On Economy 7, the cost was £2,133, higher than for the single-rate tariff. The percentage off-peak consumption of 33.7% was close to the value where Economy 7 became cheaper than a single-rate tariff for the tariff rates used. Despite the lower grid import in 2024, the modelled electricity cost for Economy 7 was higher than in 2023 due to the lower percentage off-peak consumption.

During a pre-installation period of about a year, the grid import for household SH-02 was 7,040kWh. Out of this, 42.8% of the consumption was off-peak. This was similar to the value for SH-01 which also used a mix of storage heaters and supplementary heaters. The modelled cost on a single-rate tariff was £1,690 and was about £100 lower at £1,585 on Economy 7.

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
SH-01	NSH	1 Jan 23	31 Dec 23	9,465	45.1%	£2,272	£2,092
SH-01	NSH + PV + Mixergy	1 Jan 24	31 Dec 24	8,852	33.7%	£2,124	£2,133
SH-02	NSH	27 Dec 22	23 Dec 23	7,040	42.8%	£1,690	£1,585
SH-02	NSH + PV + Mixergy	23 Dec 23	23 Dec 24	5,760	54.7%	£1,382	£1,176

Table 2.23 Consumption and modelled electricity cost for households with storage heaters with and without solar PV

The second analysis period for SH-02 was from 23 Dec 2023 to 23 Dec 2024 with the solar PV system installed at the end of January 2024. The grid import

decreased from 7,040kWh to 5,760kWh in the second analysis period. The percentage off-peak consumption increased from 42.8% to 54.7%.

This increase in percentage off-peak consumption may be partly due to how the household used the Mixergy smart hot water cylinder. In this case the household regularly fully charged the cylinder overnight, limiting any automated grid charging during peak-rate periods. The water was also heated by excess solar generation using the solar PV diverter on the cylinder. Another factor could be generation from the solar PV reducing the daytime consumption and increasing the proportion of the electricity imported between midnight and 07:00.

The modelled consumption on the single-rate tariff decreased by nearly £300 to £1,382 after the solar PV system was installed. On Economy 7, there was a reduction of over £400 in the modelled cost to £1,176.

2.6 Infrared heating panels with and without batteries

There were three households with infrared heating panels on the 'Evaluating solar PV with electric heating' project. All three households lived in semi-detached bungalows.

Households W-01 and W-02 originally had storage heaters, and these were replaced by a Wondrwall system combining infrared heating panels with solar PV, battery storage, a Mixergy cylinder and an intelligent home energy management system. The other household, IC-01 fitted their own infrared heating panels, and an equivalent solar PV system was installed along with a Mixergy smart hot water cylinder. Full details of the installations and the results from these properties are available in another report[17]. The results from household W-02 will not be discussed further here as they were atypical due to the household rarely using the heating and having low average room temperatures over the winter. This led to very low electricity consumption.

All the households had south-facing 5.81kW solar PV installations while the Wondrwall households also had a 6kWh battery. The Wondrwall households had external wall insulation (EWI) installed in about 2015. Household IC-01 had the old fibre cavity wall insulation (CWI) extracted during the winter of 2022-23. The cavity was left to dry out and thermal bead CWI was subsequently installed. During the spring/summer of 2023, EWI was also installed for IC-01. This was completed by the time of the solar PV installation at the end of September 2023.

Figure 2.24 plots the monthly grid import for household W-01 from the beginning of October 2022 to the end of December 2024. The household was away from home from mid-December 2022 to mid-February 2023 with perhaps just one storage heater still running. There was lower consumption than normal

[17] Rogers and Hamer (2025), Evaluating solar PV with electric heating with North Devon Homes: Wondrwall (in press)

during this period as a result. The Wondrwall system was installed during October 2023. The battery was set to charge overnight on off-peak electricity and help power the home and infrared heating panels during the day.

There were teething troubles initially and the household struggled with the controls for the heating system. This led to higher-than-normal consumption in the last couple months of 2023. After the Wondrwall system replaced the storage heaters, there was a reduction in off-peak consumption and increase in peak rate consumption during the heating season. There were several issues with the installation for the Mixergy cylinder. This meant the solar diverter for the Mixergy cylinder was not working as expected - heating water from excess solar PV generation - until early July 2024.

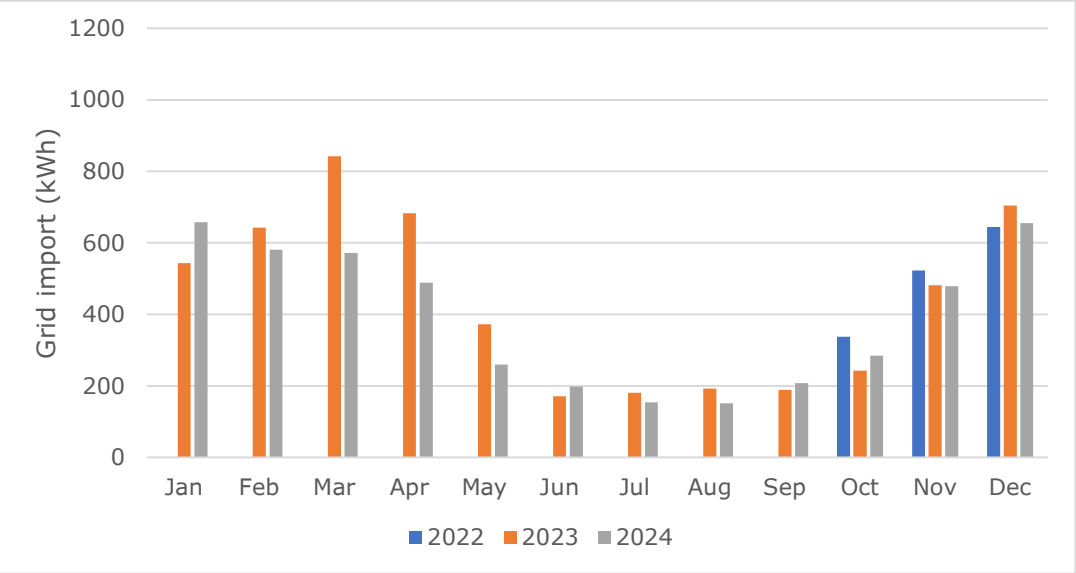

Figure 2.24 Grid import for household W-01 with storage heaters (Oct 22 to Sep 23) and with Wondrwall system (Nov 23 to Dec 24)

Household IC-01 fitted their own infrared heating panels and was control property C-01 in an earlier project[18]. External wall insulation had been fitted over the spring/summer of 2023 and the solar PV system was installed in late September 2023. The Mixergy cylinder was installed in late February 2024. The solar diverter for the Mixergy cylinder was not operating correctly until late March due to the CT clamp initially being fitted in the wrong orientation. The chart in figure 2.25 shows clear reductions in grid import from December 2023 to September 2024. Savings are not obvious in October and November 2024.

[18] Rogers and Hamer (2023), Making Heat Cheaper, Smarter and Greener, https://www.nea.org.uk/wp-content/uploads/2023/06/CP1438-Boxergy-NDH-full-report-16-Jan-22.pdf (Accessed 19 Feb 2025)

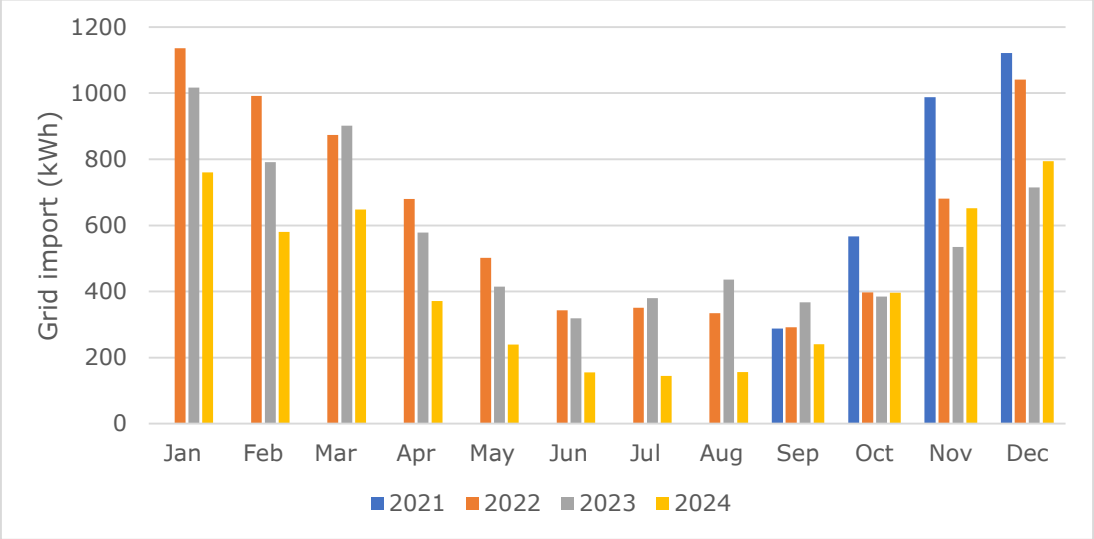

Figure 2.25 Grid import for household IC-01 with infrared heating panels and with solar PV, Mixergy cylinder and EWI (Oct 23 to Dec 24)

Code	Technology	Start date	End date	Grid import (kWh)	% off-peak	Cost for single rate	Cost for E7
W-01	NSH, EWI	1 Oct 22	30 Sep 23	5,320	87.4%	£1,277	£783
W-01	Infrared, EWI, PV, battery, Mixergy	1 Jan 24	31 Dec 24	4,686	69.5%	£1,125	£836
IC-01	Infrared	1 Jan 22	31 Dec 22	7,620	12.1%	£1,829	£2,125
IC-01	Infrared, PV, Mixergy, EWI	1 Jan 24	31 Dec 24	5,136	26.6%	£1,233	£1,302

Table 2.26 Consumption and modelled electricity cost for households with storage heaters with and without solar PV

Table 2.26 shows the grid import and modelled electricity costs for households W-01 and IC-01 before and after the installations. For household IC-01, the grid import with the infrared heating panels alone was 7,620kWh. There was only 12.1% of the consumption between 00:00 and 07:00. With such a low off-peak consumption, the electricity cost was cheaper on a single-rate tariff (£1,829) than on Economy 7 (£2,125).

After the installation of the solar PV, Mixergy cylinder and EWI, the grid import for household IC-01 decreased by 32.6% to 5,136kWh. The thermal comfort had

also improved between pre- and post-installation periods[19]. The percentage off-peak consumption rose from 12.1% to 26.6%. This may be due to a combination of lower grid consumption during the day due to the solar PV and overnight water heating by the Mixergy cylinder each night. The modelled cost on the single-rate tariff was £1,233 compared to £1,302 on Economy 7. The percentage off-peak consumption was still too low to make savings on Economy 7.

For household W-01 the grid import between 1 Oct 2022 and 30 Sep 2023 was 5,320kWh. This was likely to be lower than for a normal year due to the household being away from mid-December 2022 to mid-February 2023. The percentage off-peak consumption was high at 87.4% due to the majority of this consumption being from the storage and hot water cylinder charging overnight. This meant there were large savings on Economy 7 with a modelled cost of £783 compared to £1,277 for the single-rate tariff.

The grid import fell to 4,686kWh in 2024 after the installation of Wondrwall. This meant the modelled cost on a single-rate tariff decreased to £1,125. The percentage off-peak consumption was 69.5% for the year. Although the storage heaters had been removed, there was charging of the electrical battery and hot water cylinder overnight. The bathroom towel rail was left on for 24 hours a day as was the hall infrared heating panel during the heating season. These all contributed to a high percentage overnight consumption, but there was a reduction when compared with the storage heaters. This meant the modelled cost on Economy 7 was higher at £836. The consumption during the pre-installation period was lower than normal due to the period away, so it is likely that there would be savings on Economy 7 when comparing equivalent periods before and after installation. However, these savings might be small.

Household W-01 had significantly lower bills on Economy 7 than IC-01 had on a single-rate tariff. The battery was a major contributor to these savings primarily through grid charging overnight during the winter to help power the infrared heating panels during the day.

There are better tariffs than Economy 7 for the Wondrwall systems[20]. Wondrwall have found that Octopus has been willing to allow customers to switch to Cosy Octopus without having a heat pump. This allows them to heat their home at a cheap rate during three periods during the day. The battery is likely to be able to power them through the peak-rate period of 16:00 to 19:00. EDF has been considering widening eligibility for its heat pump tariff to other electric heating technologies. Wondrwall customers have struggled to switch to an EV tariff unless they have an electric vehicle. The system is also capable of running with Octopus Agile but the tariff could be too complex for many tenants.

[19] Rogers and Hamer (2025), Evaluating solar PV with electric heating with North Devon Homes: Wondrwall (in press)
[20] Wallis, C. (2025), Technical Support Manager, Wondrwall, Personal Communication (18 Feb 2025)

3. Conclusions and recommendations

3.1 Conclusions

This report investigated electricity tariffs for households with different electric heating technologies

- Electric storage heaters have traditionally used Economy 7 electricity tariffs, but residents are often dissatisfied with poor thermal comfort due to the heaters being cold by the evening
- Other time-of-use tariffs are starting to become available which can provide an afternoon charge period in addition to overnight charging
- These tariffs include Economy 10-type tariffs with fixed off-peak times and Snug Octopus which has an hour of afternoon charging at different times
- In the past, households with heat pumps have normally been on a single-rate tariff, but now specific heat pump tariffs are available
- These are normally time-of-use tariffs with two or more off-peak periods a day with 04:00-07:00 and 13:00-16:00 commonly off-peak times
- Households can either turn up the thermostat during off-peak periods or charge a battery to make savings
- Suppliers are starting to offer specialist tariffs for batteries – examples are Octopus Flux and EDF Empower Tracker with a low-cost period overnight for charging and a peak-rate period during the late afternoon when demand is highest
- Payments are available for solar PV export through the smart export guarantee; this can be a fixed non-zero rate or variable through the day
- It has been difficult for landlords to claim the smart export guarantee but a Good Energy pilot at the time of writing hopes to make this easier
- Electric vehicle (EV) tariffs currently have attractive rates with between five and seven hours of off-peak electricity and a day-rate only slightly more than for a single-rate tariff
- Suppliers are unwilling to allow customers to switch to EV tariffs without having an electric vehicle and charger
- There are type-of-use tariffs for EVs where the consumption by the EV is at a different rate and the charging times can vary based on wholesale prices

The Evaluating Solar PV with Electric Heating project installed solar PV systems for homes with ASHPs, storage heaters and infrared heating panels. These included homes with and without batteries. Electricity costs were modelled based on smart meter data from these properties while ignoring the cost of the standing charge.

Households that replaced storage heaters with ASHPs, batteries and solar PV saw significant reductions in grid import and electricity costs

- Earlier work showed that replacing storage heaters with a wet central heating system with an ASHP and battery led to reduced grid consumption and better thermal comfort
- Household B-05 had storage heaters in 2020, and the electricity import was 10,951kWh; the modelled cost of the electricity used was £2,088 on Economy 7
- After the ASHP and battery were installed, household B-05 remained on Economy 7 with the battery charging overnight and discharging during the day – thermal comfort improved but electricity import fell to 7,545kWh with the modelled cost on Economy 7 over £800 lower at £1,247
- With the addition of a 5.81kW solar PV system, the grid import for B-05 decreased to 5,354kWh with a cost of £875 on Economy 7
- The households with ASHPs, batteries and solar PV used 70 – 80% off-peak consumption which led to low costs on Economy 7
- The solar PV meant that on a sunny day in winter, the time the battery fully discharged was later in the day, sometimes as late at 23:00 instead of 16:00 or earlier
- In February, over the 16:00 to 19:00 period of peak demand, the average grid import for B-05 fell by 62.3% from 3.0kWh to 1.13kWh once the solar PV system was added to the battery
- Several of the households with ASHPs, batteries and solar PV switched from Economy 7 to heat pump tariffs
- The grid import for household B-02 with storage heaters was 9,505kWh with a modelled annual electricity cost of £1,694 on Economy 7
- After the storage heaters were replaced with an ASHP and battery there was an improvement in thermal comfort and the grid import decreased to 7,514kWh with a modelled cost on Economy 7 of £1,353
- Household B-02 had a 5.81kW south-facing solar PV system installed and switched to the Cosy Octopus heat pump tariff
- In 2024 there were savings of about 2,700kWh from the solar PV system; the grid import decreased to 3,939kWh
- Households on the heat pump tariffs benefited from two or more off-peak periods per day allowing the battery to charge twice a day, further reducing consumption during higher cost periods
- The electricity cost in 2024 for B-02 was £561 on Cosy Octopus with 88.9% of the consumption on the low-cost Cosy rate, 10.5% at the standard rate and 0.6% at the peak rate
- EDF offered some free electricity on a Sunday and behaviour change from one household led to average consumption on a Sunday in December being 12kWh higher than for other days of the week

Electricity suppliers offer attractive tariffs for households with electric vehicles. Households with ASHPs, batteries and solar PV could make greater savings with EV tariffs than with Economy 7

- The grid import of household B-01 with an ASHP and battery was 5,317kWh over a year with a modelled cost of £862 on Economy 7
- The household had a 5.81kW south-facing solar PV system installed in late 2023 and started using an electric vehicle in February 2024, switching to the EDF Go Electric tariff at the end of August 2024
- There was a reduction in grid import for B-01 to 4,227kWh in 2024; there was additional household consumption of 1,353kWh due to charging the EV, but savings of 2,818kWh from the solar PV
- The electricity cost in 2024 was modelled to be £712 on Economy 7 and £616 on the EV tariff with a switch to overnight charging from September

Two households in one-bedroom bungalows with ASHPs had solar PV systems and Mixergy cylinders with solar diverter installed

- Household AC-03 had a 4.74kW east-west solar PV system installed in the summer of 2023 and a Mixergy cylinder in February 2024
- There was a reduction in grid import for household AC-03 from 3,757kWh during a pre-installation period to 2,314kWh in 2024
- There were savings of 1,628kWh from the solar PV system with most of this used for water heating with the Mixergy cylinder
- The modelled electricity cost on a single-rate tariff during the pre-installation period was £902 and this decreased to £555 in 2024
- The percentage off-peak consumption for AC-03 in 2024 was 27% and the modelled cost on Economy 7 was higher than the single rate at £585
- Household AC-04 had a south facing 4.15kW solar PV system installed in October 2023 with a Mixergy cylinder in February 2024 where the diverter was operational from late March 2024
- There were changes to the insulation with external wall insulation installed by October 2023 under another funding scheme
- During a pre-installation period the grid import was 4,750kWh with 17.5% off-peak and a cost of £1,140 on single rate and £1,280 on Economy 7
- In 2024, the grid consumption for AC-04 was 2,452kWh with 1,252kWh of the savings from the solar PV system
- The percentage off-peak consumption for AC-04 was 21.1% in 2024, with a cost of £588 on single rate and £645 on Economy 7
- It was possible to model electricity costs on heat pump tariffs using half-hourly consumption data for these households
- Modelled costs for the EDF heat pump tariff were lower than on a single rate and on Cosy Octopus
- To achieve greater savings with Cosy Octopus there would need to be behaviour change, shifting consumption away from the peak-rate period

Households with storage heaters and batteries had a high percentage off-peak consumption which helped reduce bills

- Two houses with storage heaters and Tesla Powerwall 2 batteries had a high annual grid import of over 10,000kWh with over 90% of this off-peak
- Household T-03 had a grid import of 14,242kWh during a pre-installation period, with 90.2% off-peak and a cost on Economy 7 of £2,025
- T-03 had a 4.74kW east-west solar PV installation and Mixergy smart hot water cylinder but the solar diverter on the cylinder did not operate correctly which may have been due to interactions between the diverter and the battery
- There was a reduction in grid import for T-03 to 11,978kWh in 2024 with a cost on Economy 7 of £1,895
- The percentage off-peak consumption fell to 81% and this may have been due to the Mixergy cylinder reheating water during the peak-rate period
- The grid import of household T-09 was 10,025kWh during a pre-installation period with 94.9% of the consumption off-peak and a cost on Economy 7 of £1,343
- T-09 had a 4.15kW south facing solar PV system and a Mixergy cylinder installed; there were also issues with the solar diverter for this installation but not as significant as for T-03
- The grid import in 2024 decreased to 6,550kWh with savings of 2,689kWh from the solar PV and 95.7% of the consumption was at the off-peak rate
- The cost of the electricity on Economy 7 fell by £475 (35.4%) to £868

Households with storage heaters and panel heaters had a lower percentage off-peak consumption reducing savings on Economy 7

- Two households with storage heaters and panel heaters had solar PV and Mixergy smart hot water cylinders with solar diverters installed
- Household SH-02 had a 4.98kW east-west solar PV system which was installed at the end of January 2024
- During a pre-installation period, the grid consumption for SH-02 was 7,040kWh with 42.8% of the consumption at the off-peak rate
- The modelled pre-installation electricity cost for SH-02 was £1,690 on a single-rate tariff and £1,585 on Economy 7
- Over a second analysis period which included about 11 months with the solar PV, the grid import for SH-02 decreased by 18.2% to 5,760kWh, with 54.7% of the consumption at the off-peak rate
- The modelled electricity cost for SH-02 during the second analysis period was £1,382 for a single-rate tariff and £1,176 for Economy 7
- Household SH-01 had a south-facing 3.89kW PV system commissioned in mid-March 2024 but the system tripped for three weeks during the year
- In 2023, the grid import for SH-01 was 9,465kWh with 45.1% off-peak
- The modelled electricity cost for SH-01 was £2,272 on a single rate in 2023 and £180 lower at £2,092 on Economy 7

- In 2024, with the solar PV operating for about nine months, the grid consumption was about 600kWh lower at 8,852kWh with the percentage off-peak consumption falling to 33.7%
- The low percentage off-peak consumption was likely to be due to incorrect use of the Mixergy cylinder for several months which led to greater water heating at peak-rate times
- The modelled electricity cost in 2024 was £2,124 on a single-rate tariff but was higher on Economy 7 at £2,133 due to the low percentage off-peak consumption
- There was an increase in electricity cost on Economy 7 between 2023 and 2024 due to the decreased percentage off-peak consumption

Two households had storage heaters removed and Wondrwall systems fitted with solar PV, battery storage, infrared heating panels and a Mixergy cylinder. This was compared against a household with infrared heating panels that had solar PV and a Mixergy cylinder installed

- Household W-01 had a Wondrwall installation replacing storage heaters
- During a pre-installation period of a year, household W-01 was away for two months during the winter which reduced electricity consumption
- During the pre-installation period, the grid import for W-01 was 5,320kWh with 87.4% of the consumption off-peak
- The modelled pre-installation electricity cost was £1,277 on a single-rate tariff and £783 on Economy 7
- In 2024 after the Wondrwall installation, the grid import decreased by 634kWh to 4,686kWh but there was lower off-peak consumption at 69.5%
- The consumption overnight after Wondrwall was installed was due to grid charging of the battery, water heating and some overnight space heating
- The modelled electricity cost for W-01 in 2024 was £1,125 on the single-rate tariff and £836 on Economy 7
- Although the modelled Economy 7 electricity cost was £53 higher in 2024, the pre-installation analysis period included two months with the resident away; greater savings were likely with the Mixergy solar diverter operating correctly for a full year instead of six months
- Household IC-01 with infrared heating panels imported 7,620kWh in 2022, with 12.1% of this at the off-peak rate
- The modelled electricity cost was £1,829 on a single-rate tariff and £2,125 using Economy 7
- By 2024, a 5.81kW solar PV system with Mixergy cylinder had been installed for IC-01, along with external wall insulation
- The grid import decreased by 32.6% to 5,136kWh with 26.6% of this at the off-peak rate and 1,971kWh of the solar generation used in the home
- The modelled electricity costs in 2024 were £1,233 on a single-rate tariff and £1,302 on Economy 7

- Although IC-01 consumed only 450kWh more than W-01, the electricity costs were about £400-£500 more than W-01 on Economy 7 due to the low percentage off-peak consumption without a battery
- Households with infrared heating panels could benefit from smart tariffs such as those for heat pumps, but it would be necessary to have a battery or behaviour change to benefit from Cosy Octopus

3.2 Recommendations

- The benefits of specialist tariffs for different technologies can be used as an incentive to install a smart meter
- It is important that smart time-of-use tariffs for technologies will be available in the long-term, so households do not invest in technologies only to find their savings significantly reduced following a reduction in the range of tariffs offered
- There is dissatisfaction with the control, thermal comfort and running costs with storage heaters and alternative tariffs to Economy 7 with the ability to charge in the afternoon would be beneficial
- Significant savings are possible when adding a battery and time-of-use tariff to an ASHP and solar PV system
- While good savings are possible for an ASHP with battery with Economy 7, tariffs such as Cosy Octopus allow households to charge the battery twice a day which can increase the percentage consumption at the off-peak rate
- Households with a heat pump with no battery may save more with the EDF Heat Pump tariff with two off-peak periods and no peak-rate period
- There is a need to widen the availability of tariffs beyond specific technologies so more households with electric heating can benefit
- Households with infrared heating panels could benefit from heat pump tariffs and some have been able to switch to Cosy Octopus
- Battery manufacturers should enable users to charge/discharge the battery more than twice a day so they can gain more benefit from tariffs such as Cosy Octopus with three off-peak periods in the day
- There can be challenges setting a battery to charge and discharge at the optimum times for electricity tariffs with potential complications due to changes between BST and GMT in March and October
- Battery suppliers and electricity suppliers should investigate methods of simplifying this for users – this might be a code to enter when setting the battery charge/discharge times for a particular tariff
- With some battery systems it is necessary to manually set the level of grid charging – this can mean excess PV export or greater consumption at peak-rate times if not optimised
- More battery systems should use AI to predict the level of generation by the solar PV system and consumption by the household for the day ahead
- This would allow the level of grid charging to be varied each day, maximising the use of the solar generation

National Energy Action (NEA) is the national fuel poverty and energy efficiency charity. We've worked across England, Wales, and Northern Ireland for over 40 years, to ensure that everyone in the UK can afford to live in a warm, safe and healthy home.
We work together with frontline practitioners, companies, regulators and the government for customers in vulnerable circumstances to make positive changes.