Sunamp

EastHeat

Fuel Poverty Reduction: Heat Storage Innovation

Interim Report

Fuel Poverty Reduction: Heat Storage Innovation

Local Energy Challenge Fund (LECF) Phase 2, ref GCF056

Interim Report

Sunamp Ltd
1 Satellite Park
Macmerry
East Lothian

EH33 1RY

01875 610 001
info@sunamp.com

Contents

1 At a Glance

This is an interim report for the EastHeat project, which installed solar panels and trial heat storage batteries in housing association properties across Edinburgh and the Lothians. It was made possible with £3.2m of funding from the Local Energy Challenge Fund (LECF). The EastHeat project is on track, with initial projections targeting tenant savings of up to 20% on the part of their fuel bill which provides hot water (and space heating where heat batteries have been added to the heating system). Further analysis and testing is ongoing, and an updated report will be produced at the end of the project.

1.1 Project Objectives

The objectives of this project were to:

- Develop and implement local solutions to address fuel poverty, designed around the use of innovative heat batteries, paired with local renewable energy generation.
- Test the use of these systems across a range of different property types.
- Quantify any reduction in energy consumption, and the impact on tenants' fuel bills.
- Create a replicable model for social housing providers to meet the Energy Efficiency Standards for Social Housing.

The project worked across a range of different property types, from sheltered housing for older people to individual households. In each property type a heat battery was installed and paired with other local renewable energy production. The four main scenarios were:

1) Sunamp Heat Batteries installed in individual sheltered housing apartments and family homes with no gas connection, replacing electric heating and hot water – to reduce energy costs and improve alignment with off peak tariffs.
2) Sunamp Heat Batteries installed with Solar PV and heat pumps as required – to reduce the use of gas and electric heat and hot water systems in individual properties, delivering savings.
3) Replacing old (inefficient) electric hot water tanks with new efficient heat batteries.
4) An R&D 'Living Lab' with Sunamp Heat Batteries, CHP, Heat Pump, and mini district heating delivering a wet heating system – see *Section 6.3 The "Living Lab".*

The use of the heat batteries enabled Sunamp to create a direct link between *local* energy demand and *local* renewable energy production. The project demonstrates the benefit of local heat storage and the value of integrated on-site renewable energy solutions.

1.2 Achievements

1.2.1 Heat Batteries proven at scaled deployment

- Sunamp supplied 2042 of its innovative Heat Battery cells, providing 4.6 MWh of storage in 625 properties.
- Savings on hot water and space heating costs are being monitored in detail in 225 properties.
- Project configured as a large R&D Trial between Sunamp, Castle Rock Edinvar Housing Association (CRE) and East Lothian Housing Association (ELHA).
- Funded by £3.2M from Local Energy Challenge Fund plus £800K from partners.
- 404 homes with solar PV on the roof, which charges the SunampPV heat battery and leads to higher levels of self-consumption.
  - This is a subset of 850 solar PV homes that were funded through a separate "rent a roof "commercial project
- Install teams from Sunamp, CRE, Home Care, ELHA, R3, and Edison Energy.
- Installed in properties in Rural, Semi-Rural and Urban Settings.

1.2.2 Benefits to Tenants

The comfort surveys show that of the users:

- One third are engaged and delighted with their systems: the performance, savings and enhanced level of comfort;
- One third aren't aware of the heat batteries (a positive, seamless integration); and
- The remaining third know they have heat batteries but think it is costing them more (Measurements show this is not the case – some of the highest savings are in this group).
- Key benefits highlighted by participants are: Enhanced flow rate of hot water, rapid radiator warm up, and the environmental benefits.
- A number of users highlighted that their comfort has increased dramatically without them having to spend any more.

Factually we can state that:

- Every user has some saving on their fuel usage (gas or electricity) where PV is fitted along with the heat battery. Solar PV self-consumption has increased.
- In the majority of properties with solar PV and heat battery, between 55% and 63% of hot water is provided completely free of charge.
- Even in properties where the heat battery is just used to replace an existing electric hot water cylinder, a typical saving of £67/yr is realised – the heat battery has benefits whether used with renewables or not. This is driven by the extremely high energy efficiency of the heat battery, and (unlike the hot water cylinder it replaces) the heat battery has substantially lower heat losses per day.
- Much-needed storage space is freed up when the bulky hot water tank is replaced by a slimline heat battery.

1.2.3 Benefits to the Housing Associations

The Housing Associations took a forward-thinking approach by embracing this new heat storage technology. This has delivered significant benefits to them, including:

- The majority of their tenants are saving money;
- Reduced time and costs for their maintenance teams; and
- Improved heating & hot water system efficiency, which flows into SAP scores and supports their EESSH targets.

1.2.4 Benefits to Sunamp Ltd

This trial was the first step on the route to global impact. It demonstrated that Sunamp could make heat batteries at full production scale and that they could be installed easily with very low ongoing maintenance.

Sunamp has now produced its 3rd generation heat battery (the UniQ™ range) which incorporates the technical learnings from EastHeat and has delivered a more flexible, lower cost heat battery. This makes it even easier to provide quick solutions, which are smaller in size, whilst keeping the look and feel that the users enjoyed. The Sunamp UniQ Heat Battery is now 60-90% cheaper than the cheapest Li-Ion batteries on the market, per unit of energy stored.

1.2.5 Benefits to Scotland

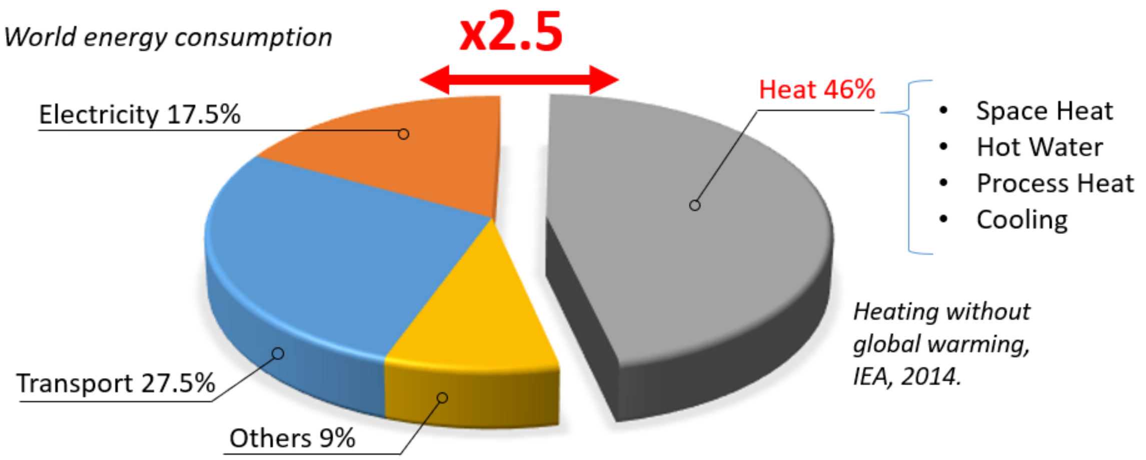
Renewable Energy Association recorded Eastheat as the biggest energy storage trial in the world, at the time. It continues to receive both local, national and international recognition. Delegations and companies from all over the world including Japan, China, US, Chile, Australia, and Germany, have been to visit the reference sites for this project.

2 Executive Summary

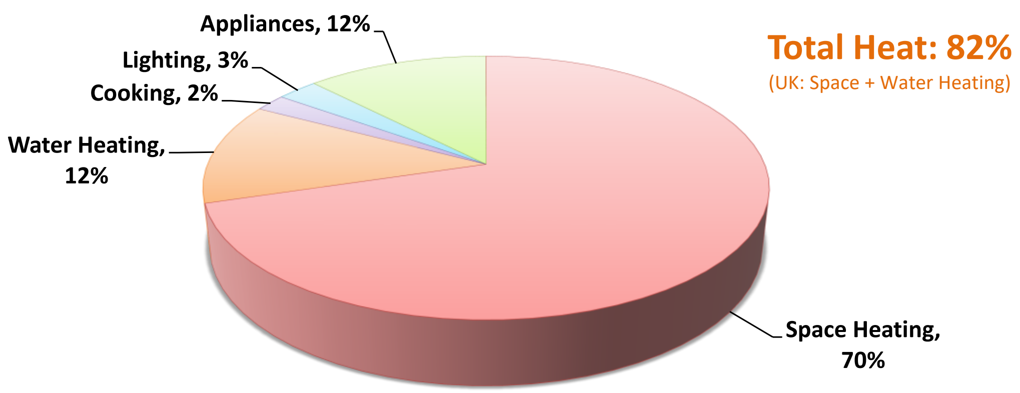
2.1 Context

Heat

At a national and global level, the energy required for 'heat' is significant. It makes up 46% of global energy use (and 51% of Scotland's total energy).



In energy storage, the main focus to date has been on *electric* storage, but globally a focus on *heat* storage could have a larger impact. At the domestic level it is even more pronounced – **heating and hot water account for 82% of the energy used in UK homes**. The remaining 18% is made up of electricity for cooking, lighting, and appliances.



Emissions and Grid Constraints

Scotland has made significant progress developing low-carbon renewable generation, and a variety of sources now feed the electricity grid. The carbon footprint of electricity has been falling steadily, and is now roughly the same as gas for central heating.

However:

- Electricity from solar panels is sometimes 'lost' to the grid – the sun shines through the day when people are often out working.
- Wind farms in Scotland are constrained – switching off when a) there's not enough grid capacity to transport the electricity to where it's needed, or b) there's not enough demand at that particular time to absorb all the wind generation.

Heat storage (at the point of use) combined with smart controls can help solve these problems by integrating with solar and renewables and capturing electricity when there's excess generation. Heat storage can also enhance the comfort and responsiveness of other renewable technologies such as air-source heat pumps.

2.2 EastHeat focus

Over a quarter of Scottish households were living in **fuel poverty** in 2016. Those in social housing are more likely to be affected than those in private housing, and this is where the EastHeat project is focussed.

Eastheat was created to address the following key objectives

- Develop and implement local solutions to address fuel poverty, designed around the use of innovative heat batteries, paired with local renewable energy generation.
- Test the use of these systems across a range of different property types.
- Quantify any reduction in energy consumption, and the impact on tenants' fuel bills.
- Create a replicable model for social housing providers to meet the Energy Efficiency Standards for Social Housing.

Out of these, 3 key questions emerged:

- **Is it possible to help those in fuel poverty by installing heat batteries alongside solar panels?**
- **How do people react to having next generation heat storage in their homes?**
- **Are there any benefits for the housing associations, in addition to direct tenant benefits?**

2.3 Delivering the EastHeat Project

The project was undertaken as follows:

Phase 1 (August 2014-March 2015): Initial application to Local Energy Challenge Fund, leading to selection of the project as a feasibility study and the formation of the phase 2 partners. Building of phase 2 application which was competitively judged.

Phase 2a (April 2015-March 2016): Contract negotiation, property selection, solution development and installation.

Phase 2b (April 2016-March 2019): Monitoring, analysis and support of install systems.

2.4 EastHeat Innovations

At the outset of the project Sunamp had deployed heat batteries in only a dozen homes (primarily working with air-source heat pumps) along with a number of protypes in the workshop. There were a number of key innovations required to deliver the project:

- Develop the heat battery into a white-good style appliance, with easy installation (this 2nd generation heat battery was used for the EastHeat project).
- Develop compatibility with other equipment such as electric flow boilers for central heating, Solar PV systems, and combi boilers. Combi boilers were particularly challenging as many are not designed to take preheated water.
- Create control systems to maximise energy and financial savings while delivering full control with minimum complexity.
- Develop manufacturing and installation systems to meet the tight project deadlines.

A number of key learnings were made through the EastHeat project, and these were fed into further R&D within the business. The latest 3rd generation heat battery – the UniQ range – is more compact, with better connectivity, lower cost, and is now available at full production scale to the market.

UniQ 3 **UniQ 6** **UniQ 9** **UniQ 12**

In a recent study, the Tesla Powerwall 2 was noted as leading the *electricity* side of energy storage. On *heat* side, Sunamp is now the market leader and has demonstrated that:

- The **Sunamp heat battery is now 50-80% cheaper than the Tesla Powerwall 2 electric battery**, per unit of energy stored.
- The Sunamp heat battery accelerated lifecycle testing has already performed **over 40,000 full charge/discharge cycles – the equivalent of 100+ operating years** – with zero failure and minimal capacity degradation, and the testing continues.
- The Sunamp Heat Battery (new UniQ range) gives better performance for lower price, is smaller and more compact, and has the flexibility to connect to all renewables. In electric properties, when paired with heat pumps, heating can be delivered at the price and performance of gas.

2.5 Key Findings

- The project is on track, with its initial projections targeting tenant savings of up to 20% over the life of the project.
- Where solar panels were connected to the heat battery, households received a significant amount of **free** hot water – the battery captured solar energy that would otherwise have been lost to the grid and avoided them having to buy as much fuel (gas/electricity) to make hot water.

- Replacing a hot water tank with a compact heat battery enhanced energy efficiency, reducing heat losses by up to 75%, saving money, and freed up much needed cupboard space.
- Old systems suffered from poor water pressure. The new heat batteries provide hot water at mains pressure, and tenant feedback was overwhelmingly positive.
- Adding a heat battery to an electrically heated home with PV allows it to be heated with nearly 100% off peak (low cost) electricity. The heat battery increased comfort by avoiding temperature fluctuations faced by tenants with older heating systems.
- The in-house maintenance teams of the Housing Associations and installers from the wider supply chain can easily be trained to install and maintain Sunamp Heat Batteries. The maintenance requirements are lower than conventional hot water cylinders.

2.6 Conclusions

2.6.1 Is it possible to help those in fuel poverty by installing heat batteries alongside solar panels?

The Conclusion from the EastHeat trial: **YES**

Evidence:

- For the majority of properties in this trial (1 and 2 bed properties with combi boilers and PV on the roof), between **55%** and **63%** of the hot water was supplied from Solar PV. This is 'free' hot water, and will reduce tenant bills, helping to alleviate fuel poverty.
- Solar PV consumption is significantly higher because of the Sunamp heat batteries.

Note: This is in no way reduces the amount of free solar PV electricity available for electrical loads (lights, appliances, phones, TVs etc.) The Sunamp heat battery only uses the excess which would otherwise have flow back to the grid.

Recommendation:

Local Authorities and Housing Associations seeking to reduce fuel poverty, who have already installed solar PV (e.g. under rent a roof schemes) on their housing stock, should follow the best practice of the EastHeat project and install heat batteries. This will provide free hot water to tenants in addition to the current benefit of free electricity from PV.

New-build properties with solar PV can benefit by the addition of heat batteries.

2.6.2 How do people react to having heat storage in their homes?

Two thirds of heat battery users in EastHeat have expressed either delight at the combination of bill savings, comfort, and "doing our bit for the planet", or have no issues with the seamless integration of the system. In general, the small footprint of the heat battery has either saved space (when replacing a hot water tank) or been small enough to easily fit into existing spaces. The lower heat losses and 55-63% free hot water are a real benefit to tenants.

The remaining third of tenants worry that they may be paying more, but evidence from this study shows that all of these properties are in fact benefiting from the heat batteries. Communication is key in informing tenants of the benefits they are receiving, and further dissemination work will be done through the remainder of the project.

2.6.3 Are there any benefits for the housing associations?

Key benefits:

- Easy to train their in-house installer or subcontractors.
- Low maintenance:
  - **no mandatory annual maintenance**, unlike combi boilers and unvented cylinders, which require annual maintenance by law every year along with the associated access issues.
  - **No legionella risk or testing** required (less than 5 litres of water held in the heat battery).
- **Compactness** frees up storage space, helping Housing Associations meet mandatory space standards.
- 3rd Generation UniQ™ Heat batteries are now **competitively priced** against conventional solutions, as Sunamp has worked on bringing costs down throughout the project.
- Sunamp has now established the benefits of heat batteries in terms of energy savings which flow through to **SAP scores** and the methodology to apply this in SAP software. This helps the housing associations meet their EESSH obligations.

2.7 Additional topics for final report

This is an interim report and the project will run for another year. A final report will be prepared to include an update on:

- Value for money and replicability;
- Linkages to demand side management and grid carbon intensity:
  - “Can we have it all?” Low carbon, renewable heat and low cost?
  - Electrification of heat – “When should we stop installing more gas combi boilers and make the move to all electric for heat?” Does a heat battery mean this can be done now?
- Influencing policy to improve SAP, EESSH, etc;
- Monitoring updates.

3 Introduction

3.1 Project Scope & Aims

The project: **“Fuel Poverty Reduction: Heat Storage Innovation”**

The aim of the project is to create a direct link between *local* renewable energy generation and *local* energy demand, using heat batteries. If more efficient use of different renewable technologies can be made, then there is a benefit for tenants as they seek to reduce energy costs.

The main objectives of the project are to:

- Develop and implement local solutions to address fuel poverty, designed around the use of innovative heat batteries, paired with local renewable energy generation.
- Test the use of these systems across a range of different property types.
- Quantify any reduction in energy consumption, and the impact on tenants’ fuel bills.
- Create a replicable model for social housing providers to meet the Energy Efficiency Standards for Social Housing.

The project worked across a range of different property types, from sheltered housing for older people to individual households for social rent. In each domestic property a heat battery was installed and paired with other local renewable energy production where possible.

The initial project scope focussed on thermal energy storage to provide *hot water*, but through discussion with the Housing Associations and the LECF project team, it was agreed that further benefit could be gained by expanding the scope to include thermal energy storage to provide *space heating*. An extension to the scoping phase was included and details presented in section 6.2

A high-level overview of the phases is shown below in section 3.5.

3.2 Project Name and Target Region

The project was named “**E**dinburgh **A**nd **S**urrounding **T**owns **H**eat **E**nergy **A**ction through **T**hermal storage” – EastHeat.

The target region was Edinburgh and the surrounding areas.

3.3 Project partners

3.3.1 Project Lead

Sunamp

Sunamp delivers market leading thermal energy storage to homes, businesses and communities around the world. Sunamp's unrivalled super-compact Heat Battery technology has been intelligently designed to provide a clean, efficient and cost-effective thermal energy storage solution.

Working with everything from gas boilers to solar and heat pumps, Sunamp Heat Batteries deliver cascades of hot water and highly responsive space heating with superb efficiency and proven savings of up to 75% on utility bills. This technology comes at an accessible price and offers limitless scalability for residential, commercial or industrial projects

Andrew Bissell, CEO, Sunamp Ltd.

Already a veteran technology entrepreneur having built and sold one of Scotland's most successful medical technology businesses, Andrew founded Sunamp in 2005. His aim was to develop an affordable and sustainable solution for heat energy storage for commercial and domestic markets. Sunamp Ltd is headquartered near Edinburgh and employs 28 staff in the UK and Europe

3.3.2 Partners

CASTLE ROCK EDINVAR
HOUSING ASSOCIATION

One of Scotland's leading housing associations, a Scottish Charity and part of the Places for People Group, Castle Rock Edinvar owns and manages 8,000 homes and works with over 8,000 customers across 8 local authority areas. As well as a strong business ethos, it is an ethically minded green organisation, tackling environmental challenges through their energy strategy.

Richard Jennings, Managing Director, Castle Rock Edinvar

Richard was appointed Managing Director in January 2017. He was previously Head of Property from October 2014 handling their capital investment and commercial activities. Before joining Castle Rock Edinvar Richard was Head of Development at East Lothian Council. Richard has strong public and private sector experience, having worked in local and central government, as well as for KPMG and PwC. Richard is a Board member of Volunteer Scotland and chair of the Audit and Scrutiny Committee.

elha.com
east lothian housing association

East Lothian Housing Association (ELHA) is a Scottish Charity founded in 1988 with the aim of providing good quality affordable housing within East Lothian. While their early work was in building new homes for rent, they now own and manage a wide variety of housing, all in East Lothian.

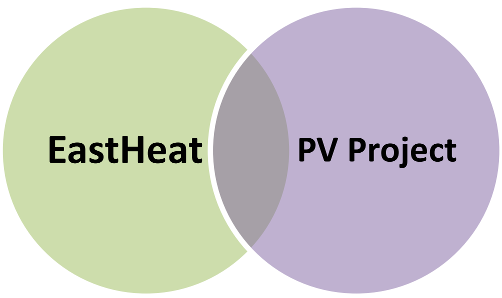
Martin Pollhammer, **Chief Executive, East Lothian Housing Association (ELHA)**
Martin, originally from Yorkshire, started his career as a housing officer working his way to chief executive, working for Berwickshire and Scottish Borders housing associations before taking the helm at East Lothian in 2006.

3.4 Project funding

The EastHeat project was funded by:

- The Scottish Government's Local Energy Challenge Fund. The LECF was launched in August 2014 to support large-scale low carbon demonstrator projects which show a local energy economy approach linking energy generation to energy use. This includes projects to develop innovative energy distribution and storage solutions that have an overall aim of creating local value and benefit.
- The Housing Associations and Sunamp provided match funding.

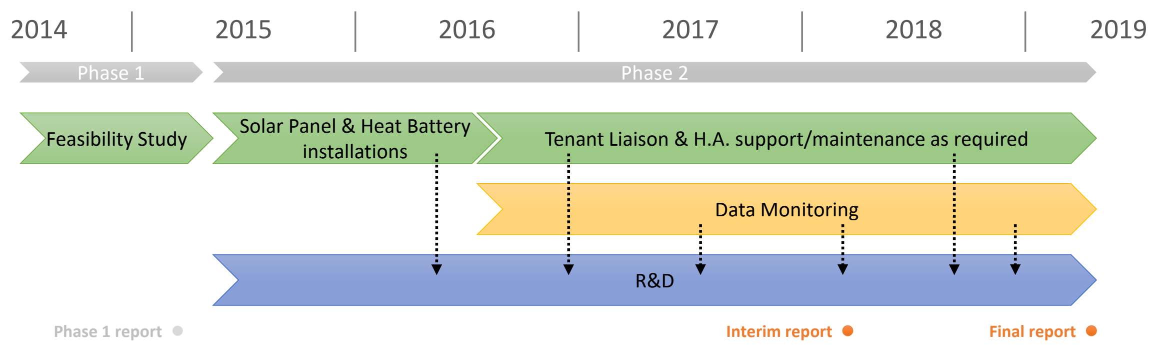
Parallel Solar Photovoltaic Project



The EastHeat thermal storage project covered 625 properties. A large subset of homes (>400) were also to be fitted with solar PV. The LECF mechanism could not fund deployment of PV, so these were delivered in a parallel and co-ordinated (but financially separate) project, using third party funding and the UK Government Feed in Tariffs. The PV project was not directly part of the LECF project, so will only be referenced tangentially in this report, but was a key contributor to the success and implementation of the EastHeat project.

The implementation and the installation of the solar PV panels was completed by Edison Energy, using a specialist workforce and Social Housing contract management. There is a dedicated reporting and control system for the solar PV project which supports the data for this project.

3.5 Phases



LECF Project phases

The LECF operated over two competitive phases - the Development Project (phase 1) and the Capital Demonstration Project (phase 2):

Phase 1 of the project was used to build partner relationships, identify sites where the proposed solution could be implemented, and scope out the technology mix, costs and benefits to social housing tenants. At the end of Phase 1, the project team presented their vision to the LECF committee, and was one of six successfully projects to secure support for Phase 2.

Phase 2 was the physical construction, procurement, and deployment of equipment, along with tenant liaison, technical support and maintenance, and data monitoring and reporting. It consisted principally of:

- Installing Heat Batteries and associated equipment into tenants' houses – this part is funded by LECF, and is the focus of this report.
- Installing solar PV panels onto the roofs of tenant houses (separate project).

This report is an interim report for phase 2 of the LECF/Heat Battery component.

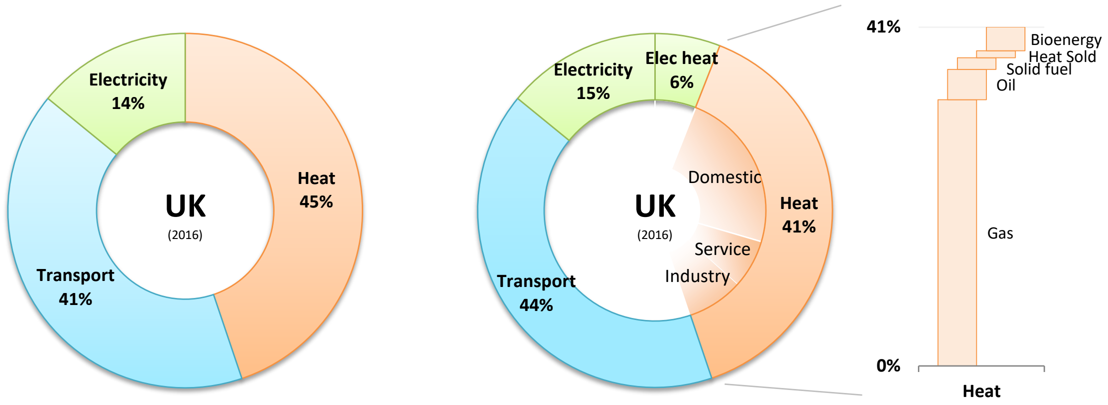
4 Context

4.1 UK Energy

There are two main energy networks feeding people's homes: the electricity network, and the gas network, and either of these can provide heat.

Across all sectors, *heat* makes up almost half of the UK's final consumption (45%, Figure 1), the vast majority of which is provided by burning gas. However, this will have to change as we move towards a low-carbon world.

Figure 1: Heat % of total energy (UK) [1]

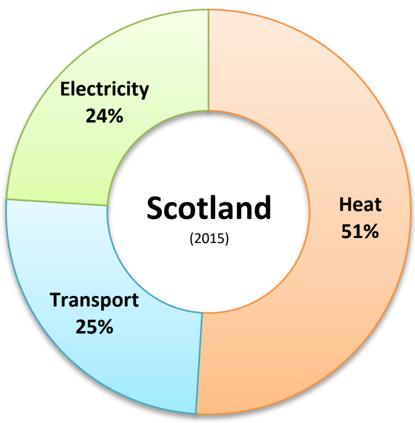


(with electric heating reclassified)

4.2 Scotland's 'Heat Trilemma'

Electrification can address many of the challenges faced in the heat market.

Figure 2: Heat % of total energy (Scotland) [2]



1. Reducing Emissions – Heat is estimated to be responsible for 47% of Scotland's greenhouse gas emissions.

2. Costs & Funding – Scotland spends £26bn annually on heating and cooling.

3. Fuel Poverty – around 27% of Scottish households are in fuel poverty.

"A largely decarbonised energy system by 2050, which meets our climate change targets, can be achieved in a number of ways…"

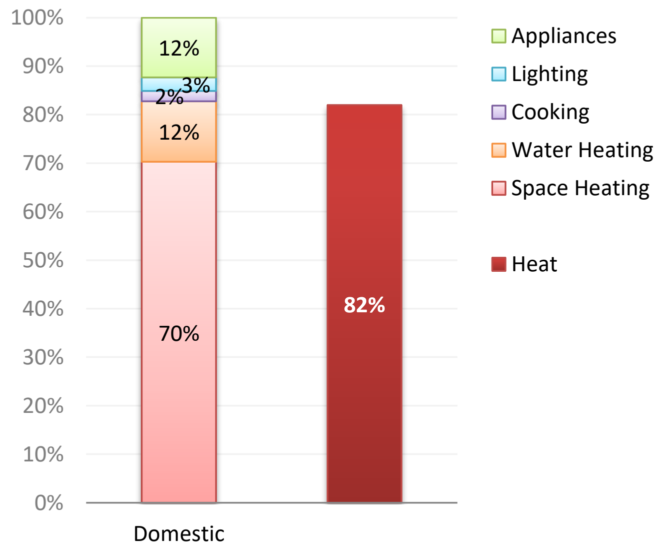
"A greater proportion of both heat and transport demand is likely to be met by electricity. This would allow the continued growth of low carbon electricity generation, combined with technologies such as smart storage heaters and heat pumps, to provide highly efficient ways of delivering low carbon end-use space and water heating. However, the uptake of electric heating and transport on a large scale would place extra pressure on the electricity system, and on the network's ability to generate, store and deliver the capacity necessary to meet peaks in demand."

– Scottish Energy Strategy 2017 [3]

4.3 Domestic homes

Heating and hot water accounts for 82% of the energy used in UK homes [4], with electricity used for cooking, lighting, and appliances making up the remaining 18% (Figure 3 below).

Figure 3: Domestic energy breakdown



If energy storage is to be implemented, it seems sensible to store that energy as heat – the way it's likely to be used.

4.4 The Need for Energy Storage

In the electricity grid, there is increasingly high penetration of wind and solar plants ("intermittent renewable generation") which cannot be turned up and down on demand. At the same time, a large reduction in traditional coal and gas thermal generation (controllable "dispatchable power") has been seen across the UK, and includes the closure of Longannet and Cockenzie in Scotland's central belt. The electricity grid requires that demand and generation are balanced second to second, and this is increasingly difficult as the generation mix shifts towards intermittent sources. Energy storage could help, and technologies generally focus on storing energy as *electricity* or *heat*.

4.4.1 Electric Storage

Electrical energy storage in the form of pumped hydro has been widely used for many years. Lithium ion batteries in the electricity network, or within the home ("behind the meter"), are an emerging option but still face a number of barriers:

- Li-Ion batteries are currently high cost, with low lifecycles. Mass deployment is not yet cost effective although early adopters are emerging and trials are ongoing.
- Demand Side Management (DSM) control systems need to be developed. These are required to provide power to the home when the grid is under-supplied with renewable electricity, and to charge from the grid during times of over-supply (e.g. when the wind is blowing strongly at night).
- Fair business models for domestic users don't yet exist. These need reward everyone: householder, bill payer, battery owner, Distribution Network Operator (DNO), electricity supplier, renewable energy generator.

Final domestic energy consumption from *electricity* is a small proportion of total energy consumption, with the UK domestic average estimated at 3,800 kWh p.a.[5]

4.4.2 Heat Storage

By comparison, UK average gas consumption is estimated at 15,000 kWh p.a.[ibid], which ends up being delivered as *heat*. There is a much greater opportunity to use heat stores for mass deployment and grid balancing.

Domestic homes already have some energy storage, but it is old technology and largely inefficient. For example, night storage heaters and hot water tanks store *heat*. There are a very limited number of domestic *electric* batteries although the market is expanding.

Old-tech heat storage is already widely deployed in two main ways:

- **Storage heaters** provide space heating by charging in off-peak times, using electricity at lower cost per kWh (typically overnight Economy 7). The drawback is they are quite bulky, and conventional units are poorly insulated. As a result, they often overheat homes in the morning, lose heat through the day, and don't have enough heat left by the evening. This requires householders to buy expensive peak-rate electricity to top up their heating in the evening, or just stay cold. This lack of control and high running costs is widely reported. Modern "high heat retention" storage heaters have improved on this somewhat, but there is only one supplier and costs are typically high.
- **Hot water cylinders** are used in many homes and are either charged by electrical 'immersion', or by a system boiler using gas, LPG, or oil. Older units are poorly insulated and suffer from high heat losses, and may develop leaks over time.

Heat batteries were developed to reduce the heat loss issues, provide higher levels of control and performance, and allow heat storage to be added in very compact spaces. All-electric solutions "beyond the combi" can start to make inroads:

- Dealing with the intermittency in the grid;
- Enabling more renewable energy uptake;
- Delivering on the Renewable Heat targets;
- Providing all-electric homes with a viable alternative to gas;
- Enhancing the use of domestic solar PV systems;

- Making efficient, cost effective heating systems.

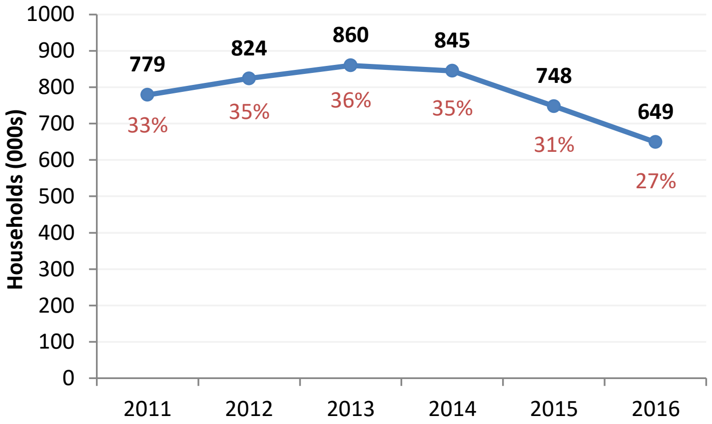
Around half of UK homes have combi boilers [6] and therefore no heat storage as they receive on-demand hot water. While these are convenient and easy to install wherever the gas grid is present, they can be under-sized, resulting in low hot water flow rates – this is the reason that most larger homes have a hot water cylinder. In addition, the fossil fuels burned are a major contributor to climate change. Therefore, a strategic policy objective in decarbonisation is to increase the amount of heat storage, which the growth in combi boilers diametrically opposes.

In the shorter term, heat batteries can be combined with combi boilers to deliver lower carbon and lower cost hot water by using spare electricity from solar PV to provide free hot water and displace fuel use in the combi.

4.5 Fuel poverty

In 2016, over a quarter of Scottish households were living in fuel poverty (649,000 out of the 2.8m households: 27%) [7] Progress is being made, but there is still a long way to go to meet the Scottish government's target of eradicating fuel poverty completely [8].

Figure 4: Households in Fuel Poverty, Scotland



Those living in social housing are more likely to be in fuel poverty than those in private housing. Older people are particularly at risk. This allowed EastHeat to focus on working with social landlords, and the project specifically included some homes for older or vulnerable people.

With austerity and pressure on all government budgets, savings made on energy accrue directly to those most in need, and could have a huge impact on the economy.

4.6 Social Landlords

Under the Energy Efficiency Standard for Social Housing (EESSH), social landlords have a duty to address the energy efficiency of their stock and to achieve statutory targets by 2020. Typical solutions include condensing boilers, double/secondary glazing, heating controls, storage heaters, loft insulation top-up, floor insulation, compact fluorescent lighting, and external solid wall insulation.

The EastHeat project goes a step further. By integrating renewable generation with compact heat energy storage (Sunamp Heat Batteries), the aim is to maximise the efficiency and use of on-site energy production, for the benefit of those individuals and families most in need.

Joan outside her house in Whitecraig, one of the ELHA properties. Joan received solar panels and a Sunamp Heat Battery. She has her existing gas combi boiler. Joan and her Sunamp Heat Batteries have been featured on both an STV and BBC report, and she is delighted with her new system.

5 The Technology

Sunamp has developed a ground-breaking, highly innovative heat storage system, packaged into modular Heat Batteries.

5.1 History of development

Sunamp has been developing its technology for over 10 years, in collaboration with the University of Edinburgh School of Chemistry. The aim is to disrupt the hot water cylinder market with a better, smaller, more efficient heat store that fits beautifully into small, modern living and working places.

5.2 How does the Sunamp Heat battery work?

One of the key innovations in the Sunamp Heat Battery is the Phase Change Material (PCM). This is a substance which melts and solidifies at a certain temperature, in this case 58°C.

When the battery is charged, heat or electrical energy is directed into the material which causes it to warm up. As it reaches the 'phase change' temperature of 58°C, it starts to melt from solid to liquid. This melting requires a huge amount of energy, so the battery can absorb a large amount of heat in this way.

When cold water is passed through the battery, the Phase Change Material starts to cool from liquid to solid again, and a large amount of energy is released. This energy is transferred into the freshwater and heats it up almost instantaneously as it passes through, in the same way that a gas combi boiler heats water instantly.

5.3 What is a Sunamp Heat Battery?

A high-powered, high flow-rate heat exchanger is immersed in phase change material and encapsulated in a red moulded, polypropylene cell. (Cold batteries use a blue cell.)

The red cell is surrounded by non-flammable vacuum insulation panels. These offer superior insulation, in minimal space. As a result the *whole* range is ErP A+, with regulatory and energy efficiency benefits.

Finished in a cuboid, white powder-coated aluminium case, which offers pipework knockouts on any face for very easy installation.

Our new factory enables us to ramp up production fast.

Very reliable, safe. Non toxic, non flammable. 40,000 cycle life already proven (>50 years of use).

5.4 Benefits

The Sunamp Heat Battery has a number of characteristics that make it an excellent replacement for traditional hot water tanks (thermal store) as well as other applications:

- It can be **charged from a variety of sources** – including electricity (from Solar PV, or off-peak mains electricity) or directly with heat (from ASHP [i], GSHP, Solar Thermal, or other heat sources).
- It delivers **fast-flowing hot water on-demand**. Water is heated instantly at high power (up to 30kW) and high temperature, and blended via a thermostatic mixing valve to a selectable temperature between 35-55°C. This can also help reduce scald risk.
- It's **very compact** – smaller than a slimline dishwasher – and can be floor mounted, fitted in a small kitchen unit, in a cupboard or in the garage. The technology enables it to store four times more energy than hot water tanks for a given volume of material, and this compact size could free up a cupboard where a traditional hot water tank would have been. If it's located nearer the tap it can also reduce the time taken to provide hot water.
- Hot water is at **mains pressure** – rather than the slow dribble from many hot water taps. UniQ heat batteries have a flow rate up to 24 L/min and equivalent power up to 30 kW of instant hot water heating.
- It's **long lasting** – there are units which have been charged and discharged over 40,000 times, the equivalent of over 100 years daily usage, without a single failure or degradation to the Phase Change Material (PCM).
- **Lower heat losses** than a traditional hot water tank – saving money and CO_2.

---

[i] Air Source Heat Pump (ASHP), Ground Source Heat Pump (GSHP)

- There's **no water to leak** – the PCM material is naturally self-sealing in the event of a puncture.
- It's **safe** – the PCM material is inorganic, non-toxic, and salt-based.
- **No legionella** risk assessment required in the UK – the Heat Battery doesn't store hot water directly, it stores energy and heats the water on demand.
- Avoids the annual inspection and service **required for unvented cylinders**.
- It **can help with grid balancing** – by charging up in off-peak periods, it shifts load away from peak periods and helps reduce the strain on the electricity system.

5.5 Product and Company Certifications

5.5.1 Sunamp Certifications

Sunamp Ltd has achieved the following International and UK quality certifications. These certifications monitor and improve quality systems within the company. They are audited annually and recertified every three years. These certifications are essential when working with larger organisations e.g private house builders, and in the public sector e.g. Housing Associations.

Sunamp achieved the following certifications in 2014:

- ISO 9001:2015- Quality Management
- ISO 14001:2015 – Environmental Management
- OSHAS 18001:2007 – Health and Safety

Whilst the Quality and Health and Safety standards are critical in the running of the business the Environmental Management illustrates Sunamp commitment to sustainability

5.5.2 Sunamp Product Certification

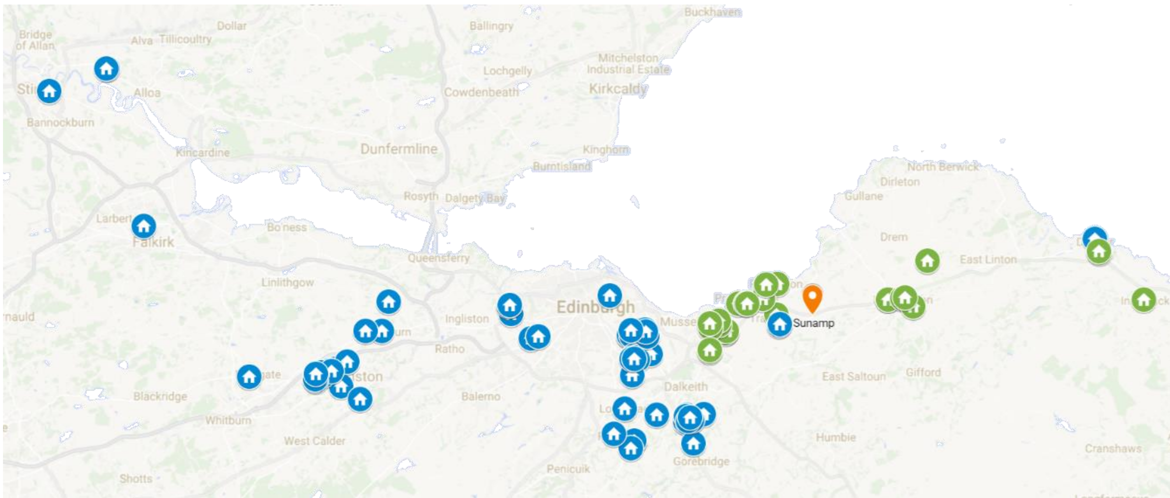
Sunamp had all product certification required for installation in domestic dwellings prior to installation.

Sunamp achieved the CE mark for all products installed under EastHeat. This included: Safety, Low Voltage Directive (LVD) and Electromagnetic Compatibility (EMC) for the heat battery products e.g. SunampPV and its controller. In addition, compliance with the water regulations, including Water Byelaws 2004 Scotland, was established by KIWA in consultation with the Water Regulations Advisory Scheme (WRAS) Technical Committee.

6 Property Types & Locations

The EastHeat project installed Sunamp Heat Batteries into properties managed by Castle Rock Edinvar (CRE) and East Lothian Housing Association (ELHA). A mix of properties types and locations were selected for this phase of the project – see Figure 5 below.

Figure 5: Map of installed locations (groups of properties)



Key: CRE properties ELHA properties NB Multiple properties in each location.

6.1 Number of Properties

There are 625 properties in the EastHeat project, with installations in a variety of flats, houses and bungalows, ranging from one to four bedrooms. There was a mix of gas and electrically heated properties, and many of them had solar PV. A full breakdown is noted in Table 1 and Table 2 below.

There are a number of properties where data has been collected, manually or using the GSM network. In some cases, data collection has proved impossible due to poor cellular network coverage, but the number of operational and reporting systems was more than sufficient to meet the project's objectives. 225 properties with usable data are included in the analysis – see section 7 (Data Methodology) and 8 (Results: Monitoring Data).

Table 1: EastHeat Property Count, by Property Type

	Bedroms: 1	2	3	4	--	Total Properties
Flat	181	49		1	4	235
Bungalow - Mid-terrace	12	19				31
Bungalow - End-terrace	10	8	1			19
Bungalow - Semi-detached		24	3	1		28
Bungalow - Detached		3	2		1	6
House		34	62	6		102
House - Mid-terrace		16	44	6		66
House - End-terrace		14	29	1		44
House - Semi-detached		31	49	6		86
House - Detached	1		1			2
--		1			5	6
Total Properties	**204**	**199**	**191**	**21**	**10**	**625**

Table 2: EastHeat Property Count, by Heating Type & Solar PV

	Heating type: Elec.	Gas	District Heating	--	Total
Flat	164	3	68		235
Bungalow - Mid-terrace		31			31
Bungalow - End-terrace	1	18			19
Bungalow - Semi-detached		28			28
Bungalow - Detached		6			6
House		102			102
House - Mid-terrace	4	62			66
House - End-terrace	2	42			44
House - Semi-detached	13	73			86
House - Detached		2			2
--		5		1	6
Total	**184**	**372**	**68**	**1**	**625**

	Solar PV: Yes	No	--	Total
Flat	17	216	2	235
Bungalow - Mid-terrace	31			31
Bungalow - End-terrace	18	1		19
Bungalow - Semi-detached	28			28
Bungalow - Detached	6			6
House	102			102
House - Mid-terrace	66			66
House - End-terrace	44			44
House - Semi-detached	86			86
House - Detached	2			2
--	4		2	6
Total	**404**	**217**	**4**	**625**

6.2 Types of Installation

To fully test the thermal energy storage, a number of different solutions were developed for this project, depending on whether the properties were supplied by gas or electricity, whether solar PV panels were installed on the roof (in which case they were connected into the Sunamp Heat Battery), and what type of heating system was fitted.

All properties received one or more Sunamp heat batteries, and in some properties, there were additional interventions as shown in Table 3 below.

Table 3: Property Count by Heating type / Solar PV

	Before		After				Total Properties	with Monitoring Data
group	Heating	HW	Heating	HW	Solar	Locations		
DH1	Electric Night Storage	Electric Tank	Gas boiler + HW buffer tank → **D.H. direct feed**	→ D.H. → **indirect heat exchanger**	-	Newcarron Court (CRE) (the "Living Lab")	**28**	phase 2
DH2			CHP + ASHP + Central heat battery → **D.H. direct feed**	→ D.H. → **indirect heat exchanger**	-			
DH3			Gas boiler → **D.H. direct feed**	→ D.H. → **Local heat batteries**	-			
DH4						Salisbury View (CRE)	**40**	27
E1	Electric Night Storage	Electric Tank	*Unchanged*	**Heat Battery**	-	Harrismith Place (CRE) Lauderdale House (CRE)	**37**	26
E2			*Unchanged*		**PV**	Bankfoot (ELHA) Manse View (ELHA) Mansefield (ELHA)	**19**	8
E3	Wet electric + E10 meter		Wet Electric + E10 + **Heat Battery** ("Mini-stack")		-	Balfour Court (CRE) Hunterfield Terrace (CRE) Ross Glen Court (CRE)	**112**	27
E4					**PV**	Osborne Court (ELHA)	**16**	4
G1	Gas Combi	Gas Combi	*Unchanged*	**Heat Battery** (pre-feed → gas combi)	**PV**	Various (ELHA / CRE)	**371**	133
*			*Other*	**Heat Battery**	*	*	**2**	-
						Total	**625 properties**	225 properties

** Other/Unclassified*

Notes:

- All properties received at least one new Sunamp Heat Battery for hot water – either 4.5 kWh, or 9.0 kWh for larger properties. Old hot water tanks were removed.
- In some properties (E3 & E4) the heating systems were changed – flow electric boilers already present were supplemented by a heat battery. The radiators are now warmed on demand by energy from the heat battery, which is charged with off-peak electricity (saving the tenant money).
- For properties with gas (G1), the heat battery was integrated with the existing combi boiler. Hot water flows from the heat battery through the combi boiler directly to the taps, and is topped-up with gas if the heat battery becomes empty.
- Many of the properties also had solar PV fitted. In a typical solar PV installation, only a small amount of electricity is actually used by the household. This is because most people are out during the day when the sun is shining and the solar electricity is being generated. In this project, the solar PV was connected into the heat battery. This captures electricity that would otherwise have been exported to the grid, providing free hot water for the householders.

- The heat battery can be topped-up with off-peak mains electricity using a 'boost' function.

6.3 The "Living Lab"

Combining and Comparing Different Technologies (groups DH1-DH3 from Table 3 above)

A retirement complex in Newcarron Court, Falkirk, was selected to trial different energy solutions within the same environment. Each of the three floors contains 8 or 10 apartments, and was fitted with a different combination of plantroom and dwelling heating & hot water system (see Figure 6).

The building previously used night storage heating, which was not providing the desired comfort levels and was due for replacement. This was removed and replaced with:

2nd floor:

- **Plantroom:** 2x conventional gas boilers
- **Distribution**: mini district heating network (DHN) around the apartments
- **Apartments**: Sunamp heat battery storage
- ✓ Sunamp heat battery is the same size as the HIU but adds 100 litres of heat storage.
- ✓ The DHN can therefore be switched off much of the time, with heat and hot water provided from the local store.

1st floor:

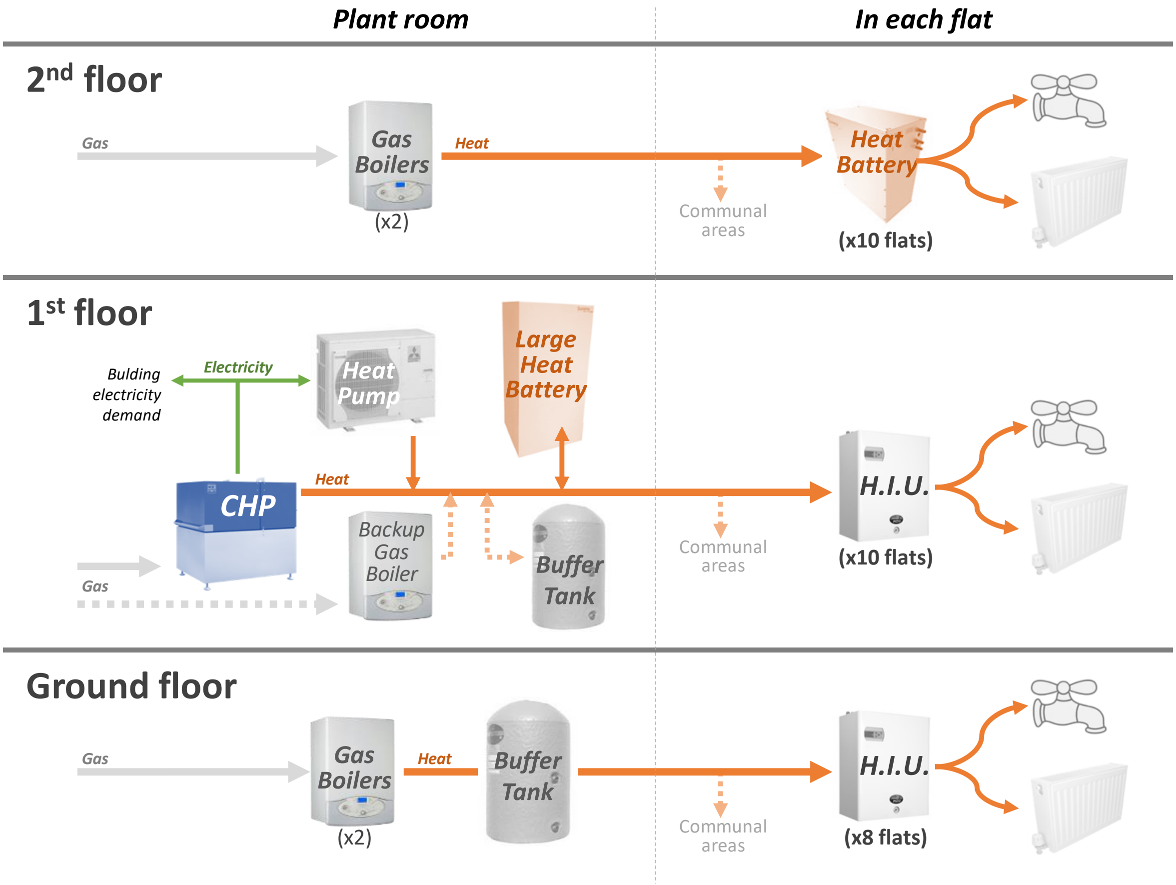
- **Plantroom**: CHP, Heat Pump, large central Sunamp heat battery. Backup buffer tank, backup gas boiler.
- **Distribution**: mini DHN
- **Apartments**: Danfoss Heat Interface Units (HIUs)
- ✓ The high efficiency CHP provides electricity to drive the heat pump, with the aim of providing a higher effective COP.
- ✓ A large Sunamp heat battery provides centralised storage, with low cost/low maintenance HIUs in each apartment.
- ✓ Because of the central storage, generation equipment (for heat) can be run independently of the times required for heating demand.

Ground floor:

- **Plantroom**: 2x conventional gas boilers, 1000 litre buffer tank
- **Distribution**: mini DHN
- **Apartments**: heat interface units (HIU) in each apartment.
- ✓ Reference case

The 1st floor system is an ambitious combination of CHP and Heat Pump. These are down-sized (saving capital); run continuously at their optimum load points (increasing efficiency); work only from low-cost gas (no grid electricity); and are expected to have a combined gas efficiency up to 150%, compared with a new gas boiler at 90% efficiency. All of this is possible because of extensive heat storage – in this case 120 kWh, the equivalent of a 3000 litre hot water tank (a tank which would have been impossible to fit into the plant room). Instead Sunamp delivered three fridge-freezer size SunampStack devices, fitting easily in the small plant room. They were even provided as flat-packs (like IKEA furniture) and were hand-carried up the stairs and assembled in place. The whole operation took just 6½ hours.

Figure 6: Newcarron Court, 3x different configurations



Newcarron Court, Falkirk: 28 assisted living apartments (the "Living Lab")

7 Data Methodology

The project was monitored remotely using two main systems:

- **Sunamp Heat Batteries**: using '*Sundat*', a custom-built system for the EastHeat project. This provides a record of the daily hot water output from the heat batteries. Communication boards were fitted to a subset of the heat batteries, and data was sent back via the GSM network.
- **SolarPV generation**: using the '*PassivPro*' interface from PassivSystems. This data from the parallel solar PV project is used in specific case studies in section 10.1 below, to investigate how much of the solar energy is captured by the heat batteries.
- In addition, some on site data collection (e.g. electricity meter readings, heat meter reading) and pre and post-installation temperature monitoring was conducted.

The project also monitored a number of properties by conducting comfort surveys. The aim is to visit the best and worst performing domestic properties to gain customer feedback on the performance of the systems and the level of comfort. This can then be compared to the remote monitoring findings.

7.1 Heat Batteries – Data quality review

Of all the Heat Batteries installed, a number were fitted with a remote monitoring system. The data streams were analysed and a quality check and cleanse undertaken. The remaining dataset covered 225 properties with detailed monitoring data.

8 Results: Monitoring Data

8.1 Balfour Court: Pilot Site, Pre-Installation

In one particular property, Balfour Court, tenants had complained that they couldn't maintain comfortable living temperatures with their existing heating systems. Due to the urgency of solving this problem, the site was selected for a pilot and initial investigations were undertaken.

8.1.1 Tenant Survey

A pre-installation survey was completed by residents at Balfour Court [ii] who were using wet-electric heating, without heat storage, with an Economy10 off peak tariff [iii]. The results were:

58% were never comfortable in their home
67% rated the level of heat as poor (58% as terrible/couldn't be worse)
58% used their heating constantly
50% found it hard to use the heating
42% didn't always have hot water available when required
75% were in fuel poverty [iv]

And some of the comments included:

"The flat in winter time is VERY cold. Wearing extra 'woollies' is not the answer but is essential. In the winter it is pretty dire."

"Off-peak times are inconvenient. Heaters and room cool down very quickly after 10 mins. Varies in temperature quite extensively."

"I am housebound and not very mobile so find it hard to keep warm. Heating is also very expensive."

Electricity costs for these 1-bed sheltered housing flats averaged £76 per month.

8.1.2 Temperature monitoring

The comfort surveys at this site were followed-up with detailed temperature monitoring in four properties for a period of two weeks. Properties at Balfour Court originally had electric flow boilers and wet radiators, configured to run during the off-peak times of Economy 10 (3 off-peak blocks throughout the day). Whilst this can provide some benefits of low-cost heating, the poor insulation of the building meant that the properties cooled down significantly in the times between the off-peak blocks when the heating was turned off.

The results of the monitoring highlighted that:

- There was significant variability in the temperature of those flats, indicating poor heating control and inefficient heating patterns. Temperatures were routinely above the target level – this is unnecessary and wastes energy.

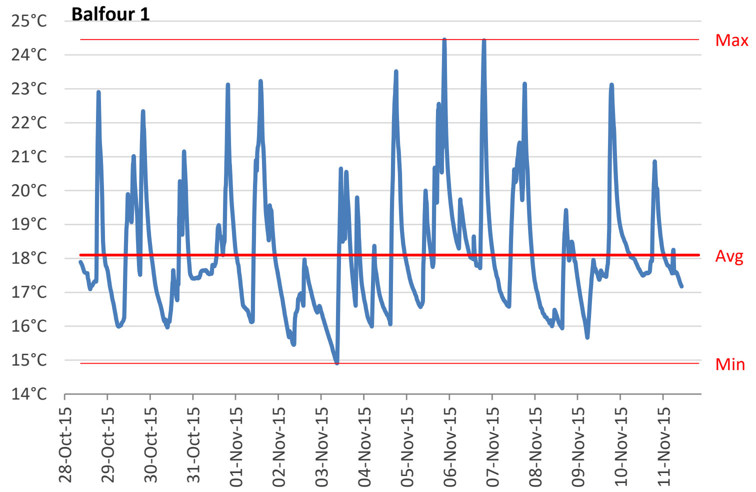
[ii] Balfour Court - sheltered housing for vulnerable adults, hard to heat construction.

[iii] For further information on the Economy10 tariff see: www.Economy10.com

[iv] Defined as >10% of after-tax income spend on energy bills.

- In one property the temperature fluctuated from 15°C to 24°C in order to achieve an average of 18°C – see Figure 7 below.
- One property achieved an average of 17°C, but this regularly fell to under 15°C.
- The cost of energy meant that some households had to restrict the use of their heating; a classic symptom of fuel poverty.

Figure 7: Temperature monitoring graph

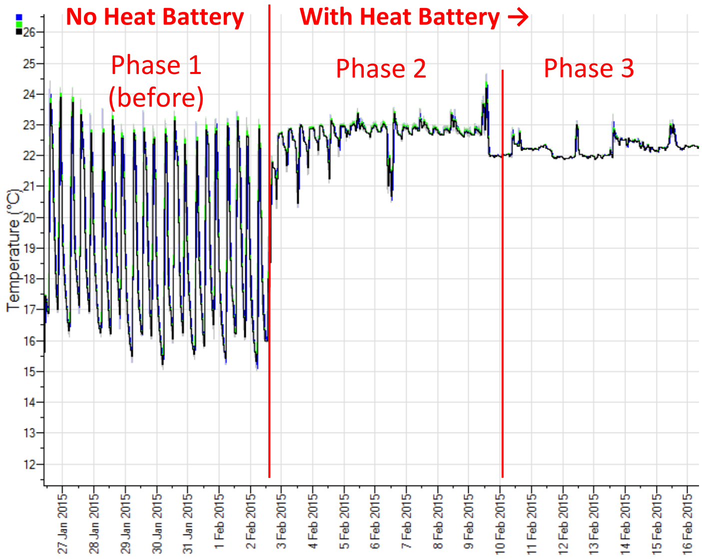


8.1.3 Proposal and results

The EastHeat project was initially focussed on storage for *hot water*, but was extended to include storage for *space heating* as a result of the Balfour Court investigations.

It was proposed that storage for heating could help smooth these peaks and troughs and increase tenant comfort. The graph below shows the impact of adding a Heat Battery to this system. The three main phases are:

- **Phase 1** (27 Jan – 2 Feb): The electric boiler and radiators switched on and off three times per day. However poor building fabric meant that heat was not retained between the heating times. Wild temperature swings from 15°C to 24°C.
- **Phase 2** (3 Feb – 9 Feb): New Sunamp Heat Battery was installed, which allowed all heating energy to be charged in the cheap Economy 10 off-peak periods. The thermal store 'bridged' the expensive periods. Temperature was maintained at a constant 23°C with less than a degree of deviation – vastly superior to the old system.
- **Phase 3** (10 Feb – 16 Feb): Improved comfort allowed the target temperature to be reduced from 23°C to 22°C.



8.2 All Properties – Grouping the data

The heat batteries were installed in a number of configurations (see Table 3 replicated below).

Table 1: Property Count by Heating type / Solar PV

	Before		After				Total Properties	with Monitoring Data
group	Heating	HW	Heating	HW	Solar	Locations		
DH1	Electric Night Storage	Electric Tank	Gas boiler + HW buffer tank → **D.H. direct feed**	→ D.H. → **indirect heat exchanger**	-	Newcarron Court (CRE)	**28**	phase 2
DH2			CHP + ASHP + Central heat battery → **D.H. direct feed**	→ D.H. → **indirect heat exchanger**	-			
DH3			Gas boiler → **D.H. direct feed**	→ D.H. → **Local heat batteries**	-			
DH4						Salisbury View (CRE)	**40**	27
E1	Electric Night Storage	Electric Tank	*Unchanged*	**Heat Battery**	-	Harrismith Place (CRE) Lauderdale House (CRE)	**37**	26
E2			*Unchanged*		**PV**	Bankfoot (ELHA) Manse View (ELHA) Mansefield (ELHA)	**19**	8
E3	Wet electric + E10 meter		Wet Electric + E10 + **Heat Battery** ("Mini-stack")		-	Balfour Court (CRE) Hunterfield Terrace (CRE) Ross Glen Court (CRE)	**112**	27
E4					**PV**	Osborne Court (ELHA)	**16**	4
G1	Gas Combi	Gas Combi	*Unchanged*	**Heat Battery** (pre-feed → gas combi)	**PV**	Various (ELHA / CRE)	**371**	133
*			*Other*	**Heat Battery**	*	*	**2**	-
						Total	**625 properties**	225 properties

For data analysis these can be grouped into two broad categories depending on their main heating energy supply:

- **Electric properties (E1-E4)**: the Sunamp Heat Battery replaced a traditional hot water tank, charged by solar PV in many cases.
- **Gas & DH properties (G1)**: the Sunamp Heat Battery is charged by solar PV, and installed as a pre-feed to the gas combi boiler. Heat is delivered first from the Heat Battery and then topped up by the boiler when the battery is depleted.
- **Total**: 225 properties with monitoring data.

This will allow us to answer two specific questions:

- **How much hot water did these properties use?;** *and*
- **What percentage of the hot water was from solar PV via the heat battery?** *('free' hot water)*

8.3 Heat Batteries – Hot Water output

Table 4: Heat Battery – Data showing Hot Water output per unit (kWh/day)

	Property Count:					*Heat Store output (kWh/day):*					
	1	2	3	4	Total	1	2	3	4	Total	
Electric Heating	**41**	**22**	**2**		**65**	**1.8**	**2.9**	**5.1**		**2.3**	(A)
With solar	4	6	2		12	2.5	3.9	5.1		3.7	
No Solar	37	16			53	1.7	2.6			2.0	
Gas Heating	**8**	**47**	**70**	**8**	**133**	**1.0**	**1.9**	**1.8**	**2.1**	**1.8**	(B)
With solar	8	47	70	8	133	1.0	1.9	1.8	2.1	1.8	
District Heating	**27**				**27**	**1.1**				**1.1**	
No Solar	27				27	1.1				1.1	
Total	**76**	**69**	**72**	**8**	**225**	**1.5**	**2.2**	**1.9**	**2.1**	**1.9**	

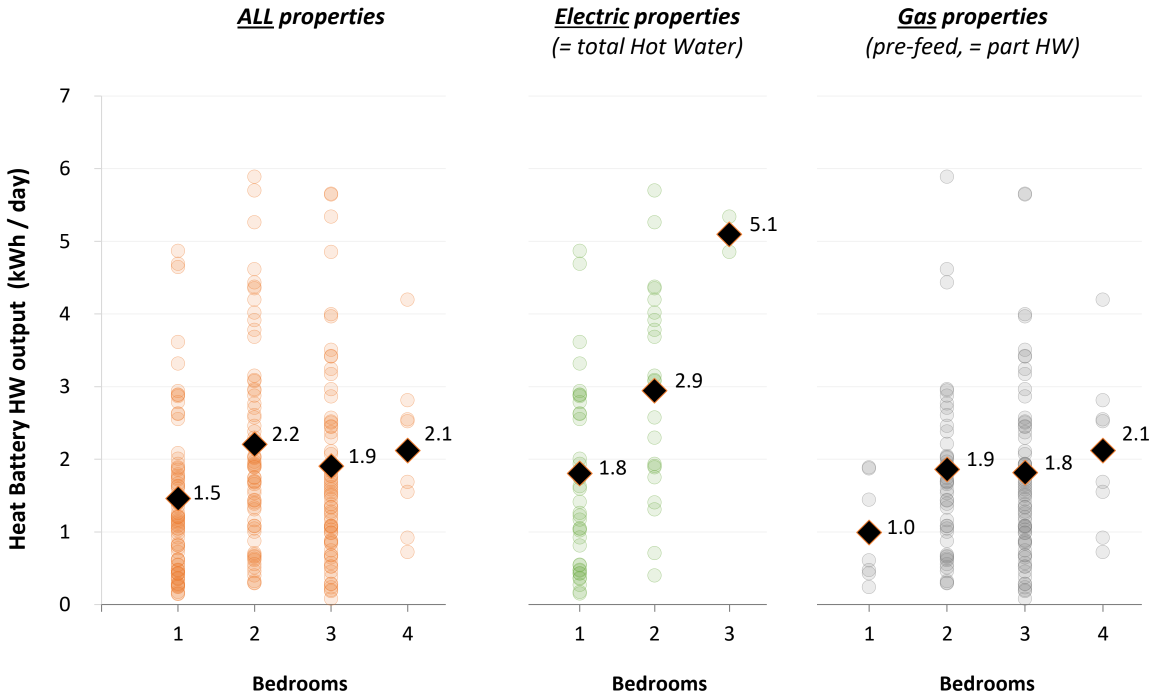
Conclusions (see Table 4 above):

- **Electric properties**: total hot water output for the properties averaged 2.3 kWh per day[A]. This is proportional to the property size, and ranged from 1.8 kWh/day for the 1-beds to 5.1 kWh/day for the 3-beds. The energy is a mix of solar PV and grid-supplied.
- **Gas heated properties**: the heat battery contributed an average of 1.8 kWh/day towards the total hot water requirement [B]. These values are lower and less correlated to property size. This is because they are only the proportion of hot water from solar PV, and any remaining hot water is supplied by the gas combi. Further investigation will be carried out in the remainder of phase 2.
- **People with solar PV appear to use significantly more hot water than those without PV**:
  - 1-bed hot water usage: 2.5 kWh/day (with PV) vs 1.7 kWh/day (no PV).
  - 2-bed hot water usage: 3.9 kWh/day (with PV) vs 2.6 kWh/day (no PV).

  This could be due to an awareness of the system providing 'free hot water', or could be a limitation of the small sample size. Further research is required.

The distribution of Heat Battery output can be seen in Figure 8:

Figure 8: Heat Battery output, analysed by Electric and Gas properties



The data from Figure 8 is categorised in Figure 9 below:

Figure 9: Property Groups

Property Group	No. of properties with data	Heat Battery is charged by	Use for **'Total Hot Water'**?	Use for **'% Solar PV Captured'**?
Electric heating	65	Solar PV + Mains electricity (boost)	**Yes.** All hot water in the property is supplied from the heat battery. *See 8.3 Heat Batteries – Hot Water output*	No. The battery could have been charged partly by solar and partly by mains electricity.
Gas heating	160	Solar PV only	No. Hot water from the heat battery could be topped-up by the gas combi boiler, so is only part of the Total Hot Water.	**Yes.** All hot water from the heat battery came from excess solar PV generation. *See 8.4 Heat Batteries – % Hot Water from solar PV*

8.4 Heat Batteries – % Hot Water from solar PV

The data can be split into two populations, based on main heating type:

- **Electric properties**: where the Heat Battery is the sole hot water supply for the home (ie it replaces a hot water tank), a 'boost' function can be used to top up the battery, like the boost function on a standard hot water tank. This means that hot water from the battery is partly supplied by solar PV ('free') and partly from top-ups from mains electricity.
- **Gas properties**: in these properties, the Heat Battery is exclusively charged from solar PV. All of the hot water from these heat batteries is 'free', as the electricity would otherwise have been exported to the grid. This group is analysed in Figure 10 below.

It is assumed that:

- **Total Hot Water consumption** is represented by the *electric properties*, and
- **Hot Water from solar PV** is represented by the Sunamp heat battery output, which is used as a pre-feed for the combi boiler in the *gas properties*,

We can therefore estimate the percentage of hot water coming from solar PV:

Table 5: % of hot water supplied by Solar PV (due to Sunamp Heat Battery)

	1	2	3	4		
Total Hot Water	1.8	2.9	5.1		*kWh/day*	(A)
HW from Solar PV (via Sunamp)	1.0	1.9	1.8	2.1	*kWh/day*	(B)
% of HW from solarPV	**55%**	**63%**	36%	-		
kWh p.a. of HW from solarPV	362	680	663	774	*kWh p.a.*	
Total property count	**204**	**199**	**191**	**21**	**10**	**625**
	403					

Conclusion:

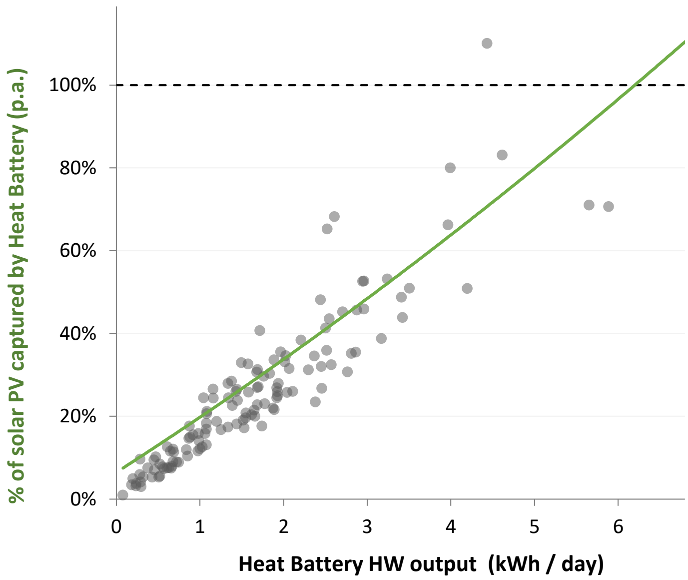
- For the majority of properties in this trial (1 and 2 bed properties), **between 55% and 63% of the hot water was supplied from Solar PV** – 'free' hot water.
- Solar PV consumption is significantly higher because of the Sunamp heat batteries.

Note: This is in no way reduces the amount of free solar PV electricity available for use for electrical loads (lights, appliances, phones, TVs etc.). The Sunamp heat battery is only taking the excess which would otherwise flow back to the grid with no recompense to the householder.

8.5 Heat Batteries – % Solar PV captured

Figure 10: % of Solar PV Generation delivered by Heat Battery as Hot Water

Gas properties only



Confirmations of the expected result from Figure 10:

1. The more hot water you use the more Solar PV output you capture for free hot water.

2. Solar arrays installed (2-4 kWp) were at least large enough. Further work will look to see if they were oversized and establish optimum size of PV for a given hot water demand.

Other Observations:

3. There are a number of low use properties. Two different scenarios could explain this:

- **A)** Low hot water demand limits the amount of solar PV captured. ie. ***The Heat Battery is always full***, and recharges after the small amount of hot water is used. There would be minimal top-up from the gas combi, and higher electrical export to the grid. Small households using minimal hot water are likely to fall into this scenario; or
- **B)** The system configuration, incidence of solar PV generation, or high electrical self-consumption, limits the amount of solar PV diverted to the Heat Battery. ie. ***the Heat Battery always discharges to zero*** each day, and fully captures the small amount of excess solar PV available. There would be significantly more top-up from the gas combi in this case, and minimal electrical export to the grid. Households who are in most of the day, and using almost all of the solar PV generation, are likely to fall into this scenario.

The ambiguity arises as the project is not measuring the total hot water use or the combi boilers' hot water output. This requires further monitoring equipment to be fitted and the project would seek further funding to put this in place.

4. There are a few properties where Heat Battery output exceeds the amount of solar PV generation. This could only occur in a gas property if the boost function was inadvertently used. These cases will be monitored in the remainder of Phase 2 to establish the cause of this.

9 Results: Financial and Other Outputs

9.1 Comfort Studies & Behavioural Change

Comfort surveys have been carried out in a number of homes in the EastHeat portfolio. The aim was to get the users perception of the system and match that with the data results.

The comfort surveys show that of the users:

- One third are engaged and delighted with their systems: the performance, savings and enhanced level of comfort;
- One third aren't aware of the heat batteries (a positive, seamless integration); and
- The remaining third know they have heat batteries but think it is costing them more (Measurements show this is not the case – some of the highest savings are in this group).

9.2 EastHeat Case Studies

Real People – The Lynne Family

Situation

The property is a 2 bedroom, semi-detached family bungalow off the gas grid. The tenants are a family consisting of two younger girls. Each night both the girls receive a bath and this consumes a lot of hot water and limits hot water available for use on other things.

Heat Battery Solution

A > 4kWp Solar PV array was installed, enabling the tenants to benefit from free electricity generated during the day. The Power Diverter self-consumption device monitors the generation, and diverts any excess solar generation to 2 **SunampPV heat batteries.** This then provides hot water even when there is no generation at night. As high water users 2 SunampPV batteries were installed as the family use a great deal of hot water. They were placed side by side in the airing cupboard, still significantly smaller than a water tank and cupboard. (Space is of value and an issue in every house.)

Comments

"Our hot water is plentiful, comes out of the taps quickly and is an excellent temperature"

2 SunampPVs installed side by side

Real People – John and Jayne

Heat Battery Solution

A 4kWp (approx) Solar PV array was installed, enabling the tenants to benefit from free electricity generated during the day, the Power Diverter self-consumption device monitors the generation, and diverts any excess solar generation to the **SunampPV Heat Battery**. This then provides hot water, on demand whenever it is required. The existing gas boiler was replaced with a new Intergas ECO RF 30 energy-efficient boiler.

Situation

The property is a three bedroom, house with 2 retired adults who are home for a large part of the day. The replaced system, required a timer to be set every time hot water was required, and was not flexible. If the tenants needed hot water out with these times it could be expensive

Results

The trial had only been in place for a couple of months, and savings are still being gathered, however the tenants use a card payment meter and have been able to replace their £20 payment every two weeks to £12. Estimated saving: £208 a year, or more.

Comments

"It gets a bit of getting used to, switching on the hot tap normally you would hear the sound of the gas boiler that doesn't happen any more"

9.3 Heat storage vs Electricity storage

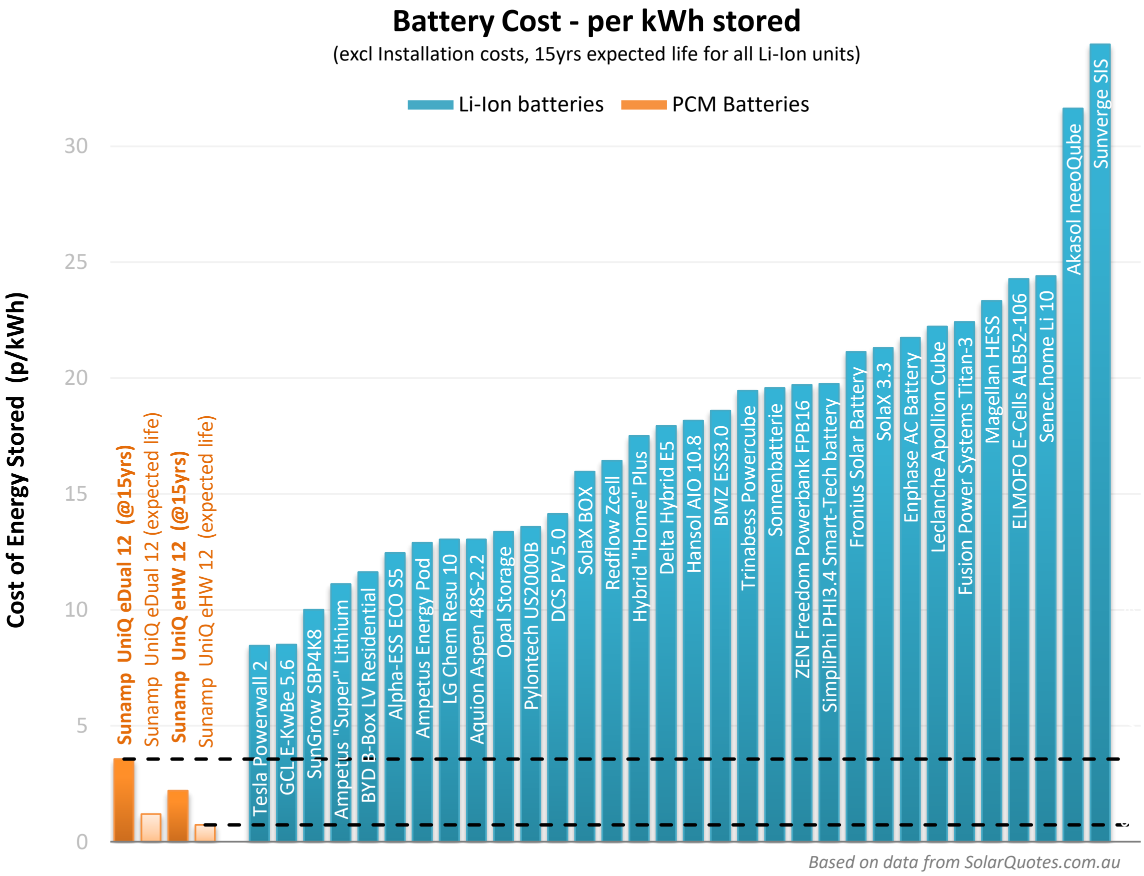
Sunamp's Phase-Change Material has a number of benefits over lithium-ion batteries which are used for electricity storage.

Typical characteristics:	Electricity storage	Heat storage
Material	Li-Ion (Lithium-Ion)	PCM (Phase-Change Material)
Lifespan – cycles	~ 5,000	30,000+
Lifespan – years	10-15	50+
Degradation (Capacity after 10yrs)	to 70-80%	~ 99%

In a recent study, the Tesla Powerwall 2 was noted as leading *electricity* storage. However for *heat* storage, the advanced characteristic of PCM means that.:

- The **Sunamp heat battery is now 60-90% cheaper than the Tesla Powerwall 2 electric battery** per unit of energy stored – Figure 11.

Figure 11: Battery cost comparison



10 Conclusions

10.1 Is it possible to help those in fuel poverty by installing heat batteries alongside solar panels?

The Conclusion from the EastHeat trial: **YES**

Evidence:

- For the majority of properties in this trial (1 and 2 bed properties with combi boilers and PV on the roof), between **55%** and **63%** of the hot water was supplied from Solar PV – 'free' hot water.
- Solar PV consumption is significantly higher because of the Sunamp heat batteries.

Note: This is in no way reducing the amount of free solar PV electricity available for use for electrical loads (lights, appliances, phones, TVs etc.) The Sunamp heat battery is only taking the excess which would otherwise flow back to the grid with no recompense to the householder.

Recommendation:

Local authorities and Housing associations seeking to reduce fuel poverty who have already installed solar PV (e.g. under rent a roof schemes) on their housing stock should follow the best practice of the EastHeat project and install heat batteries to provide free hot water in addition to the current benefit of free electricity.

A further recommendation could be that solar PV and heat batteries be fitted in combination in all suitable homes providing substantial free electricity and hot water.

10.2 How do people react to having heat storage in their homes?

A third of the recipients of the heat battery systems under EastHeat have expressed delight at the combination of bill savings, comfort, and "doing our bit for the planet". In general the small footprint of the heat battery has either saved space (when replacing a hot water tank) or been small enough to easily fit into existing spaces. The lower heat losses and 55-63% free hot water are a real benefit to tenants.

The remaining two thirds of tenants are either unaware they have the system, or worry that they may be paying more. Evidence from this study shows that all of these properties are in fact benefiting from the heat batteries. Communication is key for tenants to understand the benefits they are receiving, and further dissemination work will be done through the remainder of the project.

10.3 Are there any benefits for the housing associations?

Key benefits:

- Easy to train their in-house installer or subcontractors.
- Low maintenance:
    - **no mandatory annual maintenance**, unlike combi boilers and unvented cylinders require annual maintenance by law every year this can lead also to access issues.
    - **No legionella risk or testing** required (less than 5 litres of water held in the heat battery).

- **Compactness** frees up storage space helping them to meet mandatory space standards.
- 3rd Generation UniQ™ Heat batteries are now **competitively priced** against conventional solutions, as Sunamp has worked on cost down throughout the project.
- Sunamp has now established the benefits of heat batteries in terms of energy savings which flow through to **SAP scores** and the methodology to apply this in SAP software. This helps the housing associations meet their EESSH obligations.

10.4 A great partnership!

This was a technically challenging project, including a significant number of different parties: Sunamp and Edison and private companies; two Housing Associations and their DLOs; the LECF team managing the challenge fund; and 625 householders and tenants!

Large projects are often fraught with difficulties, but this project is delivering results and working well. The partners have the same vision, and have supported each other through the project, sharing their enthusiasm and experience along the way.

The time scales were a challenge but enabled EastHeat to achieve a huge amount in a very short time, largely possible because of the team-working approach within the consortium, and between the Eastheat consortium and LECF team, who were a pleasure to work with. Having the right team made the difference!

But the most important thing is the outcome – reduced fuel bills mean reduced fuel poverty, along with greater comfort for the householders. And the fact that it's created using natural renewable resources will support the long-term environmental aims of the country.

11 Dissemination

11.1 Community Engagement

The EastHeat team engaged with the community from the begining of the project. Tenant liason was important to make sure everyone was aware of the project and the changes being made to their properties. This engagement happened across all housing types and required co-ordination across the partners including tenant liaison and housing managers in the Housing Associations, project manager and others at Sunamp, and delivery teams at Edison for the solar PV elements.

11.2 Presentations

Sunamp has presented EastHeat at:

- Scottish Renewables conference
- Scottish Enterprise – Low Carbon Heat and Hot Water Conference
- CARES - conference
- CIH - conference
- Scottish Rural & Islands Housing Conference
- All Energy 2015, 2016, 2017 and 2018
- SSN conference 2016
- SMART Energy Wales
- Innovation to Tackle Fuel Poverty 2017 (with CRE)
- French Housing Association Conference, Dunkeld 2017

11.3 Media

Sunamp has used a full social media and PR toolkit to promote the project. The project featured on the partner websites of all project partners.

There have been a number of articles in a diverse range of publications from local newspapers to Housing Publications and featured in boiler manufacturer's promotional materials. We continue to promote EastHeat through Maggie Wright Associates, Sunamp's and CRE's PR agent.

Sunamp and the EastHeat team have been featured on:

- STV – news item
- BBC – Reporting Scotland, Ken Macdonald, Special Correspondent, News and Current Affairs. This feature also included University of Edinburgh and Interface (https://www.youtube.com/channel/UCjIuT_RjpBFBpQQEgGlgUqA)

11.4 Awards

Solar Power Portal Award 2016

The winner of the Residential Energy Management Project in 2016 for the EastHeat Project.

Beating a strong field:

Nottingham Energy Partnership
The Pheonix Works
Joju Solar

Sunamp/EastHeat has won or been shortlisted for the following awards:

- **Solar Power Portal Awards 2016,** – nominated, shortlisted, won
- **Regen Renewable Future & Green Energy Awards 2017** – nominated, shortlisted, won
- **Ashden Awards 2017** – nominated, shortlisted, finalist
- **REA Award** – nominated and shortlisted
- **SHIFT award 2016** – nominated, shortlisted, finalist
- **InnovateUK** – nominated and shortlisted

Regen Renewable Future & Green Energy Awards 2017

The winner of the "Best Business Innovation"

Beating a strong field:

Origami Energy Limited
Thrive Renewables (Triodos Bank)
Limejump

11.5 Education

Sunamp worked with all the Primary 5's from Windygoul Primary School in Tranent and Mary Turner Thomson from White Water Publishing Ltd to develop the first ever published children's Energy Storage Book [v]. This was an innovative and interesting project for pupils and teachers alike. Windygoul Primary is a modern school with several renewables energy features including a green roof, solar PV on local buildings, and it is sited not far from Cockenzie power station (which was in fact demolished shortly after the project). This gave added interest, as the pupils could see the energy transition in their backyard!

Sunamp worked with Mary and the teachers to set the scene, and the pupils imagination worked on poems and stories about energy storage. Some didn't quite get the full implications of energy storage; however, they were very creative.

The feedback was that they learned lots about renewables, energy storage and really gave some thought as to how the water comes out their taps hot and how their houses stay warm. They also had great fun writing the poems and stories. We held an awards ceremony and the best stories were recognised with awards.

[v] ISBN 978-1-909797-46-8, £8.99

11.6 EastHeat Interest

This project has been of interest not only in Scotland but all over the world.

11.6.1 Worldwide Interest

Delegations have visited from Denmark, Finland, France and Australia with diverse agendas including the EastHeat project.

This report highlights two of them. The first one has direct link to the EastHeat Project and has similar motivation to our Housing Associations; the second is interested in the technology, how innovation happens in Scotland and the partners we work with to exploit the technology.

1) Les Entreprises Sociales pour l'Habitat

esh les entreprises sociales pour l'habitat

ESH, Les Entreprises Sociales pour l'Habitat (The Social Housing Companies) dedicates its mission to the establishment and management of housing destined to the low-income groups in the population and to the participation in societal projects**.**

ESH is also responsible for the housing environment for tenants and future owners. ESH promotes a new housing concept that takes into consideration aspects related to social integration and non-discrimination. It supports local communities in their participation in urban development, maintenance and renovation of cities and territories.

Sunamp's CEO and Materials Development Manager presented the EastHeat project at their annual conference held in Dunkeld in 2017, and other members of the Sunamp team showed them a trial house.

2) Victoria Government, Australia and Veski

veski

Veski's vision is to foster an innovation economy.

"Our mission is to identify globally competitive individuals and leading researchers and bring them to Victoria for the benefit of the Australian economy."

Each year, **Veski** delivers a dynamic program of fellowships, awards and international networks including the **Veski** innovation fellowships. This established and prestigious program brings Australian expatriates and leading researchers, with outstanding skills in science and innovative technology, typically in the top five percent of their respective fields, to Victoria.

Sunamp's CEO and Materials Development Manager presented the EastHeat project to this visiting delegation who also visited a trial house.

11.6.2 Scottish and UK Interest

EastHeat has been of interest to local MPs, MSPs and Scottish Ministers who have visited Sunamp HQ and a number of the trial properties in both Housing Associations.

Visits have also been made by the Energy Savings Trust (and presented to a number of their field offices).

WWF CEO Tanya Steele, accompanied by Lang Banks, director of WWF Scotland, visited Sunamp to discuss EastHeat.

Scottish Federation of Housing Associations coordinated a visit for themselves and a number of other interested parties.

CRE hosted a visit to one of the trial sites for BEIS and UK Treasury officials.

11.6.3 Organisations

Indirectly attributable to EastHeat: Because Sunamp now has proven technology that can be implemented at scale, visits have been received from companies from Scotland, England, Wales and Ireland, Chile, Brazil, US, Japan, Korea, Japan, Spain, Switzerland, USA, China and Canada. Sunamp has also engaged with social enterprises working on projects in Africa and India developing new products to be implemented in special projects.

12 Case Studies (other exemplar properties)

12.1 West of Scotland multi storey apartment (Linstone Housing Association)

Property type: **1-bed flat**

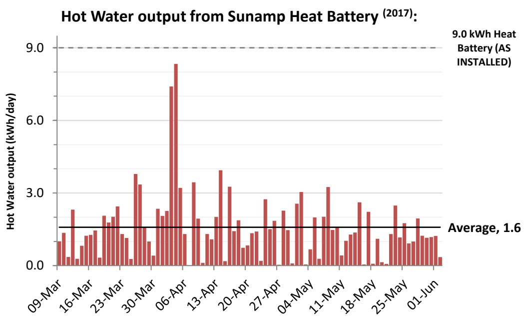
Before: **Traditional copper tank (for HW).**
Night storage heaters.

The problem:
- Very low water pressure from the existing hot water tank & high heat losses.
- Expensive energy bills.

After: **Sunamp Heat Battery (for HW) – charged by mains electricity, as before.**
Heating unchanged.

Conclusions:

- Hot Water usage averaged 1.6 kWh/day. Typical consumption rarely exceeded double the average (3.2 kWh/day).



- The traditional hot water tank would not have been able to meet the HW demand for two days of high usage. The Sunamp Heat Battery had a larger capacity so had no issues. A smaller Heat Battery could have been installed, and the 'boost' function used for the two high-usage days.

- Heat Losses (from hot water tank) reduced:
  from: 2.3 kWh/day – old copper tank
  to: 0.6 kWh/day – new Sunamp Heat Battery
  saving: 1.6 kWh/day = 600 kWh p.a.

12.2 Proof of concept trial house (DECC/Berwickshire Housing Association)

Property type:	**3-bed terraced house**
Before:	**Traditional copper tank (for HW).** **Night storage heaters.**
The problem:	• Low water pressure from the existing hot water tank & high heat losses. • Expensive energy bills. • Poor heating control. • Not the most environmentally friendly.
After:	**Solar PV panels** **Air Source Heat Pump** **Sunamp Heat Battery – for heating and hot water** **Wet electric radiators** • The Heat Battery captures solar PV which would otherwise have been exported to the grid. This gives 'free hot water'. • The Heat Battery is charged by the ASHP. Heating is available instantly on demand.
Conclusions:	• Radiators now warm up within 90 seconds (fed from the heat battery), rather than the 45 mins it would have taken with just the ASHP alone. • Cost of energy fell substantially, saving £700 p.a. (46% saving) • Tenant has increased average heating levels slightly – fuel poverty was restricting tenant comfort. • Grid electricity consumption has reduced by 38%. • Heat storage allows total energy flexibility – electricity consumption is now almost exclusively off-peak (95%).

"Perfect in the morning, the bathroom was never warm before"

"A lot better than the old system!"

"Better pressure for the shower"

12.3 Solar PV Super producer, Super consumer

Property type:	**4-bed detached house**
Before:	**Traditional copper tank (for HW).** Gas central heating. Solar PV.
The problem:	• Solar PV generation was being 'lost' to the grid.
After:	**Sunamp Heat Battery for hot water storage.** • The heat battery pre-feeds the gas combi boiler with hot water, which flows through to taps and showers as before. No changes required to the heating or other systems.
Conclusions:	• Approx 1,600 kWh p.a. of solar energy captured by the Heat Battery. This would otherwise have been exported to the grid, and is 'free' hot water for the household. • Gas consumption reduced by 2,000 kWh p.a. (more gas is saved, because the boiler is not 100% efficient). • No impact to Solar PV Feed-In Tariffs – they are paid on the 'deemed' amount regardless of actual export.

[1] Table 1.04 (2016), ***Energy Consumption in the UK: 2017 update***, Jul 2017, BEIS / UK Government

[2] Scotland: Figure 4.1 (2014), ***Energy in Scotland 2017***, Feb 2017, Scottish Government

[3] ***Scottish Energy Strategy: The future of energy in Scotland***, Dec 2017, Scottish Government

[4] Table 1.04 (2016), ***Energy Consumption in the UK: 2017 update***, Jul 2017, BEIS / UK Government

[5] ***Special feature: Revisions to DECC domestic energy bill estimates***, Annual domestic energy price statistics, Mar 2014, UK Government

[6] Tables 6a & 6e, 2011 data, ***UK Housing Factfile***, DECC URN: 13D/277

[7] Data table 29, ***Scottish Housing Condition Survey: 2016***, Dec 2017, Scottish Government

[8] s3.6, ***Heat Policy Statement***, June 2015, Scottish Government