The Solar Heat Energy Demonstrator (SHED) Case Study: 2011 - 2021

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specific®

Credits

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Contents

1.0 Introduction

Site Location

The Solar Heat Energy Demonstrator (SHED) is located just off Junction 38 of the M4 motorway, between Port Talbot and Margam, marking a former entrance to Tata Steelworks. The SHED occupies a large industrial building that has a varied history of occupancy, including Tata (when known as British Steel and Corus) and The Welding Institute (TWI).

It is a Welsh Government owned building, which has been leased by Swansea University since 2014, to be used as a technology demonstrator for industrial buildings. The aerial view taken from Google Maps in Figure 1.1 below shows the building and its site curtilage outlined in red.

Figure 1.1: Aerial View of the SHED and its location

2.0 Building History

The building housing the SHED was originally constructed in 1990 and has had a varied 30-year history, as detailed in the timeline below.

The First 20 Years – Pre-Demonstration Programme

1990	The building consisting of a double height production area, with a higher bay at one end to accommodate lifting equipment; some office space at first floor level and single height storage and plant areas on the rear elevation; was originally constructed as a British Steel Customer Technical Centre.
2008	A single storey extension was built to house the Corus (formerly British Steel) Visitor Centre. This remained in use by Tata (formerly Corus) until 2014.
2010	The Welding Institute (TWI) took occupation of the main building, using the space for their Technology Centre, which specialises in the applied research, development and application of state-of-the-art non-destructive testing (NDT) methods. In 2014, the Centre relocated to new bespoke premises in Harbourside Park, Port Talbot.

The Next 10 Years – Demonstration Programme

2011	A collaborative project led by Tata Steel involved retrofitting the southwest elevation with a Transpired Solar Collector (TSC) which would replace the existing gas-fired boiler used for space heating within the building. The aim of this project was to explore the full potential of the TSC to provide all-year space heating through combining it's heat generation capabilities with diurnal heat storage. At this time, the building was still occupied by TWI. The TSC was divided into two collection areas, 250m^2 each – one feeding warm air directly to the main production area and the second supplying warm air to a novel diurnal thermal storage test rig.
2013	The INTRESTS project commenced to investigate inter-seasonal heat storage through a collaborative 3-year project, led by Tata. SPECIFIC were subcontracted to the project by BASF, one of the other main partners. This involved installing a TSC on the roof of the building, which would supply warm air into a thermo-chemical test rig.
2014	SPECIFIC, Swansea University, took over the lease for the building (now owned by the Welsh Government), enabling them to use the building as a demonstrator for other technologies alongside the two solar thermal demonstrators.
2017	Low temperature hot water, fan assisted convector radiators were installed in some of the office spaces, using heat from the solar store, enabling SPECIFIC to trial an alternative to gas central heating systems.
2018	A test rig was designed and constructed on the southeast elevation of the building, to test different types of PV and solar thermal panels under real-world conditions. This project is ongoing.
2019	Following an introduction between SPECIFIC and Transport for Wales (TfW) during a Constructing Excellence in Wales (CEW) awards presentation for the Active Classroom, a collaborative project with TfW commenced. This involved exploring possibilities for developing solar-powered railway shelters in remote areas of Wales, which would significantly enhance waiting areas for commuters.
2020	One of TfW's existing shelters was installed outside the SHED and fitted with flexible PV and battery storage, providing power for lighting and an information screen. This will be monitored in terms of energy generation and the viability of installing these along the TfW network will be assessed
	Also in 2020, SPECIFIC offered space and engineering support to a small company called Rotaheat, who are developing technology that converts motor power into thermal energy, using no combustion processes and no electricity, offering a zero carbon heating system. This is ongoing.
2021	The Inter-seasonal heat storage project re-commenced and the building is being adapted to accommodate SPECIFIC's thermal storage team.

Table 2.1: History of Building Usage

3.0 SHED Overview

3.1 Site Analysis

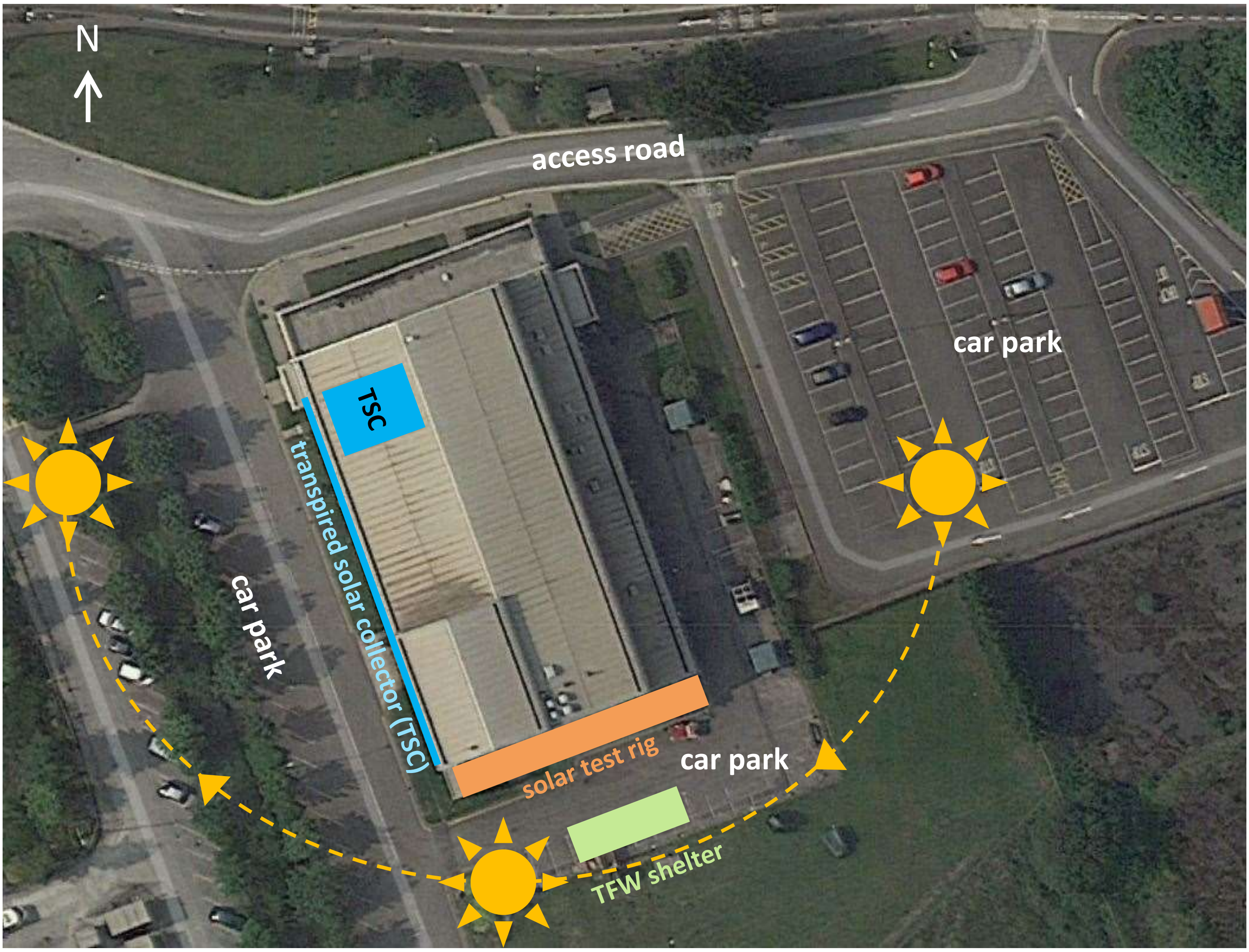


Figure 3.1: Site Analysis of the SHED highlighting the demonstration areas

Figure 3.2: Southwest elevation showing Roof and Wall TSCs

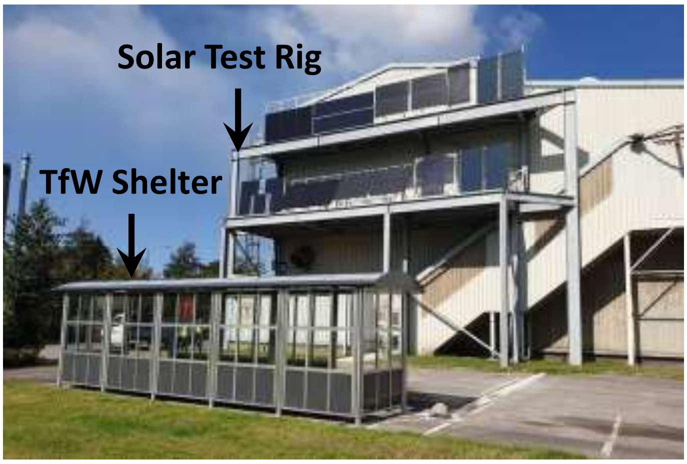


Figure 3.3: Southeast elevation showing Demo Rig and TfW Shelter

3.0 SHED Overview

The SHED is heated from a solar air collector on the southwest elevation, which supplies warm air either directly to the workshop space or to a diurnal thermal store. A roof-mounted solar air collector supplies warm air into an inter-seasonal thermal store test rig, as illustrated in Figure 3.4 below.

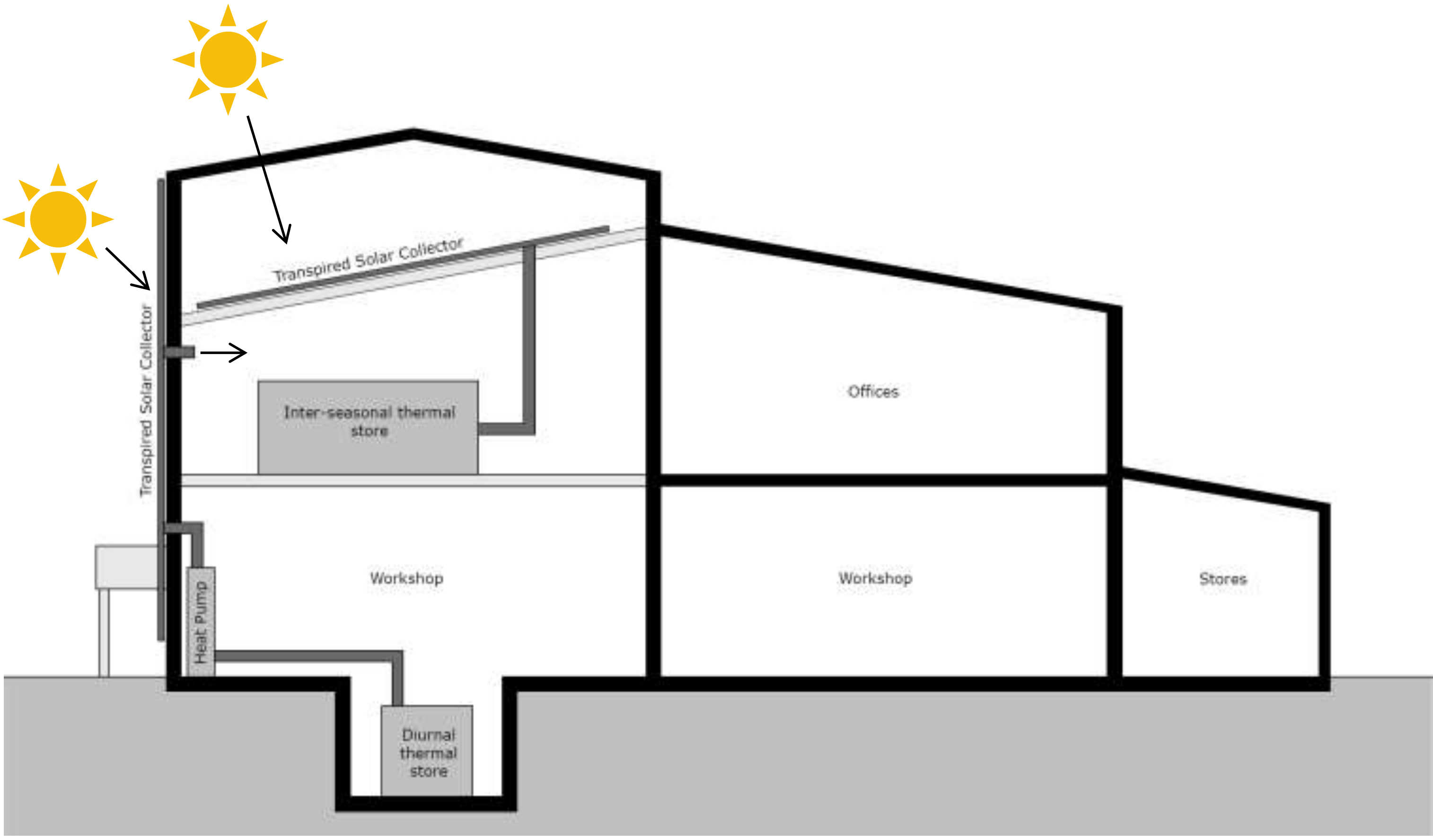


Figure 3.4: Diagrammatic Section through the SHED

3.2 Key components

- Existing steel framed industrial building
- Double height factory space with higher bay at one end
- Office space on first floor overlooking the factory space
- Mezzanine level housing the Inter-seasonal thermal store
- Constructed in 1990 with no insulation
- Gas heating system decommissioned in 2011 and a Transpired Solar Collector (TSC) installed to provide space heating.

3.3 Purpose of the SHED as a Demonstrator

- To demonstrate adaptable use of a steel-framed building – with a focus on benefits of steel as a construction material
- An example of how an existing empty industrial unit can be used as a test-bed for industrial retrofit and highlights the benefits of utilising an empty building in this way to enable technologies to be tested in a live environment
- To provide a research space for large, building-scale demonstration

3.4 Accommodation Schedule

Figure 3.5: Ground Floor Layout

Ground Floor.

Accommodation	Area (m^2)
Production Area	571
Laboratory Spaces	539
Rear Stores and Plant	265
Single Storey Extension, Reception & WCs	374

GIFA = 2.400m^2.

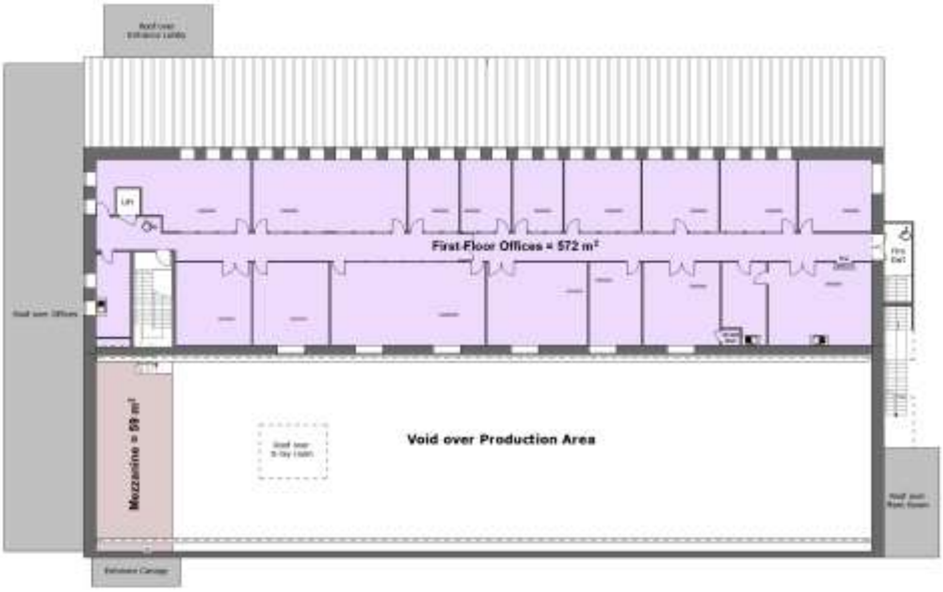


Figure 3.6: First Floor Layout

First Floor.

Accommodation	Area (m^2)
Office Space	572
Mezzanine Level	59

4.0 Solar Air Collector with Diurnal Store

4.1 Introduction

In 2011, the southwest elevation of the SHED was overclad with a transpired solar collector (TSC), manufactured and supplied by Tata Steel. For information on how a TSC works, please refer to the Active Building Technology Showcase.

Tata's product name for their TSC is Colorcoat Renew SC®. Some of Tata's key selling points include:

- It is a highly effective renewable energy system:
    - Up to 75% instantaneous collector efficiency
    - 1m^2 of collector area typically delivers 250kWh heat per annum
- Payback is typically under 10 years
- Low capital installation costs
- Cost effective operation
- Minimal maintenance requirements

Colorcoat Renew SC®

- Typically provides up to 50% of space heating demand operating either in parallel with another heating source or in series as a pre-heater to an alternative heat generator powered by conventional means.

- Active solar air heating provides renewable heat energy which often exceeds demand, as shown in Figure 4.1 below.

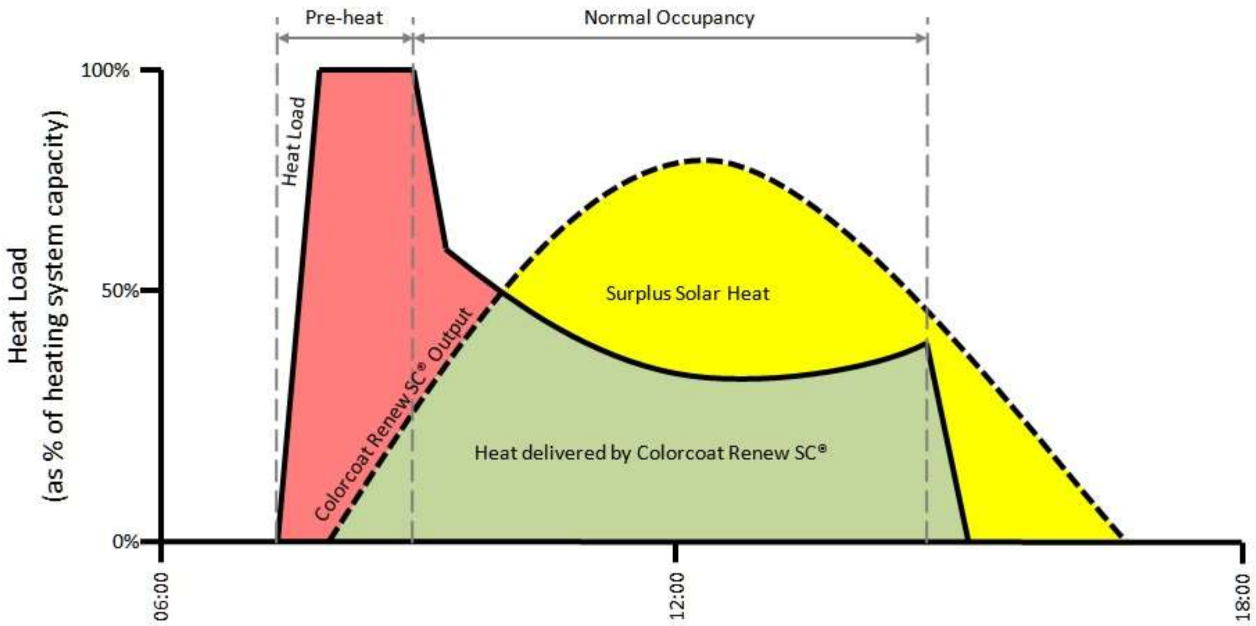


Figure 4.1: Renewable heating produced by Colorcoat Renew SC® in relation to heating demand

4.0 Solar Air Collector with Diurnal Store

4.2 Colorcoat Renew SC®: How it Works

- An active solar air heating system – using the sun to generate usable heat
- Incorporates a micro-perforated Colorcoat Prisma® pre-finished steel solar collector
    - Installed as a second skin to a conventional south-facing wall system
- The Colorcoat Prisma® solar collector absorbs and traps sun’s energy and converts it to usable heat
- The Colorcoat Renew SC® system is designed to generate and control the optimum amount of space heating for an individual building
- Suitable for all building sectors (industrial, commercial, residential)

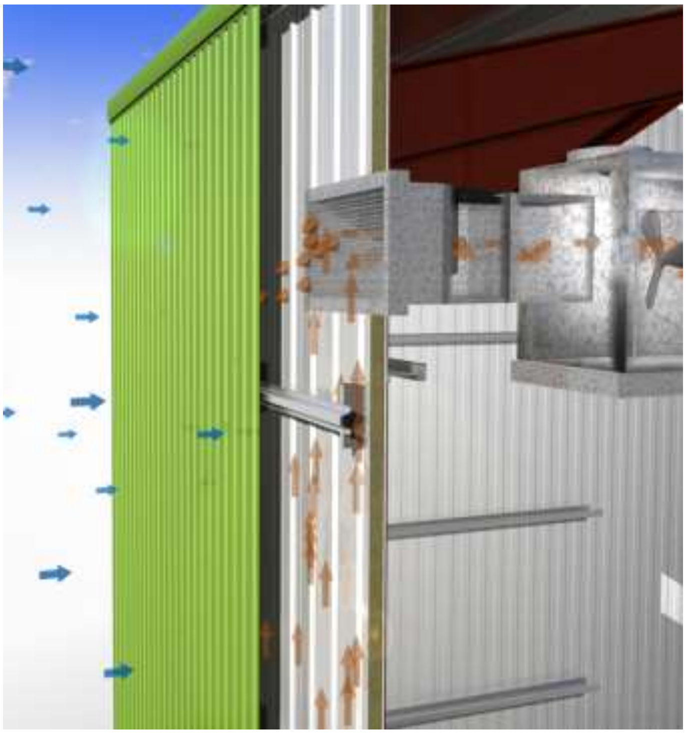


Figure 4.2: Section through solar collector wall

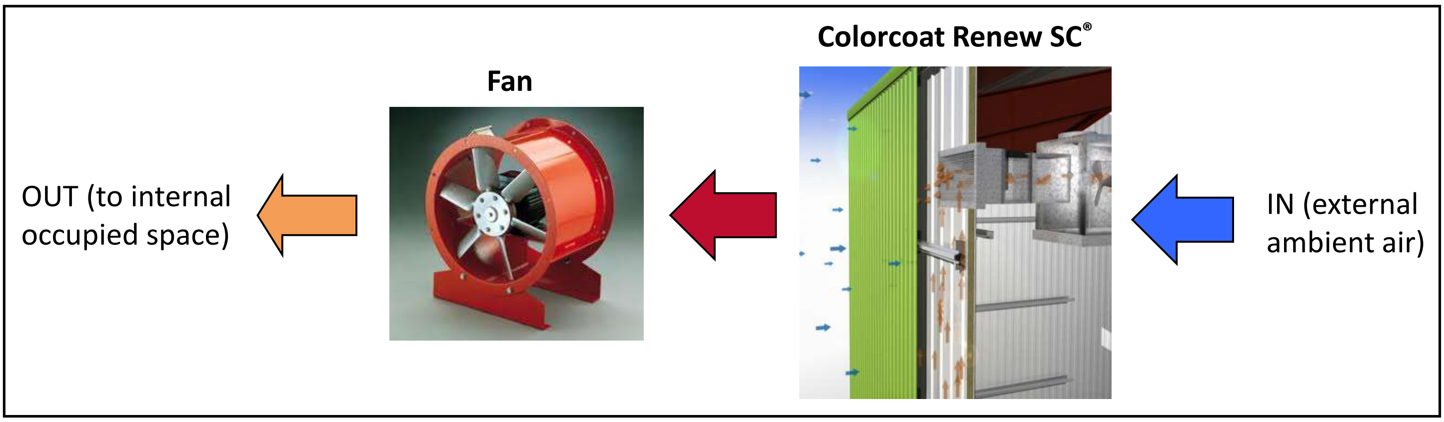


Figure 4.3: Diagram showing air transfer through the solar collector for space heating

4.0 Solar Air Collector with Diurnal Store

4.3 Colorcoat Renew SC® + Storage: How it Works

Combining a solar air collector with a diurnal storage system enables that excess energy generated to be stored for use either in the evening or first thing the following day, before the sun has risen. Tata refer to this combination as:

Colorcoat Renew SC® and Colorcoat Renew SSD®

Combining energy generation with energy storage in this way has the potential to deliver 100% of the daily heating demand.

Colorcoat Renew SC® for
Space Heating

- An efficient use of solar thermal heat
- Provides up to 50% of space heating demand
- Provides warm fresh air ventilation

Colorcoat Renew SSD® for
Heat Storage

- Uses low to zero carbon technologies to generate, store and dissipate renewable heat
- Heat is exchanged from air to water and then either stored or dissipated directly

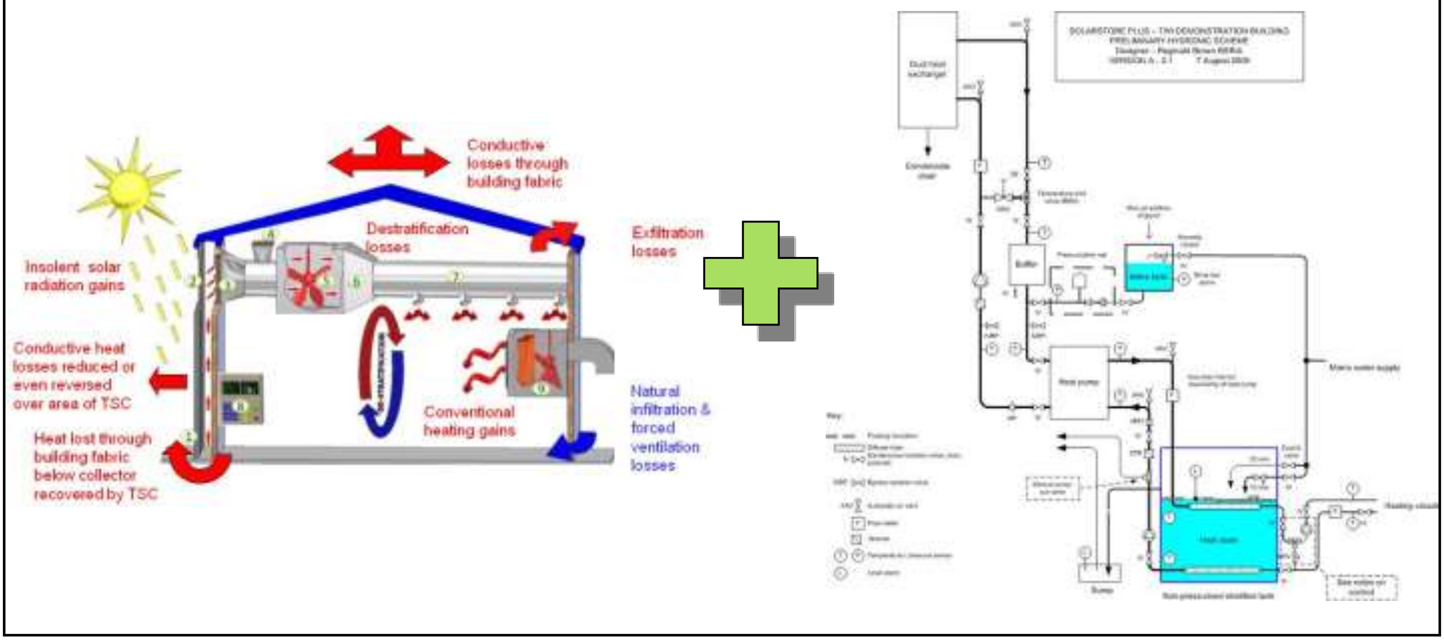


Figure 4.4: Diagram illustrating combination of Colorcoat Renew SC® and Colorcoat Renew SSD®

Research into this system has been ongoing since the year 2000. Since then, considerable optimisation and thermal modelling work has been undertaken. Tata (Corus UK Ltd at the time) were granted a Worldwide patent for the system in August 2010.

4.4 Colorcoat Renew SSD® Prototype System

The SHED houses the first prototype of this diurnal storage system, which has the following characteristics:

- Non-optimal building, due to its poor quality envelope
- Formerly gas-fired boiler with warm air heating system to both the production area and the offices, to be converted to use of fan coil units
- Approximately 500m^2 of TSC on south west elevation – 2 x 250m^2 – in anthracite grey
- Temperature set point for space heating to the production bay = 16ºC

Figure 4.5 below illustrates the system.

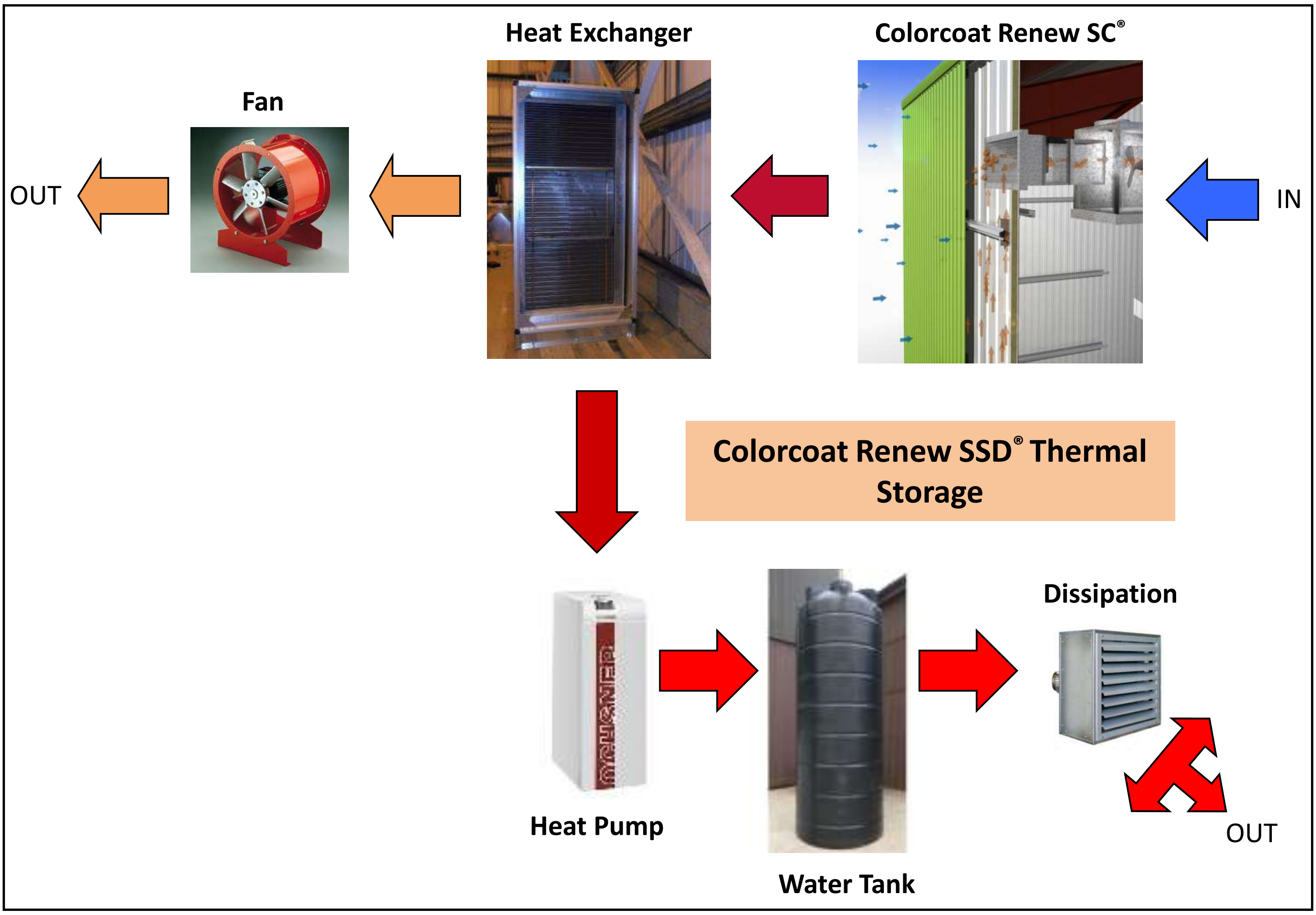


Figure 4.5: Diagram illustrating the Colorcoat Renew SSD® prototype system

The individual elements of the system are described on the following pages.

4.4.1 Colorcoat Renew SSD® - Heat Exchanger

- Transfers heat sensibly from the collector air flow to the heat pump primary water closed loop
- Designed to maximise heat transfer for given thermodynamic and fluid mechanic conditions

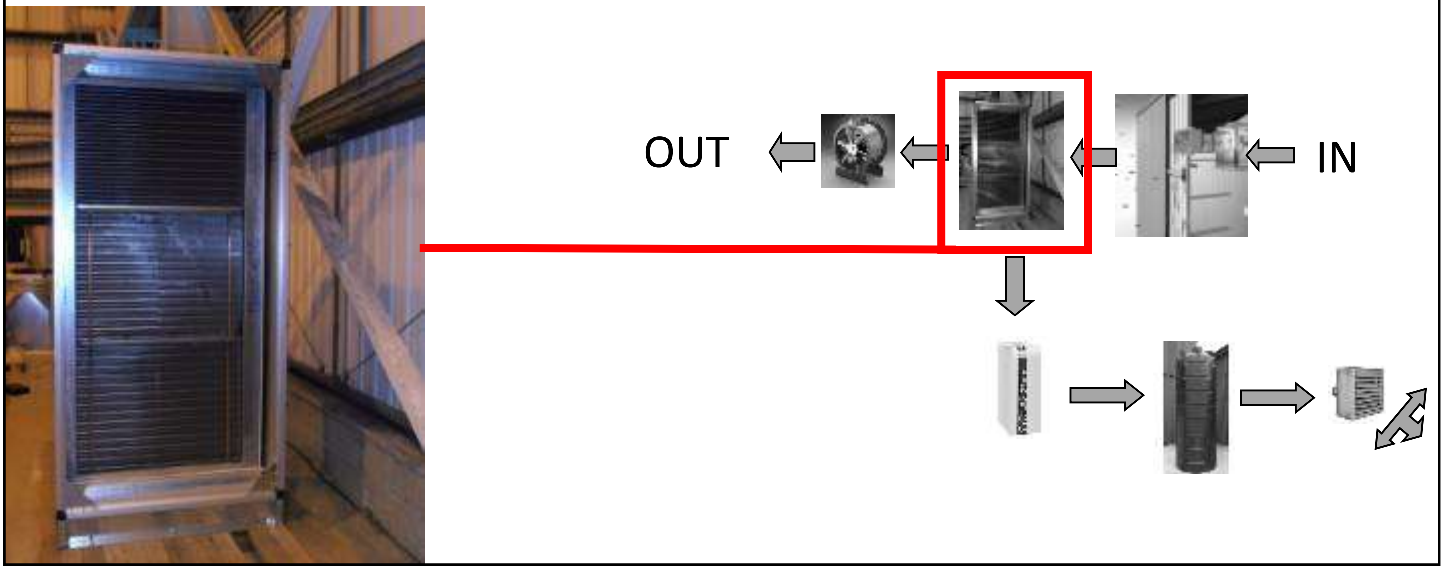


Figure 4.6: Colorcoat Renew SSD® Heat Exchanger

4.4.2 Colorcoat Renew SSD® - Fan Unit

- Axial fan
- Powered by an inverter driven motor
- Project specific designed flow rate
- Acoustics consideration for specific locations

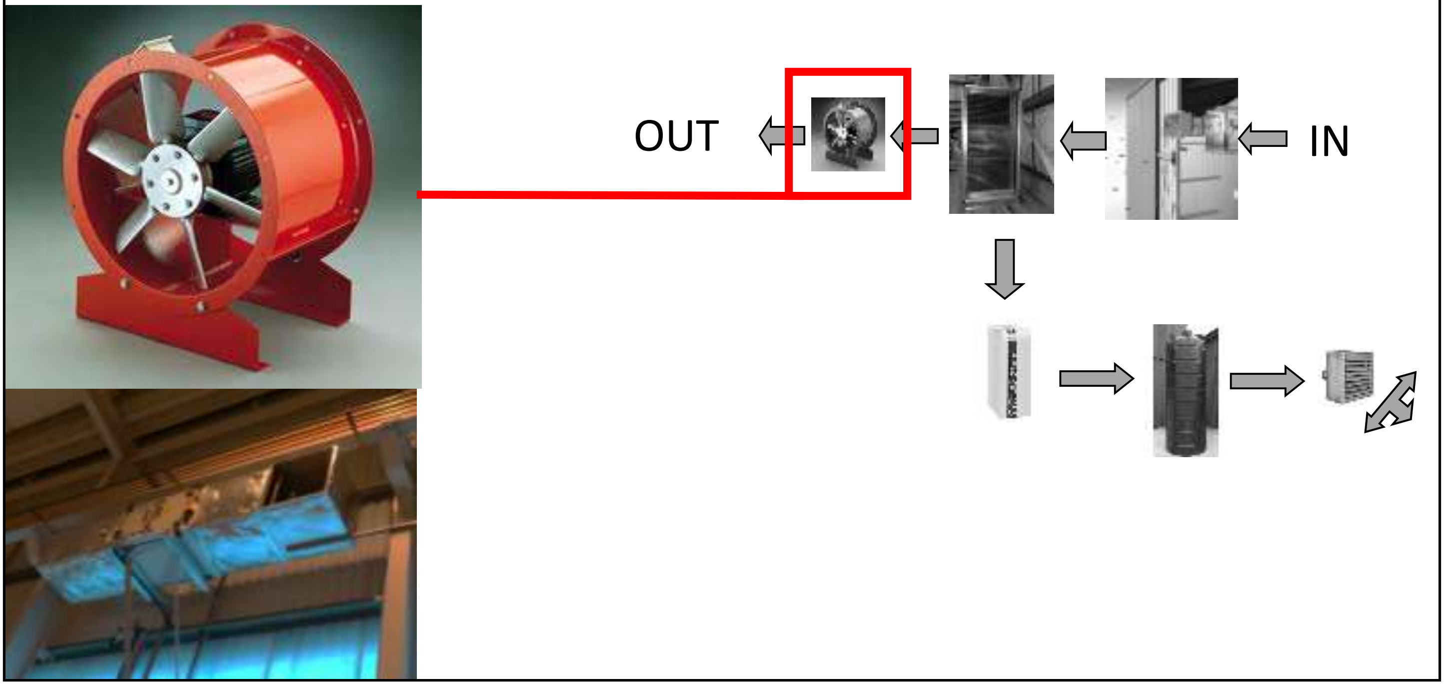
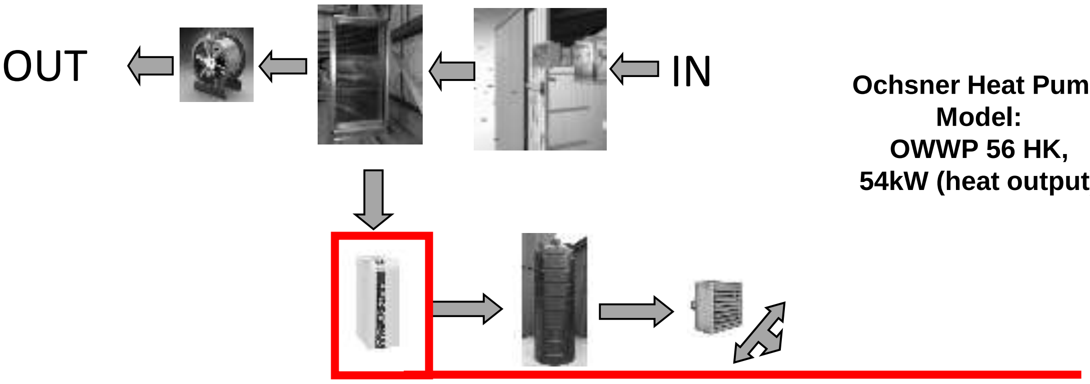


Figure 4.7: Colorcoat Renew SSD® Fan Unit

4.4.3 Colorcoat Renew SSD® - Heat Pump

- Heat pumps when in heating mode take heat from source (low temperature) and deliver it to a store (higher temperature)
- Electricity is consumed to drive the compressor
- Heat output efficiency is described as the pump's coefficient of performance:
    - CoP = heat output / electricity consumed



Ochsner Heat Pump Model: OWWP 56 HK, 54kW (heat output)

Figure 4.8: Colorcoat Renew SSD® Heat Pump

4.4.4 Colorcoat Renew SSD® - Heat Storage

- Via a water storage tank
- Capacity:
    - Volume = 20,000 litres ($20m^3$)
    - Temperature range = 30 - 50°C
- Control of temperature according to demand improves system efficiency
- De-couples space heating supply and demand
- Can be internal, external or underground

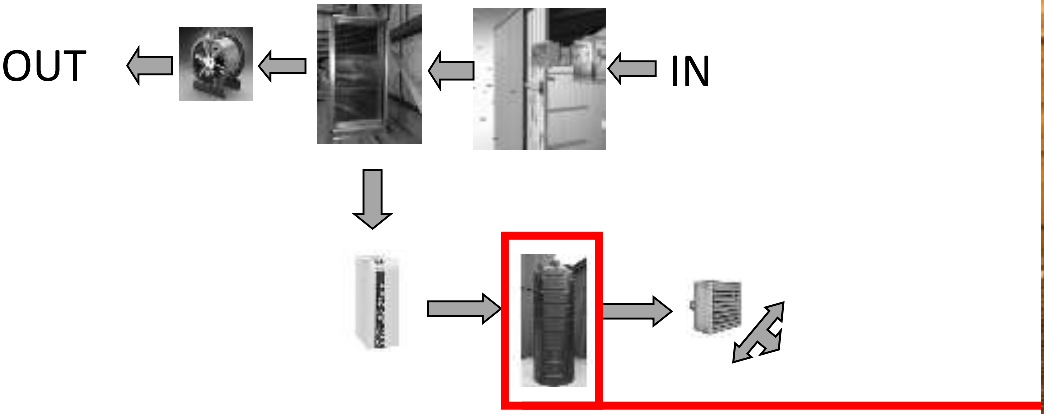
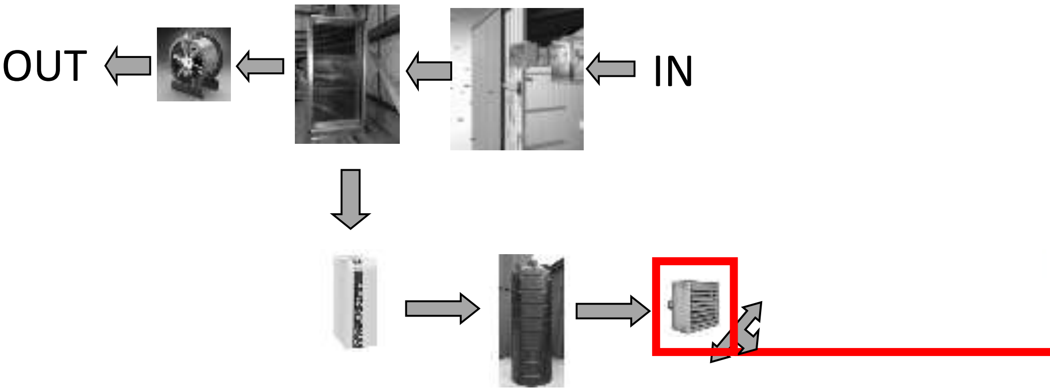


Figure 4.9: Colorcoat Renew SSD® Heat Storage

4.4.5 Colorcoat Renew SSD® - Heat Dissipation

Options for heat dissipation:

- Fan coil units
- Contact heating, e.g. underfloor heating
- Other low temperature radiators
- Into alternate heat reservoir, e.g. swimming pool



Distribution System Delivery	Temperature Required (°C)
Underfloor heating	30 – 45
Low-temperature radiators	45 – 55
Conventional radiators	60 – 90
Air (fan coil unit)	30 - 50

At the SHED, the heat dissipation is via fan coil units and low temperature radiators

Figure 4.10: Colorcoat Renew SSD® Heat Dissipation Options

4.4.6 Colorcoat Renew SSD® - Control System

- BMS control philosophy drives all components, including those with in-built control options, e.g. the heat pump
- BMS configured to maximise system performance whilst remaining within operational constraints of system components, e.g. heat pump anti-icing levels
- BMS controls all elements of system including generation, transfer, storage and dissipation, to maintain space temperatures and maximise system efficiency

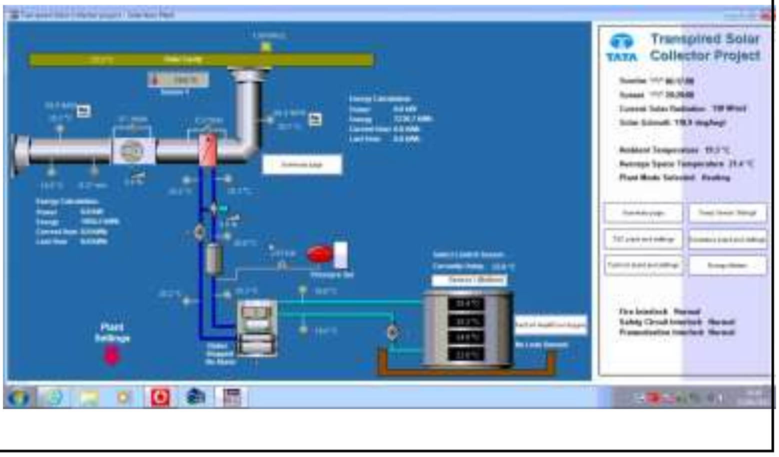


Figure 4.11: Colorcoat Renew SSD® Control System

4.5 Colorcoat Renew SSD® - Output

The graphs below show the amount of surplus heat generated by the **Colorocat Renew SC ®**, which could be captured using the **Colorcoat Renew SSD®** storage system and utilised for space heating. Two different occupancy patterns are illustrated.

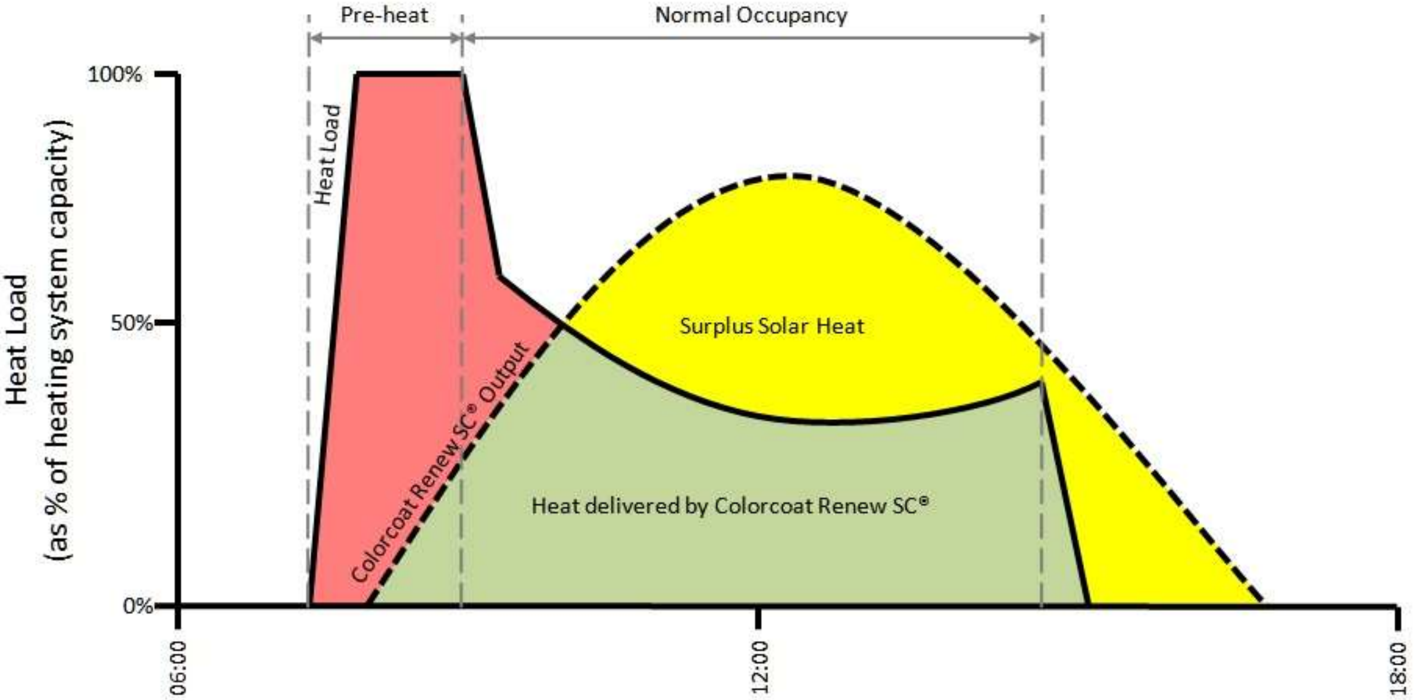


Figure 4.12: Surplus heat that could be provided by Colorcoat Renew SSD® system – Daytime only occupancy, 08:00 – 17:00

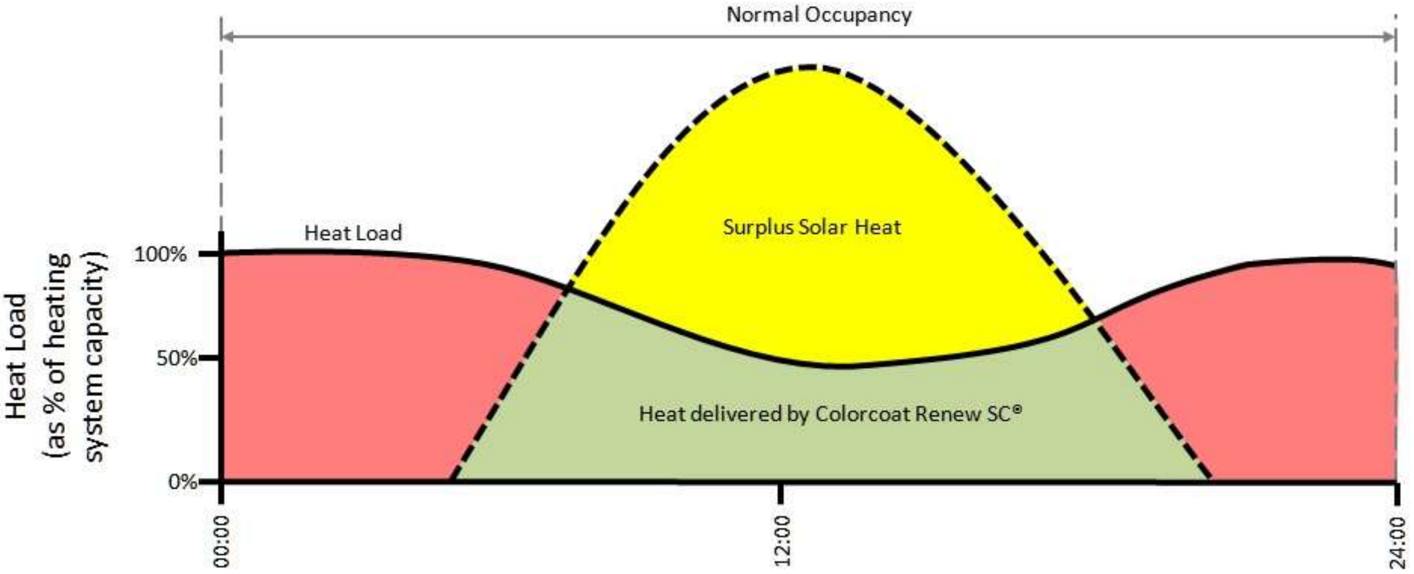


Figure 4.13: Surplus heat that could be provided by Colorcoat Renew SSD® system – 24-hour occupancy

4.0 Solar Air Collector with Diurnal Store

4.6 Colorcoat Renew SSD® - Operations

- Spatial Requirements:
    - Floor area required for the system components is consistent with a typical boiler room
    - Storage tank could be located internally, externally or underground

- Maintenance
    - Sealed system to eliminate legionella concerns
    - Annual maintenance requirements
    - Service 3 – 5 years
    - Life expectancy of components > 20 years

4.7 Colorcoat Renew SSD® - Performance

An independent report prepared by BSRIA for the operating period September 2012 – November 2013 concluded this provided a viable low carbon and economical heating system. During this operating period the report cited one important benefit of the system, that it demonstrated the performance of a ground source heat pump (GSHP) with the flexibility of an air source heat pump (ASHP).

Based on the operating strategy and procedure used at that time, the report author concluded that it provides 100% of the heat demand of the building with no gas connection: 40% direct heat from the TSC and 60% heat from the solar store.

This equated to a 44% saving in operating costs compared to the original gas-supplied system, with a 48% CO_2 saving on emissions against the original system.

Further analysis undertaken in 2020 found that the SHED struggles to reach the setpoint temperature of 16°C during the winter months, which is likely due to the poor thermal performance of the uninsulated building envelope and the large roller shutter door opening within the production bay.

The combination of **Colorcoat Renew SC®** for direct space heating and **Colorcoat Renew SSD®** for heat storage has the potential to provide a total heating system for a well-insulated building, eliminating the need for a gas connection.

Summary of main benefits:

- 80 – 90% renewable energy
- Uses low to zero carbon technologies to generate, store and dissipate renewable heat
- Low capital, maintenance and operating costs

5.0 Solar Air Collector with Inter-Seasonal Store

5.1 Introduction

In 2012, the Low Carbon Infrastructure Co-ordination Group (LCICG) launched a Technology Innovation Needs Assessment (TINA) for low carbon heating. The aim of TINAs was to identify and value the key innovation needs of specific low carbon technology groups, to inform the prioritisation of public sector investment in low carbon innovation. For each low carbon technology, they:

- Analyse the potential role of the technology in the UK's energy system
- Estimate the value to the UK from cutting costs of the technology through innovation
- Estimate the value to the UK of the green growth opportunity from exports
- Assess the case for UK public sector intervention in innovation
- Identify the potential innovation priorities to deliver the greatest benefit to the UK

SPECIFIC were part of a group developing a system that would capture the excess heat generated by Colorcoat Renew SC® during the summer period and release it, on demand, in winter. The INTRESTS project aimed to utilise thermochemical storage materials to enable the storage of a large quantity of low grade heat energy in a relatively small space; and the capability of this material to store heat energy for a long-term period – summer to winter, providing a whole heating system with renewable energy as its source.

The original project was co-funded by Innovate UK's Collaborative Research and Development (R&D) programme, following an open competition, and there were 6 project partners.

The INTRESTS project was completed in 2016, but the Thermal Storage research group at SPECIFIC has continued this work and grown in size since the original project completion.

Fig

5.2 The Roof TSC and Inter-Seasonal Store Installation (2015)

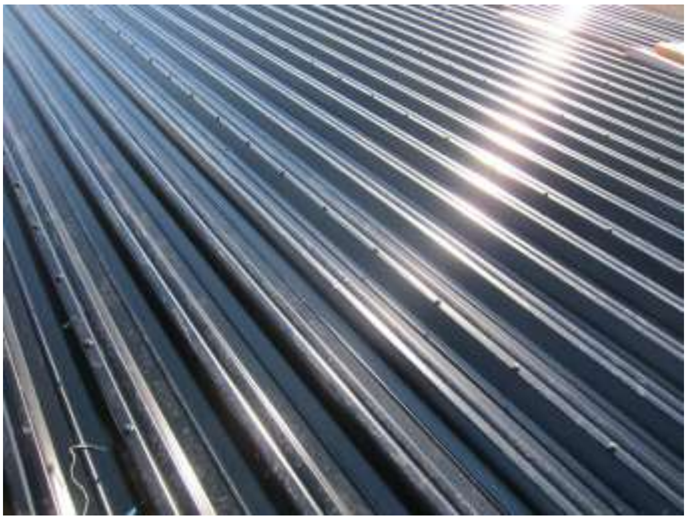


Figure 5.1: Roof-mounted TSC (external view)

Figure 5.2: Roof-mounted TSC (internal view)

Figure 5.3: Installation of the shipping container for the storage vessels

Figure 5.4: Installation of the shipping container for the storage vessels

Figure 5.5: The storage vessel shipping container in situ

Figure 5.6: The thermochemical storage material

5.3 How it works

The inter-seasonal heat storage system uses a Salt in Matrix, or “SIM” material, which is able to store thermal energy through a thermochemical process. Thermal energy (heat) is stored by passing hot air over the SIM, initiating a chemical reaction that locks the energy into the material. The reverse reaction is exothermal, meaning that heat is released, and is instigated by passing humid air over the SIM. Provided the SIM is kept dry it is able, to store the heat indefinitely, thus making it suitable for the inter-seasonal storage of heat and for transporting heat from one location to another.

Thermochemical storage is governed by a reversible endothermic/exothermic chemical equation:

$$\boldsymbol{AB + heat \rightleftharpoons A + B}$$

In this case, ***A*** and ***B*** are a chemical salt and water. The energy required to separate ***A*** and ***B*** (captured solar thermal energy driving off moisture) is stored via an endothermic event. Exposing the salt to humidity allows the recombination of salt and water, and it is this reaction that emits heat, which is subsequently distributed into the building.

Figure 5.7 below shows the potential energy generation of solar thermal systems in summer months, which could be stored for use in the winter months, using this process, to supply the heating demand.

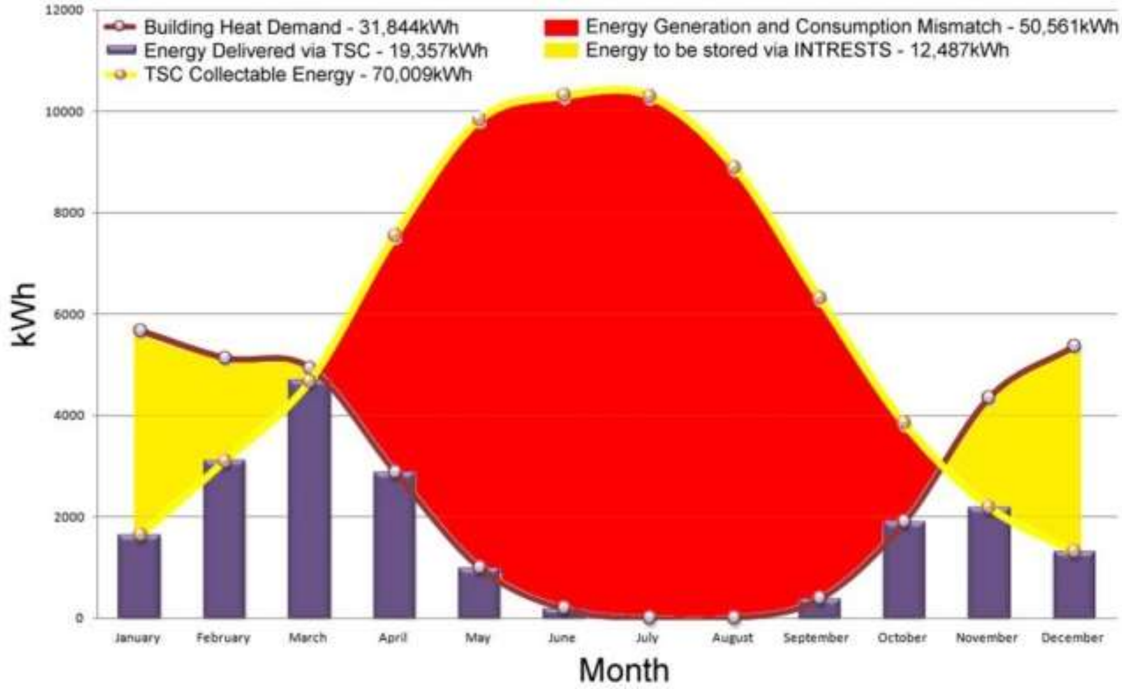


Figure 5.7: Energy delivered by a TSC vs Annual heating demand

5.4 Collaborative Projects

The thermal heat storage team at SPECIFIC is exploring a range of commercial applications of the SIM, with project partners, including:

- providing heat to large buildings as a substitute to gas, through storage and transportation of industrial waste heat; or from solar thermal energy generation
- the drying of agricultural produce.

6.0 Retrofit Heating System

6.1 Introduction

Fan convector heaters use lower temperature and less water than conventional radiators, meaning they are an ideal system to use in conjunction with heat pumps. In 2017, two low temperature, fan assisted radiators, *Olimpia Splendid SL Smart 1000B*, were installed in the SHED Boardroom and connected to the diurnal heat storage system, which could supply the low temperature water required to operate them.

To provide space heating, these utilise a compact, high efficiency heat exchanger and intelligently controlled fan to assist convection and heat delivery. In conventional radiator systems, water temperature is reduced for thermal efficiency, so radiators tend to be oversized to maintain the thermal output required from a lower temperature differential. Fan assisted convectors reduce the need for oversizing, as the fan element increases the thermal output at lower temperatures. Therefore, these heaters can be much smaller than conventional convector radiators with the same level of output.

As the UK decarbonises heating, building owners, developers and designers seek alternative heating systems that offer low-energy, low-carbon solutions. By trialling products such as these fan convector heaters, we can test the viability of electrical heating to replace gas heating.

At the SHED these heaters provide an efficient space heating solution, that works in combination with heat pumps – ideal for situations where retrofitting underfloor heating is not viable.

6.2 Performance Data

Heat meters were installed on the heating pipework between the solar store and the heater units to measure the actual thermal performance in use. It should be noted that the SHED, including the Boardroom, is poorly insulated, which impacts on the amount of energy used by any heating system to provide comfortable indoor temperatures.

In an experiment where, over a 24-hour period, the room was heated continuously, an average air temperature of 19.5 (+/-1)°C was achieved, during which time the external ambient air temperature averaged 8.2 (+/-4)°C. With an average water supply temperature of 38 (+/-4)°C, drawn from the solar store, a continuous power output of 3.3kW was delivered by the two heaters during this time.

Figure 6.1: Olimpia Splendid, SL SMART 1000B heater in SHED Boardroom

Figure 6.2: Cutaway diagram of Olimpia Splendid fan convector heater

In a separate experiment, the time taken to achieve a room temperature setpoint of 20°C from a starting temperature of 15°C and external ambient temperature of 10°C was monitored. This was achieved in two hours, i.e. exhibiting a ramp rate of 2.5°C/hour. These results show thermal efficiency close to that expected for a wet underfloor heating system, but with faster response times.

7.0 PV and Solar Thermal Test Rig

7.1 Introduction

The Solar Test Rig was constructed on the southeast elevation of the SHED to analyse five commercially available and emerging PV and solar thermal technologies. Data collected from the rig provides an understanding of performance of the technologies in real weather conditions, such as cloud cover, insolation and precipitation. This will aid technology choice for buildings in the future.

Five different types of technology are used in this experiment: three solar thermal and two solar electric (PV). Each technology is mounted in two orientations on the façade of the building to simulate wall or roof installation. The moving rigs can be tilted through a range of pitches to investigate the effect on generation.

Figure 7.1: The Solar Test Rig

Figure 7.2: The Solar Test Rig – Close up

Study Aim

The results from the solar thermal generation and solar electric energy generation can be compared to investigate the optimal use of space on a vertical façade for a given usage profile.

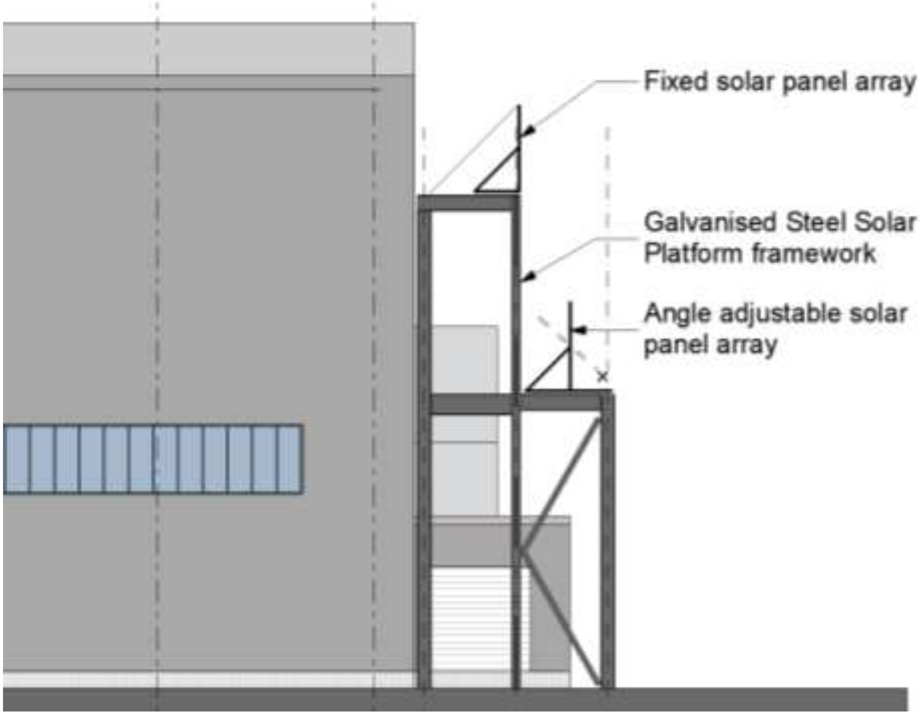


Figure 7.3: Side elevation of the Solar Test Rig

Project Partners

Solar PV System:
Panasonic
Solibro

Solar Thermal System:
Pursey & Ball
Hyrax Solar Ltd
Kingspan
Thermosolar
Secon Solar Ltd

7.0 PV and Solar Thermal Test Rig

7.2 Solar PV System

The study analyses commercially available PV, with two identical Energy Storage Systems installed: the panels for one system mounted on a stationary frame, and the other on a dynamic, sun tracking test frame. The two separate off-grid systems installed on the Solar Test Rig are shown in Figure 7.4 below. The upper system includes six thin film panels (SOLIBRO SL2 CIGS 125W) and three silicon high power panels (Panasonic HIT 330W). The lower system includes five thin film panels (SOLIBRO SL2 CIGS 125W) and three silicon high power panels (Panasonic HIT 330W).

Upper level vertical array mimics installation of panels on a vertical building facade

Lower level, movable array simulates roof installation at different angles, or uniaxial solar tracking

Figure 7.4: The two solar arrays on the Solar Test Rig – PV panels highlighted

The panels are connected to battery systems to allow the combination effect of different PV technologies with one battery technology to be assessed. Different load profiles are also simulated for different home occupancies to determine how much residual energy can be diverted towards long-term heat storage. The battery systems comprise the following:

- Individual dedicated Victron MPPT charge controllers with associated panel level monitoring – nine in total per system. This individual MPPT controller configuration enables direct comparison of PV panels installed side by side and future flexibility for replacement with different PV technologies.
- DC coupled to a 5kVA Victron inverter and 10kWh BYD Lithium Iron Phosphate ($LiFePO_4$) battery bank

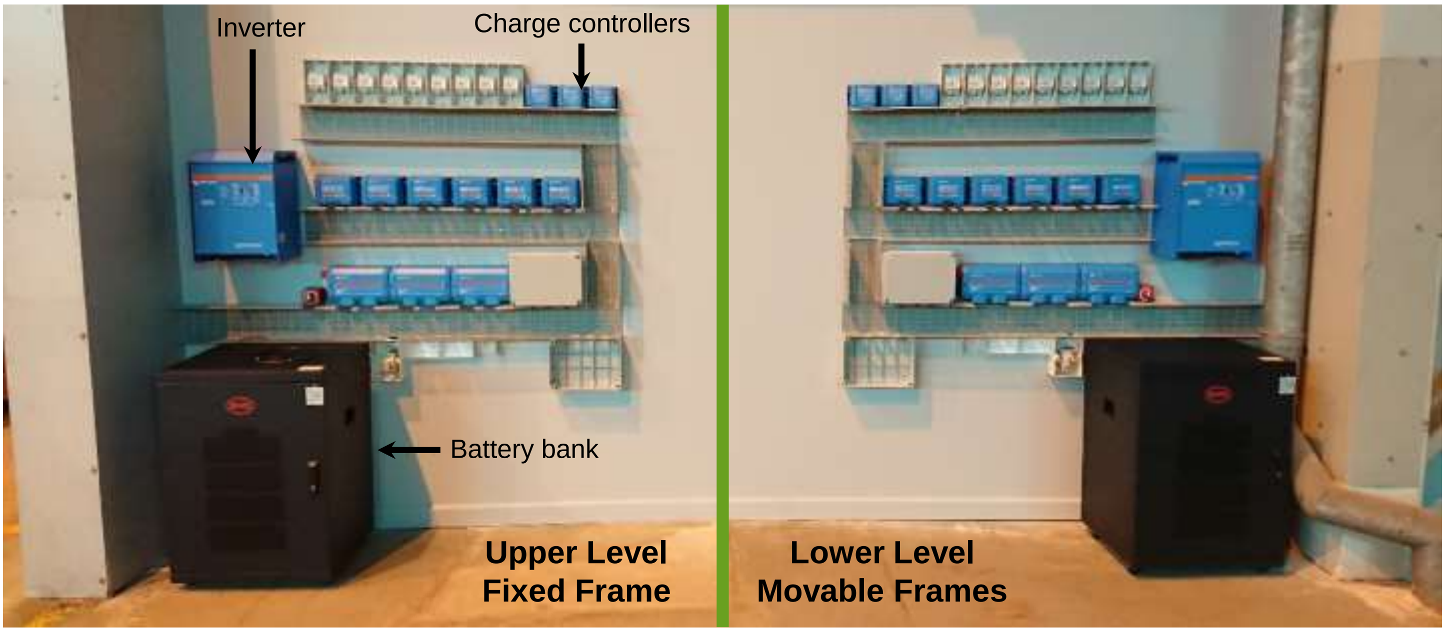


Figure 7.5: Internal support system for Solar PV Arrays

7.3 Solar Thermal System

Six solar thermal arrays are being tested – three on the upper level fixed frame and three on the lower level movable frames, consisting of:

- Two arrays of Kingspan Varisol DF400 evacuated tubes – 15 tubes per array
- Two arrays of Thermosolar TS400 evacuated flat plate connections – 2 per array
- Two Hyrax Solar 4-Star thermodynamic panels – 4 per array

Upper level vertical array mimics installation of panels on a vertical building facade

Lower level, movable array simulates roof installation at different angles, or uniaxial solar tracking

Figure 7.6: The two solar arrays on the Solar Test Rig – solar thermal panels highlighted

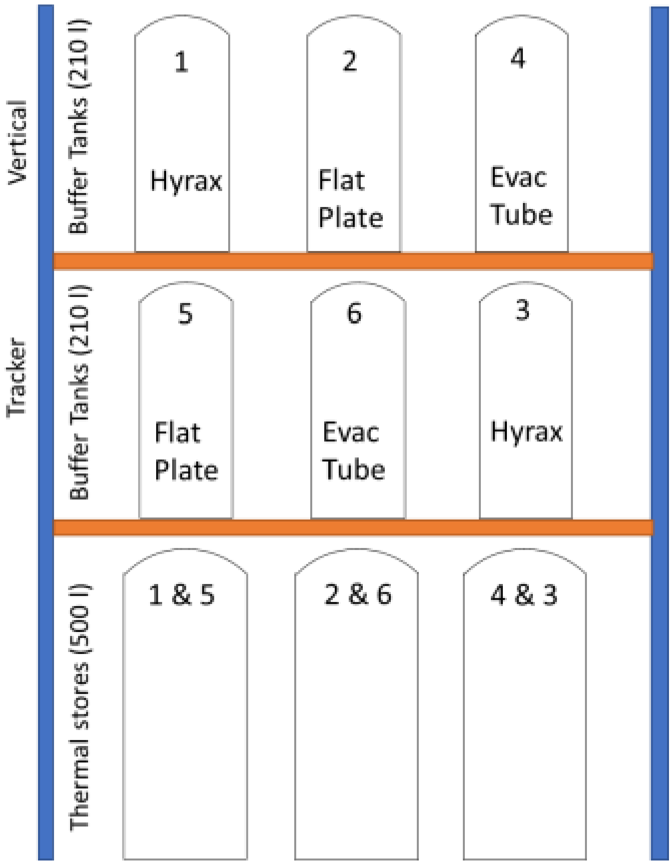


Figure 7.7: Arrangement of internal hot water tanks and thermal stores

Data from the solar thermal systems will be collected to investigate how the vertical facade of a building envelope can be best used to meet the heating requirements of a building. This data is compared to evaluate cost vs generation performance.

The data allows a side-by-side comparison of the solar thermal technologies, including thermodynamic panels, for which there has been limited rigorous, independent testing.

A series of hot water tanks located inside the building capture heat generated from the solar thermal arrays, as depicted in Figure 7.7 and described on page 25.

7.0 PV and Solar Thermal Test Rig

How it works:

- Each of the evacuated tube and evacuated flat plate solar thermal systems are plumbed into separate 210 litre calorifiers (hot water tanks) - 4 in total (tanks 2, 4, 5 and 6 in Figure 7.7). Flow between the evacuated tube and evacuated flat plate collectors and their respective tanks is controlled using individual solar pumping stations.

- Each Hyrax system acts as a heat pump where the ‘solar’ panels are the evaporators, which are connected to a heat pump condenser unit inside the building that transfers heat from the refrigerant via a plate heat exchanger, to the water circuit, which again feeds a 210 litre calorifier (tanks 1 and 3 in Figure 7.7). The systems have their own dedicated control units.

- Each calorifier tank is equipped with a fan coil ‘heat dump’ which can be used to cool the tanks if they are approaching their maximum safe temperature, or to simulate a load, e.g. running a bath.

- The three pairs of calorifiers are also plumbed via hydronically separate circuits into three 500 litre thermal stores, to provide increased thermal storage capacity. The three thermal stores can in turn provide thermal input to the 20,000 litre ‘solarstore’ (refer Section 4).

- Low powered, variable speed Wilo pumps provide flow through the various circuits, which is controlled by a series of Resol solar controllers.

- Each system has dedicated electrical submetering and three heat meters - one on the generation and two on the load side. This enables system performance monitoring.

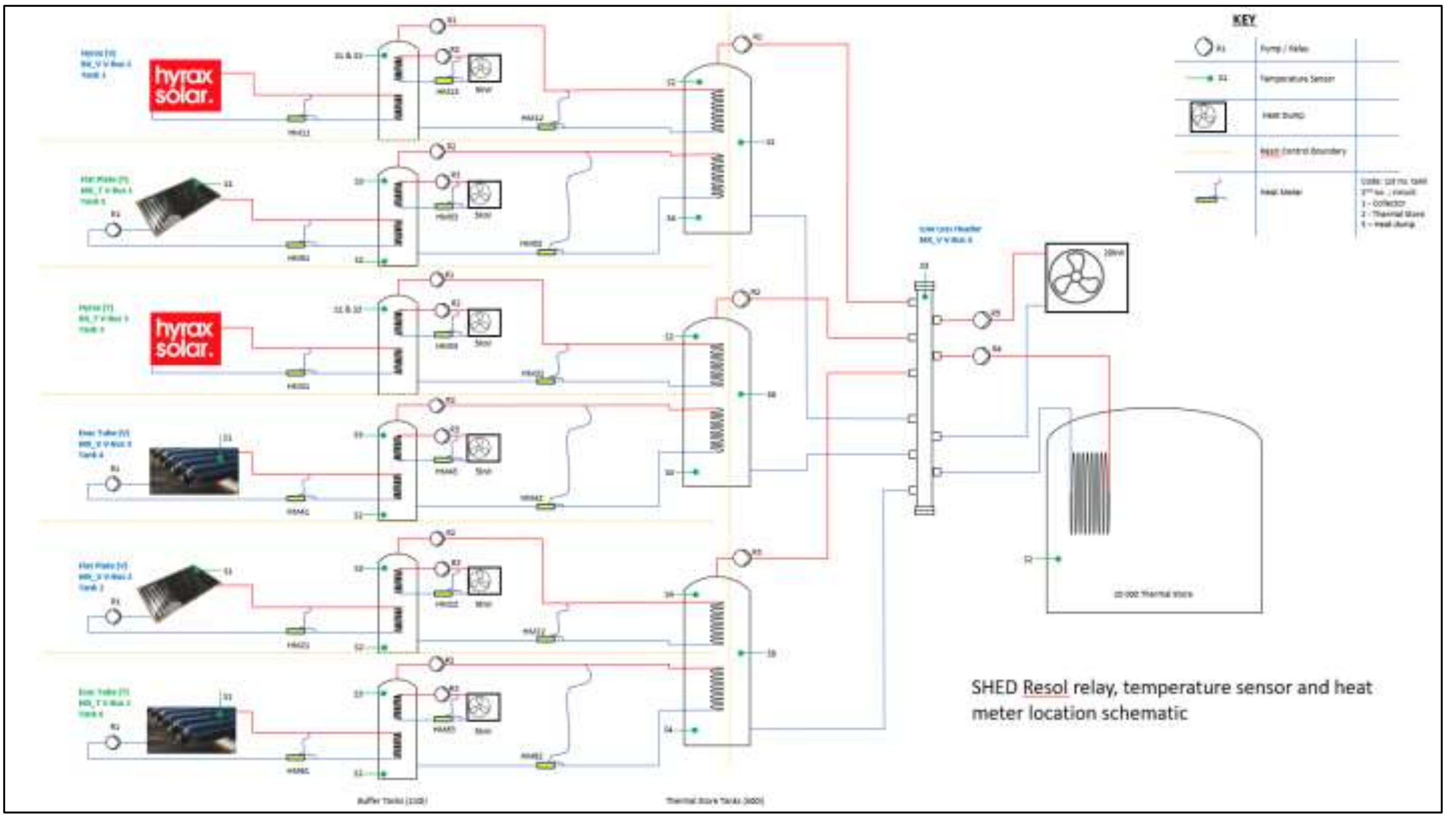


Figure 7.8: Schematic of the solar thermal system

8.0 Active Rail Shelter

8.1 Introduction

SPECIFIC first met Transport for Wales (TfW) when presenting the Active Classroom to a judging panel for the Constructing Excellence in Wales (CEW) 2017 Awards. One of the judges worked for TfW and could see the potential of adopting the Active Building approach for remote train shelters along the railway network in Wales.

In 2018, TfW delivered one of their standard approved platform waiting shelters to the SHED site and the technical team at SPECIFIC began the project of ‘activating’ the shelter.

8.2 Original Shelter Specification

The PV roof and associated technologies were added to the standard rail shelter used along the rail network. This is manufactured for TfW by a company called by Rail Waiting Structures limited (part of the BSW group), based in the Vale of Glamorgan, and comprises a 5-bay double front entry, anti-vandal platform waiting shelter, with integrated seating, from their Voyager Range, as shown in Figure 8.1 below.

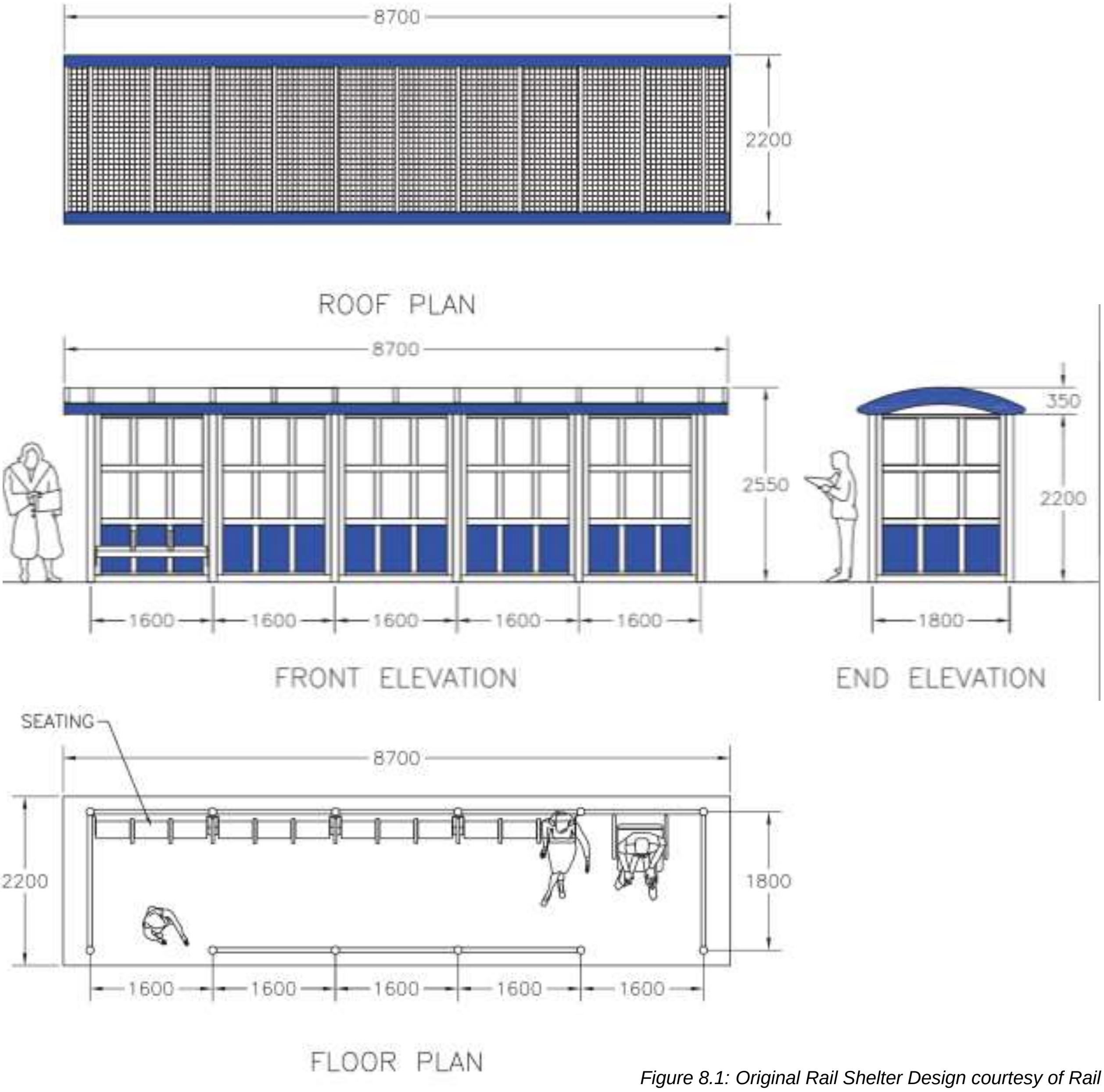


Figure 8.1: Original Rail Shelter Design courtesy of Rail Waiting Structures

8.3 ‘Activating’ the Shelter

Technologies integrated into the shelter included:

- A 2.4kWp photovoltaic (PV) array, consisting of flexible silicon panels, custom-made to size by GB-Sol Ltd – Treforest, each module being manufactured to the same size as the 10 modular roof panel sections to the shelter. The PV has a black backing for aesthetic reasons. Electrical connections are located on the back of the sheets.
- 5.2kWh $LiFePO_4$ (48v) of battery storage, supplied by Wind and Sun, with a 230v Victron inverter. The batteries were mounted in a bespoke tray slotted into one of the existing roof cavities at one end of the shelter.
- Pre-fitted LED light fittings were supplied with the structure. These were enabled through use of the AC inverter linked to the battery system. It was simpler to use the existing fittings than to replace with 48v DC lighting, which was considered as an alternative.
- Two display screens were added to the shelter – a 24” screen mounted in landscape and a 42” screen mounted in portrait. These screens are vandal-proof and weather-proof. They will display customer information and advertisements, as well as a live energy dashboard.

Figure 8.2: Side View of the Active Rail Shelter

The Active Rail Shelter will be used to test and verify suitable technologies to enable the structure to generate, store and release enough energy to run essential services in a low-carbon manner.

8.0 Active Rail Shelter

8.4 Aims

- To identify suitable Active Building technologies that will allow the structure to capitalise on solar energy availability at the location specified.
- To develop an engineering solution with aims to keep as much of the original structure as possible, potentially making it suitable for retrofit to some of the hundreds of shelters already installed across the rail network.
- To specify and install technologies in a way that meets stringent rail safety standards and ensures lifetime performance and security.
- To investigate the opportunity for installation of additional solar powered convenience services currently not provided as standard.
- To capture energy performance data and use this to understand the operational carbon impact over a one year test period.

The PV roof is capable of generating 2.4kWp of clean electricity annually

LED light fittings in the ceiling soffit connected to the battery system

The display screens are mounted adjacent to the shelter access

The batteries are housed within the roof space, hidden from view by the ceiling soffit

Figure 8.3: Annotated View of the Active Rail Shelter

8.5 What will it measure?

- The development of a standalone product, which could be installed independently, will be investigated.
- The operational carbon emission impact of this active structure will be measured and monitored, with a view to providing data on effectiveness and efficiency in situ.
- If possible, with a view on the circular economy, the project also will seek to develop bolt-on solutions, which allow Active Building technologies to be integrated into the existing structures of this type across rail platforms in Wales and across the UK.

9.0 Rotaheat Project

9.1 Introduction

Rotaheat was founded in 2012 to commercialise their innovative technology that converts motive power (mechanical rotational energy) into thermal energy as a heated fluid, using no combustion processes and no electricity, offering a truly zero carbon heating system.

Rotaheat have developed two Rotaheater devices, Pico and Micro, designed to generate up to 30 kW and 250 kW of clean heat respectively, at temperatures up to 110°C. During 2020, SPECIFIC provided space at the SHED, along with technical support for the installation of a large test rig. This test rig is used for performance analysis, along with performance verification and conformance, required for commercialisation.

The Rotaheater Pico is in the latter stages of performance verification, now being subject to rigorous safety and conformance testing, facilitating product sales later this year.

Rotaheater devices are capable of delivering heat with efficiencies in excess of 97%whilst contributing zero carbon emissions, Rotaheater devices are suitable for inclusion within a wide range of fixed and portable solutions, incorporating mechanical rotational energy, such as wind turbines, hydro turbines, and turbo machines. The application of most interest to SPECIFIC is the coupling of the Rotaheater devices with wind turbines, generating clean thermal energy when a turbine is unable to operate due to electrical grid capacity. Rotaheat have recently submitted a grant application, which, if successful, will lead to the installation of a wind turbine coupled with a Rotaheat device at the SHED site.

9.2 Aims

- Internal and external evaluation of the performance of Rotaheat’s 30 kW and 250 kW devices.
- Collate and analyse the data and produce a report for Rotaheat to help with product development.
- Examine the use of coupling Rotaheater devices with wind turbines as a source of low carbon energy potentially suitable for storage via thermochemical systems.
- Couple 30 kW device with an oil distillation process utilising thermal storage materials.
- Attain UKCA marking and subsequent commercialisation of Rotaheater devices.
- Install an outdoor test rig coupling a Rotaheater with a wind turbine.

Figure 9.1:: Photo of the Rotaheat Test Rig (Courtesy of Rotaheat)

9.3 Impact

- Installation of a 30 kW Rotaheater device (Pico) coupled with 30kW electric motor to simulate energy input.
- Installation of a 250 kW Rotaheater device (Micro) coupled with 350kW electric motor to simulate energy input.
- Design improvements to both Rotaheater Pico and Micro devices.
- Attained a peak performance of 42kW out of the Rotaheater Pico device.
- Consistently record efficiencies more than 98%.
- Energy metering to determine energy efficiency of the devices at various input powers.
- Investigation of peak temperature outputs from a range of input parameters.
- Investigation of compatibility with novel thermal devices and storage mechanisms.
- Investigate the efficacy of thermal energy generation from wind power.

Figure 9.1:: Photo of the Rotaheat Test Rig (Courtesy of Rotaheat)

10.0 The Future – 2021 and beyond

10.1 Introduction

Whilst providing an ideal location for the various demonstrators detailed within this case study, the SHED has also provided space for other activities over the years. These include:

- Hosting many engagement activities.
- Housing the hand sanitiser project during 2020. The large industrial areas provided space for production lines, storage and work spaces in a well-ventilated area, which allowed safe, socially distanced working to take place. Further information on the hand sanitiser project can be found here.

Figure 10.1:: Group of visitors reviewing the Diurnal Solar Store

Figure 10.2:: Hand sanitizer production

10.2 Thermal Storage Team Expansion

As the Thermal Storage team grows and starts to develop larger prototypes, the team (currently located in SPECIFIC's PMRC) are expanding to occupy the SHED. This building can provide the team with office accommodation, laboratory spaces and larger open industrial spaces. It also already houses the diurnal and inter-seasonal thermal storage systems (refer Sections 4.0 and 5.0) and the Solar Test Rig (Section 8.0), making it an ideal choice for the team to grow further.

To facilitate this move, the following upgrade works are proposed:

First Floor Office Accommodation

Works to ensure the office spaces comply with current building regulations. This will include upgrades to:

- Heating and ventilation systems
- Electrical installations
- Internal partitions – fire safe and adequately insulated, including new doors where required
- For fire safety, a complete review, which may require additional compartmentation and an upgrade to the fire and smoke detection systems.

Ground Floor Accommodation

- The production spaces cleared to provide space for prototype development.

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