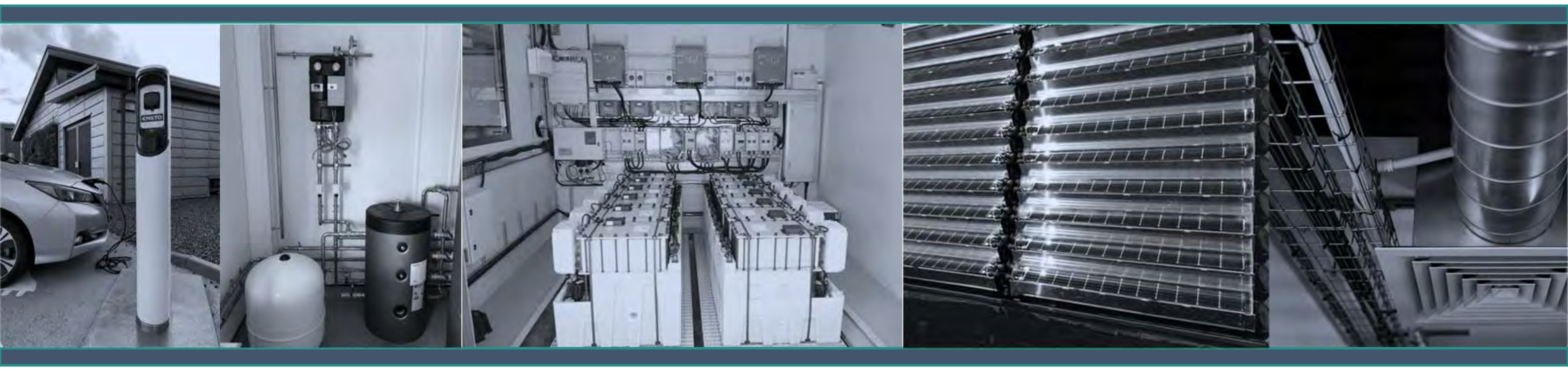
Active Building Technology Showcase

Version 2.0, August 2021



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Credits

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Contents

1.0 Introduction

This document forms part of a toolkit, highlighting some of the possible technologies that could be deployed on Active Building projects to reduce overall energy consumption. The information provided is not exhaustive and is accurate at the time of producing this document – September 2020.

1.1 Purpose

- Provide some suitable technologies for use in an Active Building project
- Illustrate how technologies might be utilised within an Active Building project

The document should be read in conjunction with the following documents:

- Active Building Code of Conduct
- Active Building Glossary
- Active Building Design Guide
- Active Building RIBA Plan of Work Checklists (not yet available)
- Active Building Project Template (not yet available)
- The Active Classroom Case Study
- The Active Office Case Study
- The SHED Case Study
- Active Building Energy Dashboard Design Guide

Version 2 additions

- Additional information on energy efficient hot water systems added to Section 2.0: Energy Efficient Systems.
- Information about thermal screw piles added to Section 6.0: Thermal Storage.
- Additional information added to Section 8.0: Data Capture and Visualisation.
- New section added – Section 9.0: Low Carbon Construction Materials.
- Document reformatted to provide easier access to information.

Note

The collection of technologies highlighted within this document is by no means exhaustive. Further energy-saving technology options can be found on the UK Government's **Energy Technology List**.

The Energy Technology List (ETL) is a list created and updated monthly by the UK Government's Department for Business, Energy and Industrial Strategy (BEIS), which provides details of energy-saving products for businesses and the public sector. Since its inception, the scheme has assessed nearly 60,000 products, and now features 56 technology categories.

2.0 Energy Efficient Systems

2.1 Low Carbon Heating Systems

In 2019, the UK government amended the **Climate Change Act 2008** and their commitment to reduce greenhouse gas emissions by 80% below 1990 levels by 2050, to legislate for a net zero greenhouse gas emissions target by 2050. To meet this target and align with the UK's strategy for decarbonising heat, alternative, low carbon heating systems are needed to replace traditional fossil fuel (mainly gas) heating systems. Some of the available options are described here.

2.1.1 Heat Pumps

Heat pumps use the refrigeration cycle to extract heat from either the ground, air, or water at a low temperature, absorbing the heat into a fluid. This heat can then be used to heat radiators, underfloor heating systems, or warm air convectors, and hot water. The system selected will depend on site specific conditions and financial or legislative constraints. Although they use electricity, the power input required is typically between half to a fifth of the available heat output. This is known as the coefficient of performance (COP) and is used as a measure of efficiency of a heat pump. The COP will vary depending on temperature input and output and the seasonal performance factor (SPF), which is the average COP of a heat pump over a full heating season. Ground source heat pumps tend to have a higher COP than air source heat pumps, for example, as the temperature of the ground is more stable and generally warmer than ambient air temperature.

$$COP = \text{useful heat output (kW)} \div \text{electrical power input (kW)}$$

The low electrical consumption of heat pumps in relation to their thermal output is further improved when used in conjunction with renewable electricity generation, making them a low energy and low carbon choice for heating buildings.

2.1.2 Air Source Heat Pumps (ASHPs)

ASHPs use the refrigeration cycle to absorb heat from outside air at low temperature into a fluid. This fluid then passes through a compressor where its temperature is increased, and transfers its higher temperature heat to the heating and hot water circuits of the building.

Key Design Considerations:
Space, location, acoustics, heating system

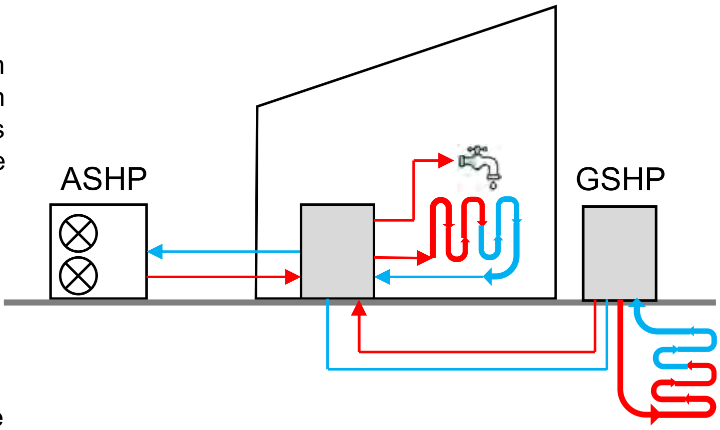

Figure 2.1: Diagram of ASHP or GSHP connected to heating and DHW circuit

2.1.3 Ground Source Heat Pumps (GSHPs)

GSHPs use the refrigeration cycle to harness heat from the ground by pumping water through pipes within the ground to provide space heating and hot water.

Key Design Considerations:
Ground conditions, available area, heating system

2.1.4 Ground to Air Heat Exchangers (GAHEs)

Also known as earth tubes, GAHEs are used to pre-temper ventilation air by drawing air through underground pipes at a depth of 1.5m – pre-cool air in summer and pre-heat air in winter, using the near constant temperature of the ground.

Key Design Considerations:
Location of air intake pipe, ground conditions, required flow rate, pipe length, pipe diameter, condensate trap location

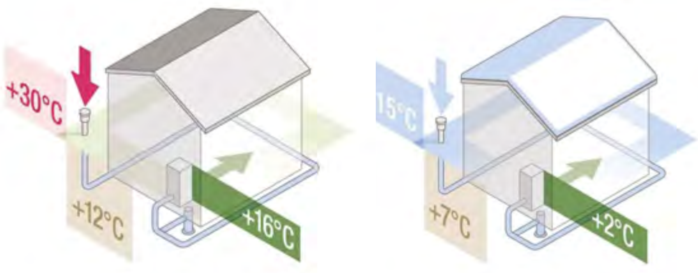

*Figure 2.2: Representation of **Rehau Awudukt** GAHE system*

2.1.5 Mechanical Ventilation and Heat Recovery (MVHR)

An MVHR system provides fresh filtered air into a building whilst retaining most of the energy that has already been used in heating the building, as well as providing the ventilation needs of an Active Building. An MVHR system can provide a constant supply of fresh filtered air, maintaining the air quality whilst being practically imperceptible. It works by simply extracting the air from polluted sources such as kitchens, bathrooms and toilets, and supplying air to occupied spaces. Extracted air is taken through a central heat exchanger and the heat recovered into the supply air. This works both ways, if the air temperature inside the building is colder than the outside air temperature then the coolth is maintained in the building.

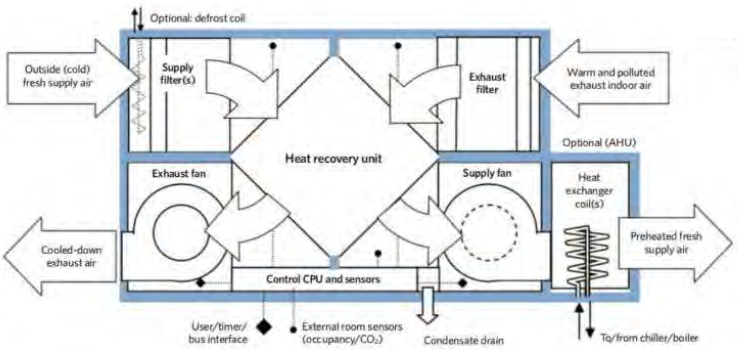

Figure 2.3: Cross section through a typical MVHR unit

- ***Air-tightness of <3m^3/m^2/hr is required for optimal MVHR use, although they can improve ventilation and lower carbon emissions at any level of air-tightness****

2.1.6 Decentralised MVHR (dMVHR)

Decentralised MVHR systems are typically installed through outside walls, resupplying fresh, tempered air into the room they are extracting from. They are generally small, compact units, using less energy than a standard MVHR system and have minimal to no ductwork, reducing restrictions on their locations and making them ideal for retrofit situations. Their flexibility in location also reduces time, disruption and costs associated with installation.

Examples include:

- LUNOS: http://lunos.co.uk/index.php
  - See p.42 – 49 of Passive House Plus magazine, issue 34, for an example of use in a deep retrofit scheme: https://issuu.com/passivehouseplus/docs/ph_issue_34_uk_digital
- Ecostream: https://www.ecostream.org.uk/decentralised-mechanical-ventilation-with-heat-recovery-dmvhr/

2.1.7 Combined MVHR with ASHP

The **Genvex Combi 185** unit combines MVHR with an ASHP to provide space heating and to supply a 185L integral water tank, which also has a 1kW immersion heater for fast delivery of hot water. This unit is Passive House Institute (PHI) certified for a heat recovery efficiency of around 70%.

The integrated ASHP prioritises the production of domestic hot water, providing space heating once the hot water cylinder has been fully charged. The hot water cylinder can be connected to solar thermal generation.

Another example of a combined unit is the Pichler PKOM4.

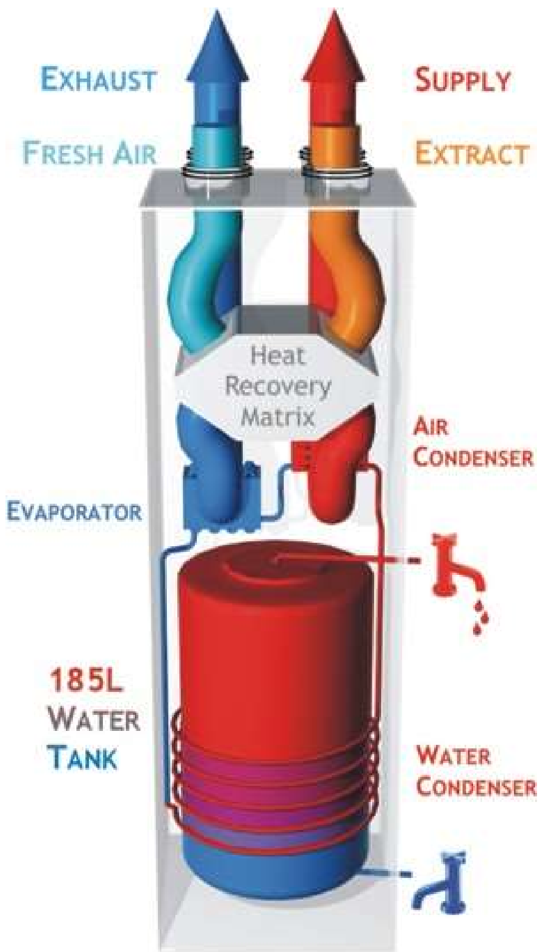

Figure 2.4: Cross section through a Genvex Combi 185 unit

* https://passivehouseplus.ie/news/coronavirus/new-report-questions-long-held-mvhr-assumptions

2.0 Energy Efficient Systems

2.1.8 Electric Infrared (Radiant) Heating

Radiation emitted from the heating unit travels through the air until it hits an object or person, at which point the object or person absorbs the radiation, causing molecules to vibrate, producing heat. As radiant panels heat objects or people in this way, rather than heating the air, they can be more efficient in large volume spaces.

There are no direct carbon emissions from electrical radiant panels and their electrical consumption can be supplemented with solar PV.

Panels are typically located on walls or ceilings.

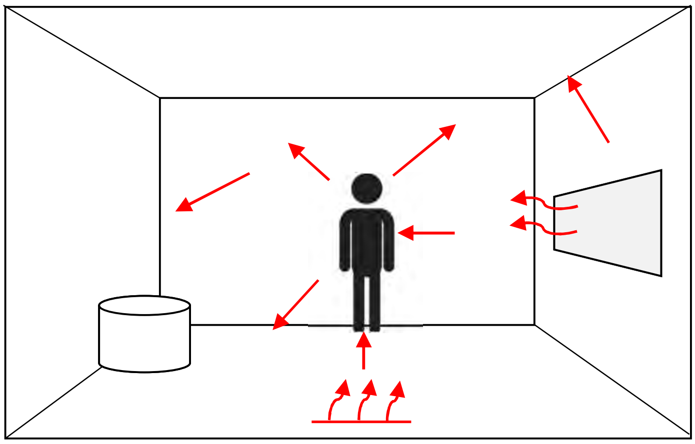

Figure 2.5: The infrared heating source bounces infrared rays all around the room, heating the objects they come into contact with, including walls and people

2.1.9 Emerging Technology

Researchers at SPECIFIC have developed a novel form of electric resistive heating that can be incorporated into floor panels, providing a low-temperature electric underfloor heating system. It can also be used in wall panels. The technology uses a conductive coating applied to floor or wall panels, which simply heats up when an electric current is passed through the coating. The coating is applied to a substrate using a screen printing process at SPECIFIC's Pilot Manufacturing Resource Centre.

Significant work has been undertaken at SPECIFIC to develop suitable control systems to enable the heating panels to be incorporated into the overall energy strategy for a building. The key benefit of this technology is that the modular nature of the printed panels enables them to be used in raised access floor systems, while maintaining the flexibility of the raised access floor.

Note: This technology is not yet commercially available, but further information can be found here.

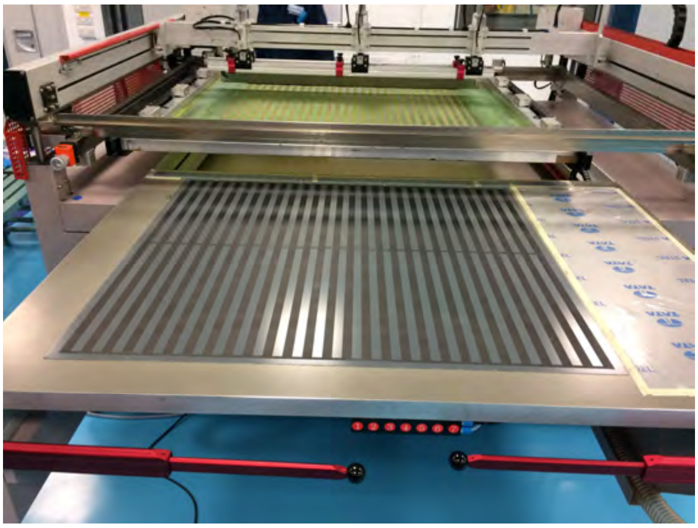

Figure 2.6: Screen printing of resistive heating system at SPECIFIC's Pilot Manufacturing Resource Centre

A note about underfloor heating

Traditional warm water underfloor heating systems, when used in conjunction with an air source heat pump (ASHP) and/or rother renewable energy sources, such as solar thermal, can reduce energy consumption and running costs of heating systems. Heat pumps are particularly efficient when operating at the low temperatures and low flow rates required for underfloor heating systems.

Companies, such as Nu-Heat offer a range of different underfloor heating systems suited to different types of construction and different user requirements, including electric systems.

2.1.10 Low temperature, fan assisted convection radiators

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.

An example of a low temperature, fan assisted radiator is the **Dimplex Smartrad.** 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, the 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.

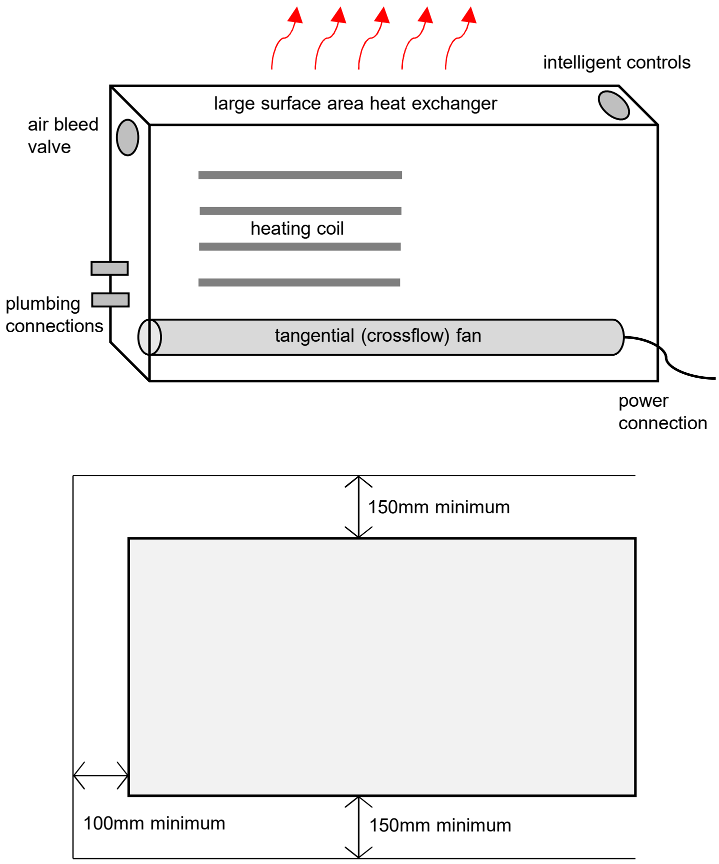

Figure 2.7: Section through low temperature convection radiator and minimum space requirements

2.1.11 Low Carbon Heat Networks

The key elements of a low carbon heat network are:

- Ground temperature heat distribution circuit (can avoid expensive insulation to pipework)
- Heating and cooling provided by a heat pump in each building
- Demand side response (DSR) to reduce the cost of electricity and reduce carbon emissions at peak times
- Thermal energy storage to extend the benefits of DSR
- Opportunities for integration of waste heat from buildings or processes that reject heat above ambient ground temperature
- Flexibility to expand or contract the network to meet changes in demand

Source: https://www.icax.co.uk/Fifth_Generation_District_Heating_Networks.html

2.1.12 Hydrogen

Hydrogen is deemed a potential low carbon heat source as it emits no CO_2 at the point of combustion. However, there are still (2020) significant challenges with use of hydrogen, some of which are listed below:

- Burning hydrogen in the air may produce up to six times the level of NO_x emissions than burning gas
- Upgrading the exiting natural gas network would incur huge cost and disruption. The existing high pressure pipelines are not suitable for hydrogen, so will need to be upgraded or replaced
- Safety concerns – potential of hydrogen leaking from pipe network
- Hydrogen meters would need to be installed in buildings
- Hydrogen is only a low carbon heating source if the hydrogen is generated from renewable energy sources
- Hydrogen boilers do not yet exist (2021), although Bosch have launched a prototype hydrogen gas boiler

Further information: https://www.sciencedirect.com/science/article/pii/S0360319913006800
LETI Climate Emergency Design Guide – Appendix 3, p.136
https://www.icax.co.uk/Low_Carbon_Heat-Heat_Pumps_in_London.html

2.0 Energy Efficient Systems

2.2 Energy Efficient Hot Water

Hot water systems designed to optimise energy consumption and increase the utilisation of renewable energy through intelligent control strategies are now available. One example of this is the Mixergy tank, which can utilise different energy sources and make use of time of use tariffs to maximise benefits to consumers and to the energy grid infrastructure.

Energy efficiency is achieved by only heating the water needed, rather than heating the whole tank. This in urn allows faster delivery of hot water. The tank can be heated from a variety of energy sources – conventional gas or electric boilers, solar PV, solar thermal or heat pumps. They can be controlled either via the Mixergy App, or are compatible with other smart home management devices.

Further information can be found here: Mixergy.

[refer also to Section 5.2 and Section 6.2]

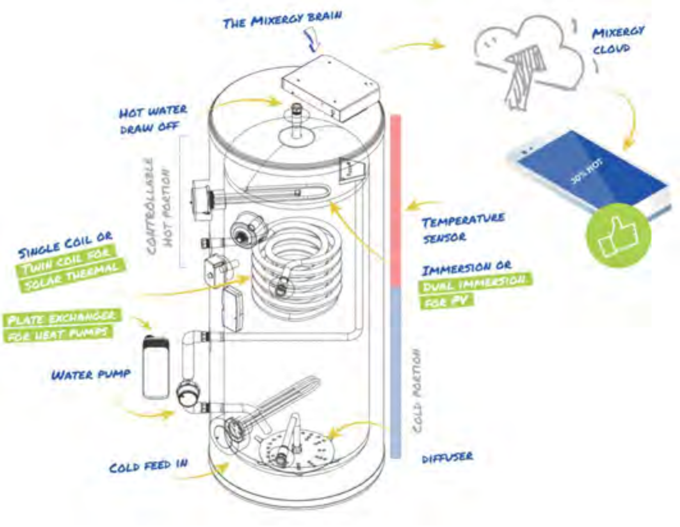

Figure 2.8: Diagram of a Mixergy tank (Source: https://www.mixergy.co.uk/technical-information/)

3.0 Electricity Generation

3.1 Photovoltaics

The most commonly used type of photovoltaics (PV) in buildings are silicon, but there are other alternatives. Decisions on which type of panels to use will depend on different factors, such as:

- Building type
- Weight
- Cost
- Geometric efficiency – how effectively the available generation area can be utilised for generation - note that although silicon panels are more efficient by area than thin film PV panels, there is often scope for greater coverage with thin film PV, due to the ability to cover entire roof areas, without the need for access routes, for example. Thin film PV is also flexible, so its application is not limited to straight surfaces.
- Aesthetics
- Planning characteristics, e.g. silicon panels may be rejected due to glare in some locations, aesthetics (in Conservation Areas or on Listed Buildings), or due to fears of vandalism - CIGS could be a viable alternative.

This section highlights just some of the alternative ways PV can be used in buildings.

3.1.1 Thin Film - BIPVCo

BIPVCo are a company located in South Wales, UK, who manufacture photovoltaic modules using CIGS (Copper, Indium, Gallium and Selenide) solar cells, which they connect to make modules that can be bonded to steel, aluminium or Thermoplastic Polyolefin (TPO) single ply membrane roofing substrates. The modules are flexible, so can be used on curved roof profiles (see Active Office Case Study).

Benefits of the technology include:

1. Lightweight
2. Works well in low light conditions (ideal for the UK)
3. Can be used at any roof angle
4. Subtle aesthetics when used with appropriate roofing materials

Figure 3.1: BIPV on the Active Office curved roof

3.1.2 Thin Film - GB-Sol

This is another Welsh company who also manufacture thin-film PV modules. These have recently (2019) been installed on a Transport for Wales prototype shelter, where they will be used to power lighting and display screens within the shelter. These will be particularly relevant for remote rail shelters, which are difficult to get power to.

Figure 3.2: BIPV on a curved rail shelter roof

Figure 3.3: Thin film and silicon PV on solar shading devices

Figure 3.4: Silicon PV in glass entrance canopy

3.0 Electricity Generation

3.1.3 Photovoltaic Windows

NSG Pilkington have developed a PV window called Pilkington **Sunplus™ BIPV** which consists of narrow strips of silicon wafer embedded into the double-glazed unit, covering 50% of the window pane. The ratio between opaque and transparent area can be adjusted depending on the required power output or shading desired. In individual window applications, this can be classed as micro-generation and the energy generated in this situation is better used locally, to avoid too many losses in power. In the Active Classroom the 77Wp window powers it's own data logging system and small display screen.

Figure 3.5: Pilkington Sunplus™ BIPV window

If used in curtain walling applications on larger buildings, it has the potential to generate a significant amount of power, contributing to the overall power supply for the whole building. It could also be used in areas such as conservatories or atriums, in either the roofs or walls, where it could serve a dual purpose in helping to control solar glare and reduce overheating.

Potential future developments for the window include linking the PV power to electronic blinds, where the demand for closing blinds to cut out glare corresponds directly to times of generation. Similarly it could be linked to thermochromic coatings in glazing units, enabling windows to become darker when the sun is strongest.

3.1.4 Emerging Technologies

At SPECIFIC researchers are developing a range of solar cell technologies and processing techniques that will allow high-efficiency thin-film photovoltaics to be manufactured at scale using earth-abundant, low cost materials. They are also working to understand the stability and lifetime of these devices, by characterising their degradation mechanisms and finding ways to improve longevity.

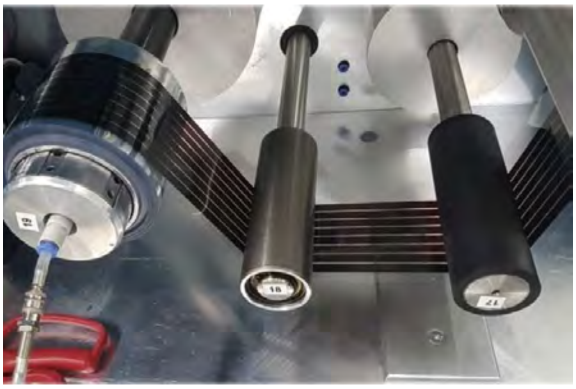

Figure 3.6: Roll-to-roll printing of perovskites

The researchers work with the most promising photovoltaic technologies to find ways to manufacture them at scale. Currently these include three distinct technologies: perovskites, CZTS (copper, zinc, tin, sulphur) and organic photovoltaics.

Perovskite Solar Cells (PSCs) are a relative newcomer to the photovoltaic industry but, with efficiency now reaching similar to that of the current market leader, silicon PV, researchers are focused on upscaling PSCs.

Contrary to silicon PV, which requires high temperature and high vacuum depositions, PSCs can be solution-processed at a low temperature, significantly reducing their manufacturing cost and embodied carbon (Crystalline silicon PV is processed at 1800ºC. Low temperature processing enables use of plastic substrates to make flexible solar cells, while the ability to solution process allows use of well-developed printing and coating techniques, such as: Screen printing; Inkjet printing; Gravure printing; Slot-die coating; and Spray coating.

These advantages combined enable use of roll-to-roll manufacturing.

Oxford PV, who the team at SPECIFIC work closely with, are currently working on commercialising this technology.

3.2 Electricity Generating Landscape Features

Here are some alternative ways to generate electricity within the built environment:

Figure 3.7: Street furniture

Figure 3.8: Art installations

Figure 3.9: Wind trees

Figure 3.10: Transport Shelters

Other renewable technologies for electrical generation:

- Wind power – dependent on location and specific site conditions
- Freshwater turbines – dependent on specific site conditions
- Combined heat and power (CHP) if low-carbon source, such as bio-methane fuel used
- Tidal power – dependent on location. Would need energy storage
- Hydrogen, if generated using low-carbon energy source

4.0 Heat Generation

4.1 Evacuated Tubes

The most popular and efficient type of solar thermal collectors are evacuated tube collectors which comprise rows of insulated glass tubes with copper pipes at their core, which transfer heat to a water tank. An inner glass tube is suspended inside a larger outer tube, which are fused together at one end. The air is pumped out of the space between the small inner tube and the larger outer tube creating a vacuum thermal insulation layer, which is key to reducing the heat loss from the collector. The inside of the inner glass tube is coated with a selective light absorber such as aluminium nitrate or titanium nitrate oxide, which helps maximise the absorption of solar radiation over a large range of wavelengths. An absorber plate, normally made of copper, then runs the length of the inner glass tube, which absorbs the heat and transfers it to a heat transfer fluid. In passive systems, convection drives the movement of the heating fluid in each solar collector tube and when the transfer liquid is heated it evaporates and turns into a vapour. This rises to the top of the collector where the heat is transferred via a heat exchanger to another liquid – usually water, that is then stored in a hot water storage tank. The transfer liquid then condenses and falls back down the evacuated tube ready for the next cycle.

Figure 4.1: Photograph of an Evacuated Tube Solar Thermal Collector

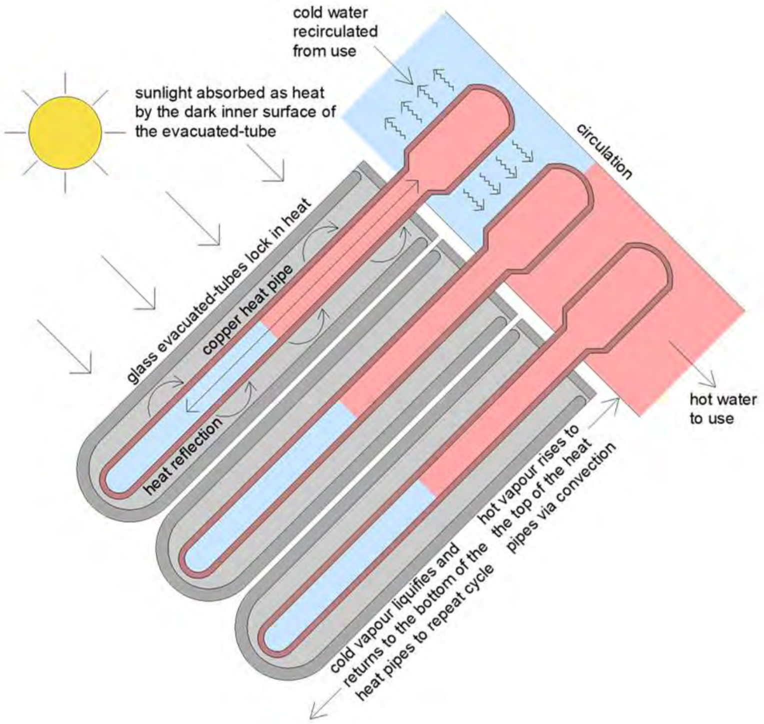

Figure 4.2: Cross Section through an Evacuated Tube Solar Thermal Collector

Evacuated tubes have a conversion efficiency of over 70%, enabling them to produce enough heat to provide hot water to use in heating systems. This is achieved by their construction, i.e. with an insulation layer, and as they are virtually unaffected by air temperatures. The cylindrical shape of the evacuated tubes enables them to collect sunlight throughout the day and at all times of the year.

Benefits:

- Relatively easy to install as they are light, compact and can be carried onto a roof individually.
- If one tube fails, it can be replaced without the need to replace the whole collector.
- The vacuum inside the tubes can last for over twenty years, providing an efficient and durable system which prevents the reflective coating inside the tube from degrading.

(Source: https://www.thegreenage.co.uk/article/how-do-evacuated-tube-solar-thermal-hot-water-systems-work/.

4.2 Flat plate collectors

Another common type of solar thermal collectors are flat plate collectors, which consist of a dark coloured flat plate absorber (usually copper or aluminium) with an insulated cover, a heat transferring liquid containing antifreeze (such as glycol) to transfer heat from the absorber to the water tank, and an insulating backing. The flat plate increases the surface area for heat absorption and is capable of generating 50 litres/m^2. A well-designed commercial solar thermal system may be able to satisfy around 30 to 40% of the annual hot water load, known as the solar fraction (SF)" (and 100% during the summer)[1]. The heat transfer liquid is circulated through copper or silicon tubes contained within the flat surface plate.

An alternative to metal is to use a polymer flat plate collector, which are less prone to freezing, so can use water as the heat transferring liquid instead of antifreeze. This enables them to be plumbed directly into a water tank removing the need for a heat exchanger, hence increasing their efficiency.

Flat plate collectors are generally less compact and less efficient than evacuated tube collectors, so are less expensive, and have a life expectancy of over twenty-five years.

4.3 Thermoslate®

THERMOSLATE® is natural slate roofing that makes use of the properties of natural slate to convert sunlight into energy to produce heating, hot water, or pool heating. This solar thermal collector system adapts to all types of construction requirements and is imperceptible once installed.[2]

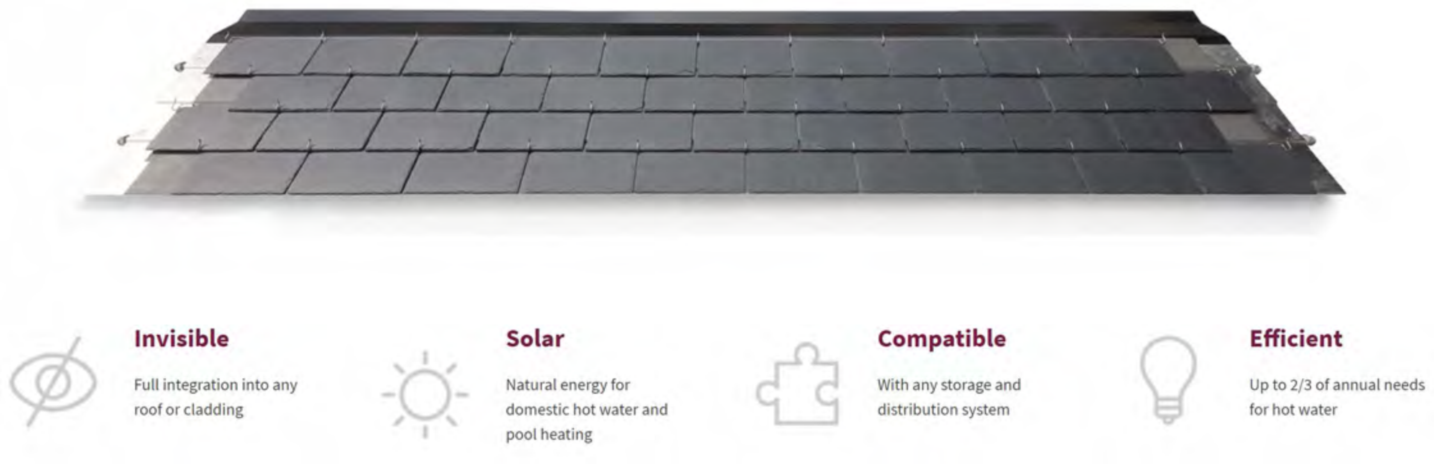

Figure 4.3: Features of Thermoslate system

4.4 Emerging Technology: Evacuated flat plate collectors

A high-vacuum flat plate collector can rival evacuated tube collectors in terms of efficiency, reaching peak yields by avoiding convection losses inside the solar collector, through use of a high vacuum thermal insulation. Combining the insulation properties of the vacuum with a large surface area offers excellent visual and thermal characteristics, and means they are much thinner than conventional collectors[3]. They can also utilise diffuse irradiation.

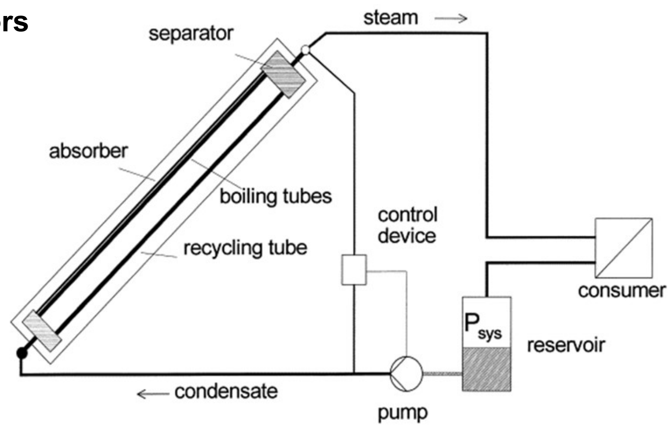

Figure 4.4: Section through Evacuated Flat Plate Collector

1. https://www.cibsejournal.com/cpd/modules/2009-02/
2. https://www.cupapizarras.com/uk/thermoslate/
3. https://core.ac.uk/download/pdf/287021181.pdf

4.0 Heat Generation

4.5 Transpired Solar Collectors (TSCs)

Most industrial and commercial buildings require large quantities of ventilation air to maintain a healthy work environment. In some months of the year this needs to be heated to provide a comfortable work environment. TSCs provide pre-heated fresh air to a space, as well as lower fuel bills and improved indoor air quality. Maintenance costs are low as it is so simple and it has a 30-year life span. While this is a good choice for large volume spaces, such as industrial buildings and sports halls, it has also been used on smaller buildings, such as the Active Classroom and Active Homes Neath, where it provides a pre-heat to the ASHPs used for space heating and DHW, discreetly fitting into the cladding panels.

How they work: The pre-finished steel has enhanced thermal absorption properties and absorbs the sun's radiant energy, subsequently heating the boundary layer of air to the exposed side of the metal skin. Negative air pressure created within the cavity by a ventilation fan draws ambient outside air, warmed from the surface of the steel, through the micro perforations in the transpired solar collector's surface. Fresh heated air from the cavity is then fed either directly into the building as ventilation air (industrial applications) or ducted into a HVAC unit (commercial & residential applications), where it is used as a pre-heater to the main heating system.

Case Study: The Solar Heat Energy Demonstrators (the SHED)

A solar air collector and a solar store are being demonstrated on an industrial unit in Margam which was constructed in 1990 and has a poor-quality building envelope. Two collectors, each approximately 250m^2 have been installed on the southwest facing wall of the building. One collector is used to heat the space directly via a simple fan unit, while heat gained from the second collector is stored in a large water tank to be used the following day. This is the first prototype of the solar storage system and has been operating since 2011.

The building was formerly heated via a gas fired boiler, but since this system was installed, the gas boiler has been decommissioned and no gas has been used for five years. The building is heated purely from the solar air system.

Heat from the collector is passed through a heat exchanger and into a heat pump to raise the temperature before delivering it to the thermal store. Heat is then dissipated through fan coil units as and when it is required. This operating strategy provides 100% of the heat demand of the building with no gas consumption: 40% direct heat from TSC and 60% heat from the solar store.

This equates to a 44% saving on the operating cost of the previous gas-fired system, and a CO_2 saving of 48% on emissions, demonstrating a viable renewable heating system.

Performance of a TSC is affected by factors such as :

- size of collector; cladding profile; colour of cladding; shading; exposure to wind; location in relation to connected services; elevation orientation

4.6 Photovoltaic Thermal Hybrid Solar Collectors

It is possible to combine both PV generation (for electricity) with a solar thermal collector (for heat) in one system. On a PVT panel system, excess heat generated is transferred via a heat exchanger on the back of the PV panel and into a heat transfer liquid that is supplied to the heating system. This improves the efficiency of the PV element, as it cools them down. These are particularly useful for space-constrained areas, as the two functions of generating heat and electricity are combined into one panel. While research into this technology has been underway for many years, PVT systems are not currently (2020) widely used in buildings. Examples include:

4.6.1 Virtu by Naked Energy

Evacuated tubes contain PV plates to enable capture of both solar thermal (T) and solar photovoltaic (PV) energy in a combined PVT system. A solar absorber behind the PV plate cools the PV plate by drawing heat away from the plates and transferring into a thermal store. This maintains the efficiency of the PV plates, while providing valuable heat energy for the building. The evacuated tubes reduce thermal losses. These can be installed on roofs or facades. An example of the first façade installation of this system is shown in figure 4.5 below.

Figure 4.5: PV-T tubes on Active Office

4.6.2 PowerCollector™ by Solarus

This C-PVT system consists of a concentrating, hybrid solar photovoltaic (PV) and solar thermal (T) panel. A curved mirror concentrates the solar energy and allows the system to collect and reflect maximum sunlight throughout the day. Water is used to draw heat away from the solar PV cells, which improves electrical performance and extends cell longevity. While cooling the cells, it transfers the heat into a heat exchanger for space heating and hot water.

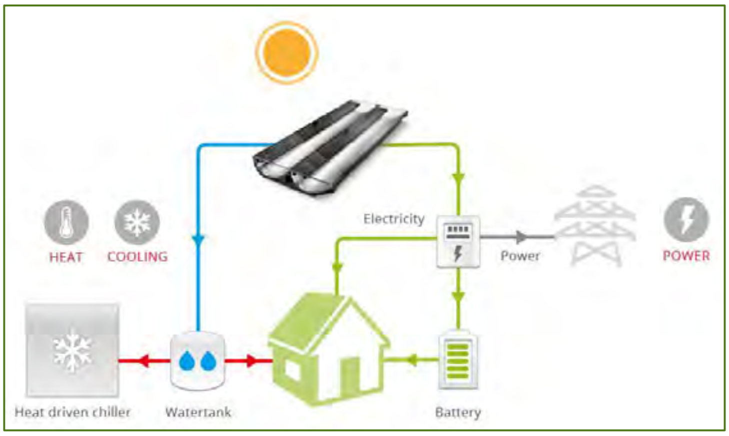

Figure 4.6: Diagram courtesy of Solarus

Other renewable technologies for heat generation:

- Geothermal with Ground Source Heat Pumps (GSHPs)
- Water-source thermal
- Clean Combined Heat and Power (CHP) systems
- District heating from low carbon source
- Biomass from waste products
- Biogas
- Mine water (specific sites)
- Grey water heat recovery
- Fuel cells if using renewables
- Waste heat recovery solutions

5.0 Electrical Storage

5.1 Introduction

Electrical storage enables solar energy produced during the day to be stored for use in the evenings and overnight, or to provide higher power than the current PV output would be generating – essentially buffering PV generation. The most commonly used form of electrical storage in buildings is electrochemical, i.e. batteries, the most widely used battery technology being lithium-ion (li-ion). Lithium-ion batteries have developed such that they are virtually maintenance free. The cost of battery storage is rapidly reducing, making it a financially viable solution for buildings. Other emerging battery technologies include:

- Aqueous Hybrid Ion (AHI™)
- End-of-life EV batteries (li-ion)
- Flow batteries

Figure 5.1: Aqueous hybrid-ion batteries in the Active Classroom

Aquion Aqueous Hybrid Ion (AHI™) “Aspen” batteries were installed in the Active Classroom as part of the construction phase in 2016. These batteries are sealed electrochemical energy storage systems based on a saltwater electrolyte. They are manufactured using earth abundant, non-toxic materials and low cost manufacturing techniques. They were purported to be maintenance-free and optimised for daily deep cycling. This 60kWh installation comprised two 30kWh batteries, consisting of individual modules.

This technology is relatively immature, so should be considered for use in building projects with caution. The particular batteries installed in the Active Classroom were found to be underperforming after two years of operation, so were removed for testing.

Figure 5.2: Flow batteries in the Active Classroom

In 2020, the Aquion batteries were replaced with twelve 10kWh **Redox flow batteries**, providing a total of 120kWh. These modular zinc-bromine batteries represent another emerging technology and this was the UK’s first installation of the technology. This installation will test claims that the battery system is capable of delivering 100% of the rated energy every day, without degradation in capacity over a 10-year lifetime.

Further information about the installation can be found here.

Other less widely used forms of electrical storage include:

- Hydrogen fuel cells (if hydrogen is produced from renewables)
- Compressed air
- Flywheels
- Ice
- Electrochemical
- Immersion heaters in combined thermal and electrical systems

5.2 Solar Power Diverters for Hot Water

It is possible to divert excess solar power generation to a hot water tank, using a controlling device, such as **IMMERSUN** or others reviewed **here**. This enables maximum utilisation of solar power or other renewable energy sources, such as wind or hydro power.

How they work:
PV export is monitored at the meter connection point and the required energy is diverted to the resistive immersion heater to maintain a zero export or zero import scenario. Such diverters work to prioritise direct electrical usage, only storing excess electricity when available and not required as power. Many systems have two controllable outputs – the first to an immersion heater and the second to either a second immersion or another resistive load, such as electric towel rails, swimming pool heaters or electric underfloor heating systems.

Solar Power Diverters can also be controlled to divert excess energy to electric vehicles (EVs). In this instance, they will charge the EV at a different speed depending on the amount of solar energy available. To operate effectively, these need an export in excess of 1.4kW (the minimum EV charger power in the charge protocol). Chargers can be overridden to charge from the grid if charging at a faster rate is required.

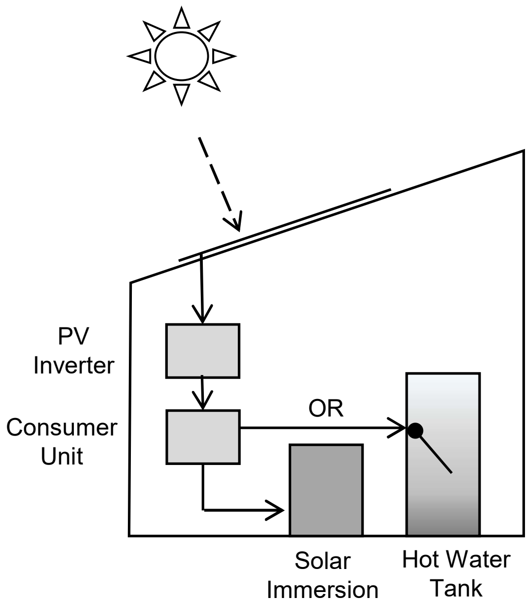

Figure 5.3: Solar Power Diversion for Hot Water

5.3 Emerging Technology

Cornish Lithium

As mentioned above, the main type of rechargeable battery storage currently used in both buildings and electric vehicles is lithium-ion (Li-on).

A UK company called **Cornish Lithium** is currently investigating extracting lithium from geothermal brine and hard rock in Cornwall, using innovative mineral exploration techniques, which they claim to have a net zero carbon footprint. Demand for lithium is set to increase rapidly over the next decade to supply electric vehicles and to store renewable power for buildings. This will provide a secure and resilient supply of lithium for the UK, contributing to a sustainable UK supply chain for Li-ion batteries.

The company is currently (2020) constructing a pilot lithium extraction plant, with a view to starting extraction within the next 5 – 10 years.

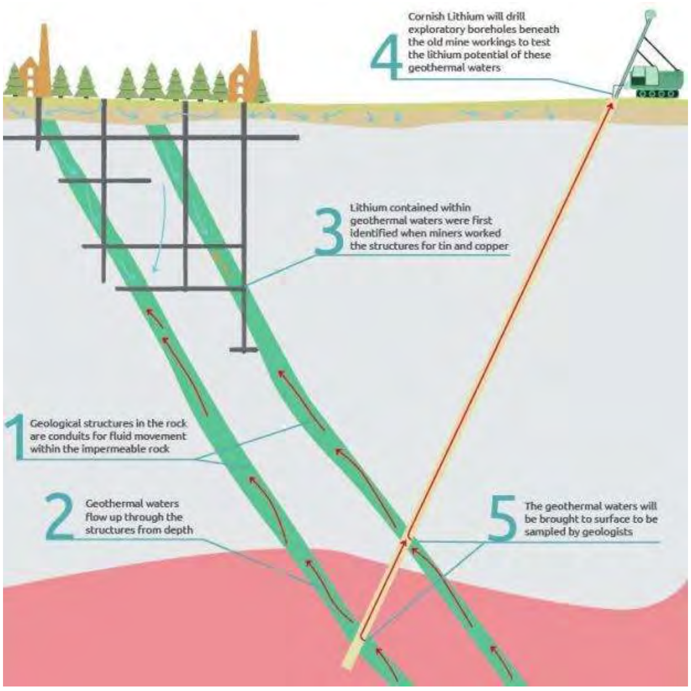

Figure 5.4: Image of test boreholes, courtesy of Cornish Lithium

6.0 Thermal Storage

This section was co-written with Nic Wincott of ***Enviga Geothermal***

6.1 Introduction

Often overlooked in favour of Electrical Energy Storage, Thermal Energy Storage (TES) is an important technology for both energy conservation and the efficient large-scale deployment of renewable energy. It successfully addresses the intermittent nature of renewable energy generation by storing excess heat during periods of low demand for use later when demand is high.

6.2 Sensible

Short term (diurnal) – long term (inter-seasonal)

heat causes a change in temperature in a body or thermodynamic system.
Energy density typically 30 kWh/m^3

- Water
- Thermal mass of building
- Thermal mass of ground

Thermal Energy Storage (TES) systems for sensible heat were, until recently (2021) typically diurnal, with the most common examples being water tanks with integral copper coils or heat exchangers. These enable heat generated and stored during the day to be released overnight or the following morning, although some allow longer "periodic" storage. The scale varies from domestic systems storing up to 100 litres for use as domestic hot water (DHW), to district network scale installations containing 10,000 m^3+.

The heating system for the Active Office utilises a 2,000 litre water cylinder, which stores heat generated by PV-T tubes and an air source heat pump (ASHP); and enables time-shifting of heating demand, with the capability to charge the tank on sunny days or overnight for use when it is needed to heat the building. A significantly smaller cylinder could be used in an Active House, similar to those used in conjunction with traditional gas-fired boiler systems.

6.2.1 Underground Thermal Energy Storage (UTES)

Underground Thermal Energy Storage (UTES) is where thermal energy is stored in the ground for later extraction using Ground Heat Exchangers (GHE) e.g., ground loops or similar structures. The ground is suitable for thermal energy storage because it has high thermal inertia and, if undisturbed, below a depth of 10-15 m, the ground temperature is only mildly affected by local climate variations and maintains a stable temperature approximating to the local annual mean air temperature.

UTES can retain thermal energy for extended periods of time - inter-seasonal storage is most common, but storage from one year to the next is possible. The thermal energy may be captured from a variety of renewable sources, including ambient air (with or without a heat pump to modify storage temperatures), solar and by-product or waste heat from industrial and other cooling processes, such as from Data Centres.

Using stored thermal energy from renewable sources instead of "newly generated" fossil fuel derived energy is the key to achieving Net Zero Energy Buildings (nZEB) and/or Positive Energy Buildings (PEB), and should be considered an integral part of the UK's decarbonisation strategy.

Among UTES technologies, Aquifer Thermal Energy Storage (ATES) & Borehole Thermal Energy Storage (BTES) are the most familiar, although Foundation Energy Storage (FES) is increasingly employed, combining energy storage with structure, hence reducing total capital costs. Disused mine workings, as well as pit and earthbank storage, for example ThermalBanks™ by **ICAX**, are all viable options.

While ATES can be highly effective, it requires suitable hydrology and due to the capital costs can often be hard to justify economically. BTES may be used at a local scale to supply cooling and/or heating to houses and other domestic buildings, at settlement or community scale for districts or groups of houses and at grid scale for larger district heating and cooling networks or commercial and industrial buildings. BTES's ability to store heat inter-seasonally at scale was first explored in detail in Sweden at the University of Lulea from 1982-1988 where waste heat captured from a steel works was recovered and recycled to heat student accommodation. The following section describes BTES in more detail.

6.0 Thermal Storage

Borehole Thermal Energy Storage (BTES)

Borehole Thermal Energy Stores may be used to provide inter-seasonal heat storage, flexibility, additional capacity and/or load balancing to District Heat and Cooling (DHC) networks. They are ideal to store what would otherwise be waste heat especially from commercial and industrial processes, such as from Data Centres, Foundries, Combined Heat and Power (CHP) systems, or even bakeries and cold stores.

They consist of a series of boreholes identical to those used solely to collect or reject heat, but with the positioning and spacing of the boreholes optimised during the design process, specifically for heat storage.

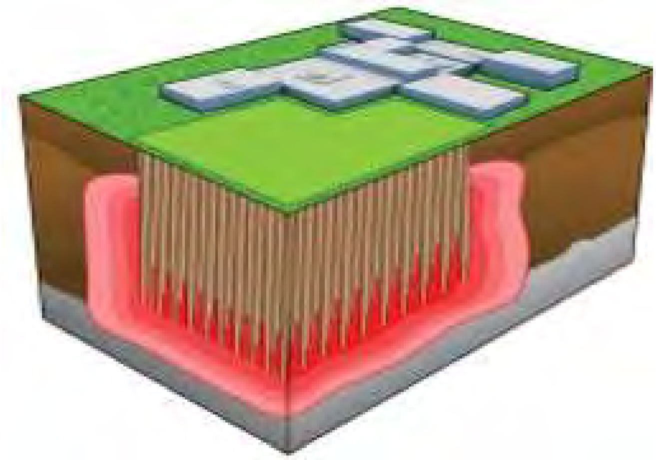

Figure 6.1: Diagram showing how BTES works (Source unknown)

Case Study: The GeoTermos BTES Headworks

At GeoTermos, in the municipality of Drammen, Norway, there is a project to store solar energy as heat. The system stores energy provided by 150 m^2 of solar thermal collectors and 1,000 m^2 of PV panels in 100 x 50m boreholes in granitic gneiss rock.

"GeoTermos is expected to return around 350,000 kWh/year in the form of heat at various temperature levels during the heating season"

Computer aided simulation techniques are used to model the heat flows into and within the store. This both optimises operation and minimises size and installation work to yield considerable savings.

Figure 6.2: Photograph of the GeoTermos BTES site

Additional Resources:

UTES is not a new concept, but is underpinned by considerable detailed research and experimentation. For example, Professor Hellström of Enviga Geothermal has been researching thermal energy storage since the 1990s and his PhD thesis on Ground Heat Storage can be accessed **here.** His subsequent work on BTES builds on this work.

Dr Fleur Loveridge of the University of Leeds is a leading UK expert on Foundation Energy Storage. Her belief is that use of the ground as a thermal store in conjunction with a ground source heat pump systems is an essential technology in our route to decarbonising heat and achieving the UK's Net Zero targets.

6.0 Thermal Storage

6.2.2 Foundation Energy Storage (FES)

Foundations, primarily piled foundations, are being designed to work as Underground Thermal Energy Stores. This is attractive because a building **must** have foundations so the cost of modifying these to also function as Underground Thermal Energy Stores is a marginal additional cost compared to boreholes which have only one purpose.

The viability of using foundations to provide large-scale inter-seasonal heat storage was explored in detail in the UK between 2012 and 2015. Much of this work was undertaken at Southampton and Cambridge Universities and led to the UK Ground Source Heat Pump Association (GSHPA) **Thermal Pile Standard**. This work is now in use worldwide.

Screw piles are increasingly being specified for domestic projects and developments to simplify and speed installation especially on brownfield and problem sites and for offsite manufactured homes. They may be modified to become Ground Heat Exchangers (GHE) and then used to create an UTES below the building.

Thermo Screw Pile™ System

[information provided by **Enviga Geothermal**]

Thermo Screw Piles™ (TSPs) combine the structural functions of a screw pile with the thermal functions of a ground heat exchanger (GHE), in one quick to install, low-cost construction component.

They may be used to create thermally active foundations which both support the building and collect heat from, or reject heat into, the earth below. This arrangement works very effectively to retain heat for later use diurnally; periodically; or, more unusually, inter-seasonally, where surplus heat is stored in summer for use in winter when there is a shortage. Cold may also be stored in winter to provide summer cooling.

Diurnal and periodic thermal energy storage improves energy efficiency generally, especially during the spring and autumn when cool nights are balanced by warm days. **However, the ability to store heat inter-seasonally is the key to achieving major energy savings and ultimately to deliver Positive Energy Buildings (PEB).**

The system is ideal for storing heat generated onsite, although any source of heat, ideally renewable or recovered heat, can be employed.

Individual buildings may be networked to manage occupancy variation, load diversity, etc.

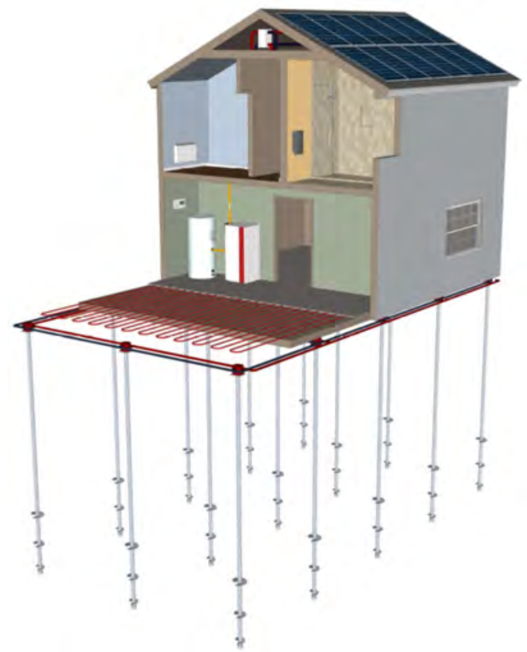

Figure 6.3: Diagram of Thermo Screw Piles (courtesy of Enviga Geothermal)

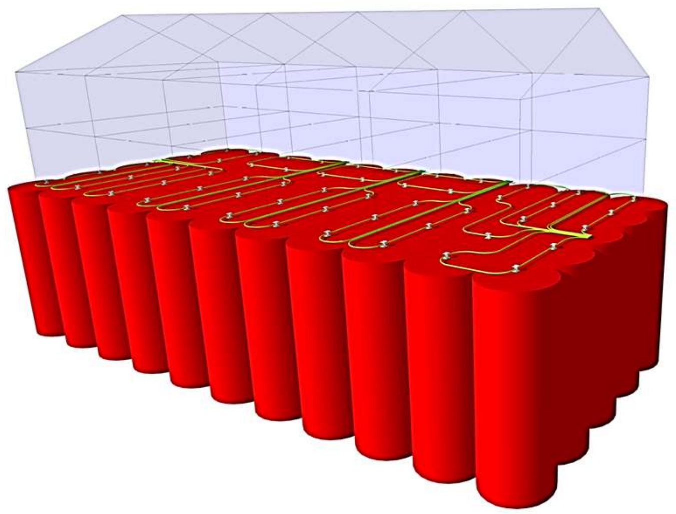

Figure 6.4: Diagram indicating "heat battery" effect of Thermo Screw Piles – the red areas representing energy stored (courtesy of Enviga Geothermal)

Key Benefits of Thermo Screw Piles™ (TSPs):

Standard screw piles are ideally suited to lightweight, off-site construction methods and low carbon building design. They are quick and easy to install and remove, saving both time and money. The installation and removal of screw piles causes minimal ground disturbance and piles can often be used again. Their use minimises the amount of excavated material (arisings) to be removed from a construction site and avoids the use of concrete for the substructure, beneficial for both environmental and time reasons.

The addition of an inter-seasonal thermal storage capability to screw piles provides further economic and environmental benefits for little additional cost and effort. The ability to store heat longer than a few days enables Zero Energy Buildings (ZEB) and Positive Energy Building (PEB) to be constructed economically, which has previously been challenging.

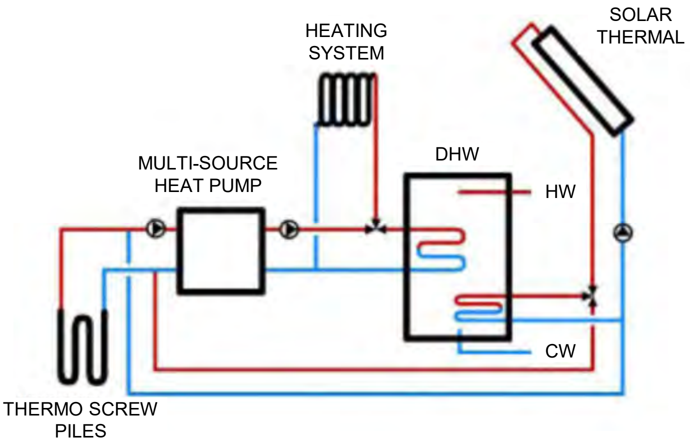

Figure 6.5: Schematic of thermal generation for hot water and space heating (courtesy of Enviga Geothermal)

Summary of Key Benefits:

Cost savings achievable by using the foundations to store renewable thermal energy for space heating and/or cooling contributes to the thermal comfort and affordability of low to zero carbon buildings.	Constant monitoring of the system by intelligent and intuitive controls maintains the equilibrium of the thermal store, meaning it can compensate for variations in thermal load as well as changing climatic and ground conditions.
TSP foundations may be networked to improve diversity and flexibility. They are particularly well suited to modern (5G) networking techniques.	Using underground thermal energy storage adds “virtual” thermal mass to low thermal mass construction methods to further improve operating efficiency.
TSPs have low embodied energy and may easily be reused or recycled.	TSPs replace much if not all the concrete used in the construction of the buildings substructures.
Rapid installation, with minimal spoil excavation reduces the construction costs and environmental impact.	

Keltbray HIPER® Piles

A collaboration between Keltbray Piling, Converge, DB Group and Arup have developed a hollow pile system to combine load bearing qualities of traditional concrete piles, with less and lower carbon materials, and energy generation.

The HIPER® (Hollow, Impression-enhanced, Precast, Energy-generating and Re-useable) Pile uses a hollow pile design and light-weight cement-free concrete to provide the same shaft-bearing capacity with fewer or narrower piles. The pile incorporates smart technology to monitor performance and the void can be used to integrate renewable technologies. HIPER® Pile helps achieve carbon reduction and circular economy aims, with its 80% reduction in materials and emissions, greater on-site productivity and reusability.

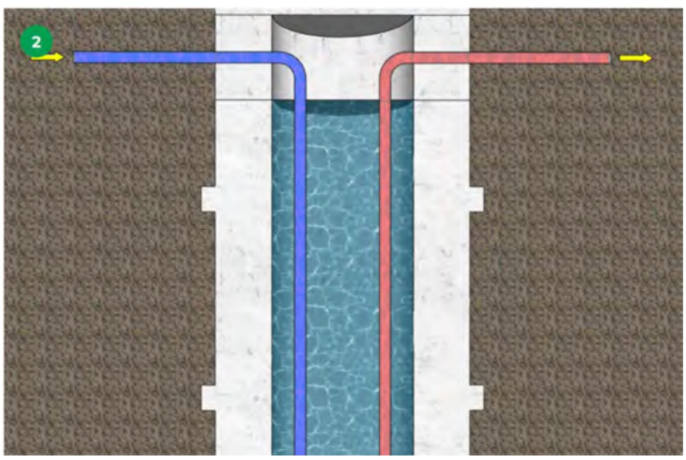

Figure 6.6: Diagram of HIPER® Pile from HIPER® Pile Brochure

6.0 Thermal Storage

6.3 Latent *heat physically changes a material either by melting, crystallisation or evaporation. Energy density typically 70 kWh/m^3*

Short-Mid term (weeks)

Organic or inorganic phase change material (PCM)

An example of a latent heat storage system has been developed by a UK company called **Sunamp**. This is a compact heat battery technology, which consist of high energy density, high power density batteries which store heat generated from renewable electricity either via a heat pump or via a direct electric heater. This can replace the need for a hot water cylinder or gas-fired boiler and, if controlled by an intelligent energy management system, can optimise charging to use renewable energy when it is available. This system is well-suited to domestic buildings due to its compact nature, but is also applicable to commercial and industrial use.

Phase change materials (PCMs) can be used in elements of the building fabric, e.g. ceilings, to replicate the effect of thermal mass, to avoid overheating in summer and to increase heat retention in winter.

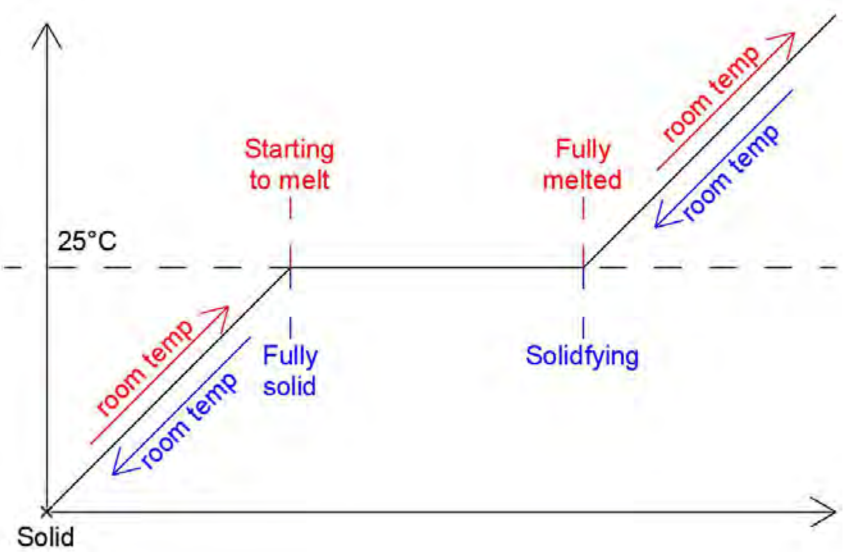

Figure 6.7: Behaviour of phase change material

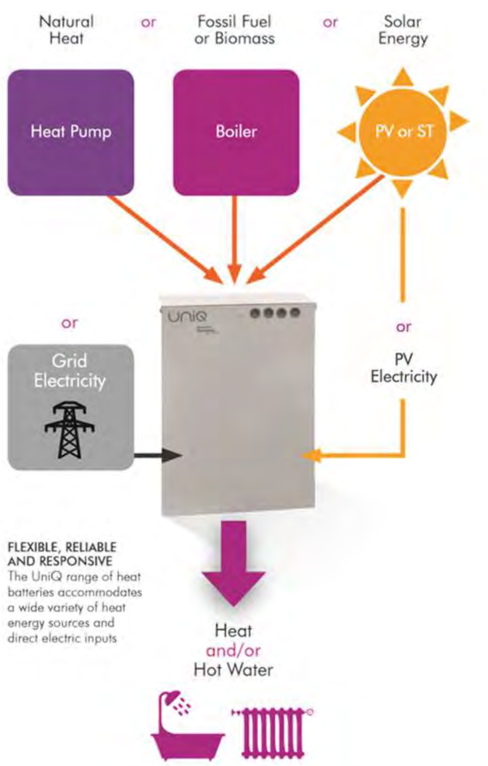

Figure 6.8: Diagram courtesy of Sunamp

PCMs can also be used in ceiling tiles or flooring to regulate room temperatures

(Source: https://www.global-e-systems.com/en/about-us/)

Another example of a latent heat storage system is the Warmstone Heat Battery developed by **Caldera.** This heat battery uses electrical elements that can be charged either by renewable energy sources or from the grid at off-peak, low-cost times of day. Heat can be stored in the battery until it is needed, providing both hot water and heating, using a heat exchanger. Furthermore, the battery is manufactured using a combination of recycled and natural materials, and is 100% recyclable at its end of life.

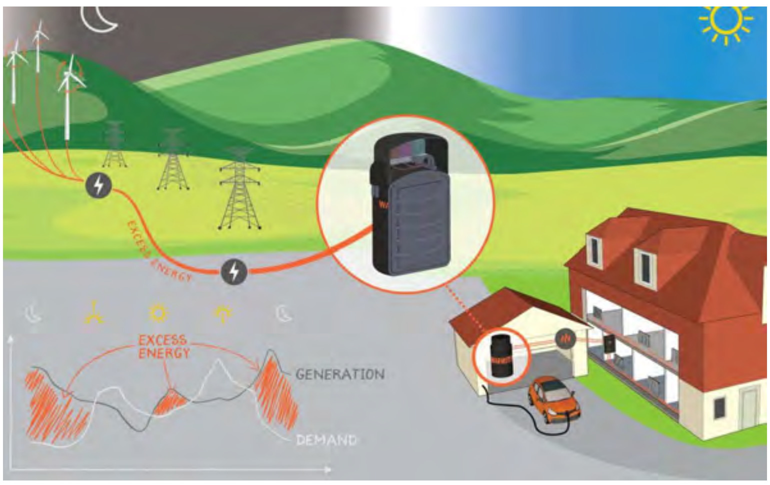

Figure 6.9: Diagram courtesy of Caldera

6.4 Emerging Technology: Thermochemical heat storage

Long term (inter-seasonal)

Energy density typically 140-830 kWh/m^3

A research group at SPECIFIC is developing a novel form of inter-seasonal heat storage, using Salt in Matrix (or "SIM") material, which is able to store thermal energy through a thermochemical process[1]. This has a much higher density than water, so has the ability to store more heat in a smaller unit, and has huge potential to reduce energy use and fuel poverty.

Thermal energy (heat) is stored by passing hot air over the SIM, creating a chemical reaction that locks the energy into the material. The reaction is reversed exothermically, meaning that heat is released, by passing damp air over the SIM. Provided the SIM is kept dry it is able to store the heat indefinitely. This makes it suitable for the inter-seasonal storage of heat and for transporting heat from one location to another. As the heat is stored chemically, there is no self-discharge that is associated with other thermal storage technologies due to thermal losses. Provided the material is kept dry, the energy is stored at ambient temperature indefinitely.

It can be used in the following ways:

- Storing solar energy generated in summer months for use in winter;
- Storing waste heat from industrial/manufacturing processes and transporting this for use in housing;
- Storing heat generated by one building to heat another that needs the heat, providing an alternative to expensive and energy intensive air-conditioning, which would otherwise be needed in, for example, office buildings. By drawing the heat away from a space into a thermal store, no additional cooling is needed and the heat can be used where needed.

While reducing imported heat for buildings and hence energy costs, this also has the potential to protect the environment from rising CO_2 emissions, helping the UK meet it's **Net Zero Carbon goal**. Use of industrial waste heat could also ensure that it is economically viable for manufacturing companies to remain in the UK, reducing their Climate Levy charges and reducing their fuel bills, hence providing economic stability for UK businesses.

Note: This technology is not yet commercially available, but further information can be found here.

Figure 6.10: Diagram courtesy of SPECIFIC

Other considerations for energy storage

- Space requirements
- Location – close to generation to minimise losses, safe, self-contained area for safety, ventilated space to avoid heat build-up

7.0 Electric Vehicle Charging

Here are just some examples of different EV chargers available for use within the built environment.

7.1 Free Standing Chargers

Figure 7.1: ***Ensto Chago*** *Pro Dual Outlet*

Figure 7.2: ***Etrel Inch*** *Pro Single Outlet*

Figure 7.3: ***Zappi Eco-smart***

Wall mounted Chargers

Figure 7.4: ***Rolec Securicharge*** *wall unit*

Lamp post mounted Chargers

Figure 7.5: ***Rolec EV charging streetlight***

Figure 7.6: ***Bender Chargespot Berlin***

7.2 Parking Canopies

Kappion

Kappion[1] offer two designs for their solar carports – a cantilevered option, capable of spanning up to 6.5m; and an option with intermediate supports.

Figure 7.7: Kappion Cantilevered Solar Carport

Figure 7.8: Kappion Solar Carport installation at BIPVCo HQ

GRIDSERVE

GRIDSERVE[2] have developed a design for a fully electric forecourt, complete with PV parking canopies and battery storage. Their design includes a building which offers customers a space to work in, learn more about EVs, or get some refreshments, while they wait for their car to charge. The first electric forecourt to be constructed in the UK is in Braintree, Essex, due for completion in 2020.

Figure 7.9: Artists impression of the Braintree Electric Forecourt

1. Kappion. 2020. Solar Carports. https://carports-canopies.com/solar-carport/
2. GRIDSERVE. 2020. GRIDSERVE *Electric Forecourts*. https://www.gridserve.com/electric-vehicle-charging

8.0 Data Capture and Visualisation

8.1 Remote monitoring systems

Particularly suited to asset management, such as social housing providers; universities, local authorities, health board estate owners, etc.

Such systems can monitor temperature, relative humidity, CO_2 levels and correlate this with information such as house type, construction method, and insulation levels. This could help analyse any issues identified within buildings and help make savings in fuel bills and carbon emissions.

Benefits:

- Assist with building performance evaluation (BPE)
- Enable optimisation of building performance
- Reduce fuel bills
- Reduce carbon emissions
- Reduce maintenance visits
- Educate and illustrate the impact of behaviour on building performance

Examples:

- iOpt Assets: https://www.ioptassets.com/
- Radmiser Lightwave: https://www.radmiser.co.uk/
- Z-Wave: https://www.z-wave.com/
- LoRaWAN: https://lora-alliance.org/about-lorawan/
- EnOcean: https://www.enocean.com/en/applications/building-automation/

Emerging Technology

Safehouse Technology provides end-to-end environmental monitoring solutions using LPWAN (low powered wide area network) technology to accurately monitor a wide range of internal environmental and wellbeing factors, including temperature, humidity, light, noise, CO_2, VOCs, air pressure, air quality, and movement.

Read about a collaborative pilot project at SPECIFIC's Active Office here.

Measurable Energy provides a building control and management system that reduces electricity waste through real-time monitoring of small power used in buildings.

Read about their collaborative pilot project with SPECIFIC here.

Environmental Dashboard Case Study

Oberlin College in Ohio, USA, have developed a Citywide Dashboard and individual Building Dashboards to visualise energy flows through the city and engage with the citizens to "create more vibrant, resilient and sustainable communities".

The dashboards provide information on current environmental conditions, together with a real-time figure of electricity consumption per person, information on water consumption, citywide electrical consumption, building consumption figures, carbon emissions, electricity consumption for different uses, etc.

This serves to increase awareness of energy and water consumption, connecting the citizens to their consumption and enabling comparisons between buildings or uses within the city. With the ability to visualise their consumption, this introduces an element of competition whereby citizens aim to improve their consumption and carbon emissions in relation to others within the city and on behalf of the city overall.

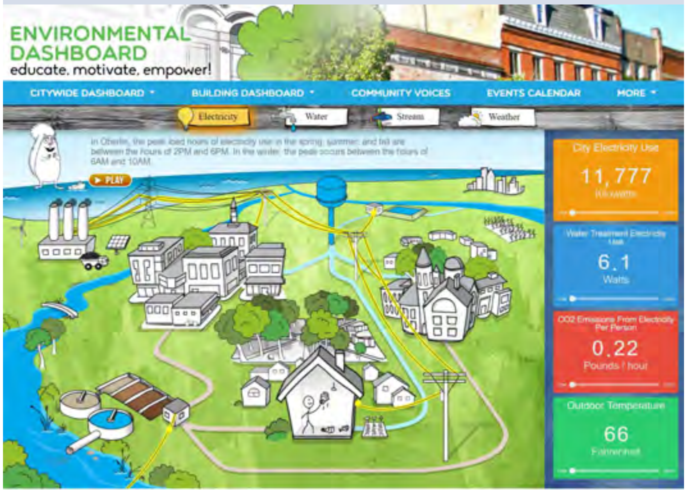

Figure 8.1: Screen shot of Oberlin Environmental Dashboard

For more detailed information on Active Building energy monitoring, please refer to the following documents:

- Active Building Monitoring Specifications
- Active Building Energy Dashboard Guide and Active Office Case Study

9.0 Low Carbon Construction Materials

9.1 Foundations

9.1.2 Steel Screw Piles

Steel screw piles are a versatile, environmentally friendly and cost-effective foundation technology, ideally suited to lightweight structures; and are faster to install than most other foundation solutions. They are typically manufactured from high-strength steel using varying sizes of tubular hollow sections for the pile or anchors shaft.

For an example of screw piles in action, check out our Active Classroom Case Study

Benefits of Steel Screw Piles:

- Quick to install – saving time, money and carbon
- No concrete or curing time – enables faster commissioning of sites
- Flexible design – frames can be designed to bridge services and other obstructions, allowing areas with congested services, for example, to be built on
- Installation in low temperatures is possible – no down time, unlike concrete
- Cost effective solution in soft ground, where traditional piling is more expensive and concrete is technically unsuitable
- Sustainable – they are removable and reusable
- Minimal vibration - working next to existing buildings is no issue
- No excavations or spoil to cart away – saving money (particularly if there is contaminated ground), transport, carbon
- Minimal noise - dependant on excavation, but most installs below 80db

For added benefits refer Section 6.1 on Energy Piles

9.2 Low Carbon Concrete Products

Concrete is the most widely used man-made material on earth; and cement, one of the key ingredients of concrete, is the source of about 8% of the world's carbon dioxide (CO_2) emissions. In fact, it has been reported that, if the cement industry were a country, it would be the third largest emitter in the world - behind China and the US.

There are two ways to significantly reduce the embodied carbon of concrete – one is to use a cement substitute and another is to reduce the carbon emitted of the manufacture of concrete.

Here are some examples of available low-carbon concrete products:.

Hanson EcoPlus® Range – sustainable concrete solution that replaces up to 70% of Portland Cement with Hanson Regen GGBS (Ground Granulated Blast Furnace Slag) – For more information you can book a free CPD seminar here.

The process of manufacturing concrete is highly energy intensive and the second largest contributor to carbon in concrete products. An innovative project in Port Talbot, South Wales, is trialling generation of green hydrogen (via a wind turbine) to use as an alternative fuel source in the manufacture of concrete that utilises GGBS.

Cemfree Concrete – an Alkali-Activated Cementitious Material (AACM) using GGBS and Pulverised Fly Ash (PFA) to create a binder to replace cement.

Carbicrete – a Canadian company who combine cement substitutes, such as GGBS with carbon capture technology, where the carbon emissions from their industrial process are captured, hence reducing the amount of emissions being pumped into the atmosphere. Their future plans include use of direct air capture (DAC) to draw CO_2 from the atmosphere.

Cenin Renewables – at their site in Stormy Down, South Wales, Cenin utilise anaerobic digestion, wind and solar energy generation to manufacture ultra-low-carbon cement substitutes using recycled materials.

9.0 Low Carbon Construction Materials

9.3 Building Fabric

9.3.1 Reducing Thermal Bridging

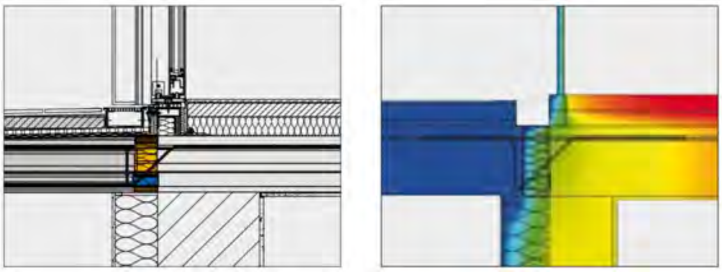

Figure 9.1: Illustration to show how Schöck Isorkorb® minimises thermal bridging (Credit: Schöck)

Schöck Isokorb® has been designed to thermally separate elements, such as balconies, parapets or canopy roofs, acting as part of the thermal insulation, while at the same time forming part of the structure. As such, the Isokorb ® products can significantly minimise thermal bridging issues.

Keystone Hi-therm+ Lintels are thermally broken steel insulated lintels with a Psi value of 0.3 – 0.6 W/m^{2}K, significantly lower than a standard insulated lintel.

Figure 9.2: Hi-therm+ lintel by Keystone

9.3.2 Low Carbon Insulation

Many of the mainstream insulation products contain recycled content and/or are recyclable at end of life. ROCKWOOL, for example, use waste material from refurbishment and demolition, as well as off-cuts in their insulation products, which are themselves recyclable. They have a dedicated recycling facility in Bridgend, South Wales, where contractors can recycle unused ROCKWOOL insulation. Here are a few examples of other low carbon insulation products:

Warmcel insulation is manufactured from recycled newspapers, with the addition of naturally occurring mineral salts, which provide fire resistance and fungal/insect protection.

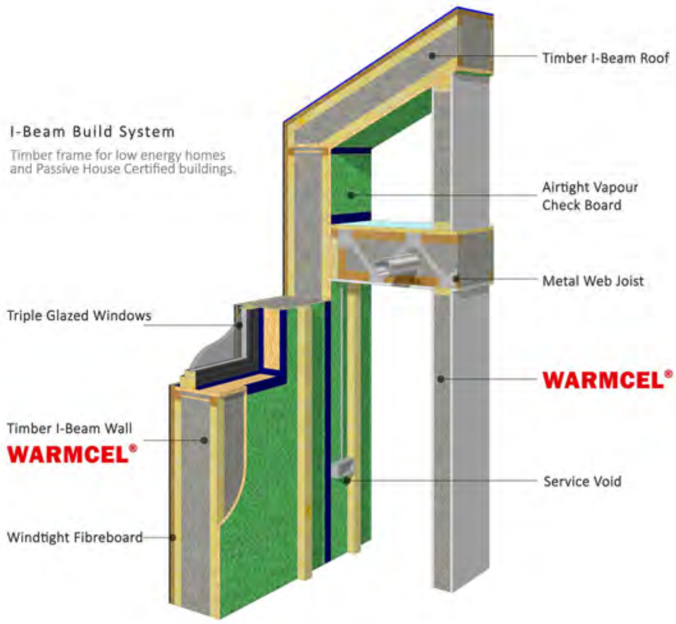

Figure 9.3: Warmcel insulation detail (Credit: Warmcel)

Thermafleece is a natural and sustainable sheep's wool insulation made in the UK (using wool from UK sheep), comprising a blend of 75% wool with recycled polyester fibres, to provide the enhanced performance of sheep's wool with durability and sustainability. It can be used in roofs, walls, lofts and floors and can be supplied in different sizes, formats and densities to suit different performance needs.

Natural Insulations – manufacturers of Thermafleece – also manufacture other low carbon insulation products, including:

- SupaSoft – recycled plastic bottles
- Thermofloc – recycled newspaper
- NatraHemp – hemp fibres and recycled polyester
- Steico – wood fibre from forest thinnings

Inno-Therm®/Métisse® consists of 85% recycled denim/cotton and is recyclable at end of life. It's manufacture uses 70% less energy than conventional insulation, adding to its low embodied carbon credentials.

Emerging Technology

A London-based company, Biohm, have created a range of bio-based materials, for example mycelium to create building insulation that is naturally fire retardant and removes carbon from the atmosphere as it grows. Mycelium is a biomaterial that forms the root system of fungi, feeds on agricultural waste and in the process sequesters the carbon that was stored in this biomass. It is fast-growing and cheap to produce in custom-made bioreactors..

9.3.3 External Cladding

The lowest carbon cladding systems are those made of natural materials, such as timber. Recyclability of cladding is also an important factor – steel, for example is infinitely recyclable - and the lifetime environmental impacts of any cladding material can be checked via its Environmental Product Declaration (EPD). Cladding materials made out of recycled materials are also increasingly available. One example is recycled plastic cladding by a UK company called **Kedel**.

Emerging Technology
A German company called **Made of Air** has developed a carbon-negative bioplastic, using wood waste, that can be used for external cladding. The material contains biochar, a carbon-rich substance made by burning biomass without oxygen, which prevents the carbon from escaping as CO_2.

Figure 9.3: Image of cladding by Made of Air

9.3.4 External Doors and Windows

Glazed elements of a building envelope are often the biggest sources of heat loss, but this can be mitigated through use of high performance glass units and through framing choices. Timber frames, for example, have better insulating properties than metal or uPVC frames. However, timber requires more maintenance than the man-made alternatives. Combining materials such as timber and aluminium can provide a solution to this, and there many manufacturers who provide this hybrid solution. A couple of examples are:

- **Norrsken**: a UK manufacturer of high performance, double or triple glazed, timber framed windows and doors, with exterior aluminium cladding.
- **Vellacine**: another UK organisation manufacturing aluminium clad timber framed windows.

This combination is beneficial to overall building performance, as the timber frames have a low thermal conductivity, while the exterior aluminium cladding provides a durable and low-maintenance outer skin.

These manufacturers also deploy other measures to further reduce their carbon footprints. For example, to minimise waste, the sawdust from Norrsken's manufacturing process is used for heating; while Vellacine collect recycled glass from old windows for reprocessing into new glass units.

Figure 9.4: An example of an aluminium clad, timber framed, triple glazed window

9.4 Internal Finishes for good Indoor Air Quality

Auro Breathable Paints: A wide range of natural plant and mineral based, paints, free from synthetics, pollutants and non-degradable plastics. The use of natural materials creates healthy indoor environments.

Dulux Forest Breath Eco-sense: A high-tech emulsion paint with an air purifying function designed to capture formaldehyde and a range of other VOCs (Volatile Organic Compounds), as well as effectively killing bacteria. The paint utilises solvent-free technology which incorporates natural bamboo and charcoal to give it anti-bacteria, anti-virus anti-benzene and anti-formaldehyde properties.