3.3 Technical Feasibility Study of Renewable and Low Carbon Technology Energy Options

3.3.1 Solar Photovoltaic (PV) Panels

Solar photovoltaic panels convert solar radiation into electrical energy through semiconductor cells. They are not to be confused with solar panels which use the sun's energy to heat water (or air) for water and space heating.

Figure 2 - CPW Photovoltaic Installations: Project Epic (BREEAM Excellent Office –left) and Castle Wood (BREEAM Excellent School –right)

Photovoltaic panels are available in a number of forms including mono-crystalline, polycrystalline, amorphous silicon (thin film) or hybrid panels (discussed later). They are fixed or integrated into a building's un-shaded south facing façade or pitched roof ideally at an incline of 30º to the horizontal for maximum energy yield.

Figure 3 - Solar PV Louvres on the South Facade

It is essential that the panels remain un-shaded, as even a small shadow can significantly reduce output. The individual modules are connected to an inverter to convert their direct current (DC) into alternating current (AC) which is usable in buildings.

Although sloping rooftops provide an ideal site for fixing PV panels using traditional mounting frames, there are a number of alternative solutions whereby PV panels can be incorporated into the actual building fabric of the development.

Solar louvres use PV panels to provide solar shading on the south façade of buildings as part of the brise soleil (see above), and this can be a highly effective way of controlling overheating and help reduce glare.

Solar glazing uses a combination of solar PV and glass, where the PV cells are laminated between two panes of specialised glazing (see above). The resulting glass laminate serves the dual function of creating energy and shade at the same time, reducing the risk of overheating.

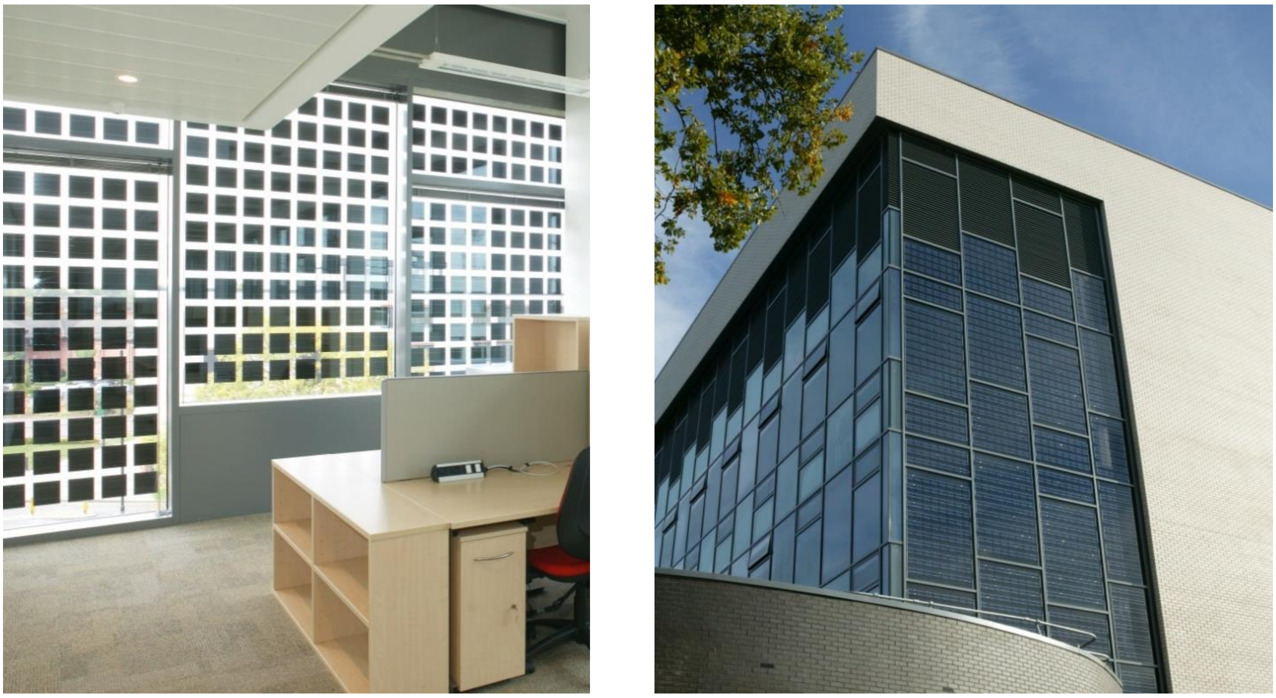


Figure 4 - CPW Solar Glazing Installation, University of Warwick - Materials and Analytical Sciences Building

Solar glazing can be used wherever conventional glass would be specified, especially in atria. Bespoke designs allow for varying light penetration by changing the spacing between individual cells. Typically, a combination of 50% PV and 50% translucent glazing is used.

Vertical solar facades can be used to directly replace conventional rain screen cladding materials providing a smooth, flat facade surface for the building. Where circumstances allow, the PV panels can be tilted towards the sun to maximize the energy yield.

As mentioned earlier, there are a number of types of PV cell:

Mono-crystalline Silicon Cells: These are made using cells saw–cut from a single cylindrical crystal of silicon. The principle advantage of mono-crystalline cells is their high efficiency, typically around 15 – 24%, although the manufacturing process required to produce mono-crystalline silicon is complicated, resulting in slightly higher costs than other competing technologies.

Polycrystalline Silicon Cells: These are made from cells cut from an ingot of melted and re-crystallised silicon. In the manufacturing process, molten silicon is cast into ingots of polycrystalline silicon. The ingots are then saw-cut into very thin wafers and assembled into complete cells giving a granular textured finish. Polycrystalline cells are cheaper to produce than mono-crystalline types, due to the simpler manufacturing process but tend to be slightly less efficient, with average efficiencies of circa 13 – 16%.

Thick-Film Silicon: This is another polycrystalline technology where the silicon is deposited in a continuous process onto a base material giving a fine grained, sparkling appearance. Like all crystalline PV, this is encapsulated in a transparent insulating polymer with a tempered glass cover and usually bound into a strong aluminium frame.

Thin-Film Amorphous Silicon: Amorphous silicon cells are composed of silicon atoms in a thin homogenous layer rather than a crystalline structure. Amorphous silicon absorbs light more effectively than crystalline silicon, so the cells can be thinner. For this reason, amorphous silicon is also known as a ‘thin film’ PV technology. Amorphous silicon can be deposited on a wide range of substrates, both rigid and flexible, which makes it ideal for curved surfaces and ‘fold-away’ modules. Amorphous cells are, however, less efficient than crystalline based cells, with typical efficiencies of around 6%, but they are easier and, therefore, cheaper to produce.

Other Thin Films: A number of other promising materials such as cadmium telluride (CdTe) and copper indium diselenide (CIS) are now being used for PV modules. The attraction of these technologies is that they can be manufactured by relatively inexpensive industrial processes, certainly in comparison to crystalline silicon technologies, yet they typically offer higher module efficiencies than amorphous silicon. New technologies based on the photosynthesis process are at early stages of commercialisation.

Photovoltaic technology may be feasibly incorporated into the building design with little/no maintenance or on-going costs. Installations are scaleable in terms of active area; size being restricted only by available façade and/or roof space.

Consider roof mounted mono-crystalline PV panels with a peak output of 290kW as determined by the BRUKL model data.

- Capital cost circa £208,800
- Savings circa £54,097 per year
- Simple payback 4 years
- Energy saving circa 225,406kWhr/yr
- % Energy saving 120.6%
- CO_2 saving 24,821kgCO_2/yr
- % CO_2 saving 92.8%

A particular advantage of solar PV, even over other types of LZC technology, is that running costs are very low (requires no fossil fuel for operation) and, since there are no moving parts, very little maintenance is required.

3.3.2 Solar Thermal

Solar thermal energy can be used to contribute towards space heating and hot water requirements. In the UK, most applications focus on hot water installation as the solar availability during the space heating season is limited.

Figure 5 - CPW Solar Thermal Evacuated Tube Systems: William Brookes School (left) and Police Federation Headquarters (right)

The use of solar water heating installations is widespread throughout Europe. The systems use a heat collector, generally located at roof level on support frames, orientated in a southerly direction to maximise solar heat absorption.

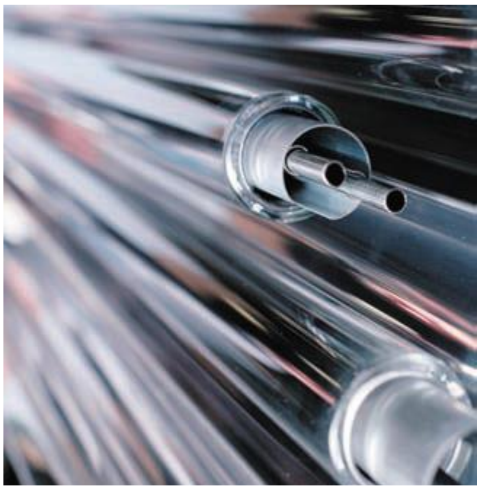


Figure 6 - Evacuated Tube Type Collectors

A working fluid is used to heat water that is stored in either a separate hot water cylinder or more commonly a twin coil hot water cylinder with the second coil providing top-up heating from a conventional boiler.

The two most common forms of collector are panel and evacuated tube.

The panel type collectors are generally more robust and reliable while manufacturers claim that the evacuated tube versions offer better winter all-round performance.

The design of the flat plate panels is relatively straightforward; consisting of water tubes arranged behind solar glass and an absorber plate. The absorber plate absorbs the sun’s rays and transfers energy to the water flowing through the tubes. In contrast, the evacuated tube type collectors are more complicated consisting of double wall glass tubes with a space in the centre containing a heat pipe and a liquid.

Coatings on the inner glass ensure that around 93% of the absorbed heat is retained within the system and the vacuum prevents loss of heat through conduction and convection. The circular design helps maximise the potential to collect solar energy all year round when the sun is at different angles.

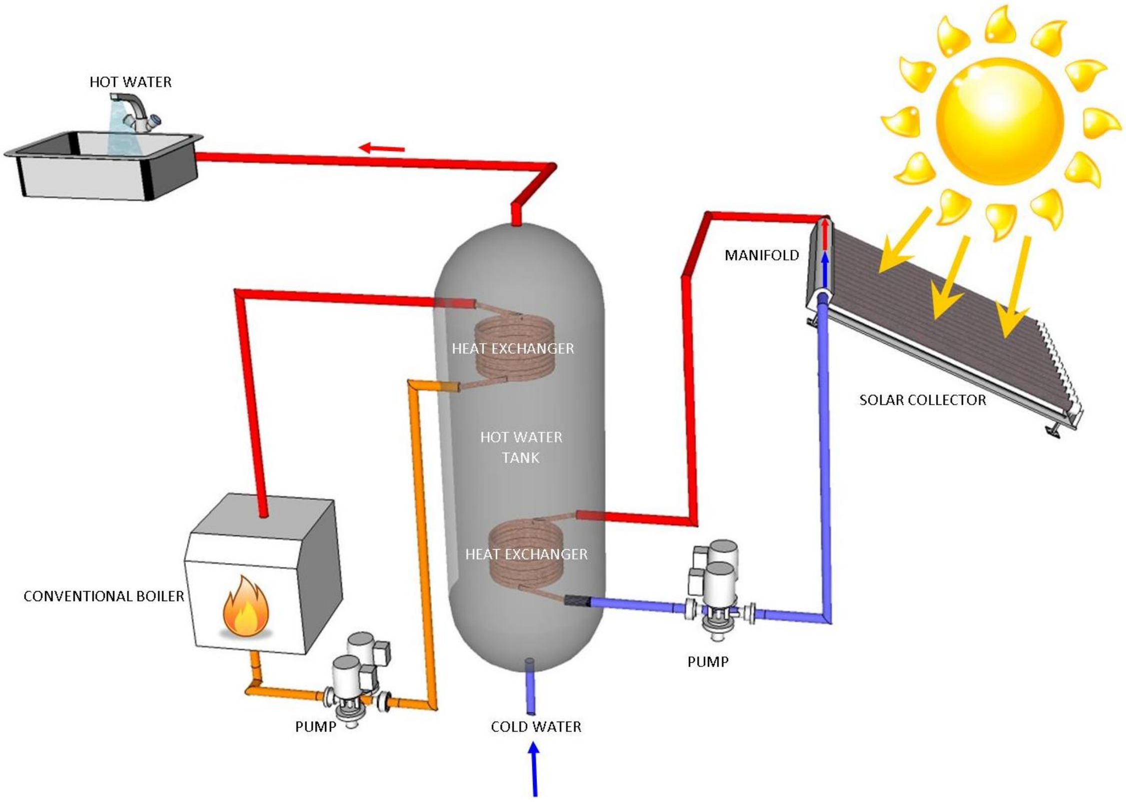


Figure 7 - Schematic Diagram of Solar Thermal Energy Transfer and System Operation

The heat pipes are connected to a manifold containing circulating water (see Figure 7 above). The liquid in the heat pipe is evaporated by the suns energy and rises to a heat exchanger within the manifold where it condenses and gives up its latent heat energy to the water. This heated water is then pumped to a coil in the hot water cylinder sized to meet the demand of the installation. Evacuated tube systems deliver higher temperature water than flat plate types, with little decrease in efficiency, making them more effective with thermal storage solutions.

As a general rule, the evacuated tube collectors can deliver around 700kWhr/m^2/yr when in optimum orientation (inclined at 30^o to the horizontal facing a southerly direction). This compares to around 580kWhr/m^2/yr for the flat plate collectors under similar conditions.

Solar thermal installations can be designed to fit the available roof space and/or building façade. Each evacuated tube is approximately 2m in length with an external diameter of 58mm. They weigh around 2kg each and can be spaced from 10mm to 500mm apart in an array. A typical panel array, 2.1m x 1.0m, will provide around 1.33m^2 of absorber area and weigh approximately 45kg. Bespoke mounting frames can be fashioned to provide the ideal inclination of 30° to the horizontal facing a southerly direction. Access to the roof mounted solar collectors will be necessary for occasional cleaning of the active tubes.

Solar thermal technology on a large scale is often difficult to support where there is a limited domestic hot water demand. As the office will have minimal hot water demand, a solar thermal installation will not be considered further on this project.

3.3.3 Ground Source Heating and Cooling

The design, installation and operation of Ground Source Heat Pumps (GSHPs) is well established. These geothermal systems tap into the earth's considerable energy store to provide both heating and cooling to buildings. They take advantage of the fact that at a depth of a few metres, the temperature of the ground remains at a constant 12ºC throughout the year.

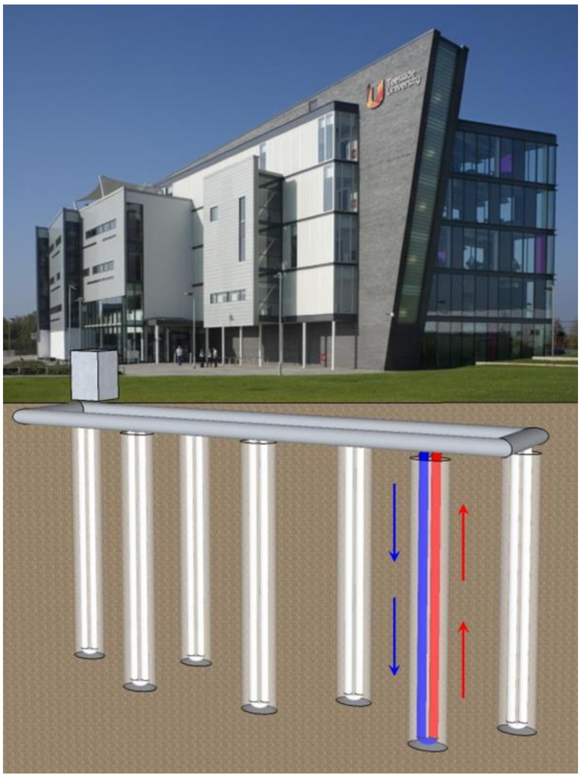


Figure 8 - Ground Source Heat Pump Schematic

In heating mode, GSHPs absorb energy from the earth and transfer it into the building using highly efficient heat pumps. The effectiveness of heat pumps is measured by the ratio of the heating capacity to the power input, referred to as the Coefficient of Performance (COP). Typically, manufacturers state that for every 1 unit of electrical energy used to drive the pump, around 4 to 5 units of thermal energy can be produced. When operating in cooling mode, during the summer months, the system reverses its cycle and heat is extracted from the building and dissipated into the earth.

The ground loops can be installed either vertically in boreholes (typically 50m – 100m deep), or horizontally in trenches at a depth of 1.5m – 2.0m. Either method is dependent upon local geology conditions and space available. The system also benefits from the fact that most of the components are hidden below ground or in plant room enclosures.

Costs for drilling vary according to the location and ground conditions. A preliminary site investigation, by means of a desktop study, can usually determine the viability of a ground source heating and cooling system. Fine tuning of the design may be required once actual site ground conditions are established.

It should be noted that GSHPs generally deliver water at a temperature approaching 50ºC (which would be ideal for under floor heating). Additional heat sources would be needed to satisfy the requirements for domestic hot water to raise the temperature well above 60ºC.

The design intention is not to employ under floor heating on the scheme. This, coupled with the fact that there is no available space on site for sinking of boreholes and/or trenching for pipe work, means that a GSHP system cannot be considered further on this project.

3.3.4 Air Source Heat Pumps

Electric driven air source heat pumps extract thermal energy from the surrounding air and transfer it to the working fluid (air or water). Like GSHPs they can provide both heating and cooling to buildings and have an associated Coefficient of Performance (COP). This is typically around 3 to 4 for heat pumps driven by compressors powered by electric motors and incorporating Variable Refrigerant Flow (VRF) technology. With VRF technology, there is an opportunity to heat and cool separate spaces and recover the heat between them.

Care should be taken when mounting the units to avoid any acoustic problems associated with operating the fans. The outdoor units normally operate with sound levels typically in the range 55 - 60dB(A).

Figure 10 - Air Source Heat Pump

A downside of electric driven air source heat pumps is that they require a defrost cycle in extreme conditions which impacts on the system efficiency. Heating capacity also falls off as the ambient temperature drops below 5ºC but still maintains 80% capacity at -5ºC.

Units are either roof or ground mounted and coupled to a thermal buffer store with additional back-up electric immersion heaters in the cylinder, to make up any shortfall. Alternative heat pump solutions can be supplied for internal installation within a plant room.

Air source heat pump systems are scaleable to meet the specific demands of the development, but for the purposes of this comparative study, assume that office heating and cooling demand is being targeted, although for BREEAM, only heating can be taken into consideration.

An air source heat pump system features as part of the base build solution for this project, so no further savings will be taken as part of this report.

3.3.5 Wind Turbines

Wind generation equipment operates on the basis of wind turning a propeller, which is used to drive an alternator to generate electricity. Small scale wind turbines are typically in the range of 1kW – 15kW, with rotor diameters of 2.5m – 9.0m respectively. These systems can be stand-alone or, in some cases, building mounted.

Figure 11 - CPW Designed Helical Roof Mounted

The efficiency and effectiveness of wind turbines depends on many factors, not least the average wind speed and wind pattern of the proposed site. Exposed sites, free from obstacles such as buildings and greenery, are more viable than sheltered sites. Column mounted (stand-alone) wind turbines installed at a suitable height above the building line are more effective than wind turbines located at roof level. There are often some planning difficulties associated with the use of wind turbines. Background noise and a phenomenon known as shadow flicker are also potential issues.

Typical noise levels measured 20m from the base of an operating 5kW wind turbine (both upstream and downstream) in the range 4m/s to 8m/s are 48 – 50dB(A). At 100m, the predicted noise level would be below 35dB(A).

The use of wind turbines is often seen as an obvious statement of a development's dedication to the use of sustainable technologies.

The proposed development does not lend itself to small-scale stand-alone or roof mounted wind turbines due to the high density of multi-storey buildings, obstacles and greenery causing problems with downstream turbulence. At this stage, assume that a large stand-alone column mounted wind turbine will meet with major objections from local residents. For the reasons outlined above, the installation of wind turbines on the site is not practical and will not be considered further.

3.3.6 Combined Heat and Power (CHP)

A CHP installation is effectively an on-site mini power plant providing both electrical power and thermal heat. CHP is strictly an energy efficiency measure rather than a renewable energy technology. A CHP system operates by burning a primary fuel (normally natural gas) by use of either a reciprocating engine or turbine, which in turn drive an alternator to generate electrical power. The heat emitted by the engine and exhaust gases is recovered and used to heat the building or to provide hot water.

Figure 12 - Gas Fired CHP System

The viability of CHP is dependent upon the building base load requirements for both heat and power. 24 hour buildings with high heat demands and constant power demands lend themselves to CHP.

The noise levels associated with a CHP installation should not be overlooked. Typically, acoustic enclosures and upgraded low noise attenuators are employed to ensure noise levels don't exceed 65dBA when 1m from the unit. On confined sites, the plant room structure can be enhanced and attenuators fitted to the mechanical ventilation to prevent any noise issues.

An initial evaluation indicates that the base heating load, associated with the domestic hot water requirements, does not support the installation of a CHP system. As such, CHP plant will not be considered further on this project.

3.3.7 Bio-fuel CHP

Consideration has been given to the possibility of utilising a bio-gas, bio-diesel or dual fuel CHP engine.

Figure 13 - Schnell Dual-Fuel Biomass CHP System

A dual fuel engine (normally based on field-proven diesel engine technology) can run on oil alone, or a mixture of gas and oil.

It should be noted that the engine cannot run on gas alone because it doesn't have a spark ignition system.

Schnell (Germany) supply a range of dual fuel 6 cylinder Scania turbo CHP engines that can be driven on diesel oil, vegetable oil or a mixture of biogas and oil.

ENER-G supply a series of 6 to 20-cylinder turbo charged reciprocating CHP engines for biogas applications. As an option, natural gas can be connected into the system, albeit via a separate unit, to provide back-up electrical and heat energy, if required. Dual fuel engine options (biogas and natural gas) are available, but this requires a special upgrade on the engine management system.

Fleetsolve Ltd supply a range of 8-cylinder turbo charged reciprocating CHP engines with power options from 18kWe to 2,500kWe. The engines run on a wide range of liquid biomass fuels including a version produced by Fleetsolve from waste vegetable oil and fish oils. This fuel is accredited by Ofgem as a renewable source and is supplied at £0.76 per litre.

The Fleetsolve CHP unit is housed in its own plant enclosure measuring approximately 4.5m long by 2.0m wide and 2.4m high. The engine is fuelled via a 2,500 heated fuel tank, held at 40ºC, providing 30 days run time between fill-ups from a road tanker. An exhaust particulate filter and a De-NOx catalytic converter are fitted in the exhaust system. Dry air coolers provide a means of dumping heat energy during periods of over production.

The engine is optimised at 1,500rpm with 100% modulation, and operates with a noise level of 45dBA at 10m. Hot water is supplied at 95ºC with a return temperature of 80ºC.

Figure 14 - Fleetsolve Liquid Biomass CHP System

An initial evaluation indicates that the base heating load, associated with the domestic hot water requirements, does not support the installation of a CHP system. As such, CHP plant will not be considered further on this project.

3.3.8 Bio-Renewable Energy Sources – Wood-fuel Boiler Plant

Bio-renewable energy sources are considered to be those which are grown, harvested and replaced by new stock. Modern wood-fuel boilers are highly efficient, clean and smokeless. Wood-fuel is almost carbon neutral as an energy source (the tree growing process effectively absorbs the CO_2 that is emitted during combustion).

Figure 15 - CPW Designed Biomass Boiler House, Conkers YHA

The viability of installing an automated feed wood-fuel boiler at the development has been considered to meet 100% of the total peak heating and hot water demand. Biomass boilers require bulk fuel storage on site to avoid constant deliveries and mechanical handling systems between storage silo and boiler plant are recommended.

These requirements create the need for a substantial amount of external plant space (typically $150m^2$). A large area would have to be sacrificed to accommodate the wood-fuel facilities. An underground fuel bunker 5m x 5m x 3m deep would be needed for a boiler of 500kW capacity. Furthermore, the logistics of fuel deliveries and ongoing maintenance costs could be a potential issue.

Ultimately, the lack of available space on site for the wood fuel storage facilities means that the installation of a biomass boiler system cannot be recommended in this case and will not be pursued further.

3.3.9 Fuel Cells and Fuel Cell Combined Heat and Power

Fuel cells convert the energy of a controlled chemical reaction, typically involving hydrogen and oxygen, into electricity, heat and water vapour. Direct electrochemical conversion is environmentally attractive because of the inherently low emissions and high electrical efficiency (c. 40% – 50%). Fuel cell stacks operate in the temperature range 65°C – 800°C, so thermal management systems are required. This provides co-generation opportunities in the form of Combined Heat and Power (CHP) solutions that can be implemented in buildings.

Fuel cell CHP systems generally have a heat to power ratio of approximately 1:1, with overall efficiencies in the region of 80% when fired on pure hydrogen.

Figure 16 - Fuel Cell Operational Schematic and Fuel Cell CHP Installation

Pure hydrogen fuel cells have zero CO_2 emissions but the hydrogen supply and distribution infrastructure is somewhat limited in the UK. As a result, commercially viable systems use alternative fuels in the form of natural gas, LPG and bio-fuels from which hydrogen is derived through a process called reforming. Extracting hydrogen in this manner, comes at the expense of system efficiency and an increase in emissions due to the presence of impurities in the fuel.

High temperature fuel cell systems typically use an internal reforming process where the source fuel is introduced directly to the anode plate. Lower temperature fuel cells rely upon an integrated fuel processor that converts the source fuel into a hydrogen rich reformate needed by the cell stack.

There are a number of commercially available fuel cell CHP systems, classified by the type of electrolyte they employ, and these include; Proton Exchange Membrane (PEM), Molten Carbonate, Alkaline, Phosphoric Acid and Solid Oxide. Systems range in capacity from those that produce a few kilowatts (PEM type) to those that are capable of generating several megawatts (phosphoric acid and molten carbonate based arrangements).

Logan Energy Limited supply a range of phosphoric acid and molten carbonate fuel cell CHP systems suitable for use in buildings. However, these systems are in the early stages of commercialisation and so projects have substantial technology risk. For this reason, fuel cell CHP systems have not been considered for use on this project.

4.0 Energy Storage

Storage of both electrical and thermal energy is becoming increasingly common, particularly on large scale developments.

The obvious advantage of storing energy is to solve the intermittency problem of renewables, the wind is not always blowing, and the sun is not always shining when there is demand for electricity. The converse is also true in that the demand can be low when the renewable sources are highly active. Typically, extra electricity produced is sold back to the power company in grid connected systems. However, energy storage lets the user decide when to buy and use power from the grid which means that they can purchase electricity at off-peak prices and use energy from their own storage during peak times (this is a method called peak shaving).

Energy storage also addresses the variation of supply and demand of heat. The most common example of this is the domestic hot water tank, which stores hot water so it is available at any time and does not require a boiler to start up when there is a sudden demand. Heat demand has a large seasonal variation from summer to winter; seasonal storage of heat underground is a growing method used to store excess heat in the summer for heating in winter.

4.1 Battery Storage

Battery Energy Storage Systems (BESS) can be used to balance the site energy requirements through mechanisms known as renewable firming, load shifting and peak shaving, thereby modulating the use of grid electricity and, in turn, reducing costs. There are a number of battery types available including Redox-Flow, Metal-air, Sodium-nickel Chloride, however the most common is Lithium ion (Li-ion) batteries.

Lithium ion (Li-ion) batteries are a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging. They are commonly used in consumer electronic products, where a high energy density is required and now are also commonly used in electric vehicles. Many companies are now developing larger-format cells for use in energy-storage applications. The deployment of which is expected to drive down cost and improve performance.

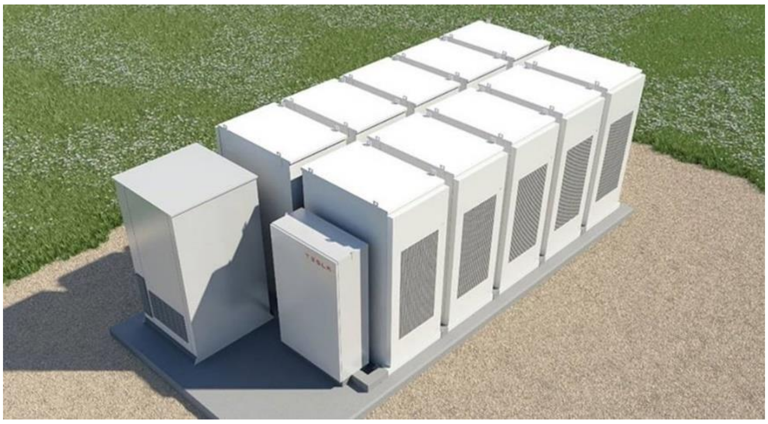


Figure 17 - Battery Energy Storage System (BESS)

The efficiency of lithium-ion battery system is high, about 90-95% and it has a high energy density in comparison to other storage technologies. They have been deployed in a wide range of energy-storage applications, ranging from batteries of a few kWh in residential systems with rooftop photovoltaic arrays, to multi MWh containerised batteries for the provision of grid ancillary services. However, their cost/performance characteristics make them unlikely to be further developed for large grid scale storage projects.

The energy demands on the Symmetry Park Bicester Phase 3, Unit F, are not expected to be large enough to make an electrical battery storage viable.

4.2 Thermal Storage

The best known thermal energy storage technology is the hot water tank which is common and fully commercialised. Water is stored in an insulated tank where it can be heated via a heat exchanger by a variety of sources (usually a boiler). They are already widely used at a building scale in combination with electrical or solar thermal water heating systems. Hot water storage can also be used in conjunction with district heating (DH) systems when heat is provided from CHP, biomass boilers and/or largescale solar water heating. High temperatures can be stored in tanks (90°C) which means that the water can be used directly for space heating. Water is the most common storage medium because of its abundancy and high heat capacity, but gravel, concrete and ceramics are also sometimes used. When solids such as gravel or concrete are used for heat storage, a liquid or gas will be ran through them to add or extract thermal energy.

Using hot water tank storage is particularly useful when use in conjunction with CHP and biomass burners. Log burning biomass systems need to be loaded by hand and so by using a tank as a thermal buffer means that the burner may only need to be fired once a day or less. A thermal store will also reduce the time lag between lighting the burner and the demand for hot water, as the hot water was stored when the boiler was lit. Also, wood fuelled burners are generally more efficient when ran at full output rather than kept ticking over, a thermal store mitigates the need to keep a burner on low throughout the day.

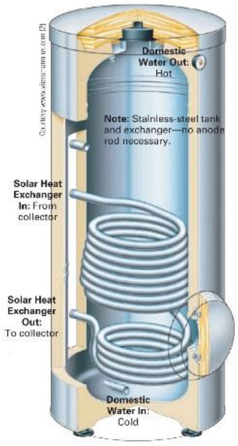


Figure 18 - Tank Cross-section

Tanks are used in a wide range of demands from the domestic hot water tank, to large tanks used to heat communities which are common in Scandinavia. Due to economies of scale, large storage tanks are cheaper per unit volume of storage and the heat losses are lower. Large-scale buffer stores can serve a number of functions but are particularly suited to developments with diverse building stock served via a central CHP/boiler house and district heating system.

The Symmetry Park Bicester Phase 3, Unit F, is not expected to have a high enough DHW demand to make a thermal store viable.

5.0 Summary of Capital Cost and Energy/CO_2 Saving Data

The table below summarises the approximate capital cost and estimated energy/CO_2 saving associated with each technology when applied to the Symmetry Park Bicester Phase 3, Unit F. The table also shows the percentage of the building's total annual energy demand that could be met by each LZC technology and the potential CO_2 saving per pound of capital investment.

Technology and Description	Capital Cost (£)	Revenue Saving (£/yr)	Simple Payback (Years)	Energy Saving (kWhr/yr)	Energy met by LZC Technology (%)	CO_2 Saving ($kgCO_2$/yr)	CO_2 Saving (%)	CO_2 Saving per £ Investment (kg)	Recommended for Further Consideration
Solar Photovoltaic *Roof mounted PV panels*	208,800	54,097	4	225,406	120.6	24,821	92,8	0.12	Yes

Table 4 - Summary of Capital Cost and Energy/CO_2 Saving Data

6.0 Recommendations

A high-level report has been compiled to appraise the renewable and low carbon technology energy options currently available for the proposed new Symmetry Park Bicester Phase 3, Unit F.

Solar photovoltaic (PV) mono-crystalline roof panels can be incorporated into the building design with little maintenance or ongoing costs. PV installations are scaleable in terms of active area; size being restricted only by available roof space. On the current scheme, an installation of PV panels could reduce the building's CO_2 emissions by approximately 92.8%.

To conclude, having taken into account the impact of each solution; its cost, complexity, benefits and drawbacks, the following LZC technologies are recommended for inclusion on the Symmetry Park Bicester Phase 3, Unit F, in order to meet the requirements of BREEAM in reducing CO_2 emissions (CO_2 saving data derived from IES model):

- **Roof mounted Solar Photovoltaic panels (c. 92.8% CO_2 reduction)**
- **Air Source Heat Pump installation for office heating – part of the base build solution**

Total: 92.8% CO_2 reduction.

7.0 Appendix A – PV Life Cycle Costs

Solar Photovoltaic Life Cycle Costings

	2024	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	
Initial Capital and Additional Costs	£208,800	£0	£0	£0	£0	£0	£0	£0	£0	£0	£9,000	
Maintenance/Servicing/Fuel	£500	£525	£551	£579	£608	£638	£670	£704	£739	£776	£814	
Total	**£209,300**	**£525**	**£551**	**£579**	**£608**	**£638**	**£670**	**£704**	**£739**	**£776**	**£9,814**	
		Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	
		£0	£0	£0	£0	£0	£0	£0	£0	£0	£9,000	
		£855	£898	£943	£990	£1,039	£1,091	£1,146	£1,203	£1,263	£1,327	
		£855	**£898**	**£943**	**£990**	**£1,039**	**£1,091**	**£1,146**	**£1,203**	**£1,263**	**£10,327**	
		Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30	Total
		£0	£0	£0	£0	£208,800	£0	£0	£0	£0	£0	
		£1,393	£1,463	£1,536	£1,613	£1,693	£1,778	£1,867	£1,960	£2,058	£2,161	
		£1,393	**£1,463**	**£1,536**	**£1,613**	**£210,493**	**£1,778**	**£1,867**	**£1,960**	**£2,058**	**£2,161**	**£470,980**

🟩	**Inverter Replacement**
🟪	**Panel Replacement**

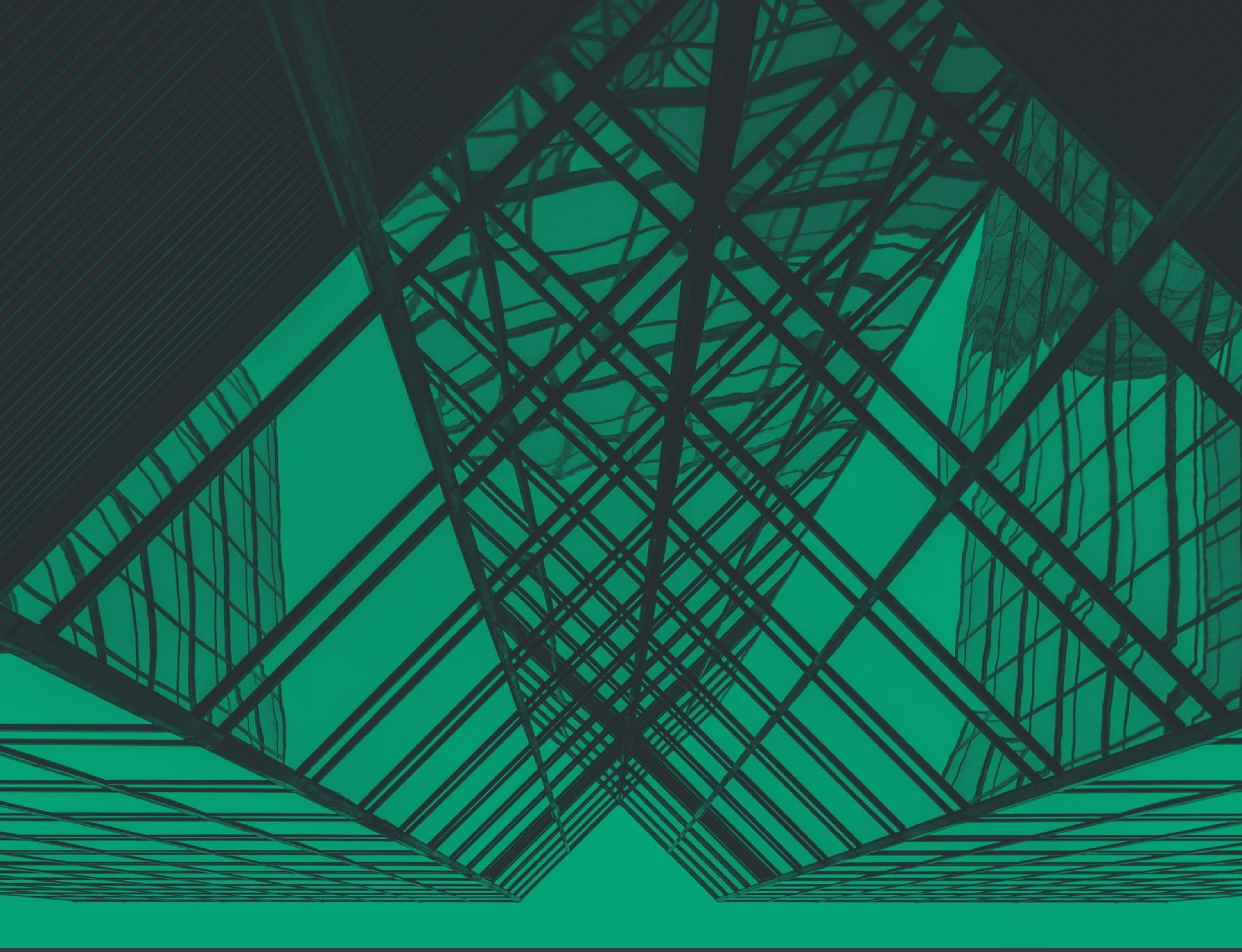
Assumptions:

1 - Inflation rate of 4% has been assumed for the life cycle cost. Allows no fluctuations

2 - Exclusions include V.A.T, Fees and Design Contingency

3 - Fuel prices have been used as first quarter of 2024

4 - CIBSE life cycles and manufacturers data has been used for replacement of plant



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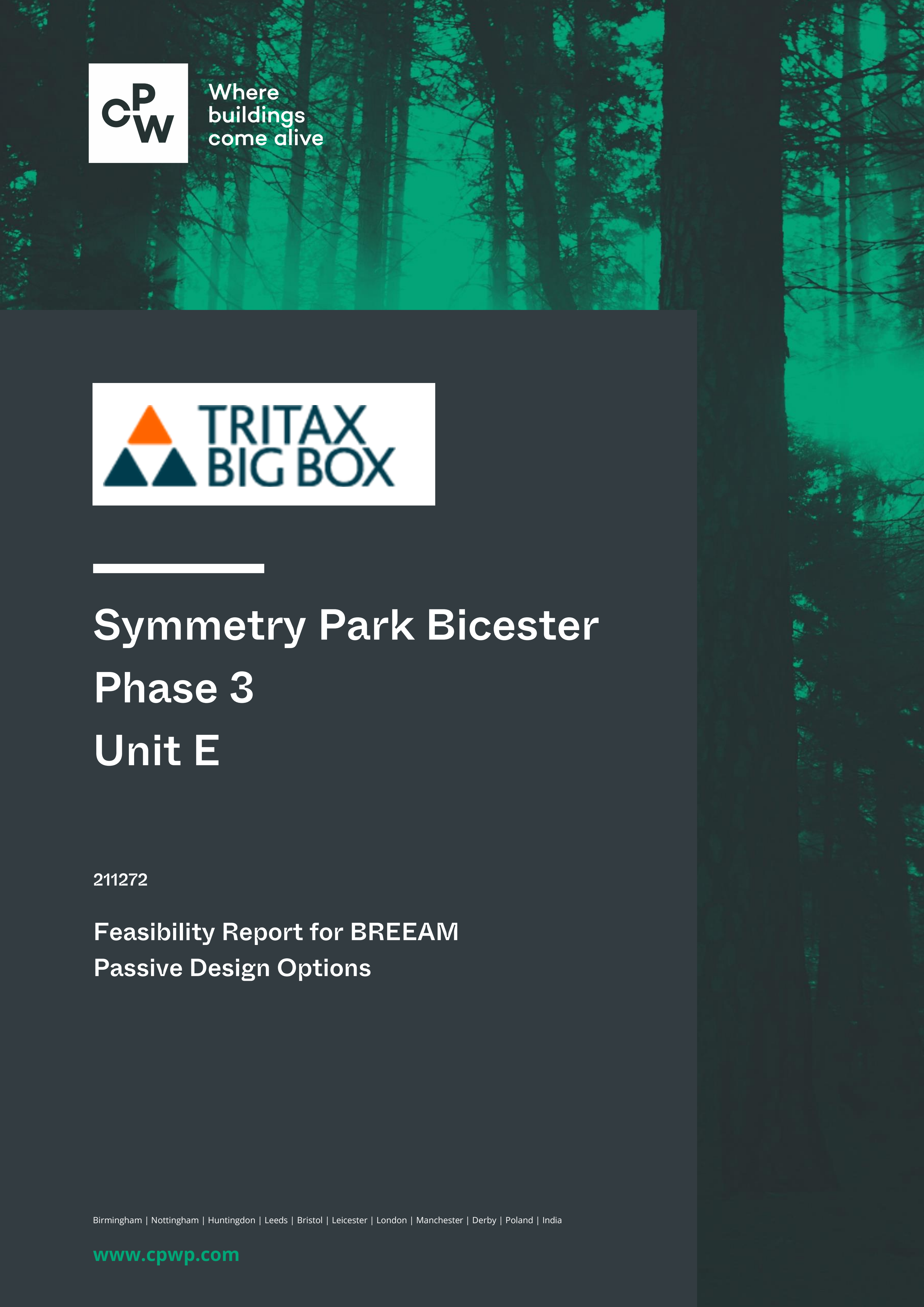
APPENDIX C – PASSIVE DESIGN ASSESSMENT REPORT



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211272

Feasibility Report for BREEAM
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Document Revision History			**Ref**	**211272 - Symmetry Park Bicester Phase 3 , Unit E**	
Rev	**Author**	**Verification By**	**Date**	**Suitability**	**Comments / Status**
-	S. Tu	Dr S.J. Ball	25/09/2024		First Issue
A	S. Tu	Dr S.J. Ball	17/10/2024		Final Issue

Prepared on behalf of Couch Perry and Wilkes by

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1.0 Introduction

Couch Perry Wilkes has been appointed to summarise the passive design features of the Symmetry Park Bicester Phase 3, Unit E. The planned development of approximately 15,807.6m^2 Gross Internal Area (GIA) comprises distribution and associated office space. The brief is to target a BREEAM 'Very Good' rating under the BREEAM New Construction V6 Assessment criteria.

With the current emphasis placed on energy conservation, the client is keen to enhance the development's sustainable credentials, both from an estates and public perspective, by delivering an environmentally responsible building. To this end, the proposed design will incorporate passive design and best-practice measures, so as to exceed the requirements of the current (2021 Edition) Part L Building Regulations.

This high-level report has been compiled, in accordance with the requirements of BREEAM New Construction V6 credit Ene 04 criteria 1-3 "Passive Design Analysis", to summarise how passive measures have been incorporated into the building's design.

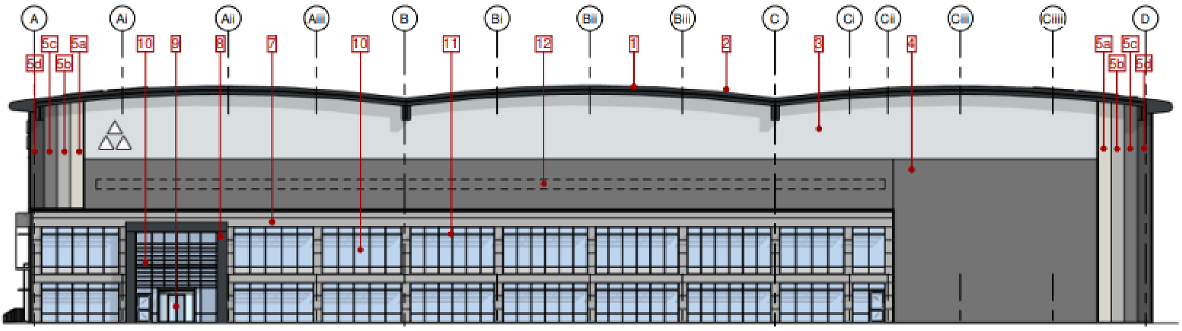

Figure 1 – Symmetry Park Bicester Phase 3, Unit E – *South-West Elevation*

2.0 Energy Benchmarking

2.1 Estimated Energy Demands and CO_2 Emissions

In order to benchmark the proposed new development, estimated energy demands and CO_2 emissions data have been calculated. These estimated energy consumptions are indicative only at this stage. They will, however, be used as a guideline to assess the percentage of the building's total energy consumption and CO_2 emissions that could be reduced or offset by applying passive design solutions.

The estimated regulated energy consumption for the notional development has been derived from approved Dynamic Simulation Model (DSM) software which uses government and industry agreed National Calculation Method (NCM) room templates containing standard operating conditions.

The total predicted regulated notional building energy consumption is: **257,114kWhr per year**
The total predicted regulated notional building CO_2 emissions are: **35,082kgCO_2 per year**

Note 1. CO_2 emission factors of 0.210 for Gas and an annual average of 0.136 for electricity have been used to calculate the above and are taken from Building Regulations Approved Documents.