QODA

St. Hilda's College

Decarbonisation Strategy, Executive Summary

2862.R02

QODA

Revision Summary

Issue	Document prepared			Document checked		
	Name	Signature	Date	Name	Signature	Date
P1	M. Swann C. Swinburn		13/04/2022	R. Turner		13/04/2022
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Contents

1 Introduction

This is an executive summary report derived from the main report from QODA, 2862.R01. Its purpose is to provide the key findings of the report in a shorter format for decision makers. Key findings of the study are:

1. CO_2 emissions from energy use are dominated by the burning of natural gas for space heating.
2. There is significant potential to reduce space heating energy demand.
3. There is some potential to reduce electricity demand.
4. The site can move from gas boilers to heat pumps, but cost and complexity are high.
5. Both water-source and air-source heat pumps are technically feasible, but further work is needed to establish whether either or both is the optimal solution for the site.
6. Solar PV is technically feasible, but complex to implement with the heritage context and roof shapes. Partnering with the adjacent school might be a viable option.

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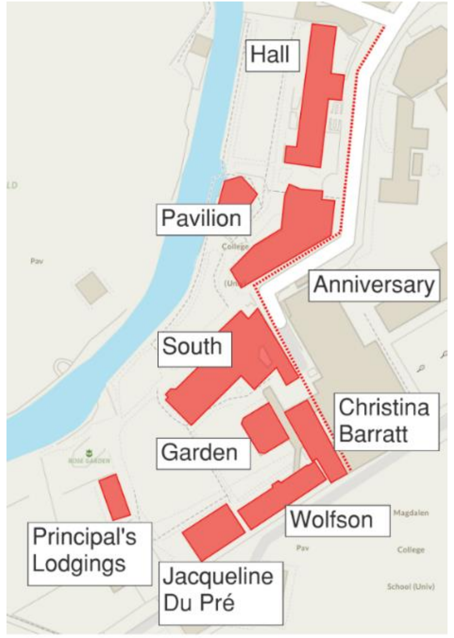
2 Summary

This study has been commissioned by St. Hilda's College to plot a pathway to Scope 1 and 2 net zero carbon[1] for the main College site. Using utility data for both gas and electricity, we have established that the current annual carbon footprint of the fixed building services and unregulated energy use for the site is approximately: **580 tonnes of CO_2.**



The purpose of this study is to make this number zero by 2030 if feasible, or soon after that if not.

We have reviewed all the buildings across the site for both building envelope/fabric condition and building services. This review and survey data has informed our view of what is achievable on the site, and led to the proposal of three options or pathways that lead the College to the net zero carbon target. All three utilise heat pumps in different ways to decarbonise the source of heat, while different levels of building fabric energy retrofit are proposed. All three propose to utilise the full extent of available roof area for solar PV, though available area varies depending on heat pump deployment and possible partnering with neighbours to share roof space.

Pathways to net zero carbon:

Pathway 1: Building envelope retrofit/upgrade, plus building services energy efficiency improvements, with air source heat pumps serving each building providing space heating and hot water

Pathway 2: Building envelope retrofit/upgrade, plus building services energy efficiency improvements, with site-wide water source heat pump network and air source systems deployed for local top-up where needed

Pathway 3: No energy demand reduction, with air source heat pumps serving each building providing space heating and hot water

The three options yield very similar carbon reduction results of between 73 and 79% in 2030, where 100% is net zero carbon, and 0% is the buildings of today. If carbon emissions reductions were the only concern here, then the lowest capital cost pathway could be selected. Running costs are a significant additional factor, however, which must also be considered.

We have assessed likely running costs of the three options above against a do-nothing gas-fired baseline over the period 2030-2050 and concluded that Pathway 2 is significantly lower running cost than other options, but with potentially higher capital costs due to building fabric retrofit. Pathway 3 is likely to incur high costs for electrical infrastructure upgrades.

[1] Throughout this report we use the term 'carbon' or 'carbon emissions' to refer to kilograms of carbon dioxide equivalent, $kgCO_2e$

We therefore propose that Pathway 2 is developed into a detailed design with complete capital works costings, and these are compared to our projected running cost figures, to ensure that Pathway 2 presents good whole-life value to the College.

Within this report we outline a pragmatic route from today to 2030 using Pathway 2, but with the option to revert to Pathway 1 if capital costs of Pathway 2 are prohibitive, or if air source heat pumps improve in cost or efficiency during the period in which the plan is being developed.

Our approach to this decarbonisation strategy is informed by the latest industry thinking (Including guidance from PAS2035, LETI, AECB) and an holistic view of buildings and wider energy supply issues. Below we list the order of priorities for the QODA whole building approach, an expansion on our summary to the College in November 2021:

1. **Metering & Monitoring**- establishing energy end uses and peak loads
2. **Eliminate Fossil Fuels** – essential for removal of all Scope 1 emissions
3. **Reduce demands** – enables buildings to fit within the wider infrastructure of a zero carbon UK, and reduces running costs while increasing occupant comfort and building lifespan
4. **Supply Low Carbon Heat** – this follows the demand reduction point above, as otherwise new heat sources would be oversized and more capital cost intensive than needed
5. **Renewable Generation** – this contributes both to the net zero target and to College revenue in the form of reduced energy bills
6. **Energy storage** – building and site level energy storage enable the College to make use of 'time of use' electricity tariffs at lower cost, and limit their impact on the future national electricity grid (both thermal and electrical storage in view here)
7. **Offsetting** – a controversial but probably necessary component of overall net zero carbon; care must be taken to select biodiversity-enhancing measures from approved suppliers

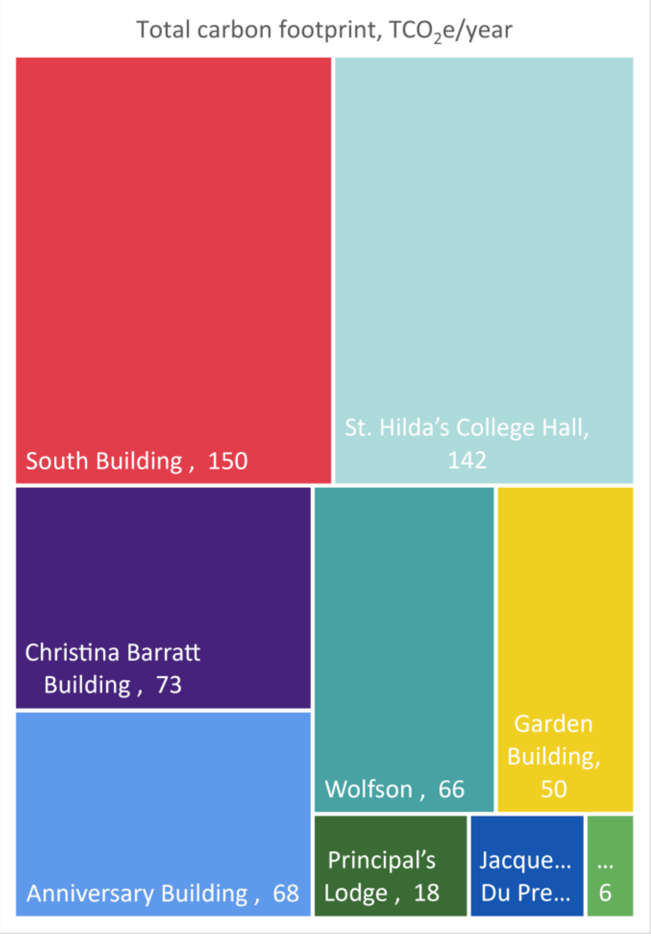
3 Baseline Carbon Emissions

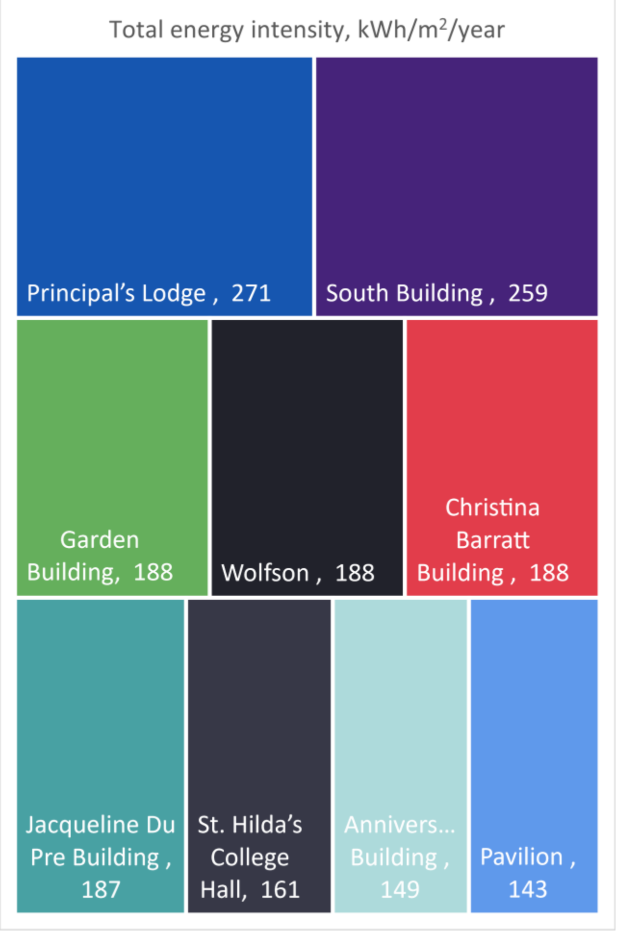
3.1 Calculation Method

The baseline carbon emissions for the site have been calculated based on energy consumption data obtained from energy bills. The energy associated with each fuel has then been multiplied by the corresponding emissions factor, using predicted 2030 figures (see section above about ESO FES carbon intensity estimates)

3.2 Energy Demand and Carbon Emissions by Building and demand

The figure below shows a comparison of the total energy consumption of each of the buildings under assessment based on current utility data, where total energy is represented by area. The largest area is at the top left of the chart, and the smallest at the bottom right. The data shows that the South Building and College Hall have the largest carbon footprint, while the Pavilion and Jacqueline Du Pre buildings have the smallest footprint – slightly less than the Principal's Lodge. Energy intensity, however, shows a different picture, with the Principal's Lodge being the most energy intensive building on site. Total energy usage and energy intensity are helpful tools to use alongside carbon emissions, as it helps identify where largest consumption is taking place – the scale of the challenge.





The utility date shows that space heating demand is the largest site energy consumption, primarily in the form of mains gas. Next largest is electricity demand, and hot water is somewhat smaller, although the split between this and space heating gas consumption is estimated. There is also a relatively small amount of gas used for catering. As with many sites that have historic buildings, space heating demand is the largest load and the largest contributor to carbon emissions. Reduction of this demand, and decarbonisation of the source of heat is therefore a priority in targeting a net zero carbon outcome.

4 Existing MEP Services

Before any recommendations for de-carbonising the college's estate can be concluded, the existing buildings and associated building services must first be understood, as any constraints from the findings will influence the outcome.

4.1 Existing Heating

Heating for some of the buildings is served from adjacent building heating plant. **Table 1** shows the total capacity, the buildings served by each plant room and the age of the installed heating plant. The rule of thumb heating demand is also shown, and this shows that there is a large discrepancy between the peak capacity and the typical expected capacity which should be investigated further.

Table 1 - Summary of Existing Heating

Building/Area	Area (m^2)	Peak Installed Capacity (kW)	Rule of thumb peak demand (kW)	Age of Installation
1.Hall	3894	420 kW	389 kW	2003
2. Anniversary Building	3252	218 kW	195 kW	2020
3.Pavilion	272	38 kW	16 kW	2020
4 & 5. South & Garden	4459	1134 kW	446 kW	1977 (original casing) 1999 (Burner replacement) 2020 (Ideal Boiler) 2021 (Garden HWS)
6 & 7. Christina Barratt & Wolfson	3527	688 kW	353 kW	2001 (CBB Boiler & HWS) 2013 (Wolfson HWS)
8. Jacqueline Du Pre Building	638	46 kW	56 kW	2021 (although boiler dates from ~2016
9. Principal's Lodge	305	50 kW	31 kW	2021
Total	**16042**	**2594 kW**	**1485 kW**	

4.2 Existing Electrical Infrastructure

There is a total of 5No. separate low voltage SSE supplies that serve all the buildings on the site. These terminate into the South Building, CBB Building, Anniversary Building, Hall Building & Principals Lodgings. The Jaqueline du Pre Building is fed from the South Building, the Garden & Wolfson Buildings are fed from CBB and the Pavillion Building is fed from the Anniversary Building.

The Anniversary, Pavilion & Principal Lodgings buildings have new electrical installations throughout (less than 18 months old) whereas all the other main distribution centers in the other buildings are generally over 20 years old. The electrical installations in the other buildings are of a variety of ages as refits and modifications have been carried out in local areas.

5 Solutions for Decarbonisation

5.1 Reducing Heat Demand

Level of Heat Reduction Measures

We have considered three levels of intervention with respect to the breadth and effectiveness of heating reduction measures:

- Light – measures with low levels of disruption, relatively easy to implement, but collectively with limited impact.
- Significant- increased level of disruption, costs, and risks, but with a marked impact on heat demand
- Deep Retrofit- major works to the building with high levels of disruption, but transformative in terms of energy use and comfort. As typified by the AECB Retrofit or perhaps even approaching/achieving the EnerPHit standard.

Table 2 summarises the types and breadth of measures in each category and provides an estimated reduction in the space heating demand associated with such works. These reductions are based on data from previous projects and should be considered as indicative only. However, they provide a reasonable basis for establishing an overall site strategy. As the decarbonisation plan is implemented, energy modelling should be carried out for each building to establish energy savings with greater precision.

It should be noted that the peak heating loads for each building are unknown at present. Therefore, for the purposes of this report it is assumed that the peak loads are 85% of the peak installed plant capacity (to allow for plant resilience and over-sizing), with a further percentage reduction as shown in Table 2, depending on the fabric measures.

Table 2 - Heat Reduction Measures

Level of heat reduction interventions	Assumed reduction in annual space heating demand (kWh)	Assumed reduction in peak space heating load (kW)	Example of range of measures implemented for category	
Light	**15%**	**8%**	• Loft insulation, • draught proofing windows,	• TRVs on radiators
Significant	**30%**	**15%**	• Secondary glazing • Heating controls • Cavity wall insulation	• Flat roof insulation • Airtightness measures
Deep Retrofit	**80%**	**60%**	• Triple glazing • Wall Insulation (internal or external) • Pitched roof insulation	• Heat recovery ventilation • Airtightness to AECB/EnerPHit levels

Table 3 summarises the types of heat reduction measures proposed for each building, and the overall interventional level designated to each. The following section discusses the associated corrected peak design loads after these measures.

Table 3 - Summary of Heat Reduction Measures

Building	Floor	Roof	Walls	Windows	Airtightness	Ventilation	Heating & Water Systems	Overall Intervention Level	% Heat Demand Reduction
Hall Building								Light	15%
Anniversary								Light	15%
Pavilion								Light	15%
South Building								Significant	30%
Garden Building								Deep Retrofit	80%
Christina Barratt								Significant	30%
Wolfson								Significant	30%
Jacqueline Du Pre Building								Significant	30%
Principal's Lodge								Significant	30%

Key
No improvement
Partial Improvement
Extensive Improvement

5.2 Reducing Electrical Demand

This section considers opportunities to reduce electrical energy demand in the buildings in respect of:

- Appliance energy use (selection and behavioral aspects)
- Lighting (type and controls)
- HVAC systems (e.g., pumps, fans, controls)

The impact of these elements is challenging to estimate without detailed energy modelling backed up with sub-metering data. We have therefore applied simple factors based on the extents and culminative effective of various improvement measures, as shown in the table below.

Level of reductions	Assumed Reduction in electrical demand	Example of range of measures implemented for category	
Low	**5%**	• Behavioral changes	
Medium	**10%**	• Low energy appliances • Low energy pumps and fans • Behavioral changes	
High	**20%**	• Extensive replacement of lighting with LED. • Phase out of inefficient IT equipment Low energy appliances	• Low energy pumps and fans • Phase out of inefficient IT equipment • Behavioural changes

5.3 Decarbonising the heat source

Replacing the existing gas-fired boiler with electrically driven heat pumps is the only feasible way to decarbonise the existing heating systems. Heat Pumps move low grade heat from a heat source and convert it into useful temperatures for heating buildings using a vapour compression cycle (this operates on the same principle as a fridge but in reverse). Principally, there are 3 sources for the heat – Ground, Water and Air, and these are respectively referred to as Ground Source Heat Pumps (GSHPs), Water Source Heat Pumps (WSHPs) and Air Source Heat Pumps (ASHPs). Due to the limited land available on the site to install GSHP collector arrays they have been discounted from this feasibility, although it is worth noting that they may be feasible for one of the smaller buildings such as the Principal's Lodge. Therefore, it is determined that either ASHPs or WSHPs are the most appropriate to decarbonise the site. 3 Pathways have been identified that can be considered by the college:

Pathway 1: Building envelope retrofit/upgrade, plus building services energy efficiency improvements, with ASHPs on each building providing space heating and hot water

Pathway 2: Building envelope retrofit/upgrade, plus building services energy efficiency improvements, with site-wide WSHP network and ASHP systems deployed for local top-up where needed

Pathway 3: No energy demand reduction, with ASHPs on each building providing space heating and hot water

Refer to Table 4 below for corrected peak heating loads for different pathways. This shows the peak load is over 400kW less if fabric interventions are undertaken. It is strongly recommended that heating circuits are sub-metered over the next heating season, prior to designing/ordering replacement heating plant so that the current 'base-line' load is known to a reasonable degree of accuracy.

Table 4 - Corrected Peak Design Heating Loads

Building/Area	Pathways 1 and 2 Peak Installed Heating Capacity (kW)	Pathway 3 Peak Installed Heating Capacity (kW)
Hall	328 kW	357 kW
Anniversary Building & Pavilion	200 kW	217 kW
South & Garden	675 kW	964 kW
Christina Barratt & Wolfson	497 kW	585 kW
Jacqueline Du Pre Building	33 kW	39 kW
Principal's Lodge	36 kW	43 kW
Total	**1769 kW**	**2205 kW**

5.3.1 Technical constraints of Heat Pumps

The application of heat pumps presents challenges to existing building stock due to the technical constraints of heat pumps – they operate most efficiently with a flow temperature that is close to the source temperature, and prefer a small temperature difference between the flow and return temperatures. Conventional gas boilers operate typically at 80°C flow and 60°C return, whereas the majority of heat pumps would prefer 50°C flow and 45°C return (ideally less). In order to get improved heat pump temperatures. This presents an issue as an equivalent radiator at 50/45°C rather than 80/60°C provides 55% less heat output – therefore unless the peak heating load is reduced by almost 60% then the existing emitters and pipework will be undersized on the coldest days. The only area that may achieve these kind of reductions would be the deep retrofit option of the Garden Building. Therefore, for the purposes of this report, High Temperature Heat Pumps have been considered, which can be provided with water at 80°C flow, as replacing all emitters in the buildings is considered very disruptive and challenging unless a deep retrofit is considered. High Temperature Heat pumps are consequently less efficient (more energy intensive and have a higher capital cost, therefore all opportunities to reduce the demand should ideally be considered first).

5.3.2 Pathways 1 and 3 - Air Source Heat Pumps (ASHPs)

Pathways 1 and 3 consider the application of ASHPs. Pathway 1 assumes that energy efficiency and building fabric measures to reduce demand are implemented first prior to the ASHP, whereas Pathway 3 assumes that no fabric measures are undertaken and boilers are replaced with like for like High temperature ASHPs. Therefore the size of ASHPs for Pathway 3 is larger than for Pathway 1. Compared to WSHPs, the electrical input is higher due to the air temperature (the heat source) being colder than the river temperature in peak conditions.

Error! Reference source not found. shows typical selections of ASHPs for both pathways 1 and 2. As can be seen the l argest difference is for the plant serving the South and Garden buildings with the large reduction in peak loads reflected in the size of the plan selected from Pathway 3 to Pathway 1.

Table 5 - ASHP Summary

Building/Area	Pathway 1 Typical Unit Spec required	Pathway 3 Typical Unit Spec required2	Typical Unit Spec kW (each)	Pathway 1 Typical area for external plant required (m x m)	Pathway 3 Typical area for external plant required (m x m)2
Hall	3no. Pure thermal OHT 235	4no. Pure thermal OHT 235	110	10 x 11.6	10 x 14.9
Anniversary Building & Pavilion	2no. Pure thermal OHT 235	2no. Pure thermal OHT 235	110	10 x 8.4	10 x 8.4
South & Garden	6no. Pure thermal OHT 235	9no. Pure thermal OHT 235	110	18.2 x 11.6	18.2 x 18.1
Christina Barratt & Wolfson	5no. Pure thermal OHT 235	6no. Pure thermal OHT 235	110	18.2 x 11.6	18.2 x 11.6
Jacqueline Du Pre Building	1no. Mitsubishi Ecodan	1no. Mitsubishi Ecodan	40	5.4 x 4.5	5.4 x 4.5
Principal's Lodge	1no. Mitsubishi Ecodan	1no. Mitsubishi Ecodan	40	5.4 x 4.5	5.4 x 4.5

Figure 1 highlights possible locations for ASHPs. It should be noted that this is for illustrative purposes only to highlight the challenge in locating large amounts of ASHPs – a proportion of these locations will not be aesthetically pleasing and will likely present planning and/or noise issues. In particular, the Hall building location shown is not likely to be permitted due to local heritage/planning restrictions. Any roof mounted equipment will need to be signed off by a structural engineer (further structural reinforcements may be required) and safe access provided for maintenance (i.e. for the Garden Building, Anniversary Building and the CBB).

Any roof mounted plant also limits the opportunities for PV installations to be installed on site.

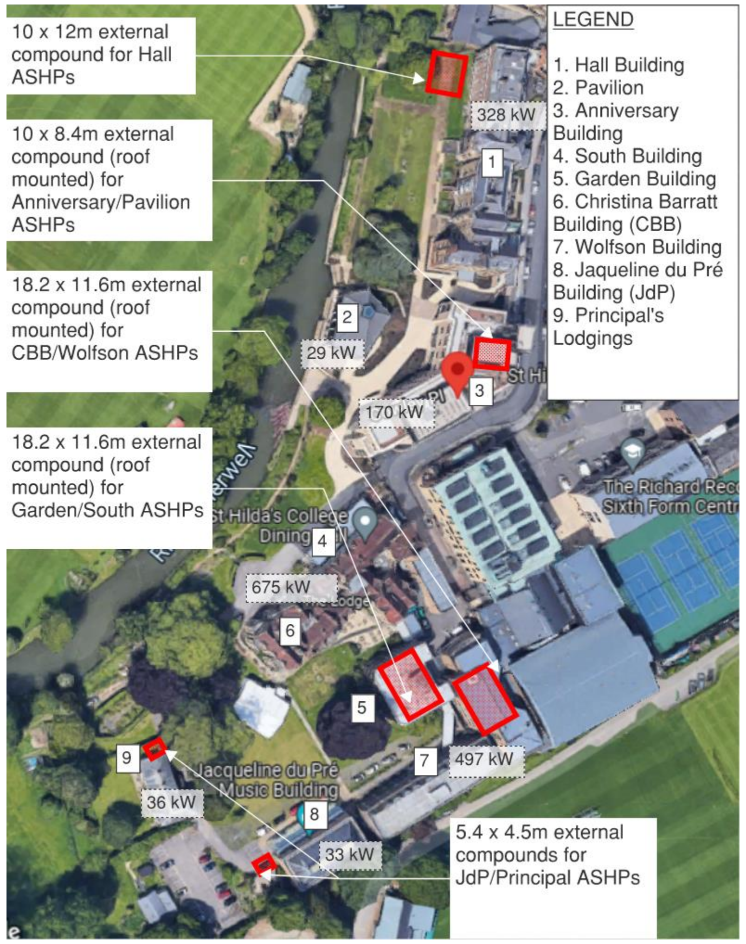


Figure 1 - ASHP Layout

Given the potentially difficulties in siting ASHPs sensitivity on the site, it is plausible that one of the solutions for decarbonising the systems will involve a hybrid of both WSHPs and ASHPs. As an alternative, it is feasible that a central heat pump plant room could be located on site, which could distribute to a low temperature 'ambient loop' that could be distributed around the site in much the same way as is proposed for the WSHP option – i.e. a low temperature air source heat pump providing low temperatures (circa 10-20°C flow temperature) with individual building WSHPs to bring the water up to 80°C. This will be more energy intensive but may represent a good hybrid solution that won't negatively detract on the architectural heritage of the site. This should be explored as part of a range of WSHP/ASHP hybrid options during the next design stage along with likely capital/operational expenditure of each option.

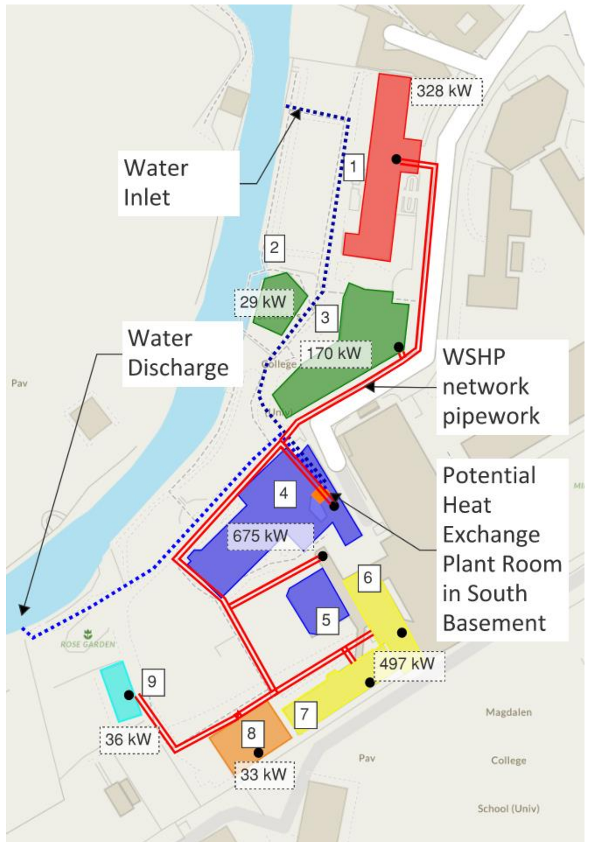
5.3.3 Pathway 2 - Water Source Heat Pumps (WSHPs)

WSHPs have good potential to be applied to the site. Closed loop systems are not suitable for the site due to the intensive use of the river (punts etc), plus the river itself is not owned by the College. Open Loop systems abstract water from the river upstream, put it through a heat pump and then discharge it further downstream. This allows an entirely concealed system, highly resilient to damage by river users.

A suggested location for this plant room is shown potentially within the South Basement plant room, although a full feasibility should be undertaken to ascertain the size and location of the plant room. It should be noted that the following environmental consents will be required for abstracting and discharging river water (these are described in greater detail in the main report:

- Abstraction license required from the Environment Agency
- Discharge licenser required from the Environment Agency
- Permission to install a structure required from the Environment Agency
- Flood Risk Assessment
- Planning permission for new structures

Temperature differences between the abstracted flow and the discharged return will typically be 3°C (this shall be confirmed with a specialist) but can be as high as 8°C.



From the plate exchanger water would be circulated via a site wide 'ambient loop' – this is a sealed low temperature water, brine, or a water/glycol mix. This would distribute flow and return collector water into each building as indicated. Water Source Heat Pumps would then be installed in the existing plant rooms and connected to the existing heating systems. Refer to Figure 2 for typical site layout.

This approach allows a modular approach to the design and installation. The primary heat exchanger, circulation pumps and loop pipework can be installed on day 1, with capped and valved branches allowing a phased installation going forward, so each building's WSHP can be connected in line with budgets and to maximise the lifetime of existing boiler plant where it has only recently been installed (for example the Anniversary building).

Where buildings cannot be retrofitted, heat Pumps shall be selected to be able to deliver 80C so that existing heating systems do not require replacing. Retrofitted buildings can make use of higher-efficiency, lower temperature systems.

Figure 2 - Potential WSHP site Layout

An alternative solution would be to extend the river loop network around the site with local filtration plant and Plate Heat Exchangers in each plant room rather than in one central location. **Error! Reference source not found.** 3 shows an i mage and conditions of a typical WSHP on the secondary side of the circuit.

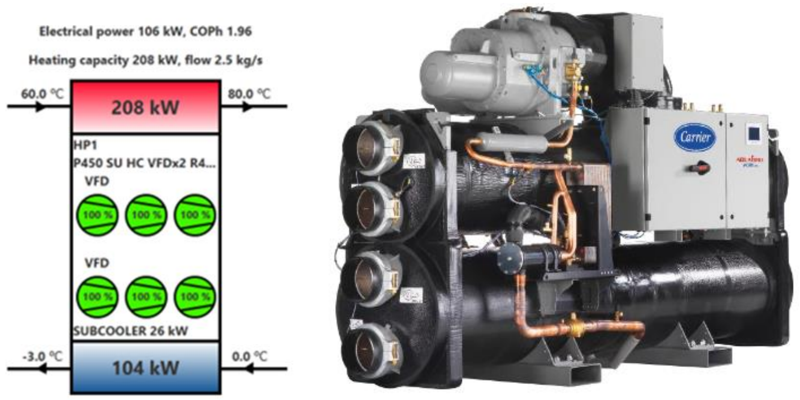


Figure 3 - Typical WSHP

5.4 Electrical Impact of Heat Pumps

The following table shows the increased electrical loads associated with the 3 pathways considered as part of this report.

Building/Area	Pathway 1 - ASHP Electrical Input (based on peak COP of 1.7)	Pathway 2 - WSHP Electrical Input (based on peak COP of 1.96)	Pathway 3 - ASHP Electrical Input (based on peak COP of 1.7)
Hall	193 kW	168 kW	210 kW
Anniversary Building & Pavilion	118 kW	102 kW	128 kW
South & Garden	397 kW	344 kW	567 kW
Christina Barratt & Wolfson	292 kW	254 kW	344 kW
Jacqueline Du Pre Building	20 kW	17 kW	23 kW
Principal's Lodge	21 kW	18 kW	25 kW
Total	**1041 kW**	**903 kW**	**1297 kW**

To serve the above new electrical demands we anticipate the need for two additional sub-stations to be installed on site. A 500kVA transformer situated between the Hall and Anniversary building and a 1000/1500kVA set located at the corner of the South building by the kitchens. As SSE do not like electrical supplies from two sources serving the same building these transformer loads and sizes include for transferring the existing building loads onto them, so the existing five SSE supplies around site can be eventually removed and just left with two.

The 500kVA transformer will serve the Hall Building, Anniversary and Pavilion and will be required whichever pathway is chosen but will have spare capacity in it for any future loads. The anticipated cost for this transformer and associated switch panel would be £170K, once this is in place the works to the individual buildings could be programmed at any time with no SSE involvement.

The 1000 or 1500kVA transformer will serve the remaining buildings on site. If pathways 1 or 2 are chosen then a 1000kVA transformer would be required but if pathway 3 is chosen a 1500kVA transformer would be needed. The 1500kVA transformer is not a regular size for SSE and is only normally allowed for use purely by one customer as this one would be but the decision would be down to the SSE designer. If it is not permitted than two smaller transformers would be required in its place. The anticipated cost for a 1000kVA transformer installation would be £210k and for a 1500kVA transformer £310k, but again like the 500kVA transformer once this work is done the individual building supplies could be carried out at any time.

Depending on legal timescales on getting wayleaves agreed for the sub-station location etc the 500kVA transformer should be able to be installed within 12 months of making an application. The 1000 or 1500kVA units may take a bit longer due to availability of them and the additional loads involved so 18 months should be allowed. But once one or both transformers are installed the works to connect up the buildings and heat pumps can be programmed at any time by the college.

Electrical Infrastructure Cost	Pathway 1 - ASHP Electrical Input (based on peak COP of 1.7)	Pathway 2 - WSHP Electrical Input (based on peak COP of 1.97)	Pathway 3 - ASHP Electrical Input (based on peak COP of 1.7)
Cost £	£635,000	£635,000	£725,000

Note:

- No allowance has been made for any potential off site SSE Infrastructure Upgrades
- Pathway 3 costs assume SSE allow the client to install a 1500kVA transformer, if not then two separate transformers will be required at an extra cost of approximately £150K.
- Trenching costs included in WSHP & ASHP trenching costs as run similar routes.

5.5 Energy Generation Opportunities

Figure 4 - Roof area across the College site for PV deployment

We have analysed potential roof areas for PV at a high level using Google maps. A more accurate survey is needed to establish a firm feasibility figure, but at a strategic level, this calculation will give some guidance as to the scale and significance of solar PV as part of the decarbonisation strategy. We estimate there is around 968m^2 (say 900-1100m^2, given approximations) of suitable South-facing roof within the College campus, and a further 1089m^2 on the immediately adjacent roofs of the Magdalen College School buildings. The latter could potentially be rented from the school, or a joint-venture entered into to share both the cost and benefit of PV energy generation. For our study we have assumed that only the College roof spaces have PV installed, but would recommend opening up conversations with the School. Given the heritage status of many of the College buildings, and the sensitivity of the site position, there may be significant parts of the roof area that are technically feasible for PV, but not possible to utilise. This will have to be investigated on a case-by-case basis in discussion with Planners and in particular the Conservation Officer.

For the purpose of estimating savings as part of Pathways 1, 2 and 3, we have assumed a reduced roof area across the College of around 950m^2, comprising around 400m^2 on low-risk College roofs, and a 500m^2 share of output from the rooftops of the neighbouring school. This is labelled ‘Option D’ in the following table. The total output of the system per year would be in the region of 145,000 kWh. Based on current consumption without retrofit measures, this would account for 15% of College electrical energy use, or 4% of total site energy use today. Under Pathway 2, this percentage would rise to nearly 10% by 2030.

	Indicative Risk rating	A: maximum PV (WSHP)	B: pragmatic PV (ASHP)	C: shared PV (WSHP)	D: shared PV (ASHP)
Building	(1 = high likelihood/low risk, 5 = very low likelihood)	m^2 of roof area			
St. Hilda’s College Hall	5	60	0	60	0
Anniversary Building	5	159	0	159	0
Pavilion	3	81	0	81	0
South Building	5	84	0	84	0
Garden Building	2	186	186	186	186
Christina Barratt Building	5	0	0	0	0
Wolfson	2	272	216	272	216
Jacqueline Du Pre Building	4	70	0	70	0
Principal’s Lodge	3	56	0	56	0
MCS roof areas, gross	1	0	0	1089	1089
Sum of areas (50% of shared roof)		**968**	**402**	**1513**	**947**
kWh generated for SHC		**145000**	**60000**	**226000**	**142000**
% of College energy 2022		**4.3%**	**1.8%**	**6.8%**	**4.2%**
% of College energy Pathway 2, 2030		**9.6%**	**4.0%**	**15.0%**	**9.4%**

5.6 Energy Storage

5.6.1 Batteries

Building-integrated battery solutions is a fast developing area of building energy design, and includes a range of technologies, both established and emerging. Lithium Ion batteries, for example, are very similar to those used in electric vehicles, and are available off the shelf from suppliers like Tesla, at a cost.

Electrical energy storage in batteries is not a key enabler of the first 10 years of College decarbonisation, but is very likely to be a part of overall energy strategy over a 10-20 year timescale. Benefits of battery deployment include possible reductions in peak heating plant size or electrical infrastructure, though modest in scale, and more likely, a reduction in utility costs by increasing utilisation of solar output and collection of lower cost night tariff electricity. This is discussed further in the full QODA report.

5.6.2 Thermal/Phase Change Storage

As with electrical energy storage above, thermal energy storage (heat battery) is a fast-emerging technology, but in our opinion is at a lower level of market maturity than electrical energy storage and should therefore be approached with care today. As with electrical energy storage above, thermal energy storage is primarily useful for reducing peak plant size and peak grid load, but can also have advantages when coupled to heat pumps and TOU tariffs.

Reductions in peak power load will need to be assessed as part of detailed design, and we propose a simple metric for this purpose: overall peak site kVA/MVA electrical load, and % of that load that is shifted into an off-peak demand period.

6 Energy & Carbon Analysis

Our analysis above shows that small but worthwhile reductions are possible in site electrical load, and very significant reductions in site thermal load are possible. These, combined with decarbonisation of the source of heat and the decarbonisation of the UK national power grid, should allow the College to move down a pathway towards and eventually past net zero carbon. Generation of solar power by rooftop PV installations can also play a small but significant part – up to about 10% of College energy requirements depending on levels of retrofit.

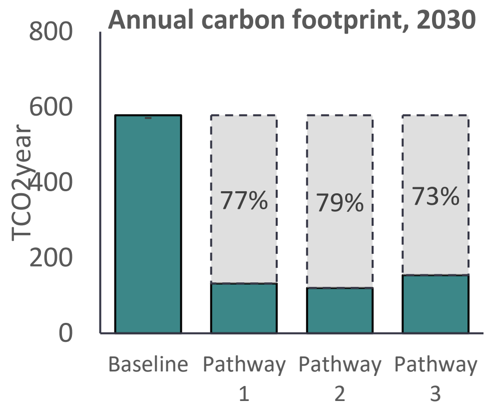
The sections below detail some options for that pathway, and our view on optimal steps to achieve the College objective of zero site carbon by 2030 or as soon as practicable. Each option is built from the energy Baseline of the existing utility bills, and then improved upon using the mix of building improvements that we have proposed for both fabric and services. This could produce an enormous range of options with various permutations and sub-options, so we have deliberately kept the primary options as simple as possible to give clear guidance to the College.

Below we present three options:

Pathway 1: Energy demand reduction as per our proposals above, with air source heat pumps provided locally to each building

Pathway 2: Energy demand reduction as 1., but with site-wide water source heat pump network and air source systems deployed for local top-up where needed

Pathway 3: No energy demand reduction, with high-temperature air source heat pumps provided locally to each building



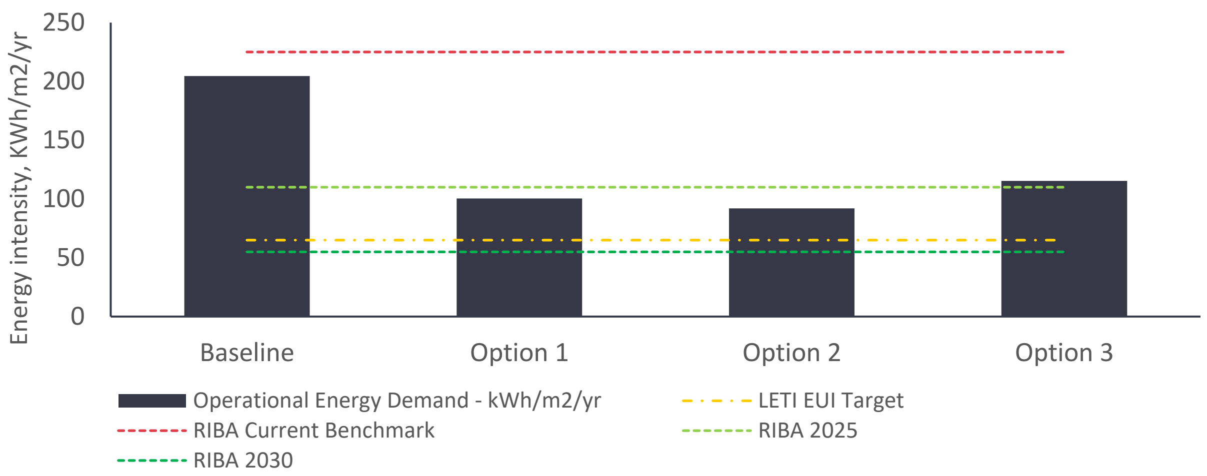


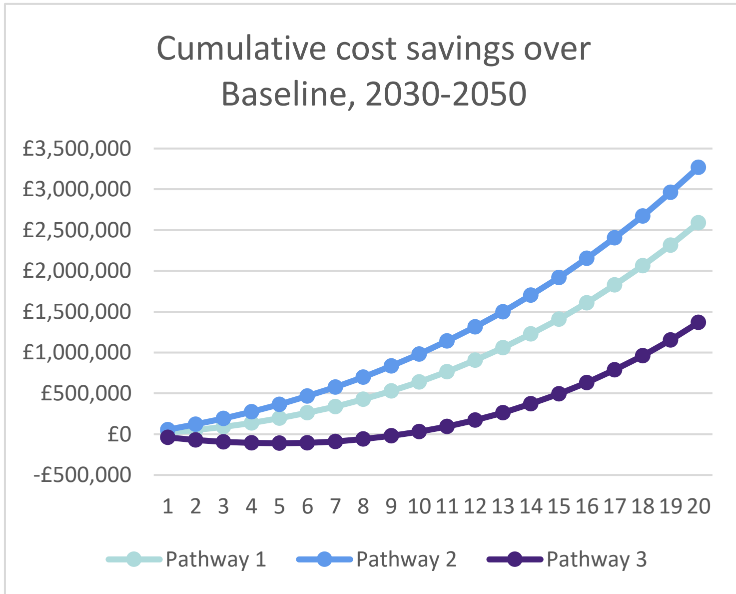
Figure 5 - Site annual CO2e footprint and : Site annual energy intensity against benchmarks, Pathways 1-3

The figures above show that dramatic carbon reductions are possible by 2030, but in no case are the Scope 1 and Scope 2 emissions of the College zero by that date. Reductions in annual footprint vary from 73 to 79%, but do not achieve 100%. This result is consistent with other studies on buildings of similar types, which suggest that net zero carbon on site is not generally possible by 2030 unless a large roof area is available for PV, or if site energy demands can be dramatically minimised (e.g. by construction of a new Passivhaus building). Encouragingly, this does not mean that zero carbon is impossible, but simply that it occurs gradually as the UK national power grid decarbonises. In the case of St. Hilda's, while circa 120 tonnes of CO_2 are still emitted by 2030 under our projections of Pathway 2, this would fall to zero some time in the mid-to-late 2030's depending on grid decarbonisation speed. Strangely, the UK grid is projected to go 'carbon negative' as carbon capture scales up, meaning that the College would hit net zero carbon, and then pass it and become 'carbon negative'.

The above illustrates why our view is that energy intensity is, and will become, a key metric for building environmental performance in addressing the climate emergency. Carbon emissions by themselves are a confusing and contradictory metric in a world where the electricity we consume is carbon negative. By contrast, decreasing energy intensity has benefits for carbon reduction, running costs and grid capacity regardless of carbon intensity at a given time.

6.1 Pathways review

We have proposed Pathways 1, 2 and 3 as ways in which the College could travel towards and ultimately, past, net zero carbon for Scope 1 and 2 emissions. The options, however, are not of equal validity or benefit to the College. A key reason for this is the financial implications of each option. In this strategic review, we don't have access to detailed capital cost comparisons, but we can produce likely running costs based on projections of utility prices in the coming years. The graphs below plot cumulative utility cost across the College site, and cumulative costs over (or under) the current, gas-fired baseline, for the years 2030 to 2050. We have assumed a unit cost of 7p/kWh for gas, and 25p/kWh for electricity in 2030. Fuel price inflation is taken as 5% for gas, and 0% for electricity. The latter is assumed on the basis that a number of sources predict a stabilising of electricity prices once the grid is dominated by renewable energy generation.



The running cost outputs that these calculations show allow us to judge the three proposed options which are:

Pathway 1 and Pathway 3 are the simplest in terms of new heating plant, as local ASHP units need not be linked to each other. There is a significant challenge to this approach in terms of finding space for each ASHP, but most units could be positioned on roof spaces, or concealed at ground level, although this presents challenges in how the ASHPs are sensitively integrated in with the architectural heritage of the site. Pathway 1 has the full range of fabric upgrades discussed above.

Pathway 2 requires a more site-wide investment in heating infrastructure, alongside the fabric upgrades above. This leads to a more holistic outcome, including the capacity to draw heat from the river using the WSHP system. This will likely have the highest Capital Expenditure (Capex) due to the site wide WSHP scheme but lowest Operational Expenditure (Opex) due to the efficiencies of the WSHPs compared to ASHPs.

Pathway 3 is presented as a comparison to Pathways 1 and 2, and is effectively Pathway 1 but with no fabric upgrades. This appears to present the simplest approach. The cost of the heat pump installation and electrical infrastructure is higher than Pathway 1 due to peak and annual loads being higher as a consequence of no fabric upgrades. Conversely, there would be a Capex saving against the fabric upgrades, so overall, this is likely to be the lowest Capex option, but highest Opex.

The utility cost graphs above show clearly that Pathway 2 is the lowest cost over the projected 20 years of operation. In total, it is something like £3.5m lower cost than the gas-fired baseline, but perhaps more significantly, is nearly £2m lower cost than Pathway 3. If electricity prices are higher than our assumptions, then this gap will be even larger. What this means in practice, is that if the capital cost gap between Pathways 2 and 3 is less than £2m, then there is a positive financial position for Pathway 2, when judged over 20 years. Our indicative capital cost figures suggest that the fabric upgrade costs are significantly higher than this. Given that the building envelope upgrades proposed will have a useful life in excess of 60 years in many cases, however, our opinion is still that Pathway 2 presents a better financial case than Pathway 3, unless capital costs prove prohibitive.

It is worth noting that Pathway 3 will require significantly greater heat pump peak capacity than Pathways 1 and 2, and this is likely to lead to higher capital cost for both the provision of heat pumps, and upgrading of electrical infrastructure to supply the heat pumps. We would suggest that detailed costings for these options are developed in parallel with the necessary design work to progress the decarbonisation plan. If fabric retrofit can offset electrical infrastructure upgrade costs, then this would be a much better use of College funds, viewed over longer timescales.

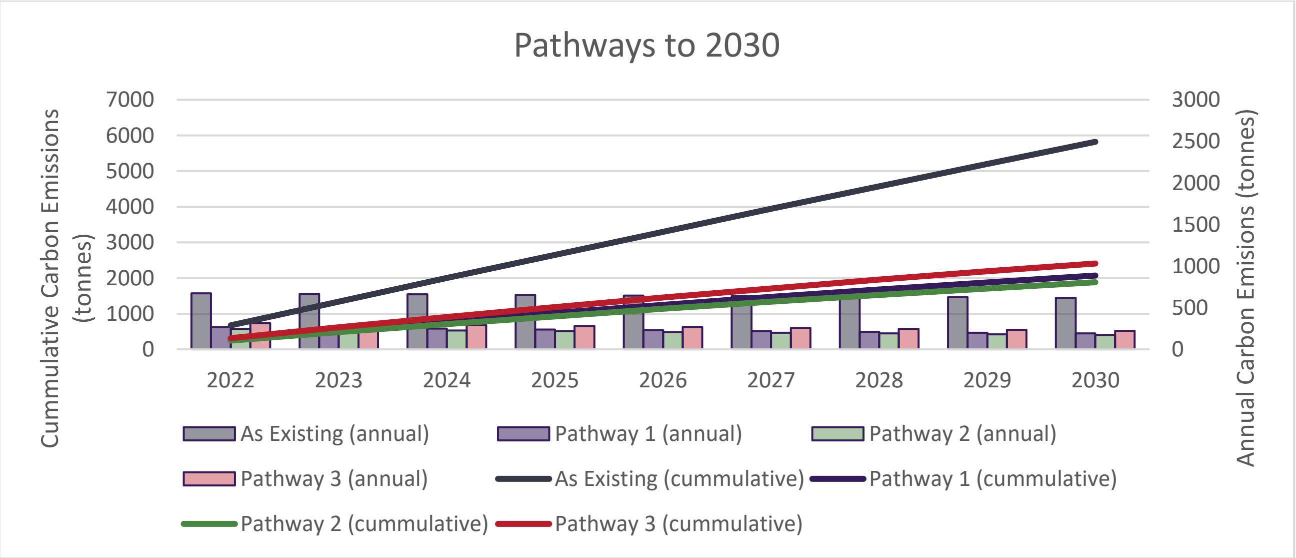


Figure 6 - Pathways to 2030

A final piece of analysis shows the cumulative carbon emissions that result from the baseline building operation, and the three options presented. This shows clearly that urgent action is worthwhile, as carbon emissions immediately decrease when heat pumps and fabric measures are deployed, resulting in a significantly reduced overall carbon footprint. Pragmatically, a phased approach is necessary, and this is dealt with below, but in terms of the zero carbon target, it is right to view this as urgent, and prioritise decarbonisation as fast as is feasible.

7 Phasing Plan

Figure 7 below shows a possible phasing plan, with elements numbered in order of priorities.

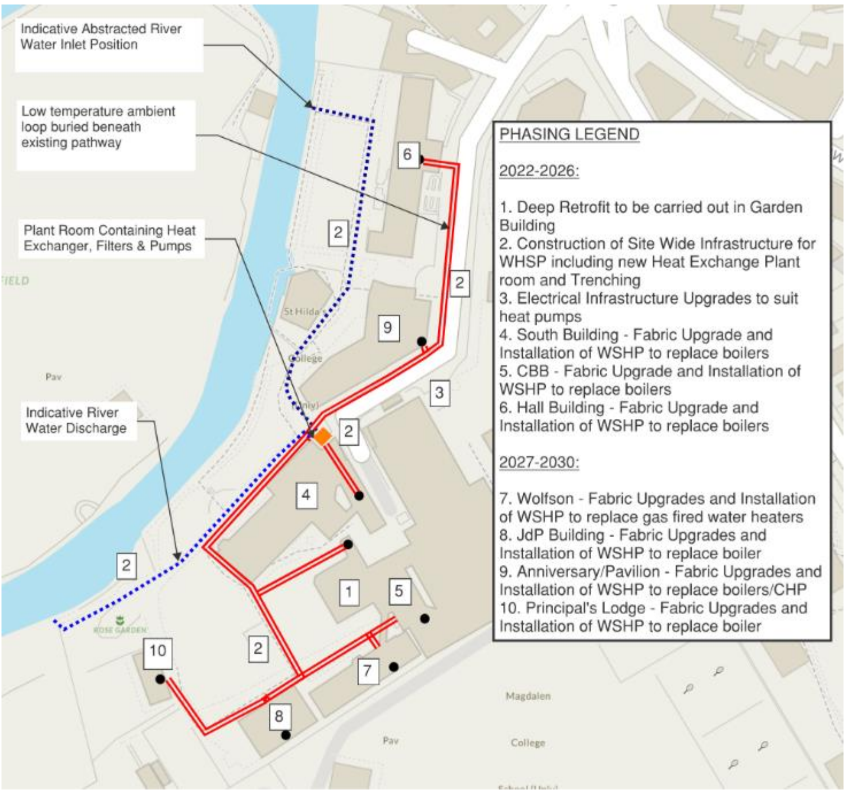


Figure 7 - Proposed Phasing

This highlights that a deep retrofit of the Garden building should be prioritised, along with major plant infrastructure upgrades including:

- Construction of a WSHP or ASHP central plant room
- Install centralised ambient loop pipework to around site with valved and capped terminations ready for future extension into each building
- Electrical infrastructure upgrades required to facilitate new heat pumps.

The proposal after the major infrastructure upgrades is to upgrade the gas fired heating and domestic hot water systems one at a time in order of age of existing installation – i.e. the South, CBB and Hall buildings are the priority, whereas the JdP and in particular the Anniversary/Pavilion and Principal's Lodge can wait due to much newer boiler plant located in those spaces. This allows economic use out of new equipment and reduces wasteful embodied carbon impacts associated with stripping out new equipment. The phased approach also allows budgets to be distributed across multiple years to 2030, although the up-front infrastructure cost will be inevitably higher. Table 6 shows very approximate costs for each area. It should be noted that these are rough area based costs based on previous similar projects, and have not been vetted by a Quantity surveyor. A professional chartered Quantity Surveyor should be appointed to obtain accurate costings for the proposed work.

Table 6 - Indicative Cost Phasing

Year	Area	Pathway 1 - ASHP & Fabric Upgrades	Pathway 2 - WSHP and Fabric Upgrades	Pathway 3 - ASHP Only
1-2	Garden Building Deep Retrofit	£ 1,586,250	£ 1,586,250	£ 222,075
1-2	Trenching & pipework for WSHP	£ -	£ 945,000	£ -
1-2	WSHP Plant Room	£ -	£ 150,000	£ -
1-2	Electrical Infrastructure Upgrades	£ 635,000	£ 635,000	£ 725,000
3	South Building	£ 2,233,000	£ 2,233,000	£ 558,250
3	CBB	£ 930,500	£ 930,500	£ 325,675
4	Hall	£ 1,752,300	£ 1,752,300	£ 681,450
5	Wolfson	£ 1,166,200	£ 1,166,200	£ 291,550
6	JdP	£ 446,600	£ 446,600	£ 111,650
7	Anniversary	£ 440,500	£ 440,500	£ 616,700
8	Principal's Lodge	£ 213,500	£ 213,500	£ 53,375
All	**Total**	**£ 9,403,850**	**£ 10,498,850**	**£ 3,585,725**
Year 1-4	**Total**	**£ 7,137,050**	**£ 8,232,050**	**£ 2,512,450**
Year 5-8	**Total**	**£ 2,266,800**	**£ 2,266,800**	**£ 1,073,275**

8 Conclusions and Recommendation

In this report we have considered the feasibility of reducing operational carbon emissions of the St. Hilda's College Building portfolio in Oxford to zero by 2030. In our survey of the site, and subsequent analysis, we have observed that:

- The buildings have a range of space heating demands, which overall are within the expected range for buildings of these types and ages, but are still the dominant load and source of carbon emissions.
- Buildings in general have energy intensity values roughly in line with industry benchmarks

The buildings on the site vary considerably in their sensitivity in terms of Planning and heritage, as well as the technical feasibility of energy efficiency upgrades. We have therefore structured levels of efficiency retrofit into three broad categories: light, significant, and deep retrofit.

As well as reducing building energy consumption, such measures would reduce the peak size rating of any alternative heat generation such as heat pumps, reducing capital cost, and would also result in improved thermal comfort by reducing cold draughts and exposure to cold surfaces. This in turn may lead to further reductions in space heating demand (set points can be lowered etc). We note also that draughtproofing and window improvements have an additional positive effect on occupant comfort and should therefore be considered seriously and urgently where windows are single glazed or in poor condition.

Existing building services are of varying ages – some are around 20 years old (South, CBB, Hall) and as such need upgrading and replacing, however more recent buildings (such as Anniversary) have efficient building services installed where we identified only minor opportunities for improvement. These improvements will have a small but significant effect on carbon reductions but are still worth pursuing as they potentially reduce the size of renewable energy systems required to get to net zero carbon. Note that here we refer to building services other than boilers, as all boilers will ultimately require retiring, to enable the College to achieve a net zero carbon outcome[2].

A review of renewable energy technologies has identified the following opportunities for the site, in tandem with the energy efficiency steps listed above:

- Ambient-loop district heating – shared site system, with local ASHP[1] to some areas, possibly with an open-loop water source heat pump from the river (Pathway 2)
- Individual ASHP units per building, no district heating (Pathway 1, 3)
- Solar PV on various sections of South-facing College roof space but excluding high-risk roof areas, and allowing for rooftop PV (included in Pathways 1, 2 and 3)
- Solar PV on the adjacent school building roof spaces, shared with or rented from the school (included at 50% in Pathways 1, 2 and 3)

Based on the current peak heating loads with ASHP, the electrical infrastructure will require upgrading in some of the buildings and the overall incoming supply may require upgrading. A further detailed site wide load assessment is recommended for the next design stage.

We have used the above fabric measures and renewable energy options to present 3 site-wide strategies:

1. Energy demand reduction as per our proposals above, with air source heat pumps provided locally to each building
2. Energy demand reduction as 1., but with site-wide water source heat pump network and air source systems deployed for local top-up where needed
3. No energy demand reduction, with high-temperature air source heat pumps provided locally to each building

These strategies were reviewed for cumulative carbon emissions and cumulative running costs, and Pathway 2 was found to save circa £2m over 20 years compared to Pathway 3, with Pathway 1 between these two figures. Given the comfort and durability benefits of the fabric upgrades in Pathway 2, plus the diversity of a site-wide heat network, it is proposed that this Pathway be developed into a detailed design, with Pathway 1 as a fallback/alternative. Only if the fabric upgrades proposed are unreasonably high capital cost should Pathway 3 be considered.

Analysis of the carbon emissions reduction achieved by the various improvement options demonstrates that:

- It is not realistic to achieve zero carbon for the entire site by 2030 because there will continue to be carbon emissions associated with electricity used for heat pumps and appliances, and there is insufficient space available on site for solar PV to offset these emissions in their entirety. Not long after that, however, the UK national grid is predicted to be net zero carbon[3], and shortly after that, the grid carbon factor is predicted to go negative.
- Carbon emissions can in theory be reduced from **around 580 to 120 tonnes** per year through a combination of fabric improvements and site-wide deployment of air and water source heat pumps, both local and shared-network, based on an estimate of the 2030 grid carbon intensity. It should be noted that 80% cuts are anecdotally recognized to be the required level for the built environment to be in line with a 1.5°C climate change outcome, and that the timescale for this is 2025-2035 in developed countries for the majority of buildings[4].
- Given the proximity of the river, and the nature of its use in the summer particularly, an open-loop water source heat pump is proposed for further feasibility investigation, alongside air source heat pumps. Closed-loop heat pumps were discounted due to the likelihood of damage by river users. Similarly, because there is very limited suitable open ground on the site for deployment of ground source heat pumps, these were excluded from the study, but can be investigated as part of more detailed engineering design of heat pump systems. Our view is that water-sourced systems are likely to be more cost effective, however.

[2] See www.endgasnow.uk for a focused explanation on the removal of gas as a heating fuel in the UK

[3] The UK Government announced in their recent Energy Security Strategy that they intend to convert the UK national electricity grid entirely to zero-carbon sources by 2030 British energy security strategy - GOV.UK (www.gov.uk) but our report uses a slightly more conservative value for 2030 electricity carbon intensity

[4] Interpretations of the latest IPCC report 'Climate Change 2022: Mitigation of Climate Change' by their Working Group III (Climate Change 2022: Mitigation of Climate Change (ipcc.ch)) from several media outlets including the Guardian newspaper and Dezeen:
It's over for fossil fuels: IPCC spells out what's needed to avert climate disaster | Climate crisis | The Guardian (ampproject.org)Architecture "lagging behind other sectors" says IPCC climate report author (ampproject.org)
(17) Key takeaways for buildings from the IPCC 6th Assessment Report | LinkedIn

9 Next steps:

1. College decision-makers review QODA proposals and agree the preferred route forward
2. Funding sought for early design and feasibility work
3. Heat sub-metering to be undertaken on heating circuits
4. Individual buildings selected for retrofit measures, and design team(s) appointed to develop detailed designs
5. Engineering feasibility and design of heat pump systems commences in parallel with consultations with external bodies, including, but not limited to:
   a. Early formal consultations with the Environment Agency for WSHP feasibility
   b. Engagement of a WSHP specialist to get site-specific plant selections
   c. Arrangement with SSE to get quotations and lead times for electrical infrastructure upgrades
   d. Annual Monitoring of College-side branch of river Cherwell Flow and Water Temperatures
   e. Planning department
   f. Listed Building Consent, etc.

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