Hywel Dda

RIBA STAGE 0 - CARBON STRATEGY

Hywel Dda University Health Board

70104118
AUGUST 2023

CONFIDENTIAL

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TYPE OF DOCUMENT (VERSION) CONFIDENTIAL

PROJECT NO. 70104118

OUR REF. NO. 70104118

DATE: AUGUST 2023

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QUALITY CONTROL

Issue/revision	First issue	Revision 2	Revision 3	Revision 4
Remarks	First Issue	Second Issue		
Date	April 2023	August 2023		
Prepared by	Shamma Tasneem	Shamma Tasneem		
Signature				
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Authorised by	Andrew Wilkinson	Andrew Wilkinson		
Signature				
Project number	70104118			
Report number	01			
File reference	\\uk.wspgroup.com\Central Data\Projects\70104xxx\70104118 - Hywel Dda Land Services\03 WIP\01 Sustainability\02 Documents\01 Carbon Strategy			

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1 INTRODUCTION

WSP have been appointed by Hywel Dda land services to undertake an energy policy technology appraisal as part of the RIBA Stage 0 work for the design of new build Hospital 'Hywel Dda University Health Board (HDUHB)' to provide healthcare services to a total population of 384,000 throughout Carmarthenshire, Ceredigion, and Pembrokeshire.

The development consists of acute, Primary, Community, Mental Health and Learning Disabilities services via General and Community Hospitals (including 4 main acute hospitals site) as well as Health Centres, GPs, Dentists, Pharmacists and Optometrists and other sites.

The aim of this report is to discuss the overall energy strategy and various low and zero carbon options that could be implemented in this building to help the building to operate efficiently and reduce the carbon emissions. Furthermore, this study looked into the potential future technologies that could be feasible for the proposed development to achieve optimized embodied and operational carbon emission.

Finally, a set of recommendations for the next Stage are proposed.

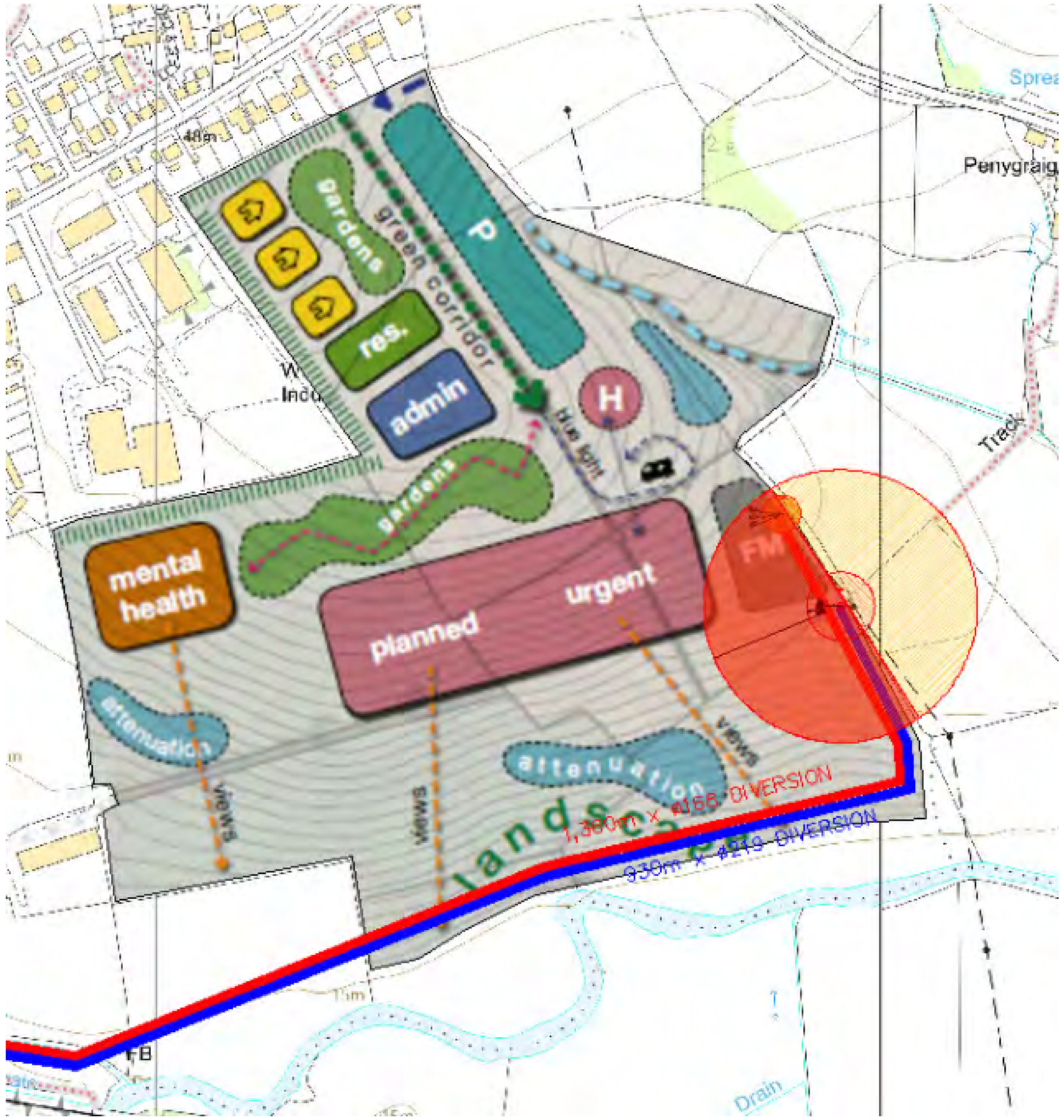


Figure 1 – Arrangement of the Hospital in One of the Proposed Sites

2 THE NHS TARGETS

2.1 THE CARBON COMMITMENT

The UK has set a legally binding target to meet net zero carbon by no later than 2050. This commitment has been taken as part of the global effort to reduce the carbon emissions and to limit the global temperature rises to 2°C (preferably 1.5°C). The NHS is one of the highest contributors to the National carbon emissions with 5.4% of the total UK carbon emissions. For this reason, decarbonising the NHS is of paramount importance to sustain the UK effort in meeting this ambitious target. Echoing the UK Government, the NHS has pledged to better the 2050 target by 10 years, with a target of net zero carbon by 2040. Given that 41% of the NHS carbon footprint comes from building energy, decarbonisation of the NHS estate portfolio is a crucial step towards meeting this target.

2.2 THE NHS ENAGLAND NET ZERO BUILDING STANDARD (2023)

As the climate change threatens the foundations of good health, with direct or indirect consequence for humans, the NHS became pioneer in committing to net zero emissions, launching its new National Programme for a greener NHS.

The purpose of the standard is to respond to the NHS commitment to achieve net-zero carbon, as set out in ‘Delivering a Net-Zero National Health Service’. The ‘Delivering a Net-Zero National Health Service’ document sets out the ambition to achieve a net zero carbon NHS carbon footprint by 2040 (with an 80% reduction by 2028-2032), and a net zero NHS carbon footprint ‘plus’ by 2045 (with an 80% reduction by 2036 – 2039).

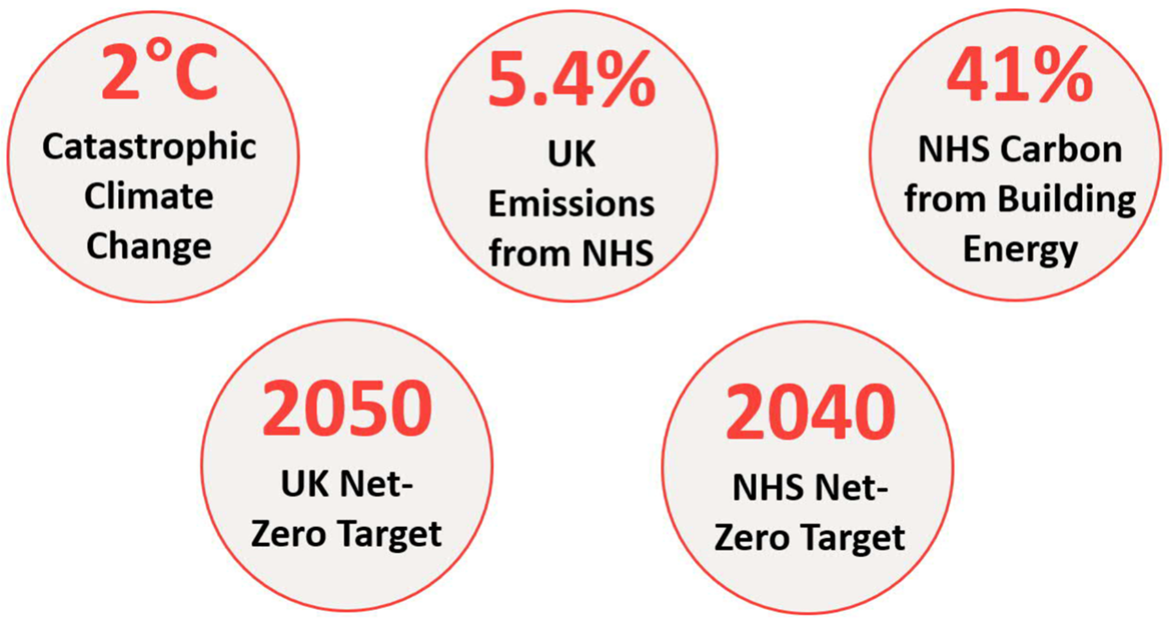


Figure 2 – The Carbon Emission Scenario and NHS Target

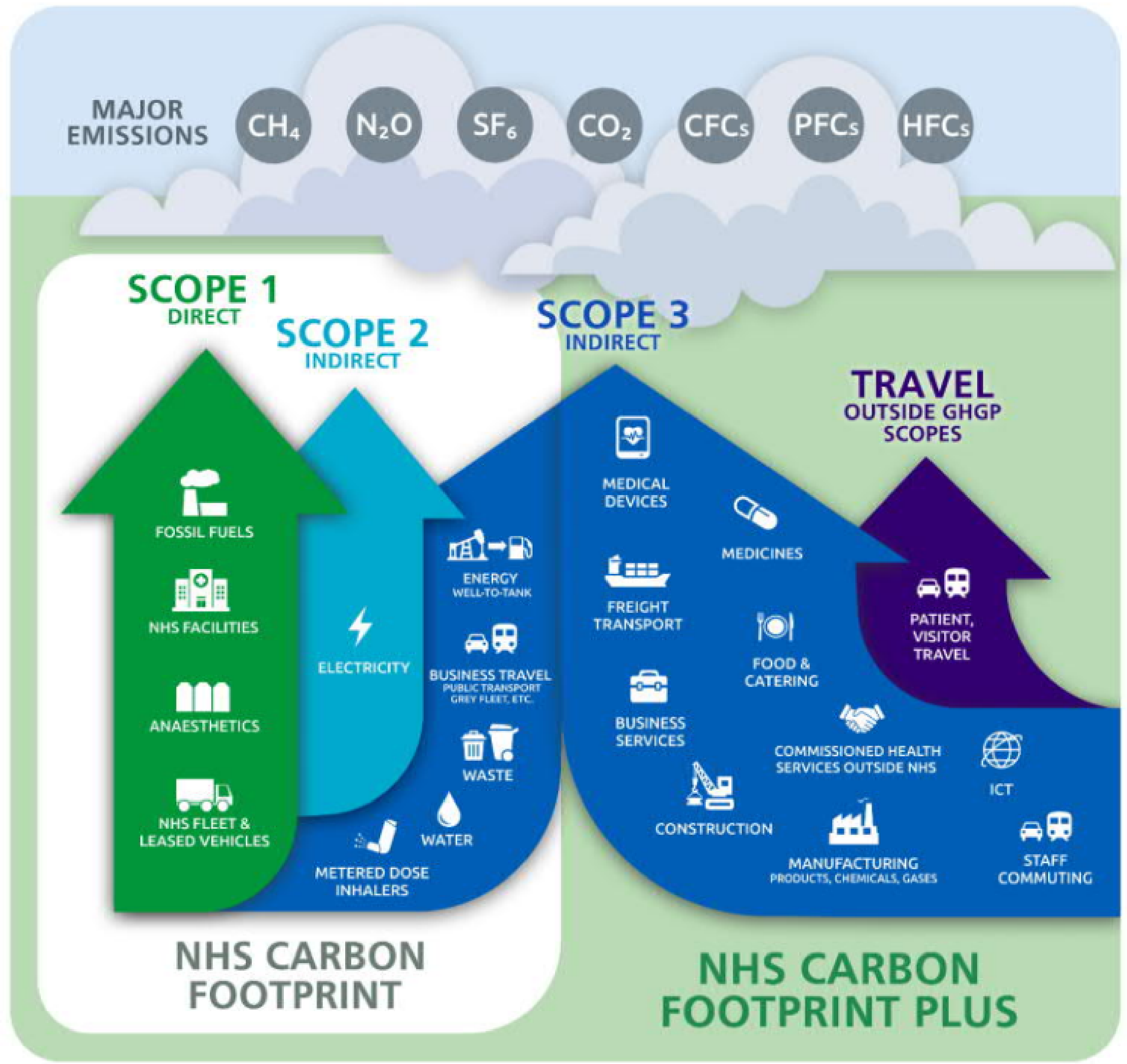


Figure 3 – Green House Gas Protocol (GHGP) Scopes in the Context of the NHS

The NHS Net Zero Building Standard (“the Standard”) creates a clear set of performance criteria relating to various elements of a net zero carbon building – both in construction and in operation The Standard lays the foundation for major construction and refurbishment projects in the NHS that are expected over the next decade, and it will be periodically updated to ensure it remains relevant as technology and modern methods of construction evolve. The Standard sets out a vision for achieving whole life net zero carbon buildings whilst improving patient care, with a clear roadmap for reducing operational building energy demands, embodied carbon in construction and the whole life carbon of building elements used within them.

Application:

There are different healthcare typologies that the Standard is applicable to in different forms, as it is recognised that there are a multitude of healthcare developments that take place within the NHS. The five core typologies and this Standard apply to all investments as below.

- New acute healthcare facilities;
- Acute healthcare facility extension;

- New mental health facilities;
- New large community or primary care facilities; and
- Major refurbishment of facilities.

<u>The Purpose of the standard is to:</u>

- Create a clear set of performance criteria relating to various elements of a net zero carbon building;
- Lay the foundation for all major construction and refurbishment projects in the NHS, including the New Hospital Programme (NHP) and wider Healthcare Infrastructure Plan (HIP); and
- Be periodically revisited and updated to ensure it remains current and relevant within the progressive landscape of net zero.

<u>To achieve this, the NHS NZC Building Standard includes:</u>

- Targets for operational energy and capital carbon;
- A requirement to measure whole life carbon;
- Minimum performance targets for elements such as fabric u-values and HVAC efficiencies;
- Guidance for how these targets can be achieved;
- Standardised formats for capturing data; and
- Guidance on activities and processes to be undertaken across the project lifecycle.

2.3 THE NHS WALES DECARBONIZATION STRATEGIC DELIVERY PLAN (2021-2030)

The Welsh Government declared a Climate Emergency in 2019 supported by Members of the Senedd. This Strategic Delivery Plan responds to this declaration and is aligned to Welsh Ministers ambition for the public sector to be net zero by 2030 with a focus on the NHS Wales related carbon emissions.

The NHS Wales decarbonisation strategic delivery plan has been issued in March 2021 and highlights the approach and strategy to be adopted by NHS Wales regards the usage, refurbishment and minimum requirements for new developments. This document capitalises on the previous released Plans issued by the Welsh Government in an effort to create a more sustainable, fair and innovative County.

The required initiatives aimed to reduce the related carbon emissions for all the New Builds and Major Refurbishments for NHS Wales can be found below:

- Develop and build low carbon buildings to net zero standard – engage and collaborate with NHS partners across the UK on the emerging net zero building standard for hospitals and adopt a net zero building accreditation approach which will be defined in 2022;
- All project teams to have an independent client-side sustainability representative to provide due diligence support for the optimal low carbon design across all development stages – and be responsible for ensuring the Net Zero Framework process is followed;
- Integrate Modern Methods of Construction (MMC) into the design and construction of new buildings – this will consider modular design, offsite fabrication, and just-in-time delivery to minimise construction-related carbon emissions;
- Every building will have undergone an energy-efficient upgrade – low carbon heating will be utilised and renewable energy will be generated on site;
- Aim for all natural-gas combined heat and power plant to be decommissioned;
- Carbon sequestration land will have been developed and included within carbon accounting;
- Install electric vehicle charging points in new developments beyond minimum requirements, and future-proof new car parks by installing infrastructure to enable straightforward installation of future charging points;
- Prioritise low carbon heating solutions as a key design principle. No fossil fuel combustion systems are to be installed as the primary heat source for new developments; and
- Incorporate the principles of sustainable transportation into the design of new sites (in addition to electric vehicle infrastructure) in line with the Welsh Government's Active Travel Action Plan for Wales.

With the strategic initiatives, NHS Wales aims to reduce carbon emissions by 34% equivalent to 383,000 tCO_2e as a minimum contribution to a net zero Welsh Public Sector by 2030.

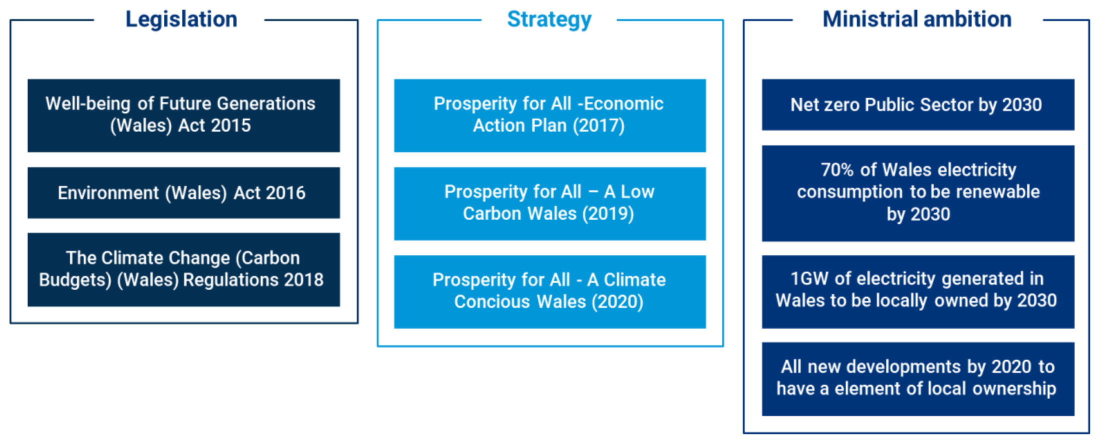


Figure 4 – Legislative Background. Courtesy of "*The NHS Wales Decarbonisation Strategic Delivery Plan*"

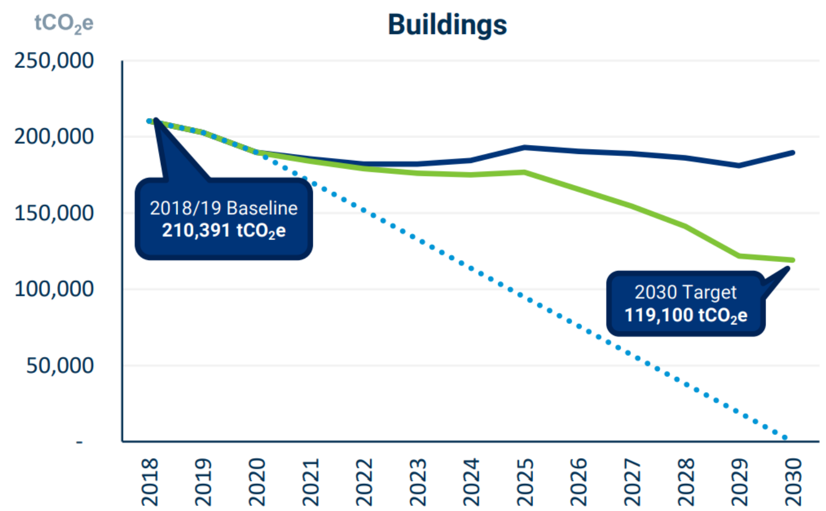


Figure 5 – Building Energy Target for 2030. Courtesy of "*The NHS Wales Decarbonisation Strategic Delivery Plan*"

3 WHOLE LIFE CARBON

3.1 BACKGROUND

Climate change is one of the most important environmental challenges of our time. Global warming is becoming an increasing issue resulting from anthropogenic (man-made) greenhouse gas emissions into the atmosphere, with carbon emissions being the most relevant and discussed. If temperatures continue to increase as effect of these emissions, this may have severe adverse environmental, economic, and social implications at a global level. International treaties and initiatives such as the Paris Agreement, adopted in 2015, aim to limit temperature rise to 1.5°C by limiting carbon emissions which are also associated with natural resource depletion and pollution. To achieve this the UK and NHS have committed to having zero net emissions of greenhouse gases by 2040.

The built environment produces significant amounts of carbon emissions that can be attributed to both the creation and operation of constructed assets (embodied emissions). Operational emissions are attributable to the everyday running of a building whereas embodied emissions result from the production, procurement and installation of the building's materials and components (construction). Embodied emissions also include the lifetime emissions from maintenance repair, replacement, demolition, and disposal.

Assessing operational and embedded emissions over the course of the building's lifetime is important to determine the overall built project's total carbon impact. The consideration of both the operational and embodied emissions over the projects expected lifecycle constitutes the whole life approach.

The use of whole life assessment to inform the building design can allows for the identification of the most effective opportunities to reduce emissions over the lifetime of the building, including avoiding unintended emissions. This integrated approach is necessary to achieve a more sustainable, lower carbon future.

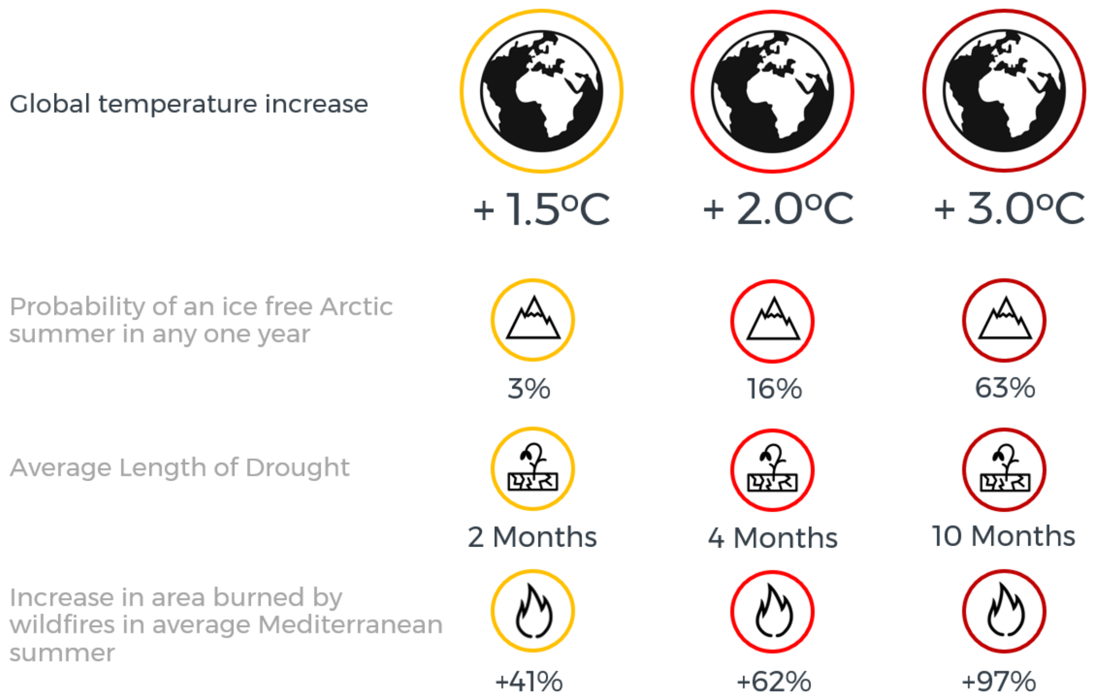


Figure 6 – Critical Global Temperature Increase and Likely Impact on the World

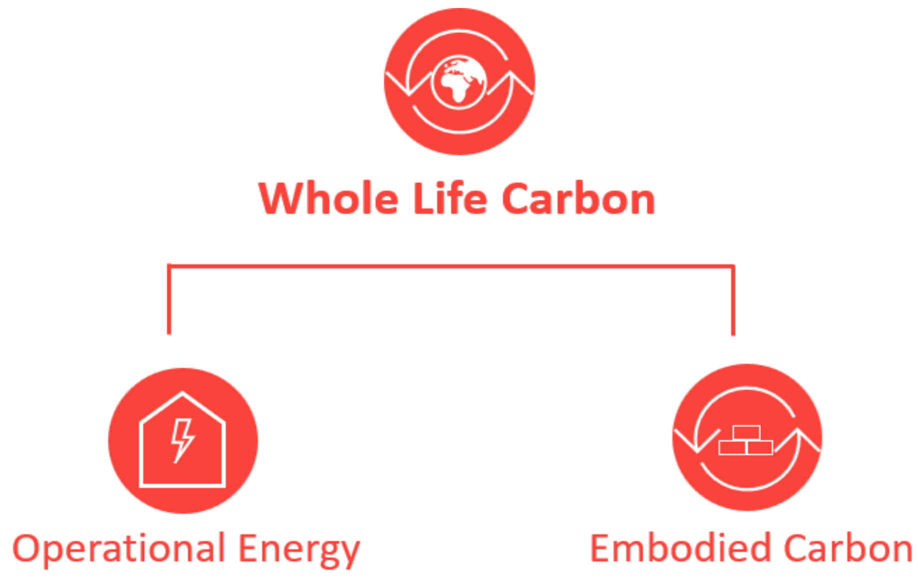


Figure 7 – Whole Life Carbon in the Built Environment

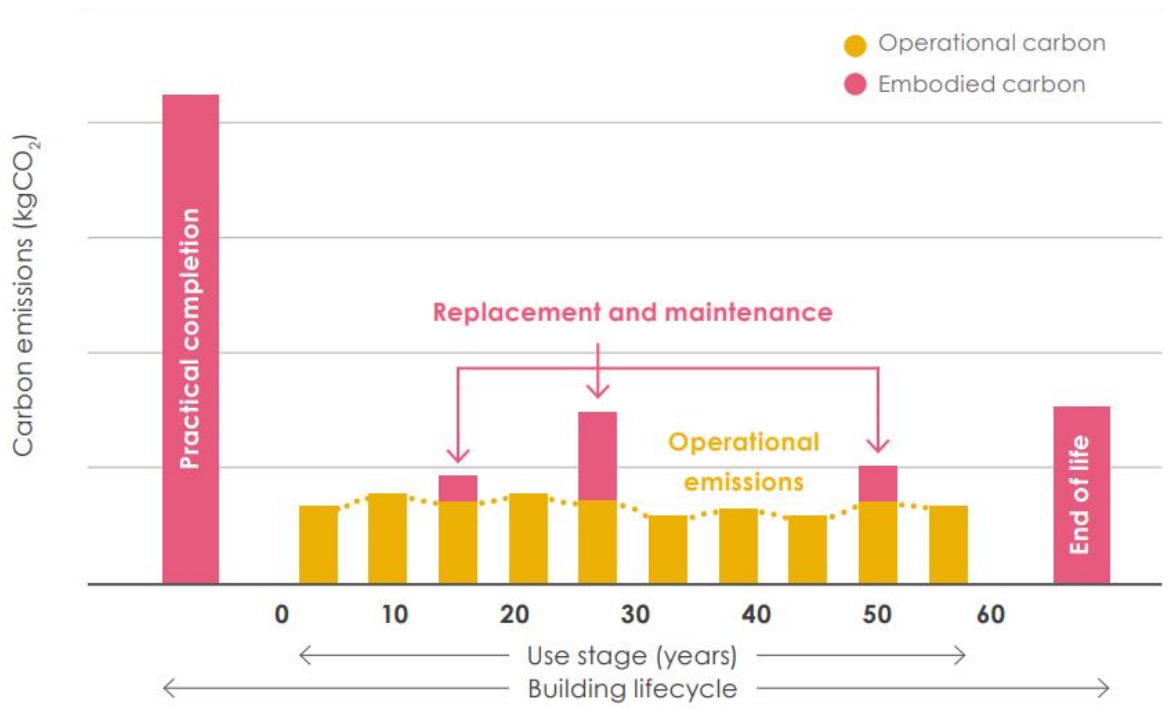


Figure 8 – Emission Breakdown of a Building's Life Cycle (Source: LETI)

4 ENERGY STRATEGY APPROACH

4.1 THE THREE TIER APPROACH

The UK Government's ambition to move towards a low carbon economy has seen the implementation of a number of national policies for new and existing developments. These policies have been subsequently passed down through regional and local policies and often form part of the minimum requirement for any major work.

As a result of the current climate emergency and to the push toward a more sustainable design approach, WSP has decided to propose the adoption of the energy hierarchy to the design of new and existing buildings. This effort is commonly shared across WSP, and it designed to be an effective design framework aimed to design better performing buildings. This hierarchy is developed to offer a great flexibility to the design team but at the same time, it offers a structured and efficient with the main aim to drive down the primary energy demand for new and existing building so to support the national efforts to reduce the carbon emissions of the built environment.

A number of studies have shown that planning for renewable and low carbon energy is most effective at the design stage. It is therefore important that such technologies are considered at the earliest opportunity during the design and, where relevant, as part of the planning application process.

The energy strategy uses the methodology set up in the current Building Regulations Part L as assessment approach so to provide a robust and consistent framework throughout the entire design stage. The energy strategy approach is based on the below:

Be Lean Metrics such has envelope thermal performances, window-to-wall ration, window's position and external microclimate should inform the proposed design. This stage requires a close collaboration with the architects so to optimise the design (i.e., maximise the gains during winter but also to minimise the external gains during summer so to reduce the unwanted gains and alleviate the potential for overheating, optimise building orientation, natural ventilation and lighting, thermal mass and solar shading);

Be Clean Exploit local energy resources and supply energy efficiently: this includes, where appropriate, connecting to a heat network.

Be Green Consider appropriate renewable energy technologies for the site: these includes all the low or zero-carbon technologies including renewables and heat pumps.

Be Seen This last step of the hierarchy has been recently introduced and it reflects the aim to reduce the gap in performance between the design stage and the real-life operational stage.

The final step of the process would be to quantify the remaining carbon emissions and quantify the required offset cost. This offset payment contribution then should be paid to companies or society focused on environmental improvement such as peat restoration and reforestation.

It is recommended that the new proposed Hywel Dda scheme will follow this approach, clearly detailing all the steps done on each of the proposed energy stages and validating the results obtained using the Part L assessment methodology using additional bespoke calculations following the TM54 methodology.

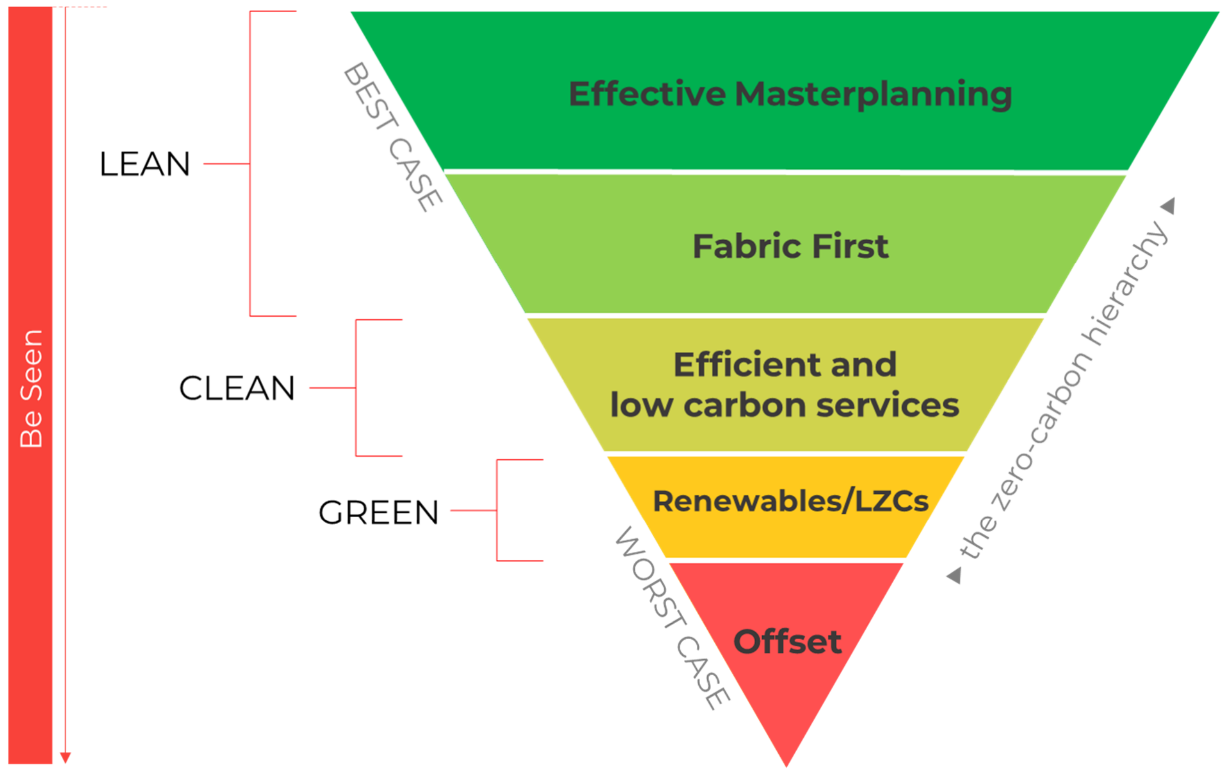


Figure 9 – Three Tier Approach

4.2 OPERATIONAL CARBON

Operational energy refers to the energy consumed by a building associated with heating, hot water, cooling, ventilation, and lighting systems (regulated energy), as well as small and specialist equipment (unregulated energy). Accordingly, operational carbon represents the quantity of carbon emissions linked to the building's operational energy usage.

A new building with net zero operational carbon does not burn fossil fuels, is 100% powered by renewable energy and achieves a level of energy performance in-use in line with recommended climate change targets.

Several studies have demonstrated that integrating low-carbon and renewable energy planning during the design phase is the most effective strategy. As a result, it is essential to consider such technologies as early as possible in the design process and, if relevant, as a component of the planning application process.

As presented in the previous section, WSP will use the energy hierarchy method and will apply the three-tier approach to the proposed design. The purpose of developing this hierarchy is to provide the design team with a high degree of flexibility, while still maintaining a structured and efficient approach that is focused on reducing the primary energy demand. This, in turn, supports the national goal of decreasing carbon emissions in the built environment.

4.2.1 BE LEAN

The first step of the energy hierarchy is to reduce the energy demand. The measures associated with the reduced energy demand include both passive and active measures.

As starting point, a baseline model should be established to provide an energy benchmark reflecting the standard energy demand of that building prototype. This baseline would then be used to test the various measures to estimate their impact in the overall energy demand.

An energy modelling exercise should be undertaken to establish the “baseline” model as a representative of the Notional building. Starting from this base model, several measures will be discussed and tested.

4.2.1.1 Passive measures

During the concept design stage, significant consideration is necessary to be given to how the shape and position of the new proposed building, context, thermal envelope performances and base services will respond to the environmental conditions so to reduce the energy consumption of the building.

Building geometry and massing optimisation

Passive design optimisation is the initial step to reduce the building energy design that should be incorporated in the early design stage. WSP will work together with the architects and parametric simulations would be done by ‘Grasshopper’ software to have the optimum energy efficient geometry and massing. The objective is to investigate an optimal solution of a building massing design meeting solar radiation criteria as early as in the conceptual design stage.

Thermal Envelope Performance

Building fabrics and thermal property are generally embedded within the external envelope and are considered “passive measures” because once they are included, they are assumed to stay essentially unchanged until major alterations are done. They are considered a robust and cost saving option and do not degrade with the time offering a life-long energy saving opportunity.

To minimise energy consumption for heating and reduce the risk of overheating in summer, it is advisable to optimise the thermal performance of the proposed building, which would involve minimising heat loss during the winter months and limiting heat gains during the summer months.

The building fabric should be designed to exceed the limiting fabric requirements of the Building Regulation. We will consider the most stringent regulation available, being “Part L2: for use in Wales” and we will aim to improve our performances against those minimum targets. Table below summarises the fabric assumption suggested for the proposed building:

Table 1 – Hywel Dda proposed building fabrics performances.

Fabric Assumption	Part L2 Limiting Fabric Parameters	Proposed Fabric Parameters	Percentage of Improvement
Ground floor U-value	0.22 W/m²K	0.08 W/m²K	**64%**
Roof U-value	0.20 W/m²K	0.08 W/m²K	**60%**
External wall U-value	0.26 W/m²K	0.12 W/m²K	**44%**
Glazing U-value (including frame)	1.60 W/m²K	1.20 W/m²K	**25%**
Glazing g-value and light transmission	-	0.5	**NA**
Air permeability ($m^3/m^2.h$ @ 50Pa)	8.0	3.0	**62.50%**

4.2.1.2 Building services

Efficient building systems help the building to be fully functional and they can help reducing the base building load and energy demand. The following systems are proposed for the current design:

Table 2 – Proposed Energy Conservation Measures

Element		Plant	Design rationale
	Ventilation	Mechanical ventilation with heat recovery (MVHR)	All occupied spaces are recommended to be served by MVHR units with a heat recovery seasonal efficiency of 80% and achieve a specific fan power (SFP) of 1.60 W/l/s.
	Lighting	Lighting control	Lighting energy consumption can be reduced with the use of presence detecting and photoelectric sensors. All the building spaces to be provided by absence detection control except cabins where occupant manual control has been applied.
		Lighting power	High efficiency lighting should be provided throughout to significantly exceed the minimum requirements of the non-domestic building services compliance guide. This includes the use of high efficiency LED luminaries.

4.2.2 BE CLEAN

District heating network

After consumption has been reduced through the application of energy efficiency measures, the next step is to consider efficient distribution infrastructure to provide further reduction in carbon dioxide emissions.

In order to achieve a net zero-carbon future, it's crucial to incorporate district heat networks into the energy strategy with the aim of creating a sharing system across the various buildings. These networks connect individual buildings and support a circular approach to energy usage, allowing for the storage, use, and share of energy sources. This not only helps to minimise wasted energy within the system, but also promotes a more effective and efficient use of energy, reducing primary energy demand. By doing so, an energy system that is both sustainable and flexible can be created, leading to an optimal pathway towards achieving net neutral emission scenario.

For Hywel Dda a fifth-generation district heating network is suggested. This new generation of district heating distributes heat at near ambient temperature, minimizing grid losses and thus, insulation needs. The main design characteristics are:

- Bi-directional exchange of thermal energy: supply of heat means receiving cold and vice versa;
- Thermal storage at large and small scale, appropriately places, are integrated with the thermal system to balance the demand for heat and cold; and
- Demand driven algorithm-based control that optimizes the exergy flows using real-time data and monitoring.

It is our understanding that the proposed Hywel Dda scheme will include several buildings located within the Site. This offers a great opportunity to implement a local DH system which relies on the above discussed principles to share energy across the various building. Furthermore, it is recommended to explore potential connections with building nearby the final selected Site so to maximise the DH efficacy in delivering low carbon solutions.

Therefore, such measures would be considered to be viable for the proposed development.

Furthermore, Hywel Dda University Health Board (HDUHB) are invited stakeholders in the West Wales consultation process for the Welsh Government Local Area Energy Plan. Develop partnership and local-wide strategy is an important milestone to reduce the carbon emissions so it is recommended the engagement with the Welsh Government is maximised. This collaboration should be focused on defining an overarching strategy that both satisfy the Trust and Wales Government requirements and actively contribute to reducing the local area operational carbon emissions.

Local Combined Heat and Power (CHP)

CHP engines can provide a significant proportion of the space heating and domestic hot water demand with electricity also being generated and locally used. This technology burns fossil fuels such as gas or biomass so to generate heat and to activate a local system to generate electricity. Because of the combustion technology used on these systems, local emissions are generated, and this may have a detrimental effect on the local air quality. Furthermore, this approach goes against the UK Government and Welsh Government aspiration for new developments to be fossil-fuel free.

Although CHP engines possess the same positive attributes as gas fired boilers and work well as the main heat generator in district/shared heat networks, they are considered less feasible for this project due to below reasons:

- CHP engines burn fossil fuels on site: this can lead to a negative impact on the local air quality;
- It is our ambition to provide a scheme which does not rely on gas, or other fossil fuel, to meet the heat demand; and
- Wales Government has clearly set the target to avoid the use of gas in all the new development.

For the above mentioned reasons, we would discourage the use of CHP and other gas-burning technologies on site.

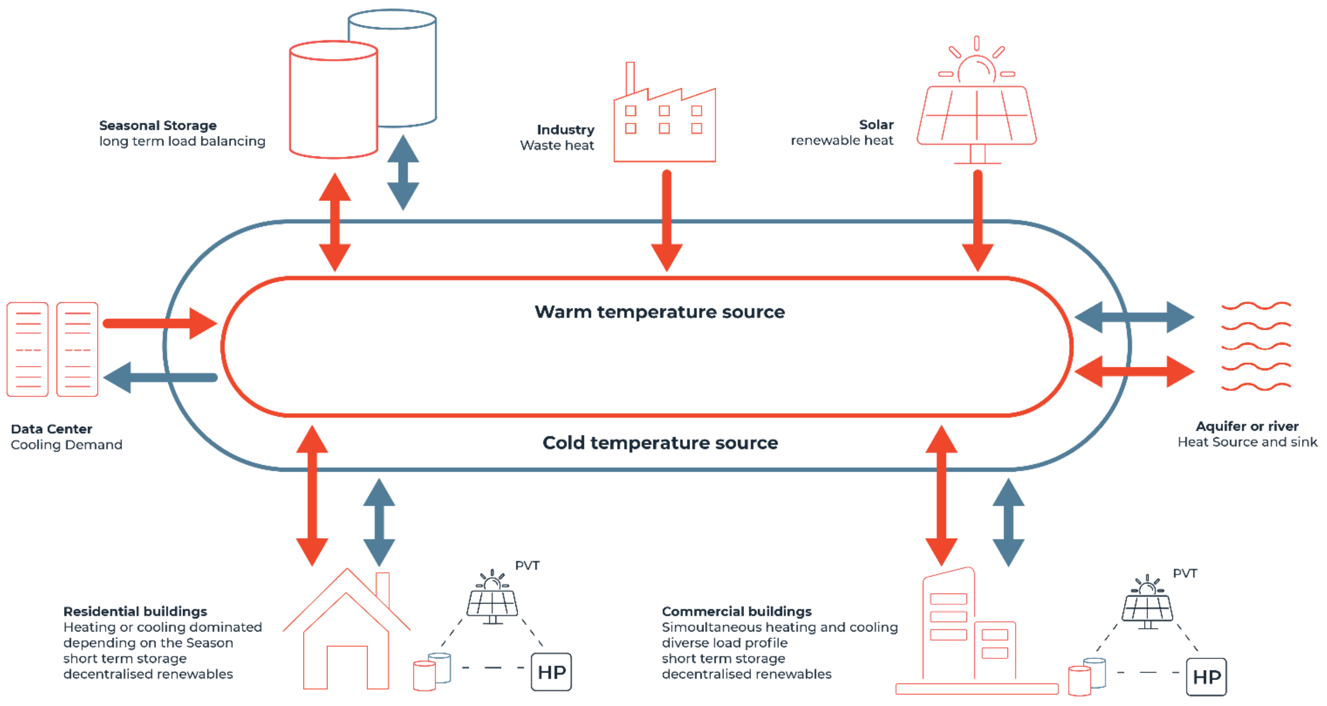


Figure 10 – District Heating Network Diagram

4.2.3 BE GREEN

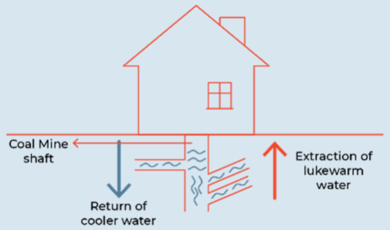
CURRENT AVAILABLE TECHNBOLOGIES

Low or zero carbon technologies (LZT) are defined as all those systems that can generate energy both on-site and off-site. Heat Pumps (HP) are also part of this category, and their impact is evaluated within this chapter. Generally, renewable energy technologies can provide a source of energy that is not primarily based on the consumption of fossil fuels.

In accordance with the project requirements and feasibility, a number of LZT have been evaluated and the pros and cons have been presented.

Table 3 – Preliminary appraisal of Low or Zero Carbon Technologies

Technology	Pros, Cons & Feasibility Comments
AIR SOURCE HEAT PUMP (ASHP)	**A device which uses heat pump technology to provide heating and cooling, using electricity as a power source. Can be either 'air-to-water' or 'air-to-refrigerant'**
	**PROS** ▪ Can serve a significant proportion of heating for certain types of buildings, including offices, airports, sports facilities etc; ▪ Can generate heat and chilled water with a seasonal coefficient of performance > 300%, with favourable conditions; and ▪ It can gradually reduce the carbon footprint of the building thanks to the further de-carbonisation of the electricity grid.
	CONS ▪ Not always effective at providing heat during periods of exceptional cold weather (<-10°C); ▪ Rooftop plant / external plant requirements. ▪ Not fully renewable since it uses fossil-fuel derived electricity with a high carbon factor. This factor, however, is expected to reduce significantly with the de-carbonisation of the grid; and ▪ Can be more expensive to run, due to the higher tariff of electricity.
GROUND SOURCE HEAT PUMP (GSHP)	**Similar to air source heat pumps this technology uses electricity to provide heating and/or cooling for buildings. Ground source heat pumps use the ground as the heat exchanger as opposed to the air**
	**PROS** ▪ Can serve a significant proportion of heating and cooling demands for certain types of buildings, including offices, hospitals, sports facilities etc; and ▪ Can generate heat energy and chilled water with a seasonal coefficient of performance > 400%.
	CONS ▪ Expensive solution due to the costs associated with excavating boreholes – typically £5-10k per borehole (providing around 5 kW heating and cooling each); ▪ Potential problems associated with installing pipework deep underground, due to leaks/ blockages; and Payback period can be long (40-60 years).
WATER SOURCE HEAT PUMP	**Similar to air source and ground source heat pumps, this technology uses electricity to provide heating and/or cooling for buildings. Water source heat pumps use a body of water (a dock, for example) as the heat exchanger as opposed to the air or ground**
	**PROS** ▪ Can serve a significant proportion of heating and cooling for certain types of buildings, including offices, airports, sports facilities etc; and ▪ Can generate heat and chilled water with seasonal coefficient of performance of up to 800%.
	CONS ▪ Can only produce heat up to around 45°C, therefore hot water usually has to be boosted using other technologies; and Licences may require (for open abstraction) to extract from/ discharge to water bodies (local Environment Agency for example) which can be a long process.

USING MINE WATER FROM ABANDONED MINE FOR GSHP & WSHP  	**Traditional GSHP/WSHP systems use the naturally available geothermal gradient of earth for heating and cooling purposes using open or closed loop systems. If any mine water is present near the project site from a disused coal mine, it can be used to heat the building using GSHP or WSHP technologies. The potential of using mine water should be investigated for the project site and can be implemented accordingly.**
PHOTOVOLTAICS 	**Panels or sheets which can generate electricity directly from sunlight, which can be installed on the roofs or facades of buildings, or as a standalone ‘array’.**
	PROS - Fully renewable (energy generated is from sunlight); - Can offset a significant proportion of the building’s electricity consumed; - Can be installed on the roof of the building(s); - ‘Spare’ electricity can be exported/sold back to the local distribution network (national grid), providing this is arranged and the correct equipment is installed. Surplus can also be stored if battery storage is provided; and - Electricity generation profile from PVs matches an office’s occupancy profile, so most of the energy can be consumed on site.
	CONS - A significant area of clear, unshaded roof space is typically required with access for cleaning and maintenance.
SOLAR THERMAL COLLECTOR (WATER HEATING)	**Collectors which generate heat directly from sunlight can be installed on the roofs / walls of buildings to contribute towards satisfying the domestic hot water demand**
	PROS - Fully renewable (energy generated is from sunlight); - Can reduce a building’s hot water demand by up to 50% and be installed on the roof of the building; and - Could generate income through Renewable Heat Incentive payments.

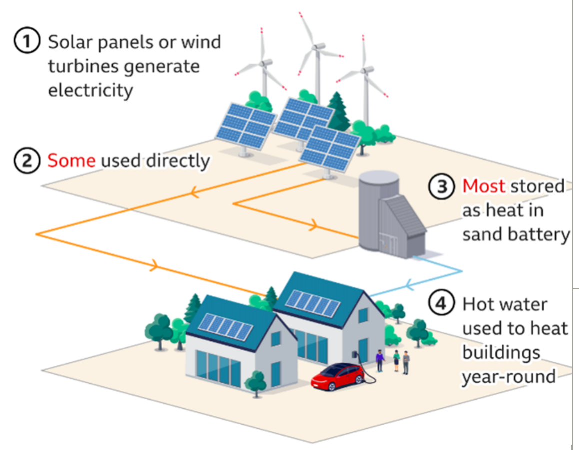
	**CONS** - A significant area of clear, unshaded and optimally orientated roof space is typically required with access for cleaning and maintenance; - Normally ineffective during winter and periods of cold weather; and Requires centrally generated, stored and distributed heat for hot water provision.
BIOMASS BOILER 	**A type of boiler which typically uses wood chips, pellets or logs to heat water for space heating and domestic hot water, although other sources of biomass can be used**
	PROS - Typically considered renewable (providing sustainable forestry techniques are used and locally sourced); and - Can provide very low carbon heating given an appropriate location, within 30-40 miles of a sustainable woodchip source and with suitable access for deliveries and storage.
	CONS - Potentially high maintenance, particularly if woodchip is used; and - Not particularly effective when high cooling loads exist on the site – an alternative technology such as ground source heat pumps could serve heating and cooling loads with a single technology.

OTHER TECHNOLOGIES CONSIDERED	TECHNOLOGY	COMMENTS
	Fuel cells	No particular benefit to be gained. Sourcing hydrogen gas could be challenging.
	Wind turbines	Fully renewable, but not appropriate to the site or location.
	Anaerobic digestion	Lack of sufficient/suitable feedstock (organic waste). Space and maintenance intensive, therefore not appropriate to the development
	Micro-hydro generation	No suitable moving water body available locally (waterfall for example).

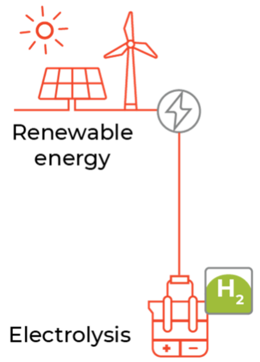
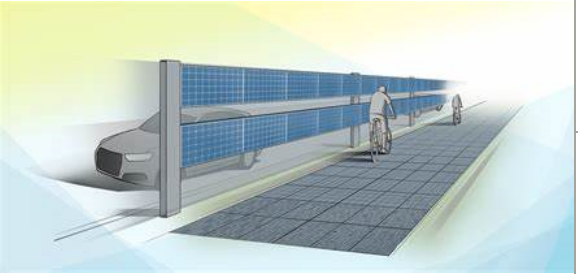
POTENTIAL FUTURE TECHNOLOGIES

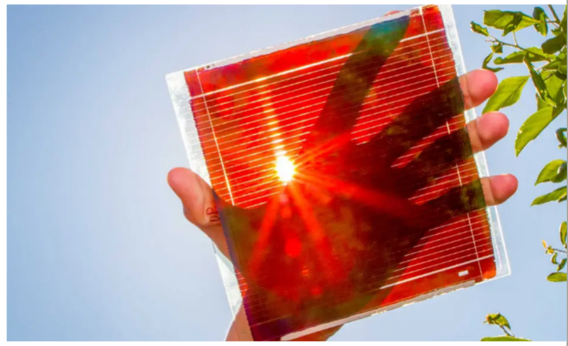
Potential future Low and Zero carbon technologies have been considered along with their potential opportunities and the risks associated for the project. Several technologies are under research which would be available for commercial use within the next couple of years. Considerations should be taken into account for these future technologies that could contribute to the lower operational and embodied carbon emission. The considered technologies can be found below.

Table 4 – Potential future Technologies and feasibility.

Technology	Opportunities, risk & Feasibility Comments	
Sand Battery  	**Sand battery technology is a high temperature thermal energy storage that uses sand or sand-like materials as its storage medium. It stores energy in sand as heat, which can be generated by solar panels or wind turbines. The sand battery can operate at temperatures of 600-1000 °C, with high power, capacity, efficiency, and life span. When the cost of keeping building warm is higher, the battery can give off hot air which warms water which is then pumped around homes, offices and other big size developments.**	
	Opportunities - low-emission and low-cost solution for storing excess green power for months at a time; - It can provide heat for homes, buildings, industries, and cities, especially in cold and dark regions; - The sand stores the heat at around 500C, which can then warm homes in winter when energy is more expensive; and - The proposed technology can be feasible as low emission and low-cost solution for storing heat in winter.	**Risk** - Intermittency: The battery is charged up with heat made from cheap electricity, like solar energy from the sun or wind power. Hence intermittency can be a challenge; and - Challenges in scaling up at the moment.

Technology	Opportunities, risk & Feasibility Comments
Building Integrated Photovoltaic (BIPV) 	**BIPV stands for Building Integrated (Mostly Building Envelope) Photovoltaics that replace traditional building materials like glass, siding, roof and the facade with solar integrated materials.**
	Opportunities - Unlike traditional PV modules, the BIPV is attractive in architectural aesthetics, rather than a simple renovation of architectural design; - Improving energy efficiency; - High thermal insulation and sound insulation; - Clean and free solar output; - Reduce operation and maintenance costs; - As a building material, photovoltaic glass not only plays the role of power generation, but also does not block the sunlight, which is just like the traditional building glass; and - Though the technology is more cost intensive, it can still be a feasible option for the building with wider facades.
	Risk - Some people think BIPV is more aesthetically pleasing that traditional solar panels, but it tends to cost more and be less efficient; - From a design perspective, knowing where we need sunlight to hit before building an entire structure is near essential for integrating solar products; and - The technology is currently not readily available in the market
	Green hydrogen is produced through electrolysis, a process that separates water into hydrogen and oxygen, using electricity generated from renewable sources, which offers a decarbonization solution to the industrial, chemical and transportation sectors.
	Opportunities - For many – including oil and gas players, large utilities, industries from steel to fertilizers, and more – green hydrogen is regarded as the best bet for harmonizing the intermittency of renewables whilst decarbonising the energy-hungry sectors.

Technology	Opportunities, risk & Feasibility Comments
GREEN HYDROGEN 	**Risk** ▪ Reduced knowledge on optimum design and return on investment, thus limiting bankability; ▪ Limited specialised workforce and high operational cost; and ▪ High energy losses (30%-35%); Green hydrogen off-takers and value.
Road-integrated photovoltaics (RIPV)/Solar roadway 	**RIPV encompasses the incorporation of solar modules into and near land areas reserved for transportation. It can be directly installed into the surfaces of roads, footpaths, or public squares, but also between railway tracks or associated areas such as noise barriers or highway verges.** **Opportunities** ▪ Full renewable energy; ▪ Extended lifespan (20 years) then the normal asphalt roads (7-12 years); ▪ In the event of any environmental disaster or military emergency, solar roadways can provide power when needed as no external connection is needed; ▪ Do not require the development of unused and potentially environmentally sensitive land as the road is already there; ▪ By adding LEDs beneath the transparent panel, roads can be lightened up for safe travels; ▪ Aesthetically pleasant; ▪ Ice management is possible; and ▪ Though the technology has higher maintenance cost, the proposed technology can be feasible as low emission solution which can be applied on the roads and pedestrian ways.

Technology	Opportunities, risk & Feasibility Comments
	Risk ▪ Higher maintenance cost, lower durability; and ▪ Seasonal efficiency will depend on solar radiations. Integrated town planning is needed for successful integration.
Perovskite solar cells (PSCs) /Solar Skin 	**The solar skin is a new photovoltaic technology, which integrates customized design into the solar panel system as the shell of buildings, cars, toys, and other items. While the global progress of silicon PVs continues to dominate the industry, advanced materials such as perovskite solar cells (PSCs) are reaching new levels of efficiency and making them a potential alternative.** **Opportunities** ▪ Relatively easy to manufacture and deposit onto a surface using low-cost processes; ▪ Potential for high power conversion efficiency; ▪ Tuneable bandgap, meaning it can be manufactured to be almost ideal for solar energy generation; ▪ Production requires 20 times less material than silicon cells, and doesn't use rare earth metals; ▪ Manufacturing process is less energy intensive than traditional solar cells; and ▪ Though the technology has lower cost & higher efficiency which can be implemented as kinetic solar blinds and other forms, the technology is not yet ready for commercial sales. It is expected to be ready for commercialisation in next couple of years. **Risk** ▪ Perovskites break down over time when exposed to moisture, light, heat and oxygen, meaning there needs to be additional technologies developed to stabilize the cells for widespread use; ▪ The very best perovskites at generating energy contain lead, which is a neurotoxin; however, the industry is working on ways to reduce potential perovskite toxicity; and ▪ Perovskite cells are not yet ready for commercial sales.

Technology	Opportunities, risk & Feasibility Comments
Solar Fabric	**Solar cell fabric is a fabric with embedded photovoltaic (PV) cells which generate electricity when exposed to light.**

Opportunities

- Traditional silicon based solar cells are expensive to manufacture, rigid and fragile. Although less efficient, thin-film cells and organic polymer-based cells can be produced quickly and cheaply. They are also flexible and can be stitched onto fabric.

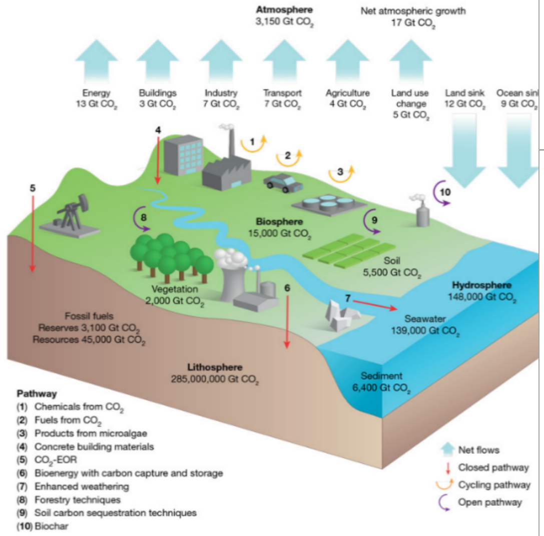
The combination of solar fabrics and solar panels may include:

- Building façade: it can provide shadows and power generation;
- Awning: it can light up the streetlamp; and
- Curtain: it can open and close by itself.

Risk

- Normally, photovoltaic panels are made of glass or another rigid material, which isn't exactly practical for clothing. Consequently, researchers have worked to create a functional solar cell component that is flexible and breathable;
- Photovoltaic cells must be pliable to be integrated successfully into a textile. Otherwise, bending the fabric would cause their seals to break, destroying their ability to harvest light energy from the sun; and
- The proposed technology is under research and not ready for commercial use yet.

Technology	Opportunities, risk & Feasibility Comments
Carbon Capture & Storage (CCS)	**CCS is a low-carbon technology which captures CO_2 released from coal and gas for power generation and from other industrial processes and transports it offshore for safe and permanent underground storage. In GB storage of CO_2 will only take place offshore**



10 specific pathways of CO_2 utilisation, best categorised by considerations of how easily the carbon flows around the Earth's spheres and where it ends up, are as below.

1. Chemicals from CO_2;
2. Fuels from CO_2;
3. Products from microalgae;
4. Concrete building materials;
5. CO_2-EOR;
6. Bioenergy with carbon capture and storage;
7. Enhanced weathering;
8. Forestry techniques;
9. Soil carbon sequestration techniques; and
10. Biochar.

Opportunities

- **CO_2 chemicals:** Reducing CO_2 to its constituent components using catalysts and using chemical reactions to build products such as methanol, urea (to use as fertiliser) or polymers (for use as durable products in buildings or cars);
- **CO_2 fuels:** Combining hydrogen with CO_2 to produce hydrocarbon fuels, including methanol, synfuels, and syngas could address a huge market;
- **Microalgae:** Using microalgae to fix CO_2 at high efficiencies and then processing the biomass to make products, such as fuels and high-value chemicals; and
- **Concrete building materials:** CO_2 can be used to "cure" cement, or in the manufacture of aggregates. Doing so stores some CO_2 for the long term and could displace emissions-intensive conventional cement.

Technology	Opportunities, risk & Feasibility Comments
	▪ **Bioenergy with carbon capture and storage (BECCS):** In bioenergy with carbon capture, the operator captures CO_2 by growing trees, produces electricity through bioenergy and sequesters the resulting emissions; ▪ **Forestry:** Timber from both new and existing forests is an economically valuable product that could potentially store CO_2 in buildings and, by doing so, displace cement use; ▪ **Soil carbon sequestration:** Land management techniques for soil carbon sequestration can not only store CO_2 in the soil but also enhance agricultural yields; and ▪ **Biochar:** Biochar is "pyrolyzed" biomass plant material that has been burnt at high temperatures under low oxygen levels. Biochar application to agricultural soils has the potential to increase crop yields by 10%– but it is very hard to make a consistent product or predict soil reactions.
	Risk ▪ **Energy source**: CO_2 utilisation technologies can be energy-intensive. This energy needs to be renewable; ▪ **Broader decarbonisation context:** Some of these technologies only make sense as mitigation strategies at certain points of the global decarbonisation process; ▪ **Scale:** In order to make an appreciable difference to the global flows of CO_2, pathways need to have the potential to scale quickly.
Biofuel 	**Biofuel, any fuel that is derived from biomass—that is, plant or algae material or animal waste. Since such feedstock material can be replenished readily, biofuel is considered to be a source of renewable energy, unlike fossil fuels such as petroleum, coal, and natural gas**.
	Opportunities ▪ Relatively green energy; ▪ Renewable and sustainable; ▪ Low energy unit price; ▪ Large amounts of biomass available on a global scale; ▪ Low level of dependence on other countries; ▪ Scalable and flexible energy source; ▪ Mature technology due to extensive research in the past; ▪ Diversification in raw materials possible; ▪ No long transportation distances; ▪ Biofuel technology is relatively safe; and ▪ Low levels of greenhouse gas emissions.
	Risk ▪ Production of biofuels can be quite inefficient; ▪ Large amounts of raw materials have to be used; ▪ Significant greenhouse gas emissions in the production chain; ▪ Use of chemical fertilizers and pesticides; ▪ High initial investments required; ▪ Increase in global food prices; ▪ High water demand; ▪ Pollution in the production chain; ▪ Large areas of land are needed for biofuel production; ▪ The production of biofuels may contribute to deforestation; and ▪ Biodiversity loss. As the project has an aspiration to be full electric development, integration with biofuel is conflicting
Artificial Intelligence (AI) in Energy	**The possibility of creating smaller, interconnected networks of energy grids powered by AI is a go-to option for reducing the reliance on central utilities. This way, Artificial Intelligence in the energy sector can balance the supply needs in real-time and ensure the resilience of power resources in the long run.**

Technology	Opportunities, risk & Feasibility Comments
	**Opportunities** ▪ Data digitalization; ▪ Smart forecasting; ▪ Resource management; ▪ Failure prevention; ▪ Predictive analytics for renewables; ▪ AI-powered energy efficiency programs oversee energy usage, provide a framework for smart forecasting, and regulate usage during peak hours. When using model-based predictive control, it's possible to yield an energy-efficiency improvement of 10% to 40%. Predictive analytics and Machine Learning can present up-to-the-point predictions. Consequently, these estimates are used for designing and implementing energy efficiency plans; and ▪ AI can balance the electricity supply & demand needs in real time, optimise energy use & storage to reduce rates. The proposed system can be a feasible technology for the project. **Risk** ▪ Even though AI has the potential to benefit the environment, for instance, by creating smart grids that can match energy demand or smart, low-carbon cities, however, one of the drawbacks of artificial intelligence is today that, due to its high energy consumption, it can also seriously harm the environment; and ▪ High cost to implement & use.
Lithium-Ion Battery 	**A lithium-ion battery is a type of rechargeable battery which uses the reversible reduction of lithium ions to store energy. The anode (positive electrode) of a conventional lithium-ion cell is typically graphite made from carbon. The cathode (negative electrode) is typically a metal oxide. The electrolyte is typically a lithium salt in an organic solvent. Lithium-ion batteries offer twice the energy density of nickel-cadmium, making their charging capabilities much more robust.**
	Opportunities ▪ Light weight: The lithium-ion battery's high energy density is perhaps its biggest edge over other rechargeables; ▪ Low Self-Discharge Rate & prolonged storage; ▪ Low maintenance: Lithium-ion batteries don't require any extra maintenance. Unlike other types of batteries that may need periodic discharge or topping off with fluid and priming; and ▪ Fast charging capabilities and higher energy density. **Risk** ▪ Expense: The cost of the average lithium-ion battery often exceeds that of NiMH and NiCd batteries of the same capacity; ▪ Lithium-ion batteries can be tricky to handle. One problem with these types is that they lose power faster than other battery types, such as nickel-cad or NiMh ones which typically have self-discharge rates of less than 5%; and The major disadvantage to lithium-ion batteries is their ageing. The battery can only withstand so many charge-discharge cycles before capacity falls.

4.2.4 BE SEEN & OFFSET

Be Seen

The climate emergency is driving a requirement to deliver highly performing buildings, with operational energy use consistent with net zero targets. Following this push toward greener building, the concept of "performance gap" has been developed. This new term has been used to describe the practical gap that exists between the predicted energy usage during the design stage, to the real-life energy performance during the operation of the building. In order to address this issue, new approaches such as the new CIBSE TM54 methodology, have been developed by the wider industry.

CIBSE TM54 Evaluating operational energy use at the design stage provides guidance on the tools and techniques that can reliably and robustly model in-use energy performance based on design proposals that can be used to inform design decisions.

CIBSE TM54 was originally issued to cover the 'performance gap' between the expectations around the performance of new buildings set out by Part L of the building regulations and the actual in use energy performance. This gap is mainly due to omission of unregulated energy use in the Part L compliance model, where items such as small power (electrical appliances e.g., PCs), elevators, catering facilities, external lighting, server rooms etc. are not included.

CIBSE TM 54 gives clear guidance on how to evaluate operational energy use at the design stage giving an indication of the real energy use and carbon dioxide emissions. The estimated energy use of the building can then be assessed against energy generation from renewables to demine the operational energy status of the building.

The calculations include items of plant and equipment, usually not included in the Part L compliance model such as:

- Small power
- External lighting
- Catering facilities
- Server rooms; and
- Elevators/Escalators etc.

Complex systems (i.e., heating, cooling, auxiliaries, and domestic hot water) are evaluated using a dynamic simulation model (DSM) that provides an accurate estimation of energy use if compared to steady-state calculations.

For the proposed Hywel Dda scheme, it is recommended that an assessment in line with the CIBSE TM54 criteria is undertaken at each design stage as minimum, so to keep a close control on the compliance gap and practical impact of potential changes.

As part of the design process, a building management system (BMS) combined with an extensive network of meters and sensors should be proposed. This metering and monitoring network should be designed so to record energy consumption and demand on a half-an-hour interval for each big equipment item, floor, function and building so to constantly monitor the room-by-room energy demand. This will provide data at a suitable level of granularity to be then analysed by the Trust's specialist and compared against the forecasted values. If discrepancies are reported, it would be possible to investigate the source of the irregularity and actions can be put in place to rectify it.

Offset

The final step of the hierarchy is to quantify the residual carbon after all the proposed measures have been implemented and enrol in an offset scheme. This will assure the entirety of the carbon emissions are offset and the building can be claimed to be Net-Zero carbon.

Some of the offset scheme may involve the use of "green electricity" or the funding of programs aimed in capturing carbon from the atmosphere via carbon sequestration technologies, peatland preservation and enhancement, reforestation programs etc.

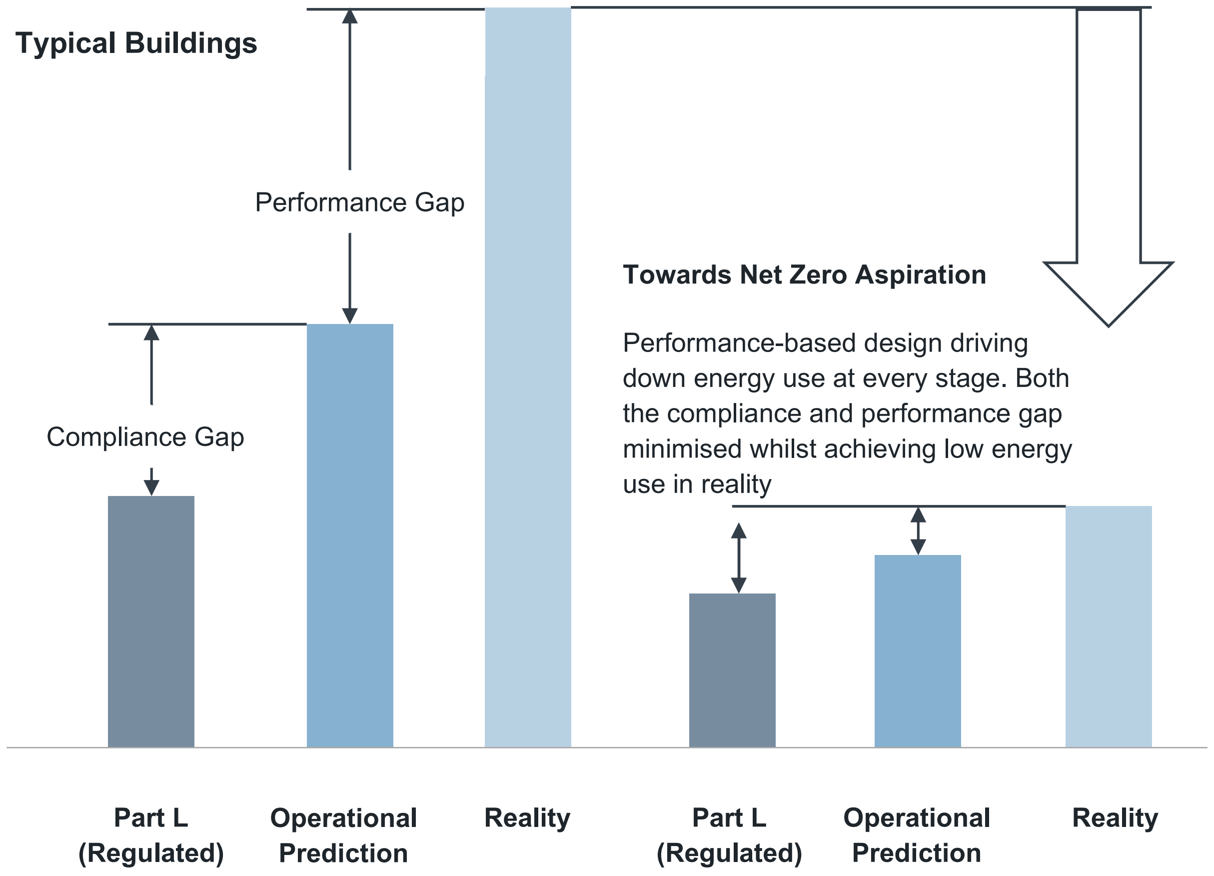


Figure 11 – Energy Performance Modelling Can Help with Dual Aims: Reducing the Performance Gap and Producing Better, Lower Energy Use Buildings (CIBSE)

5 EMBODIED CARBON

Embodied energy is the total primary energy consumed from direct and indirect processes associated with the production of a material or a system. This aspect is considered within the boundaries of the cradle-to-gate lifespan. Accordingly, upfront carbon refers to the initial carbon emissions linked to the construction of a building, which involve the extraction and process of materials, as well as the energy and water usage during the production of material and assembly, and construction of the building. When considering the whole-life embodied carbon of a building, not only the upfront carbon is considered, but also all the carbon emissions associated with the building's 'in-use' phase (i.e. maintenance, replacement, and refrigerant leakage) as well as its 'end of life' phase (i.e. demolition, disassembly, and disposal of any components or the entire building), are calculated.

The conventional “cardon reduction” approach has concentrated on reducing the carbon emissions associated with the operational energy consumption of buildings. Nevertheless, with the growing energy efficiency of buildings and the transition to decarbonised electricity generation, the operational carbon emissions of new constructions are expected to considerably decrease. As a result, embodied carbon will likely constitute the greater portion of the whole life carbon emissions (WLC). Consequently, the importance of embodied carbon is rising, and studies suggest it could account for up to 70% of the whole life carbon emissions for a new low carbon building.

There are key actions that can be taken to reduce the embodied carbon of a building and its constituent elements. Table 5 summarise these primary actions.

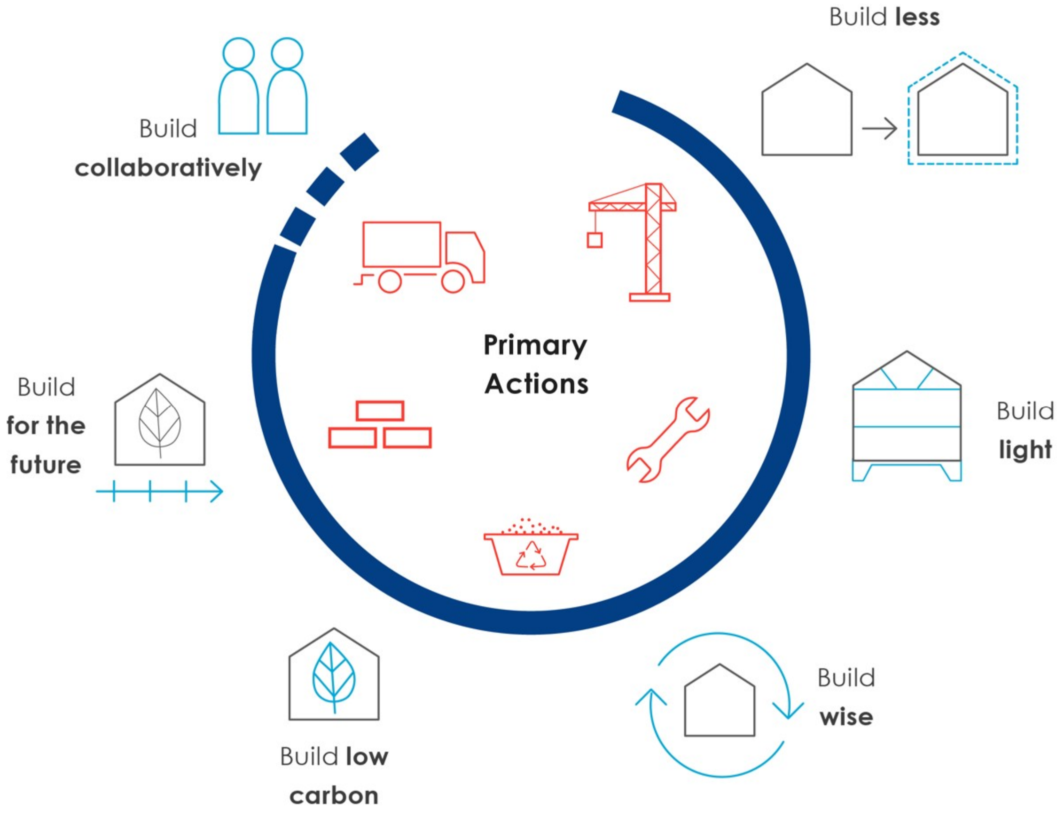


Figure 12 – Embodied Carbon Reduction - PRIMARY Actions Diagram

Table 5 – Primary Actions to Reduce Embodied Carbon for a Whole Building

Primary Actions	
Build less: Refurb and re-use	▪ Is a new building necessary to meet the brief, has retrofit been considered? ▪ Can existing materials on or near the site be used? ▪ Has the brief been interrogated against client need and represents the most efficient solution? ▪ Can uses be shared or spaces be multi-functional? ▪ Carry out a material efficiency review - are all materials proposed necessary? ▪ Seek to simplify the design - simple designs usually means less embodied carbon.
Build light: Consider the building structure	▪ Reduce the weight of the dead loads where possible. ▪ What loadings are really required to meet the brief? ▪ Can long spans be restricted?
Build wise: Longevity and local context	▪ Ensure longevity of material and systems specifications; ▪ Review material efficiency options like designing to standard building sizes or for a repeating module; ▪ Structural members should be designed for 100% utilisation rate where possible; and ▪ Analysing a site is an important activity at the start of a project and this can be extended to the identification of ways of reducing embodied carbon. Possible opportunities include: • There may be existing structures or buildings that can be reused or become a source of recycled materials; • There may be locally sourced material options, reducing transport to site while allowing architectural expression of the context; and • Designing a project around a site topography, reusing excavated soil, and reducing the amount removed from site.
Build low carbon: Review material specifications	▪ Reduce the use of high embodied carbon materials; ▪ Identify ‘Big ticket Items’ and focus on the big wins first including structure and envelope; ▪ Consider natural and renewable materials; and ▪ Explore Design for Manufacture and Assembly (DfMA) solutions if this reduces embodied carbon.

Primary Actions	
Build for the future: Assess end of life and adaptability	▪ Ensure future uses and end of life are considered and adaptability is designed in; ▪ Consider soft spots in the structure; ▪ Consider regular structural grid and future-proofed risers and central plant space; ▪ Mechanically fix systems rather than adhesive fix so they can be demounted and re-used or recycled, supporting a circular economy; and ▪ Explore methods of creating longevity for materials without additional coatings, as they can reduce the recyclability of the material.
Build collaboratively: Involve the whole team	▪ Solutions must involve the whole design team and the client; and ▪ Use 'rules of thumb' data to drive decision making in meetings, especially in the early stages of design.

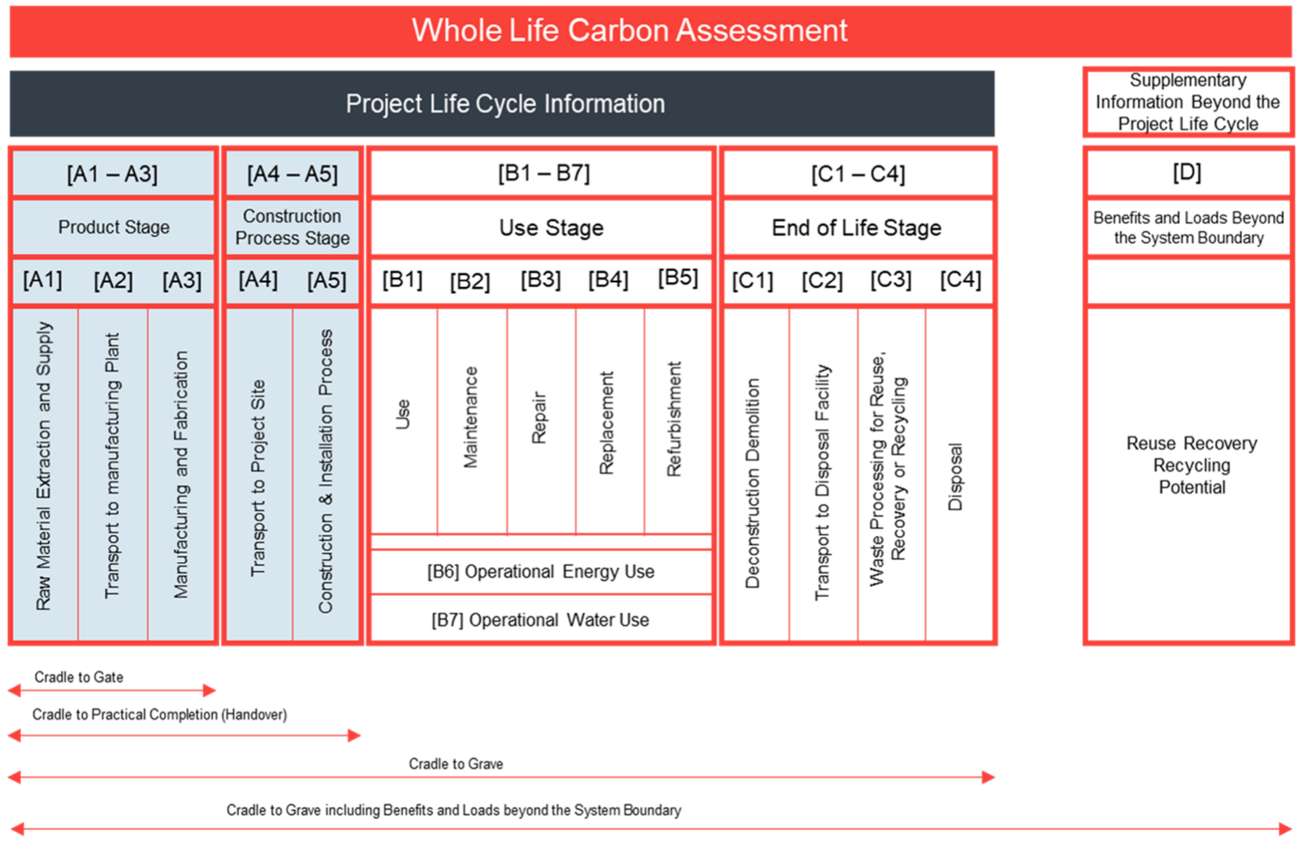


Figure 13 – RICS Whole Life Carbon Assessment Phases

6 CONCLUSION

The purpose of producing this report is to present to the design team some of the strategies that can be employed to improve the net zero carbon design for the proposed Hywel Dda University Health Board (HDUHB) development with the aim of achieving a very efficient building from a carbon perspective. It is worth to highlight that hospital buildings are one of the most energy intensive in the built environment, both because of their requirements but also because of the specialist equipment that are required. It is therefore very likely that even the most efficient hospital will still require a certain degree of offsetting in the form of "green electricity" provision and offset payments to finance projects focused on sequestering carbon emissions from the atmosphere. Defining a suitable strategy to reduce the energy and carbon emission of all new and existing building should therefore be seen as fundamental step in the design process. This process should aim to minimise both the operational and embodied carbon emissions for the entire life of the building with the final aim to deliver tangible and significant savings in both energy demand and final offset costs.

Strategies for reducing whole life carbon, both operational and embodied carbon, were investigated and reported in this document with a short summary reported below.

6.1 OPERATIONAL CARBON

BE LEAN

By implementing the passive and active measures identified in this study, it is possible to achieve a substantial decrease in the heating and cooling requirements of the building.

- The initial action should involve building geometry & massing optimisation collaborating with the architects by using parametric simulation using Grasshopper software; and
- Improving the building fabrics to decrease heat loss, followed by the implementation of functional building services to lower the base building load and energy demand.

BE CLEAN

After reducing building's energy demand through the application of energy efficiency measures, the feasibility to connect to a district heating network have been investigated. It was concluded that:

- A creation of a local fifth generation district heating network is desired;
- CHP engines burn fossil fuels on site: this can lead to a negative impact on the local air quality and it is not recommended by the NHS Wales;
- It is our ambition to provide a scheme which does not rely on gas, or other fossil fuel, to meet the heat demand; and
- Wales Government has clearly set the target to avoid the use of gas in all the new development.

BE GREEN, BE SEEN & OFFSET

The feasibility of a range of Low and Zero carbon Technologies (LZC) was assessed in the context of the project. Aside with the presently available viable options for the project like photovoltaics and heat pumps, it is advisable to explore the viability of the other systems in greater depth during the subsequent design stages. The potential of using mine water to use in the heat pumps should be further investigated and the use of future technologies which can be feasible and ready to use within the upcoming years also explored.

As part of this process, bespoke assessments in line with the CIBSE TM54 methodology should be undertaken for each design stage so to confirm the achieved performance and to evaluate potential design changes.

Finally, the Trust should consider allocating a budget to cover the potential offset payments required to offset the remaining carbon emissions.

6.2 EMBODIED CARBON

Traditional climate change mitigation efforts for buildings have prioritised the reduction of carbon emissions from operational energy consumption. However, with the improvements in building energy efficiency and the transition to decarbonised electricity, embodied carbon is projected to become a more significant contributor to a building's whole life carbon. It may account for 40-70% of the WLC for a new low carbon building.

There below identified key actions are proposed for this project to reduce the embodied carbon of a building and its constituent elements.

Table 6 – Primary Actions to Reduce Embodied Carbon for a Whole Building

Actions	
Build Less	▪ Reuse existing structures or materials; and ▪ Working to an appropriate GIA.
Build Light	▪ Reduce the weight of the building.
Build Wise	▪ Reduce unnecessary materials (i.e., finishes, optimise the structure); and ▪ Reduce on-site construction operations (i.e., MMC).
Build Low Carbon	▪ Specify low carbon materials; and ▪ Use recycled materials.
Build for the Future	▪ Allow for disassembly and re-use.
Build Collaboratively	▪ All the people involved in the project should be part of the process.

Increasing the utilisation of recycled and reused materials in the new construction can yield numerous positive outcomes for society, economics, climate, and technological development. Recoverable steel profiles, concrete, and light fittings can be salvaged, processed, and repurposed in the new building, leading to minimised waste and greenhouse gas emissions and the potential for decreased construction costs.

6.3 NEXT STEP

- Appoint a Sustainability Representative;
- To optimise the operational carbon, passive design optimisation should be incorporated in the early design stage to reduce the building energy demand. This requires a continuous collaboration with the design team from the early Stage 1;
- Building fabric specification should be satisfactory to decrease heat loss;
- To ensure the implementation of functional building services design to lower the base building load and energy demand;
- The feasibility of implementing a 5^{th} generation district heating network should be explored;
- Energy recovery and energy sharing principles should be adopted early on during the design stages and should form a core set of principles to follow;
- Alongside already existing and adopted Low and Zero carbon technologies, future technologies should be explored and discussed;
- Minimum requirements in terms of both operational energy and upfront carbon should be set at the next stage;
- The appointments to the various consultants and designer should reflect the stricter guidance to design an efficient and net-zero carbon building;
- Consideration should be given to the following:
  - Operational energy (assessed using a CIBSE TM54 methodology or other similar suitable methodology);
  - Upfront Carbon: defined as the carbon emissions related with the product and construction stages any new building (RICS stages A1 to A5);
  - Embodied Carbon: defined as the carbon emissions connected with the product and construction, use and end-of-life of any new building (RICS stages A, B and C, excluding B6 and B7).

APPENDIX A: DECARBONISATION OF THE GRID

The choice of building services to provide heating and cooling to buildings is heavily influenced by the carbon content, or 'carbon factor', of the electricity supplied by the grid. As the electricity grid carbon factor decreases with the removal of heavy polluting fuels such as coal, and the introduction of more renewables such as solar and wind power, this enables all-electric buildings to become a viable solution.

In the last decade, the UK electric grid has decarbonised significantly as result of the reduction of reliance on fossil fuels and the increase in renewable technologies such as photovoltaic and wind farms. The inclusion of smart controls such as demand anticipation and an increased automation on how the grid is controlled has helped to decrease even further the carbon impact of the electricity production and distribution.

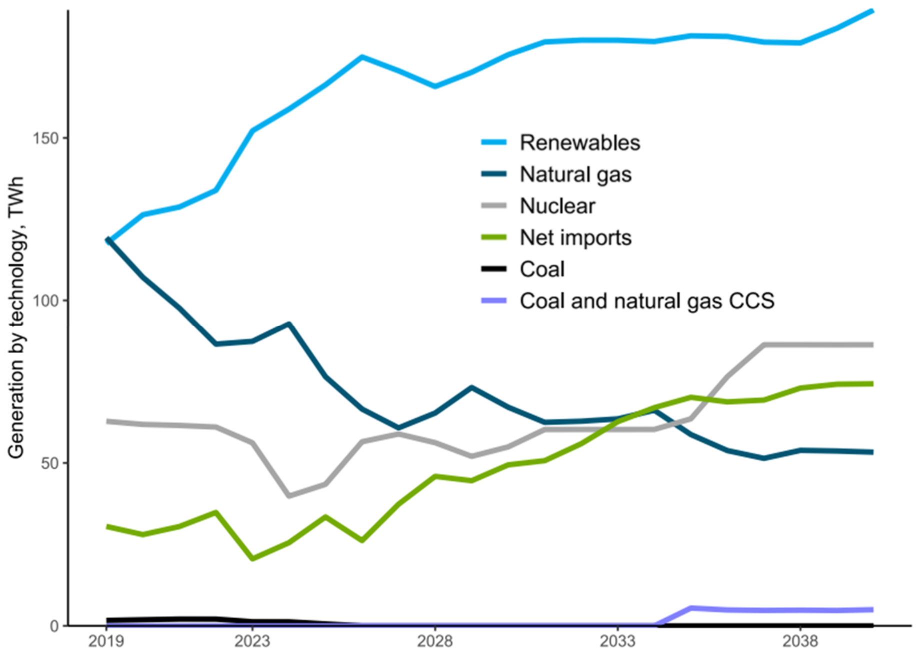


Figure 14 – Electricity Generation by Fuel Source, TWh

As Figure 14 suggests, the fuel mix for the near future is projected to change rapidly in favour of low or zero carbon technologies. Furthermore, BECCS technology (BioEnergy with Carbon Capture and Storage) is predicted to become more and more viable, hence increasing its beneficial impact.

When the old Building Regulations was issued, the electricity carbon content was estimated to be around 519 gCO_2/kWh (SAP 2012 carbon factors). Currently, the electricity carbon intensity is calculated to be 210 gCO_2/kWh (SAP10 carbon factors) which represents a reduction of circa 60% against the initial SAP 2012 values. The presented trend is also forecasted to continue in the upcoming years so further reductions in the carbon content of the electricity grid is expected. It is currently estimated that the electricity grid can achieve a value lower than 50 gCO_2/kWh by 2035.

On the other hand, gas-combustion related carbon emissions are expected to achieve a more modest reduction. The main factors helping in the reduction of the gas carbon factor are related to the indirect benefit of the decarbonisation of the electricity grid (indeed electricity is used to deliver gas within the national network) and the increase in quantity of bio-gas and hydrogen that will slightly change the blend of the gas network.

The graph below shows the predicted carbon factor for the electricity grid (in blue two lines showing different predictions) and for the gas (in red).

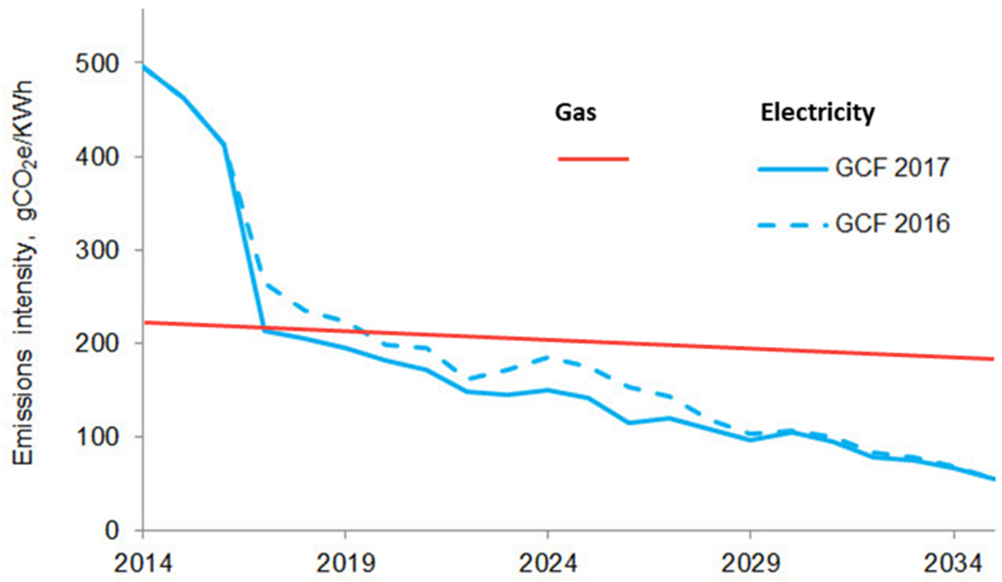


Figure 15 – Current and Forecasted Electricity Grid Carbon Emissions

APPENDIX B: TECHNOLOGIES DESCRIPTION

District Heating Networks (DHN)

District heating is an alternative method of supplying heat to buildings, using a network of highly insulated pipes to deliver heat to multiple buildings from a central heat source. Heat is generated in an energy centre and then pumped through underground pipes to the building. Building systems are usually connected to the network via a heat exchanger (also known as a heat interface unit (HIU)), which replaces individual boilers for space heating and hot water.

Whilst there is some amount of thermal loss from the heat distribution infrastructure, the aggregation of small heat loads from individual buildings into a single large load allows the use of large-scale heat technologies, including the capture of waste heat from industrial processes or power generation, or other large scale heat generation technologies which are not viable at a smaller scale. Of particular interest is combined heat and power (CHP) technologies. Connection to a heat network also provides opportunities to rapidly reduce carbon emissions in the future by changing of the lead community heat source (e.g., to heat pump or biomass technologies).

Hight Temperature Heat Generation

The first two generations of DHN systems are based on pressurised hot water with temperature above 100°C. The third and fourth generations are also based on hot water, supplied by a centralised energy centre but with temperature below 100°C, with fourth generation having significantly lower operating temperature. The proposed network temperatures for these systems are:

- Supply temperature: 80°C
- Return temperature: 60°C

The advantage of running at these temperatures are that heat emitters in existing buildings do not require replacement and there will be less disruption to in-building operations.

A study aimed on comparing the DH system to run at a lower supply temperature of 65°C has been undertaken to determine the benefits in terms of cost and carbon. The assessment shows that a supply temperature of 80°C is more beneficial when considering capital costs against carbon saved (£/tCO2). The disadvantages include lower efficiencies compared to lower temperature operations, leading to higher operating costs and carbon emissions, and potentially higher network heat losses.

Ambient Temperature Heat generation

Ambient temperature, or 5th generation, networks differ to standard 3rd or 4th generation heat networks in that the working fluid is at much lower temperature, approaching that of the pipe surroundings. The temperature of the low-grade heat being transferred through the network must be increased to usable levels using water-to-water heat pumps (WtWHPs) sited local to the buildings that are being served by the network.

Some of the advantages of an ambient temperature network are as follows:

- Less need for insulated pipework to reduce heat losses as the fluid temperature is similar to the surrounding ground. Potential savings on pipework costs and installation costs as the method of installation and jointing requires less specialised personnel and equipment than that for pre-insulated systems;
- Better ability to make use of low grade naturally occurring heat sources such as ground, water and waste heat;
- Potential of enabling an "energy sharing" virtuous system which can reduce the energy required by the entire system; and
- Requirement for centralised plant can be reduced or omitted completely, resulting in significant cost savings.

Figure 16 below illustrates the concept of a shared ground loop array; this is a form of ambient temperature network which uses one or more closed loop boreholes as the heat source to serve a group of properties. In this approach, boreholes are interspersed within the site, rather than in a separate borehole field; typically, under front gardens or other soft landscaping, driveways and pavements. This solution allows the boreholes to be spaced adequately to improve the natural recharge of ground temperatures over the summer. It also provides capital cost savings by removing large pipe runs from the borehole field to the heat pumps.

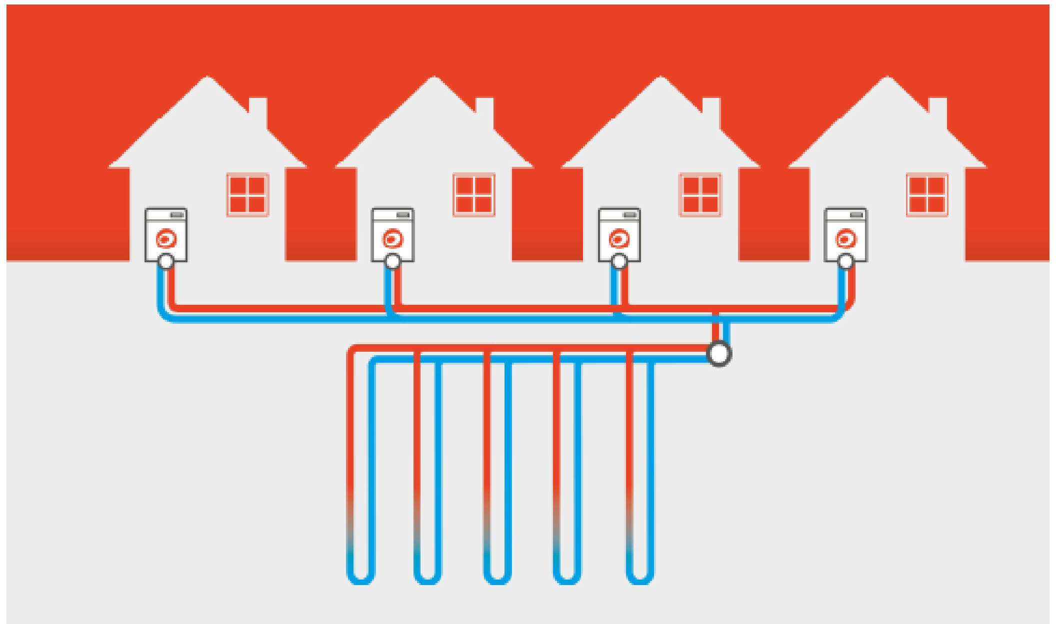


Figure 16 – Shared Ground Loop Concept, a Form of Ambient Temperature Network (Image Courtesy of Kensa)

Renewable Technologies

As part of this study, in the **Be Green** section various low or zero carbon (LZC) technologies were assessed. The use of Photovoltaic (PV) panels and air source heat pumps (ASHP) was recommended for the Proposed Building. Furthermore, a full electric strategy reliant on ASHPs has the potential to be zero carbon subject to the electricity power generation method and the grid decarbonisation process.

A basic comparison between a strategy based on a standard combustion technology (gas-fired boiler- **Be Lean**) and a strategy based on a full electric approach (based on the use of heat pumps on site- **Be Green**) has been carried out and the conclusions are reported here.

From an energy perspective, the typical efficiency of a standard gas-fired system can be estimated to be in the range of 80-90%. This means that for each kilowatt (kW) of energy used (in the form of gas usage) between 0.8 kW and 0.9 kW are delivered to the final user. When looking at the Heat Pumps (HP) technology, the average efficiency sits between 250-350% with the potential to increase the overall efficiency even further through the use of new or alternative technologies. This mean that for each kilowatt of energy used (in the form of used electricity), the system will return somewhere between 2.5-3.5 kW.

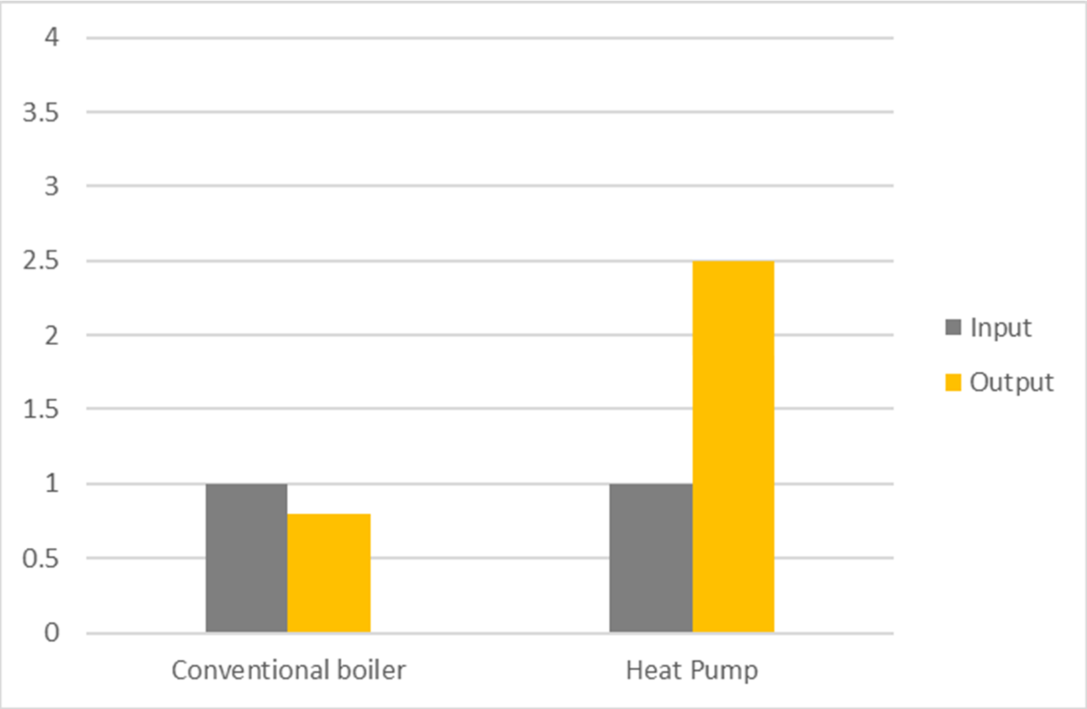


Figure 17 – Comparison between Input and Outputs for Conventional Boilers and Heat Pumps

When looking at the carbon emissions arising from the two alternatives, it is worth to highlight that currently the carbon emissions related to the production of 1kWh of electricity is almost the same of the carbon emissions associated with the production of 1 kW of energy from a gas combustion technology (see Figure 15). When considering the efficiency of the systems, it becomes clear that a full electric strategy based on the HP technology can deliver a substantial reduction in the carbon emissions.

With regards to the cost perspective, a gas-fired system presents a cheaper CAPEX and OPEX than the electric counterpart (HPs or direct electric system) which has driven the decision-making process in the past and still does, for some projects. Following the environmentalist movements and the recognition of the global climate emergency, carbon emissions have become a “hot topic” and this is reflected in the decision taken by several local authorities, governments, organisations and financial institutions to declare a “climate emergency”. This environmental-conscious approach is now steering the design of new buildings away from gas-burning technologies.

Finally, when looking at the trend for the upcoming years, it is clear that the decarbonisation process for the electricity grid is still in progress and a significant reduction is forecasted for the years to come (based on recent Government documents, FES reports and EEP analysis). This trend will greatly reduce the carbon emissions associated with the electricity production and it is likely to lead all developments which use a full electric strategy to become net-zero in the future years.

Based on the above, this report agrees on the principle that a full electric strategy is likely to deliver the most significant energy savings and, as a consequence, the highest reduction in carbon emissions. This is valid for the short-term scenario as well as for the long-term scenario.

Low or Zero carbon Technology description

The table below summarises the description of the low or zero carbon technologies considered in this assessment. This is set out to identify the pros and cons of the range of LZC technologies and identifies those appropriate to the site. Reasons for discounting inappropriate technologies are discussed in section 4 of the report.

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