



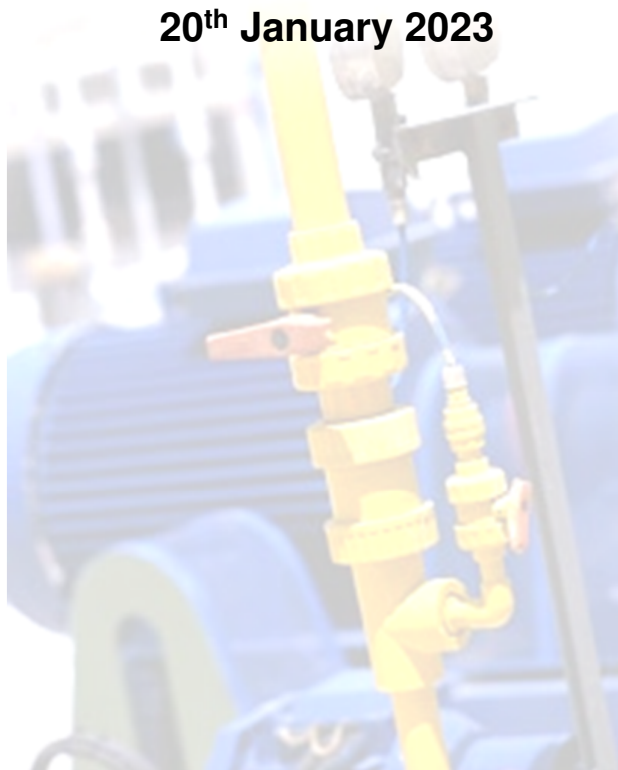
Steven A. Hunt & Associates

**MANCHESTER UNIVERSITY NHS FOUNDATION
TRUST**

**WITHINGTON COMMUNITY HOSPITAL ENDOSCOPY AND
CARDIORESPIRATORY DEVELOPMENT**

LOW AND ZERO CARBON TECHNOLOGY REPORT

20th January 2023



**Job No.3841
Prepared by G Becerra**

Harnessing all **elements** of Mechanical and Electrical Engineering





Steven A Hunt & Associates

Manchester University NHSFT Withington Community Hospital Low And Zero Carbon Technology Report

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1.0 Executive Summary

Manchester University NHSFT has commissioned Steven A Hunt & Associates (SHA) to produce a report, at concept design stage, that considers the various low or zero carbon solutions that are available to contribute towards good sustainable design and to maximise the potential for incorporating renewable energy solutions.

This project is subject to a BREEAM assessment and will require a report into options for Low and Zero Carbon technologies.

Various low or zero carbon solutions have been considered and a number of these technologies were eliminated on the basis of capital cost and payback periods which are too extreme to be viable, available space for the provision of such technology was also considered. Typically, these included biomass boilers.

The final selection of plant and equipment will take place in a later, more detailed design stage of the project.

The report has been compiled by Gabriel Becerra.

2.0 Introduction

This project is subject to a BREEAM assessment and will require a report into options for Low and Zero Carbon technologies.

This report outlines the available LZC technologies for the building type as well as providing estimated annual energy consumption and analysis of energy generated by LZC technologies.

The methods evaluated within this report will contribute towards good sustainable design and maximise the potential for incorporating renewable energy solutions into the mechanical and electrical services design within the Withington Community Hospital.

The energy strategy to be developed aims to make the best use of the energy available by considering the following:

- Reduction of energy consumed by use of construction elements with good thermal properties.
- Reduction of energy consumption by efficient lighting design with occupancy and daylight control.
- Simplicity of environmental controls to assist users.
- Maximising heat recovery.
- Use of low energy lighting.
- Consideration of summertime temperatures.

3.0 Sustainability

The main objective of any energy strategy should be to reduce the CO₂ emissions from the building. The strategy should also aim to reduce the use of non-renewable resources and to reduce the other emissions related to building energy use.

An initial review of the opportunities and constraints of the site has been undertaken from an engineering perspective covering issues such as:

- Sun path and shading.
- Potential biomass resource.
- Ground conditions for ground source heat pumps.
- Prevailing wind.
- Wind resource.
- Sources of noise or air pollution.
- Orientation of building.
- Building fabric.
- Avoidance of potential pollutants (refrigerants)
- Use of water.

The objective has been to identify opportunities to integrate alternative and sustainable energy options when considering the new heating system and the development as a whole.

In addition to these practical issues relating to the construction, clients should also be aware that sustainability extends far beyond the methods used in building and should consider long term operational issues such as:

- Waste management and recycling.
- Transport to and from the place of work.
- Materials and equipment considering the embodied lifetime environmental impacts.
- Social issues
- Health and well-being.

The objective must be to produce a design which achieves compliance with Part L2 of the Building Regulations and BREEAM accreditation in line with a 'Outstanding' as a minimum.

4.0 LZC opportunities

4.1 Heating and Cooling Systems

The opportunities for providing Low or Zero Carbon technologies as part of the heating plant on this site are as follows:

Biomass

- Biomass boilers

Combined Heat and Power (CHP)

- Biomass
- Natural gas
- Sewerage Gas and other biofuels
- Absorption Cooling

Heat Pumps

- Ground Source Heat Pumps
- Water Source Heat Pumps
- Air Source Heat Pumps

Reuse of existing services

- Existing Gas fired boilers
- Existing storage calorifiers
- Existing CHP

The current Part L of the Building Regulations reduces any previous penalties incurred for the use of electricity as a source of generating heating and hot water in new buildings by lowering the carbon factor of electricity. This is based on the national electricity grid using more power produced by renewable forms of electricity generation than at any point in the past and that this trend is forecasted to rise even further in the future.

The government is also likely to set targets on the existing stock of buildings in the UK with regards to overall reductions of CO₂ emissions as we move towards a Carbon Neutral aspiration in 2050.

This is likely to mean that forms of producing heating and hot water will use electricity more as a fuel source, though this needs to be considered alongside the fact that currently natural gas is a cheaper fuel to buy than electricity and so a balance needs to be reached whereby fuel bills are not excessive for end users whilst still meeting the requirements of Energy Consumption and CO₂ emissions covered in the Building Regulations.

A similar balance must also be struck with the project costs to ensure that the electrical load for the building does not require a substantial upgrade of the existing below ground network infrastructure.

With this in mind we would suggest that a solution that uses air source heat pumps to provide the heating load for the majority of the time with a means of on-site generation of electricity would represent a sustainable energy approach for this building that eliminates the reliance on natural gas and represents a low carbon solution.

An option to provide a small contribution to the heating load by natural gas, with the majority provided by ASHP's, will also be considered with a final decision made during detailed design once the infrastructure costs are known.

Another consideration is to use the existing gas fired boilers and CHP to provide heating and hot water for the new extension, either as a top up for the local heating generation or as the main source.

4.2 Remaining LZC Opportunities

The remaining opportunities for providing Low or Zero Carbon technologies on this site are as follows, and we detail the concepts in the following pages.

Solar

- Solar Hot Water
- Photovoltaics (PV)
- Solar combined hot water and PV

Wind

- Wind Turbines

Water

- Small Scale Hydro Power

4.3 Solar

4.3.1 Photovoltaics (PV)

Solar energy emitted by the sun can be harnessed using specifically designed mechanical systems which use solar cells to convert sunlight in to electricity. Each cell has one or two layers of semi-conducting material which respond to light to create an electric field across its layers causing electricity to flow.

There are three basic types of solar cells and these are:

Monocrystalline: These have a typical efficiency of 15% and are the most expensive.

Polycrystalline: These have a typical efficiency of 13%

Thin Film: These are generally applied to other materials such as glass or metals and have a typical efficiency of 7%



A collection or an array of these cells are linked together and their total output is normally installed in parallel to the grid. Current glazing technologies are seeking to combine PVs within standard glazing elements which in time will become more economically viable.

To maximise output PVs are best located at an angle of 30- 40° south facing. Shaded areas will seriously reduce output and should be avoided.

A typical 5Kw system will generate 5,000kWh per year saving nearly 2.5 tonnes of CO₂.

Systems are completely silent in operation and have minimal local impact but may require planning approval from a visual perspective.

In this instance they are to be considered alongside the introduction of an electrically operated heating system as a means of offsetting increased energy costs because of the increased use of electricity as a heating source.

Alongside the addition of photovoltaic cells a method of storing excess energy produced via the PV's would be beneficial. This could allow any stored energy to be used during the evening to allow the benefit of the PV installation to match the profile of the building operation. In reality the building will use the energy produced via the PV during the daytime and as such stored energy does not fit the building's operation profile.

Battery storage would need to be considered separately to this study. Typically they occupy a large area externally to the building and consist of lithium ion battery technology. The lifespan of the batteries is such that they are generally replaced in 10 to 15 year cycles and the costs of such a system including the lifespan running costs would need to be considered.

4.3.2 Solar hot water

Solar energy emitted by the sun can be harnessed using specifically designed mechanical systems which use solar collectors to absorb the sun's energy and provide heat for hot water.

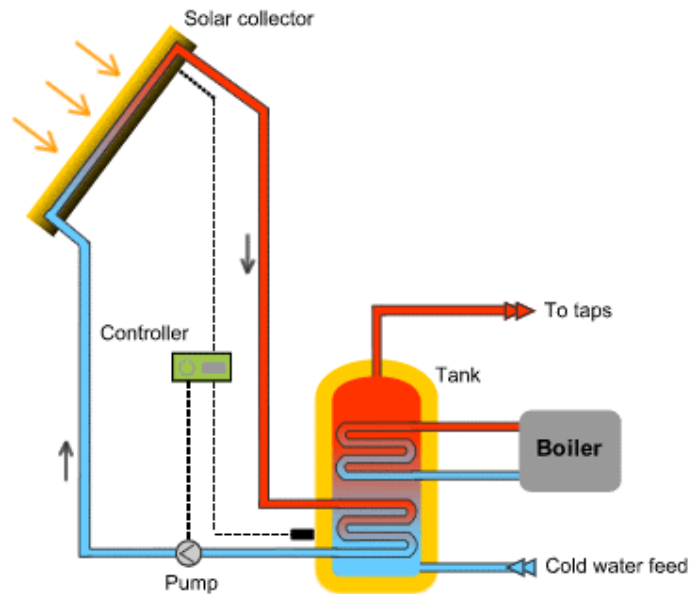
The heat energy absorbed by the collectors is transferred through interconnecting pipework linking an internal storage vessel which enables the demand to match availability.

The circulation of heat can either be by passive means i.e. relying on the natural convection to circulate the water through the system or by active means which uses a circulation pump often powered by a small built in photovoltaic collector to run the pump.

There are several types of hydronic solar collectors but the two most common are:

Flat plate collectors: These are simple but effective devices containing a dark plate within an insulated box with a glass or plastic cover.

Evacuated tube collectors: These are more sophisticated devices offering higher efficiencies under a wider range of conditions but are more expensive.

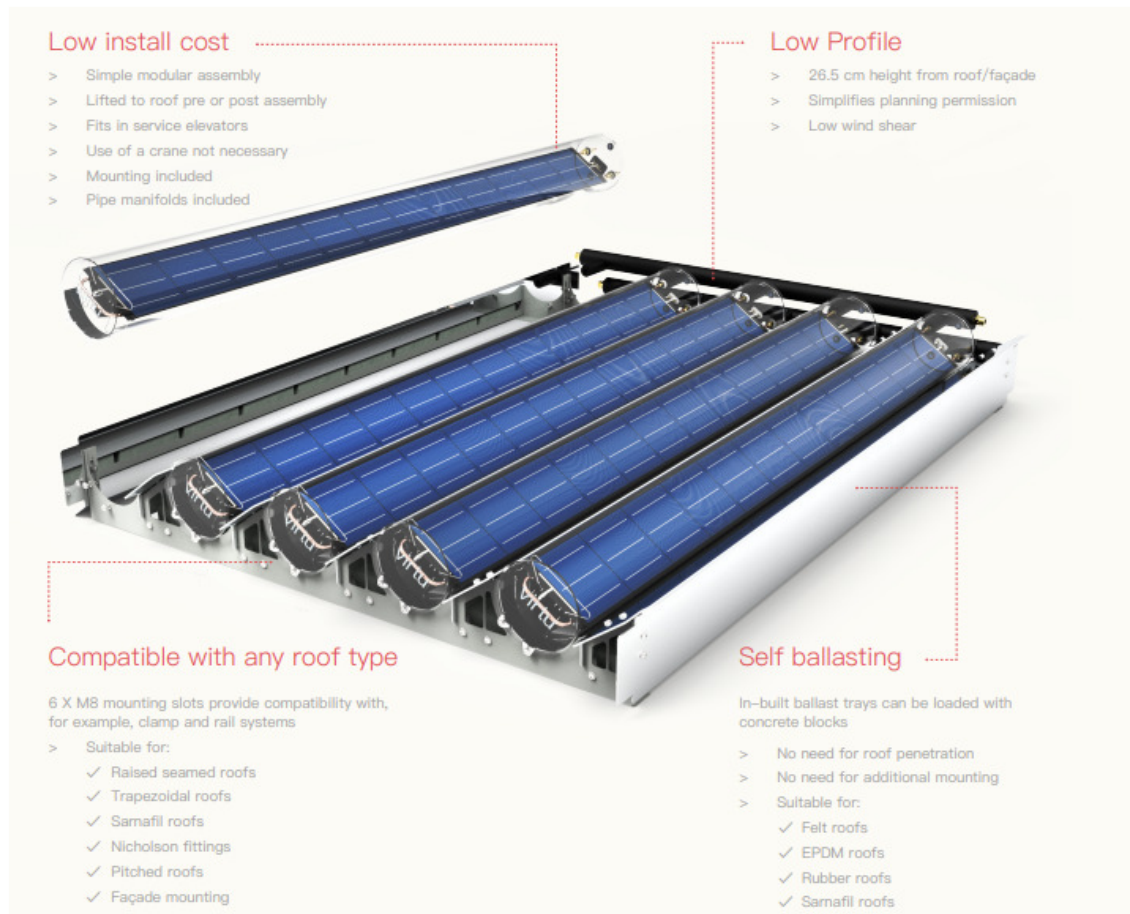


To maximise output solar collectors are best located at an angle of 45° and facing south.

Systems are completely silent in operation and have minimal local impact but may require planning approval from a visual perspective.

4.3.3 Combined PV & Solar hot water

PV panel performance varies with temperature, being at it's peak at around 30-40°C. By using PV solar panels encased in a sealed vacuum tube together with water cooling pipework, the tubes can generate both electricity and heat at the same time



The PV cells generate electricity in the same manner as standard PV panels, but the vacuum tube they are encased in traps incoming heat from sunlight, heating up the environment within the tube.

To allow the tube to remain within the ideal temperature range of the PV cells, a water based cooling system circulates water through pipework behind the PV cells, cooling the tubes and the cells. The heat removed by the tube cooling system can then be reused to heating the building.

The tubes also include a reflector plate to maximize the amount of sunlight collected by the tubes when installed flat on the roof or on a wall.

The system is, however more expensive than standard PV panels, and the heating side requires the installation of a dedicated LPHW system, increasing the complexity of the installation.

4.4 Wind

4.4.1 Wind turbines

Wind power can be harnessed by the use of turbines which captures the wind energy which generates electricity. The electricity produced can be directly fed back in to the grid or can be stored via battery cells.

There are two basic types of turbines and these are:

Horizontal Axis: These are the more common typically seen with three evenly spaced blades rotating around a central hub.



Vertical Axis: These can be installed without a tower on to buildings and operate with a twisted blade structure rotating around a vertical axis.



In order to operate satisfactorily a minimum wind speed of 3.5 to 5m/s is required and ideally a consistent wind speed of 5 to 6m/s are typically required to generate worthwhile quantities of electricity.

The power output from a wind turbine depends upon wind speed and the swept area of the rotor. The higher the rotors the more opportunity there is to maximise the wind speed and increase the output.

Wind turbines are more suited to rural locations as the size and impact within an urban setting tends to limit outputs to an extent where they are unfeasible. Visually they are likely to require planning consent and noise generated by the rotor blades can be considered a nuisance. Rotating turbines can also affect electromagnetic radiation and radiological surveys may be required in sensitive areas such as close to airfields.

As with the photovoltaic cells, the wind turbines are to be considered alongside the introduction of electrically operated heat pumps as a means of offsetting increased energy costs as a result of the increased use of electricity as a heating source.

4.5 Biomass

4.5.1 Biomass boilers

Heat energy is generated by the burning of organic matter such as trees, crops or animal waste which is harvested and processed to create bio-energy. Liquid fuels can also be generated from plant matter and this is referred to as biofuel.

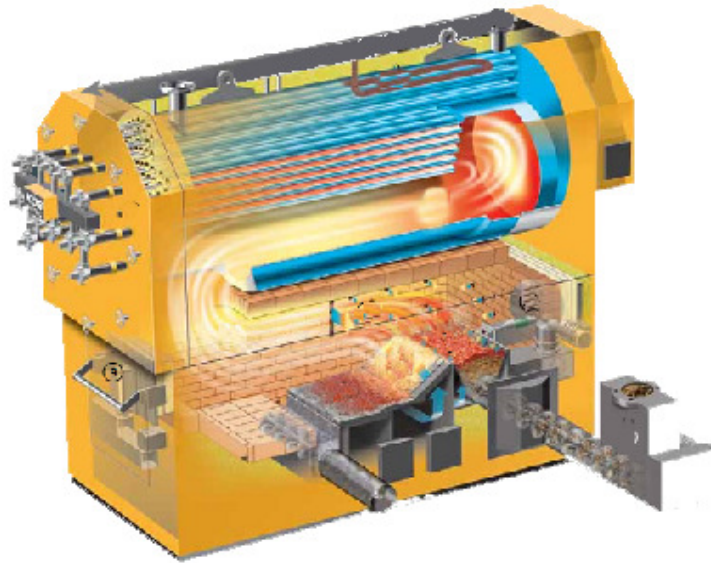
Whilst biomass produces carbon emissions when used as a fuel the carbon released during combustion is equivalent to the amount that was absorbed during growth and the technology is therefore considered to be carbon neutral. However, the availability of the fuel is important to consider as there are secondary carbon emissions generated by transport and treatment.

The main types of biomass are:

Woody Biomass: These are wood based which include forest products, short rotation coppice such as willow, hazel, poplar, miscanthus and other wood wastes such as pallets and construction timber waste. Most products require drying out as the moisture content of woody biomass affects the energy content.

Biofuel: Liquid fuel can be created from cellulose and vegetable oil crops such as palm oil and rapeseed which can be processed and used as vehicle fuel and to power engines and generating plant.

Animal Residues: Cattle, chicken and pig waste can be converted in to bio-energy by conversion to gas or other fuel types.



The use of biomass as a fuel can be used to generate heat within a specifically designed boiler which can replace traditional boilers or can be used as a lead boiler to deal with the base load in a system thus satisfying the requirement to supply a certain percentage of renewable resources and the comfort of a back up system when employing both technologies.

Ideally the use of biomass boilers is best utilised when a healthy supply of fuel is available locally. Provision should be made to store a sufficient supply of fuel and the overall design of such systems tend to be space hungry in comparison with traditional boilers. Provision must be considered for operational maintenance and the disposal of ash.

The installation of such systems may require consultation with the local authority to ensure compliance with the Clean air act if located in a smoke control area and to ensure access is available for the delivery of fuel.

4.6 Combined Heat and Power (CHP)

Combined heat and power (CHP) is the term used to describe the process of generating electricity whilst producing heat as a by-product. Electricity is generated using an engine and heat is recovered from the exhaust gases and cooling system.

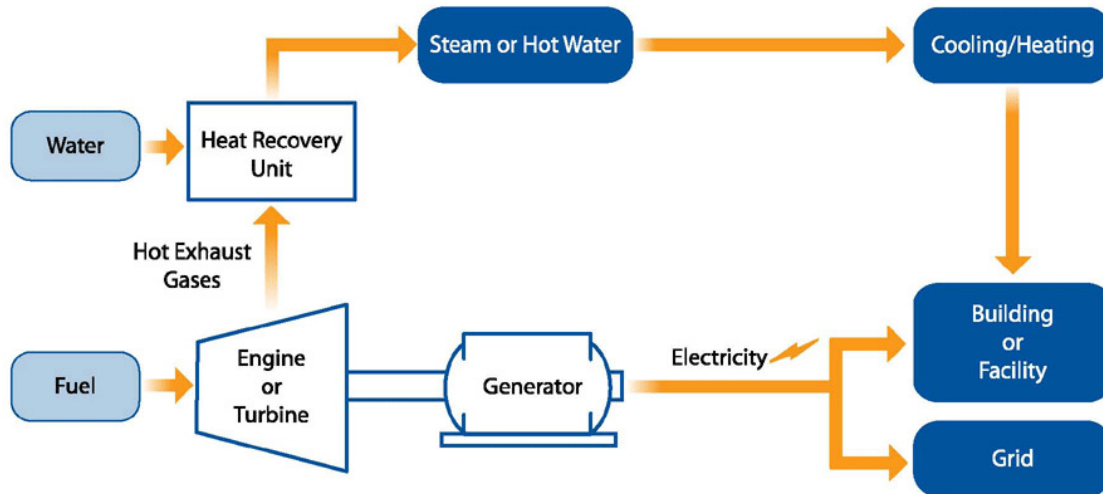
The fuel used to produce electricity within a CHP can be:

- Biomass
- Natural gas
- Sewerage gas
- Biofuel

The process of burning gas fuel still releases carbon but the by product of heat as a result of the primary function offsets the emissions and the production of electricity on

site is far more efficient than an average power station increasing from typically 40% to 80% efficiency.

The use of CHP is most appropriate to buildings which have a constant year round base load demand for heat and can operate at a minimum of 4000 to 5000 hours each year. Units are available to match any output but systems can be employed in parallel with traditional heating boilers thus satisfying the requirement to supply a certain percentage of renewable resources.



Micro CHP are now also entering the market for small systems but at present they are cost prohibitive.

The demand for heat during the summer can often diminish leaving a limited hot water requirement which may be insufficient to satisfy the economies expected to efficiently run a CHP system, but use can be made of the heat energy during summer to operate an absorption cooling system which can provide an effective medium for cooling a building during the summer period.

CHP systems like other generating systems do produce noise but can be effectively treated by use of purpose designed acoustic enclosures. The space requirements are generally larger than traditional boilers and consideration is needed in relation to the products of combustion but these are similar to those that would be required for boilers.

The advantage of the CHP is that it can produce electricity whenever the heating system is in operation. However, they generally provide water at higher temperatures than new air source heat pump systems and so it may be difficult to incorporate CHP into this building.

CHP can also be either Biomass, Biofuel or Sewerage Gas that would reduce CO₂ emissions further. We are aware of CHP providers that can also guarantee the provision of a biofuel based on using waste fats and greases that would help to lower CO₂ emissions further.

For the current project, one possible alternative to installing a new CHP system would be to try to use the existing CHP plant located in the roof plantroom of the existing

building, as it would provide an additional thermal load for the CHP's to work against, and at the same time reduce the primary energy use of the heat pumps for the new extension by both reducing their load and producing the electricity they need.

4.7 Heat Pumps

4.7.1 Ground Source Heat Pumps

The principle operation of a heat pump is the use of refrigerant gases and an electrical compressor to take heat from a source and deliver it to an output. For many years this process has been used by refrigerators to remove heat from a product and to remove heat from a building. This process can be used in reverse to add heat to a building by converting the energy available into useful energy as heat.

The ground acts as a vast solar collector and thermal store which has a relatively all year round stable temperature and a good source of energy for this process to tap in to.

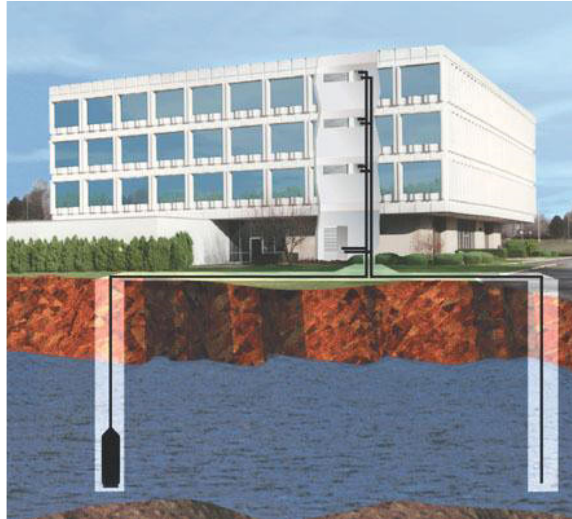
A fluid is circulated via a series of pipework buried in the ground which can either be vertically driven in to the ground or if the area permits, horizontally laid out in loops. The length of the pipework is proportional to the extent of energy required to satisfy the design conditions. The fluid is circulated through a heat pump which extracts the energy and converts this in to usable heat with temperatures in the region of 40 to 50°C which can be used to heat buildings via underfloor heating or radiant panels.



In order that the process can be considered renewable it is important that the depletion of the heat energy is matched by the rate of heat flow back in to the surrounding earth. The process can be used in the summer in reverse and buildings can be cooled by the same technology which assists in maintaining the energy balance.

4.7.2 Water Source Heat Pumps

The principles of water source heat pumps are the same as ground source but larger systems can use groundwater directly from suitable aquifers which can result in very efficient solutions.



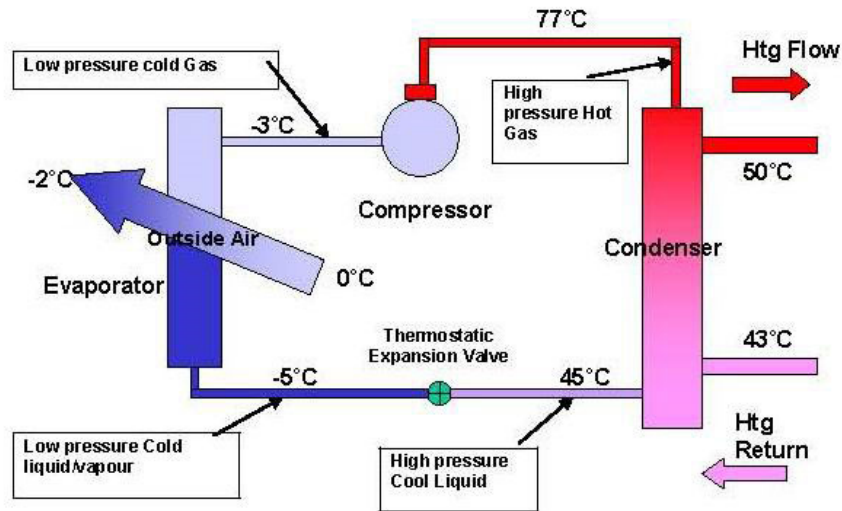
4.7.3 Air Source Heat Pumps

‘Air to air’ source heat pumps have been around for a long time and are used extensively to cool buildings during the summer and heat buildings during the winter.

‘Air to water’ source heat pumps are less prominent but use the same technology and instead of heating air within a building they are used to heat water which in turn can be circulated within a traditional low temperature heating system such as underfloor heating.

This technology has recently seen much improvement and provides a medium for servicing a conventional underfloor heating system and other low temperature heating systems without the need for boilers and yielding high efficiencies.

We are now also seeing the introduction of Air Source Heat Pump technology into hot water storage cylinders for hot water production within dwellings. These systems can make use of air intake and air exhaust connections to atmosphere or return air connections from kitchens & bathrooms that make use of the air temperature to contribute to the hot water load in a dwelling, whilst also using electric heating to make up any shortfall in the required temperature for hot water generation. They are predominantly used when electric panel heaters are installed as the primary heating system.



The choice of heat pump is very much dependent upon individual design circumstances. Whilst GSHP can offer high efficiencies its viability is very much dependent upon the geology of the site which will remain unknown until significant expenditure is committed to testing.

Water source heat pumps require careful design and tend to be more suited to larger scale schemes and can come under scrutiny of local authorities in terms of the impact on the aquifer.

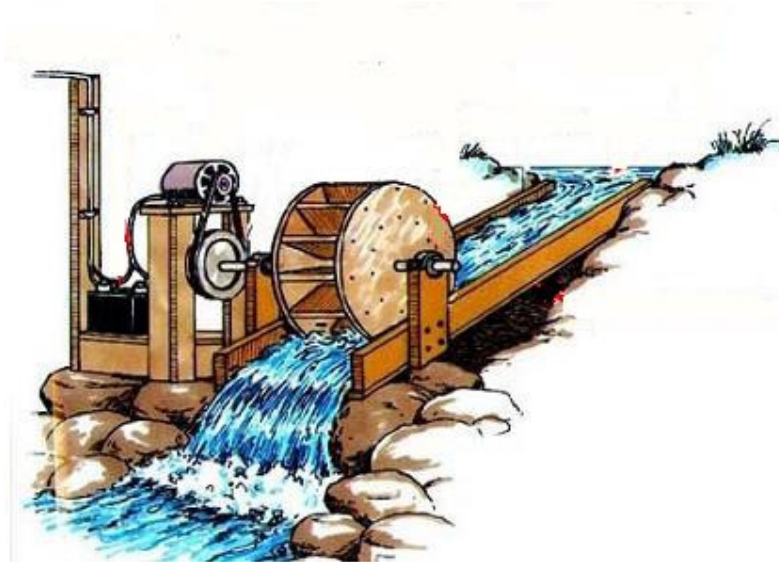
'Air to air' and 'air to water' heat pumps are more safe in terms of technology as they are not dependent upon unknowns and whilst not as efficient as the other two technologies they are still high in comparison to more traditional techniques for heating and cooling and are renewable.

Systems are quiet in operation and have minimal local impact environmentally and visually.

4.8 Water

4.8.1 Small Scale Hydro Power

Hydroelectricity systems generate electricity from running water - usually a stream or river which converts potential energy stored in water to kinetic energy. Hydro power systems use the running water to turn a turbine which generates electricity. The faster the water flows and the more water there is, the more electricity can be generated.



The amount of electricity a system actually generates depends on how efficiently it converts the power of the moving water and how much water is available. However there is considerable opportunity to generate electricity from such a resource.

Such systems are limited to specific sites with available resources but by default tend to be noisy due to the flowing water.

5.0 Suitability for Project

Having identified the various options for LZC technologies these can now be considered with respect to the project. We can summarise their suitability as detailed below, with summaries for each type of building also provided.

5.1 Solar hot water

Whilst the use of Solar hot water systems is an option for the building they are not being proposed at this stage due to their usual long payback period

At this stage of the design it is felt that the use of photovoltaic cells for the production of electricity will offer a better contribution to energy efficiency and be a better use of available roof space rather than the provision of solar hot water, unless the heating is provided in addition to the electricity (combined PV and solar thermal).

The hot water on this scheme is to be derived via Air Source Heat Pumps (ASHP) and therefore the design could be adapted to incorporate heating from solar collectors at a point in the future.

5.2 Solar Photovoltaics (PV)

The roof of the building could be used on this scheme to mount suitable photovoltaic cells and it would be possible to orientate these to achieve the maximum potential.

PVs are considered viable for this scheme especially when introduced alongside heat pumps as a means of providing heating and hot water.

5.3 Combined Solar PV and hot water

The use of combined PV and hot water heat pumps would be the best option for a roof installation, as it would both reduce the load of the Air Source Heat Pumps, and also generate the electricity to run them.

This would be the ideal option for the project, as it would result in the largest reduction on primary energy use and CO2 emissions

5.4 Small Scale Hydro Power

The use of small scale hydro power on this scheme is not viable as there is not a water course within the vicinity of the development that would be considered suitable to generate the level of energy required to make a significant contribution.

5.5 Wind turbines

Typical micro roof mounted wind turbines provide between 300 and 2500watts output with diameters of 900mm to 2500mm. In order to contribute to a net zero carbon initiative; many of these units would be needed.

These figures are based on a minimum of 5m/s velocity however wind analysis from national database figures suggest a figure lower than this for the area and therefore the use of wind turbines is not considered viable for this scheme.

5.6 Biomass boilers

The first consideration for a biomass boiler solution is to determine if there is sufficient space for both the boiler and the fuel supply. On this scheme ground floor space is at a premium and the space required for the Biomass system is not available, we are also unsure if a reliable source of fuel supply could be provided, and the regular delivery of fuel will be made more difficult by the residential nature of the access roads to the site.

To be comfortable with the use of a biomass boiler on the scheme it could only be installed in conjunction with a form of back-up heating to enable its use if the fuel supply was interrupted and to provide back-up during maintenance.

On the basis that ASHP's are being used as the primary means of producing heating and hot water across the development and they are an energy efficient method of providing heating / hot water then it lessens the need for Biomass boilers to be considered. When we also consider that there is no guarantee of fuel supply and the overall cost then the use of Biomass boilers as a renewable energy solution is not considered viable on this scheme.

5.7 Combined Heat and Power (CHP)

The use of CHP as a viable technology relies on a constant base load of heating / hot water requirement and a base electrical supply load.

There is not always an adequate constant base electric load in this type of building. Similarly there is not likely to be a base level thermal demand of sufficient capacity by the use of the heating system and the hot water system.

With an aspiration for the building to use a solution that doesn't use natural gas as the heat source and the unlikelihood of a gas fired CHP providing a net carbon emissions reduction then the fuel use for the CHP would need to be Biomass, Sewerage Gas or Bio-fuel, which are not readily available to the site.

The lack of a large constant base load, both thermally and electrically would mean that this type of technology is excluded as a viable option.

Reuse of the existing CHP's is a more viable alternative, as the thermal and electrical load of the extension will allow the existing units to operate more continuously, however, this will also increase the CO2 emissions of the building, which will negatively impact the part L compliance of the extension and its BREEAM rating, and therefore is not a suitable solution for the current proposal.

5.8 Heat Pumps

The use of ground source heat pumps, in principle, is possible however a more detailed study at a later design stage would be required to understand if an in-ground pipework array solution or a borehole solution is best suited for this project.

There are no aquifers that the design team are aware of within the region of the site that are large enough to support the kind of heat load required and therefore the use of water source heat pumps is not considered viable for this scheme.

Air to water heat pumps are less efficient than ground and water source heat pumps but provide a technology which has less risk. The use of air to water heat pumps would provide a medium for producing low pressure hot water but at a lower temperature than traditional heating systems. Typically electrical air to water systems used to provide LPHW at 50°C but have now been developed further and can provide higher temperatures (up to 68°C) which is more suitable for localised hot water generation along with hot water storage contribution however their energy efficiency diminishes the higher the water temperature they are asked to produce.

We must aim to select the seasonal coefficient of performance for the heat pumps at their optimum level and as such for the purpose of this report we would not recommend that they are used to produce hot water at a temperature which is any higher than 55°C (except for specialized CO₂ heat pumps, which can easily provide 80°C flow).

Ground Source Heat Pumps are more efficient than Air Source Heat Pumps. However, the Ground Source Heat Pumps and the associated cost of the in-ground pipework arrangement will prove more expensive than an Air Source solution and as such Air Source Heat Pumps cannot be ruled out as a more cost-efficient alternative that can still achieve a good level of CO₂ reduction.

The technology of air source heat pumps is the same as that used in refrigerant based heating & cooling systems. With heating and cooling being provided to the activity areas then they will also make use of this technology.

The use of air to water heat pumps using electricity as energy fuel is potentially viable for this scheme.

6.0 Estimation of Annual Energy Consumption

In order to quantify the potential savings some analysis is required on the proposed development to determine the likely base energy consumption.

Based on CIBSE energy benchmark figures the estimated annual consumption for this type of building with a traditional heating and hot water system is as follows:

CIBSE – Energy Benchmarks

20 - Hospital – General Acute Hospital – Good Practice

229 kWh/m²/annum – Gas
84 kWh/m²/annum – Electric

Total floor area = 2120m²

Therefore:

$$\begin{array}{rcl} 2120 \times 229 & = & 485,480 \text{ kWh} \times 0.210 = 101,950.8 \text{ KgCo}_2 \\ 2120 \times 84 & = & 178,080 \text{ kWh} \times 0.136 = \underline{24,218.9 \text{ KgCo}_2} \\ \text{Total} & & 126,169.7 \text{ KgCo}_2 \end{array}$$

Note:- Using carbon intensity values from SAP version 10.2.

In terms of energy bills based upon the following fuel costs we can estimate the energy bill per annum excluding standing charges as follows:

Gas 10.5p/kWh
Electric 31.5p/kWh

$$\begin{array}{rcl} 2120 \times 229 & = & 485,480 \text{ kWh} \times 10.5\text{p} = \pounds 50,975.4 \\ 2120 \times 84 & = & 178,080 \text{ kWh} \times 31.5\text{p} = \underline{\pounds 56,095.2} \\ \text{Total} & & \pounds 107,070.6 \end{array}$$

7.0 Analysis of Energy Generated by LZC technologies

7.1 Heat Pumps

It is intended to use 4No 40Kw electric air to water heat pumps as the main heat source to generate the heating. To establish the energy saving generated we need to compare the consumption of a traditional system against the proposed.

The cost of the ASHP technology over an equivalent boiler is approximately £10,000

	Gas boiler	Heat Pump
Load (Kw)	160	160
Annual heat output (kWh)	435,456	435,456
Seasonal Efficiency	0.91	3.24
Annual heat input (kWh)	478,523.1	134,400
Annual cost (£)	£50,244.9	£42,336
Carbon Emission (KgCo2)	100,489.9	18,278.4

The energy saving between a traditional gas boiler and the proposed electric heat pump is:

$$100,489.9 - 18,278.4 = \mathbf{82,211.5 \text{ KgCo2}} \text{ per annum.}$$

$$£50,244.9 - £42,336 = £7908.9$$

$$\text{Pay back} = 40000/7908.9 = 5.1 \text{ years}$$

7.2 Solar Photovoltaic

It would be the intention to install the maximum number of photovoltaic panels possible with the available roof space: a total of 184 2m wide by 1m high panels rated at approximately 71kWe on an A frame on to the roof.

A simple site-specific calculation has been produced below using below formula;

$$E = A * r * H * PR$$

E = Energy (kWh)

A = Total solar panel Area (m²) r = solar panel yield (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9)

$$368 * 0.20 * 959 * 0.75 = 52,936.8 \text{ kWh/Annum}$$

Carbon Reduction

$$\text{Electricity carbon factor} - 0.136\text{kg/CO}_2 \text{ per kWh } 52,936.8 \times 0.136\text{kg} = 7199.4\text{kg/yr}$$

Based on a installation cost of £100,000 for 368m² array without any incentive or grant the payback is;

$$\text{Simple Payback} = \text{Total Cost} / (\text{Annual Energy Saving} * \text{Electricity Cost (p/kWh)})$$

$$100,000 / (52,936.8 * 0.315) = 6 \text{ years.}$$

$$\text{Annual Energy Saving} = 52,936.8 \text{ kW/h/Annum} * 0.315 = £16,675.1$$

7.3 Summary

The savings in energy for each of the technologies, is as follows:

	Capital cost £	Carbon saving kg/co2	Cost saving £/annum	Pay back Years
Air source heat pump	£30,000	82,211.5	£7908.9	5.1
Photovoltaic	£100,000	7,199	£52,936.8	6

The use of air source heat pumps when compared with equivalent thermal output gas fired boiler plant provides significant reductions in Kg of CO₂. However, the present high level of electricity prices means that the payback periods estimated are much longer than they might ordinarily be.

The current high electricity price has the opposite effect on the proposed cost saving of providing photovoltaic panels. The ability to self-generate and use your own electricity has a marked effect on the amount of money that can be saved in electricity use.

8.0 Conclusion

Having examined all of the possible options for providing low or zero carbon technologies throughout the project we can provide a final summary as follows:

Opportunity	Observations	Decision
Solar Hot water	Photovoltaic panels are a better use of roof space at present.	Not considered
Photovoltaics Combined PV and Hot Water	Viable	To be included
	Suitable, but more expensive and complex than PV	Not considered
Hydro power	No water course present	Not considered
Wind Turbine	Quantity is impractical and wind speed inadequate	Not considered
Biomass boiler	Not viable as fuel source unreliable and requirement for large plant space associated with the boiler and feeder system	Not considered
Combined heat and Power	Not viable due to inadequate base loads.	Not considered
Water source heat pumps	Water course insufficient	Not considered
Air to water heat pumps	Viable	To be included.

9.0 Grants

Renewable Heat Incentive

The Renewable Heat Incentive (RHI) is designed to provide financial support that encourages individuals, communities and businesses to switch from using fossil fuel for heating, to renewables such as wood fuel.

Lottery Funding for Bio-Energy Projects

The BIG Lottery Fund hands out half of the good causes' money from The National Lottery, some £630 million a year. Seven projects have each been awarded grants of up to £500,000 under the Bio-Energy Capital Grants Scheme (BECGS), part of the former New Opportunity Fund's (NOF) Renewable Energy programme which is now administered by BIG.

Information can be found on the BIG website:

www.biglotteryfund.org.uk

Enhanced Capital Allowance Scheme

Enhanced Capital Allowances (ECAs) enable a business to claim 100% first-year capital allowances on their spending on qualifying plant and machinery. There are three schemes for ECAs:

- Energy-saving plant and machinery
- Low carbon dioxide emission cars and natural gas and hydrogen refueling infrastructure
- Water conservation plant and machinery

Businesses can write off the whole of the capital cost of their investment in these technologies against their taxable profits of the period during which they make the investment. This can deliver a helpful cash flow boost and a shortened payback period.

Within the ECA Energy stream are Solar Heating Systems, CHP, Biomass boilers and Ground, Air and Water Source Heating Systems.

Information can be found on the ECA website:

www.eca.gov.uk/etl

Details of the ECA Low Emission Transport stream can be found at

www.hmrc.gov.uk/manuals/camanual/Index.htm

Included in the ECA Water Conservation Stream are low water use showers and toilets and Rainwater Harvesting. Information can be found at:

www.eca-water.gov.uk