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WAST ARC
Low Zero Carbon Report

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			Prepared by	Checked by	Approved by
		Name	Andrew Haines	Hywyn Jones	Daymon Brocklebank
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
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1 Introduction

This feasibility study has been prepared in order to establish the most appropriate local low or zero carbon (LZC) energy sources for the proposed development at the proposed Ambulance Resource Centre (ARC), Wrexham.

The report has been prepared in accordance with the Ministerial Interim Planning Policy Statement (MIPPS) 01/2009 and Draft Technical Advice Note (TAN 22) on Planning for Sustainable Buildings. It is also intended to satisfy the requirements of the BREEAM assessment for a feasibility study at RIBA Stage C.

The following LCZ technologies are discussed in detail:

- Solar Hot Water
- Biomass
- Combined Heat and Power (CHP)
- Photovoltaic
- Wind
- Water Cooling (lake)
- Ground Source Heat Pump
- Air Source Heat Pump
- Rainwater Harvesting and Grey Water Use

1.1 Building loads

The proposed development will consist of the ARC building which is to be approximately 3012m², which will house the make ready bays and associated store rooms, locker rooms, kitchen, rest room, office areas and plant room.

The majority of the energy loads will be for standard room types which has been taken into account during initial modelling results that have been used in this report.

The building loads used in this report are based on:

- Energy Consumption Guide 81 – Industrial
- BISRIA Rule of Thumb
- WAST ARC IES thermal model results

Building loads for the ARC have been estimated as:

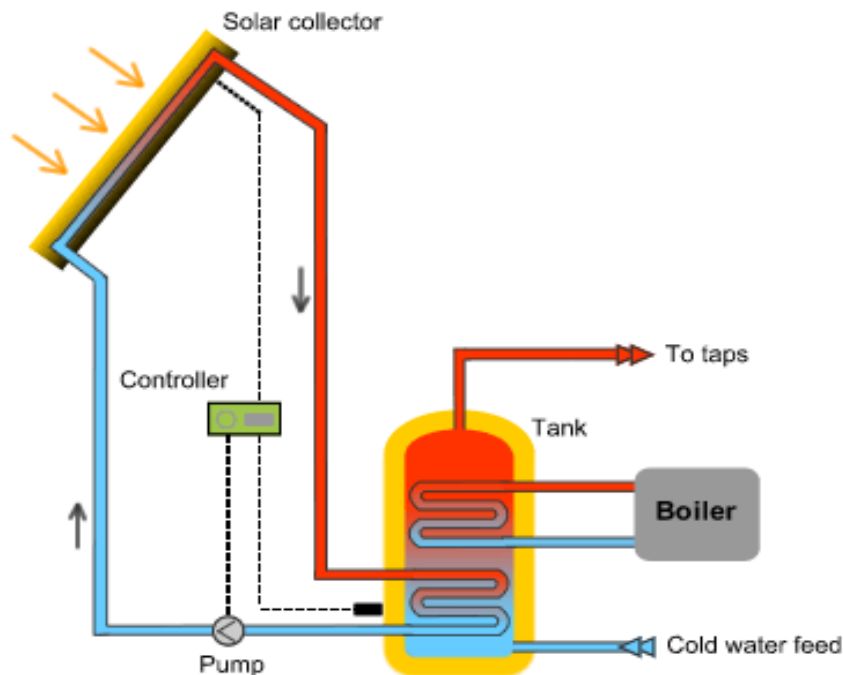
Heating annual consumptions:	157 kWh/m ² /year
Base load annual consumptions:	39 kWh/m ² /year
Electricity annual consumptions:	153 kWh/m ² /year
Electrical peak demand:	40VA/m ²

1.2 Utility Rates

The following utility rates, based on the DECC UK average for Quarter 3 2011, have been used in any calculations presented:

- Electricity: 9.8 p/kWh
- Gas: 2.5 p/kWh

2 Solar Hot Water



Example of a Typical Solar Hot Water System © Payless Solar System

Solar Hot Water (SHW) heating systems utilise solar collectors to gather solar radiation. The solar energy absorbed by the collectors is most commonly used for the generation of domestic hot water in commercial, industrial and domestic applications.

There are two main types of solar collector namely:

- Flat plate collector
- Evacuated tube collector

Evacuated tube solar collectors are generally more efficient than flat plate collectors but require additional maintenance.

Solar collectors should where possible be mounted on south facing roofs at an elevation angle of between 10° and 60°.

For the volume of domestic hot water that will be required the most appropriate system will be to integrate the solar water heating system with the main domestic hot water generation plant to provide pre heating of the incoming cold feed supply via a secondary hot water storage calorifier (or calorifiers). During periods of high solar radiation the solar water heating system should be capable of providing the majority of domestic hot water with little need for temperature boost from the main storage plant.

Solar water heating systems are efficient at generating domestic hot water and can typically meet approximately 50% of building domestic hot water requirements.

Domestic hot water needs to be generated and stored at 60°C - 65°C to eliminate growth of legionella bacteria. Solar collectors cannot generate water at such temperatures all year round and need to be backed up with low temperature hot water, oil or gas fired water heaters/calorifiers.

Plant space for location of pre heat cylinders needs to be provided in close proximity to solar collectors.

Integration of a solar hot water system into the buildings cladding could be investigated when complete loads and collection areas are confirmed.

2.1 Energy generated

Based on similar sized buildings, the likely domestic hot water energy requirements of the building can be estimated using the following calculations:

ANNUAL DOMESTIC HOT WATER LOAD : **≈ 118,435 kWh**

The positioning and size of any solar hot water system is important. The best location for solar thermal hot water panels on the building is on a southerly facing roof where obstructions from shadowing are likely to be at a minimum. The contribution to the domestic hot water that could be made via the installation of solar hot water can be estimated using the following assumptions:

- The average annual output of a 1m² flat plate solar hot water panel in the UK is ≈ 650kWh
- Roof top space can potentially hold 30m² of solar panels

From the above assumptions the average flat plate solar hot water contribution to domestic hot water supply can be estimated:

System Contribution = 30 x 650

POTENTIAL ESTIMATED ANNUAL : **≈ 19,500 kWh**

It is important to note that this does not mean that 100% of the annual hot water load will be supplied from the solar panels. This is an average amount. Due to variances in solar levels a higher percentage will be contributed during summer months than the winter.

2.2 Costs

As well as the cost of the panels, there are other items of equipment that are necessary for the full system to function such as expansion vessels, buffer tanks and plate heat exchangers. Therefore to accurately estimate the installation costs of a system it is important to source a quote. For the early stages of this assessment, IaniSolar have been used for the system costing.

Budget installed costs: £38,907

Government grant: N/A

TOTAL INSTALLATION COSTS: **≈ £38,907 +VAT**

Once installed, the annual running costs will be governed by the cost of any maintenance or repair work and the circulation pumps. The fuel, solar energy, will

be free. To estimate the annual running costs of the circulation pumps the following assumptions have been made:

- The pumps will be active when a high enough temperature can be achieved within the solar tubes: typically 80% of the average 8 hours of daily sunshine within the UK across a 365 day year
- The total load of the circulation pumps and associated control gear will be approximately 1kW
- The electricity required will be 9.8p/kWh

From the above assumptions the annual energy consumption would be:

$$(365\text{days} \times 8\text{hrs} \times 80\%) \times 1\text{kW} : \approx 2,336 \text{ kWh}$$

The average annual running cost can be calculated as follows:

$$2336 \text{ kWh} \times £0.098$$

ANNUAL RUNNING COST: **≈ £230**

2.2.1 Electricity

As the solar hot water supply cannot be guaranteed during the winter months, it is usual to install a water heater sized at the base load. For the purposes of this report the installation costs of the energy that the solar hot water would be replacing can be assumed as:

TOTAL INSTALLATION COSTS: **≈ £1,200**

To calculate the annual fuel cost for the electrical immersion heater the following assumptions have been made:

- The cost of electricity will be 9.8p/kWh

From the above assumptions the cost per annum of the heating of the domestic hot water if it was electric immersion heated would be:

$$19,500\text{kWh} \times £0.098 =$$

ANNUAL RUNNING COST: **≈ £1,911 + VAT**

2.3 Payback

2.3.1 Without Renewable Heat Incentive

To calculate the payback the difference in installation costs between solar hot water system and the existing grid supply can be divided by the annual savings in fuel costs as follows:

$$\begin{aligned} \text{Payback period in years} &= \frac{\text{Difference in Installation Cost}}{\text{Annual fuel saving Costs}} \\ &= 37,707 / (1911-230) \\ &\approx \mathbf{22 \text{ years}} \end{aligned}$$

2.3.2 Considering Renewable Heat Incentive

In this calculation the tariff rate has been estimated to be an average of 8.50p/kWh.

$$\begin{aligned}
 \text{Payback period in years payment} &= \text{Difference in installation/Annual RHI} \\
 &= (38,907 - 1,200) / ((19,500 \times 0.085) + 1681) \\
 &\approx \mathbf{12 \text{ Years}}
 \end{aligned}$$

Once the initial 12 year payback period has been met the trust would continue to earn £1,657.50 per year for 8 years from the RHI.

2.4 Land use

Solar hot water panels could be located on the roof area of the building. Orientation of the arrays could be such that their efficiency is maximised.

2.5 Local planning requirement

Planning permission would be required due to the visual impact of the panels on the roof. However, if a solar hot water system is proposed, the position of panels could be incorporated within the design of the buildings.

2.6 Noise

There is no noise issue associated with this technology.

2.7 Carbon emissions

The annual reduction in CO₂ emissions is calculated using estimations. To calculate the reduction the following assumptions as detailed in Approved Document Part L2A have been used:

- Grid supplied electricity has a CO₂ emission factor of 0.517 kgCO₂/kWh
- Solar hot water has a CO₂ emission factor of 0 kgCO₂/kWh

From the above assumptions:

$$\begin{aligned}
 \text{Grid electricity CO}_2 \text{ Emissions} &= 19,500 \text{ kWh} \times 0.517 \\
 &\approx 10082
 \end{aligned}$$

$$\begin{aligned}
 \text{Solar hot water CO}_2 \text{ Emissions} &= 19,500 \text{ kWh} \times 0 \\
 &\approx 0
 \end{aligned}$$

$$\begin{aligned}
 \text{Circulation pumps CO}_2 \text{ Emissions} &= 4,368 \text{ kWh} \times 0.517 \\
 &\approx 2258
 \end{aligned}$$

$$\mathbf{ANNUAL \text{ CO}_2 \text{ EMISSIONS REDUCTION:} \approx \mathbf{7.8 \text{ tonnes}}}$$

2.8 Grants

Excluding the Renewable Heat Incentives mentioned above there are no known grants available for this technology and building type.

2.9 Cost/Tonne CO₂ Saved Over Lifetime

The life cycle cost of a solar hot water system is calculated as follows, based on a 20 year life expectancy:

$$\begin{aligned}
 \text{Life Cycle Cost} &= \frac{\text{Installation} + [\text{Annual Fuel} \times 20] + [\text{Maintenance}]}{[\text{CO}_2 \text{ reduction} \times 20]} \\
 &= \frac{£38,907 + [230 \times 20] + [585 \times 20]}{[7.8 \times 20]} \\
 \text{Life Cycle Cost} &\approx \mathbf{£354 / \text{tonne CO}_2 \text{ saved}}
 \end{aligned}$$

3 Biomass



Typical Biomass Boiler and Auger © BSRIA

Biomass is the burning of biological matter to produce heat and/or power. Biomass is considered carbon neutral, since the carbon emitted when the fuel is burned is re-established during the growing cycle of new plant material via the process of photosynthesis.

Carbon emissions associated with cultivating, harvesting and transporting biomass need to be considered and minimised, where possible, in order to ensure carbon neutrality.

Capital costs associated with the installation of biomass plant can be high in comparison with traditional gas-fired or oil-fired boilers. However, these costs are generally recovered over time by savings on energy bills.

3.1 Fuel Type

There are a number of different bio-fuels available for use. These are:

- Wood fuel in the form of wood chip or wood pellets;
- Energy crops;
- Agricultural and forestry residues.

Wood pellets and wood chips are the most commonly used bio-fuels in the UK. The choice of which fuel source to use is project specific and should be investigated in detail to ensure a local, reliable supply is available that can meet

the heating demand of the onsite boiler. The relative merits of each fuel source are discussed in more detail below:

Measure of Performance	Wood Chip	Wood Pellet
Cost (p/kWh)	2.00	3.75
Storage Capacity (kWh/m ³)	880	3000
Availability	Widely available in Europe & UK	Limited UK supply, widely available in Europe
Use	Wood chips boilers only	Wood chip and wood pellet boilers
Moisture Content (%)	20-70	8-10

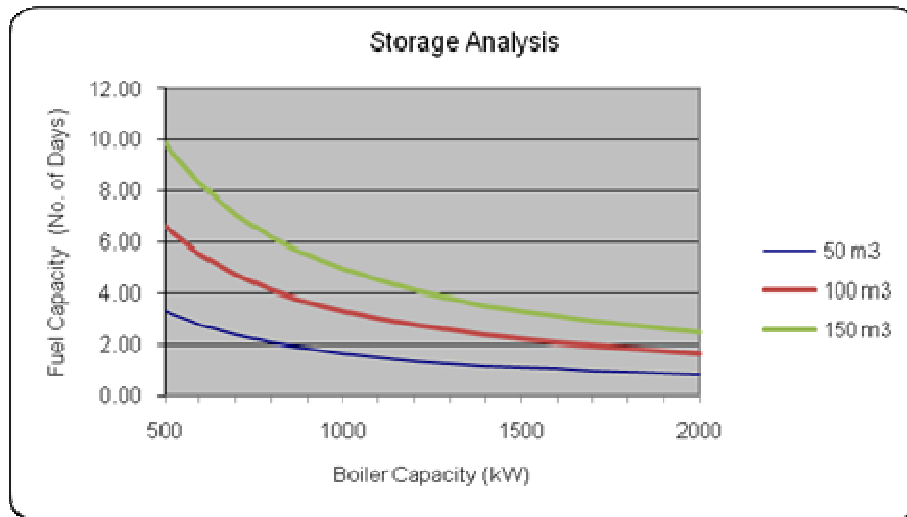
Wood pellets are formed by compressing sawdust into regularly sized pellets (6-12mm typically) with a controlled moisture content. The benefit of this procedure is that the energy content per tonne is generally higher than the wood chip alternative. This means that required storage volume is minimised and the quality of fuel is guaranteed.

However, due to the processing costs involved, the cost per unit of energy is higher for wood pellets than for wood chips. Therefore, as long as there is adequate storage space available onsite (required storage for wood chips at least 3 times that of wood pellets for the same quantity of stored energy), the use of wood chips could prove more cost effective over time. In addition, the availability of wood chip fuel within the UK is significantly more reliable than that of wood pellets.

It is therefore recommended that any decision to proceed with biomass at -ARC allows for a boiler that can fuelled with wood chip (i.e. can take fuel with a moisture content up to 70%) so as not to limit the source of fuel. Since the moisture content of wood pellets is in the region of 10%, this boiler selection would allow the use of either fuel type.

3.2 Land Use

Early planning is the key to mitigating the inherent practical risks associated with biomass systems. Onsite, the location of the boiler plant and storage vessel are paramount since it is likely to require a large floor area and frequent fuel delivery in winter months. Projected delivery requirements are shown below for wood chip and wood pellet fuels over a range a storage volumes.



Access routes for delivery vehicles need to be adequately sized to allow for manoeuvring and considerate of the safety of children and other building users.

3.3 Noise

The noise generated by biomass boilers is comparable to that generated by a traditional gas-fired or oil-fired boiler and, therefore, requires no additional consideration. However, given the frequency of fuel delivery in winter months, access routes for delivery vehicles need to be carefully designed to reduce the transmittance of noise to teaching spaces. Delivery times should also be carefully planned to minimise noise during lesson times.

3.4 Operation and Maintenance

The biomass boiler plant can be sized to meet the entire heating demand within a building or can be sized to match the base load with additional top-up from conventional gas-fired boiler plant. The benefits of this mechanism are two-fold. Firstly, running the biomass boiler at full capacity (in this case the base load) is highly recommended since efficiency significantly reduces if the boiler is over-sized. The gas-fired boiler may then be used to meet peak demands in winter months. Secondly, a suitably sized gas-fired boiler provides the system with a degree of redundancy. This can be used to provide a higher proportion (or all) of heat during maintenance to the biomass boiler. It also provides reassurance of heat if, for example, biomass fuel supplies were compromised for any reason in the future.

Users of biomass systems need to be aware of the increased need for maintenance as compared with traditional boiler systems. A maintenance programme must be in place to clean and remove ash from the boiler in order to prevent system failures. The supply of fuel also needs to be closely managed to ensure timely delivery and that fuel quality is sufficient to meet the requirements of the boiler. This ideally calls for a contract to be in place between the user and a reliable local supplier of wood chips and/or wood pellets.

3.5 Energy Service Company (ESCo) Approach

As an alternative, the user could employ an Energy Service Company (ESCo). ESCo's exist in a wide variety of forms, providing a range of comprehensive energy solutions for buildings and/or local communities. Whilst the role of an ESCo often varies from project to project, their level of involvement typically includes the design, build, finance, operation and maintenance of energy schemes. In each case, the ESCo is often contracted to supply heat for a minimum period of time. In addition, the majority of ESCo's operate with a strong emphasis on energy efficiency and sustainability.

3.6 Local planning requirements

The flue from the wood boiler will need to be co-ordinated with the massing of the building. It is likely to fall under the requirements of the clean air act and will need to be extended 3m above any area to which there is general access. This would require careful co-ordination with any naturally ventilated spaces.

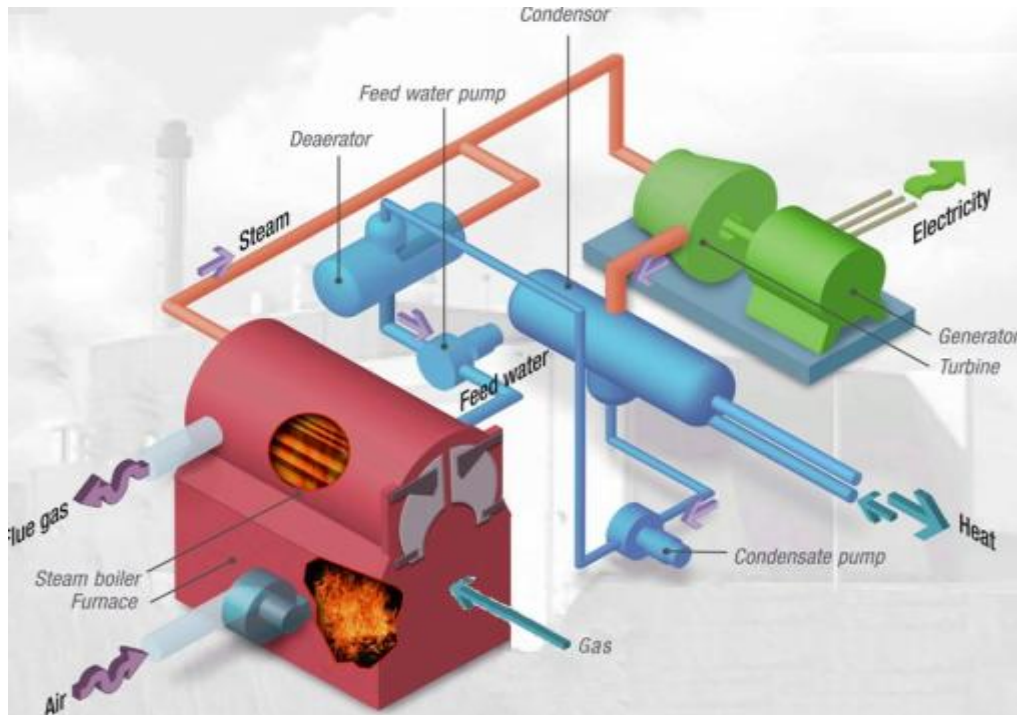
3.7 Feasibility for ARC

It is recognised that fuel deliveries for the biomass could prove problematic for a site with high ambulance traffic, as well as increase on site operational issues. The client has indicated that they do not wish to have a biomass system installed on this site due to these issues.

3.8 Costs

Costs and payback have not been considered due to the unsuitability of biomass technology as outlined above.

4 Combined Heat and Power



Typical Gas Fired CHP Plant providing both Electricity and Cooling

Combined Heat and Power (CHP) is the generation of electricity and useful heat in one process. CHP plants generate electricity using fossil fuels while using the waste heat to provide heating and hot water.

A CHP plant use a single piece of equipment to generate heat and electrical power. In order for the CHP solution to be sustainable and cost effective it must be used all year around.

In order to maximise the efficiency and reduce the running costs of the CHP plant the unit must be sized to operate at near 100% all of the year around. If the unit were sized larger than this, the excess heat from the CHP plant would have to be rejected to atmosphere during some months of the year. The CHP unit would then be operating as a power station and the efficiencies will be very low. In this case a more sustainable solution would be to buy electricity from the “Green Grid”.

At this time consideration should be given to operate the CHP plant on Natural Gas from the grid, as biomass CHP is not yet fully developed and commercially viable.

The electricity from the CHP unit can be used at any point throughout the building. The electricity demand of the building in use will be far greater than the production of the CHP plant. However, consideration must be given to when the site equipment is not in use (i.e. possibly night time or servicing periods) which may require that electricity can be passed back to the National Grid. Confirmation of this will be subject to detailed design.

4.1 Land use

The size of the CHP unit would need to be positioned within the identified plantroom, and usually requires additional space due to acoustic enclosures. Alternatively, the CHP unit could be located externally.

4.2 Local planning requirement

An internal CHP unit would not require additional planning considerations over traditional gas fired boilers.

4.3 Noise

There will be no additional noise considerations over traditional gas fired boilers.

4.4 Grants

It is unlikely that any grants will be available for CHP in this instance.

4.5 Feasibility for ARC

In order to maximise the efficiency and reduce the running costs of the CHP plant the unit must be sized to operate at near 100% all of the year around. If the unit were sized larger than this the excess heat from the CHP plant would have to be rejected to atmosphere. This means that there must be a constant and substantial heat load throughout the year for the unit to run efficiently. The heat load profile for ARC will drop considerably during the summer months, with only minimal loads generated from hot water usage.

It is therefore recommended that CHP is not suitable for the ARC.

4.6 Costs & Payback

Costs and payback have not been considered due to the unsuitability of CHP technology as outlined above.

5 Photovoltaic



Example of Photovoltaic System

Solar photovoltaic's (PVs) enable sunlight to be transformed directly into electrical power. The photovoltaic effect or interaction between radiating sunlight and the semiconductor material of the solar cell makes this transformation. This generates electrical charges that are conducted away by metal contacts. The direct current produced can be transformed into alternating current by connecting a DC/AC inverter. The most important element of a photovoltaic generator is the solar photovoltaic cell. Several solar cells are combined in series or parallel into an electrical unit, solar module.

A solar cell consists of a very thin layer of semiconductor material (usually silicon). This is doped with impurities (other elements) on both sides. As a result, one side acquires a negative charge (a surplus of electrons) and the other a positive charge (electron deficiency). When sunlight falls on the material that has been changed in this way, electrons are forced from one side to the other by its radiative energy. This produces direct current at the terminals.

PV arrays should where possible be mounted to face between south- east and south- west at an elevation of between 30° and 40°. PV arrays can be designed to integrate with roofing and vertical glazing/cladding systems.

The system should ideally be connected to the mains electricity grid and should be capable of drawing energy from the grid and exporting energy produced by the PV cells to the grid. The main advantages are:

- Part of the electrical supply would be produced on site thus reducing the amount of electricity that would need to be imported.
- By connecting the system to the grid the cost of storage can be avoided and security of supply is guaranteed.

The photovoltaic cell array size that is required is dependent upon the overall contribution to the electrical load, available budget and available area that can be utilised for installation.

With the high capital cost for the installation of PV's, the relatively small amount of electrical energy generated and the expiry of Clear-Skies government grant

funding, PV's based on payback period alone are unlikely to constitute a sound investment. However, the incorporation of PV's into the scheme will assist in lowering the building's overall carbon emission rating.

Due to the inefficiency of PV cells, typically 15%, large areas of PV array area are required to generate relatively small amounts of electrical energy. Part of the cost of PV array installation can be offset against the cost of rain screen cladding for example, however capital investment is still high.

5.1 Energy Generated

The positioning and size of any solar PV system is important. The best location for solar panels on the proposed ARC site will be on the roof, with the panels orientated towards the south.

The contribution to the electrical load that could be made via the installation of solar PV can be estimated using the following assumptions:

- The average annual output of a 1m² solar PV panel in the UK is ≈106kWh
- Assume 30m² of solar panels situated at roof level

From the above assumptions the average solar electrical supply can be estimated:

$$= 30 \times 106$$

ESTIMATED ANNUAL SOLAR PV ENERGY: **≈ 3,180 kWh**

It is important to note that this does not mean that this kWh rating is evenly distributed throughout the year. Due to variances in solar levels a higher percentage will be contributed during summer months than the winter.

5.2 Cost

To estimate an indicative cost for the installation of a solar PV system one the following assumption based upon national reports shall be made:

- Average UK PV panel installation cost is £4000/kWp

As the proposed 30m² system has a peak rating of 3.8 kWp the installation cost can be estimated as follows:

$$= 4000 \times 3.8$$

TOTAL INSTALLATION COSTS: **≈£15,200 +VAT**

Once installed the annual running costs will be governed by the cost of any maintenance and repair work required as solar energy is free. The PV array and controls have no direct running costs and require very little maintenance therefore the annual running costs can be assumed as:

ANNUAL RUNNING COST: **≈ £0**

To calculate the annual fuel cost for a national grid connection the following has been assumed;

- The cost of electricity from the grid shall be 9.8p/kWh

From the above assumptions the cost per annum of the energy supplied by the solar PV system where it to be grid sourced would be:

$$3180 \times 0.098 =$$

ANNUAL RUNNING COST: **≈ £312 + VAT**

5.3 Payback Periods

5.3.1 Excluding the Feed in Tarrifs

To calculate the payback the difference in installation costs between solar PV system and the existing grid supply can be divided by the annual savings in fuel costs as follows:

$$\begin{aligned} \text{Payback period in years} &= \text{Difference in Installation Cost} / \text{Annual fuel saving} \\ &= (15,200 - 0) / (312 - 0) \end{aligned}$$

PAYBACK PERIOD: **≈ 49 years**

5.3.2 Considering Feed in Tariffs

In this calculation the tariff rate has been estimated to be an average of 21 p/kWh. This calculation does not take into account additional payment under the FIT scheme for feeding electricity back to the grid.

$$\begin{aligned} \text{Payback period in years} &= \text{Difference in Installation Cost} / \text{Annual FIT} \\ &= (15,200 - 0) / ((3180 \times 0.21) + 312) \\ &\approx \mathbf{16 \text{ years}} \end{aligned}$$

For the next 9 years following this, the building will earn £668 revenue per year from the FIT.

5.4 Land use

PV arrays could be located on the roof of the new building. The location and orientation of the arrays could be arranged to maximise their efficiency.

There is easy access on to the roof should it be necessary to access the PV Arrays for maintenance.

5.5 Local Planning Requirement

Planning permission is likely to be required due to the visual impact of the panels, however this is unlikely to be a problem as the only viable position for the panels is on the roof, out of sight from the ground.

5.6 Noise

The solar arrays would have no noise impact.

5.7 Carbon Emissions

The annual reduction in CO₂ emissions calculated using estimations. To calculate the reduction the following assumptions as detailed in Approved Document Part L2A have been used:

- Grid supplied electricity has a CO₂ emission factor of 0.529 kgCO₂/kWh
- Solar PV has a CO₂ emission factor of 0kgCO₂/kWh

From the above assumptions:

Grid electricity CO₂ Emissions: = 3,180 kWh x 0.529 kgCO₂/kWh ≈ 1682

Solar PV CO₂ Emissions: = 3,180 kWh x 0 kgCO₂/kWh ≈ 0

ANNUAL CO₂ EMISSIONS REDUCTION (tonnes): ≈ **1.7**

6 Wind



A Wind turbine is a machine that converts kinetic energy (wind) into mechanical energy. Modern wind turbines are tough durable machines and efficient at transferring the energy from a natural source. If the mechanical energy is used directly i.e. to turn wheels etc it would be known as a windmill. However, if the kinetic energy was used to generate electricity it is known as a wind generator or wind turbine.

6.1 Energy generated

It is not feasible to supply the whole of the site's electrical requirements from wind energy. A very small proportion of the base load would be supplied by several small turbine. For the purposes of this energy calculation the quiet revolution 5 wind turbine has been used. The quiet revolution is a vertical axis wind turbine with a British Wind Energy Association (BWEA) rated output of 4.2 kW at 11m/s. The annual energy generated can be estimated using the Carbon Trusts wind power estimator with the following assumptions:

- qr5 power curve as stated by the Research Council of Canada
- Mounting height of approximately 30m
- Wind speed data taken as historically recorded for the Wrexham area

From inputting the above assumptions the following results can be estimated:

ANNUAL AVERAGE WIND SPEED: **≈ 5 m/s**

ANNUAL AVERAGE ENERGY GENERATION: **≈ 5,700kWh**

6.2 Costs

6.2.1 Installation

The installation costs for a 3.2kW Wind Turbine, data taken from Beco Solar:

TOTAL INSTALLATION COSTS: **≈ £17,000 + VAT**

To calculate the annual fuel cost for a national grid connection the following has been assumed;

- The cost of electricity from the grid shall be 9.8p/kWh

From the above assumptions the cost per annum of the energy supplied by the wind turbine system where it to be grid sourced would be:

$$4,000 \times 0.098 =$$

ANNUAL RUNNING COST: **≈ £392 + VAT**

6.2.2 Maintenance

Annual maintenance has been estimated at £350 per turbine per year.

TOTAL ANNUAL MAINTENANCE COSTS: **≈ £350 + VAT**

6.3 Payback Periods

6.3.1 Excluding the Feed in Tariffs

To calculate the payback time.

$$\begin{aligned} \text{Payback period in years} &= \frac{\text{Difference in Installation Cost}}{(\text{Annual fuel saving})} \\ &= (17,000-0) / (392-0) \end{aligned}$$

PAYBACK PERIOD: **≈ 44 Years**

6.3.2 Considering the Feed in Tariffs

In this calculation the tariff rate has been estimated to be an average of 28p/kWh. This calculation does not take into account additional payment under the FIT scheme for feeding electricity back to the grid.

$$\begin{aligned} \text{Payback period in years} &= \text{Difference in Installation Cost} / \text{Annual FIT} \\ &= (17,000 - 0) / ((5,700 \times 0.28) + 392) \\ &\approx \mathbf{9 \text{ years}} \end{aligned}$$

Once the initial 9 year payback period has been met the trust would continue to earn £1,596 per year for 11 years from the RHI.

6.4 Noise

Noise generation would need to be considered in more detail as part of the planning submittal.

6.5 Exporting heat and electricity from the system

The size of the proposed turbine does would not make this viable.

6.6 Carbon emissions

The annual reduction in CO₂ emissions calculated using estimations. To calculate the reduction the following assumptions as detailed in Approved Document Part L2A have been used:

- Grid supplied electricity has a CO₂ emission factor of 0.529 kgCO₂/kWh
- Wind energy has a CO₂ emission factor of 0kgCO₂/kWh

From the above assumptions:

Grid electricity CO₂ Emissions = 5,700 kWh x 0.529 kgCO₂/kWh ≈ 3015

Wind energy CO₂ Emissions = 5,700 kWh x 0 kgCO₂/kWh ≈ 0

ANNUAL CO₂ EMISSIONS REDUCTION (tonnes): ≈ **3.0**

7 Water (lake water cooling)

Typically a lake water cooling system consists of an open primary and closed secondary cooling system. The primary water system would include flow and return pipework from below water level with automatic self cleaning strainer / filter, twin circulating pumps, plate heat exchanger to transfer cooling energy to the secondary cooling system together with all necessary valves, fittings and controls devices.

The system operates by circulating lake water through an open circuit via automatic filtration and circulating pumps to a plate heat exchanger with return water being passed through the open system back into the sea. The secondary circuit provides cooled water through a closed system via circulation pumps to air handling equipment.

Biofouling, scaling and corrosion are common operational problems with lake water cooling systems which need to be engineered to ensure maintenance and repair is limited, while at the same time avoiding the use of chemicals which could be harmful to the marine environment.

Energy savings of 30% could be achievable if the system is viable, together with a significant reduction in building carbon emission to atmosphere.

Lake water temperatures of approximately 12-16°C could be ideally utilised in conjunction with displacement ventilation. Passive or active chilled beam air conditioning installations which utilise chilled water flow temperature of between 14°C and 17°C are also suitable for combining with this technology.

7.1 Feasibility for ARC

As the base cooling load for the ARC is very low, as the IT server room is currently the only room with a cooling requirement, and with no tempered air being introduced in to the spaces, it is recommended that this type of solution is not suitable for the ARC.

8 Ground Source Heat Pumps



Example of vertical and horizontal pipe configuration © Groenholland

Ground-coupled heat pump systems are generally used in conjunction with closed loop pipework systems installed either horizontally approximately 2 metres below ground level or vertically in bore holes with bore hole depths varying between 15 and 100 metres depending upon particular site ground conditions. Systems are available at present where vertical pipe loops can also be accommodated within pile foundations providing a more economical method of installation.

The optimum use for ground-coupled heat pumps is in the generation of low temperature hot water to serve systems which are more suited to the use of lower flow temperatures (approximately 40°C). Such systems are underfloor heating systems.

Ground-coupled heat pumps are not considered wholly renewable but when utilised can reduce building carbon emissions by between 30% and 35%.

To get the most out of this type of system the year round heating load and cooling load needs to be approximately equal to ensure that there is no net increase/decrease in ground temperature.

8.1 Feasibility for ARC

The anticipated heating and cooling loads for the ARC suggest that the heating load will be far greater than the cooling load therefore this type of system does not lend itself to this development.

8.2 Costs & Payback

Costs and payback have not been considered due to the unsuitability of GSHP technology as outlined above.

8.3 Local planning requirement

As this any visible equipment will be internal there will be no additional planning considerations over traditional gas fired boilers.

8.4 Noise

As this is internal there will be no additional noise considerations over traditional gas fired boilers.

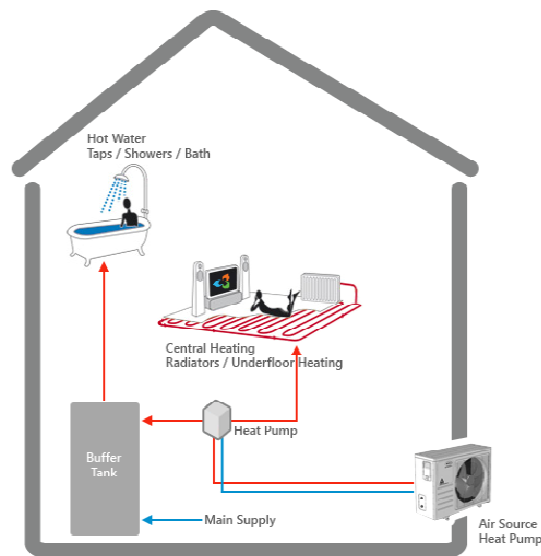
8.5 Carbon emissions

These have not been considered due to the constraints identified above.

8.6 Grants

Some grants are available for GSHP, however these have not been explored in detail the project constraints have directed that this technology is not suitable.

9 Air Source Heat Pumps



Example of Air/Water system © FutureProof Energy

Air source heat pumps utilise the heat from the outside air to feed heating systems and domestic hot water systems. They use electrical energy and convert this into thermal energy, utilising a refrigerant system to absorb the heat from the external air and use release it to the heating system, the opposite to an air-conditioning unit or fridge.

The pump makes use of an environmental energy as the source of the heat; this will reduce the thermal power consumption required.

There are two types of systems; all air systems, where the heat is transferred to the space via the air. The other type is an air to water system, where the heat absorbed from external conditions is transferred to the water heating system via a heat exchanger.

The optimum use for air source heat pumps is in the generation of low temperature hot water to serve systems which are more suited to the use of lower flow temperatures (approximately 40°C, such systems are underfloor heating systems).

9.1 Feasibility for ARC

To access whether this system is feasible for the ARC a quick calculation was undertaken accessing what the Coefficient of Performance needs to be to be financially viable:

Assuming 1kWh of heat from a 90% efficient gas Boiler

1kWh from 90% efficient gas boiler	=	2.50 p/kWh @ 90%
	=	2.77 p/kWh
1kWh from electricity	=	9.8 p/kWh

$$9.8/2.77 = 3.54$$

Typically if this type of system was compared to a standard gas-fired boiler solution, a CoP >3.54 would be required to be financially viable. Currently these systems operate with a CoP in the range of 2-2.5.

As there are no Renewable Heat incentives available for ASHP, the payback of this system would never be met.

9.2 Costs & Payback

Costs and payback have not been considered due to the unsuitability of ASHP technology as outlined above.

9.3 Local planning requirement

As the air source heat pump will have an external unit, planning permission maybe required as it will be visual from the external.

9.4 Noise

As this is internal there will be no additional noise considerations over traditional gas fired boilers.

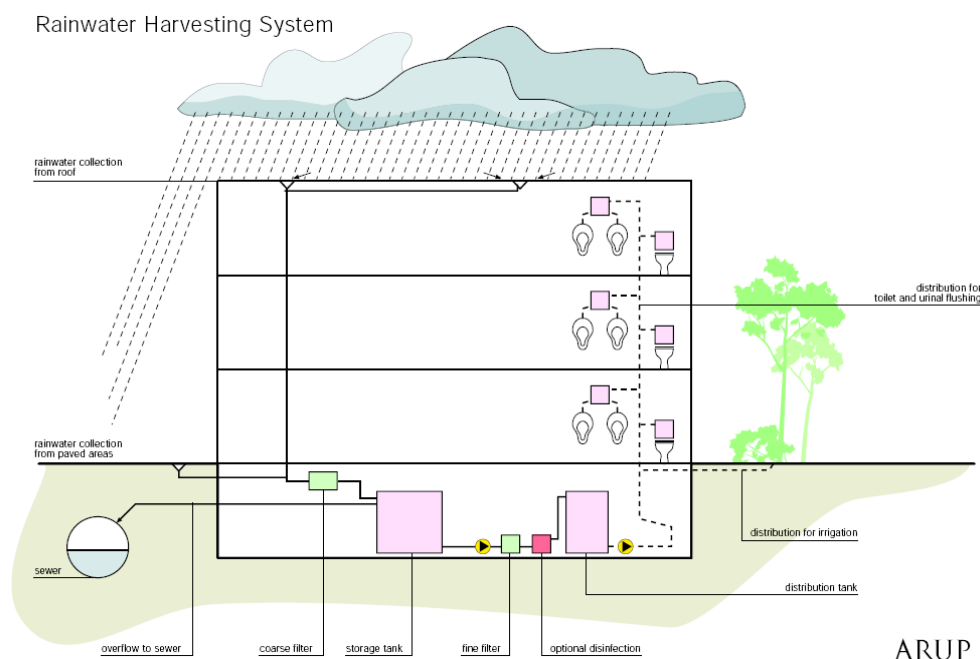
9.5 Carbon emissions

These have not been considered due to the constraints identified above.

9.6 Grants

There are no known grants available for ASHP at present.

10 Rainwater & Graywater Harvesting



Rainwater Harvesting Schematic

While not strictly a low or zero carbon technology for the building, a rainwater harvesting system does help reduce the carbon footprint of our water industry. At present a significant amount of energy is consumed in collecting, treating and distributing potable water, which is then used for WC flushing, which does not require water to be purified to drinking standards. Therefore rainwater harvesting technologies can help reduce the UK's overall carbon footprint.

A rainwater recovery system captures rainwater which falls on the roof of a building. It is stored in a tank for future use within the building. Typically the water is used for WC and urinal flushing and replacing water which would have been taken from the mains, hence reducing the demand and reliance on the mains water system.

The main collection tank is often located below ground to save space. The water is then pumped to a smaller header tank located in the roof. This header tank is then used to gravity feed the WCs and urinals.

The header tank will also have a mains cold water connection to ensure that during periods of low rainfall the tank does not empty completely.

It is also possible to recycle grey water from wash hand basins and showers. This can be used for urinal and toilet flushing or cleaning. This requires a separate collection, treatment and re-distribution system to rain water harvesting. The feasibility of this is unlikely to be cost-effective, as there is not envisaged to be a large wash hand basin and shower use within the building.

For complete self-sufficiency, systems would need to treat the harvested rain water to potable water standards. Foul water would be collected and treated to non-potable standard for toilet flushing. However, this is costly and has safety considerations that are likely to make it impractical.

10.1 Water Usage

To calculate the potential of a rainwater harvesting system it is necessary to take into account the estimated rainfall on the site that can be harvested, and compare it to the annual non potable water demand. The client has advised that the use of rainwater for flushing WCs is not preferable. However, the client is keen to explore the feasibility to using rainwater to supply the water requirement of the washdown area and the fire fighting training area.

10.1.1 Washdown Area

The annual water usage can be calculated using the following assumptions:

- The average number of ambulances washed per day will be 19 ambulances.
- The average water usage per ambulance wash will be 135 litres.

Therefore the annual non potable water demand for the washdown can be approximated as follows:

ANNUAL AVERAGE NON POTABLE WATER DEMAND : $\approx 936\text{m}^3$

10.1.2 Fire Fighting Training Area

The annual water consumption can be calculated the following assumptions:

- The flowrate to a standard fire hydrant is 500 litres per minute.
- The hydrant will be used for 30 minutes a week.

Therefore the annual non potable water demand for the fire training area can be approximated as follows:

ANNUAL AVERAGE NON POTABLE WATER DEMAND : $\approx 780\text{m}^3$

10.1.3 Water Savings

The potable water saving made from the harvested rain can be approximated using the following assumptions:

- The average rainfall on the site is approximately 1111mm, (1.1m)
- The useable collection area on the roof is 2,500m²
- Due to roof obstructions, losses in filtering equipment surface run-off and evaporation 50% of the potential collected rainfall will be lost

The potential collected rainfall can be calculated as:

$$= 1.1 \times (2,500)$$

Annual estimated potential rainfall collection: $\approx 2,750\text{m}^3$

$$= 2,750 \times 0.5$$

POTENTIAL AVERAGE ANNUAL WATER SAVING: $\approx 1375\text{m}^3$

This represents approximately 80% of the estimated annual average non potable water demand. The remaining demand will be supplied by the main incoming mains water.

It has been identified that the washdown water can be recycled to replenish the rainwater harvesting tank. This form of graywater recycling would minimise the use of incoming water to refill the tank, and increase the potential average annual water saving to 1716m^3 (assuming losses will be less than 50%).

10.2 Costs

10.2.1 Washdown Facility

From experience a tank of approximately 15 m^2 will be required and hence this figure has been used to estimate the costs and payback periods.

Based on recent quotations the estimated installation costs are as follows:

TOTAL INSTALLATION COSTS: $\approx \text{£}13,000 + \text{VAT}$

Once installed the annual running costs will be governed by the cost of any maintenance or repair work and the circulation pumps used to pump the rainwater up to the header tank. The fuel, rainwater, will be free. As with other sections of this report these costs are being ignored for the purposes of calculations. To estimate the annual running costs of the circulation pumps the following assumptions have been made:

- The pumps will be active for a period whenever the washdown facility is in use. They will top up the header tank to maintain the pressure in the system. It is assumed they will be active for 8 hours a day.
- The total load of the circulation pumps and associated control gear shall be approximately 3.5kW.
- The electricity to required shall be 9.8p/kWh

From the above assumptions the annual energy consumption would be:

$$(365 \times 8) \times 3.5: \approx 10,220 \text{ kWh}$$

The average annual running cost can be calculated as follows:

$$10,220 \times 0.098$$

ANNUAL RUNNING COST: $\approx \text{£}1,002$

10.2.2 Fire Training Facility

From experience a tank of approximately 10 m² will be required and hence this figure has been used to estimate the costs and payback periods.

Based on recent quotations the estimated installation costs are as follows:

TOTAL INSTALLATION COSTS: **≈£12,000 +VAT**

Once installed the annual running costs will be governed by the cost of any maintenance or repair work and the circulation pumps used to pump the rainwater up to the header tank. The fuel, rainwater, will be free. As with other sections of this report these costs are being ignored for the purposes of calculations. To estimate the annual running costs of the circulation pumps the following assumptions have been made:

- The pumps will be active for a period whenever the washdown facility is in use. They will top up the header tank to maintain the pressure in the system. It is assumed they will be active for 8 hours a day.
- The total load of the circulation pumps and associated control gear shall be approximately 3.5kW.
- The electricity to required shall be 9.8p/kWh

From the above assumptions the annual energy consumption would be:

$$(365 \times 8) \times 3.5: \approx 10,220 \text{ kWh}$$

The average annual running cost can be calculated as follows:

$$10,220 \times 0.098$$

ANNUAL RUNNING COST: **≈ £1,002**

10.2.3 Mains Supplied Water

To calculate the annual cost for the water that the rainwater harvesting system is collecting if it was supplied by the local water company, the following assumptions have been made:

- A reduction in incoming metered water will also reduce the outgoing sewerage costs
- The cost of supply and removal of the water by the local water board is £2.50 m⁻³

From the above assumptions the cost per annum of the water provided by the rainwater harvesting were it to be supplied by the water utility company would be:

$$=1,375 \times 2.50$$

ANNUAL RUNNING COST: **≈ £3,438 + VAT**

$$(ANNUAL RUNNING COST – with recycling: =1,716 \times 2.50$$

$$\approx £4,290 + VAT)$$

10.3 Payback

To calculate the payback the difference in installation costs between rainwater harvesting and the existing water supply can be divided by the annual savings in water board costs as follows:

$$\begin{aligned}\text{Payback period in years} &= \text{Difference in Installation Cost} / \text{Annual water saving} \\ &= (26,000 - 0) / (3,438 - 2,003) \\ &\approx 19 \text{ years}\end{aligned}$$

Payback period in years - with washdown recycling: $\approx 11 \text{ years}$

10.4 Land use

The 15,000 litre tank for the ambulance washdown will be approximately 6.2m long x 1.85m diameter and would ideally be located below ground.

The 10,000 litre tank for the fire training will be approximately 4m long x 1.85m diameter and would ideally be located below ground.

10.5 Local planning requirements

If the tank is below ground then planning permission is unlikely to be required. If an above ground tank is specified planning permission is likely to be needed due to the visual impact on the site.

10.6 Noise

There are no noise issues to consider.

10.7 Grants

We are not aware of any grants however it is eligible for enhanced capital allowance.

11 Conclusion

Each technology has been considered in turn through this report. A summary of these have informed which should be considered in the next stage;

- **Solar Hot Water** - This is a viable option for the ARC facility. It is noted however that if point of use electric heaters are implemented, it will be incompatible with a solar hot water system.
- **Biomass** - Although a potential viable option, it is recognised that the client could have operational concerns with having fuel delivery on a high traffic site and the requirement for staff to clean and maintain the biomass boiler.
- **CHP** – Due to the nature of the heat load profile of the ARC, a CHP is not recommended as a suitable technology.
- **Solar PV** - This is a viable option, however as it produces a low energy yield relative to its install costs and payback times being 49 years. If, however, the FITs are used for this installation a payback period of 14 years, and an additional £6,000 from the FIT over the 25 year period, would make this system desirable.
- **Wind Power** – This is a viable option, however as it produces a low energy yield relative to its install costs and payback times, the payback period of approximately 90 years make this a seemingly inappropriate option. It is also recognised that gaining planning permission for this technology could prove problematic.
- **Water Cooling** – Not a viable solution due to the minimal cooling demands associated with the ARC.
- **Ground Source Heat Pumps** - Due to the nature of the heating and cooling profile of the ARC it is recommended that heat pumps are not a suitable technology.
- **Air Source Heat Pumps** – Due to the low COP performance of most ASHP, this technology is not financially and environmentally compatible with the ARC.
- **Rainwater Harvesting** – This technology should be considered to reduce both reliance and demand on the mains cold water systems. Its low installation cost coupled with a high annual return gives it a reasonable payback period. Although using for WC flushing is not desirable to the client, the high use of water for ambulance washdown and fire training facility gives a good opportunity to reduce water usage considerably.

In conclusion this report has looked at various low carbon options for implementation within the ARC. By looking at different requirements, costs and benefits of each system it is possible to rule out a number of unfeasible technologies as detailed above.