

Power Hall & Decarbonisation
Project

M&E strategy report

Power Hall and Site Salix Works

21 April 2021

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1.0 INTRODUCTION

This report has been prepared by Max Fordham LLP on behalf of and in collaboration with the Science and Industry Museum team.

1.1 Overview

The Museum is looking to develop a site wide sustainability strategy with the aim to meet the carbon emission targets set by the Manchester City Council by 2030.

The Museum, as a public body and relevant Institution that promotes scientific progress, aims to provide a tangible contribution to a more sustainable future and contribute to improve awareness on the Climate Change issue.

As part of this vision, technical investigations will be carried out to explore how innovative solutions can contribute to reducing the operational carbon footprint of Site, with reference to the heating and cooling demand of the buildings.

1.2 Objectives

The purpose of this report is:

- To illustrate the overall upgrading of the M&E systems across the Science and Industry Museum site
- To describe the proposal for the new M&E systems serving the Power Hall building and to explain how this option has been preferred across others
- To present the heating system upgrades to the 1830 Warehouse and the New Warehouse buildings
- To illustrate the interfaces of the new systems with a listed building requirements.

A set of drawings will accompany this document, to illustrate graphically the assumptions and the proposed new scheme.

2.0 THE PROJECT

The Power Hall and Decarbonisation project is to be delivered as one project. However, the required Planning and Listed Building Consent applications must be split into several separate applications due to the different Listings of the buildings and the deadlines for the Government’s Public Sector Decarbonisation Scheme which needs to be completed this year. Splitting the consent packages will also allow construction works to start on site earlier and ensure the Government deadlines will be met.

Below is the timeline table for the applications. This report will focus on work packages 1A and 1B

Power Hall & Decarbonisation - Work packages

WORK PACKAGES	PACKAGE DESCRIPTION	PLANNING AND LISTED BUILDING CONSENT APPLICATIONS	SUBMISSION DATE
1A	Water Source Heat Pump Network (External) Water Source Heat Pump and other associated plant in the Power Hall	• Application for Listed Building Consent for alterations to the Grade II Listed Power Hall for the creation of openings and the installation of plant plus the introduction of a services trench within its curtilage. • Application for Listed Building Consent for installation of a services trench within the curtilage of the Grade II Listed New Warehouse. • Application for Planning Permission for external works to the Boiler Room including removal of an external staircase and making good in addition to the installation of a new balustrade and new doors. • Application for Listed Building Consent for alterations to the Grade I Listed 1830 Warehouse for the creation of openings and the installation of pipework plus the introduction of a services trench and borehole cover within its curtilage.	April 2021
1B	Boiler House External Modifications (to facilitate installation of a new sub-station) Pipework in the 1830 Warehouse (to facilitate installation of a new water source heat pump)		
2	Power Hall Roof and 1980s Platform Removal (to allow early investigative work)	Planning Permission & Listed Building Consent	May 2021
3	Power Hall New Roof, Windows & Doors	Planning Permission & Listed Building Consent	May 2021
4	Power Hall Gallery Refurbishment	Planning Permission & Listed Building Consent	Autumn 2021

3.0 THE SITE

The Science and Industry Museum is located on the west of Manchester city centre, between Castlefield, to the south, and St John's Quarter, to the north. It is within the Castlefield Conservation area and it represents a significant heritage of the Industrial history of the City.

This report will focus on the energy strategies related to:

- The Power Hall
- The 1830 Warehouse
- The 1830 Station

The Power Hall is Grade II listed, alongside the Science and Industry Museum's New Warehouse, the Air and Space Museum and the Colonnaded Railway Viaduct. The former Liverpool Street Station is Grade I listed, alongside the 1830s Old Warehouse.

3.1 Existing Heating & cooling systems

The site presents different HVAC (Heating, Ventilation & Air Conditioning) solutions across the buildings, mainly as a result of new installation, refurbishment and interventions that followed along the past years.

At the moment heating & cooling strategy of each building can be summarised as follows:

THE NEW WAREHOUSE

This building is currently served by 3 gas fired hot water boilers (460 kW each, 2 duty + 1 spare) installed in the 2010. These boilers produced heating for the New Warehouse, the Restaurant and shop areas and the SEG (Special Exhibition Area) and distribute hot water to the 1830 buildings as well.

The New Warehouse is equipped with an 875 kW air cooled chiller, installed outside beside the building, providing cooling capacity to main AHUs (Air Handling Units), and local FCU (Fan Coil Unit). Currently this is the only building with cooling provision across the site.

Domestic hot water is produced via 2 main electric water heaters, with a dedicated recirculating system to maintain domestic water temperature across the sanitary points

THE 1830 WAREHOUSE

Heating for this building was supplied by a gas fired boiler, installed in the building basement and distributed to the 1830 Station as well.

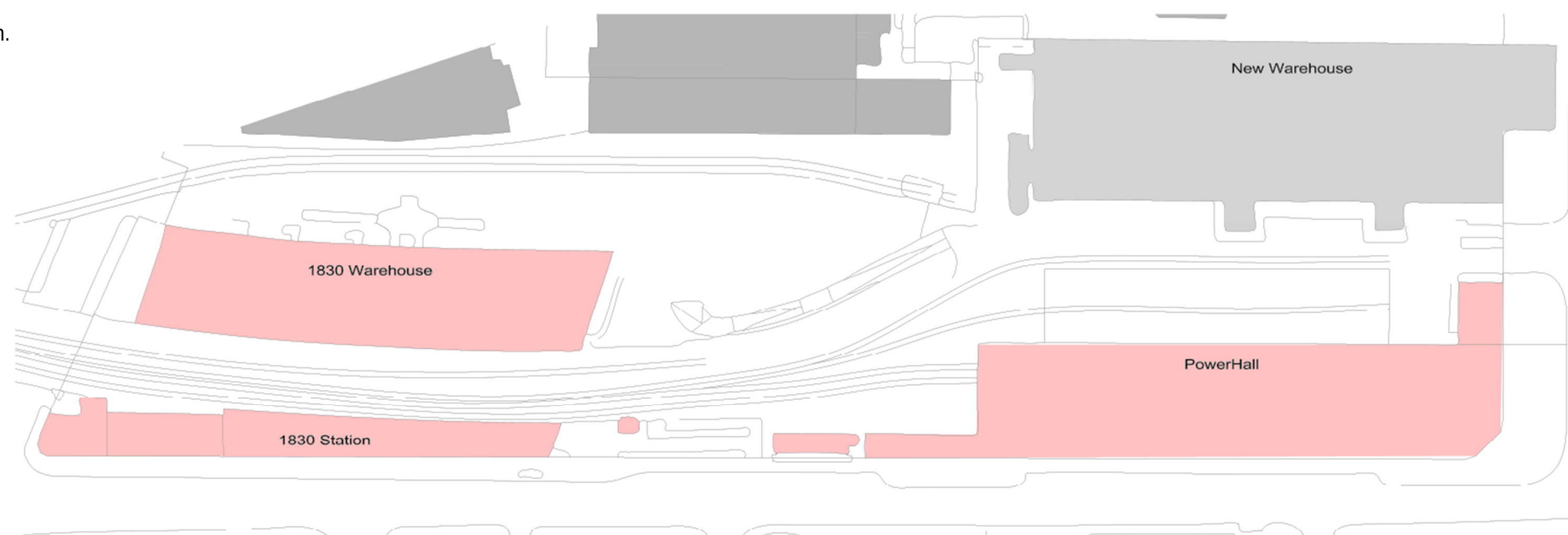


Figure 3-1 - SIM site keyplan

However the boiler is not in operation anymore and failed probably due to the poor plantroom conditions. Heating is currently provided by the New Warehouse boilers, via a heat network running between the 2 buildings (see beside keyplan). The general conditions of the plantroom are poor and a major renovation is recommended.

The building is heated via ambient emitters and radiators, generally in good condition.

Hot water to the 1830 Warehouse is generated in hot water cylinders housed in WP01 in the Lower Ground Floor. A Megaflow Eco 210l unvented indirect hot water cylinder is heated by LTHW (low Temperature Hot Water) with electric immersion back up. This appears to be a recent installation and the serial number suggests 2016.

THE 1830 STATION

A plantroom in the basement provides heat to the Station Masters House. It also serves part of the 1830's Warehouse, the heating to the First- and Second-Class Booking Halls are provided from this system.

Heating is generated by a 70 kW gas fired boiler, wall mounted, with limited life expectancy left. Domestic hot water is prepared via an hot water cylinder supplied by the boiler hot water.

The heating system of this building is linked with the 1830 Warehouse heating system, making difficult to separate them in a future "re-configuration" of the HVAC strategy. The current configuration would suggest treating the 1830 buildings as only one building.

THE POWER HALL

The Power Hall building is closed at the time this report is produced, and undergoing a major fabric renovation, mainly driven by the roof damages that cause water leaks and damp.

The building is not currently heated and a new energy strategy will be presented in the following chapters.

When this gallery was in operation, heating was provided by a dedicated Air Handling Unit installed within the Power Hall itself. The AHU used to distributed warm air at high level to warm up the place.

The AHU was powered by 2 heating coils, one connected to a gas fired hot water boiler and one supplied by the live steam produced for operating the historic steam engines: as a part of the Museum interpretation strategy, a series of historic steam engines were powered by a gas fire steam boiler. This boiler had enough capacity to operate the historic engines and supplied excess heating to the AHU.

Both the steam and hot water boilers serving the Power Hall are not in operation at the moment and the building is not conditioned.

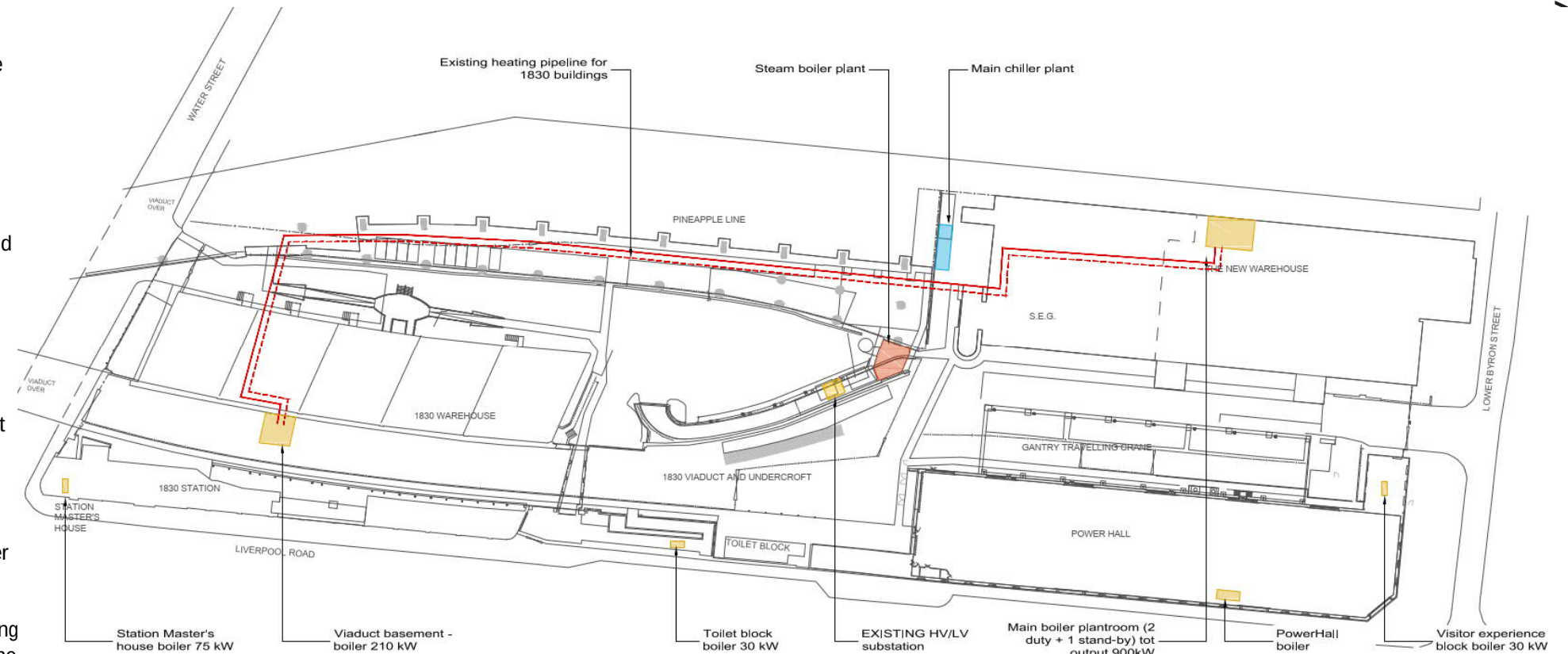


Figure 3-2 - SIM site - main services keyplan

4.0 SITE ENERGY ANALYSIS

The energy analysis of the site is essential to investigate the next sustainable options. In particular, the understanding of how the buildings are used, what are their average energy consumption and peak energy demand will help to identify viable solutions that can provide both environmental benefits and a cost-effective scheme.

4.1 Main assumptions

THE POWER HALL
For this building an energy model has been produced using IES (Integrated Environmental Solutions) software. The main assumptions for the energy models are:

- As the building is under renovation, it has been assumed that the roof, windows and main doors will be replaced with well-insulated elements according with the current standard regulations.
- Only a heating system will be provided to the refurbished building (no cooling).
- A new heating system will be provided, capable of working with relatively “low temperature” water, suitable to be interfaced with future heat pump solutions.
- Natural ventilation will be provided via the new window openings. For this analysis no mechanical ventilation is assumed, maintaining the existing solution.
- No domestic hot water demand has been assumed at this stage. If any hot water points will be introduced during the refurbishment design, the energy impact will be negligible over this analysis.

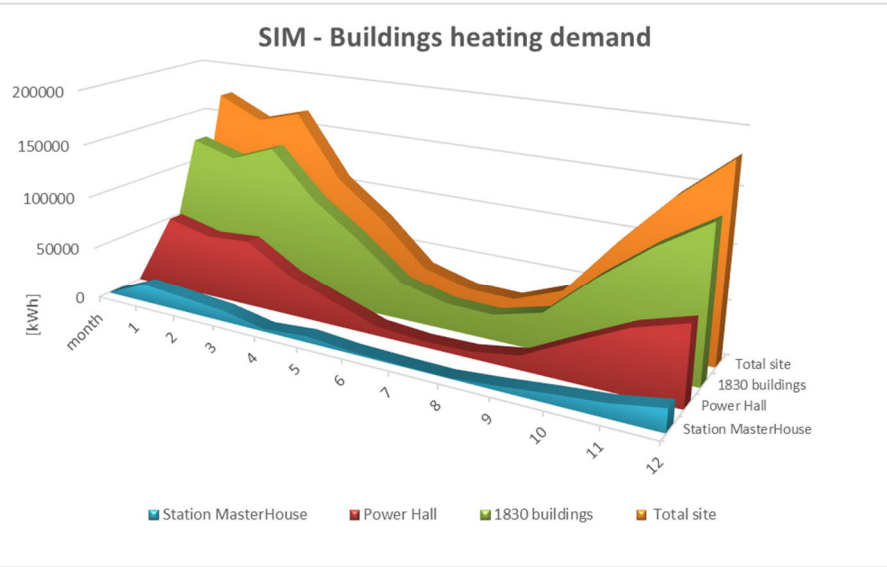
A different approach is needed for the historic steam engines. The building houses 10 steam engines connected to the existing steam line that were used to be powered for display purposes. The steam demand for these units was in region of 1.7 – 1.8 tons/h, which is equal to a heating capacity of 1.3MW. For how these engines work, it was necessary to condense the steam, bringing it back to liquid state to re-pressurise it again within the steam boiler. This meant to dissipate into atmosphere all the latent heat of steam during the process.

As part of this energy analysis, the possibility to recover the steam heating was assessed. For this, it has been assumed that a lower steam demand will be provided in future, when and if the historic steam engines will be brought back to operation.

For the sake of this exercise it has been assumed that a max steam demand of 1000 kg/h will be needed in future to re-power these units. Energy analysis can be re-arranged if different steam consumptions figures will be considered.

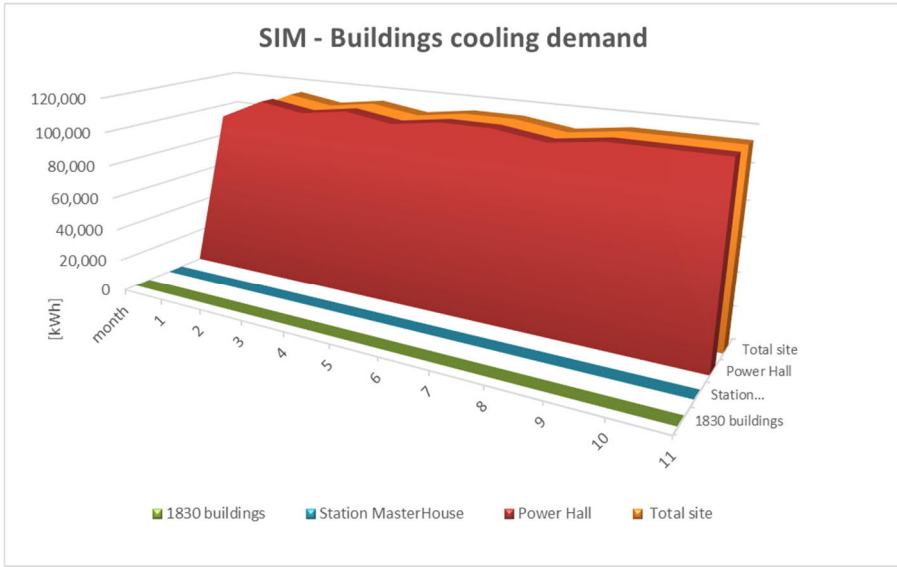
SIM - Science Industry Museum - site energy summary - existing scenario

Building monthly energy demand - HEATING				
Month	Power Hall building	1830 buildings	Station Master	
	[kWh]	[kWh]	[kWh]	
Jan	70,916	138,523	17,707	
Feb	61,082	126,918	14,225	
Mar	64,051	142,165	10,795	
Apr	38,909	99,267	2,560	
May	23,521	69,903	5,800	
Jun	8,950	36,082	2,256	
Jul	5,471	25,312	1,119	
Aug	6,193	24,064	467	
Sep	13,346	35,694	4,276	
Oct	36,503	76,740	8,994	
Nov	58,673	112,100	13,031	
Dec	72,481	140,846	20,956	
Total	460,097	1,027,615	102,182	



SIM - Science Industry Museum - site energy summary - existing scenario

Building monthly energy demand - COOLING				
Month	Power Hall building (steam engines)	1830 buildings	Station Master	
	[kWh]	[kWh]	[kWh]	
Jan	694	0	0	
Feb	101,250	0	0	
Mar	113,400	0	0	
Apr	109,350	0	0	
May	113,400	0	0	
Jun	109,350	0	0	
Jul	113,400	0	0	
Aug	113,400	0	0	
Sep	109,350	0	0	
Oct	113,400	0	0	
Nov	113,400	0	0	
Dec	113,400	0	0	
Total	1,223,794	0	0	



The tables summarise the energy demand for conditioning the buildings, both in winter and in summer, with the following notes:

- Energy values are intended to represent the amount required by the building BEFORE the heating generation system. The PRIMARY energy will therefore depend on the different type of generators, as explained on the following paragraphs.
- It has been assumed that cooling capacity will be provided only for the New Warehouse
- The Power Hall cooling demand represents the total energy to be dissipated by the steam system. As highlighted on the chart, this energy dissipation is overall constant through the year, as it is not related with the outdoor temperature conditions.

The results suggest the possibility to recover part of the heating energy dissipated by the steam system, in order to partially offsetting the energy demand for heating of the buildings.

THE 1830 BUILDINGS
The energy demand for these 2 buildings have been calculated mainly for the heating requirements due to building envelope losses. As historic buildings, the construction presents poor insulation properties, that makes the energy demand quite significant, compared with other energy usages.

Ventilation has been accounted in terms of infiltration; however no mechanical ventilation requirements have been considered at this stage.

4.2 Domestic hot water

At this stage energy demand for domestic hot water was estimated for the New Warehouse, where most end-users are (visitors toilet blocks, showers and restaurant).

4.3 Primary energy, CO₂ and cost

The three main aspects to assess while considering how to offset the building energy demand are:

- The CO₂ production associated with that demand
- The Primary energy taken from the primary sources to provide the final net building demand
- The economic cost of that energy demand.

CO₂ FACTOR
The carbon impact of different types of energy is summarised by the CARBON FACTOR, that expresses the amount of kg of CO₂ produced by a system to provide 1 kWh of net energy. Carbon factors depend both type of fuel/source and how this fuel/source is distributed.

In the past the carbon emissions intensity of the UKs electricity supply has been at least double that of natural gas. This has now changed and currently the carbon emissions intensity of the UKs electricity is roughly equal to natural gas. In the near future the carbon emissions intensity of the national grid is projected to fall to less than 25% of natural gas by 2030.

The projected emissions of the UK's electricity supply shown in Figure 4-1 mean that by the government's definition grid electricity will reduce carbon emissions compared to conventional use fossil fuels and thus be a low carbon technology.

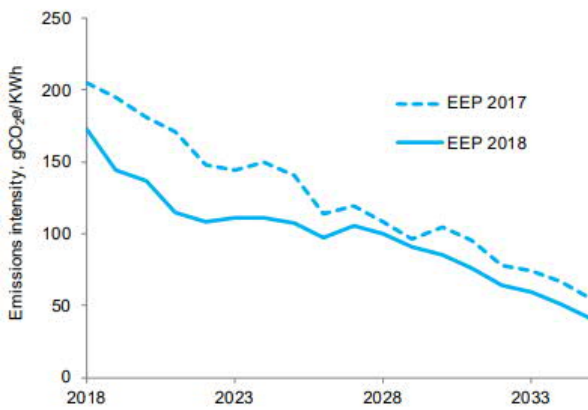


Figure 4-1 - Projected CO2 emission for electric grid - UK

PRIMARY ENERGY
Primary energy is an energy contained in fuels and other forms of energy like oil, coal, natural gas, wind and water before any extraction, conversion and transformation processes is called PRIMARY ENERGY (PE). After conversion processes PE is converted into the final energy (FE). FE is a form of energy available to the user following the conversion from primary energy carriers.

Primary energy factors (PEF), often referred to as conversion factors, are required to calculate the total energy consumption including the chain of energy generation based on the final energy consumption data. For each type of delivered energy, a so-called PEF is assigned.

As per the latest figures, Natural gas has a lower PEF (1.13) than electricity (1.5), mainly because natural gas is subject to less generation and transformation processes than electricity before to be available to the final user.

ENERGY COST
The Energy cost represents the charge of the Utility company for the different type of energy supplied (gas, fuel, electricity, etc.). Comparing the natural gas with electricity, it seems the fossil fuel is cheaper than the electrical energy.

	Carbon factor [kgCO ₂ /kWh]	Primary Energy factor [kWh/kWh]	Unit cost [£/kWh]
Natural gas	0.204	1.13	0.0236
Electricity	0.2	1.5	0.1228

However, the heat pump technology allows to multiply the efficiency on the heating production. In fact the heat pump uses electricity just to transfer heating from a source to the user. The efficiency of the heat pump is defined as COEFFICIENT OF PERFORMANCE (COP), that represents how many kW of heating are transferred to the building with 1 kW of electricity.

A COP of 3 means that 3kW of heating will be produced by the heat pump, using only 1 kW of electricity.

Using heat pump technology makes using electricity for heating purposes more convenient than using natural gas. This convenience will increase while the heat pump COP increases. That is the reason why it is convenient to maximise the COP in a process with heat pumps.

4.4 Summary

The energy analysis above will support the following considerations:

- To provide an effective site decarbonisation, heating demand should be satisfied via the ELECTRIFICATION of the system, avoiding combustion in situ
- The electrification of the heating system is ONLY beneficial if a HEAT PUMP is used
- The benefit of heat pumps, for CO₂ and cost reduction, increases as the COP of the heat pump increases

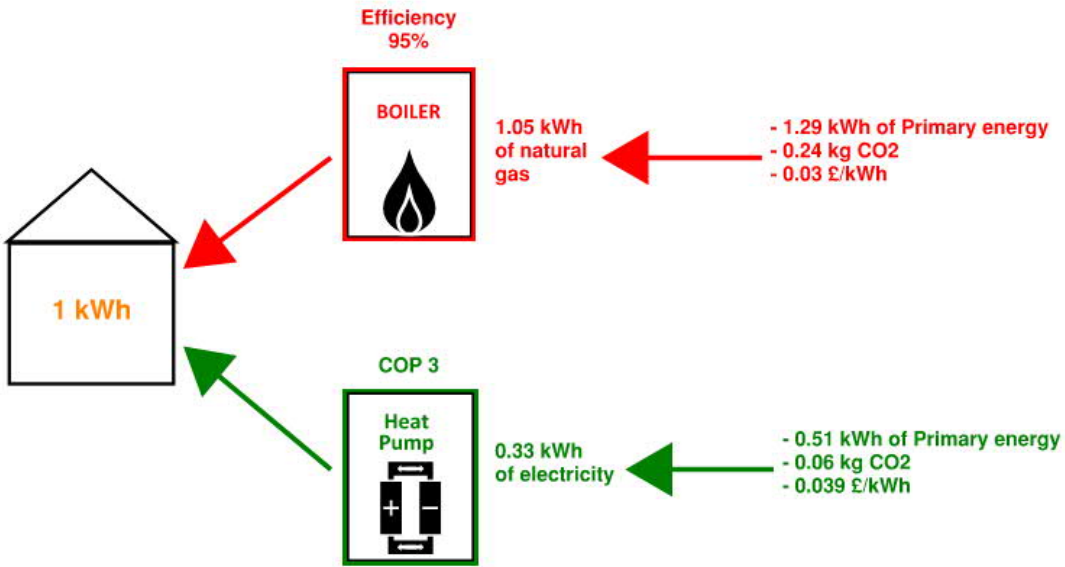


Figure 4-2 - Boiler VS Heat pump comparison

5.0 THE HOLISTIC APPROACH

The Department for Business, Energy and Industrial Strategy (BEIS) launched the Public Sector Decarbonisation Scheme (referred to as the Grant Scheme) which will be delivered by Salix. The scheme puts huge encouragement into green investment, supporting the Government's net-zero and clean growth goals, which also align with the City's own carbon net zero objectives.

The SIM group, together with the Design Team have proposed a holistic refurbishment of the existing M&E site infrastructure with the intent to:

PROVIDE AN EFFECTIVE DECARBONISATION APPROACH TO THE SITE

INTEGRATE THE NEW CARBON NEUTRAL TECHNOLOGIES WITHIN THE RE-INTERPRETATION OF THE POWER HALL COLLECTION

The Power Hall requires a new sustainable heating system, together with a modern way of dissipating the excess condensate heating from the historic steam engines.

When in operation, the historic steam engines dissipate an important amount of energy. The idea is to recover and reuse this energy across the site.

To do so, we needed a flexible system: able to recover heating when required, able to transfer heating to other buildings, able to dissipate heating when it's not demanded, in a safely manner.

The best option to achieve these requirement is to use borehole water: this source can be used for heating purposes (via a water-to-water heat pump), for cooling purposes (for the steam condensing system), and for heat transfer purposes (as a mean of district heating across building).

The overall site scheme can be then summarised as per the following diagram:

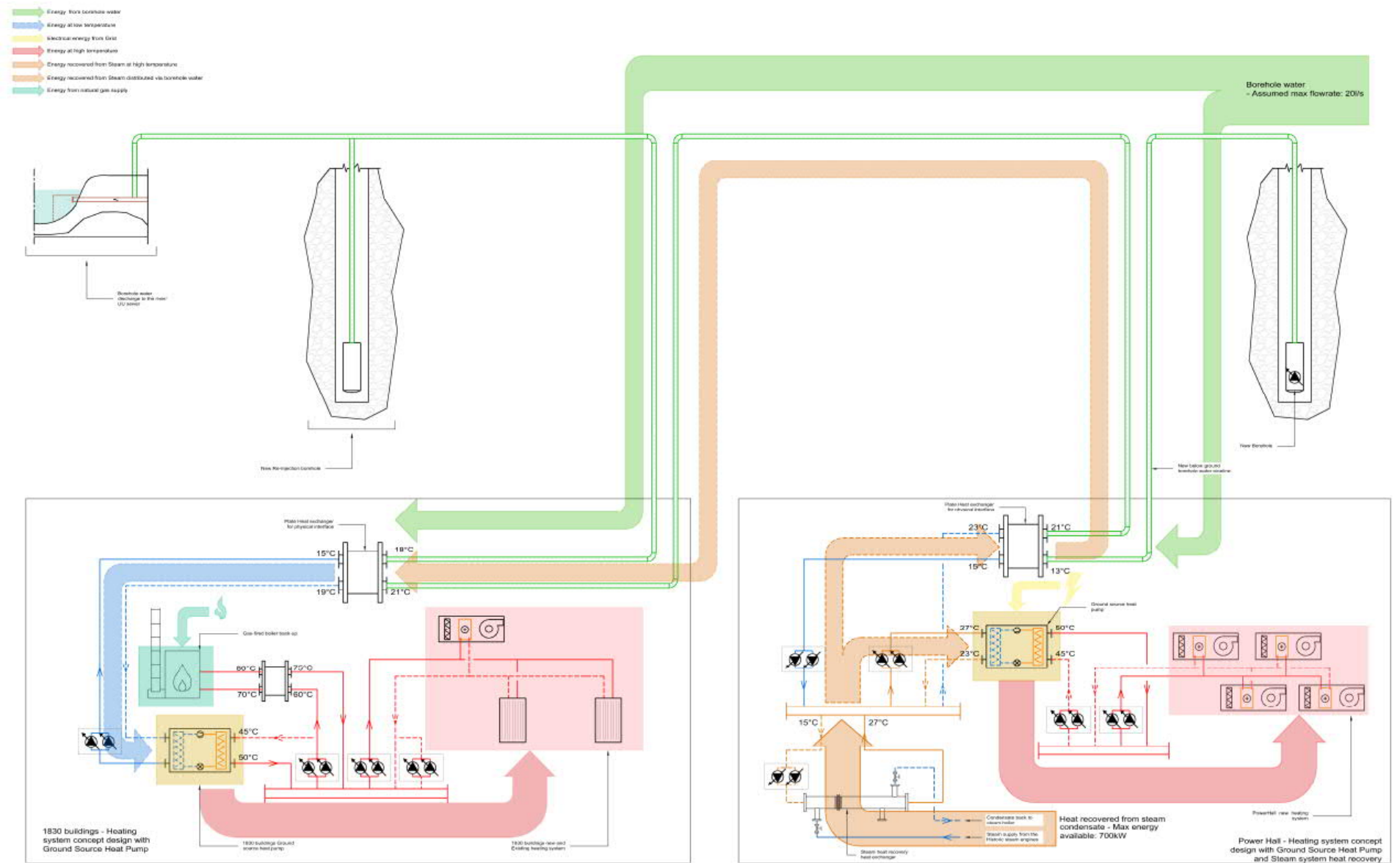


Figure 5-1 - SIM site - synopsis of the new proposed scheme - refer to the related drawing for the readable version

6.0 1A – Water source heat pump network

The holistic approach will require to interface the Power Hall and the 1830 Warehouse with a new heating network. This will allow to recover heating energy from the steam system in the Power Hall and transfer it to the 1830 Warehouse and Station buildings.

This process will be done using borehole water, transferred across the site via a new below ground pipeline, creating a new Water source heat pump network

A new services trench is proposed across the site, in order to:

- accommodate the new electricity supply from ENW to the new substation
- accommodate the new electricity supply from the new site substation to the Power Hall

- accommodate the borehole water pipe,
 - o from the abstraction borehole to the Power Hall
 - o from the Power Hall to the 1830 warehouse
 - o from the 1830 warehouse to the re-injection borehole
- provide flexibility for the future connection in terms of data and BMS, laying within the trench corrugated plastic ductwork for future cabling.

The new trench will follow the route shown below and on the attached drawings. The route is indicative at the moment and subject to re-routing within the hatched area, based on the unknown below ground existing services and constraints.

A number of trial pits are proposed in key areas to investigate the below ground conditions and to confirm the proposed route.

Refer to the DAS and the accompanying methodology for further details.

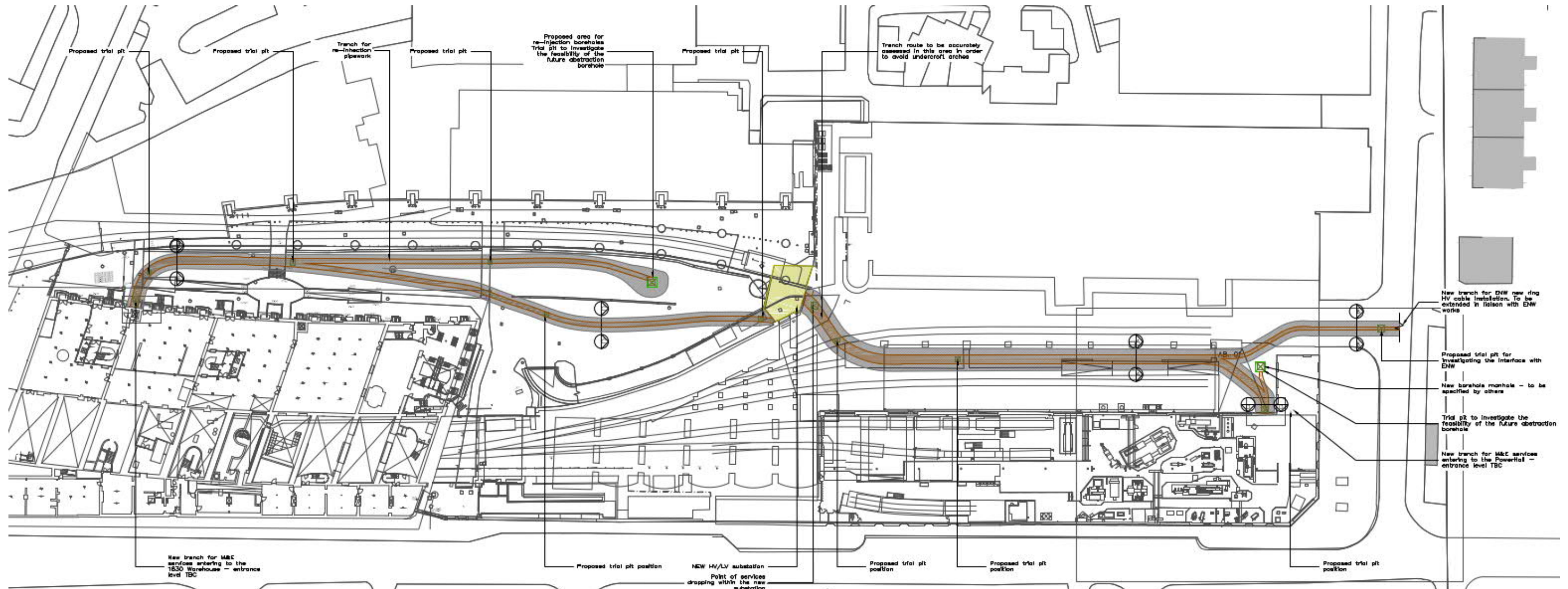


Figure 6-1 - Proposed trench layout snapshot for the new WATER SOURCE HEAT PUMP NETWORK – refer to the related drawing for the readable version

6.1 Abstraction borehole and WSHP

As part of the new Sustainable approach, it has been investigated in the recent past the possibility to use underground water in a water source heat pump scheme to meet cooling and heating demands.

Based on this, investigation works were carried out back in November 2016 to assess if the existing well built in the 1830 Warehouse basement could have been used as existing source of ground water.

The report produced by Advisian described the test results. In particular, the well performance test did not achieve the objective of abstracting 20 l.s⁻¹ due to dewatering of the well. The constant rate test was successfully undertaken at an average rate of 4.8 l.s⁻¹.

However, an assessment of abstracting and disposing 20 l.s⁻¹ to support a wider district scheme was identified that the aquifer can supply this quantity of groundwater.

Water quality samples collected indicated that the abstracted water is of near potable quality and could be used within a grey water system. It has also identified that the abstracted water has a potential to form scale within any system. Bacterial presence also indicates the potential for biofouling.

6.2 Open loop water source heat pump

Open-loop water source heat pumps utilise borehole water abstracted from an aquifer via a water well as a thermal resource to provide heating or cooling. After use, the water is returned directly to the ground via an injection borehole or soakaway (non-consumptive) or diverted elsewhere for use as a private water supply, to a sewer or a watercourse (consumptive).

The advantage over surface water source heat pumps (SWSHPs) is that groundwater temperatures at 10–15 m below the surface are usually reliable and predictable throughout the year (approximating to the mean annual air temperature at that location) and increase with depth according to the local geothermal gradient (UK average 2.6 °C per 100 m depth). Predictable source temperatures simplify the design process and can enhance heat pump performance.

An open-loop WSHP is similar to shallow ground source or surface water source heat pumps but set up or modified to maximise the benefit of the reliable and predictable source temperature.

This technology represents an interesting opportunity for implementing an effective and innovative sustainable strategy for the Museum.

A water source heat pump:

- can provide a source of heating AND cooling all year around.
- reduces the space for equipment location: an abstraction well can be installed in below ground chambers and heat pumps are similar in size to standard gas fired boilers.

- Heat pumps and other equipment can be installed inside, within the existing plantroom, without compromising the external space.
- It guarantees a much higher COP, as the main energy source (ground water) is a relative stable temperature all year around.

Based on these benefits, the proposal is to provide a new abstraction borehole in the proximity of the Power Hall, supplying ground water to the new Power Hall systems, then transferring the same water (and its content of recovered energy) to the 1830 building where it can be further used via a Water Source Heat Pump to warm the building in a sustainable manner.

Borehole water will be returned back to the aquifer in a dedicated re-injection borehole in the loweryard.

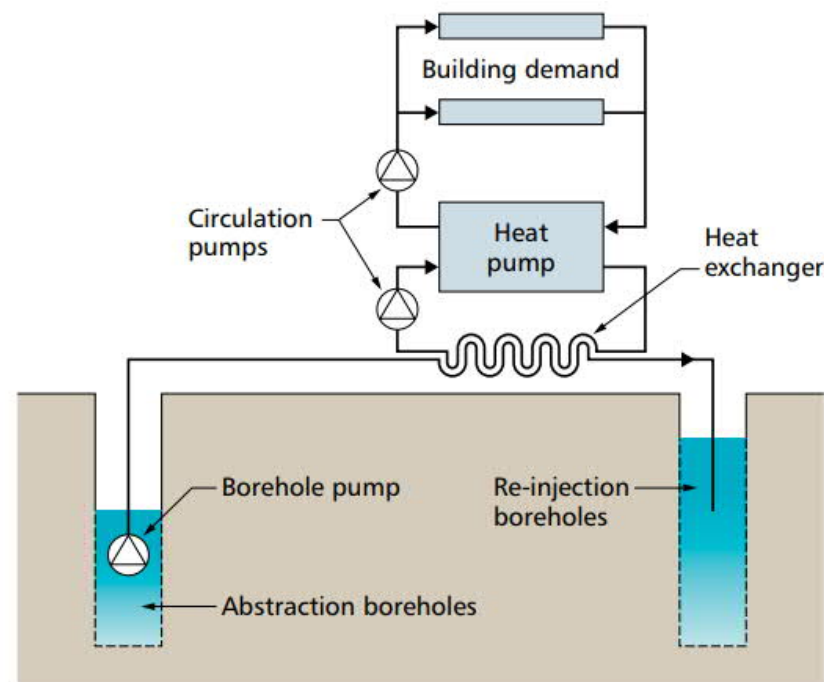


Figure 6-2 - Typical open loop water source heat pump scheme



Figure 6-3 - Typical Water-source heat pump (WSHP) equipment (Courtesy of Mitsubishi Electric)

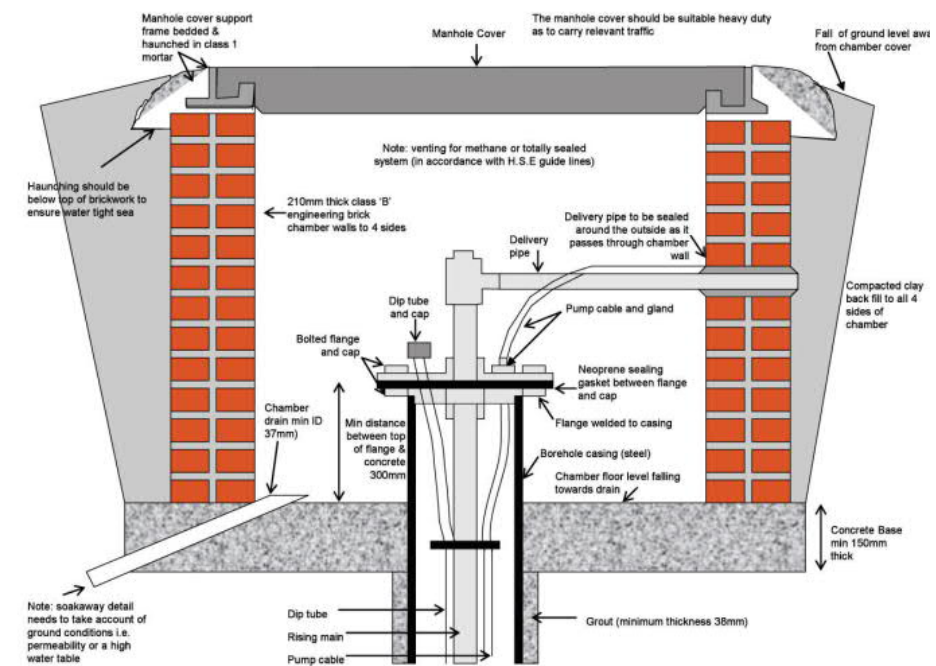


Figure 6-4 - Typical borehole manhole section

6.3 New Boreholes – considerations

Despite the several advantages, an open loop water source heat pump presents some aspects to be investigated, in order to safely propose this as a reliable option for the site.

6.4 Flood risk

Water abstracted from the ground will need to be either re-injected back into the ground, disposed of in a surface water body (rivers, canals), or delivered to the public sewer. Re-injecting water may cause a flooding risk on the lower areas of the buildings (in particular the New Warehouse and the 1830 Building basement).

An hydrogeologic study comprising with a 3D numerical model has been constructed to represent the conceptual understanding of the groundwater system with the proposed scheme, using an industry standard model SEAWAT.

The model has been used to:

- assess the impact of re-injection on groundwater levels from the current borehole array;
- assess alternative borehole arrays should flooding be of concern;
- Vary re-injection flow rates to a value where no adverse flooding is observed; and,
- assess the thermal impacts of the scheme to understand the long-term sustainability of the aquifer and system.

The groundwater flow model was set to look at a number of re-injection scenarios, where the abstraction rate of 20 L.s-1 was kept constant. The following scenarios were considered:

1. Total re-injection rates of 20, 10, 7.5 and 5 L.s-1 were reviewed to determine if groundwater flooding of the basements occurred as an outcome of the re-injection rate. The re-injection rates were distributed across the four re-injection wells evenly;
2. Re-injecting at a rate of 10 L.s-1, using only the re-injection wells located furthest east of the 1830 Warehouse – RB02 and RB03;
3. Re-locating the re-injection wells so that they are configured in a linear formation, alongside the 1830 Warehouse;
4. Switching the abstraction well and re-injection well locations for an injection rate of 20 L.s-1 ;
5. Injecting with a single re-injection point

The results show that the re-injection of all 20 L.s-1 of abstracted water could potentially create a flood risk to the basements, however, this risk is reduced when the re-injection rate is decreased to less than 10 L.s-1. The sensitivity analysis indicates that a maximum of 7.5 L.s-1 can be re-injected. A 90% level of confidence can be assigned to re-injecting groundwater at 7.5 l/s based on river flow data (CEH) and Manchester City, Salford City and Trafford Councils Level 2 Hybrid SFRA

This means that 12.5 to 15 L.s-1 of abstracted water will need to be discharged at an alternative location, which is currently identified on discharging the borehole water into the river Irwell, passing beside the Museum plot.

This could be done by:

- Connecting to the storm overflow pipe which discharges directly into the River Irwell
- Running a discharge pipeline along the bridge and create a new discharge location off the bridge footings

This option would require an environmental permit from the Environment Agency. To support the environmental permit (and abstraction licence) a hydrogeological impact assessment would also be required to be submitted with the application. The hydrogeological impact assessment would need to consider the impacts on flow within the River Irwell and any other surface water bodies; the impacts on water quality (both ground and surface waters) and set out a monitoring strategy. In discussion with the Environment Agency, modelling is likely to be required to support the impact assessment to show no adverse effects from the scheme.

These studies and liaison with the Environmental Agency are currently taking place to grant the relevant permissions and licences.

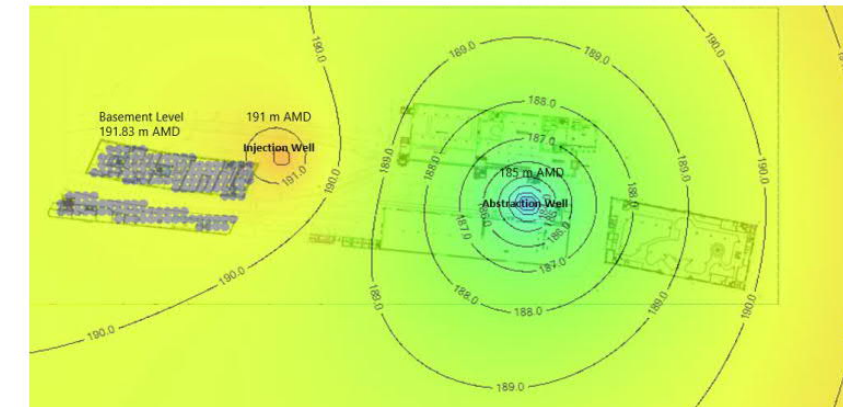


Figure 6-5 - floor risk model - Courtesy of Advisian

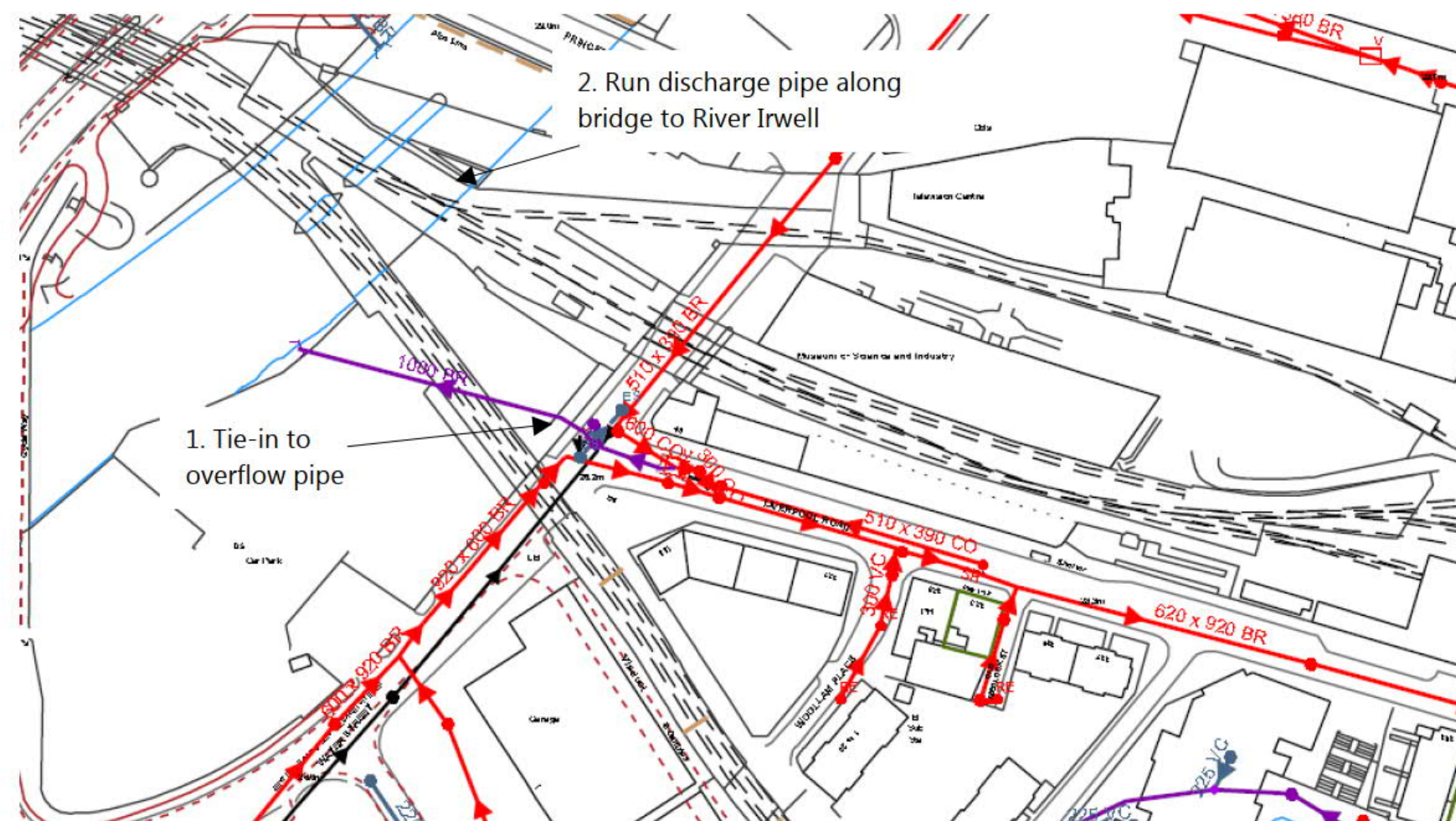


Figure 6-6 - below ground drainage map abstract near the site

7.0 1.A – WATER SOURCE HEAT PUMP – POWER HALL PLANT

The proposed works for achieving the Scheme targets on the Power Hall can be summarised as:

- WSHP for heating of Power Hall
- Electric steam boilers for provision of steam to Historic Working Machines to replace gas fired steam boiler
- Heat recovery of steam condensing for heating Power Hall
- All new main equipment and Heat Recovery plant is displayed as part of museum interpretation on decarbonisation

7.1 Electric steam boiler

The Power Hall refurbishment will include the restoration of the historic working machines.

The new interpretation will see these artefacts as the synthesis link between the historic heritage and the current sustainability approach: how to provide an energy-demanding system (steam) in the most sustainable way.

Steam requires high temperatures to be produced, which can't be reached with the modern heat pump technologies. That leaves two main possible options, gas-fired boilers and electric boilers:

Electric boilers present several advantages on our scheme:

- No combustion is needed. The boiler will not need flues, or gas supply. There is no requirement of special ventilation or gas leak detection.
- Electric boiler is silent. Due to the lack of flames, burners and flues, this equipment does not require any acoustic mitigation
- Electric boiler is more compact. Electric boilers take up less space than an equivalent gas boiler.
- Electricity can be purchased by a Green utility company. This will offset the carbon footprint of the operation
- The electric boiler can be installed visible to public, with less constraints due to the fire regulation

7.2 Steam heat recovery

The historic steam engines will demand steam to operate based on their display operation time, which it will not be continuous. However, the display operations require a significant warm-up period, to bring the units and the system into temperature. Based on the previous exhibition figures, it has been assumed that there might be 2 displays/day, which can be translated in 110 MWh/month of recoverable heating.

Heating from the steam system will be recovered with a special steam-to-water plate heat exchanger, designed to transfer the steam latent heat to

the ground water, so it will be available as heating source for the Power Hall and other buildings.

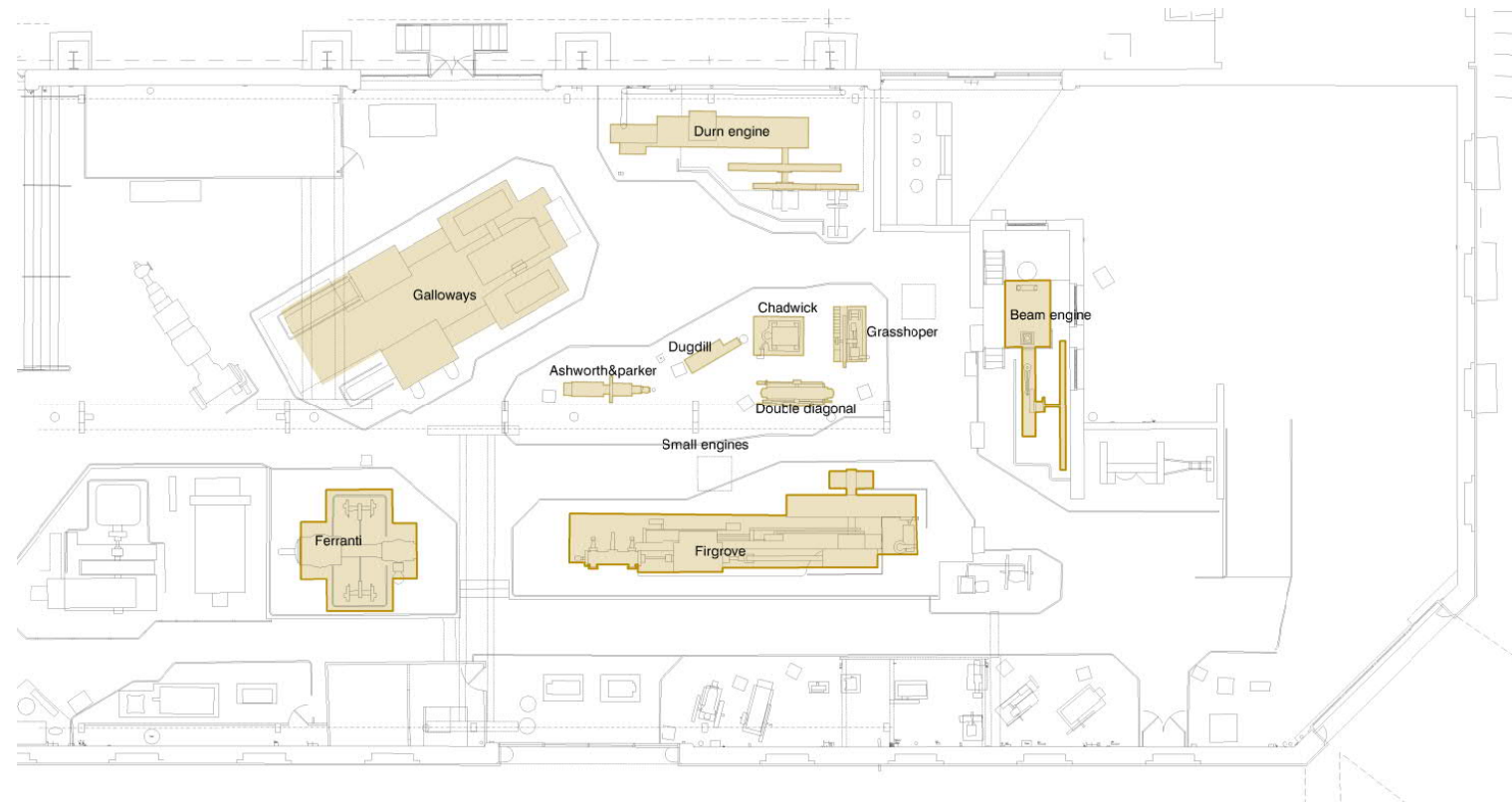


Figure 7-1 – Power Hall historic steam engines layout

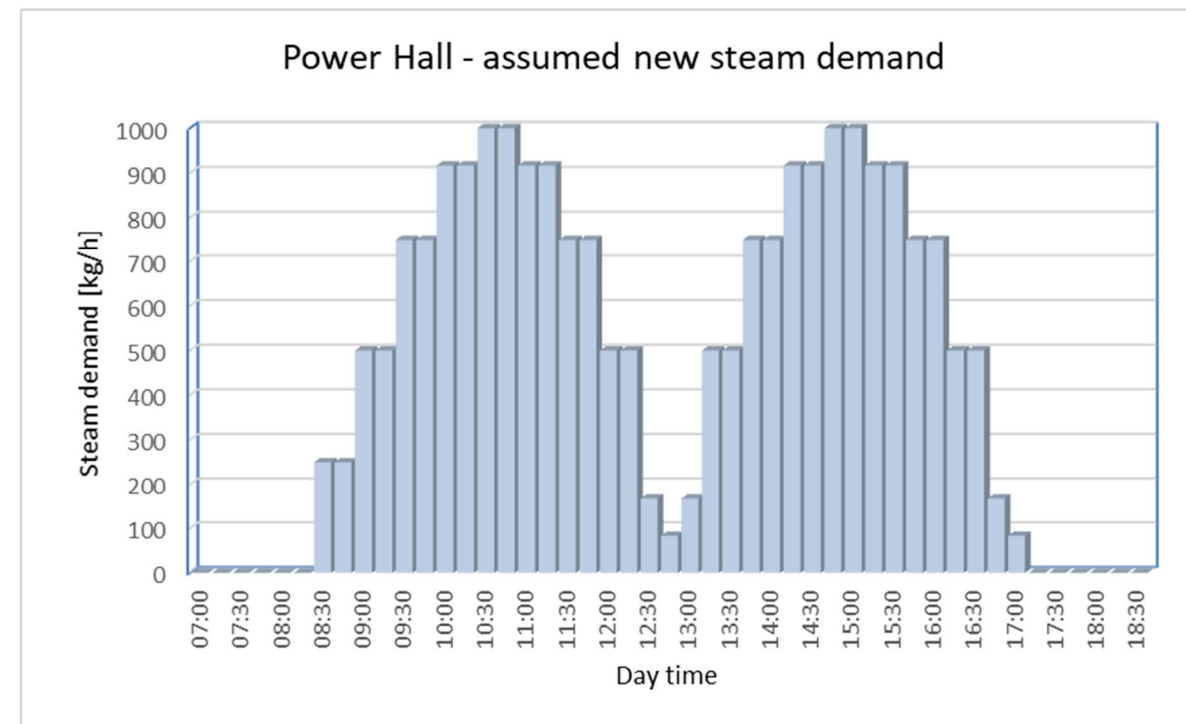


Figure 7-2 - steam heat recovery package - courtesy of Spirax Sarco

7.3 Plantroom on display

The major renovation at the Power Hall aims to connect the historic working machines - which have a high energy demand and were powered by high pollution coal fired steam - with a modern and sustainable system, able to offset the carbon footprint and enhance the overall efficiency of the site.

Efficiency is achieved by saving energy for further use.

The re-interpretation of the Power Hall wants to celebrate this synthesis between the past and the present and wants to emphasize the story behind this synthesis with the public.

The best way to interact and create awareness with the public is to display, to make it visible. That's the aim to build the new plantroom within the Power Hall, visible to the public, so the public can appreciate how the system works in "circular" (from ground to ground), rather than "linear" (from ground to atmosphere).

The concept will highlight the main equipment, make them lead on the interpretation. Pipework and valves will highlight the energy transfer across the systems.

The element finishes will be in metal polish cladding, with custom-made insulated boxes to protect the main equipment.

The visual result will be in line with the examples here reported.

7.4 New equipment in the Power Hall

The new main equipment that will be installed within the Power Hall plantroom area will be:

- 1 No. electric steam boiler and associated equipment (water treatment, blow down vessel, hotwell)
- 1 No. packaged steam-to-water heat exchanger
- 4 No. water source heat pumps
- 2 No. water buffer tanks
- 1 No. plate heat exchanger
- 4 No. pump set
- 1 transformer (housed in a suitable enclosure)
- 1 Main switchboard (housed in a suitable enclosure)

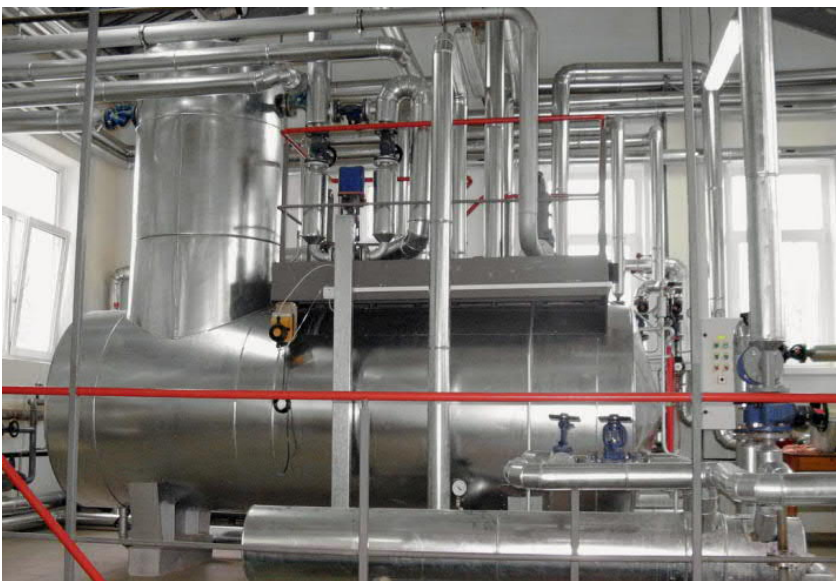
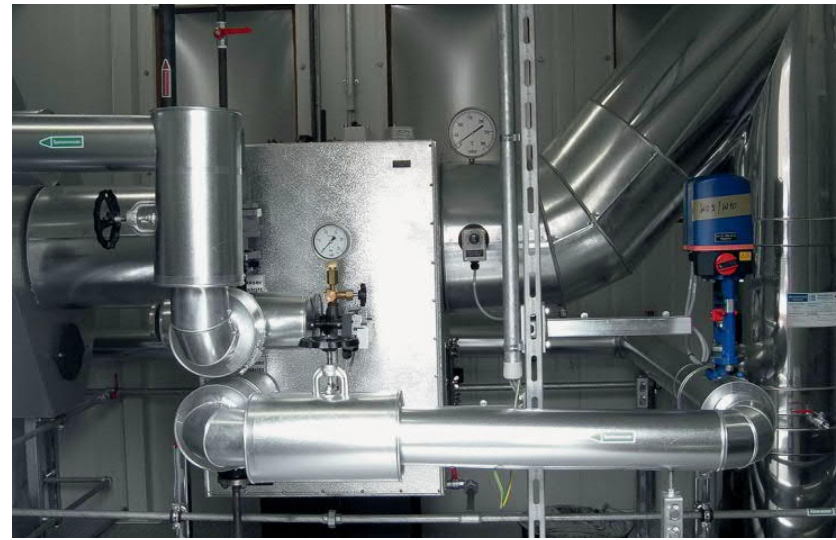


Figure 7-3 - Plantroom cladding - examples

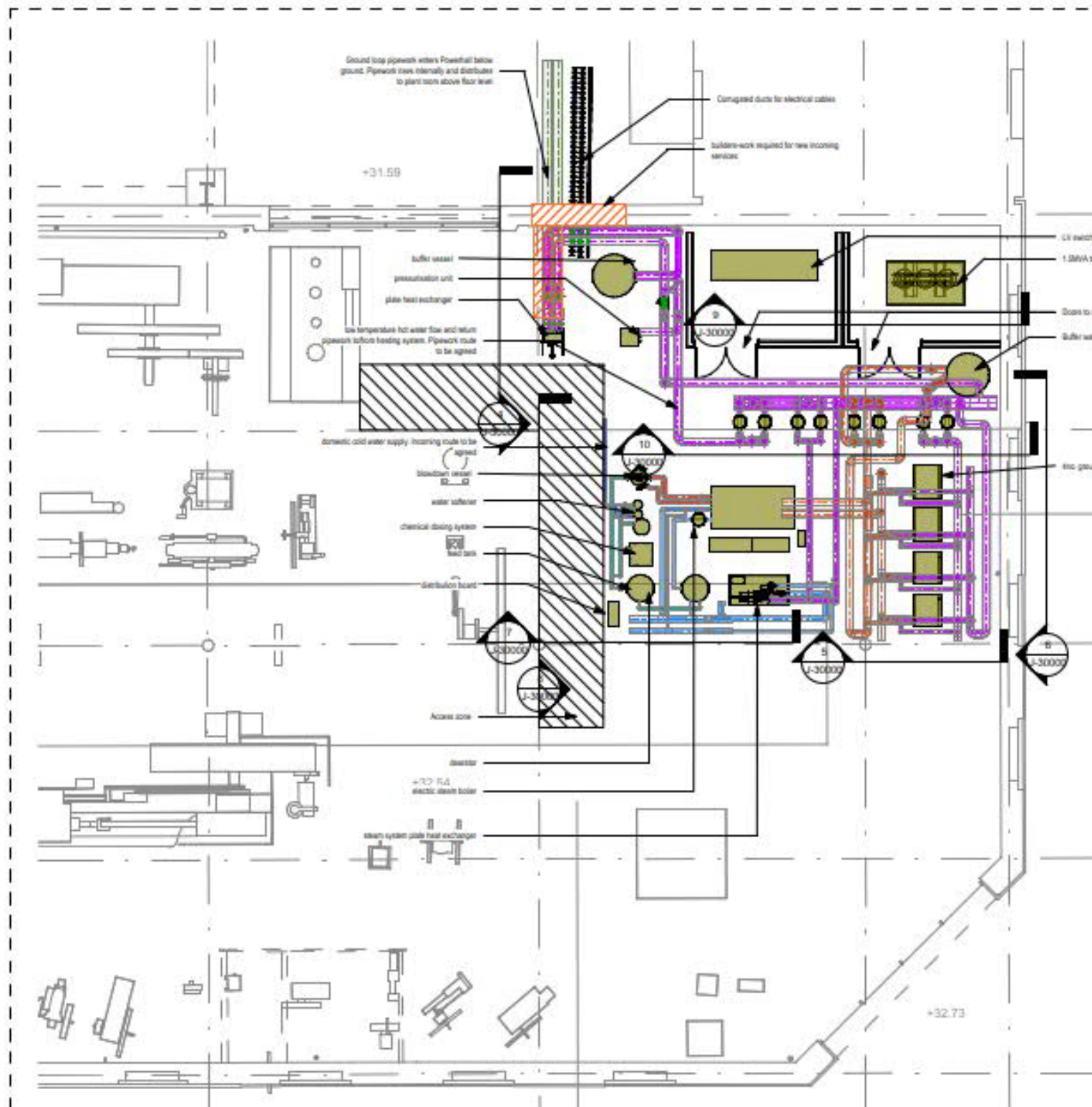
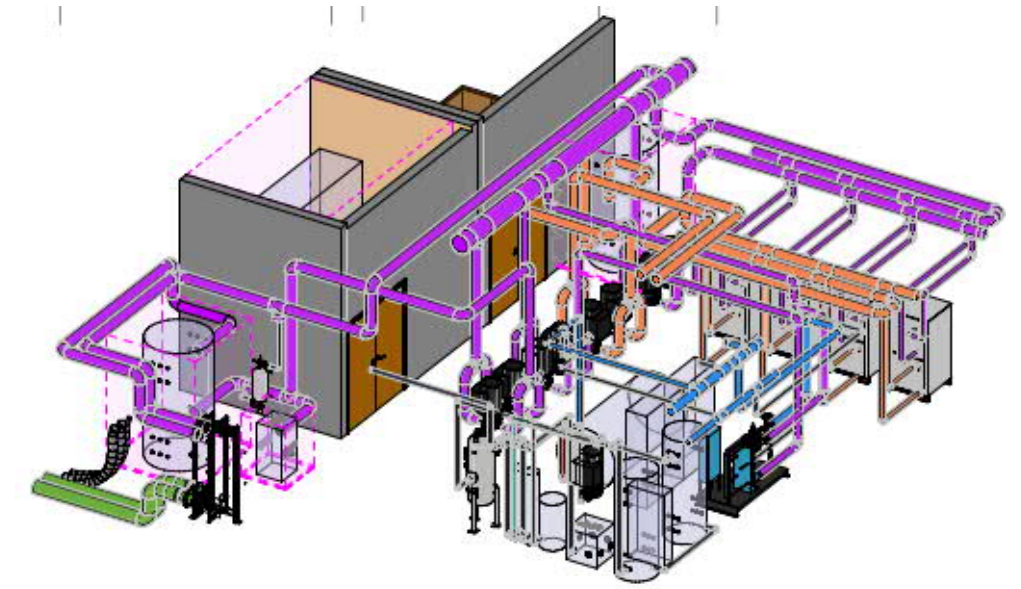
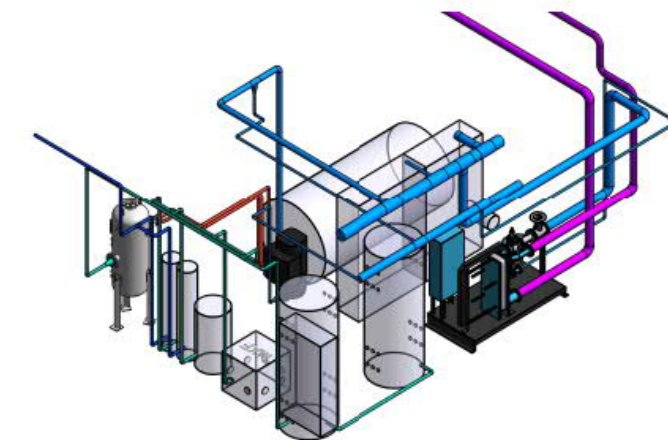


Figure 7-4 – Power Hall new plantroom layout – sketch - refer to the related drawing for the readable version



12 PH plantroom 3D view



2 PH - Steam System 3D View

7.5 Considerations

7.5.1 Interface with the Listed Building

The integration of the new works with the GRADE II listed building “Power Hall” will be the main priority for these works.

Bringing the new energy concept within the Power Hall will be realised with the highest respect to the building fabric. Main equipment will be freestanding, with limited interference with the brick walls. Main distribution will be at high level and concentrated to the plantroom areas. All other services will run concealed beneath raised platform volume.

However, the interface with the new borehole and the electrical energy demand of the new boiler will require new main services entering to the building.

The services entrance will be limited in one point only, below the ground, to limit the impact on the historic building.

It is proposed to realise a new opening on south east wall, close to the VE block connection, where services can enter in proximity of the new plantroom area.

Please refer to the Design and Access Statement for more details on this point.

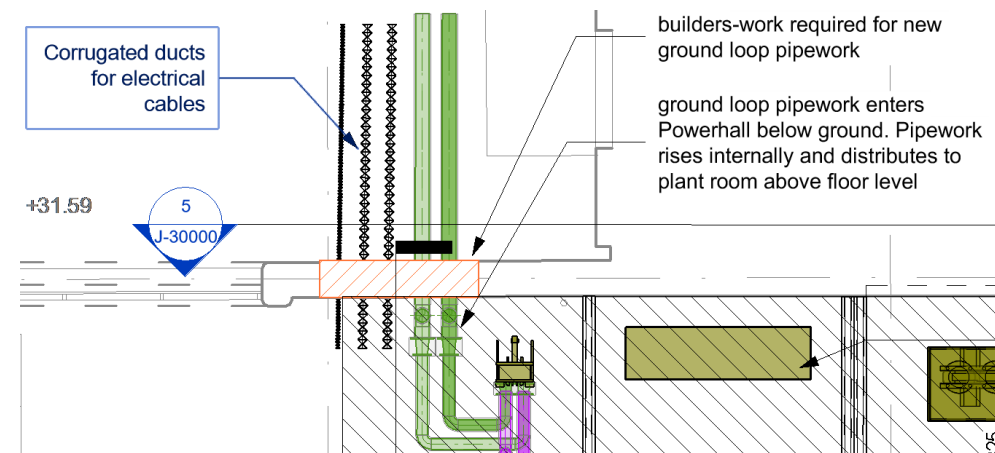


Figure 7-6 – Power Hall - new builderswork position 1/2

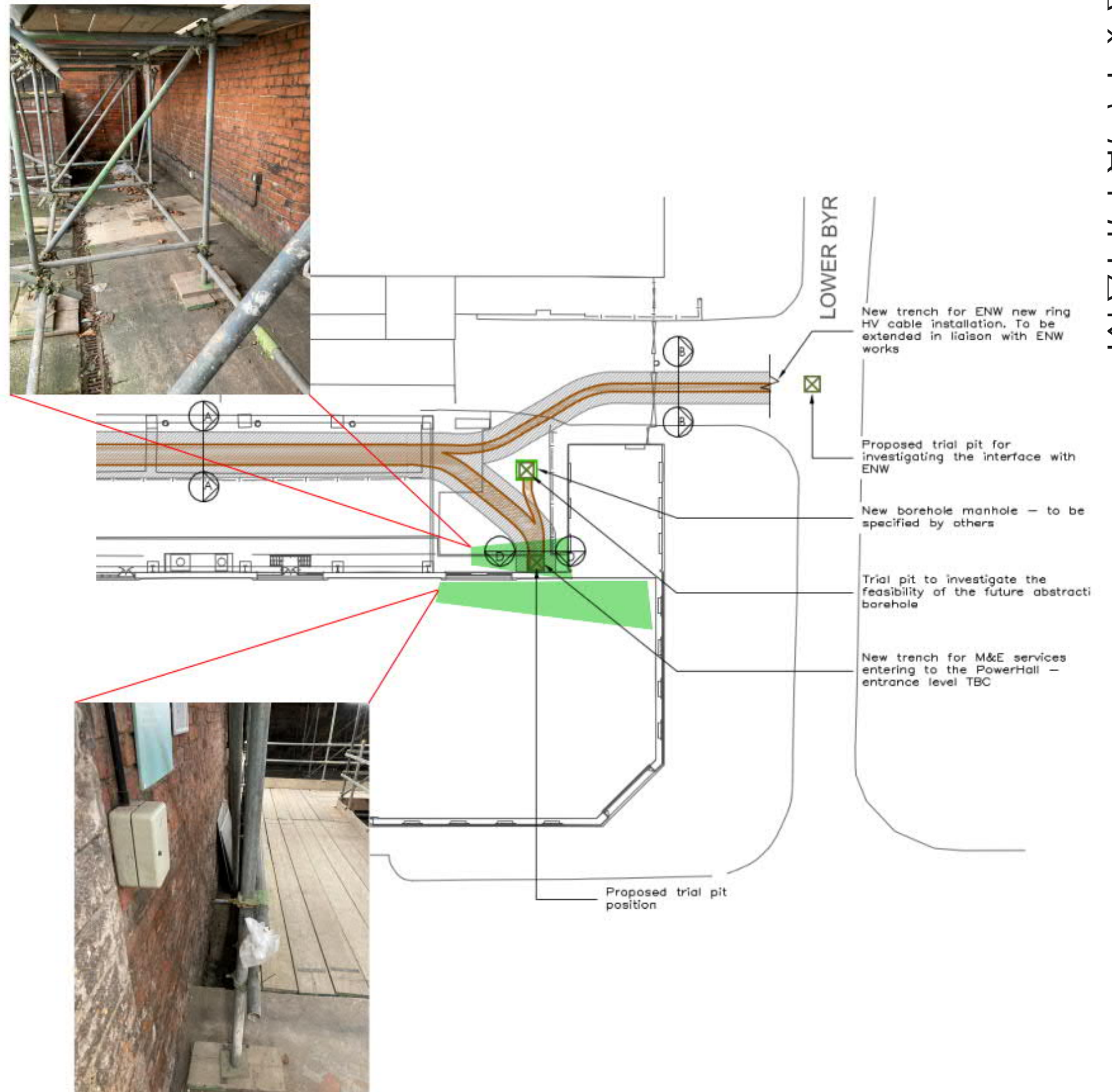


Figure 7-5 – Power Hall - new builderswork position 2/2

7.5.2 Plant noise

Noise of the displayed plantroom will be carefully assessed. The choice of the equipment will be carefully selected to take into account the acoustic aspects of them. The main items features will be

- Electric steam boiler: this unit will work without major moving components. As no combustion will occur, the equipment noise will be extremely limited and it will be covered by the normal historic machines when in operation
- Ground Source Heat Pump. One of the most significant benefits of this technology is that it does not need fans to work. Hence they are compact in size and silent in operation. For this solution, particular attention has been paid for the GSHP selection. The choice is to select a “cascade” system of 4 GSHPs, each of the modules properly acoustically insulated within an acoustic case.
- Pumps and ancillaries. All the pumps will be carefully selected to minimise operation noise, and properly boxed in to mitigate the acoustic impact.

It should be note that the Power Hall was a relatively “noisy” gallery in the past, when it was open to public. Historic units used to operate exposed, creating the characteristic noise that was part of the workshop atmosphere surrounding the gallery. This project aims to bring back to life that atmosphere.

7.5.3 Health & safety

Health and safety will be of paramount importance on this project. Even the new plantroom will be part of the re-interpretation story, a careful design will consider all health and safety related aspects.

- The new boiler will be equipped with the most advanced automatic controls, as required by the BG01 ed.2 – 2019 regulation and PED 2014/68/EU directive. Access from the public will be carefully restricted.
- Transformer room and main swithroom will be properly housed and protected and placed in a suitable location to preclude any accidental access from the public.
- High temperature pipes and line ancillaries. All steam pipes will be properly insulated and installed either at high level or under the raised platform, to avoid any risk of accidental contact with the public or with the Museum operational team.

7.5.4 Material

Particular attention will be given to material choice. As presented on the paragraph above, the idea to display the new plantroom is linked to the aim to make this plantroom look good.

All the finishes will be in metal polished cladding, giving the appeal of a modern, ordered and efficient system.

Main items will be properly boxed across their shape to highlight their function and characteristics



Figure 7-7 - typical steam equipment - polished metal cladding - example

7.5.5 Ventilation

The new plantroom will not require dedicated ventilation. All equipment is combustion-free, no flues, natural gas or fumes will be needed/produced. The ground source heat pump will be water-to-water type, designed to be installed indoor, with no ventilation requirement

Steam system will be solely used electricity. The hot well will require a small pipe (DN32mm) to be vented to atmosphere, that will be coordinated as part of the new roof refurbishment at later stage.

8.0 1.B – 1830 WAREHOUSE PIPEWORK

As part of the holistic system refurbishment across the Museum site, it has been considered to interface the 1830 Warehouse and Station buildingd with the water source heat pump network so the building can take benefit of the decarbonisation strategy.

The listed building is currently supplied via a sort of district heating pipework from the New Warehouse boilers, as the existing plant is out of operation.

The building relies on the combustion of natural gas, with a significant impact on the CO₂ production

The proposed works are to remove the plant & equipment currently not in operation on the basement (plantroom) of the 1830 Viaduct (Grade II).

This will enable:

- To interface the 1830 buildings with the water source heat pump network
- To provide a new water source heat pump unit sized to provide the building heating demand across the 80% of the heating season time
- Modifying the existing district heating connection to guarantee a heating back-up for the colder days of the heating season, in case the existing emitters will not be able to provide enough heat.

This new solution will bring a significant reduction in CO₂ production (-54% compared with the current solution), leaving similar economic running costs for the Museum

8.1 Interface with the listed building

Again, the integration of the new works with the 1830 Warehouse (Grade I) and 1830 Viaduct (Grade II) will be the main priority of these works.

The new plantroom will be housed in the same existing plantroom, which is set within the 1830 Viaduct (Grade II), so no further spaces will be required.

Two new pipes will need to be installed to configure the new scheme. Our proposal is to install these two new pipes along the existing pipes, following the same route.

The proposal, which affects the 1830 Warehouse (Grade I), is summarised in the sketches below.

Please refer to the Design and Access Statement and Heritage Impact Assessment for more information.

SIM - Science Industry Museum - 1830 Warehouse and Station buildings - running cost summary - EXISTING - HEATING

Month	1830 buildings			TOTAL CO2	TOTAL ELECTRICITY COST	TOTAL NATURAL GAS COST	TOTAL ENERGY COST
	Building heating demand	*GSHP electrical consumption	**Natural gas for back up boiler				
	[kWh]	[kWh]	[kWh]	[kg]	[£]	[£]	[£]
Jan	156,230	0	140,607	28,684	0	3,318	3,318
Feb	141,143	0	127,029	25,914	0	2,998	2,998
Mar	152,959	0	137,664	28,083	0	3,249	3,249
Apr	101,827	0	91,644	18,695	0	2,163	2,163
May	75,703	0	68,133	13,899	0	1,608	1,608
Jun	38,338	0	34,504	7,039	0	814	814
Jul	26,432	0	23,788	4,853	0	561	561
Aug	24,531	0	22,078	4,504	0	521	521
Sep	39,969	0	35,973	7,338	0	849	849
Oct	85,734	0	77,160	15,741	0	1,821	1,821
Nov	125,131	0	112,617	22,974	0	2,658	2,658
Dec	161,801	0	145,621	29,707	0	3,437	3,437
Total	1,129,797	0	1,016,817	207,431	0	23,997	23,997

*Assuming a COP 4.3 for the GSHP

**Assuming a boiler efficiency of 90%

SIM - Science Industry Museum - 1830 Warehouse and Station buildings - running cost summary - PROPOSED SCHEME - HEATING

Month	1830 buildings			TOTAL CO2	TOTAL ELECTRICITY COST	TOTAL NATURAL GAS COST	TOTAL ENERGY COST
	Building heating demand	*GSHP electrical consumption	**Natural gas for back up boiler				
	[kWh]	[kWh]	[kWh]	[kg]	[£]	[£]	[£]
Jan	156,230	20,924	43,397	13,038	2,569	1024	3,594
Feb	141,143	18,903	39,206	11,779	2,321	925	3,247
Mar	152,959	20,486	42,489	12,765	2,516	1003	3,518
Apr	101,827	13,637	28,285	8,498	1,675	668	2,342
May	75,703	10,139	21,029	6,318	1,245	496	1,741
Jun	38,338	5,135	10,649	3,199	631	251	882
Jul	26,432	3,540	7,342	2,206	435	173	608
Aug	24,531	3,285	6,814	2,047	403	161	564
Sep	39,969	5,353	11,103	3,336	657	262	919
Oct	85,734	11,482	23,815	7,155	1,410	562	1,972
Nov	125,131	16,759	34,758	10,442	2,058	820	2,878
Dec	161,801	21,670	44,945	13,503	2,661	1061	3,722
Total	1,129,797	151,312	313,832	94,284	18,581	7,406	25,988

*Assuming a COP 5.6 for the GSHP

**Assuming a boiler efficiency of 90%

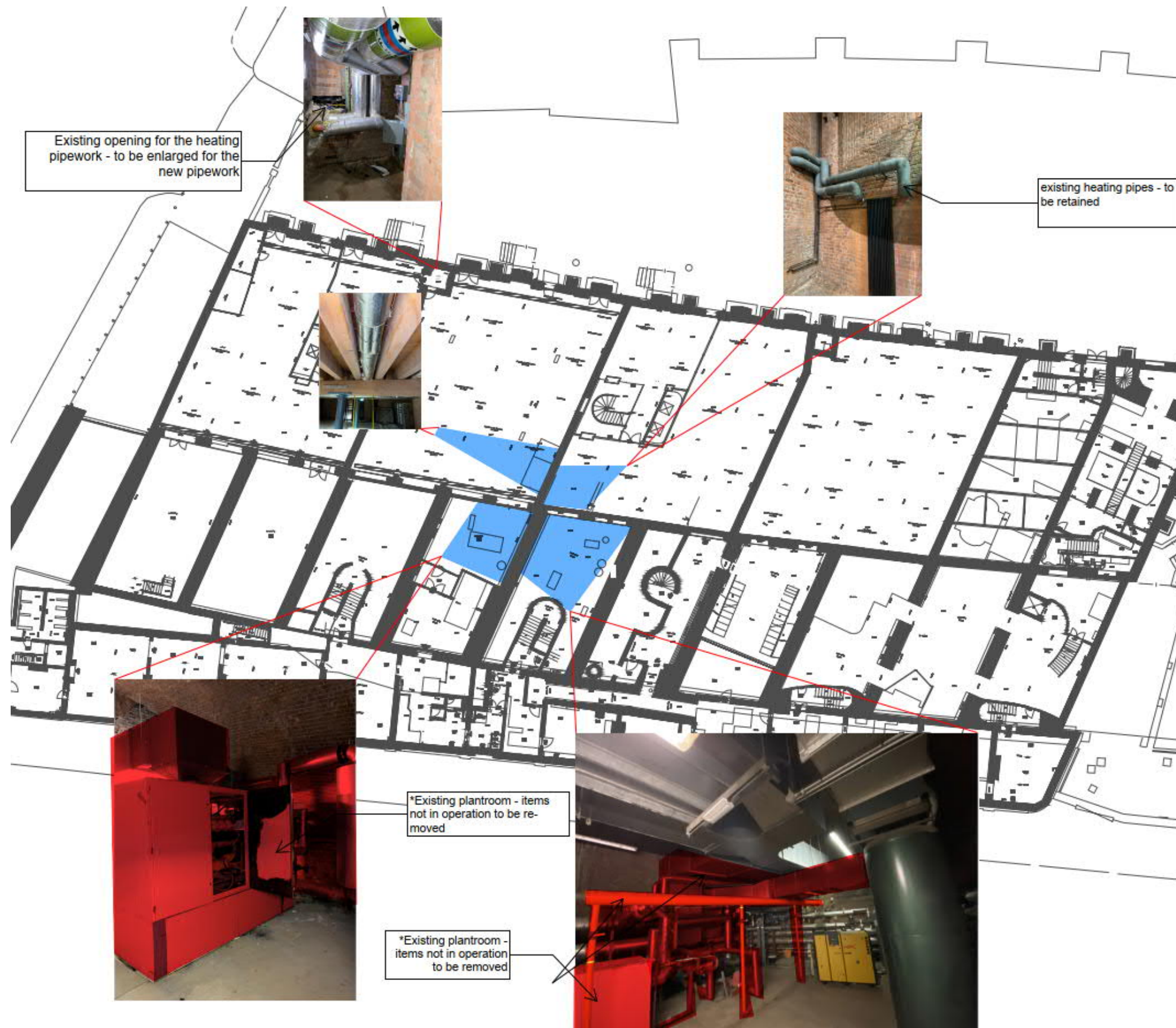


Figure 8-1 - 1830 Warehouse - services strip out works



Figure 8-2 - 1830 Warehouse - new GSHP & pipework layout – drawing snapshot - refer to the related drawing for the readable version

8.2 Water source heat network in the 1830 Warehouse curtilage

As described on the paragraph 6.0 a new water source heat network will be installed across the Museum site.

The new network will run below ground on the lower yard as well, where particular attention will be paid on respect to the methodology for the trenching to preserve the historic heritage of the site.

Please refer to the “Design and Access Statement” and “Heritage Impact Assessment for more information” and the Construction methodology description for more details.

The sketch below shows the proposed extents and routing of the trench for the new water source heat network on the lower yard.

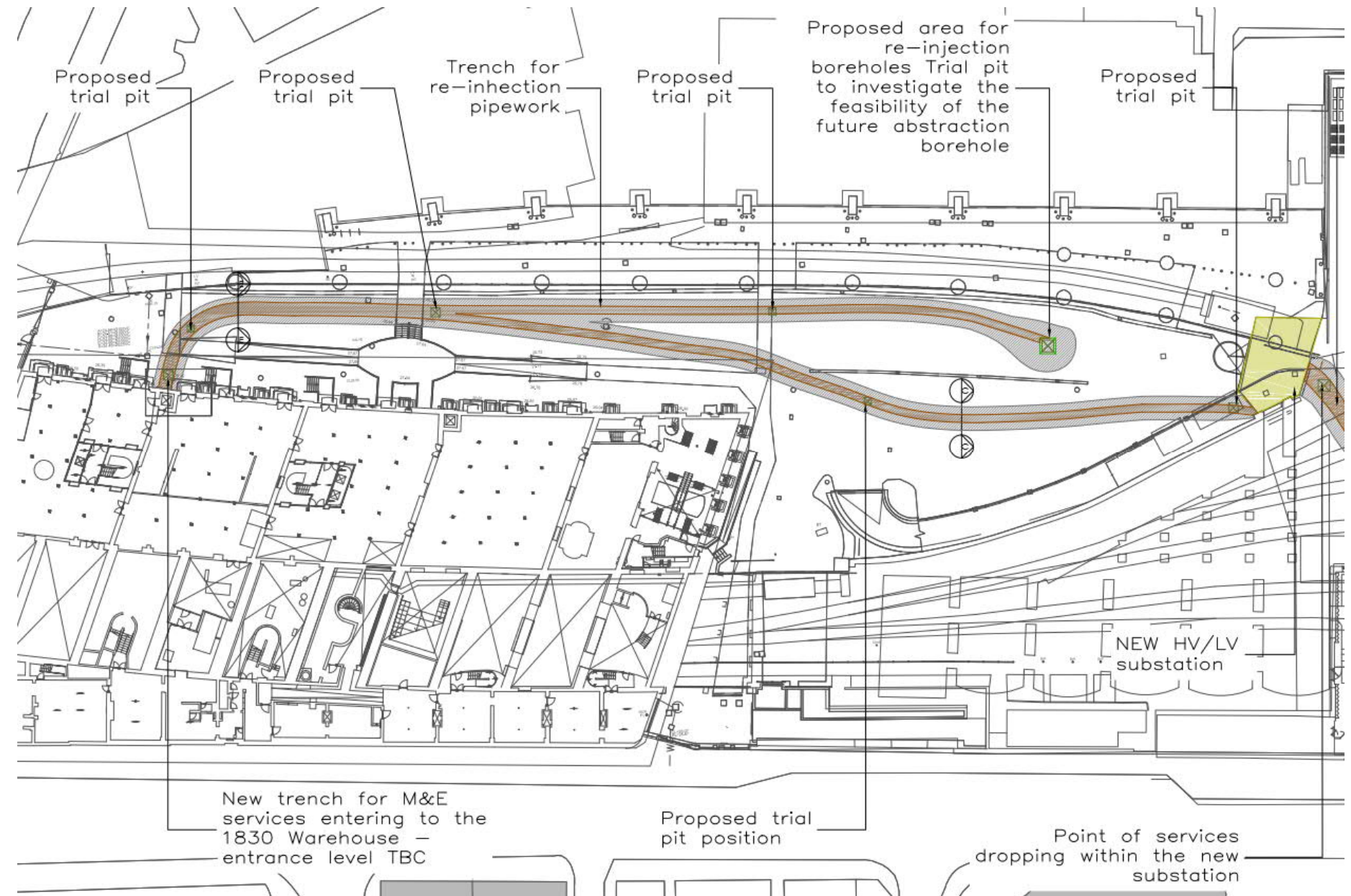


Figure 8-3 - Water source heat network - lower yard layout snapshot