AECOM

Alexandra Park And Palace: Foundations for Renewable Energy

Clean Energy Masterplan

September 2023

Delivering a better world

Quality information

Prepared by	Checked by	Verified by	Approved by
Emily Campbell Energy Engineer James Thorpe Senior Building Performance Engineer Tommy Almond Mechanical Engineer	Rodrigo Matabuena Principal District Heating Consultant	Anthony Riddle Regional Director	Rob Boyer Regional Director

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Prepared for:

Alexandra Park and Palace Charitable Trust and Haringey Council
48 Station Road
N22 7TY
London

By:
AECOM
Aldgate Tower
2 Leman Street, London
E18FA, United Kingdom
aecom.com

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Executive Summary

Low Carbon Heating

A decarbonisation feasibility study and clean energy masterplan have been produced that will provide Alexandra Park and Palace with a clear path to net zero. A review of the energy used on site was conducted, with the total annual gas, electricity and oil usage anticipated summarised in the below table, with the annual carbon emissions.

Zone	Gas Demand (kWh_G)	Electricity Demand (kWh_E)	Oil Demand (kWh_O)	Gas Carbon Consumption ($kgCO_2e$)	Electricity Carbon Consumption ($kgCO_2e$)	Oil Carbon Consumption ($kgCO_2e$)
Main Palace Building	9,100,000	3,900,000	107,000	1,670,000	538,000	19,300
Auxiliary Buildings	158,000	447,000	22,000	29,100	61,700	4,050
Combined Park and Palace Total	**9,260,000**	**4,350,000**	**129,000**	**1,700,000**	**600,000**	**23,400**

About 25% of the areas in the main Palace building are currently unused. The potential additional energy usage of the palace if these areas were reinstated to full use has also been detailed.

Energy efficiency measures have been identified that can reduce energy demand, and low carbon heat and power initiatives have been specified to reduce carbon emissions. Various low carbon heat sources were reviewed, and an appraisal was carried out to identify the most suitable method for Alexandra Palace. Ground Sourced Heat Pumps were found to be the highest scoring option through qualitative and quantitative assessment. Energy calculations and a Techno-Economic Model were used to estimate the energy demand reduction and intervention costs of 20No. long list options. As per the scope of this study interventions were grouped into three distinct packages: bronze, silver, and gold. The packages were determined based on increasing level of ambition in terms of both carbon savings and CAPEX. High level details of each package can be seen below.

Bronze – This provides the lowest carbon reduction that does not meet the decarbonisation targets but provides a “steppingstone” for a slower route to full decarbonisation. The package includes the minimum recommended fabric interventions and a GSHP system in the upper field area, retaining existing gas boilers for resilience.

Silver – This provides a fully electric solution that presents an opportunity for APP to reach net zero by their desired target date. The package includes additional fabric interventions and a GSHP system in the upper field area with electric boilers installed for resilience.

Gold – This also provides a fully electric solution that presents an opportunity for APP to reach net zero by their desired target date with greater carbon savings owning to additional fabric interventions than set out in the silver package, with a larger GSHP system in the upper field area with electric boilers installed for peaking.

The table below shows the CAPEX of each of these packages, and the anticipated carbon savings after a 25-year period. The business cases for each of these packages has been analysed and issued as a separate report and is also included as an appendix. The main outcomes of this report been summarised in the table below.

Package	Bronze	Silver	Gold
CAPEX	£8,510,800	£15,373,000	£16,350,700
Carbon Savings after 25 Years (TCO_2)	17,400	38,200	39,100
Fuel Cost Savings after 25 Years	£516,000	-£847,700	£2,260,000
Social Value	£10,180,000	£12,013,500	£12,247,600

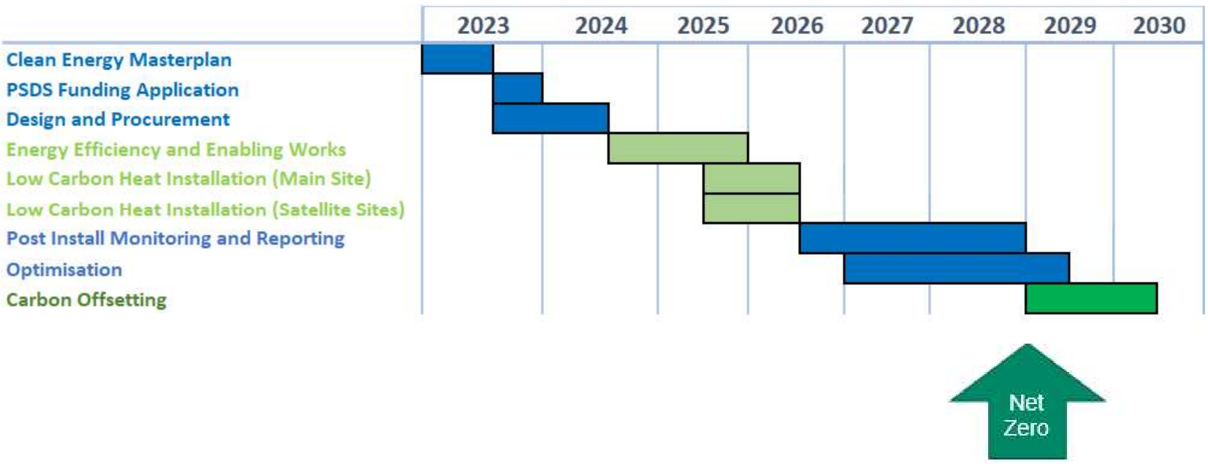
The Public Sector Decarbonisation fund (PSDS) was identified as the most appropriate funding stream for the works set out in this study. The silver and gold packages are both eligible for PSDS funding, whilst the bronze package is not. The bronze package is not eligible due to the retention of the gas boilers for boosting of low temperature heat, peaking, and resilience. More detail on funding opportunities can be found in the mini business case.

Solar PV

A separate solar rooftop feasibility study of the buildings has been carried out within the Alexandra Palace site and includes key considerations, demand and generation analysis, techno-economic analysis, and potential carbon savings available from the roof space present at the palace. The table below summarises cost and generation of PV, using rooftops identified with potential for PV installation.

Cost (£/kWp)	Capital Cost (£)	Operational Cost (£)	Generation (kWh)	Lifetime Avoidance Costs (£)	Simple Payback (years)	NPV (£)	IRR (%)
1600	258,000	4,000	124,128	627,959	15.9	94,000	5.3

Following the analysis of the performance of the packages from a carbon savings and economic perspective, the preferred option for the clean energy masterplan for Alexandra Park and Palace is the **gold package.** The gold package presents the highest fuel cost and carbon savings and is well aligned with Alexandra Palace's ambitious targets. An indicative timeline for the delivery of the preferred package can be seen below:



Please note, since the PV potential is not sufficient to meet the sites electrical demand, especially when considering the increase in electrical requirements from the installation of heat pumps, carbon offsetting will be required to reach net zero by the targeted deadline.

A. Introduction

A.1 Local policy context for Alexandra Palace

In March 2019, Haringey Council declared a climate emergency. Following this declaration, Haringey's Cabinet adopted the Haringey Climate Change Action Plan (CCAP), which sets out ambitious targets to become net zero carbon as a borough by 2041 and as a council by 2027. The Mayor of London has also set a target for London to achieve the same goal by 2030.

APP’s Board of Trustees and Haringey Council seek to tangibly reduce the site’s environmental impact and achieve net zero carbon emissions by 2041 so that its iconic status can be preserved for generations to come.

AECOM were appointed by Alexandra Park and Palace to undertake a decarbonisation feasibility and produce a clean energy masterplan that will provide APP with a clear path to net zero. This project was funded by the Greater London Authorities (GEA) Local Energy Accelerator (LEA) programme. The Park Site Plan depicting the area of this feasibility study can be seen in Figure A-1.

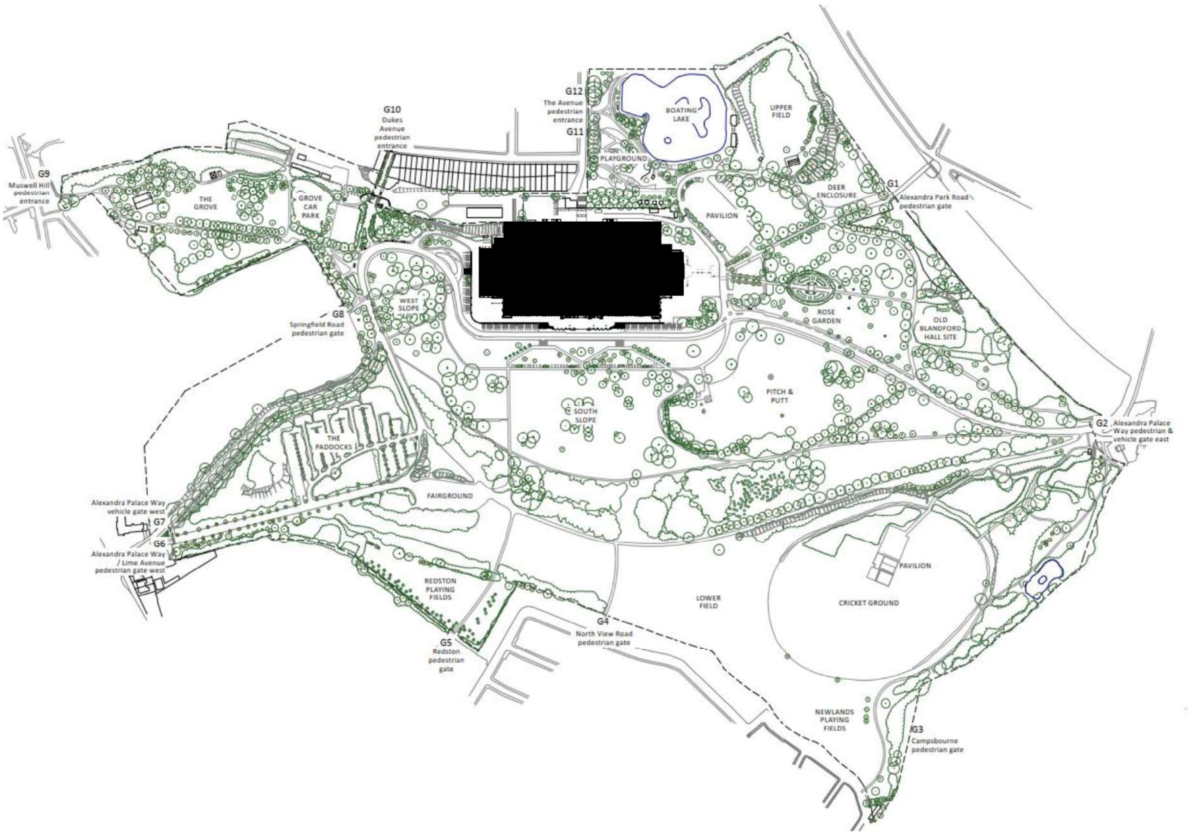


Figure A-1 - Alexandra Park and Palace Whole Site Plan

The study performed a techno-economic analysis on a number of interventions associated with both energy efficiency and generation and grouped them into three distinct packages, bronze, silver, and gold. The packages differ on a basis of carbon savings and CAPEX ambition, with gold having the highest ambition. In line with the outcome of the study and Alexandra Park and Palace’s net zero targets, the gold package was deemed the preferred option. The gold package includes highly ambitious energy efficiency and fabric intervention measures, with a ground source heat pump system extracting heat from the upper field area and electric boilers as peaking and resilience. A summary of the gold package can be seen in Table A-1 below.

Table A-1 Gold package summary

Parameter	Gold Package
CAPEX	£16,350,700
Carbon Savings after 25 Years (TCO_2)	39,100
Fuel Cost Savings after 25 Years	£2,260,000
Social Value	£12,247,600

B. Site Energy and Power Usage

B.1 Information Gathering

Initial information about the site was obtained via an RFI. AECOM worked with the client to identify subsequent data that would assist with the analysis, and this was provided where available. The information gathering process applied was iterative, with a tracker used to maintain regular updates and ensure as much information about the site was included in the assessments that followed.

Where information was not digitally available (for example LTHW plantroom schematics), site visits were carried out to collect this information. Appendix 8 summarises the information that was received/collected and how it was utilised, categorised by the initial queries set out in the RFI.

Table B-1.Summary of Information Gathered

Information Category	Information Received	Subsequent Use
Previous Works	Salix Lighting Project Details, East Wing Regeneration Project Details, Previous Energy Audits	Previous projects and assessments have been taken into account where necessary
Future Renovations	List of potential future renovations and anticipated dates	Used to establish any future energy requirements on site
Energy Usage (Main Site)	Half-Hourly Metered Electricity Data, Monthly Metered Gas Data, Purchased Oil Data	Data used to establish energy demands and profiles for the Main Palace Building
Energy Usage (Auxiliary Sites)	Monthly Metered Electrical Data, Monthly Metered Gas Data, Purchased Gas Data, Purchased Oil Data, Gas and Electricity Bills	Data used to establish energy demands and profiles for the Auxiliary Buildings
Specialist Energy Usage	Drawings and Plant information for the Ice Rink Chiller Plant and Heat Recovery Circuit	Used to understand the Ice Rink system and assess potential for inclusion in proposals
Heating Plant Information	Boiler O&M, Boiler Efficiency	Used to assess Gas consumption
Cooling Plant Information	Ice Rink Cooling Plant and AC Units Maintenance Schedule	Used to understand cooling demand on site and assess potential for inclusion in proposals
Power Generation	Purchased Oil Data	Used to assume oil input and electrical output from generator
Energy Prices	Gas and Electricity supply budgeting information	Data used to establish intervention cost impacts
Other Useful Design Information	Electrical Schematics, Maps and Plans, Room Areas, Events Schedules, Surveys	Information used to gain understanding of the site and assist in development of zoning plan and energy analysis

B.2 Data and gap analysis

The data outlined in Section B.1 was thoroughly analysed, with the quantity, granularity and accuracy of the energy data being assessed. A list of gaps was identified, and appropriate assumptions were made to fill these gaps. The full list of identified gaps and the assumptions made to allow a comprehensive analysis are outlined in the Energy Delivery Strategy report, Appendix 8. Included in this Appendix are the 'Site Energy Maps' showing the understanding of how energy is used at the park and palace, based on the information provided.

Following the initial visit to site and review of the information provided the park and palace have been divided into separate zones for a more fractionated analysis. These zones consist of:

- The 'main' rooms in the palace and their ancillary spaces (aligned to Alexandra Palace's Forward Maintenance Plan Sectors).
- The 11 auxiliary buildings in the park.

Energy data provided was analysed separately for each of the zones identified, with separate energy profiles created for each zone.

B.3 Energy and Carbon Baseline

Following the collection of information outlined in Section B.1, and the resolution of gaps through various assumptions outlined in Section B.2, a thorough analysis was carried out to estimate the current annual energy demands for each of the Main Palace zones and auxiliary buildings. The strategy is outlined in the Energy Delivery Strategy report, Appendix 8.

Table B-2 below shows the results of this analysis, identifying the current estimates for the annual energy and carbon consumption for the palace and auxiliary sites.

Table B-2. Annual Energy and Carbon Consumption by Zone

Zone	Gas Demand (kWh_G)	Electricity Demand (kWh_E)	Oil Demand (kWh_O)	Gas Carbon Consumption ($kgCO_2e$)	Electricity Carbon Consumption ($kgCO_2e$)	Oil Carbon Consumption ($kgCO_2e$)
Palm Court (Including B&K Servery, Londesborough Room)	860,000	176,000	0	158,000	24,900	0
West Hall	1,160,000	424,000	0	214,000	59,800	0
North West Hall & West Yard (Including Roman Bar, NW Tower)	1,780,000	531,000	0	327,000	75,000	0
South West Tower	0	0	0	0	0	0
SW Wing – Panorama Room	202,000	59,200	65,000	37,200	8,360	12,000
Great Hall	2,430,000	892,000	0	447,000	126,000	0
Ice Rink	1,060,000	378,000	0	195,000	53,400	0
Theatre (Including NE Tower)	556,000	636,000	0	102,000	89,800	0
TV Studios & TV Tower (Formerly BBC Studios and BBC Tower)	195,000	266,000	0	35,900	36,700	0
East Court (Including NE & SE Pavilions, NE & SE OBs)	192,000	286,000	0	35,400	40,300	0
Main Kitchen & Plantrooms	662,000*	119,000	0	121,000	16,800	0
South Basement	7,180	1,500	0	1,320	211	0
Pavilion Bunker (Including Ski Slope, Pitch and Putt & Playground)	0	49,500	0	0	6,980	0

Zone	Gas Demand (kWh_G)	Electricity Demand (kWh_E)	Oil Demand (kWh_O)	Gas Carbon Consumption ($kgCO_2e$)	Electricity Carbon Consumption ($kgCO_2e$)	Oil Carbon Consumption ($kgCO_2e$)
Main Palace Building Total	**9,100,000**	**3,900,000**	**107,000****	**1,670,000**	**538,000**	**19,300****
Little Dino Workshop	0	37,000	0	0	5,110	0
Grove Bunker Main	0	22,000	0	0	3,040	0
Lakeside Café / Go Ape	0	96,000	0	0	13,200	0
Unmetered Outside Lights	0	150,000	0	0	20,700	0
Garden Centre	128,000	89,000	0	23,600	12,300	0
Cricket Club	1,400*	15,000	22,000	258	2,070	4,050
Gas Hut (de-energised)	0	0	0	0	0	0
Meeson House	27,000	22,000	0	4,970	3,040	0
Paddock Pumphouse	0	1,400	0	0	193	0
Grove Café	1,600*	8,000	0	294	1,100	0
Campsbourne Centre	0	7,000	0	0	966	0
Auxiliary Buildings Total	**158,000**	**447,000**	**22,000**	**29,100**	**61,700**	**4,050**
Combined Park and Palace Total	**9,260,000**	**4,350,000**	**129,000**	**1,700,000**	**600,000**	**23,400**

*Gas figures identified include gas demand from catering requirements.

**There is an estimated additional 42,000kWh (4,000 litres) of oil demand for 'general' use on site, this is used for site vehicles (MEWPs, Forklifts etc) and to supply the diesel generator.

B.4 Profiling

The annual electricity and gas demands established in Section B.3 were subsequently used to create hourly profiles: estimates that determine the energy demand for every hour in an anticipated year on site. These profiles were created using benchmarked profiles combined with the understanding of the use of each zone on site. Heat demand profiles were created assuming a gas boiler efficiency of 92%.

There were 7 different profiles applied to the various zones. Table B-3 shows the profile types that were used, and the zones to which they applied. The complete description of the profiles and associated energy usage is outlined in the Energy Delivery Strategy report, Appendix 8.

Table B-3. Profile Types Associated to Main Palace and Auxiliary Building Zones

Profile Type	Zone
Cultural Activities: General Public Spaces	Panorama Room, Palm Court, Meeson House, Campsbourne Centre
Entertainment Halls: Leisure Halls and Spaces	West Hall, North West Hall, Great Hall, Theatre, East Court, Dino Workshop, Grove Bunker Main, Lakeside Café / Go Ape
General Spaces: Circulation	SW Tower, South Basement, Paddock Pumphouse
Sport Centre (no pool): Activity Spaces	Ice Rink, Pavilion Bunker, Cricket Club
Restaurant: Main Kitchen	Main Kitchen, Grove Café
Office Spaces	TV Tower & TV Studios
Garden Centre	Garden Centre

Using the established profiles, the peak loading requirements for the site were identified, and used to estimate the required size / capacity of any interventions proposed. The peak electricity demand for the whole site is estimated to be 1380kW, whilst the estimated peak heat demand is 4830kW. These profiles allowed a better understanding of the impact of any interventions that are discussed in Section D.

B.5 Future Energy Use

The Main Palace Building contains a number of derelict and semi derelict areas which have been assessed to establish energy demands for any refurbishment to these areas. The method of analysis is outlined in the Energy Delivery Strategy report, Appendix 8. Alongside refurbishment of existing derelict spaces, the energy use of future planned new developments and changes have been anticipated, following development intentions being outlined at the information gathering stage. Table B-4 shows the spaces, their potential refurbishment types and the estimated impact on annual energy demand.

Table B-4. Potential Future Energy Demand Changes

Zone	Development Description	Annual Additional Heat Demand (kWh)	Annual Additional Electricity Demand (kWh)	Estimated Year of Completion
North West Hall & West Yard (Including Roman Bar, NW Tower)	Refurbish derelict spaces	39,100	13,000	-
South West Tower	Refurbish derelict spaces	11,200	2,600	-
SW Wing – Panorama Room	New Multi Storey Building to Replace Panorama Room	492,000	160,000	2025/2026
TV Studios & TV Tower	Refurbish derelict spaces	359,000	265,000	-
East Court (Including NE & SE Pavilions, NE & SE OBs)	North East Offices Refurbishment (Workspace and Small Café)	71,600	16,200	2025
South Basement	Refurbish derelict spaces	433,000	101,000	-
Campsbourne Centre	New Community Hub Building	74,400	57,100	2025
West Yard	Inclusion of a Production Gallery	-	47,400	-
Combined Total	**-**	**1,480,000**	**662,000**	**-**

The analysis of future energy use does not allow for space cooling to be added to existing spaces if required for occupational comfort. No other future developments have been identified.

If all of the above refurbishments / developments were carried out, it is estimated that there would be an additional annual heat demand of 1,480MWh and annual electrical demand of 662MWh. The estimated completion years are indicated in the above table, with a number of dates unknown / currently unplanned.

The above values provide an indication of what the future demand on the site could be. The interventions and assessments presented in Section D do not reflect any future demand, but the current demand as outlined in Section B.3. The redevelopments that have been presently confirmed are:

- North-East Offices, anticipated completion by December 2025.
- Campsbourne Centre, anticipated completion by April 2025.
- Panorama Room Building Replacement, anticipated completion by 2025/2026.

These would add an estimated annual heat demand of 640MWh and annual electrical demand of 230MWh, see Table B-4. The gas and oil demands outlined in Section B.3 are considered a ‘worst-case’ based on current building heating demand. Alexandra Palace has already improved on this figure by the introduction of new actuation valves, BMS monitoring, and events team reduced heating requests. It is therefore anticipated that the heat demand on which the interventions are based (8,370MWh, Main Palace) will be sufficient to cover the additional demand of the above planned redevelopments. The additional Campsbourne Centre heat demand would be expected to be served via electrical means, as it is currently. Any further redevelopments should be considered separately.

B.6 Next Steps

The quantitative assessment of proposed interventions has been detailed in Section D. In addition to these proposed interventions, there are a number of means of improving data collection and quality that have been identified as a result of the energy analysis. These have been qualitatively explored, alongside actions identified that could potentially reduce energy demand.

- **Additional Heat Metering –** As a minimum, it is recommended that heat meters are included on the LTHW pipework that serves each of the zones identified. These should be linked to the BMS system and read by the BMS regularly. This will allow accurate monitoring of space heating usage, and easy identification of abnormally high loads. The Energy Maps in Appendix 8 show where heat is supplied without meters.
- **Additional Electricity Metering –** There are a number of electrical supplies shown on the electrical schematics that do not have meters associated with them. These should be included and linked to the BMS system and read by the BMS regularly. This will allow accurate monitoring of electricity usage, and easy identification of abnormally high loads. The Energy Maps in Appendix 8 show where electricity is supplied without meters.
- **Improved Metering Data Collection –** Currently, metered gas and electricity data is recorded manually monthly and input into a spreadsheet. Meters should be linked to the BMS and set to take automated readings every half hour. This vastly improved granularity of data will allow for more informed monitoring and potential to more easily identify regular processes that have high energy demands.
- **Night-time Electricity Usage –** There is not a significant reduction in electricity consumption during the unoccupied nighttime hours of the Main Palace Building. The electricity demands during these hours should be reviewed and assessed to ensure that only necessary equipment remains on during these times. A larger reduction would be expected during these hours.
- **Darts World Championships –** The PDC Darts World Championships held annually in December / January brings an additional 12% maximum electrical demand compared to the rest of the year. This suggests this event is using far more power than other events during the year. It is suggested that the reasons behind this are identified, and consumption reduced where possible. Equipment used by PDC to host the event (plug in lights, coolers etc) should be reviewed to ensure efficiency if possible.
- **BMS scheduling –** It is understood that the BMS is monitored and maintained by the site team, with the scheduling for heating being reviewed. It is recommended that this process is continued and the BMS scheduling is regularly reviewed in line with site use, especially following any potential change to usage patterns and the introduction of heat pump technology. This will ensure that the heating systems are operated in an optimal way to suit heat pump performance efficiency and are not used for more time than is necessary which could prevent routine heating of spaces at unnecessary times of day.
- **Promoting Green Initiatives and Strategies –** Alexandra Palace currently has a number of green initiatives in place, targeting energy reductions through conscious use of the palace and an appreciation of where every day changes can be made. Continuing to promote and highlight these strategies to staff and visitors will reduce the energy demand of the site.

C. Current Asset Condition

C.1 Fabric and constraints

A Condition Survey and Fabric Maintenance Plan was conducted by Purcell in 2014 that included a full inspection of the building fabric and preparation of a maintenance plan. The recommendations in this document remain valid and should be implemented if not already undertaken.

The process of decarbonisation should use a ‘fabric first’ approach to achieve lasting reliability and value. This means that energy demand is reduced before the remaining energy supply is switched to a low carbon source.

The listed status of the building brings limitations to the extent of fabric enhancements. However, improvements to aspects such as the air tightness of the building should be a priority, for example gaps around windows and leaks in roofs were found by AECOM during a non-invasive site inspection. These points of air leakage contribute significantly to the heat loss as well as energy costs and sealing these wouldn’t compromise the listed status.

C.2 Operational lifespan of building services plant

Assessments of the building services installations were made during various site visits and with references to supporting documents such as Purcell’s Condition Survey and Fabric Maintenance Plan. Selected drawings and technical datasheets were made available from the East Court regeneration in 2017 as well as electrical schematics for the site and a boiler replacement operation and maintenance guide. However, large areas of the building services systems lack documentation and so visual inspections were made, along with feedback from the site engineers.

Much of the plant is beyond its typical lifespan outlined in CIBSE (Chartered Institute of Building Services) Guide M Maintenance Engineering and Management (2014). This can lead to reduction in performance efficiency and even loss of service during failures of systems. Replacement of these components is advised to continue operations without disruption and combining the replacement with upgrades to lower carbon solutions is a useful opportunity.

Maintenance and upkeep of life safety systems should remain the priority, but, as these consume low quantities of energy, they haven’t been the focus of this decarbonisation study.

There are areas of the site where services are new and appear in good condition, such as the East Court and West Yard Building. In addition to this, there have been recent plant replacements such as some of the boilers and actuators. The BMS system is fairly new and has undergone periodic amendments to improve its performance.

In terms of whole life carbon, it doesn’t always make sense to remove plant immediately that is still in working order, even if it consumes fossil fuels, due to the embodied carbon of manufacturing new equipment. This has been considered in the proposals and, for example, is why some gas boilers installed in recent years are proposed to be retained until the end of their lifetime in some scenarios, as discussed in the intervention packages section of this report.

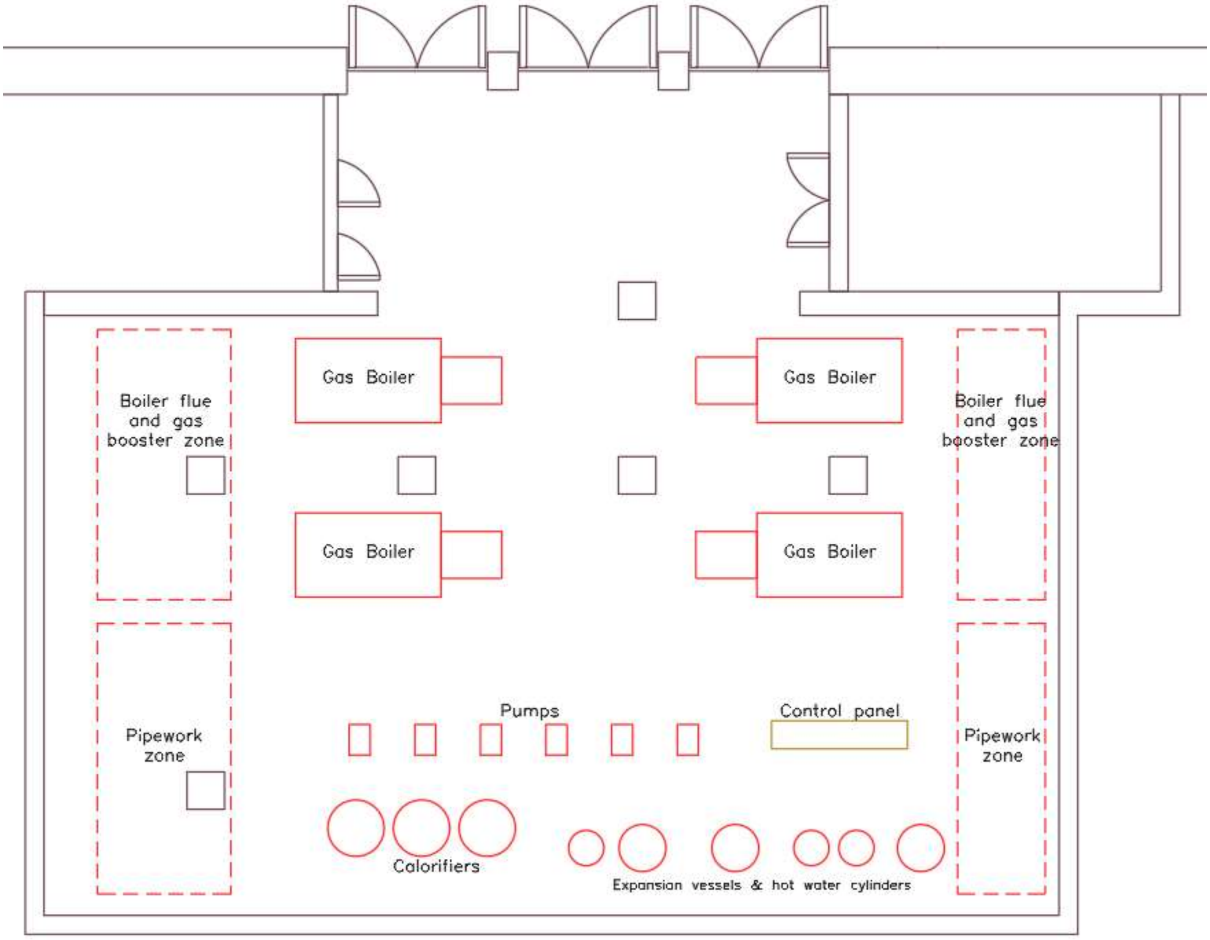


Figure C-1 - Existing boiler plantroom layout sketch

Figure C-2 - Boilers including those that have undergone recent replacement

D. Intervention Measure Assessment

D.1 Methodology

D.1.1 Interventions

To ensure a robust decarbonisation strategy which delivers lasting reliability and value, AECOM have applied a 'fabric first' approach by identifying energy efficiency measures to reduce energy demand before specifying low carbon heat and power initiatives. Energy efficiency upgrades will reduce the amount of heat and power consumed across the site, thereby increasing the proportion of energy which can be met using low and zero carbon technologies.

Once efficiency measures were assessed and the likely energy demand reductions quantified, investigations into how the remaining heat and power consumption could be met by low to zero carbon technologies were carried out.

A long list of solutions was derived, which included established solutions plus emerging technologies / innovative approaches. To identify optimal approaches, feasibility investigations were undertaken. These sought to quantify the technical, economic and operational benefits of each. The results of this feasibility assessment were scored against key metrics and criteria, aligning with Alexandra Palace's net zero goals. This appraisal led to a shortlist of options that were developed in more detail.

D.1.2 Packages

Through assessing the shortlisted options, the proposed interventions were grouped into 3 distinct categories: "bronze", "silver" and "gold" packages. These packages were ranked based on their carbon saving ambition as well as related capital cost. AECOM's methodology for assigning the packages is as follows:

The interventions have been calculated from both a cost and carbon perspective, calculating the simple payback period, lifetime carbon savings, and £/tCO2 saved for each intervention individually.

The **bronze** package does not meet the decarbonisation targets and has the lowest CAPEX.

The **silver** package meets the decarbonisation targets with medium CAPEX heat decarbonisation and medium ambition building level intervention.

The **gold** package meets the decarbonisation targets with high CAPEX heat decarbonisation and high ambition building level interventions.

D.2 Long list of potential energy interventions

D.2.1 Energy Saving Measures

D.2.1.1 Flow Restrictors

Currently the water flow rate from fixtures such as basins and sinks is uncontrolled, which results in high consumption of hot water. It is proposed to fit basins and sinks using hot water with flow restrictors to limit the flow rate to a chosen fixed value. The appliances fed from the gas boilers have been prioritised here as the carbon savings aren't as cost-effective for the direct electric systems. The sinks and basins are proposed to be limited to 6l/min. An estimate of the quantity required was made for the energy and cost calculations in this study.

Flow Rate	Colour Code (15mm)
2 l/m	Olive
4 l/m	Pink
6 l/m	Grey
8 l/m	White
10 l/m	Yellow
12 l/m	Brown
15 l/m	Blue
18 l/m	Green

Figure D-1 - Example of an inline flow restrictor and optional flow rates with replaceable insert

Opportunity #1: Flow restrictors			**Implementation Year: 2024**
Gas saving	**Electricity saving**	**CO_2e reduction**	**Capital cost per lifetime CO_2e saving**
122,173 kWh / yr	N/A	22,516 $kgCO_2e$ / yr	£10 / tCO_2

D.2.1.2 LEDs

The majority of light fittings in the Palace have been replaced with LEDs already. An assumption has been made of the amount of lighting that are still awaiting an upgrade to LED based on the site surveys, such as those in the corridors. It is recommended for all levels of retrofit that any remaining light fixtures are upgraded to LED. The cost of this energy saving measure is low and the installation is both quick and relatively simple.

Figure D-2 - Some fluorescent light fittings still await an upgrade to LED

Opportunity #2: LEDs			**Implementation Year: 2025**
Gas saving	**Electricity saving**	**CO_2e reduction**	**Capital cost per lifetime CO_2e saving**
N/A	36,442 kWh / yr	5,043 $kgCO_2e$ / yr	£61 / tCO_2

D.2.1.3 Lighting controls

Effective control of lighting systems can save significant amounts of energy. Typical methods of these include those based on sensors which detect natural daylight levels or detect the presence of occupants. A couple have been analysed here where specific issues were detected on the site surveys, but further investigation may find additional spaces where these measures could be implemented.

The lighting in the West Hall is reported to be on 24/7. This is wasteful as the space is often unoccupied. It's another factor contributing to the high overnight energy usage of the site. Installing presence detectors such as PIR (passive infrared) sensors and assigning a schedule linked to the BMS would enable the lights to be off out of hours, but to switch on if anyone entered the room.

Figure D-3 - West Hall lighting

Opportunity #3: Lighting controls			Implementation Year: 2025
Gas saving	Electricity saving	CO_2e reduction	Capital cost per lifetime CO_2e saving
N/A	70,640 kWh / yr	9,775 $kgCO_2e$ / yr	£227 / tCO_2

The lighting in the Great Hall remains on even during bright, sunny days, such as that photographed in a site survey below. There are a lot of light fittings in the Great Hall, with a high energy usage, so any period where these could be turned off or dimmed would make a significant saving. Daylight sensors could be located around the space in key locations to send signals via the BMS to control the lighting levels.

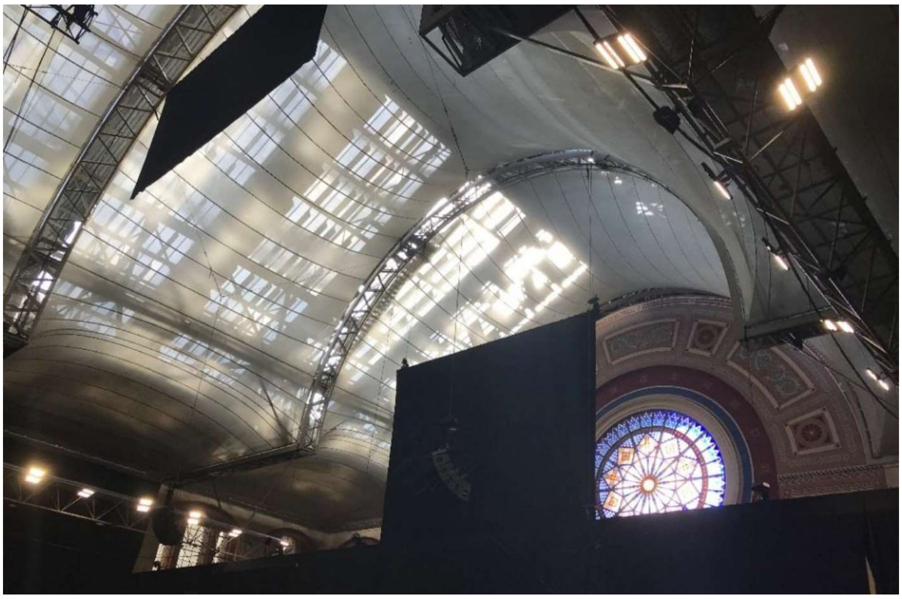


Figure D-4 - Great Hall lighting

Opportunity #4: Daylight controls			Implementation Year: 2025
Gas saving	Electricity saving	CO_2e reduction	Capital cost per lifetime CO_2e saving
N/A	160,834 kWh / yr	22,256 kgCO_2e / yr	£182 / tCO_2

D.2.1.4 Destratification fans

Alexandra Palace has two rooms in particular that have high heat loss through large, glazed roofs: the East Court and the Palm Court. Both feature underfloor heating, which condition the occupied level to the desired temperature. However, this heat rises through stratification and is lost through the uninsulated roof. This effect is less in the Great Hall where mechanical ventilation from high level creates air movement to reduce this process.

Destratification fans are a cheap way to reduce heat loss through the roof without installing a full mechanical ventilation system or altering the roof itself. Fans hang from the roof or are mounted to the wall. These recirculate the warm air back down to floor level.

As well as reducing heat loss, the fans would have the added bonus of improving occupant comfort through a more even temperature distribution and by assisting with alleviating summer overheating.

Figure D-5 - Destratification fan example by Airius Europe Ltd.

Due to the Listed status of the building, fans would have to be selected to suit the aesthetics of the space and located in a position that's not deemed too visually intrusive. Airius Europe Ltd have provided a selection that would involve nine fans in the East Court and nine fans in the Palm Court. Ideally, they would be hung from the ceiling but, due to the visual impact, this has been avoided and the fans are proposed to sit at the highest point possible on the wall construction. This leads to a slight drop in effectiveness, but this has been accounted for in the calculations and still provides a significant energy saving.

Opportunity #5: Destratification fans			Implementation Year: 2026
Gas saving	**Electricity saving**	**CO_2e reduction**	**Capital cost per lifetime CO_2e saving**
98,560 kWh / yr	N/A	17,642 kgCO_2e / yr	£929 / tCO_2

D.2.1.5 Air curtains

In each of the large halls, big entrance doors open to the space. We have been informed that these are often left open when visitors are entering, even during the winter. These contribute a large portion to the heat loss and therefore the gas consumption.

Air curtains blow a stream of warm air across the opening, which reduces the amount of air passing in and out through the door. The heat has been assumed to come from the central heating plant in this case but could be direct electric depending on the distance from existing pipework distribution.

The air curtain would likely need to be concealed due to the listed status of the halls in which they'd be installed. There are more visually aesthetic models available, or the equipment could be 'boxed in' to hide it from view.

A similar outcome for the rear doors used by events staff to load equipment would be to install fast-acting shutters. Again, these would reduce the heat loss from conditioned air leaving the space by limiting the door opening time.

Opportunity #6: Air curtains			Implementation Year: 2026
Gas saving	**Electricity saving**	**CO_2e reduction**	**Capital cost per lifetime CO_2e saving**
141,187 kWh / yr	-1,248 kWh / yr	25,848 kgCO_2e / yr	£25 / tCO_2

D.2.1.6 Improved heating distribution

Due to the high temperatures of the current heating system, a lot of heat is lost from the distribution of low temperature hot water (LTHW). This is worsened by the fact that much of the pipework insulation is in poor condition. This is particularly evident in the boiler plantroom and the pipes serving rooftop AHUs.

Figure D-6 - Damaged pipework insulation

These pipes that run through unheated spaces, such as those in Figure D-6 are the most urgent to rectify as the rate of heat loss is greatest. There are also examples of heating pipework without any insulation at all, such as that pictured in Figure D-7.

Figure D-7 - Uninsulated pipework

Sections of the heating pipework would be difficult to access and replacing the insulation of the entire network would be a costly and invasive process. Therefore, different levels of insulation retrofit have been considered in the proposals, with urgent fixes included in all proposals, but total replacement limited to the silver and gold packages.

For the silver and gold packages, the distribution temperatures would be dropped to further reduce the heat losses and improve the efficiency of the heat pumps. Flow and return temperatures of 60 and 40 °C have been proposed, subject to further assessment. To achieve this, full pipework replacement is likely to be necessary, which was recommended already in Purcell's Condition Survey and Fabric Maintenance Plan due to the ageing pipework. This proposal also takes into account changes to the heat emitters. For example, larger radiators or those with different materials or increased surface area are likely to be needed to match the existing heat emittance, although further analysis of each area may find some can be retained. AHU coils may need to be replaced. The AHU manufacturer would need to be consulted, but this is usually possible to change within the current unit. The underfloor heating should require minimal change as it already runs at lower temperatures.

Opportunity #7: Complete heating pipework replacement with reduced temps			Implementation Year: 2027
Gas saving	Electricity saving	CO_2e reduction	Capital cost per lifetime CO_2e saving
2,015,360 kWh / yr	N/A	371,432 kgCO_2e / yr	£683 / tCO_2

D.2.1.7 Variable speed pumps

The Palace heating system is driven by 6 No. belt driven end suction pumps, running in parallel. The pumps currently operate at constant speed. This is one of the contributors to the high energy usage in the building on off peak periods, including during the night when the site is largely unoccupied.

Figure D-8 - Heating circulation pumps in Boiler plantroom

Replacing these pumps with variable speed models with frequency inverters to modulate their flow would save energy when space heating demand is low. Rather than operating at fixed speed, the pumps would ramp down and reduce their power consumption to follow the demand. Pressure balancing valves within the distribution network would be required to balance the flow.

Opportunity #8: Variable speed pumps			Implementation Year: 2027
Gas saving	Electricity saving	CO_2e reduction	Capital cost per lifetime CO_2e saving
N/A	176,030 kWh / yr	24,358 kgCO_2e / yr	£121 / tCO_2

D.2.2 Interventions not proposed

A wide range of measures were considered, but not proposed for a variety of reasons, including cost, complexity, building aesthetics and occupant disruption. A selection of these are discussed below.

D.2.2.1 Mechanical ventilation changes

The majority of the mechanical ventilation systems in the building already incorporate heat recovery. For the limited air handling units that don't feature any heat recovery, such as on the east roof, the plant space is very limited and the opportunity for significant improvement is constrained. The ventilation is largely already demand-controlled based on carbon dioxide levels from sensors within the space and the running times are scheduled by the BMS.

D.2.2.2 Mechanical cooling

There are small existing cooling systems in the palace. Most of these are isolated DX systems serving office areas. It would be possible to link these to the central heat pump system to recover waste heat, but the loads are small and the distances involved in linking them are vast, making the cost prohibitive. They are powered by electric, so the need to change system isn't as essential as for the heating. Similar principles apply to the unused chiller on the eastern roof, where waste heat could be recovered, but the loads are low and this is not expected to be financially advantageous.

If additional cooling were desired in the future by the client to improve occupant comfort, then the proposed central heat pump plant could potentially be configured to achieve this, providing a relatively cost-effective solution and one with increased overall efficiency. However, overall energy use would increase as a result of the introduction of mechanical cooling, and a large capital outlay would be required for buffer vessels, pumps, pipework distribution and ancillary equipment.

D.2.2.3 CO_2 heat pumps

Heat pumps using carbon dioxide as a refrigerant gas are generally more efficient and less harmful than most of their competitors if used to feed a hot water system. They are not suitable for serving a traditional space heating network. In the Palace, some of the hot water is generated by point of use electric heaters, with the remainder from the central boilers. These widely spread locations would lead to high distribution losses and there is little roof space available to locate the plant. A localised application to serve the load supplied by the calorifiers would be technically feasible but unlikely to provide adequate payback over the alternative of supplying this via the proposed main heat pump installation.

D.2.2.4 Solar thermal

There is limited roof space available on the palace roof and the little that is available has been deemed more cost-effective to be used for solar PV rather than solar thermal or solar PVT.

D.2.2.5 Wind turbines

Although there is predictability on the average year-round generation from a wind turbine, it is a technology that is considered as an intermittent source of power. Therefore, the cost effectiveness of a wind turbine would depend on the ability of the site to consume most of the power locally and avoid exporting power to the grid.
Given the variability of the power consumption at the palace, it would be difficult to match it width wind power generation.
Moreover, installing a wind turbine on the rooftop of the main building of the palace, would face serious planning challenges. The limited space available within the main building would also significantly limit the capacity of the wind turbine that could be installed.
Therefore, even with planning consent granted, it is likely that only a small wind turbine (5kW – 10kW) could be installed. A system this size is not deem feasible as the value of the power generated would not compensate the overall maintenance and operation cost of the system.

It's also unlikely that a larger wind turbine could be installed elsewhere in the park on a scale that would become cost-effective in comparison to other low-carbon energy options.

D.2.2.6 Revolving doors / lobbies

Creating an air lock between the internal and external spaces in the main halls by installing revolving doors or functional lobbies would be a more effective method than air curtains at reducing heat loss through the doors. However, the listed status of these rooms means that architectural changes to the entrance areas of this scale could be a barrier. However, this could potentially be overcome with follow up expert advice and engagement with the Local Planning Authority.

D.2.2.7 BMS upgrades

The BMS system has recently been upgraded and ongoing changes are being made to its operations. It's possible that an upgrade could be made in the future, but progress has been proven on site by energy use reductions so it's worth continuing this process rather than starting again from scratch.

D.3 Low Carbon Heating

Heating related carbon emissions make up a large proportion of Alexandra Palace's total emissions due to the majority of the site's heating being supplied through gas fired means.

As mentioned in Appendix 8, the main heating system supplying the palace comprises of 4 x 1.3MW gas fired boilers, giving the palace a total space heating and domestic hot water installed capacity of 5.2MW. Several of the satellite sites within the park, namely, the Garden Centre, Meeson House, and the Cricket Club, are centrally heated by gas or oil. The remaining satellite sites are heated by electrical means.

Due to an increasing proportion of renewable energy generation supplying the UK electrical grid, the carbon factor of electricity supplied from the grid is set to decrease over the next 20 years. Figure D-9 below shows the estimated carbon intensity of gas and electricity over time, as provided by DESNZ.

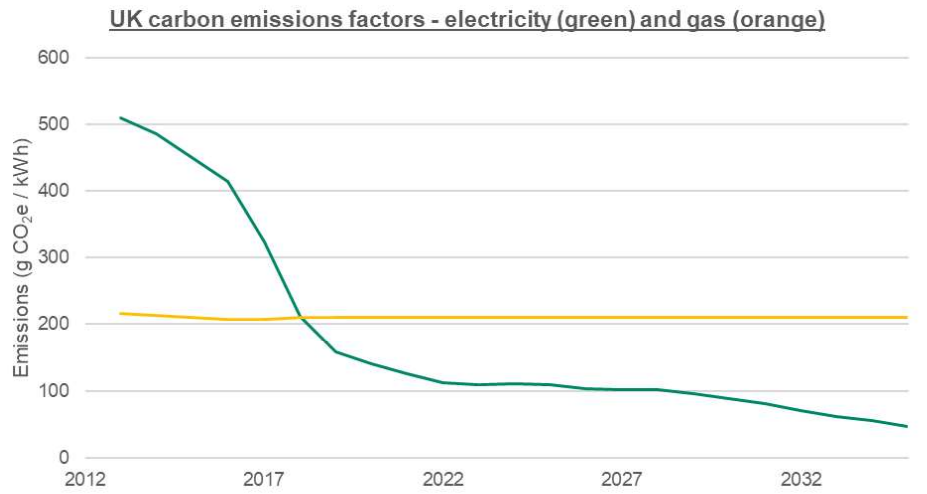


Figure D-9 - DESNZ reduction in carbon intensity of gas and electricity over time

Figure D-10 below shows the expected decrease in carbon emissions for Alexandra Palace in the business as usual/do nothing case.

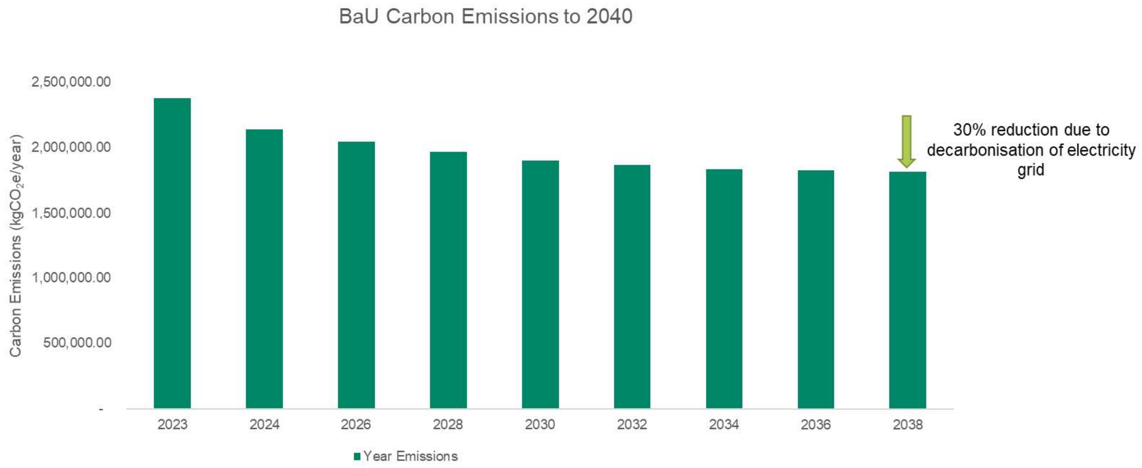


Figure D-10 - Alexandra Palace reduction in carbon emissions, Business as Usual

Due to this reduction in carbon emissions, the government's key strategies for decarbonising heat in businesses and homes is the electrification of heat either through on-site heat pumps or district heating connections. It is important to note that the pace at which the national grid is decarbonising would impact on the ability of the Palace to materialise the carbon savings. A lower-than-expected pace in decarbonisation, would inevitably delay the carbon savings.

Heat pumps are a popular choice for the decarbonisation of heat due to their high efficiencies and lower capital outlay in many situations. Heat pump efficiency is referred to as: SCoP (seasonal coefficient of performance) for heating and EER (seasonal energy efficiency ratio) for cooling. These are typically around:

- 2.5 – 3.0 for ASHP (air source heat pumps)
- 3.0 – 3.5 for WSHP (water source heat pumps)
- 3.5 – 4.0 for GSHP (ground source heat pumps)

The following sections will outline the long list of heating LZC interventions and the short list of the technologies most appropriate for the site.

D.3.1 Ground Source Heat Pump

D.3.1.1 Open Loop

Ground Source Heat Pumps operating on an open loop principle draw water from a below ground aquifer and pass the water across a heat exchanger before being reinjected back into the ground. For this, certain hydrogeological conditions need to be met by the site, including the presence of an aquifer of adequate water quality. Open loop systems can cause environmental impacts on the surrounding area and neighbouring sites. Therefore, these systems are subject to regulation by the Environmental Agency and licences and permits are required for water abstraction and discharge.

The feasibility of an open loop system is dependent on the hydrogeological conditions of the site, i.e., if a "productive" aquifer is present. Figure D-11 below shows a map from the DEFRA database highlighting the areas in which an aquifer is present in the region of Alexandra Palace

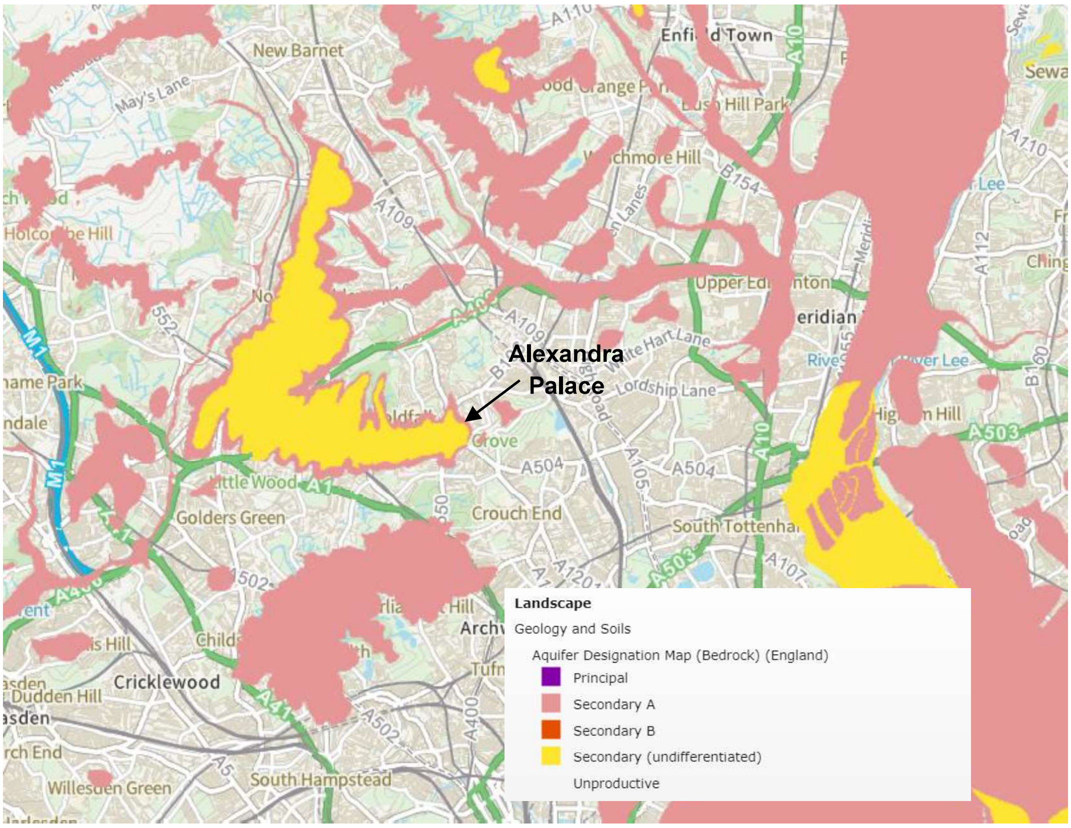


Figure D-11 - Aquifers present in Alexandra Palace region, DEFRA

It can be seen from Figure D-11 that there is no principal aquifer in the region, and the majority of the green space around the palace is characterised as "unproductive". This suggests there is minimal potential for the extraction of heat from an aquifer around APP.

D.3.1.2 Closed Loop

In closed loop systems, a secondary fluid circulates between the ground and the heat pump, enabling the transfer of heat without abstraction of water from the ground. Closed loop systems can be either horizontal or vertical. The former relies on a significant open area of land, in which pipework can be installed in trenches of 1-2 metres deep. Vertical loops can be used where the land area is more constrained and can even be incorporated into the building substructure itself. Boreholes for vertical systems can reach depths of around 200m and are generally more expensive to install than horizontal systems. It is also important to understand the hydrogeological conditions of the site when designing a closed loop system to help achieve optimum system performance. Figure D-12 & Figure D-13 show the physical arrangement of a vertical and horizontal GSHP. Please note, any ground disruption caused by drilling or digging for GSHPs is temporary and the ground can return to usual operation post drilling.

Figure D-13 - Vertical GSHP arrangement

Figure D-12 - Horizontal GSHP arrangement

There is a significant amount of open space within the park and palace grounds that could be utilised for GSHP. Given the scale of the heat demand and the topography of the site, vertical boreholes have been considered as the most appropriate means of extracting heat. Although the open space is significant, there are still constraints that must be considered when evaluating the open space, such as buried utilities and tree roots. It should also be noted that the scope of this study did not include detail thermal modelling of the ground temperatures at the palace, to properly ascertain the potential heat extraction from the identified open spaces it is recommended that ground modelling and test boreholes are carried out in subsequent stages of design development.

Please see 0 for more detail on the open space availability assessment for APP.

D.3.2 Air Source Heat Pump

Air Source Heat Pumps (ASHPs) extract energy from the ambient air and are able to function even when temperatures are as low as -5°C. However, the lower the 'source' temperature, the lower the efficiency of the heat pump. Similarly, the higher the temperature being delivered to a heating network, the lower the efficiency of the heat pump.

To extract energy from the ambient air, a portion of the equipment, the collector coil (which functions as either the evaporator or condenser depending on if the heat pump is in heating or cooling mode respectively) is located externally. This is typically achieved by placing the coils on roof-spaces (which are flat to enable plant access) or at ground level, as illustrated in Figure D-14.

Figure D-14 - Typical ASHP arrangement

Given the listed status of Alexandra Palace, it is important to consider the constraints related to ASHPs; for the purpose of this study, it has been assumed that it would not be possible from a structural and heritage perspective to install ASHP evaporators on the roof, any space assessments for ASHPs have therefore been undertaken assuming installation at ground level. See Appendix 2 for the identified available space for ASHP.

D.3.3 Waste Heat Recovery

D.3.3.1 Ice rink

Through conversations with the client and information gleaned from the site visit, it appears the heat generated from the ice rink cooling process is already being utilised in an underfloor heating system and to melt the ice scraped from the rink. The underfloor heating sits underneath a concrete layer below the ice rink in order to stop the concrete from cracking.

D.3.3.2 Thames Water Hornsey Treatment Works

Located to the east of the Alexandra Park grounds is the Thames Water Hornsey Water Treatment Works. This site treats water from the bore holes and the new river to supply water to around 350,000 homes.

This treatment plant is mainly a chemical treatment site with relatively minor pumping power, this means there is limited potential for extracting waste heat, especially when the losses associated with routing the waste heat to APP (~1.5km away) are considered.

Figure D-15 - Thames Water Hornsey Water Treatment Works

An assessment on the viability of recovering waste heat from the New River was also undertaken. Water Source Heat Pumps (WSHP) systems work on a similar principle to both air source and ground source heat pumps, but source heat from the relatively stable temperatures found in a body of water. Typically flow and temperature data can be found within the National River Archives, however, this was not available for the New River. Thames Water were able to provide a flow rate but not temperatures for the New River. The flowrate provided was $35x10^6$ l/d (35 million litres per day) which translated to around 0.4 m^3/s Assuming 10% of the river water volume is available and a water difference of 3°C, an average extractable water body heat energy of 500 kW is anticipated. Given the distance from APP and infrastructure required, this was not deemed a feasible source of heat for the Palace.

D.3.3.3 Transformer Waste Heat

Due to the nature of transformers, a high load of cooling is required to avoid overheating. Due to this there is the potential to recover heat from the cooling system of the core and windings within the transformer. See Figure D-16 for more details.

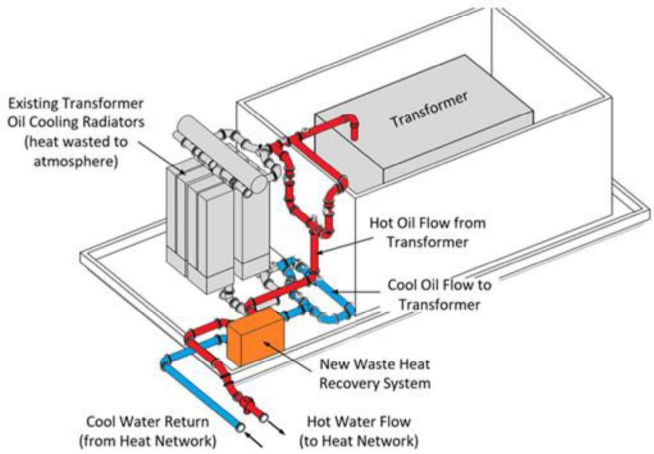


Figure D-16 - Typical transformer waste heat recovery arrangement

The temperature reduction of the core and windings is conducted through forced circulation of a mineral oil through the transformer core, which enters at the bottom and exits at the top. The oil acts as the internal primary cooling medium. The heat extracted by the oil is then passed on (using a heat exchanger) to an external secondary cooling medium e.g. air or water. The secondary medium is then fed into a water source heat pump which upgrades the temperature to fit the heating distribution requirement of the site

Alexandra palace currently has 3 x 1,250VkA of transformers on site. It is possible to achieve SCOPs higher than that of ASHPs from transformer waste heat due to a more constant temperature profile. It was estimated that there is around 300kW of heat available from the current transformers, when comparing to other heat sources such as GSHP this is not overly significant but is not marginal. AECOM are aware that the current transformers have been earmarked for replacement, it is recommended that at the next stage waste heat from transformers remain in consideration as potentially part of the supply mix. Please see Appendix 3 for more details on the assumptions and waste heat availability.

D.3.4 District Heating Connection

Haringey Council are presently developing the Haringey District Energy Network, HDEN. HDEN is a district heating network that aims to deliver low carbon heat to four distinct areas within the London Borough of Haringey, namely Tottenham Hale, North Tottenham, Broadwater Farm and Wood Green. The source of low carbon heat for this network is an energy from waste facility operated by Veolia.

Based on discussions with the London Borough of Haringey (LBH), the HDEN pipework is set to reach Alexandra Park and Palace by 2028, please note this is an indicative timeline and is subject to change. There are significant routing constraints associated with connecting to the palace, such as the crossing of a main railway line and the new river. These costs will likely be absorbed by the heat network owner but may be reflected within the connection charge to APP. LBH are open to negotiations with APP, however, for the purpose of this study a market rate connection fee of £500/kW peak has been assumed. LBH have also disclosed that HDEN will aim to supply 100% of the sites peak demand. Please see Appendix 4 for more further details on the assumptions made in relation to the HDEN connection.

D.3.5 Appraisal

Figure D-17 includes a quantitative appraisal matrix that scores each low carbon heating source/technology against key performance metrics. These performance metrics are bespoke to APPs targets and site-specific constraints, and have been weighted as follows:

Category	Criterion	Relative Importance 1 - 5	Weighting %
Technical	Technology maturity and availability	5	11
	Suitability for scale and profile of heat demand	2	4
	Security of supply	3	7
	Suitability for required supply temperatures	4	9
	Proximity to heat demands	2	4
Environmental	Level of CO_2 emission savings	5	11
	Air quality implications	5	11
	Wider environmental impacts	2	4
Financial	Technology cost	3	7
	Long term financial risks	3	7
Deliverability	Suitability to APP	4	9
	Implications for plant room design	3	7
	Implications for additional space requirements	2	4
	Reliance on third parties	2	4
			100

Category	Name Ref	Option 1 ASHP	Option 2 Open Loop GSHP	Option 3 DHN connection	Option 4 Closed Loop GSHP	Option 5 Waste Heat - Ice Rink	Option 6 Waste Heat - Transformer Room	Option 7 Waste Heat - New River
Technical	Technology maturity and availability	4	2	4	5	5	4	2
	Suitability for scale and profile of heat demand	3	1	4	4	1	3	1
	Security of supply	4	2	4	4	5	4	3
	Suitability for required supply temperatures	4	4	4	4	4	4	4
	Proximity to heat demands	4	1	3	4	5	4	3
Environmental	Level of CO2 emission savings	4	1	4	5	1	1	2
	Air quality implications	5	5	4	5	5	5	4
	Wider environmental impacts	3	3	4	3	4	5	3
Financial	Technology cost	3	2	3	2	4	4	3
	Long term financial risks	4	3	4	4	3	3	1
Deliverability	Suitability to APP	3	1	4	5	1	2	2
	Implications for plant room design	3	4	4	3	2	3	4
	Implications for additional space requirements	3	3	3	3	2	3	3
	Reliance on third parties	5	5	2	5	2	4	2
	Total score (%)	76.00	52.89	75.11	83.56	64.44	68.44	53.78
	Rank	2	7	3	1	5	4	6

Figure D-17 Low carbon heating appraisal matrix

D.3.6 Short List

From the above appraisal, the top 3 ranked LZC heating options are Closed Loop GSHP, ASHP, and District Heating connection. From a desktop space availability assessment, it was found that there is not sufficient space within the main site to employ a fully ASHP solution, however ASHPs have been considered for the satellite sites within the park grounds. More detail on the ASHP assessment can be found in Appendix 5. Therefore, the leading technology for a site level decarbonisation plan is closed loop GSHP, connection to the HDEN has been considered in isolation and will be presented as such.

E. Packages

The following section will outline the intervention methods proposed for each of the packages, as well as highlighting the key performance metrics associated with each. The interventions for the packages have been selected based on the unique conditions of the Palace. A fabric first approach has been followed, considering:

- Heritage constraints
- Specific energy profiles for the site (volatile peaks)
- Space available for low-carbon heat generation

The packages can be summarised as follows:

Bronze – This provides the lowest carbon reduction, including the minimum recommended fabric interventions and a GSHP system in the upper field area, retaining existing gas boilers for resilience.

Silver – This provides a fully electric solution, including additional fabric interventions and a GSHP system in the upper field area with electric boilers installed for resilience.

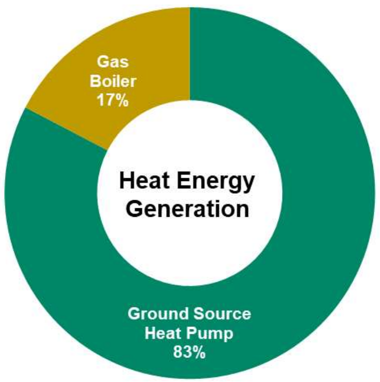
Gold – This solution provides the greatest carbon savings, including additional fabric interventions than set out in the Silver package, with a larger GSHP system in the upper field area with electric boilers installed for peaking.

E.1 Bronze

As per the proposed methodology each package employs a fabric first approach, the proposed fabric/building level interventions can be found in Table E.1.

The low carbon heating proposal for the bronze package is to install a closed loop GSHP system extracting heat from the upper field area only and retain the existing gas boilers for peaking and resilience. This solution partially electrifies the heat delivered to the palace whilst also causing minimal disruption to the grounds. Please see 0 for a site map of the proposed extraction area. Subject to the assumptions outlined in Appendix 1 the proposed extraction area has peak heating potential of ~1,700kW. 1,650kW of installed GSHP capacity is required to meet 83% of the site demand post fabric interventions

Unit	Size	% Contribution
GSHP	1,650kW	77%
Thermal Store[1]	30m3	5%
Gas Boiler	3,000kW (retain existing)	17%



Intervention	Reduction in Gas Consumption (kWh/year) [2]	Reduction in Electricity Consumption (kWh/year)	Annual Fuel Cost Saving (£/year)[3]	Capital Cost of intervention[4] (£)	Lifetime/ Persistence Factor[5]	Carbon Reduction per Year (kgCO2e/year)[6]	Capital Cost per Lifetime CO2e Saving (£/tCO2e)
Flow restrictors	122,173	N/A	7,330	3,300	14	22,516	10
Insulate pipework	172,041	N/A	10,322	71,420	15.2	31,655	148
Variable speed pumps	N/A	176,030	28,164	44,730	15.2	24,358	121
LEDs	N/A	36,442	5,830	7,800	25	5,043	61
Ground Source Heat extracted from upper field only	7,702,000	-1,865,000	163,720	8,080,400	25 years	1,247,070	259

Table E-1 Summary of proposed interventions (Bronze)

[1] The thermal store will provide heat generated by the GSHP
[2] Negative saving indicates an increase in fuel consumption
[3] Negative saving indicates an increase in fuel costs
[4] Including contractors' costs and soft costs, please see the full cost plan in the appendix for more information
[5] As defined by the Public Sector Decarbonisation Scheme Phase 3b
[6] Using Salix PSDS 3b fuel carbon factors)

E.1.1 Energy and Carbon Impact (Bronze)

The change in fuel comsumption with the implementation of the proposed interventions is demonstrated in Figure E-2 below. Post interventions the gas consumption has reduced by 85%, electricity consumption has increased by 32% due to the partial electrification of heat. The total fuel consumption has reduced by around 45%.

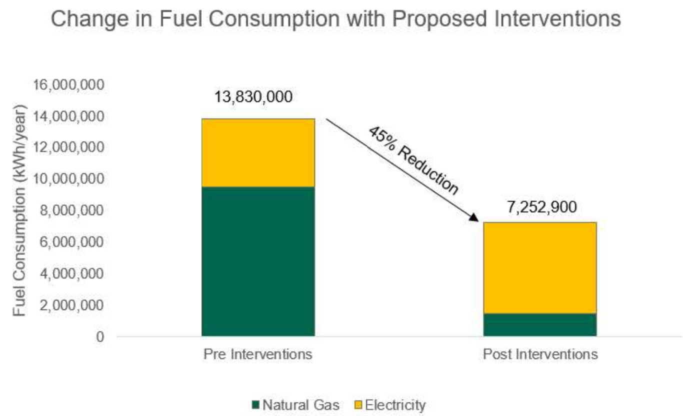


Figure E-2 Graph of fuel consumption post and pre interventions (Bronze)

As per the proposed delivery strategy, the carbon emisisons reductions per intervention can be seen in Figure E-1. This highlights the importance of implementing energy efficiency measures to achieve a new energy baseline of low carbon technologies. The remaining carbon emissions can be attributed to the site's electrical demand and any remaining gas. consumptionfrom the gas boiler top up heating.

Figure E-2 shows the predicted reduction in emissions through to 2040, these predictions are line with the DESNZ carbon factor curves for gas and electricity (found in Appendix 6).

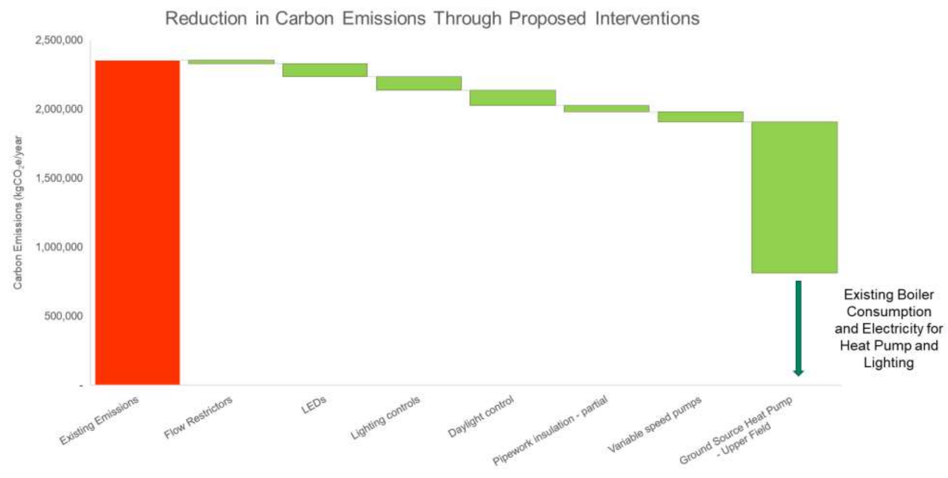


Figure E-1 Carbon emissions through proposed interventions (Bronze)

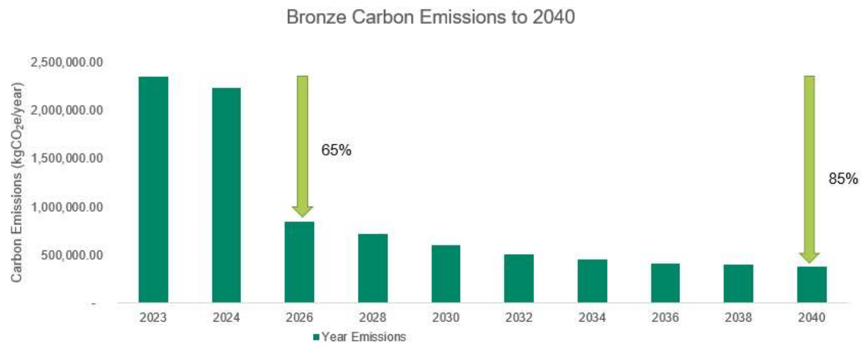


Figure E-3 Bronze carbon emissions to 2040

E.1.2 Package Summary (Bronze)

Table E-2 highlights the indicitive cost of the whole bronze package solution , as well as the potential savings in carbon emmisions per year (2040 value). Please note the figures below include contractors costs, and all soft costs , the details of which can be found in Appendix 7.

CAPEX (£)	Carbon Savings (TCO_2/yr)
8,510,800	1,390

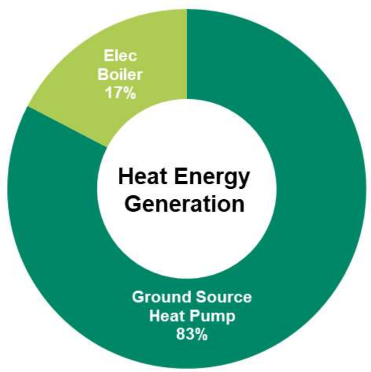
Table E-2 Bronze Package Cost Summary

E.2 Silver

As per the proposed methodology each package employs a fabric first approach, the proposed fabric/building level interventions can be found in Table E-3.

The low carbon heating proposal for the silver package is to install a closed loop GSHP system extracting heat from the upper field area only and install electric boilers for peaking and resilience. This solution fully electrifies the heat delivered to the palace whilst also causing minimal disruption to the grounds. Please see 0 for a site map of the proposed extraction area. Subject to the assumptions outlined in Appendix 1 the proposed extraction area has peak heating potential of ~1,700kW. 1,430kW of installed GSHP capacity is required to meet 83% of the site demand post fabric interventions. An option that included ASHP as peaking plant was also investigated but was not deemed a favourable option, please see Appendix 2 for more detail.

Unit	Size	% Contribution
GSHP	1,430kW	77%
Thermal Store	60m3	5%
Electric Boiler	3,000kW	17%



Intervention	Reduction in Gas Consumption (kWh/year) [7]	Reduction in Electricity Consumption (kWh/year)	Annual Fuel Cost Saving (£/year)[8]	Capital Cost of intervention (£)	Lifetime/ Persistence Factor[9]	Carbon Reduction per Year (kgCO2e/year)[10]	Capital Cost per Lifetime CO2e Saving (£/tCO2e)
Reduce LTHW flow temperatures	2,015,360	N/A	120,921	4,063,531	15.2	371,432	683
Flow Restrictors	122,173	N/A	7,330	3,300	14	22,516	10
Variable speed pumps	N/A	176,030	28,164	44,730	15.2	24,358	121
LEDs	N/A	36,442	5,830	7,800	25	5,043	61
Lighting Controls	N/A	70,640	11,302	22,730	10.26	9,755	227
Daylight Control	N/A	160,834	25,733	41,640	10.26	22,256	182
Install ASHPs at satellite sites (please see Appendix 5 for more detail)	177,000	-53,562	97,630	2,536,890	20	316,520	400
Install destratification fans in the East court and Palm Court	98,560	-3,780	5,300	116,900	14.25	8,821	929
Install central battery system to replace diesel generator	40,000	-16,000	640	28,714	10	2,586	1000
Install electric boilers for peaking	1,424,845	-1,207,500	-107,708	448,200	20	86,842	259
Ground Source Heat Pump	5,813,021	-1,660,863	83,100	7,284,000	25	918,212	317

Table E-3 Summary of proposed interventions (Silver)

[7] Negative saving indicates an increase in fuel consumption
[8] Negative saving indicates an increase in fuel costs

E.2.1 Energy and Carbon Impact (Silver)

The change in fuel comsumption with the implementation of the proposed interventions is demonstrated in Figure E-5 below. Post interventions the gas consumption has reduced by 100%, electricity consumption has increased by 61% due to the total electrification of heat. The total fuel consumption has reduced by around 50%.

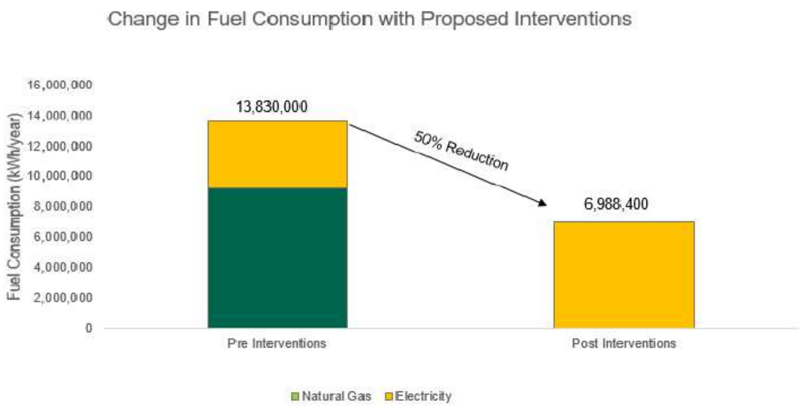


Figure E-5 Graph of fuel consumption post and pre interventions (Silver)

As per the proposed delivery strategy, the carbon emisisons reductions per intervention can be seen in Figure E-4. This highlights the importance of implementing energy efficiency measures to achieve a new energy baseline of low carbon technologies. Although all gas consumption has been completely removed within the silver package there are still some carbon emissions associated with the electricity required to run the heat pump and electric boiler, as well as the general electrical requirements for lighting and acilliary equipments. To achieve full net zero through this package, renewable electricity should be purchased.

Figure E-6 shows the predicted reduction in emissions through to 2040, these predictions are line with the DESNZ carbon factor curves for gas and electricity (found in Appendix 6)

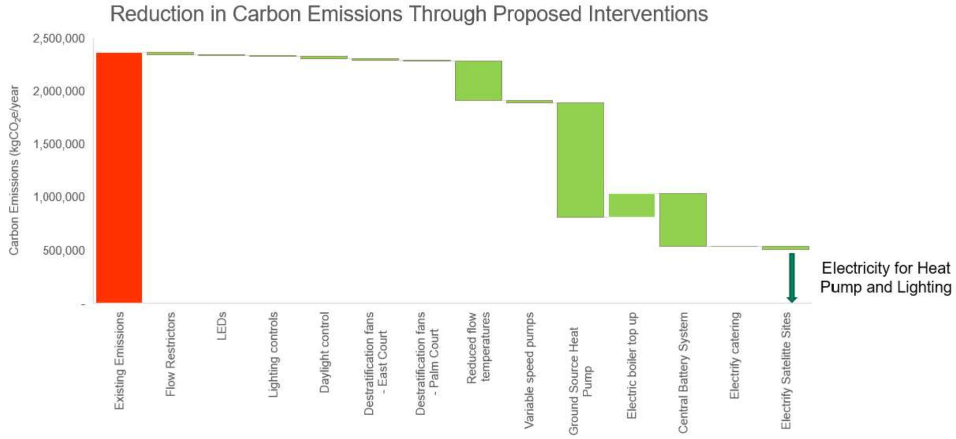


Figure E-4 Carbon emissions through proposed interventions (Silver)

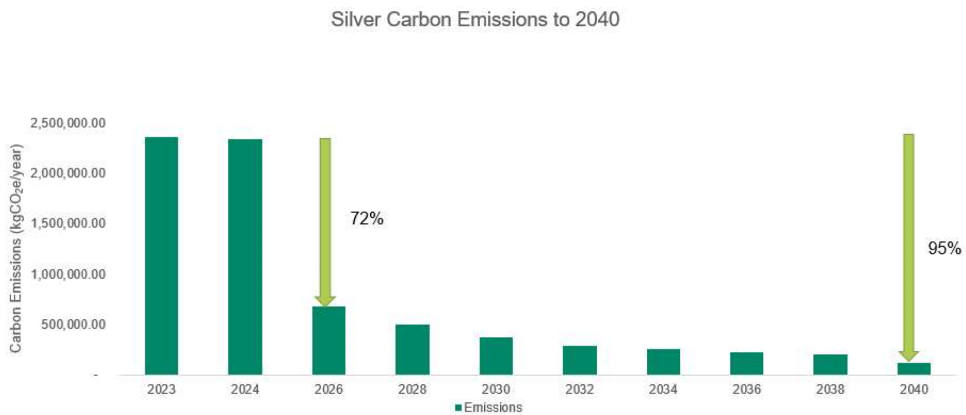


Figure E-6 Silver carbon emissions to 2040

E.2.2 Package Summary (Silver)

Table E-4 highlights the indicitive cost of the whole silver package solution , as well as the potential savings in carbon emmisions per year (2040 value). Please note the figures below include contractors costs, and all soft costs , the details of which can be found in Appendix 7.

CAPEX (£)	Carbon Savings (TCO_2/yr)
15,373,000	1,660

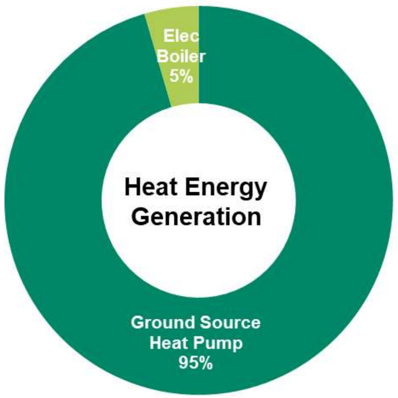
Table E-4 Silver Package Cost Summary

E.3 Gold

As per the proposed methodology each package employs a fabric first approach, the proposed fabric/building level interventions can be found in Table E-5.

The low carbon heating proposal for the gold package is to install a closed loop GSHP system extracting heat from the upper field area and install electric boilers for peaking. This solution is sized based on the reduced peak demand post fabric interventions, so the desired GSHP capacity can be achieved without further disruption to the grounds. Please see 0 for a site map of the proposed extraction area. Subject to the assumptions outlined in Appendix 1, the proposed extraction area has peak heating potential of ~1,700Kw. 1,650Kw of installed GSHP capacity is required to meet 95% of the site peak demand post fabric interventions

Unit	Size	% Contribution
GSHP	1,650kW	90%
Thermal Store	60m3	5%
Electric Boiler	3,000kW	5%



Intervention	Reduction in Gas Consumption (kWh/year) [11]	Reduction in Electricity Consumption (kWh/year)	Annual Fuel Cost (£/year)[12]	Capital Cost of intervention (£)	Lifetime/ Persistence Factor13	Carbon Reduction per Year (kgCO2e/year)[14]	Capital Cost per Lifetime CO2e Saving (£/tCO2e)
Reduce LTHW flow temperatures	2,015,360	N/A	120,921	4,063,531	15.2	371,432	683
Variable speed pumps	N/A	176,030	28,164	44,730	15.2	24,358	121
Flow Restrictors	122,173	N/A	7,330	3,300	14	22,516	10
LEDs	N/A	36,442	5,830	77,933	25	5,043	618
Lighting Controls	N/A	70,640	11,302	22,730	10.26	9,755	227
Daylight Control	N/A	160,834	25,733	41,640	10.26	22,256	182
Install ASHPs at satellite sites	177,000	-53,562	97,630	2,536,890	20	316,520	400
Install destratification fans in the East court and Palm Court	98,560	-3,780	5,300	116,900	14.25	8,821	929
Install air curtain in the Palm Court and Great Hall	141,187	-1,248	8,271	9,265	14.25	25,848	25
Install central battery system	40,000	-16,000	640	28,714	10	2,586	1000
Install electric boilers for peaking	346,760	-293,864	-26,212	448,200	20	23,250	963
Ground Source Heat Pump	6,934,600	-1,679,000	147,440	8,080,400	25	1,044,264	309

Table E-5 Summary of proposed interventions (Gold)

[11] Negative saving indicates an increase in fuel consumption
[12] Negative saving indicates an increase in fuel costs
[13] As defined by the Public Sector Decarbonisation Scheme Phase 3b
[14] Using Salix PSDS 3b fuel carbon factors

E.3.1 Energy and Carbon Impact (Gold)

The change in fuel comsumption with the implementation of the proposed interventions is demonstrated in Figure E-9 below. Post interventions the gas consumption has reduced by 100%, electricity consumption has increased by 40% due to the total electrification of heat. The total fuel consumption has reduced by around 60%.

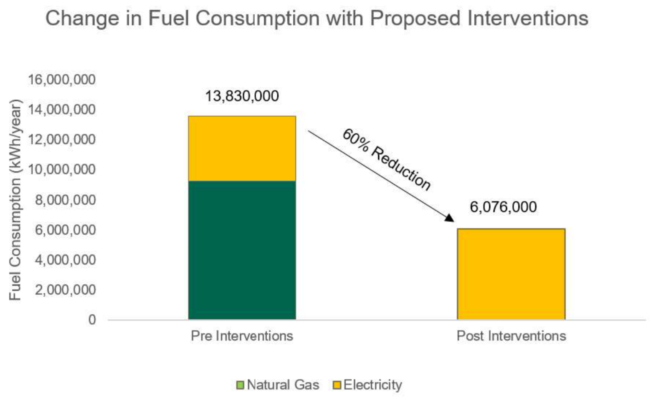


Figure E-9 Graph of fuel consumption post and pre interventions (Gold)

As per the proposed delivery strategy, the carbon emisisons reductions per intervention can be seen in Figure E-7. This highlights the importance of implementing energy efficiency measures to achieve a new energy baseline of low carbon technologies. Although all gas consumption has been completely removed within the gold package there are still some carbon emissions associated with the electricity required to run the heat pump and electric boiler, as well as the general electrical requirements for lighting and acilliary equipments. To achieve full net zero through this package, renewable electricity should be purchased or generated on site through PV (please see Appendix 1 for more details.

Figure E-8 shows the predicted reduction in emissions through to 2040, these predictions are line with the DESNZ carbon factor curves for gas and electricity (found in Appendix 6)

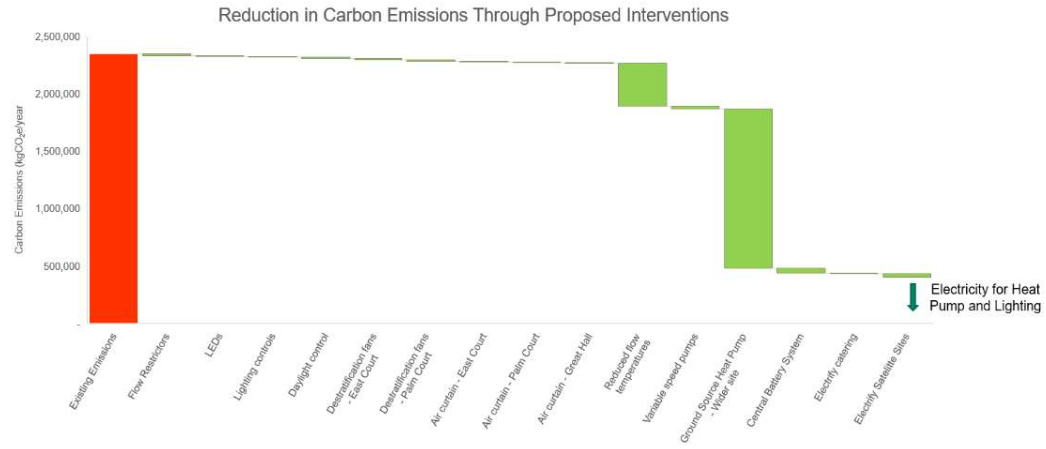


Figure E-7 Carbon emissions through proposed interventions (Gold)

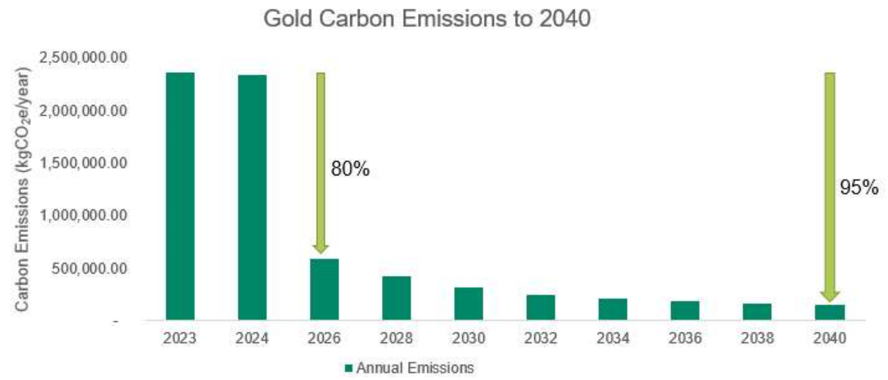


Figure E-8 Gold carbon emissions to 2040

E.3.2 Cost Summary (Gold)

Table E-6 highlights the indicitive cost of the whole gold package solution , as well as the potential savings in carbon emmisions per year (2040 value). Please note the figures below include contractors costs, and all soft costs , the details of which can be found in Appendix 7.

CAPEX (£)	Carbon Savings (TCO_2/yr)
16,350,700	1,670

Table E-6 Gold Package Cost Summary

F. Heat Network Opportunities

F.1 Connection to HDEN

As outlined in section D.3.4, Alexandra Palace has been identified as a potential future connection for the Haringey District Energy Network, the current proposed connection date in 2028. Table F-1 below highlights the cost and carbon associated with connecting to HDEN as well as a comparison to the proposed on-site GSHP solutions.

Performance Metric	GSHP Bronze	GSHP Silver	GSHP Gold	Haringey Heat Network ****Subject to change***
Capital cost	**£8,185,400** – Cost for heating associated works only, post interventions. This includes, boreholes, heat pump, energy centre and removal of existing equipment where applicable, and electrical upgrades.	**£7,957,200**[15]	**£8,773,694**	**£3,719,500 (total cost)** comprising: £2,350,000 Connection fee Based on a connection fee charged at £500/kW (final value TBC) £1,369,500 works to decommission existing boiler plant and gas connection and associated BMS and plantroom ancillary works (including soft costs)
Running cost	£405,337 per year	£483,544 per year	£315,658 per year	£1,162,640 per year Based on 9 p/kWh & £85 / kW fixed (final values TBC)
Carbon content of heat, 2030[16]	58 gCO_2e/kWh	36 gCO_2e/kWh	35 gCO_2e/kWh	50 gCO_2e/kWh

Table F-1 Cost and Carbon Assessment of HDEN Connection

Haringey Council are open to further discussions with APP, particularly regarding the negotiation of the connection fee (currently assumed to be a market rate figure).

F.2 On-site Heat Generation

Through the assessment of low carbon heat availability for this study, it was found that the APP grounds has significant potential for heat extraction through closed loop GSHP. The package proposals all recommend extracting heat from the upper field only, with the upper field having a maximum heat supply potential of 1.7MW (assumptions highlighted in Appendix 1 Applying the same assumptions, it was estimated that the Park and Palace grounds have a peak heating potential of around 8.4MW, this is also assuming a 60% reduction factor in available area to accommodate underground utilities as well as tree lines and roots.

This surplus heat could be utilised to supply sites surrounding the park grounds as a small district heating network. The low carbon heat could also be fed into an existing heat network with Alexandra Palace acting as an energy centre. The feasibility of developing a heat network around APPs GSHP potential should be determined through a full Heat Network Feasibility Study. This feasibility study would comprise of a Heat Mapping and Masterplanning (HMMP) phase as well as a Feasibility stage. The HMMP phase would identify all heating and cooling demands of sites within the area, and re assess all potential heat sources in the area and determine the economic viability of the heat network through project KPIs such as IRR and NPV. The feasibility stage would refine assumptions made in the HMMP phase to further ascertain the feasibility of developing a heat network in the area.

Funding for a study of this nature can be achieved through the Heat Network Delivery Unit (HNDU). The HNDU was originally set up to provide grant funding and guidance to local authorities in England and Wales for heat network project development. As of round 12 the HNDU grant is now also available to a wider group of organisations. Applications for round 13 opened in May 2023 and will close on the 31st of December 2023. The HNDU will fund up to 67% of eligible costs with the remainder to be provided by the applicant. For more information on the HNDU please refer to published Round 13 guidance.

[15] Note: Silver appears cheaper than Bronze in this figure as these costs reflect heating only and do not capture additional energy efficiency measures

[16] Note: Figures use Green Heat Network Fund Carbon Factors which differ from those used elsewhere in this report but offer consistency for comparison between the heat network and the on-site solutions

G. Package Design

Space will need to be found to locate plant for the heat pump systems as AECOM are unaware of any space within the Palace able to accommodate this. This energy centre could be located in a new external enclosure, following a site visit, in or behind the North Service Yard was identified as potential location. This location is also well suited to minimising the distance of pipework connections between the ground source array and the Palace distribution network. Similarly, an additional substation is likely to be required to meet the increased electrical load. This would be approximately 5x4.5m in footprint and 3m tall. The construction would need to be 4-hour fire rated and with unrestricted 24-hour access.

The current boiler plantroom can be repurposed to contain the electric boilers and their associated plate heat exchangers, pressurisation sets and expansion vessels, but limited space will be available for anything beyond this, as demonstrated in the plantroom sketches below. Heat pumps have been proposed in a separate room from the gas boilers which helps to limit the flammability risk possible from refrigerant gas leakage. If the works were conducted outside of winter, the installation could be phased to minimise disruption to the heating system.

The proposed plantroom layouts for the bronze package can be seen in Figure G-1 and Figure G-2 below:

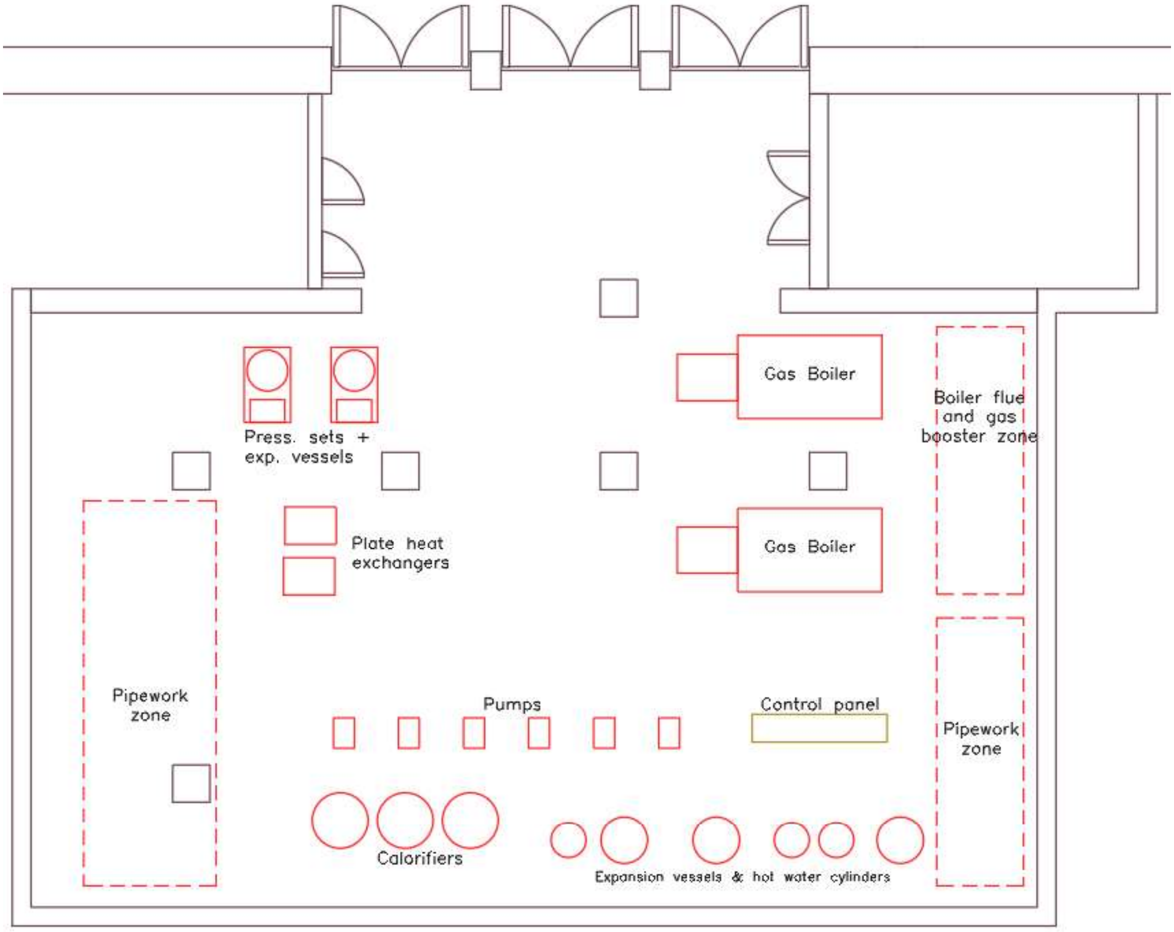


Figure G-1 - Heating plantroom for Bronze package, retaining two gas boilers

The new energy centre would contain heat pumps, primary pumps, plate heat exchangers, pressurisation and expansion plant, control panels and thermal stores. A 3.0m high plantroom would be suitable for the main plant, except for the thermal stores, where additional height is crucial. A 5.0m tall plant space has been proposed for the thermal store arrangement in the sketch below Figure G-2 though this could be adjusted by including more or fewer vessels. Alternatively, the thermal stores could be located externally.

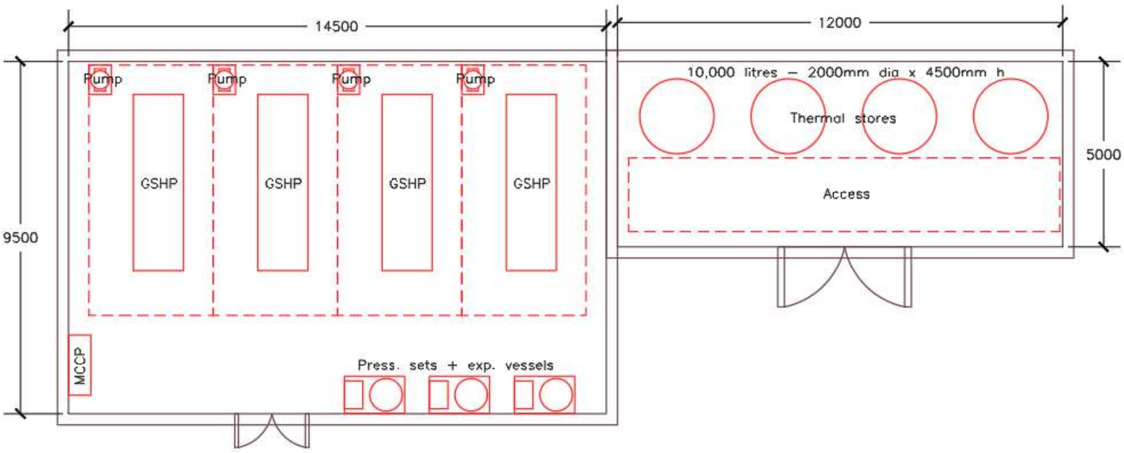


Figure G-2 - GSHP Energy centre for Bronze package

Refer to the bronze package for details on the heating plantroom and energy centre layouts. The same principles apply to the silver and gold proposals, except with larger/additional plant to suit the higher heat pump capacity. All gas boilers are removed and the space utilised with electric boilers, plate heat exchangers, pressurisation sets and expansion vessels.

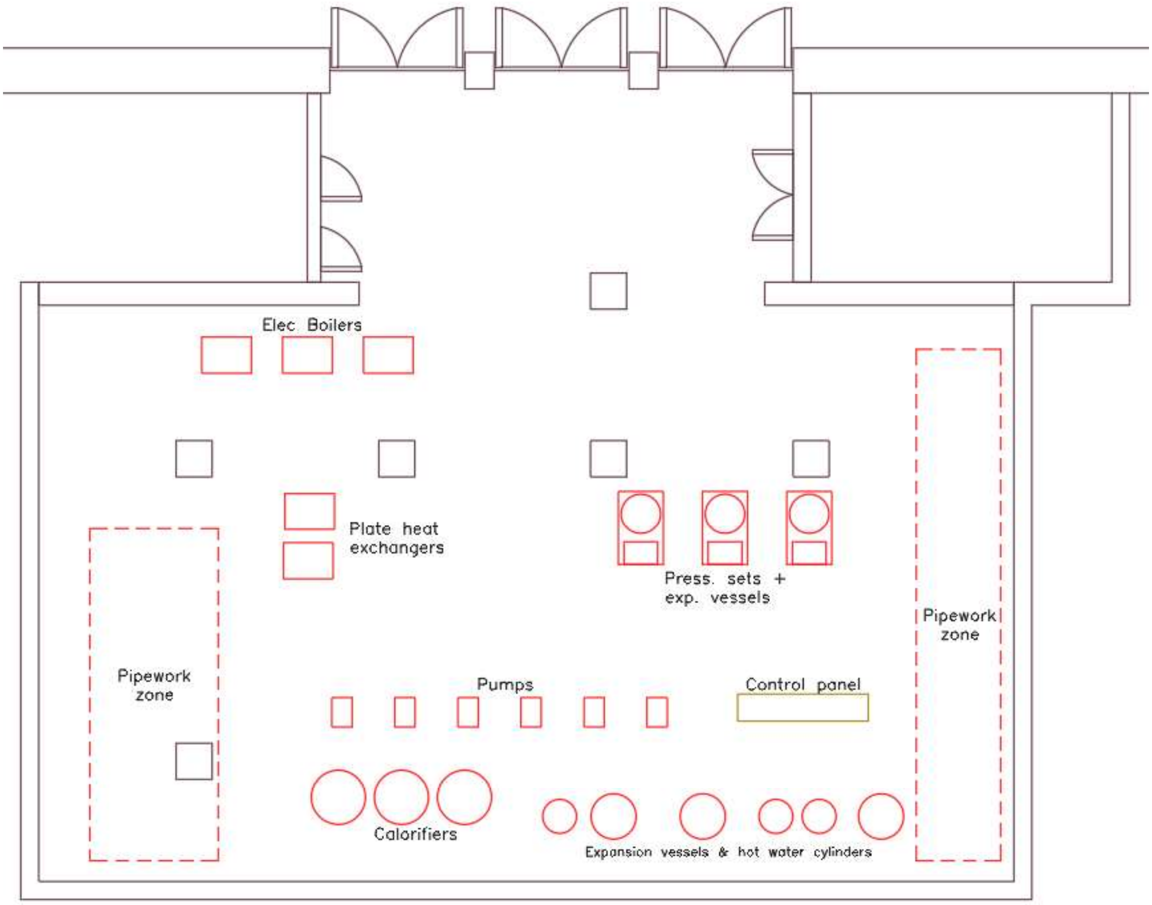


Figure G-3 - Heating plantroom for Silver and Gold packages, removing all gas boilers

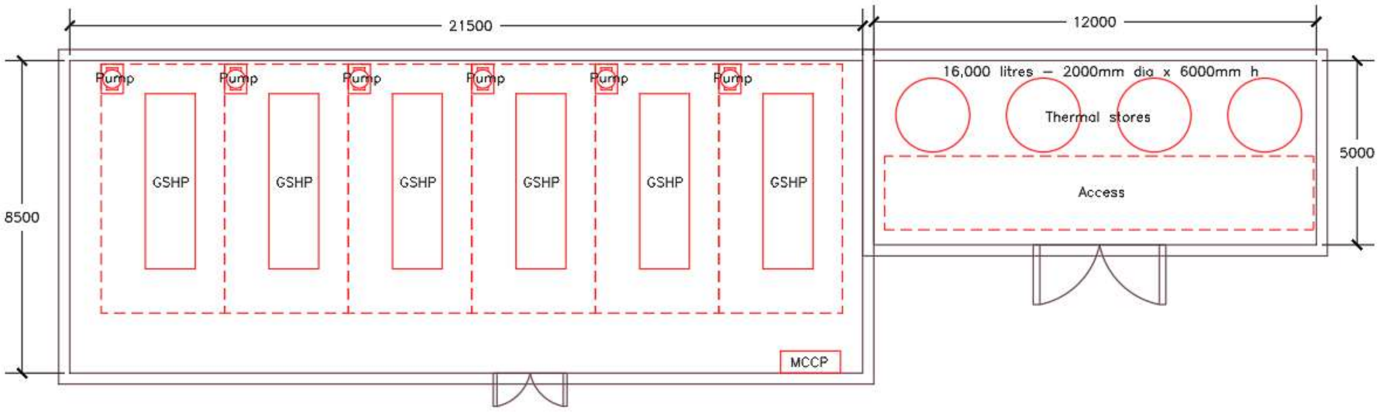


Figure G-4 - GSHP Energy centre for Silver and Gold packages

These heat pumps would be able to provide cooling as well, if desired in future. The addition of chilled water buffer vessels, distribution pumps, plate heat exchangers, pressurisation sets and expansion vessels would be required. New pipework distribution and terminal units would be installed within the building to suit the demand. As discussed in the interventions section, the cooling would be efficient as the waste heat could be recovered directly to the heating system, but it would still cause an increase in overall energy use and capital expenditure.

H. Delivery and Funding

Following the receipt of this clean energy masterplan, the Alexandra Park and Palace Executive Members should evaluate and determine their preferred package approach. This will subsequently inform the ongoing core Capital Works Programme for forth coming years.

Once the final package and proposed measures have been agreed, it is recommended that the associated mini business case be developed into a full business case, taking into account any additional grant funding opportunities that exist at the time.

H.1 Available Funding

As noted above APP will evaluate the package of measures in order to develop a full business case for investment, however it is very probable that the significant capital costs associated with delivery of all packages outlined in this masterplan will not be available through the Trust's capital fund. As such, it is critical that the alternative routes of financing available are investigated and potentially pursued in order to ensure the complete delivery of this strategy.

H.1.1 Public Sector Decarbonisation Scheme (PSDS)

PSDS is a grant funding scheme funded by the Department for Business, Energy and Industrial Strategy (BEIS) (recently changed to the Department for Energy Security and Net Zero (DESNZ) and administered by Salix Finance. The scheme seeks to provide funding for energy efficiency measures and heat decarbonisation for buildings in a 'complete' approach in order to maximise emission reductions achieved. There are a number of phases of the scheme, with the criteria becoming more stringent in the latter rounds.

Phase 3b of PSDS closed for applications in October 2022 and will allocate up to £635m of funding to public sector organisations to be spent in the financial years 2023/24 and 2024/25. A new phase of PSDS application (phase 3c) is set to open in autumn 2023. To help ensure the admission of the works in this application phase, early action is encouraged when the funding phases are announced. This Clean Energy Masterplan has been undertaken on a whole building approach to both efficiency measures and heat decarbonisation with consideration to the eligibility with PSDS requirements.

It is worth noting that the Bronze package will not be eligible for PSDS funding as the scheme will not fund a "hybrid" approach to decarbonising heat, in which fossil fuels are still partially used for heating. In the case of the Bronze package the gas boilers are retained for peaking and resilience. Alternative funding for the bronze package should be sought if this is the preferred option, such as community funding.

H.2 Project Delivery Schedule

An indicative project schedule is shown in figure H-1, this schedule works towards a 2030 net zero target which is ahead of APPs target of 2041 and inline the Mayor of London target of 2030. This timeline does not meet the Haringey Council target of 2027 as it was not deemed feasible given the scope of works required. The schedule assumes energy efficiency and enabling works will take up to one and a half years due to the complexity of shutting down the Palace. The heating system upgrades have been assumed to run in parallel with the enabling works during the summer months.

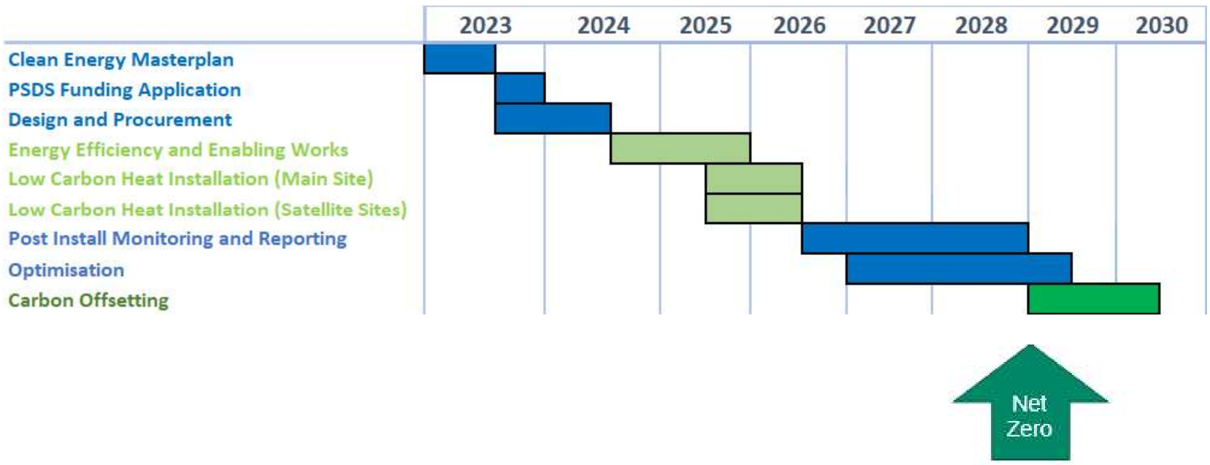


Figure H-1 Proposed delivery schedule

Please note this timeline is applicable for both the Silver and Gold packages. If APP seeks to adopt the Bronze package of works then the PSDS funding application line should be replaced with "obtain funding" and the exact nature of this task should be developed in the full business case.

H.3 Measurement and Verification

To ensure successful implementation of the chosen intervention package for this clean energy masterplan and to ensure systems are operated as intended in the design, a verification process should be carried out to monitor energy savings. This monitoring after completion will help to reduce the performance gap that is often seen between operational energy consumption and that as designed.

This can be completed by analysis of new metered data compared to the previous energy consumption baseline, whilst also being contrasted against the design value to identify any differences to the design, whether that be via construction or operation. To ensure this process is possible, the additional metering and data collection measures outlined in section B.6 should be implemented. After a sufficient data collection period, one to two years, the data can be collated and subsequently transferred for analysis.

H.4 Carbon Offsetting

If either the silver or gold packages are taken forward, any electricity demand on site in 2030 (as presented in section E) will result in carbon emissions. Given the outcome of the solar PV study, there is not sufficient generation capacity from PV to offset all electrical requirements, especially when considering the increased electrical capacity requirements due to the installation of heat pumps. At this time, APP can offset these emissions through various means:

Onsite generation – Although there is not sufficient generation capacity to offset the site's electrical requirements, installing the maximum possible PV generation capacity would reduce the amount of further carbon offsetting that will be required to reach net zero

Purchasing renewable electricity – If APP commit to purchasing their electricity from a supplier that guarantees all power is produced through renewable generation, then the carbon factor associated with the electricity on site will no longer incur carbon emissions, resulting in net zero. However, this could increase the running costs of the proposed intervention measures due to a higher electricity tariff. The current operating costs are calculated from APPs current tariffs, so this potential increase has not been accounted for in modelling and reporting.

Purchasing carbon credits – After all measures for reducing carbon emissions have been exhausted on site, the final step to reaching net zero could be to offset any remaining carbon emissions using a recognised offsetting framework. The cost of carbon offsets is variable and differs depending on what offsetting strategies are used.

I. Renewables

I.1 Solar PV

The potential for installing Solar PV at Alexandra Palace to reduce the electricity that must be imported from the grid has been analysed. The full report for this is detailed in Appendix 9. This report looks predominantly at spatial availability for inclusion of PV and does not include a structural assessment of each location. To understand the viability of PV installation from a structural perspective, an additional survey would be required. Through discussion with Alexandra Palace, the following should be noted alongside the PV report:

- The West Hall roof is often under heavy loads during events, and it is unlikely that PV would be suitable on the roof in its current state.
- The Theatre roof has been deemed unlikely to be suitable for PV installation due to its age / loading requirements.
- The Ice Rink roof has been identified as potentially problematic with loadings, but loading is not as severe as the West Hall and there could be some scope for PV on this roof.
- Given the relatively small space available for a Solar PV installation, it is unlikely that any reinforcement works would be cost-effective. Therefore, they should be considered only as part of a major retrofit project for the building.

The PV report provides details on how these restrictions could impact the total energy available from installation of PV on the site. The generational capacity for three scenarios is presented below.

- Scenario 1, Full spatial analysis with no roof discounted.
- Scenario 2, Omitting West Hall and Theatre which are both unlikely to be suitable for install.
- Scenario 3, Omitting West Hall, Theatre and Ice Rink, with the Ice Rink being only potentially suitable for install.

Table I-1. Summary - Demand and Generation

Site	Total Installed Capacity (kWp)	Demand (MWh/yr)	Generation (MWh/yr)	Generation Used (MWh/yr)	Annual % Demand Met	Annual % Self Consumption	Export (MWh/yr)	Remaining Import (MWh/yr)
Alexandra Palace Scenario 1	255	3,900	215	215	5.5	100	0	0
Alexandra Palace Scenario 2	146	3,900	124	124	3.2	100	0	0
Alexandra Palace Scenario 3	32	3,900	26	26	0.8	100	0	0

I.2 Whole Picture Summary – Gold Package + Solar PV

To provide an estimate for what the total cost and carbon savings would be if solar PV scenario 2 was installed alongside the gold package, these have been summed and presented in Table I-2 below.

CAPEX (£)	Total Carbon Savings (25 Years) (TCO_2)
16,608,700	39,246

Table I-2. Gold Package and PV Combined Summary

J. Mini Business Cases

The business cases associated with implementation of each of the three packages have been reviewed. The full report for this is detailed in Appendix 10.

K. Recommendations and Next Steps

Within the sections of the report above, there are a number of recommendations and next steps outlined, including further suggested studies and additional details that will need to be reviewed. Table K-1 below summarises these and details the sections in which these recommendations can be found. This should not be viewed as a complete list of items that will need to be completed at later design stages.

Table K-1. Recommendations and Next Steps Summary

Section	Recommendation / Next Steps
B.6	Undergo an in-depth review and implementation of a new Energy Management System and strategy, including additional heat and electrical meters, to manage all information and data. This will enhance data quality for any future review / interventions.
B.6	Undergo an in-depth review of higher than anticipated night-time energy usage and other high peak energy usages to understand what is causing high demands and if these can be reduced.
D.3.1.2	Ground modelling and borehole tests will be required in subsequent stages of the design.
D.3.3.3	It is recommended that at the next stage waste heat from transformers remain in consideration as these have not been considered in detail. Appendix 3 includes more details on the assumptions and waste heat availability.
F.2	An additional study could be carried out for the site on maximising the onsite heat generation to have an understanding of heat capacity and potential space for GSHPs / ASHPs that could potentially expand the heat network. This would include an investigation into the heat loads around the park that could connect to this network.
G	Space will need to be found to locate plant for the heat pump systems. A suggestion has been made that this energy centre could be located in a new external enclosure in or behind the North Service Yard. However, this is only a potential location, and a suitable location will need to be reviewed and agreed.
Various	A number of interventions have been excluded from review at this stage due to foreseen complications surrounding Alexandra Palace's listed status. However, these could be considered at the next design stage, if expert advice was sought and the Local Planning Authority was engaged with to overcome any issues.
Funding	Community funding could be explored as an option to raise capital funds although is unlikely that it would cover a significant proportion of the overall CapEx.

Appendix 1. GSHP Open Space Availability Assessment

Through a desktop study, areas available for borehole extraction were split into 2 categories:

1. Upper field only
2. All available green spaces

The categories were chosen to allow for a GSHP solution that poses minimal disruption (upper field) and another solution that seeks to establish the maximum possible extractable heat.

The following assumptions were applied when estimating the heating potential of the identified sites.

Assumption Description	Figure	Source/Comment
Borehole extraction power per m depth	50/W/m	Assumption from manufacturers data: http://www.kensaheatpumps.com/wp-content/uploads/2014/03/Factsheet-Closed-loop-boreholes-V4.pdf
Borehole depth	250m	Typical extraction depth is 200m, an additional 50m has been added to account for the sites topography
Output per borehole	12.5kW	Calculated from the above assumptions
Spacing (to prevent net reduction in ground temperature)	10m	Assumption based on manufacturer data (GI energy)
Thermal extraction per m²	125 W/m²	Calculated from the above assumptions
Heat Pump CoP	3.5	Assumption based on manufacturers performances
Generation temperature	60°C	Assumption based on manufacturers performances

Figure 1 below shows the areas identified for GSHP extraction

The red area represents the upper field, the yellow area is the pavilion car park adjacent to the upper field that was originally highlighted as a potential area of extraction, however the upper field proved to provide sufficient yield for the proposed packages. The blue area was identified as the wider site available area, for the purpose of this assessment a 60% reduction factor was applied to the 123,334m2 to account for underground utilities, existing infrastructure, and tree lines that may limit the extractable area, giving a "usable" area of **49,333m²**. Table 1 below shows the estimated heating potential for the identified areas.

Area	Maximum Extractable Heat	No of Boreholes Required to Achieve Heating Potential
Red (13,784m²)	1,723kW	98
Yellow (5,200m²)	650kW	37
Blue (49,333m²)	6,100kW	352
Total	8473kW	484

Table 2 outlines the proposed GSHP size for each package and the associated borehole requirements.

Package	GSHP Size	No of Boreholes Required to Achieve Heating Potential
Bronze	1,650kW	94
Silver	1,430kW	82
Gold	1,650kW	94

Appendix 2. ASHP Space Availability Assessment

An Air Source Heat Pump (ASHP) was considered to replace the existing gas boilers. The ASHP requires an external area which has good air movement to prevent recirculation of air and reduce the risk of pluming. For the purpose of this study, flat roof space within the main palace site was not considered due to the listed status of the palace and the significant structural loading requirements associated with the installation of an ASHP capable of supply the palace's heat demand. Equally, the flat roof has the potential to be utilised for solar PV.

A site within the North Service yard was identified as a potential location for ASHP plant. As seen in figure 1 below:

In order to supply the total site demand with ASHP plant, around 315m^2 would be required. This figure is based off dynamic sizing metrics held within AECOM's in house built modelling tool. This tool incorporates real project data to achieve these metrics.

Given the available space highlighted in figure 1, a fully ASHP solution is not feasible for the palace.

Considerations were made for utilising ASHP as a top up technology rather than gas or electric boiler, however, through hourly modelling it was deemed impractical and not cost effective to install a large capacity of ASHP that will be used minimally throughout the year. The following assumptions were applied to assess the heating energy potential from ASHP.

Assumption Description	Figure	Source/Comment
Source Temperature (air)	8°C	Assumed seasonal demand weighted temperature of air
LTHW temperature	60°C	Based on Pure Thermal TMA WP 682 R452b heat pump
Carnot efficiency	50%	Assumption based on manufacturers performances
Carnot COP	5.5	Calculated from the above assumptions
Heat Pump CoP	2.7	Calculated from the above assumptions and representative manufacturer information

Appendix 3. Waste Heat Availability

Transformer waste heat

On site the main palace currently has 3x1,250KVa transformers installed. Minimal access was available to the transformer room so the following assumptions were made to assess the potential available waste heat from the transformer.

Assumption Description	Figure	Source/Comment
Mass flow rate of oil	$15kgs^{-1}$	Assumption based on available literature
Mass flowrate of air	$15kgs^{-1}$	Assumption based on available literature
Mass flowrate of water	$10kgs^{-1}$	Assumption based on available literature
Specific heat capacity of water	4.2 J/g°C	Standard figure
Specific heat capacity of oil	2 J/g°C	Assumption based on available literature

The above assumptions suggest recoverable heat from the transformer room in the region of 300kW

Waste heat from New River

The following assumptions were applied to ascertain the waste heat available from the New River

Assumption Description	Figure	Source/Comment
River flowrate	$0.4m^3s^{-1}$	Thames Water
Available volume	10%	Assumption based on previous project data
Temperature difference	3°C	Assumption based on previous project data

Based on the above assumptions, an extractable water body heat energy of 500 kW is anticipated.

Appendix 4. Haringey District Energy Network Connection

The following assumptions were made when assessing cost and carbon associated with connecting to the Haringey District Heating Network

Assumption Description	Figure	Source/Comment
Connection Fee	£500/kW	Market rate figure in lieu of negotiations with Haringey Council
Blended heat network sale tariff	0.09p/kWh	Assumptions based on indexation of wholesale electricity
Heat network fixed charge tariff	£85/kW	Market rate figure in lieu of negotiations with Haringey Council
Phasing year	2028	Indicative timeline provided by Haringey Council
Size of connection	100% of APP's demand	Confirmation form Haringey Council "HESCO would seek to provide 100% of AP heat demand, whatever that is"
Carbon content of heat	50gCO_2e/kWh	Figure confirmed by Haringey Council

Appendix 5. Auxiliary Buildings ASHP Assessment

When assessing the implementation of interventions at auxiliary sites within Alexandra Park, sites currently heated through fossil fuel means were prioritised. These sites are:

1. The Garden Centre
2. Meeson House
3. The Cricket Club

The remaining auxiliary sites were identified to be heated electrically. ASHPs were deemed the most appropriate technology for these sites due to the distance from the plantroom to these sites being too significant to justify connecting to the main palace heating system, and because on a £/kW basis the peak demand requirements are too small to justify on site GSHPs at these sites. Based on the assumptions shown in table J-2, and figure J-1, the following recommendations have been made:

Table 5.1 - Auxiliary site ASHP requirements

Site	ASHP Size	Space Required
Garden Centre	70kW	15m2
Meeson House	15kW	5m2
Cricket Club	12kW	5m2

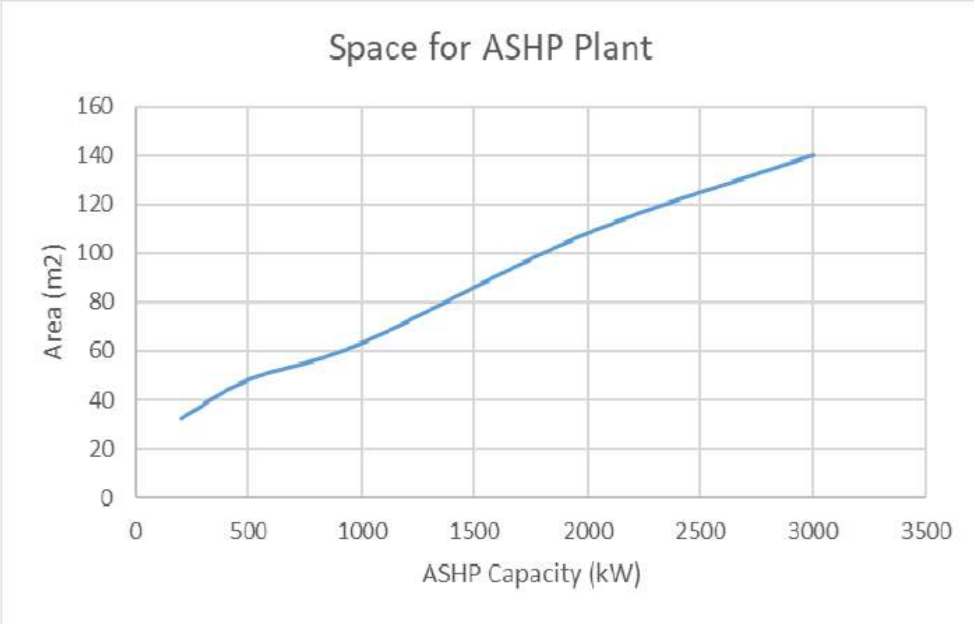


Figure 5-1 - Space requirements for ASHP

Table 5.2 ASHP assumptions

Assumption Description	Figure	Source/Comment
Source Temperature (air)	8°C	Assumed seasonal demand weighted temperature of air
LTHW temperature	60°C	Based on Pure Thermal TMA WP 682 R452b heat pump
Carnot efficiency	50%	Assumption based on manufacturers performances
Carnot COP	5.5	Calculated from the above assumptions
Heat Pump CoP	2.7	Calculated from the above assumptions

Appendix 6. Carbon Factors

BEIS Green Book Data Tables 1-19 Fuel Emissions Factors		
Year	Gas (kgCO2e/kWh)	Electricity (kgCO2e/kWh)
2023	0.183870	0.133283
2024	0.183870	0.145425
2025	0.183870	0.122997
2026	0.183870	0.090669
2027	0.183870	0.075037
2028	0.183870	0.069386
2029	0.183870	0.064966
2030	0.183870	0.051562
2031	0.183870	0.040833
2032	0.183870	0.035293
2033	0.183870	0.030649
2034	0.183870	0.027824
2035	0.183870	0.024822
2036	0.183870	0.020533
2037	0.183870	0.018263
2038	0.183870	0.017840
2039	0.183870	0.016891
2040	0.183870	0.015306
2041	0.183870	0.012706
2042	0.183870	0.012059
2043	0.183870	0.011812
2044	0.183870	0.011102
2045	0.183870	0.009429
2046	0.183870	0.008560
2047	0.183870	0.007893
2048	0.183870	0.007491
2049	0.183870	0.006971
2050	0.183870	0.006851

Salix Carbon Factors	
Gas (kgCO2e/kWh)	0.184300
Electricity (kgCO2e/kWh)	0.138376

Appendix 7. Cost Summary for Packages

Document: Bronze Package Cost Estimate
Project: Alexandra Palace Clean Energy Masterplan

AECOM

Version: 2
Client: Alexandra Park and Palace

Item		Description	Quantity	Unit	Rate	Total	Additional comments
1.0	1	**Flow Restrictors**					
1.01	1	Flow Restrictors	17	nr	£ 90	£ 1,530	Includes installation
		SUB TOTAL: Flow Restrictors				**£ 1,530**	
2.00	2	**LEDs**					
2.01	2	LEDs	72	nr	£ 50	£ 3,600	
		SUB TOTAL: LEDs				**£ 3,600**	
3.00	3	**Lighting controls**					
3.01	3	Lighting controls	105	nr	£ 50	£ 5,250	
	3	Installation	105	nr	£ 50	£ 5,250	
		SUB TOTAL: Lighting controls				**£ 10,500**	
4.00	4	**Daylight control**					
4.01	4	Daylight control	250	nr	£ 50	£ 12,500	
	4	Installation	250	nr	£ 50	£ 12,500	
		SUB TOTAL: Daylight control				**£ 25,000**	
10.00	10	**Pipework insulation - partial**					
10.01	10	Insulate piepwork with damaged or no insulation	569	m	£ 58	£ 32,991	
		SUB TOTAL: Pipework insulation - partial				**£ 32,991**	
13.00	13	**Variable speed pumps**					
13.01	13	Pump Replacement	8	kW	£ 2,755	£ 20,663	
		SUB TOTAL: Variable speed pumps				**£ 20,663**	
14.00	14	**Ground Source Heat Pump - Upper Field**					
14.01	14	New Ground Source Heat Pump	1,650	kW	£ 1,561	£ 2,575,650	
	14	Borehole array	90	boreholes	£ 8,000	£ 720,000	
	14	Thermal Stores	30	m3	£ 1,300	£ 39,000	
	14	EC Construction	265	m2	£ 1,500	£ 397,500	
		SUB TOTAL: Ground Source Heat Pump - Upper Field				**£ 3,732,150**	
		Palace Electrical Upgrades (bronze)	700	KVa	£ 150	£ 105,000	This is inclusive of the electrical upgrades required at the palace
		SUB TOTAL: Palace Electrical Upgrades (bronze)				**£ 105,000**	
		SUBTOTAL				**£ 3,931,434**	
8		**CONTRACTOR'S COSTS**					
8.01	7	Capital Works Project - Contractor's Preliminaries	15%	%	£ 3,931,434	£ 589,715	
8.02	7	Capital Works Project - Contractors OHP	8%	%	£ 4,521,149	£ 361,092	
8.03	7	Capital Works Project - Contractor Risk	5%	%	£ 4,882,841	£ 244,142	
		SUB TOTAL: MAIN CONTRACTOR'S COSTS				**£ 1,195,549**	
		CONSTRUCTION WORKS TOTAL				**£ 5,126,983**	
9		**SOFT COSTS**					
9.01	8	Phasing allowance 10%	10%	%		£ 512,698	
9.02	8	Out of hours working allowance 10%	10%	%		£ 51,270	
9.03	8	Professional Fees	0%	%		£ -	
9.04	8	Non-Works	0%	%		£ -	
9.05	8	Works - Excluding Main Contract	0%	%		£ -	
9.06	8	FFE - Equipment as per Schedule	0%	%		£ -	
9.07	8	IT	0%	%		£ -	
10.00	9	Project Risk	15%	%		£ 769,047	
11.00	10	Design Development	10%	%		£ 512,698	
12.00	11	Construction Contingency	10%	%		£ 512,698	
13.00	12	Optimism Bias	20%	%		£ 1,025,397	
		PROECT TOTAL				**£ 8,510,791**	

SILVER	Silver Package Cost Estimate	Version: 2
Project:	Alexandra Palace Clean Energy Masterplan	Client: Alexandra Park and Palace

AECOM

Item		Description	Quantity	Unit	Rate	Total	Additional comments
1.0	1	**Flow Restrictors**					
1.01	1	Flow Restrictors	17	nr	£ 90	£ 1,530	Includes installation
		SUB TOTAL: Flow Restrictors				£ 1,530	
2.00	2	**LEDs**					
2.01	2	LEDs	72	nr	£ 50	£ 3,600	Includes installation
		SUB TOTAL: LEDs				£ 3,600	
3.00	3	**Lighting controls**					
3.01	3	Lighting controls	105	nr	£ 50	£ 5,250	
	3	Installation	105	nr	£ 50	£ 5,250	
		SUB TOTAL: Lighting controls				£ 10,500	
4.00	4	**Daylight control**					
4.01	4	Daylight control	250	nr	£ 50	£ 12,500	
	4	Installation	250	nr	£ 50	£ 12,500	
		SUB TOTAL: Daylight control				£ 25,000	
5.00	5	**Destratification fans - East Court**					
5.01	5	New Fans	9	nr	£ 2,000	£ 18,000	
	5	Installation	9	nr	£ 1,000	£ 9,000	
		SUB TOTAL: Destratification fans - East Court				£ 27,000	
6.00	6	**Destratification fans - Palm Court**					
6.01	6	New Fans	9	nr	£ 2,000	£ 18,000	
	6	Installation	9	nr	£ 1,000	£ 9,000	
		SUB TOTAL: Destratification fans - Palm Court				£ 27,000	
12.00	12	**Reduced flow temperatures**					
12.01	12	Replacement of Existing Pipework & Heat Emitters	5,688	m	£ 330	£ 1,877,088	
	12	Removal of existing	5,688	m	£ 10		
		SUB TOTAL: Reduced flow temperatures				£ 1,877,088	
13.00	13	**Variable speed pumps**					
13.01	13	Pump Replacement	8	kW	£ 2,755	£ 20,663	
		SUB TOTAL: Variable speed pumps				£ 20,663	
14.00	14	**Ground Source Heat Pump - Upper Field**					
14.01	14	New Ground Source Heat Pump	1,430	kW	£ 1,561	£ 2,232,230	
	14	Borehole array	84	boreholes	£ 8,000	£ 672,000	
	14	Thermal Stores	30	m3	£ 1,300	£ 39,000	
	14	EC Construction	265	m2	£ 1,500	£ 397,500	
		SUB TOTAL: Ground Source Heat Pump - Upper Field				£ 3,340,730	
17.00	17	**Electric boiler top up**					
17.01	17	New Electric Boiler(s)	3,500	kW	£ 90	£ 315,000	
		SUB TOTAL: Electric boiler top up				£ 315,000	
20.00	20	**Central Battery System**					
20.01	20	New Central Battery	4	kW	£ 3,500	£ 13,264	
		SUB TOTAL: Central Battery System				£ 13,264	
21.00	21	**Electrify catering**					
21.01	21	Replace Gas Catering Hob with Electric Hob	2	item	£ 5,000	£ 10,000	
		SUB TOTAL: Electrify catering				£ 10,000	
22.00	22	**Electrify Satellite Sites**					
22.01	22	Air Source Heat Pump for Garden Centre	70	kW	£ 1,040	£ 72,800	
22.02		Electrical upgrade	300	m	£ 700	£ 210,000	300m from site to transformer; includes armoured cable, trenching and re instatement along with LV panel upgrades
22.03	22	Air Source Heat Pump for Meeson House	15	kW	£ 1,040	£ 15,600	
22.04		Electrical upgrade	690	m	£ 700	£ 483,000	690m from site to transformer; includes armoured cable, trenching and re instatement along with LV panel upgrades
22.05	22	Air Source Heat Pump for Cricket Club	12	kW	£ 1,040	£ 12,480	
22.06	22	Electrical upgrade	540	m	£ 700	£ 378,000	540m from site to transformer; includes armoured cable, trenching and re instatement along with LV panel upgrades
		SUB TOTAL: Electrify Satellite Sites				£ 1,171,880	
		Palace Electrical Upgrades (silver)	1,500	KVa	£ 150	£ 225,000	This is inclusive of the electrical upgrades required at the palace
		SUB TOTAL: Palace Electrical Upgrades (silver)				£ 225,000	
		SUBTOTAL				£ 7,101,245	
8		CONTRACTOR'S COSTS					
8.01	7	Capital Works Project - Contractor's Preliminaries	15%	%	£ 7,101,245	£ 1,065,187	
8.02	7	Capital Works Project - Contractors OHP	8%	%	£ 8,166,432	£ 653,315	

8.03	7	Capital Works Project - Contractor Risk	5%	%	£ 8,819,746	£	440,987
		SUB TOTAL: MAIN CONTRACTOR'S COSTS				£	**2,159,489**
		CONSTRUCTION WORKS TOTAL				£	**9,260,734**
9		**SOFT COSTS**					
9.01	8	Phasing allowance 10%	10%	%		£	926,073
9.02	8	Out of hours working allowance 10%	10%	%		£	92,607
9.03	8	Professional Fees	0%	%		£	-
9.04	8	Non-Works	0%	%		£	-
9.05	8	Works - Excluding Main Contract	0%	%		£	-
9.06	8	FFE - Equipment as per Schedule	0%	%		£	-
9.07	8	IT	0%	%		£	-
10.00	9	Project Risk	15%	%		£	1,389,110
11.00	10	Design Development	10%	%		£	926,073
12.00	11	Construction Contingency	10%	%		£	926,073
13.00	12	Optimism Bias	20%	%		£	1,852,147
		PROECT TOTAL				£	**15,372,818**

GOLD Gold Package Cost Estimate

Project: Alexandra Palace Clean Energy Masterplan

AECOM

Version: 0

Client: Alexandra Park and Palace

Item		Description	Quantity	Unit	Rate	Total	Additional comments
1.0	1	**Flow Restrictors**					
1.01	1	Flow Restrictors	17	nr	£ 90	£ 1,530	Includes installation
		SUB TOTAL: Flow Restrictors				**£ 1,530**	
2.00	2	**LEDs**					
2.01	2	LEDs	72	nr	£ 50	£ 3,600	Includes installation
		SUB TOTAL: LEDs				**£ 3,600**	
3.00	3	**Lighting controls**					
3.01	3	Lighting controls	105	nr	£ 50	£ 5,250	
	3	Installation	105	nr	£ 50	£ 5,250	
		SUB TOTAL: Lighting controls				**£ 10,500**	
4.00	4	**Daylight control**					
4.01	4	Daylight control	250	nr	£ 50	£ 12,500	
	4	Installation	250	nr	£ 50	£ 12,500	
		SUB TOTAL: Daylight control				**£ 25,000**	
5.00	5	**Destratification fans - East Court**					
5.01	5	New Fans	9	nr	£ 2,000	£ 18,000	
	5	Installation	9	nr	£ 1,000	£ 9,000	
		SUB TOTAL: Destratification fans - East Court				**£ 27,000**	
6.00	6	**Destratification fans - Palm Court**					
6.01	6	New Fans	9	nr	£ 2,000	£ 18,000	
	6	Installation	9	nr	£ 1,000	£ 9,000	
		SUB TOTAL: Destratification fans - Palm Court				**£ 27,000**	
7.00	7	**Air curtain - East Court**					
7.01	7	Air Curtains	2	nr	£ 320	£ 640	
7.02	7	Pipework Installation	50	m2	£ 30	£ 1,500	
		SUB TOTAL: Air curtain - East Court				**£ 2,140**	
8.00	8	**Air curtain - Palm Court**					
8.01	8	Air Curtains	2	nr	£ 320	£ 640	
8.02	8	Pipework Installation	50	m2	£ 30	£ 1,500	
		SUB TOTAL: Air curtain - Palm Court				**£ 2,140**	
9.00	9	**Air curtain - Great Hall**					
9.01	9	Air Curtains	2	nr	£ 320	£ 640	
9.02	9	Pipework Installation	50	m2	£ 30	£ 1,500	
	9						
		SUB TOTAL: Air curtain - Great Hall				**£ 2,140**	
12.00	12	**Reduced flow temperatures**					
12.01	12	Replacement of Existing Pipework & Heat Emitters	5,688	m	£ **330**	£ 1,877,088	Rate includes flow and return steel pipework and an allowance for valves; assumes re use of emitters
	12	Removal of existing	5,688	m	£ 10	£ 56,880	
		SUB TOTAL: Reduced flow temperatures				**£ 1,933,968**	
13.00	13	**Variable speed pumps**					
13.01	13	Pump Replacement	8	kW	£ 2,755	£ 20,663	
		SUB TOTAL: Variable speed pumps				**£ 20,663**	
15.00	15	**Ground Source Heat Pump - Wider site**					
15.01	15	New Ground Source Heat Pump	1,650	kW	£ 1,561	£ 2,575,650	
	15		90	boreholes	£ 8,000	£ 720,000	
			30	m3	£ 1,300	£ 39,000	
			265	m2	£ 1,500	£ 397,500	
		SUB TOTAL: Ground Source Heat Pump - Wider site				**£ 3,732,150**	
17.00	17	**Electric boiler top up**					
17.01	17	New Electric Boiler(s)	3,500	kW	£ 90	£ 315,000	
	17						
		SUB TOTAL: Electric boiler top up				**£ 315,000**	
20.00	20	**Central Battery System**					
20.01	20	New Central Battery	4	kW	£ 3,500	£ 13,264	

		SUB TOTAL: Central Battery System				£ **13,264**	
21.00	21	**Electrify catering**					
21.01	21	Replace Gas Catering Hob with Electric Hob	2	item	£ 5,000	£ 10,000	
		SUB TOTAL: Electrify catering				£ **10,000**	
22.00	22	**Electrify Satelitte Sites**					
22.01	22	Air Source Heat Pump for Garden Centre	70	kW	£ 1,040	£ 72,800	
22.02		Electrical upgrade	300	m	£ 700	£ 210,000	300m from site to transformer; includes armoured cable, trenching and re instatement along with LV panel upgrades
22.03	22	Air Source Heat Pump for Meeson House	15	kW	£ 1,040	£ 15,600	
22.04		Electrical upgrade	690	m	£ 700	£ 483,000	690m from site to transformer; includes armoured cable, trenching and re instatement along with LV panel upgrades
22.05	22	Air Source Heat Pump for Cricket Club	12	kW	£ 1,040	£ 12,480	
22.06	22	Electrical upgrade	540	m	£ 700	£ 378,000	540m from site to transformer; includes armoured cable, trenching and re instatement along with LV panel upgrades
		SUB TOTAL: Electrify Satelitte Sites				£ **1,171,880**	
		Palace Electrical Upgrades (gold)	1,700	KVa	£ 150	£ 255,000	This is inclusive of the electrical upgrades required at the palace
		SUB TOTAL: Palace Electrical Upgrades (gold)				£ **255,000**	
		SUBTOTAL				£ **7,552,974**	
8		**CONTRACTOR'S COSTS**					
8.01	7	Capital Works Project - Contractor's Preliminaries	15%	%	£ 7,552,974	£ 1,132,946	
8.02	7	Capital Works Project - Contractors OHP	8%	%	£ 8,685,920	£ 694,874	
8.03	7	Capital Works Project - Contractor Risk	5%	%	£ 9,380,794	£ 469,040	
		SUB TOTAL: MAIN CONTRACTOR'S COSTS				£ **2,296,859**	
		CONSTRUCTION WORKS TOTAL				£ **9,849,833**	
9		**SOFT COSTS**					
9.01	8	Phasing allowance 10%	10%	%		£ 984,983	
9.02	8	Out of hours working allowance 10%	10%	%		£ 98,498	
9.03	8	Professional Fees	0%	%		£ -	
9.04	8	Non-Works	0%	%		£ -	
9.05	8	Works - Excluding Main Contract	0%	%		£ -	
9.06	8	FFE - Equipment as per Schedule	0%	%		£ -	
9.07	8	IT	0%	%		£ -	
10.00	9	Project Risk	15%	%		£ 1,477,475	
11.00	10	Design Development	10%	%		£ 984,983	
12.00	11	Construction Contingency	10%	%		£ 984,983	
13.00	12	Optimism Bias	20%	%		£ 1,969,967	
		PROECT TOTAL				£ **16,350,723**	

Appendix 8. Alexandra Park and Palace Energy Delivery Strategy Report

Issued as an independent document

Delivering a better world

Alexandra Park And Palace: Energy Delivery Strategy

September 2023

Appendix 9. Alexandra Park and Palace PV Study

Issued as an independent document

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Alexandra Park And Palace: PV Feasibility Study

September 2023

Appendix 10. Mini Business Cases

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Alexandra Park And Palace: Mini Business Cases

September 2023

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