BURO HAPPOLD

Plymouth Sutton Harbour

District Heat Network Feasibility Study

18th November 2024

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EXECUTIVE SUMMARY

Executive Summary

This study found that a **connection to the proposed AZP pilot ambient loop network provides the lowest risk solution to decarbonizing the heat and cooling supply to the Sutton Harbour area** and is progressed to the next stage of detailed design, as part of the AZP scheme.

A combination of a 4G connection to two key connections and a 5G connection to one key connection is proposed, as this allows for the required operating temperatures to be met and reduces the additional space/land requirement to facilitate a 5G connection, and subsequent additional capital investment. An amendment to the AZP network route is proposed, to minimize the required pipework routing to the Sutton Harbour connections.

TEM results support the above solution, including heating and cooling sales to NMA. TEM analysis for AZP connection options incorporate a portion of wider AZP costs (inc. main spine pipework) to allow for reasonable comparison with standalone solutions. Results for the recommended solution in Table 1 therefore present a conservative estimate. The AZP network passes Sutton Harbour for access to city centre loads regardless of Sutton Harbour connection.

A greater heat load on the network could increase the viability of a standalone borehole scheme, by providing a greater revenue to operational cost ratio. Current results show this to be low.

Table 1: Sutton Harbour Techno-economic modelling summary

Techno-economic Metric	Unit	AZP 4G connection
Total CAPEX – not including inflation	£m	3.08
Total Connection Charge (£m)	£m	1.42
Unfunded IRR @ 40 years (%)	%	N/A
Unfunded NPV @ 40 years (£m)	£m	0.83
Average annual operating costs (£m)	£m	0.093
Funding gap for 10% IRR	£m	1.12
Funding gap for 10% IRR as % of CAPEX	%	36

Key considerations and proposed next steps

The AZP ambient loop network is the recommended primary heat source for the Sutton Harbour cluster. Should PCC wish to pursue this solution the following next steps should be taken:

- **Continue discussion with AZP key connections** on requirements for connection to the network, system arrangements, network routing to the area, and the progress of the design of the AZP network
- **Communicate timelines for AZP connection** to all stakeholders and how this could facilitate decarbonisation of heating and cooling
- **Undertake further stakeholder engagement with NMA** to confirm preferred technical connection arrangement, confirm modelled heat and cooling demands, and operating temperatures
- **Establish land use agreements with NMA/Fish Market** landowner for installation of NMA AZP interface plantroom
- **PCC confirm land PCC owned green open areas land use** for installation of an AZP interface plantroom (shared between PCH Commercial Place and UoP Marine Station)

Figure 1: Location plan for scenario 2 - AZP 4G network and connections

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INTRODUCTION

- ❑ PROJECT BACKGROUND
- ❑ APPROACH

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The Aim of This Study

This study aims to determine the most appropriate alternative low-carbon heat source to substitute the existing building level natural gas systems. It will set out a preferred technology and suggest the next steps for PCC to develop the proposal.

1. Understand the challenge

- Understand key Sutton Harbour connection architecture and demands
- Understand how the Sutton Harbour cluster could fit into the DESNZ advanced zoning programme
- Carry out stakeholder engagement to inform the study, obtain data, guide the outcomes and ensure potential heat consumers, heat producers and other parties buy into the project

2. Investigate local heat source opportunities

- Provide a long list of feasible heat supply opportunities
- Undertake a qualitative assessment of each opportunity

3. Determine the preferred heat source opportunity

- Engage with stakeholders and utilise information collected to support a prioritised list of opportunities
- Create a qualitative decision matrix based on capacity, complexity, and capital and operating costs
- Carry out an assessment of potential heat supply infrastructure locations, e.g. energy centres

4. Demonstrate the techno-economic feasibility of the selected preferred scenario

- Propose a mix of low carbon heat sources to meet demand of the key Sutton Harbour cluster connections
- Carry out initial energy modelling to meet the modelled demand of the Sutton Harbour cluster
- Assess and compare the techno-economic performance of recommended solution against air source as a counterfactual

5. Propose the next steps for Plymouth City Council

- Summarise next steps for PCC to progress the updated proposal the next stage

The AZP ambient loop network

The Plymouth advanced zoning programme (AZP) pilot is being carried out by Buro Happold on behalf of DESNZ. The pilot looks at an ambient loop network providing decarbonised heating and cooling to Plymouth city centre.

An ambient loop pipework 'spine' delivers heat extracted from South West Water (SWW) sewage treatment works central plant, **Prince Rock**, to buildings in Plymouth city centre. Where cooling is required reversible heat pumps are used to reject useful heat back into the network.

The scheme is split into two phases.

- Phase 1 – Heat On **2028**
- Phase 2 – Heat On **2032**

The ambient 'spine' (main branch) connects to either

- **Local energy centres** at a 'hot network' connection
- **Directly to buildings** as a '5G ambient' connection

In total there are 55 connections planned for the AZP ambient loop network. Key connections include the University of Plymouth (UoP) campus, Plymouth Guildhall and Civic Centre, UPP student accommodation and buildings at Millbay.

Connection to key heat loads will maintain a high linear heat density (LHD) for the AZP network through the phased build into Plymouth city centre.

Sutton Harbour cluster

Sutton Harbour cluster sits on the main branch into the city centre from SWW Prince Rock heat extraction site. The cluster is a pinch point on the AZP network, with potential to supply revenue and reduce operating cost per connection in phase 1 of the AZP network through heat and cooling sales to the network energy service company (ESCo).

The key heat loads for consideration in Sutton Harbour are the NMA, PCH Commercial Place, UoP Marine Station, Queen Anne's Quay and the Sutton Harbour Fish Market. The NMA and Fish Market are known to also have cooling loads.

There is an opportunity to supply heat to the cluster either by local energy centres or directly to buildings through a AZP 4G/5G network that could provide heat and cooling.

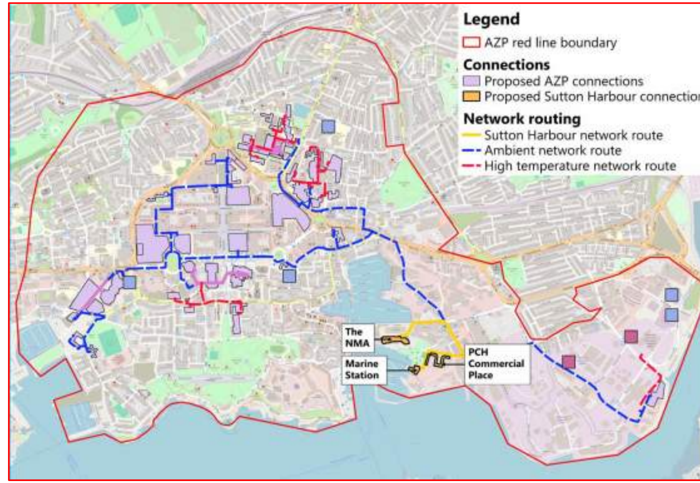

Figure 2: Plymouth AZP ambient loop network and Sutton Harbour cluster

Plymouth city wide heat network potential benefits:

- Harnessing of low grade heat from the SWW Prince Rock for reduced operating costs in decarbonised heating and cooling provision
- A reduced electrical load on the electrical grid for centralised heat/cooling supply, compared to individual electric decarbonisation solutions
- A more centralised decarbonised solution to reduce plant space take compared to alternative decarbonisation solutions
- Provide a vector for low-carbon technology funding through UK government schemes such as the Green Heat Network Fund (GHNF) and Heat Networks Investment Project (HNIP)

Sutton Harbour Cluster

The below table and figure show all major buildings in Sutton Harbour. The table provides a description of these buildings and the priority for a future decarbonised heating (and where applicable) cooling plant.

Table 2: Sutton Harbour potential cluster connections' information

Connection	Typology	Description	Plant priority
National Marine Aquarium (NMA)	Aquarium	Open to the public and open daily.	Minimum N+1 resilience to provide critical animal life support (heating and cooling).
PCH Commercial Place	Residential apartments	Social housing apartments owned by PCH. PCH Commercial Place refers to; Artillery Place and Teat's Hill flats.	Affordable and resilient heat supply to residents.
UoP Marine Station	University building	UoP owned Marine station facility, used for university marine research in the harbour, study and lectures.	Affordable heat supply, in line with net zero plans.
Fish Market	Wholesale food retail / cold storage	Owned by Sutton Harbour Holdings. Plans to bring back to full operation. Plans for future development may include retail, education and restaurants, in addition to the existing wholesale fish market operation.	Resilient cooling supply.
Queen Anne's Quay	Residential apartments	Queen Anne's Quay apartments. Privately owned.	Affordable and resilient heat supply to residents.

The following is a summary of the identified key connections in the Sutton Harbour area, and the key priorities and considerations.

Stakeholder engagement was carried out with each connection where possible; this is summarised in the following section 2.

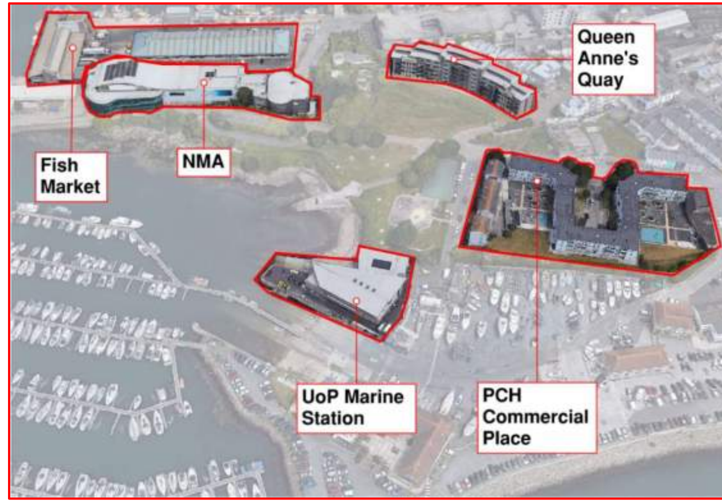

Figure 3: Sutton Harbour potential cluster connections

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BUILDING CONNECTIONS

- ❑ SUMMARY OF IDENTIFIED CONNECTIONS
- ❑ SUMMARY OF STAKEHOLDER ENGAGEMENT
- ❑ PROPOSED BUILDING LEVEL CONNECTION

National Marine Aquarium

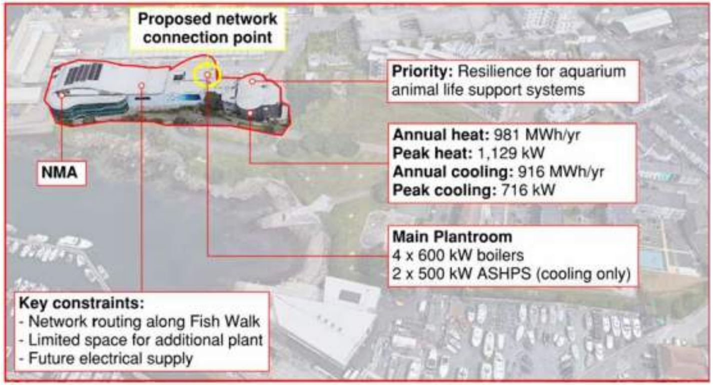

Figure 4: NMA high level stakeholder engagement summary

The NMA is currently in the process of administration changes (i.e. chief executive officer). During this transitional period, the NMA is unable to officially provide heating/cooling systems information and operational data. The NMA is keen to be included in this study and understand the potential to connect to the AZP DHN or alternative. A site visit was carried out to review the existing systems and collect high level information.

A high-level schematic of the existing heating and cooling systems is shown in Figure 4. Heating and cooling systems are used for aquarium life support, domestic heating and air handling units. Redundancy is key to maintaining the animal life support services and a non-negotiable for the NMA. Therefore, a minimum N+1 redundancy is built into the existing systems.

With exception to the ASHPs, all equipment is installed in the main plantroom. Within the main plantroom, there is minimal space for additional plant installation, the existing systems are required to stay online to maintain the animal life support systems. Therefore, complex logistics are required for any potential plant replacement. The ASHPs (heating/cooling) are installed external to the plantroom.

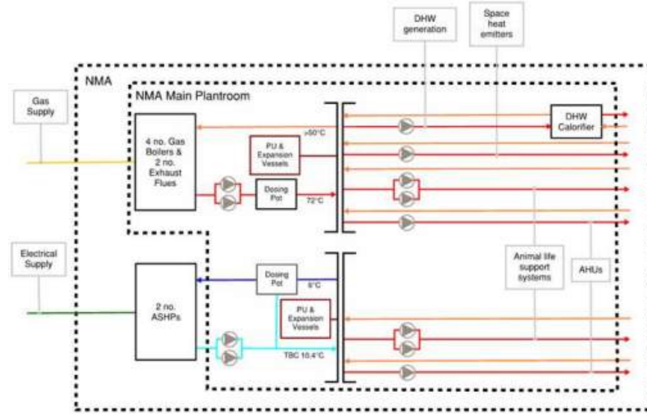

Figure 5: Existing NMA high level heating and cooling system schematic

All plant and pipework was installed in ~1998, 27 years ago. Due to the urgent need to replace specific plant at end of life, the NMA is currently undergoing a plant renewal programme as detailed below. This also provides an opportunity to facilitate future decarbonization.

- **Phase 1 (in progress):**
  - Replacement of existing chillers with 2 no. 500 kW ASHPs (heating/cooling, N+1). Temporary chiller plant currently installed in NMA car park to allow for switch to new plant whilst still maintaining life support services
  - Facilitate lowering of operating temperatures (~40°C); replace heat and cooling emitters, life support PHXs, buffer vessels and plant system pumps, install PICVs
  - Reduce energy demand via installation of AHUs with heat recovery
- **Phase 2-3 (No funding in place):**
  - Replace existing 4 no. gas boilers with 2 no. new ASHPs (heating/cooling) Replace existing DHW calorifier with high temperature heat pumps
  - Install solar PV array

Heat meters are installed onsite to establish existing demands, as part of the plant renewal programme. These are reported to not be very accurate and data has not been made available. In lieu of demand data, previously provided gas and electricity consumption data from the AZP project has been used to estimated annual demands. Similar building use energy demand profiles have been utilized to estimate peak energy demands. Typical operating temperatures were reported during the site visit carried out.

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National Marine Aquarium

System integration options
The system integration design for the planned replacement of the existing 4 no. gas boilers and DHW calorifier with ASHPs has not been provided at this stage. Presented in Figure 6 is the assumed future plant configuration, assuming the NMA would retain the existing single heating and cooling low loss headers to avoid disconnection of the critical heating and cooling supply.

The existing gas boilers could have been substituted with a connection to the network (AZP / standalone cluster) and additional resilience via ASHPs/electric boilers. However, the AZP ambient loop is set for heat on in 2028, post completion of the existing NMA plant renewal programme. The NMA remains keen to connect the AZP DHN or alternative, as part of decarbonizing. A proposed connection point is presented in Figure 7, with recommendation to lower the operating temperatures to align with the AZP ambient loop proposed 5G connection temperature regime.

The NMA also has a seawater extraction well to feed the tanks. This well could indicate marine heat supply opportunities in the area. However, historic volume flow and temperature (flow & return) have not been made available. At the site visit, the NMA reported a stable 16°C flow temperature. This is discussed further in section 4.0.

The following risks / considerations have been identified:

- NMA requires the existing N+1 redundancy is maintained. Therefore, the DHN connection would provide N+2 redundancy and may not be utilised over time.
- Connection to the single heating and cooling low loss headers could result in high return temperatures, which could reduce the efficiency of the network. Typically, separating the flow and return headers is recommended. If not, this can be managed (e.g. variable temperature circuit).
- Due to the uncommon building use type, benchmarks and profiles are not largely available. Similar use types (i.e. museum) have been used to generate heating and cooling profiles. However, demands could be underestimated and subsequent equipment sizing. Any energy demand modelling is to be confirmed with the NMA, where possible
- Location of DHN heat pumps / heat substation plant
  - Identified potential location at the Fish Market, same landlord / ownership
  - Potential to remove requirement, by installing a cluster energy centre, with relevant plant installed. Then only pipework routed to connections
- Network routing
  - A route is constrained by pedestrian access and existing rockface
  - More accessible (construction and maintenance) identified. However, longer routing that would mean higher CAPEX
  - NMA stated potentially a large service pipework below ground. This was reviewed as part of 3DTD scope and none identified
- Electricity / power supply for additional heat pumps
  - An 11kV transformer is installed at the building
  - A new switchgear is required
  - A large supply is installed (TBC - 1,000 kV), however, this could be removed in next 3 years by Wales & West if not utilised

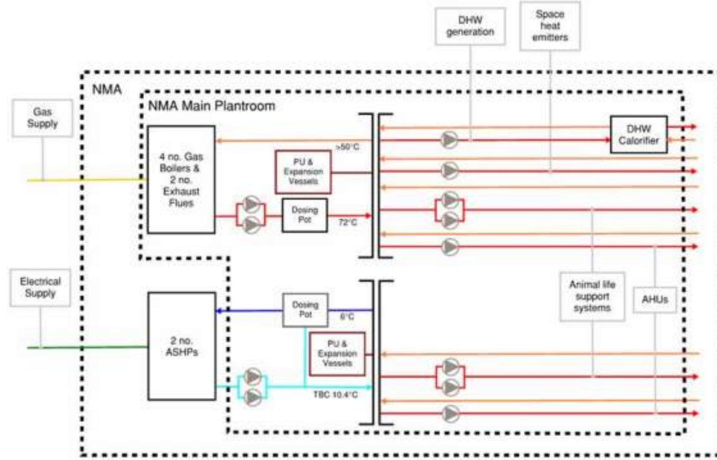

Figure 6: Existing NMA high level heating and cooling system schematic

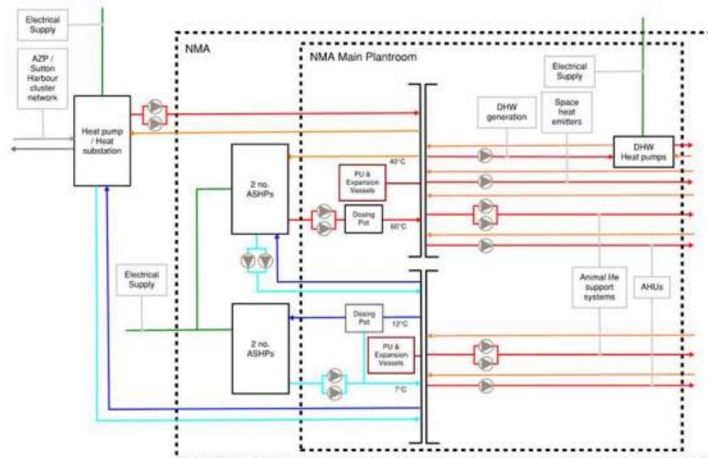

Figure 7: Proposed NMA high level heating and cooling system schematic and Sutton Harbour cluster connection

PCH Commercial Place

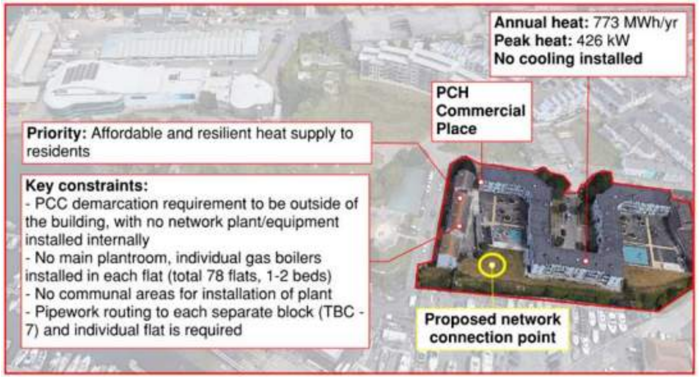

Figure 8: PCH Commercial Place high level stakeholder engagement summary

PCH Commercial Place is made up two sets of residential flats (Teats Hill and Artillery Place), with a total of 78 flats distributed across blocks (TBC -7 blocks).

There is no centralised heating supply to the each flat. Individual gas boilers are installed in the kitchen of each flat, providing LTHW for space heating and DHW (baths, basins and kitchen sinks). Electric showers are installed across all flats. The current PCH Commercial Place heating systems are shown in Figure 9.

PCH requires the demarcation of any network connection, along with ownership and maintenance of assets to be outside of the residential buildings. Therefore, a centralised connection would be required, with pipe routing to each individual flat. Further confirmation of the connection point to each flat should be investigated in the next stage of design development, estimates for pipework are included in this study.

Each flat is supplied natural gas via a supply from the national grid. The gas supply enters the building internally in some blocks via a single pipe into the block, and then distributed to each flat. Whilst in other flats there is a direct gas pipe externally, into the flat and directly to the gas boiler. This would be the recommended routing for LTHW pipes from the network/cluster heat supply connection point.

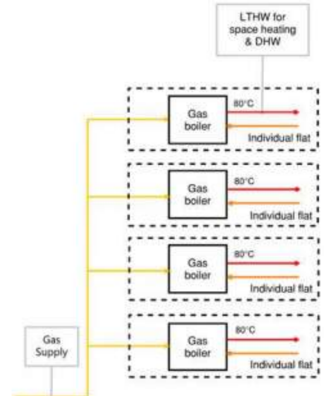

Figure 9: Existing PCH Commercial Place high level heating system schematic

A proposed solution is presented in Figure 10, HIUs in place of the existing gas boilers are installed and a heat pump/heat substation is installed external to the building. This would allow for a demarcation at the building entry point to each flat. Locations for a heat substation were identified on PCH owned land during the site visit carried out.

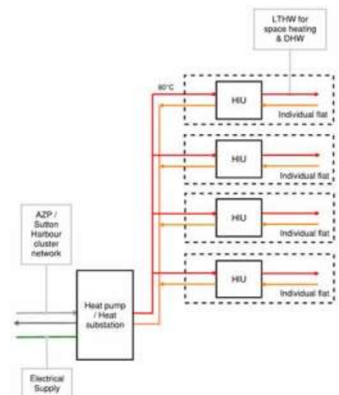

Figure 10: Proposed PCH Commercial Place high level heating system schematic and Sutton Harbour cluster connection

UoP Marine Station

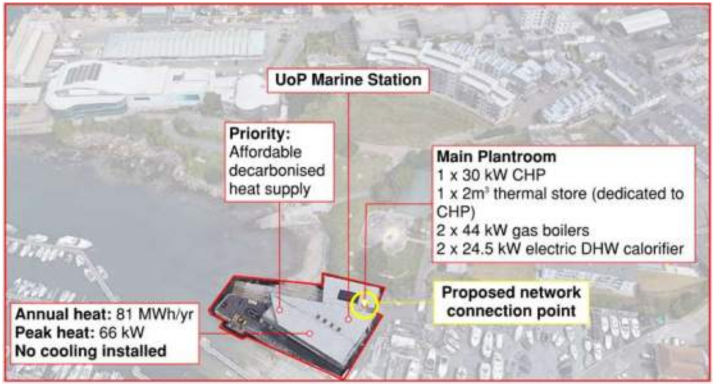

Figure 11: UoP Marine Station high level stakeholder engagement summary

The existing UoP Marine Station heat supply system is shown in Figure 12. All equipment was installed in the main plantroom during the building construction in 2014, potentially reaching end of life at ~2034.

A proposed solution is presented in Figure 13, including the following:

- The CHP is replaced with a dedicated heat pump or HIU
- Thermal stores are retained where heat pump installation is recommended, and replaced with similar units at end of life
- Gas boiler are retained as back-up and replaced with similar electrified units at end of life
- Electrical DHW calorifier is replaced with a network supply at end of life, and the proposed heat pump / HIU selection is to include for future DHW supply

From plantroom layouts and the site visit carried out, it appears the main plantroom may facilitate installation of a HIU in place of the existing CHP. There is potentially insufficient space available for a heat pump (for upgrade) installation. Also, the building is located near PCH Commercial Place, therefore a shared connection/heat substation could be installed, as both building heating systems operate at 80°/60°C flow and return temperatures.

There is easy access for connection to a DHN at the front of the UoP Marine Station building. The main plant room is located on the first floor, the gas pipe routing was identified, confirming the potential DHN pipe routing.

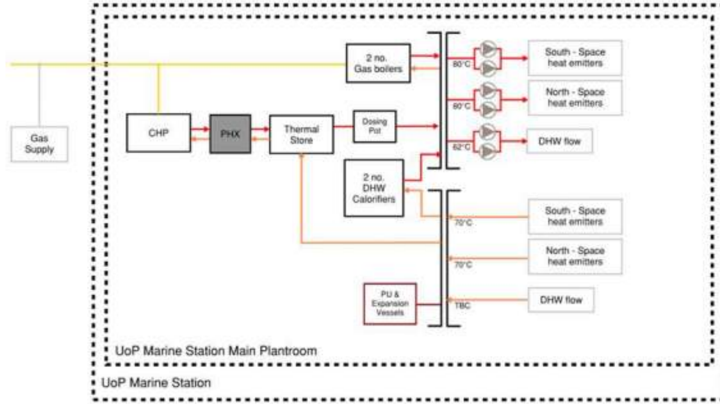

Figure 12: Existing UoP Marine Station high level heating system schematic

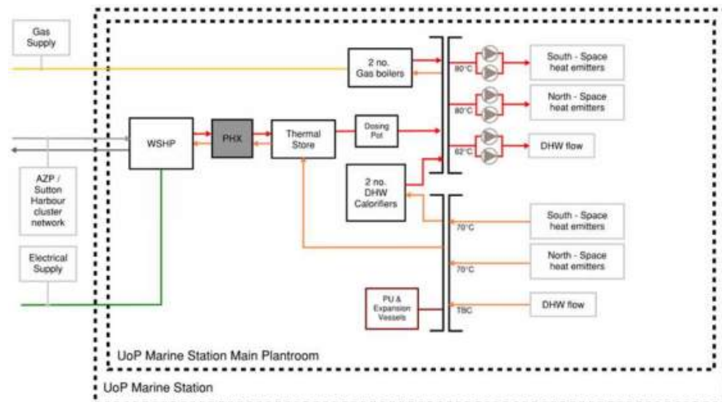

Figure 13: Proposed UoP Marine Station high level heating system schematic and Sutton Harbour cluster connection

Other potential connections

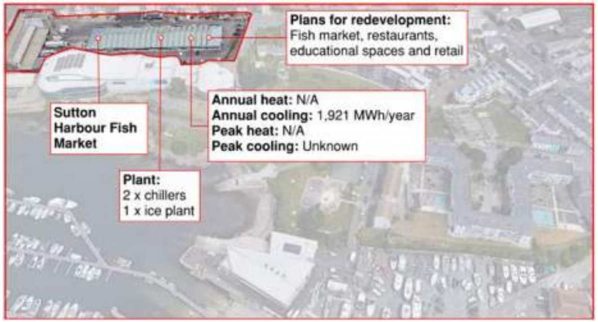

Figure 14: Fish Market high level stakeholder engagement summary

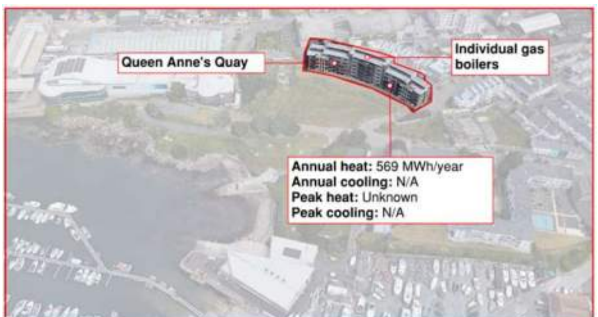

Figure 15: Queen Anne's Quay high level stakeholder engagement summary

Sutton Harbour Fish Market

Cooling for the Sutton Harbour Fish Market is provided by 2 no. chillers and an ice plant, there is currently no heating supply to the building. It is assumed that any domestic hot water (e.g. hand basin taps) is provided by dedicated electric point of use units or a small electric/gas boiler.

Initial stakeholder engagement was carried out with the chief operating officer of Sutton Harbour Group and the harbour master & marine general manager. Interest in connection of the Fish Market to the cluster network and inclusion in this feasiblity study was suggested.

Currently the Fish Market is not operating at full capacity, however, there are plans to bring the fish market to full operation. Major redevelopment plans of the entire site are being developed, including restaurants, educational spaces, retail. This could mean increased floor area, cooling and heating demands.

Based on known electricity consumption benchmarks for chillers, typical chiller performance and assuming cooling of 50% of the estimated gross floor area (3,753 m^2), the total annual cooling demand was estimated to be 1,921 MWh/year. This would equates to double the cooling demand of the NMA and a substantially large connection. Energy demands, equipment specifications and documentation (i.e. schematics, layouts) is yet to be provided. A site visit has been requested. However, at this stage further stakeholder engagement has not been successful. Therefore, the estimated demands can not be confirmed against data or equipment specifications.

Due to lack of stakeholder engagement at this stage, this building has not been taken forward for consideration in this study. Further stakeholder engagement could be carried out in future stages.

A spare connection at the NMA is being considered as part of this study, to allow for any future connections in close proximity. However, the connection of the Fish Market may require the further capital investment in the upgrade of plant and pipework to meet the established demands.

Queen Anne's Quay

Queen Anne's Quay is a privately owned and gated set of residential flats in the Sutton Harbour area. The flats are assumed to be supplied space heating and supplied DHW via individually small scale gas boilers.

Based on known heat demand benchmarks for residential flats and an estimated gross floor area (6,540 m^2 across 5 floors), the total annual heat demand was estimated to be 569 MWh/year. This would be comparable to the heat demands for the PCH Commercial Place housing.

However, a stakeholder for Queen Anne's Quay was not successfully identified. Therefore, this building has not been taken forward for consideration in this study. Further stakeholder engagement could be carried out in future stages.

4

ENERGY DEMANDS

- ❑ SUMMARY OF HEAT AND COOLING DEMANDS

Energy Demand Modelling

Figure 16 shows the combined heating and cooling demand profile for the key connections in the Sutton Harbour cluster. In summer months cooling dominates, peaking at 0.72 MW, in winter heating dominates peaking at 1.35 MW. The Sutton Harbour heating demand is predominantly (47%) made up of the NMA and all cooling demand comes from the NMA.

In lieu of demand data for the NMA, previously provided gas and electricity consumption data from the AZP project has been used to estimated annual demands. Similar building use energy demand profiles (i.e. museum) have been utilized to generate heating and cooling profiles. The estimated peak heating and cooling demands presented in Table 3 appear to correlate with the existing plant (4 x 600 kW gas boilers, 2 x 500 kW ASHPs) and redundancy (N+1). Confirmation of the energy modelling results was requested from the NMA, however, a response yet to be provided.

Figure 17 shows the overall heat supply and cooling system heat reject into an ambient loop network (connection to the AZP network). 4G and 5G network options are considered in the study. Use of a 5G network could improve network operational efficiency and cost.

Table 3: Sutton Harbour key connections heating and cooling demand summary

	Peak heat (Diversified)	Annual heat	Peak cooling (Diversified)	Annual cooling
Building connection	**kW**	**kWh/year**	**kW**	**kWh/year**
National Marine Aquarium (NMA)	1,129	981,113	716	916,147
PCH - Commercial Place	426	773,000	N/A	N/A
UoP Marine Station	66	81,000	N/A	N/A
Total	**1,352**	**1,835,113**	**716**	**916,147**

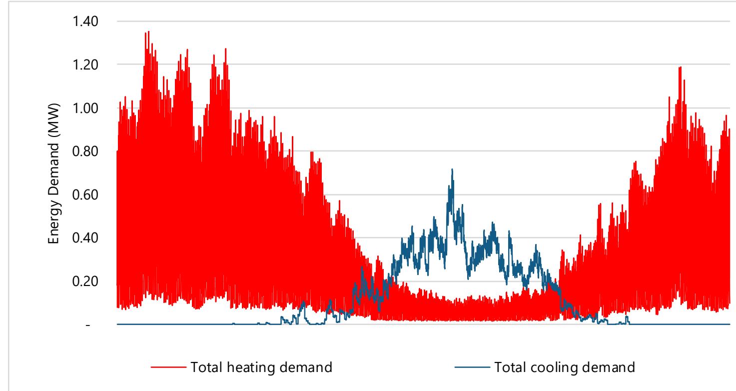

Figure 16: Sutton Harbour annual heat and cooling demand profiles

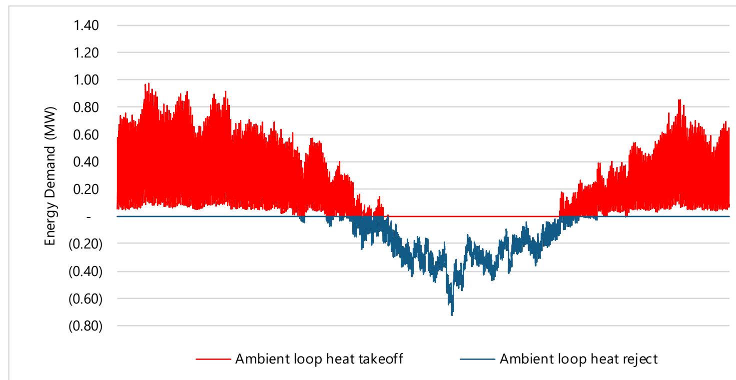

Figure 17: Sutton Harbour ambient loop heat supply and cooling systems reject annual profiles

5

HEAT SOURCES - OVERVIEW

- HEAT SOURCES MAP
- HIGH LEVEL ANALYSIS
- PRIORITISATION

Sutton Harbour's Potential Heat Sources

Connection to AZP network

Sutton Harbour is one of the key clusters planned into the Plymouth DESNZ funded AZP scheme. The scheme will supply heating and cooling to Plymouth City Centre from the SWW sewage treatment works at Prince Rock.

Open loop ground source

Sutton harbour has shown precedence for open loop ground source supply. The NMA makes use of a productive borehole to supply seawater to aquarium tanks.

Closed loop ground source

Closed loop borehole infrastructure could be installed in PCC parkland, see the highlighted area, central to all key proposed connections.

Marine source heat pump

Sutton Harbour connections are all closely located to a seawater source. Marine source heat pumps could be used to supply heat if appropriate space for extraction, rejection and energy centre can be identified

Waste heat recovery

The Sutton Harbour fish market uses year-round chillers and ice plant. The NMA also uses chillers year-round. Waste heat could be rejected into a network to supply heat to connections.

Rooftop ASHP

Flat roofs at the NMA and PCH Commercial Place may be able to hold ASHPs for individual supply or network supply of heating and/or cooling to buildings

Figure 18: Sutton Harbour heat source opportunities

Sutton Harbour Potential Heat Sources

Primary heat source	Summary	Advantages	Disadvantages	Available location/s	Project rationale
Ambient network connection (AZP)	• Each building is connected to the proposed AZP network • This network utilises waste heat from treated sewage effluent, which is cooled by a heat pump/evaporator. Heat is distributed across Plymouth city centre	• Government funding and the AZP programme may help unlock capital for the scheme • Limited additional infrastructure required to implement the system • Potential to utilise and recycle waste heat from existing chiller and ice plants	• Timescales – AZP connection likely not available until 2028 • Potential for commercial challenge – the scheme requires a critical buy-in by connections	• AZP connection heat interface units / heat pumps located at each building • Heat recovery from Fish market / NMA cooling systems	• Sutton Harbour is one of the connections planned into the Plymouth DESNZ AZP scheme • Additional option for cooling systems heat rejection into the ambient loop
Ground source heat pump: Open loop	• In an open loop system, groundwater is abstracted from an aquifer via water wells as a thermal resource, providing heating or cooling via heat pumps. Then reinjected back into the aquifer at a different location	• Low land/space take • High capacities often available if the heat source is proven	• Possibly limited development opportunity due to planning consideration/land availability • Large upfront cost • Design can only be finalised after drilling and flow, water and quality tests	• PCC owned green space/ park land	• Precedence set for open loop borehole across Plymouth • Potential for initial validation of open loop yield potential via NMA existing borehole • PCC owned land area could be used for extraction
Ground source heat pump: Closed loop	• Heat is transferred from the ground through an uninsulated pipework array, containing heat transfer fluid (often glycerol) • The ground heated heat transfer fluid passes over a heat pump/evaporator and cools, heating the DHN water	• Low maintenance cost for borehole array • Pumping costs lower than open loop • Hydraulic separation of working fluid from external variables	• Possibly limited development opportunity due to planning consideration/land availability • Capacity limited to available area compared to open loop solutions • Large upfront cost • Design can only be finalised after ground investigations and thermal response test	• PCC owned green space/ park land	• Installation on available PCC land could avoid potentially complicated commercial agreements

Sutton Harbour Potential Heat Sources

Primary heat source	Summary	Advantages	Disadvantages	Available location/s	Project rationale
Marine source heat pump	• Open loop WSHP system extracts heated water from a body of water • The water is cooled by a heat pump/evaporator, heating the DHN water before being returned to the source	• High capacities often available • High heat pump efficiencies available (thermal inertia of the water body)	• Reinjection could impact surrounding areas, needs EA and planning approval • Full water body monitoring needed • Requires an open area for extraction, rejection and placement on the edge of water body	• Pier by NMA and Plymouth fish market • Shoreline by Queen Anne's Quay	• Proximity of connections to a marine source • Evaluation performed in WSP marine heat source study
Waste heat recovery	• Waste heat recovery systems utilise thermal energy stored in effluent water from industry (e.g. chillers, fridges/freezers) • The effluent water is cooled by a heat pump/ evaporator, heating the DHN water	• Utilisation of heat that would otherwise go unused • Environmental agencies are keen on this, supplementing WSHPs would mean rejected is returned at a closer temperature to natural surface water	• Often commercially challenging, additional access agreements from waste source needed • Variable costs dependent on source integration methods and size of available source	• NMA • Plymouth fish market	• Waste heat from existing cooling systems • Would likely require large amounts of supplementary heat due to potentially low waste heat availability
Air source heat pump	• Heat from outdoor air (the working fluid) is cooled by a heat pump/evaporator, heating the DHN water	• A well developed and more affordable technology • Flexibility in design and placement	• Noise attenuation may be required based on receptors • Often requires roof space for evaporator • Efficiency is lower than through other methods (i.e. WSHPs) • Heat pump efficiency drops at low temperatures	• PCH Commercial Place (Teats Hill and Artillery Place building roofs) Note: Plant space and noise mitigation is a challenge in this area, as only PCH buildings have identified roof space.	• Could be used to complement/back-up primary generation

5.1

HEAT SOURCES - ANALYSIS

- ❑ KEY RISKS AND CONSIDERATION IDENTIFICATION
- ❑ INDIVIDUAL HEAT SOURCE RISK ANALYSIS
- ❑ REQUIRED NEXT STEPS

AZP Connection

Sutton Harbour is a key cluster in the Plymouth AZP pilot. Other key areas for connection include the University of Plymouth, UPP buildings, the Plymouth Civic Centre heat network and Millbay area (see Figure 19). There are 55 proposed connections in total.

The scheme plans to supply heating and cooling from the SWW Prince Rock sewage treatment works via an ambient loop 5G network. The network operates at flow/return temperature difference of 5°C (approximately 10°C/5C in winter and 22°C/27°C in summer), with localised upgrade either at connections for heating and cooling supply or at individual cluster energy centres to upgrade heat into 4G heat networks. Waste heat from the connections can also be rejected into the network for improved efficiencies.

The key Sutton Harbour connections (PCH commercial Place, UoP Marine Station and the NMA) are in phase 1 of the scheme, with a target connection date of 2028.

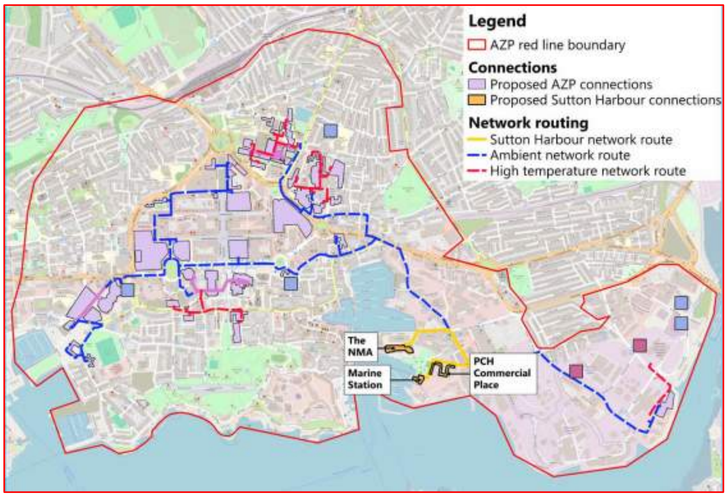

Figure 19: Plymouth AZP ambient loop network and Sutton Harbour cluster

Table 4: AZP connection risk analysis

Item	Comment	Risk Score
Capacity	The AZP network is designed to fully supply connections on the scheme, with localised heat upgrade and back-up of heat from the SWW Prince Rock sewage treatment source.	1
Complexity	<u>Key Risk</u> • Stakeholder buy in. A critical mass of the 55 stakeholders must connect to the network to make the network commercially viable <u>Technical Complexity</u> • Resilience must be ensured through effective back up systems • Integration of network supply, back up and current systems <u>Ability for connections to integrate the heat source</u> • Timelines for connection decarbonisation plans and implementation and the AZP scheme plan must align	2
Capital Cost	• Implementation Cost (cost of routing to get to Sutton Harbour and facility in the balancing EC) – ~£748,791 • Total cost of 4G connection - ~£3m (inc. implementation cost) • Total cost of 5G connection - ~3.4m (inc. implementation cost)	2
Operating Cost	• Maintenance cost for the network should benefit from economies of scale when compared to a smaller local network solution.	1
Total Risk Score:		6

<u>**Key considerations and next steps to pursue heat source**</u>

AZP connection is a heat source opportunity recommended to be pursued further. The key next steps for PCC to develop this solution would be:

- **Continue discussion with key connections** on requirements for connection to the network, system arrangements and the progress of the design of the AZP network.
- **Communicate timelines for connection** to all stakeholders and how this could facilitate decarbonisation of heating and cooling for the stakeholders

Ground Source Heat - Open Loop

As part of this study, Worley has carried out a review of the potential for ground sourced heat via open loop boreholes in the Sutton Harbour area (see attached in Appendix A). The following evidence was found to support the potential yields from boreholes in the area:

- Required geology (shallow limestone) in the area
- Tidal variation confirms strong hydraulic connection to the sea, therefore, high permeability
- NMA abstraction borehole flowrates indicate conservative yield in similar boreholes
- Site visit carried out confirmed the geology present

A total of 7 productive wells, at a total of abstraction flowrate of 71 l/s are suggested to meet the cluster peak heat demand (1,488kW, including primary network losses at 10%). A recommended contingency for 2 low output wells should be included. Boreholes are likely to require 20m spacing. Abstraction temperature are anticipated to peak at 14°C (summer) and low 11°C (winter), with 5°C difference with the discharge temperatures.

Two potential abstraction boreholes fields (green and red) are presented in Figure 20. The boreholes are recommended to be at elevations no greater than 10m AOD, ideally within 20m from high tide line/coastline. Discharge locations (white) are also shown, these are slipways into the harbour, with discharge below the tide water line. The top slipway is deemed more favorable as they are closer to boreholes an EC.

Figure 20: Open loop ground well opportunity in Sutton Harbour (Worley 2024)

Table 5: Open loop ground source risk analysis

Item	Comment	Risk Score
Capacity	Estimate >1.49 MW heat output	1
Complexity	All key risks can be substantially mitigated prior to committing to the expense of an extensive drilling and testing program. <u>Key Risk</u> • Discharge impacts / Environmental compliance - Impacts to the coastal ecosystem from discharge can lead to localised imbalances within the aquatic ecosystem. <u>Technical Complexity</u> • Required yield not achieved - The further inland from the coast, the higher the risk of not encountering productive fractures within the limestone. Therefore, requiring more/deeper boreholes and increasing costs. • Water quality - Potential for contamination ingress from unknown sources within the area. Installation of filtration systems for added resilience as part of the design • Reinjection risks (i.e. clogging and thermal feedback) are negated, as seawater is abstracted and reinjected back into the sea. <u>Ability To Integrate With Existing Proposal</u> • The PCC owned land is next to the borehole fields	2
Capital Cost	• £425,000 (+/- 30%) for construction, laboratory and field testing and reporting for 9 boreholes. • Additional costs for infrastructure (e.g. submersible pumps, piping, instrumentation and metering) at boreholes.	2
Operating Cost	• Estimated ~ £11,000 per borehole per annum, estimate for well maintenance • Additional pumping costs	2
Total Risk Score:		7

<u>Key considerations and next steps to pursue heat source</u>

Open loop boreholes are recommended for a standalone heat supply, with estimated yields meeting the Sutton Harbour cluster peak heat demand. The key next steps for PCC to develop this solution would be:

- **Engagement with the EA** to facilitate the progression of the required permits, licenses and viability of potential abstraction and discharge locations.
- **Local borehole testing** within close proximity to the study area, including but not limited to; hydrogeological testing, water quality testing, and groundwater, temperature and tidal monitoring. Potential installation of a downhole temperature logger in the NMA abstraction well and monitoring over the winter period.
- **Detailed desk study/review** of local geology and areas of potential contamination to inform the conceptual site model.
- **Establish land use agreements** with PCC to establish the land available for borehole drilling.

Ground Source Heat – Closed Loop

PCC Land by Parsonage Way and Commercial Place could be used for installation of a closed-loop borehole array, presented in Figure 21 are areas identified. GIS analysis shows area A, B and C cover ~2,400m², cover ~1,167m² and ~ 395 m², respectively.

Buro Happold have previously engaged with Kensa Utilities in the Plymouth Millbay area to discuss feasibility and capacity of a closed-loop borehole array. A benchmark of 10 kW/m² was provided by Kensa, the potential yields in the Sutton Harbour area are presented in Figure 21, with a total 378 kWh/year peak.

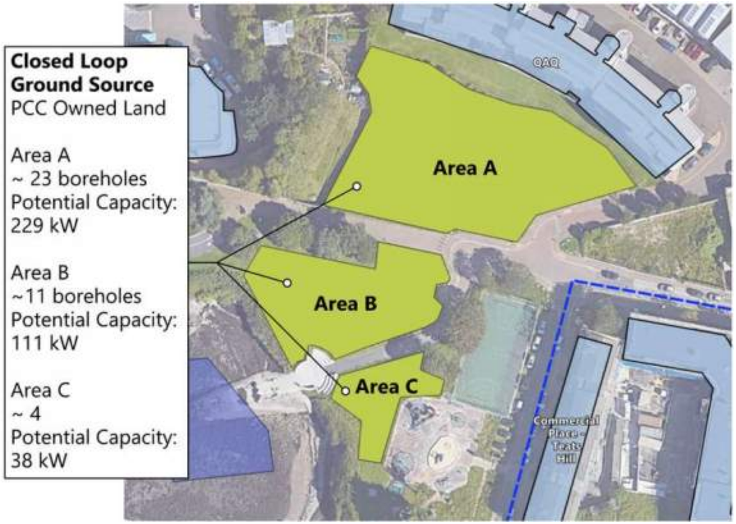

Figure 21: Areas with potential for closed-loop borehole array Sutton Harbour

Table 6: Closed loop ground source risk analysis

Item	Comment	Risk Score
Capacity	• Area A: 229 kW • Area A+B: 341 kW • Area A+B+C: 378 kW • Peak heat demand is 1,352 kW, additional heat source is required.	3
Complexity	Key Risk • Permission to drill and operate boreholes on Sutton Harbour parkland will be required by the PCC. The landscaped areas B and C may be a challenge for permission. Technical Complexity • Proximity to sea results in the sea wash effect. This limits the charging of boreholes in summer but improves thermal response in winter. Ability To Integrate With Existing Proposal • The PCC owned land is next to the proposed route.	2
Capital Cost	• 2,780 £/kW (from previous Kensa engagement) • High capital cost due to large number of boreholes required • Routing Cost - Low due to the proximity to the network and connections. • Implementation Cost - Drilling boreholes and installing pipework, manifolds etc.	2
Operating Cost	• Low maintenance cost for borehole array • Pumping costs lower than open loop	1
Total Risk Score:		8

Key considerations and next steps to pursue heat source

Closed loop boreholes could be used to supply Sutton Harbour with heat. Land availability is limited and does not fulfill heat demand requirements. Additional heat source(s) would be required, adding to the complexity of a closed loop solution. The key next steps for PCC to develop this solution would be:

- **Establish land use agreements** with PCC to establish the land available for borehole drilling.
- **Find additional heat sources,** explore opportunity for heat rejection and ASHP addition to the network to make up heat demand.

Marine Source Heat Pump

Thermal energy can be harnessed from abstracted sea water, this is typically carried out via a heat pump or plate heat exchanger arrangement. The sea/saline water is then returned to the sea at a lower or higher temperature based if it was utilised for heating or cooling, respectively.

A marine source heat pump could fulfil and has the potential to provide the 1.35 MW peak heat requirement. Limitations to large heat abstractions by the environment agency (EA) and plant area requirement are key constraints. The allowable abstraction and rejection temperatures and flow velocities set the limit of the potential capacity of marine source heating/cooling. Industry standards restrict the abstraction velocity to 0.25m/s and the allowable discharge temperature to ±3°C from the abstraction temperature.

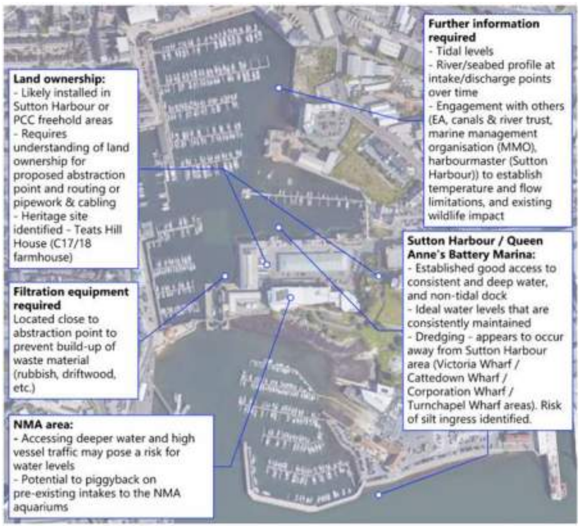

Figure 22: Sutton Harbour marine source opportunity review

The NMA also has a seawater extraction well to feed the tanks. This well could indicate marine heat supply opportunities in the area. However, historic volume flow and temperature (flow & return) have not been made available. At the site visit, the NMA reported a stable 16°C flow temperature, this is similar to open loop abstraction temperatures in the Plymouth area. Further engagement with the NMA is required.

Previous studies were carried out by others to establish the potential for utilizing marine water sourced heat across Plymouth, including the NMA. The key findings are presented in Figure 22, and potential location review is discussed on the next page.

Table 7: Marine source heat pump risk analysis

Item	Comment	Risk Score
Capacity	Requires installation of up to 1.4 MW WSHP(s) to meet area demand.	1
Complexity	Associated Risk • Approved permissions/licenses required from the EA • Restrictive EA abstraction/discharge licence conditions Confirmation of land ownership /planning red line areas Technical Complexity • Location of a suitable sea water discharge location, to mitigate impacts to sea water temperatures • Water temperatures limiting heat pump performance Ability for connections to integrate the heat source • Location of the abstraction and discharge points, in relation to plant location • Potential damage to intake point from dredging Construction • Complex construction for routing of pipework and cabling to plant, due to limited space in preferred locations	3
Capital Cost	• Infrastructure costs for connection of preferred seawater abstraction and discharge locations to plant, and connection to the district heat network (i.e. pumps, piping, heat pumps and auxiliary plant, building) • Complex filtration systems	2
Operating Cost	• Marine side maintenance and filtration • Abstraction pumping	2
Total Risk Score:		8

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Marine Source Heat Pump

Based on indicative energy centre footprints for 1 MW, 3 MW and 5 MW heat pumps were used to establish potential locations near Sutton Harbour.
Resilience of 2N for heat pumps (due to the nature of the NMA operation) and pumping & water treatment systems carried out elsewhere was assumed.
A summary of the review of the potential locations is presented in Table 8.

Marine source abstraction is not considered the preferred solution due to the risks associated with securing abstraction and rejection locations and establishing third party agreements. However, PCC could pursue this source in the future due to the high capacity potential.

<u>Key considerations and next steps to pursue heat source</u>

- **Engage with the EA** regarding abstraction and rejection temperature and flow
- velocity constraints, and licences
- **Procure a dispersion modeling desktop study** to identify preferred abstraction
- and rejection locations with the EA
- **Engage with Sutton Harbour harbormaster** to establish existing dredging and potential impacts to
- Complete a hydrogeological survey
- **Confirm with PCC & other landowners** for plant location and routing of pipework and cabling

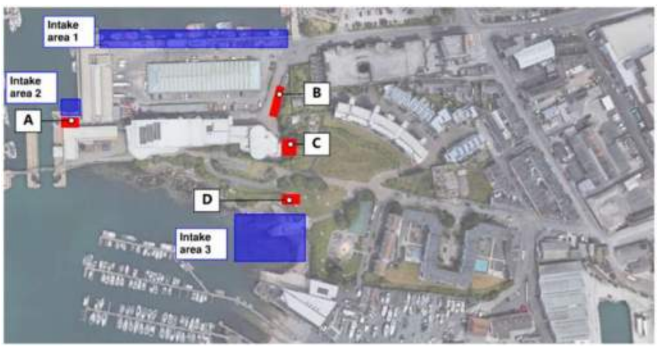

Figure 23: Marine source heat pump opportunity in Sutton Harbour

Table 8: Marine source WSHP energy centre location and abstraction area options

Plant Location	Description	Risks/Considerations
A	• Single energy centre and pumping station • Abstraction and reinjection ideally located for energy centre • Good and immediate access to heat source	• Potential short-circuiting between abstraction and discharge points, if located too close • Complex pipe routing from energy centre to main road, for connection to the network • Loss of car park spaces, i.e. revenue for landowner
B	• Good access for pipe routing from energy centre to network connection	• Located close to rockface. Therefore, limited footprint for energy centre • Limited access for construction and installation • Configuration of energy centre is limited to due to available footprint available • Pumping station located away from energy centre, due to limited footprint available • Adjacent to listed building (Teats Hill House) which would be a planning risk • Loss of trees, of great importance to the broader Plymouth area • Loss of NMA storage space
C		
D	• Single energy centre and pumping station • Good access for pipe routing from energy centre to network connection • Good and immediate access to heat source	• Not included in previous studies, therefore, requires confirmation of water levels for abstraction and reinjection points

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Waste Heat Recovery

The NMA has installed 2 no. ASHPs to provide cooling to the animal life support systems, in order to maintain the required temperatures.

It is estimated that the NMA cooling systems may reject up to 956 MWh/year of low grade heat, at a peak of 0.75 MW. This heat could be recovered and upgraded in a WSHP (i.e. heat recovery heat pump, HRHP) to provide heat to meet the demand of the Sutton Harbour cluster.

The Sutton Harbour heat demand (pre-heat pump) and heat reject (NMA cooling systems) is presented in Figure 24, showing a reverse seasonal trend between them. The heat reject would not be sufficient to meet the demand of the entire cluster across the year, however, it would aid to meet the baseload in the summer months. Thermal storage can aid to maximise the chiller/cooling systems heat recovery.

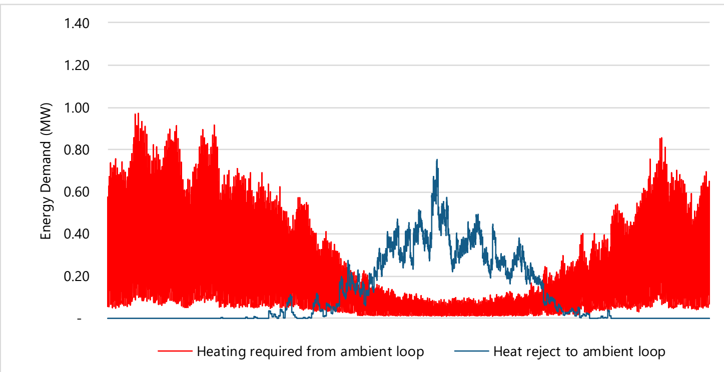

Figure 24: Sutton Harbour cluster ambient loop heat demand and heat reject annual profile

Table 9: Waste heat recovery risk analysis

Item	Comment	Risk Score
Capacity	Potential for 752 kW peak heat output via WSHP	1
Complexity	Key Risk • Technical Complexity • Control and integration to maximise chiller efficiency is required • Space requirement for HRHP Ability To Integrate With Existing Proposal • Require agreement with NMA to utilize heat and install pipework to allow for bypass of cooling systems	2
Capital Cost	• Additional cost for HRHP • Larger plantroom required to house HRHP alongside the network/AZP ambient loop connection (i.e. heat pump)	2
Operating Cost	• Low maintenance cost for HRHP routine maintenance required. However, additional cost to network/ambient loop heat pump (if required)	1
Total Risk Score:		6

As the rejected heat is recovered at the HRHP, the return to the cooling systems would be reduced in temperature. This acts as a cooling system, reducing the load on the cooling systems and subsequent electrical demand. This provides a benefit to the NMA, whilst also supplying heat to the other connections. Engagement with the NMA will be required to confirm the design/integration points and agree terms of use. The

Key considerations and next steps to pursue heat source

A waste HRHP at the NMA could be used to supply a fraction of the Sutton Harbour with heat as top-up to a network. The key next steps for PCC to develop this solution would be to **engage with the NMA, to confirm the following:**

- To confirm integration points and investigate/agree terms of use
- To install metering to confirm the existing cooling demand and heat reject

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Air Source Heat Pumps

ASHPs could be used as a core heat source or as low-carbon resilience/back-up capacity to a network in Sutton Harbour. Presented in Figure 25 are the identified areas for application of ASHPs. Permissions are required from all landowners.

Core heat source - Sutton Harbour car park is owned by Sutton Harbour holdings company, the landowner also owns land occupied by the NMA and Fish Market. The car park could house an ASHP energy centre supplying all Sutton Harbour loads. There is also space on PCC land for an ASHP energy centre.

Network low carbon resilience - At the NMA 2 no. ASHPs (cooling only) installed outside of the main plant room. There are 2 no. ASHPs to be installed as part of the NMA plant renewal programme. Any unused capacity could be supplied to the network, although may not a resilient supply.
Land owned by PCH Commercial Place and UoP Marine Station are highlighted. However, space is limited for installation of ASHPs.

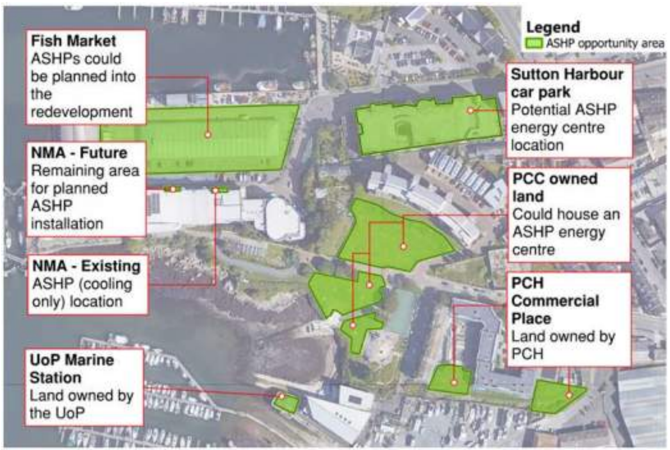

Figure 25: ASHP opportunity areas in Sutton Harbour

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Table 10: ASHP risk analysis (evaluated for core solution options at Sutton Harbour car park and PCC land)

Item	Comment	Risk Score
Capacity	• Core energy centre (PCC land or Sutton Harbour car park): • NMA: 1.13 MW • Marine Station: 0.06 MW • PCH Commercial Place: 0.43 MW Total demand (1.35 MW diversified)	2
Complexity	<u>Associated Risk</u> • Land permissions to fit ASHP / energy centre required from building/land areas <u>Technical Complexity</u> • Noise constraints on ASHP energy centres must be considered. <u>Ability To Integrate With Existing Proposal</u> • Areas close to network routing and connections	2
Capital Cost	• Routing Cost - Low due to proximity to network routing • Implementation Cost – Higher capital expenditure for energy centre, lower cost for dedicated connection HIUs	2
Operating Cost	• ASHP routine maintenance required • From an ambient loop perspective – high as having to operate two stages of heat pumps. Centralised ASHP operating cost much higher than alternative passive heat source	3
Total Risk Score:		9

<u>**Key considerations and next steps to pursue heat source**</u>

ASHPs could be used to supply Sutton Harbour with heat and cooling either as a core supply solution or as top-up to a network. The key next steps for PCC to develop this solution would be:

- **Establish land use agreements** with Sutton Harbour or PCC to establish the land available for an ASHP energy centre
- **Explore opportunity** for ASHP installation for resilience/back-up heat supply at individual connection locations

5.2

HEAT SOURCES - PRIORITISATION

- ❑ RISK COMPARISON
- ❑ PRIORITISATION LIST

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Heat Source Prioritisation

Following the qualitative assessment undertaken to identify the risk of each heat source opportunity. A weighted scoring matrix was utilized to establish a risk score for each heat source opportunity, based on capacity, complexity, apital cost, and operating cost. Scores were assigned from high to low risk; red = 3, amber = 2 and green = 1. The lowest score represents the heat source that offers PCC the lowest risk opportunity. Each score is presented on the relevant heat source opportunity page and in Table 11 below.

Connection to the AZP network is deemed the lowest risk opportunity and the one that should therefore be pursued as a priority by PCC. The primary risk to AZP connection is a lack of stakeholder buy in across the entire network and alignment with current Sutton Harbour building decarbonization plans (e.g. net zero target dates). Discussions with stakeholders to agree on the best method for connection to the network with assurances on resilience and heat sales price are required.

The next lowest risk opportunity are a ground source open loop system. Ground source heat via an open loop system is precedented in the Plymouth area, with potential to meet the entire cluster demand. The greatest risk being that the requirement for drilling and testing to confirm adequate supply, and stable boreholes.

A low risk heat source opportunity is waste heat recovery at the NMA cooling systems, which could provide part of the cluster heat demand and reduce the load on the primary heat supply (e.g. standalone energy centre). Although the cooling demand is predominantly in the summer months, the heat recovered could still meet part of the baseline cluster demand (e.g. DHW generation).

Table 11: Sutton Harbour heat opportunities risk analysis comparison and scoring

	Connection to the AZP network	Ground Source - Open Loop	Ground Source - Closed Loop	Marine source	Waste heat recovery	ASHP
Capacity	Green	Green	Red	Green	Green	Amber
Complexity	Amber	Amber	Amber	Red	Amber	Amber
Capital Cost	Amber	Amber	Amber	Amber	Amber	Amber
Operating Cost	Green	Amber	Green	Amber	Green	Red
Risk Score	6	7	8	8	6	8

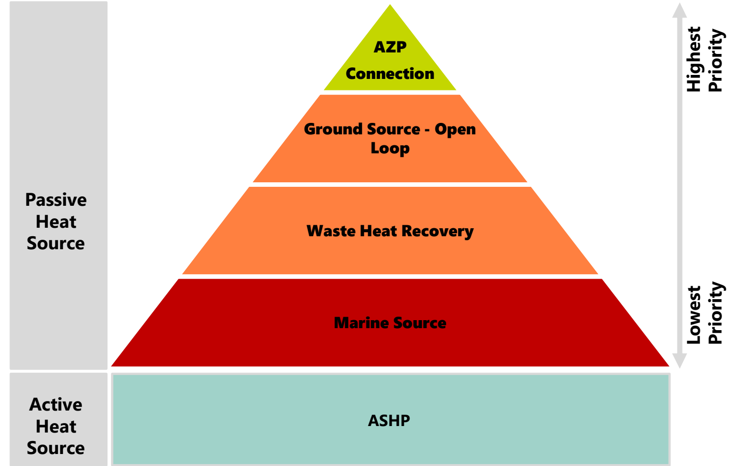

Figure 26: Sutton Harbour heat source prioritisation diagram

It is recommended that the heat source opportunities as illustrated in Figure 26.

ASHPs have been separated as they are not deemed an appropriate primary heat source for the Sutton Harbour network due to lack of space for full provision, but have the potential to serve as an effective low-carbon backup supply if installed in the future. As a highly flexible active heat source ASHPs can be used to plug gaps in heat capacity requirements and provide low-carbon resilience/back-up to the Sutton Harbour network.

Connection to the AZP network is deemed to be the lowest risk for connections. The analysis in the remainder of this study therefore considers this option, versus a standalone ground source open loop system, with waste heat recovery.

6

NETWORK OPTIONS

- ❑ NETWORK OPTIONS SUMMARY
- ❑ IDENTIFIED CONSTRAINT
- ❑ NETWORK ROUTING
- ❑ BUILDING LEVEL CONNECTION

4G and 5G network options

4th Generation Overview
A 4th generation heat network provides solely heating provision to buildings on the district heat network. The network supplies heat at around **55-60°C**, with heat returned at around **40°C**.

Heat is supplied to the network from a central heating plant within an energy centre. The energy centre contains heat production or upgrade equipment such as heat pumps and backup equipment such as electric boilers.

Heat from the energy centre is distributed to connections via buried insulated pipework between buildings where required to provide space heating and domestic hot water.

5th Generation Overview
A 5th generation ambient loop network provides both heating and cooling provision to buildings on the district network, via buried uninsulated pipework. The loop is kept at temperatures between **10-18°C** depending on the season.
An ambient loop network's main elements are:

- **Low grade temperature source**: borehole arrays, chiller rejection circuit, waste heat from data centres etc.
- **Communal balancing energy centre**: to provide resilience to the low-carbon source or maintain the loop within its temperature range, an ASHP or other low-carbon technology is located in a communal energy centre to supply the loop
- **Localised water source heat pumps (WSHPs)**: located at each connected building, WSHPs utilise the ambient loop low grade water and electricity to upgrade the heat (or cool) to a useable temperature for the building systems
- **Ambient loop distribution network**: usually buried uninsulated pipework system connecting the above three elements together, forming the primary network

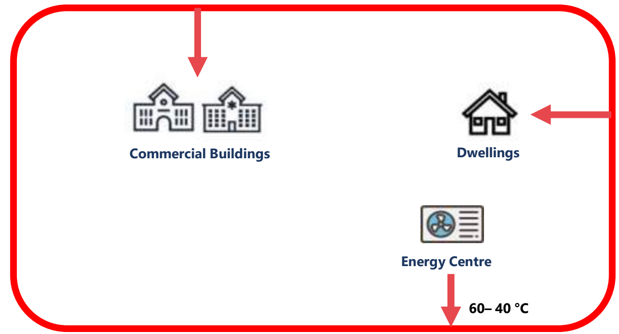

Figure 27: High level diagram of a 4th generation heat network

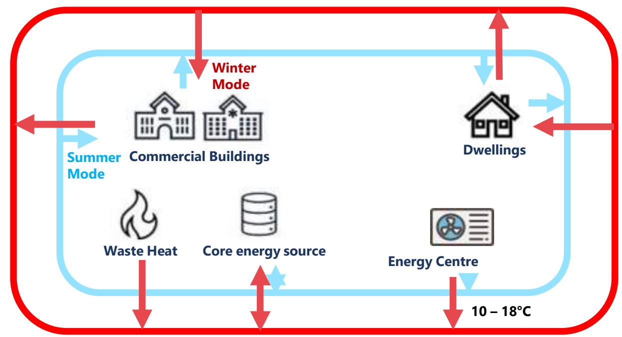

Figure 28: High level diagram of a 5th generation / ambient loop heat network

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4G and 5G network options

Table 12: Sutton Harbour cluster network options

Network option	NMA	PCH Commercial Place	UoP Marine Station
AZP 5G	Heat and cooling supply. Individual connection and heat pump / heat substation to NMA due to pipework routing constraints. Limited locations for heat pump / heat substation identified.	Heat only connection. Individual heat pump / heat substation required for heat upgrade to meet required operating temperatures. PCH requires external demarcation, so HIUs installed at individual consumers.	Heat only connection. Individual heat pump / heat substation required for heat upgrade to meet required operating temperatures.
AZP 4G	Heat and cooling supply. Individual connection and heat pump / heat substation to NMA due to pipework routing constraints. Limited locations for heat pump / heat substations identified.	Heat only connection. A shared heat pump / heat substation for UoP Marine Station and PCH Commercial Place for heat upgrade to meet required operating temperatures. PCH requires external demarcation, so HIUs installed at individual consumers.	Heat only connection. A shared heat substation for UoP Marine Station and PCH Commercial Place for heat upgrade to meet required operating temperatures. HIU installed at building level.
Standalone 5G	CAPEX is likely high for a standalone solution. Lack of balance in heating and cooling, as only cooling demand at NMA.	CAPEX is likely high for a standalone solution. Lack of balance in heating and cooling, as only cooling demand at NMA.	CAPEX is likely high for a standalone solution. Lack of balance in heating and cooling, as only cooling demand at NMA.
Standalone 4G	Based on available heat sources capacity. CAPEX is likely high for a standalone solution. CAPEX for pipework routing from central energy centre likely to be high. Not meeting cooling NMA demand.	Based on available heat source capacity. CAPEX is likely high for a standalone solution.	Based on available heat source capacity. CAPEX is likely high for a standalone solution. Additional option for a HRHP installed.

Pipework routing constraints

Analysis of the potential AZP network routing was carried out by 3DTD utility routing specialists. This analysis shows Fish Walk as a challenge for routing due to constrained walkways and tunnel. Additional constraints have been identified through review of previous studies and the site visit carried out.

Presented in Figure 29 is the proposed routing, connecting UoP Marine Station and PCH Commercial Place via Commercial Place and Artillary Place, and Lockyers Quay to connect to the NMA.

Also, presented in Figure 29 are alternative NMA routing options identified and constraints. This shows routing to the NMA is only feasible via Lockyers Quay. This would mean additional pipework routing for a standalone cluster option and a separate connection for the AZP network connection option.

Based on the RAG analysis of the network options, the AZP 4G ad 5G, and standalone 4G options were taken forward for further consideration.

Figure 29: Sutton Harbour pipework routing options and constraints

Network routing & connections

AZP network routing
As part of the AZP project, 3DTD routing consultants analysed routing options for the ambient loop network; including utility congestion analysis, emergency service routes, and sewer presence.

Shown in pink in Figure 30 is the 3DTD primary option for the route out of SWW central into Sutton Harbour, along Shapters Road/ Barbican Approach. It should be noted that there is a large diameter low pressure gas main located on this route.

An amendment to the proposed AZP ambient loop network route is presented in Figure 30 in blue. This route would allow for connection to the UoP Marine Station and PCH Commercial Place, without substantially increasing the pipe required (~194 m of pipe length saved).

3DTD recommend utility surveys at all locations and de-risking the design by selecting the least congested route to connect to Commercial Road. It should be noted that this route is slightly more congested, with a medium and high-pressure gas main present. Also, large sewers are indicated at Commercial Road (yellow vertical) and at Barbican Approach (pink horizontal). Further consideration should be made in the next design stage.

Building connection options - 5G
For a 5G network, heat upgrade is required to bring network temperatures up to required building temperatures. Shoebox heat pumps (Kensa) or HIUs alongside centralised heat upgrade can be used, see figures 31 and 32. Both HIUs and shoebox heat pumps can fit in residential sized boiler cupboards.

Shoebox heat pumps are often controlled by the network operator with the relevant expertise. Whilst, HIUs can be maintained by the building owner. Where a building owner may prefer control over internal systems, HIUs can be preferable.

In larger properties, for 5G heat upgrade, WSHPs are housed in the plant room.

Building connection options - 4G
For a 4G network, heat is distributed from a communal energy centre directly to buildings with HIUs, at the required temperatures for typical heating systems.

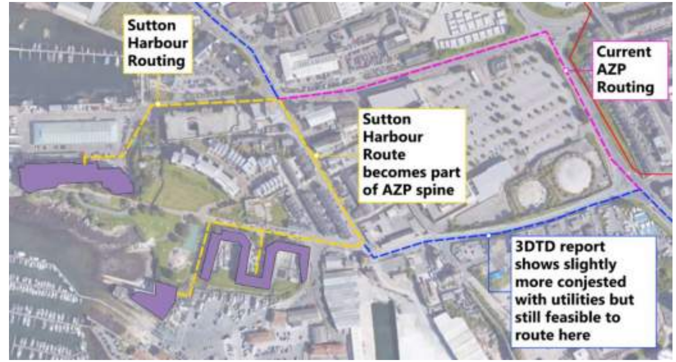

Figure 30: Sutton Harbour cluster proposed AZP ambient loop route amendment

Table 13: Sutton Harbour cluster building level connection options

Network option	5G	4G
NMA	WSHP	WSHP
PCH Commercial Place	Shoebox HP or HIU connected to a small WSHP energy centre (allows for PCH external demarcation)	HIU
UoP Marine Station	WSHP	HIU

Figure 31: Heat interface unit

Figure 32: Kensa shoebox heat pump

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7

TECHNICAL ARRANGEMENT

- ❑ SUMMARY OF SCENARIOS FOR TEM
- ❑ PLANT ROOM ARRANGEMENT

Scenario 1 – AZP 5G connection arrangement

A high level outline schematic (Figure 33) has been developed with the proposed hydraulic arrangement of the Sutton Harbour 5G connections to the AZP ambient loop. A location plan is presented alongside (Figure 34), to illustrate where instances of each of these items are present.
See Appendix B for the plantroom and building WSHP / heat substation / HIU indicative layout, and location.

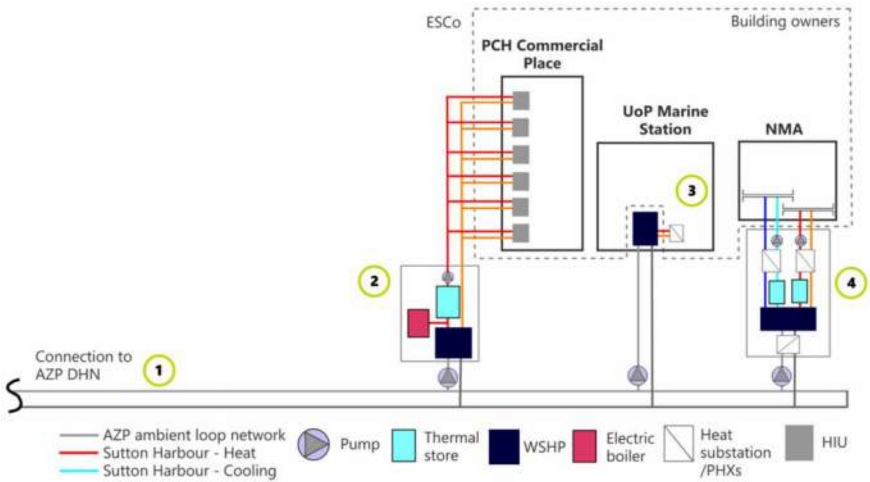

Figure 33: High level schematic for scenario 1 - AZP 5G ambient loop network and connections

Figure 34: Location plan for scenario 1 - AZP 5G ambient loop network and connections

1. Sutton Harbour connection to the AZP ambient loop network along Commercial Road.
2. A small energy centre is located on PCH owned land, including a WSHP (heat upgrade to 80°C/60°C) and auxiliary plant. This is to be owned and operated by the AZP Esco, with the demarcation for PCH Commercial Place prior to entering the building.
   HIUs controlled by PCH are located at each individual residential flat connection, replacing the current gas boilers.
3. Installation of a WSHP (heat upgrade to 80°C/60°C) within the UoP Marine Station plant room, utlising the existing plate heat exchanger as the demarcation point. All plant prior is to be operated and maintained by the ESCo. Existing heat plant (thermal stores, boilers, DHW calorifiers) to be retained. Spatial review is required, as it is anticipated there would be insufficient available footprint for a dedicated WSHP.
4. Heat and cooling is supplied to the NMA. There is limited space for additional plant in the NMA plant room, this assumed to not change in the future. An interface plantroom is to be installed outside the NMA, all plant is to be operated and maintained by the ESCo. Spatial review and land use agreement is required for installation.

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Scenario 2 – AZP 4G connection arrangement

A high level outline schematic (Figure 35) has been developed with the proposed hydraulic arrangement of the Sutton Harbour 4G network connection to the AZP ambient loop. A location plan is presented alongside (Figure 36), to illustrate where instances of each of these items are present.
See Appendix B for the plantroom and building WSHP / heat substation / HIU indicative layout, and location.

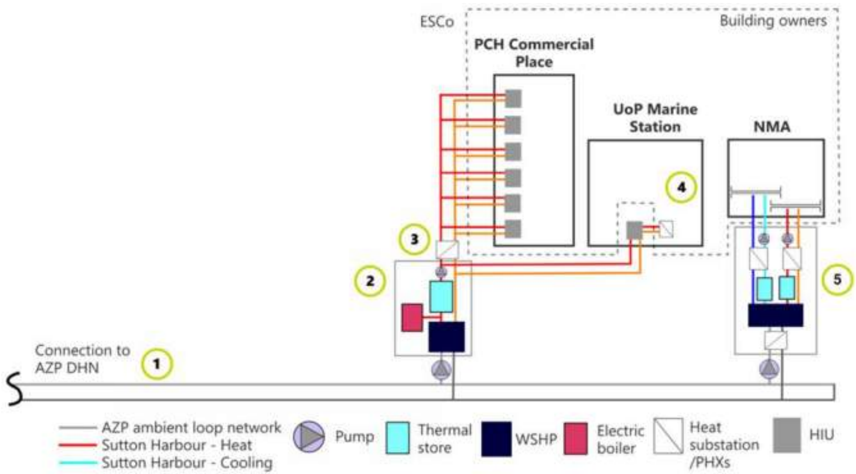

Figure 35: High level schematic for scenario 2 - AZP 4G network and connections

Figure 36: Location plan for scenario 2 - AZP 4G network and connections

1. Sutton Harbour connection to the AZP ambient loop network along Commercial Road.
2. A 4G energy centre is located on PCC owned land, including a WSHP (heat upgrade to 80°C/60°C) and auxiliary plant. Pipework distributes LTHW to PCH Commercial Place and UoP Marine Station. The energy centre is to be owned and operated by the AZP Esco, and acts a hydraulic break from the AZP network.
3. PCH Commercial Place is supplied heat only, hydraulic separation at a heat substation provides demarcation between the ESCo operation and the PCH owned building. Individual HIUs are installed are fitted to replace gas boilers in gas boiler cabinets. HIUs controlled by PCH are located at each individual residential flat connection, replacing the current gas boilers.
4. Space has been identified for HIU within the UoP Marine Station plant room, utlising the existing plate heat exchanger and thermal store as the demarcation point.
5. Heat and cooling is supplied to the NMA via 5G connection. There is limited space for additional plant in the NMA plant room, this assumed to not change in the future. An interface plantroom is to be installed outside the NMA, all plant is to be operated and maintained by the ESCo. Spatial review and land use agreement is required for installation.

Scenario 3a - Open Loop Ground Source 4G network arrangement

A high level outline schematic (Figure 37) has been developed with the proposed hydraulic arrangement of the Sutton Harbour 4G network supplied heat via open loop boreholes. A location plan is presented alongside (Figure 38), to illustrate where instances of each of these items are present.
See Appendix B for the plantroom and building WSHP / heat substation / HIU indicative layout, and location.

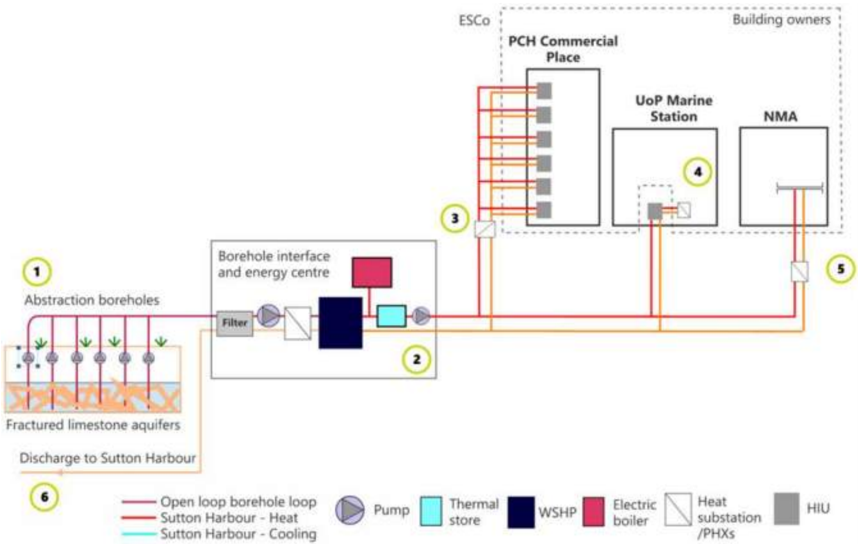

Figure 37: High level schematic for scenario 3a - Open loop ground source 4G network and connections

Figure 38: Location plan for scenario 3a - Open loop ground source 4G network and connections

1. Heat abstraction from 7 boreholes in fractured limestone, located on PCC owned land in Sutton Harbour area.
2. A 4G energy centre is located on PCC owned land, including a WSHP (heat upgrade to 80°C/60°C) and auxiliary plant. Pipework distributes LTHW to all 3 connections. The energy centre is to be owned and operated by the PCC.
3. PCH Commercial Place is supplied heat only, hydraulic separation at a heat substation provides demarcation between the network operator and the PCH owned building. Individual HIUs are installed are fitted to replace gas boilers in gas boiler cabinets.
   HIUs controlled by PCH are located at each individual residential flat connection, replacing the current gas boilers.
4. Space has been identified for a HIU within the UoP Marine Station plant room, utlising the existing plate heat exchanger and thermal store as the demarcation point.
5. The network supplies heat to the NMA. There is limited space for a heat substation/plate heat exchanger in the NMA plant room, this assumed to not change in the future. A substation at the NMA perimeter, in the Fish Market boundary, is recommended. Land use agreement is required for installation.
6. Discharge / rejection point for sea water across slipway

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Scenario 3b - Open Loop Ground Source 4G network & NMA WHR arrangement

A high level outline schematic (Figure 39) has been developed with the proposed hydraulic arrangement of the Sutton Harbour 4G network supplied heat via open loop boreholes. Waste heat recovery at the NMA cooling systems is also included. A location plan is presented alongside (Figure 40), to illustrate where instances of each of these items are present.
See Appendix B for the plantroom and building WSHP / heat substation / HIU indicative layout, and location.

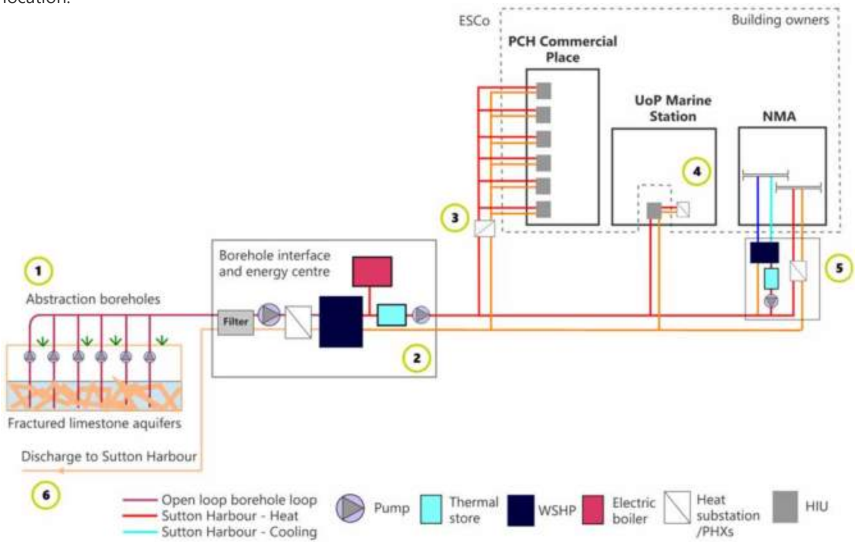

Figure 39: High level schematic for scenario 3b - Open loop ground source 4G network and connections, with NMA cooling systems waste heat recovery

Figure 40: Location plan for scenario 3b - Open loop ground source 4G network and connections, with NMA waste heat recovery

1. Heat abstraction from 7 boreholes in fractured limestone, located on PCC owned land in Sutton Harbour area.
2. A 4G energy centre is located on PCC owned land, including a WSHP (heat upgrade to 80°C/60°C) and auxiliary plant. Pipework distributes LTHW to all 3 connections. The energy centre is to be owned and operated by the PCC.
3. PCH Commercial Place is supplied heat only, hydraulic separation at a heat substation provides demarcation between the network operator and the PCH owned building. Individual HIUs are installed are fitted to replace gas boilers in gas boiler cabinets.
   HIUs controlled by PCH are located at each individual residential flat connection, replacing the current gas boilers.
4. Space has been identified for a HIU within the UoP Marine Station plant room, utlising the existing plate heat exchanger and thermal store as the demarcation point.
5. The network supplies heat to the NMA. Waste heat is recovered from the NMA cooling systems, upgraded to the required temperatures and rejected to the network. There is limited space for a heat substation/plate heat exchanger in the NMA plant room, this assumed to not change in the future. A substation at the NMA perimeter, in the Fish Market boundary, is recommended. Land use agreement is required for installation.
6. Discharge / rejection point for sea water across slipway

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8

TECHNO-ECONOMIC MODELLING

- ❑ CAPEX
- ❑ OPEX
- ❑ CASH FLOW MODELLING
- ❑ SUMMARY OF RESULTS

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Techno-Economic Modelling

CAPEX

Using an initial assessment of the required equipment for each scenario, a CAPEX estimation exercise has been performed. Estimations are based on equipment type, sizing, predicted quantities and cost estimations from supplier quotes and past BH projects.

An additional estimate of the portion of the overall AZP network pipework cost attributed to the wider AZP network and energy centre at SWW (3% of £23m) is included. Alongside the Sutton Harbour DHN cost, figure 41 shows that a significant portion of the costs is associated with the DHN pipework for all scenarios.

Heat pumps also make up a significant portion of costs for the DHN. Due to the requirement for local upgrade from a lower temperature in scenario 1 (AZP 5G connection), heat pump costs are greatest for this option.

The “Additions” includes contractor commissioning (3%), risk allowance (10%), prelims (15%), overheads & profits (5%) for the energy centre and plant.

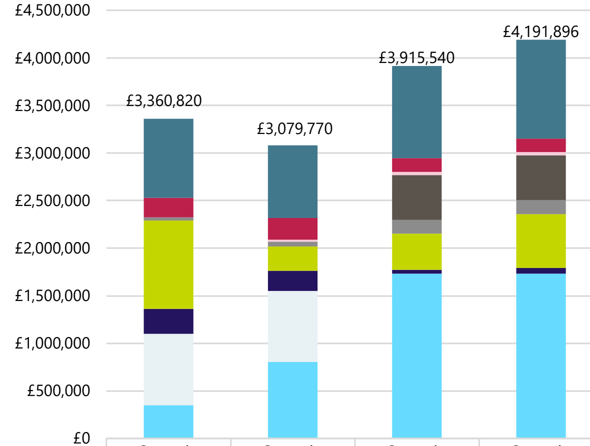
Economies of scale in the AZP network result in lower overall CAPEX for scenario 1 and 2 when compared to scenario 3.

Key assumptions

- Costs shown are for the full heat supply capacity at full build out in 2028.
- Estimates do not include costs associated with utility connection costs such as electricity, water, wastewater and communications as this would likely be the responsibility of the building owner to provide.
- Costs for connecting to each building are captured in the TEM modelling.

CAPEX reduction options

- GHNF capital funding can be leveraged to offset capital cost.



	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b
Additional costs	£833,887	£764,154	£971,525	£1,040,094
HIU/ Heat substation	£203,440	£229,440	£143,440	£143,440
PHX	£0	£19,650	£32,790	£32,790
Ground water infrastructure	£0	£0	£472,594	£472,594
Electric Boilers	£34,730	£48,500	£145,500	£145,500
Heat Pumps	£925,840	£252,924	£375,132	£562,698
Network ancillary equipment	£263,080	£211,924	£41,169	£61,389
AZP network additionals	£748,791	£748,791	£0	£0
DHN	£351,050	£804,390	£1,733,390	£1,733,390

DHN · AZP network additionals · Network ancillary equipment · Heat Pumps · Electric Boilers · Ground water infrastructure · PHX · HIU/ Heat substation · Additional costs

Figure 41 Estimated CAPEX

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Techno-Economic Modelling

Costing the AZP network for Sutton Harbour

To allow for comparison of AZP scenarios 1 and 2 with the standalone scenarios 3a and 3b, a proportion of estimated costs (CAPEX and OPEX) for the overall AZP system (from AZP techno-economic model) have been attributed to scenarios 1 and 2. These are used alongside Sutton Harbour CAPEX, OPEX and revenues to produce techno-economic results for AZP network options.

- **Connection charge** – A charge to the building owner to the ESCo, modelled in the first year of revenue and equated to the avoided cost of replacement equipment in an individual low carbon solution.
- **Standing charge** - £/kW charge calculated using the counterfactual cost of heat calculations in AZP modelling.
- **Variable sales rate** – p/kWh rate calculated using counterfactual cost of heat calculations and further cost consultant AZP modelling.
- **OPEX for the local Sutton Harbour DHN** – The ongoing cost of supplying heat to the Sutton Harbour, including staffing, local distribution pumps and general maintenance.
- **CAPEX for the local Sutton Harbour DHN** – The capital cost of heat upgrade heat pumps in Sutton Harbour (5G individual, 4G shared EC and NMA), pipework to deliver to buildings, substations, pumps and ancillaries.
- **OPEX to deliver heat to the Sutton Harbour DHN** - This accounts for AZP network pumping from SWW and wider AZP network maintenance.
- **CAPEX to deliver heat to the Sutton Harbour DHN** - A portion of the main AZP spine network and balancing energy centre plant. Taken as 3% of overall AZP pipework and balancing EC CAPEX.

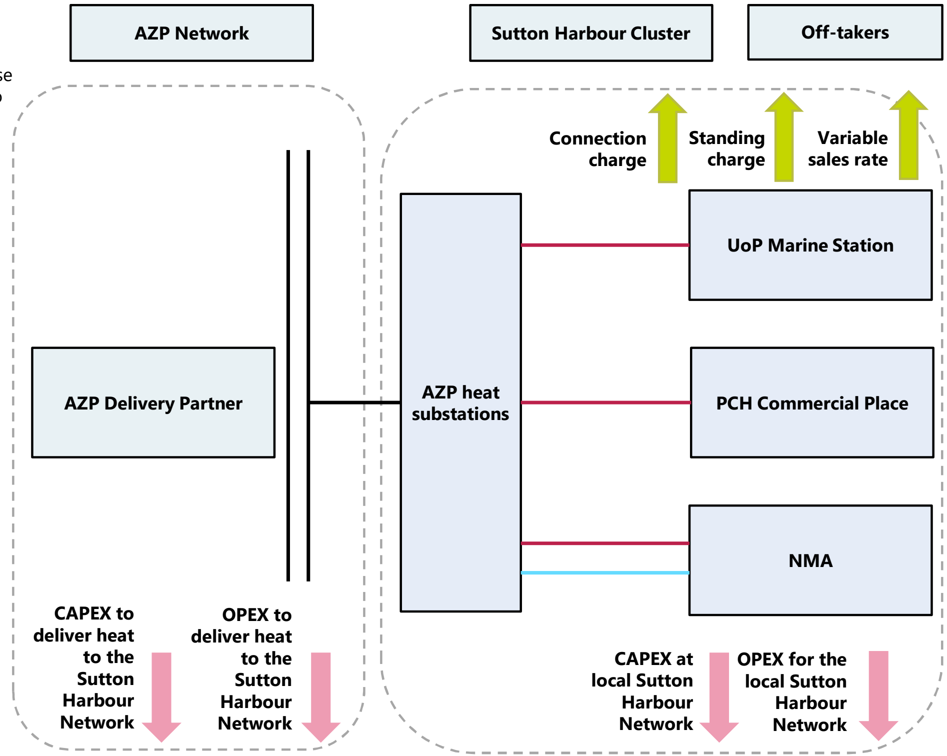

Figure 42 AZP network costing for TEM analysis

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Techno-Economic Modelling

Scenario 1 – AZP 5G Connection

Initial modelling indicates profitability for 5G connection of Sutton Harbour to the AZP network, both with and without grant funding.

A grant, such as the UK Government GHNF, of £1.44m, brings the scheme up to 10% IRR. It should be noted this is an estimate of grant requirement to support the Sutton Harbour element of the AZP scheme in connection to the AZP 5G network, which would also support the build out of the wider AZP network.

AZP network build out has been calculated at 2.5p/kWh for GHNF funding. For Sutton Harbour this 2.5p/kWh would allow for a £697,500 grant. This level of funding is less than the calculated requirement for scenario 1.

The inclusion of additional CAPEX and OPEX from the wider AZP network presents a conservative result.

The Sutton Harbour DHN branches from the main spine route for network provision into the Plymouth City Centre from SWW will be required regardless of Sutton Harbour connection.

Unfunded Results

- IRR @ 40 years: N/A
- NPV @ 40 years: £ 223,000

Grant Funded Results (10% IRR @ 40 years)

- NPV @ 40 years: £ 1,664,000
- £1,440,253 upfront grant funding

Without AZP network and balancing EC CAPEX

- IRR @ 40 years: N/A
- NPV @ 40 years: £ 972,000
- NOTE: no grant funding

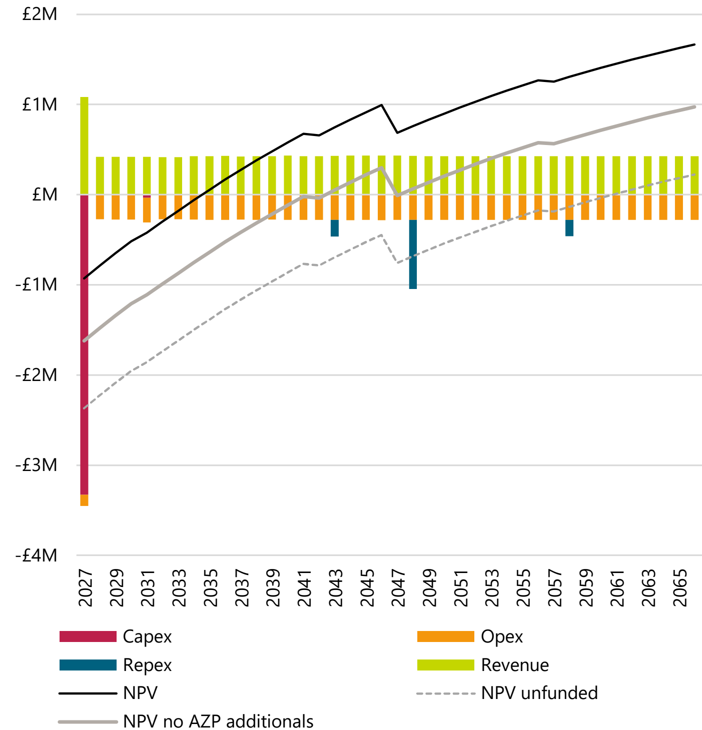

Figure 43: Sutton Harbour Scenario 1 - AZP 5G Connection NPV Cash Flow (Sutton Harbour only)

Techno-Economic Modelling

Scenario 2 – AZP 4G Connection

Initial modelling indicates profitability for 4G connection of Sutton Harbour to the AZP network, both with and without grant funding. With a greater NPV than the 5G option.

A grant, such as the UK Government GHNF, of £ 1,124,066, brings the scheme up to 10% IRR. It should be noted this is an estimate of grant requirement to support the Sutton Harbour element of the AZP scheme in connection to the AZP 5G network.

AZP network build out has been calculated at 2.5p/kWh for GHNF funding. For Sutton Harbour this 2.5p/kWh would allow for a £697,500 grant. This level of funding is less than the calculated requirement for scenario 2, but achieves 4.1% IRR.

Note: The inclusion of additional CAPEX and OPEX from the wider AZP network presents a conservative result. The Sutton Harbour DHN branches from the main spine route for network provision into the Plymouth City Centre from SWW will be required regardless of Sutton Harbour connection.

Unfunded Results

- IRR @ 40 years: N/A
- NPV @ 40 years: £ 813,000

Grant Funded Results (10% IRR @ 40 years)

- NPV @ 40 years: £ 1,937,000
- £1,124,066 upfront grant funding

Without AZP network and balancing EC CAPEX

- IRR @ 40 years: 4.7%
- NPV @ 40 years: £ 1,562,000
- NOTE: no grant funding

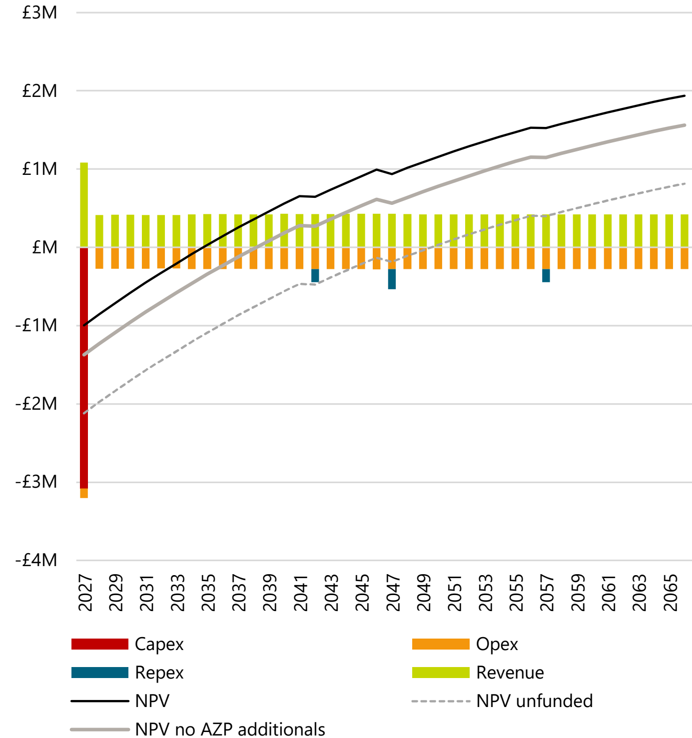

Figure 44: Sutton Harbour Scenario 2 - AZP 4G Connection Cash Flow

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Techno-Economic Modelling

Scenario 3a– Open loop GSHP Standalone 4G network

Initial modelling indicates low profitability for an open loop GSHP standalone 4G network scheme.

A grant, such as the UK Government GHNF, of £2,467,760, brings the scheme up to 10% IRR. NPV remains low at £137,000.

This is a result of low revenue from heat sales, due to the relatively small total annual demand and size of the network required (see the network routing options section) to deliver heat to Sutton Harbour in an individual solution.

Sensitivity testing in the following sections show the impact of increased heat sales price on NPV for Scenario 3a.

Unfunded Results

- IRR @ 40 years: N/A
- NPV @ 3.5% over 40 years: -£2,331,000

Grant Funded Results (10% IRR @ 40 years)

- NPV @ 40 years: £137,000
- £2,467,760 upfront grant funding

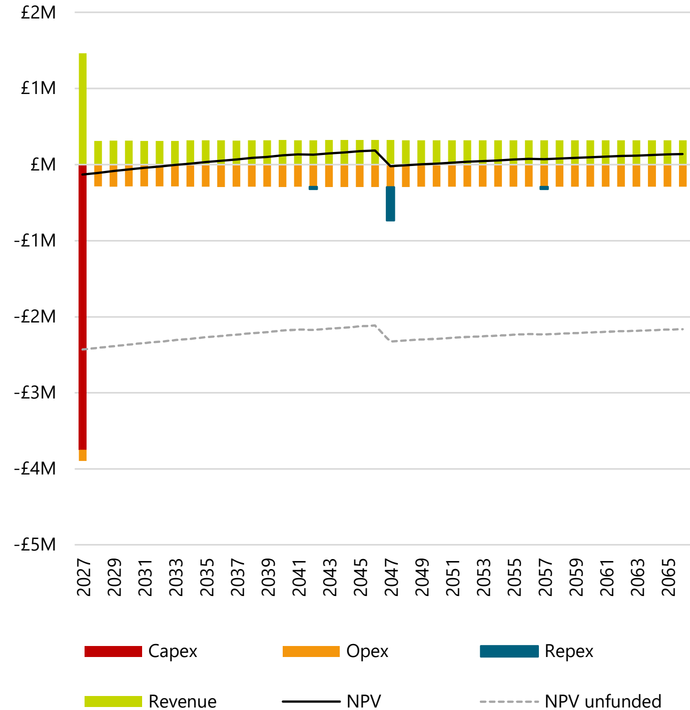

Figure 45: Sutton Harbour Scenario 3a – Open loop GSHP 4G network cash flow

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Techno-Economic Modelling

Scenario 3b – Open loop GSHP Standalone 4G network with heat recovery

Initial modelling indicates low profitability for an open loop GSHP standalone 4G network scheme with waste heat recovery.

A grant, such as the UK Government GHNF, of £3,727,856, brings the scheme up to 10% IRR. NPV remains low at £58,000.

This is a result of low revenue from heat sales, due to the relatively small total annual demand and size of the network required (see the network routing options section) to deliver heat to Sutton Harbour in an individual solution.

Sensitivity testing in the following sections show the impact of increased heat sales price on NPV for Scenario 3b.

Unfunded Results

- IRR @ 40 years: N/A
- NPV @ 3.5% over 40 years: -£3,670,000

Grant Funded Results (10% IRR @ 40 years)

- NPV @ 40 years: £58,000
- £3,727,856 upfront grant funding

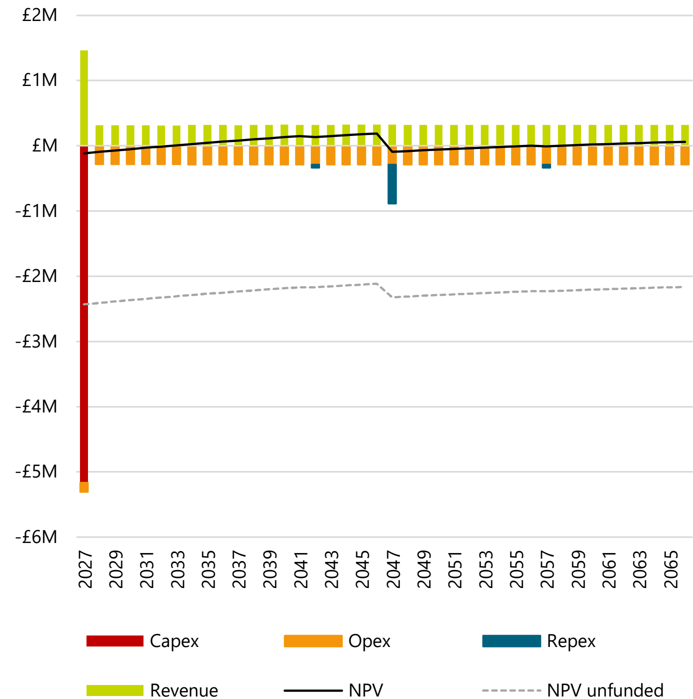

Figure 46: Sutton Harbour Scenario 3b – Open loop GSHP 4G network with heat recovery cash flow

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Techno-Economic Modelling

Connection charges

For scenarios 1 and 2, connection charges from previous AZP work have been used for each connection.

For scenarios 3a and 3b, connection charge for each connection is calculated by the avoided cost of plant and equipment to the developer or existing property owner by connecting to the heat network.

For scenario 3a and 3b, this equates to the capital cost of the low-carbon technology, that the developer or existing property owner is expected to put in place if connection to the heat network was not available. A 10% discount is applied to make the solution more economically attractive to connections.

For UoP Marine Station and PCH Commercial Place electric boilers in place of current gas boilers are assumed (there is little space for a heat pump at UoP Marine Station). For the NMA, in line with current plant renewal programme, ASHPs are used for avoided cost of plant.

The connection charges are paid to the Sutton Harbour DHN operator at the start of network operation, resulting in higher revenues early on in the network scheme.

For existing properties with gas boilers, it has been assumed that no secondary side retrofitting will be required. However, this requires further investigation.

The connection charge is calculated by the below:

Avoided cost of ASHP in new buildings + Avoided gas boiler replacement cost in existing buildings + Cost of additional ancillary plant requirements × 10% discount = Avoided cost / connection charge

Table 14: Connection charges for all scenarios

Connection Charges	Scenario 1 + 2 AZP	Scenario 3a + 3b GSHP Scheme
NMA	£903,200	£1,219,320
PCH Commercial Place	£460,080	£340,800
UoP Marine Station	£52,800	£71,280

Techno-Economic Modelling

Heat sales price calculation

For AZP scenarios 1 and 2, heat and cooling sales prices are taken from AZP modelling, initially modelled using the counterfactual cost of heat and then refined through financial modelling with a cost consultant. To allow for effective comparison the same heat sales pricing has been used for Scenarios 3a and 3b. See Table 15.

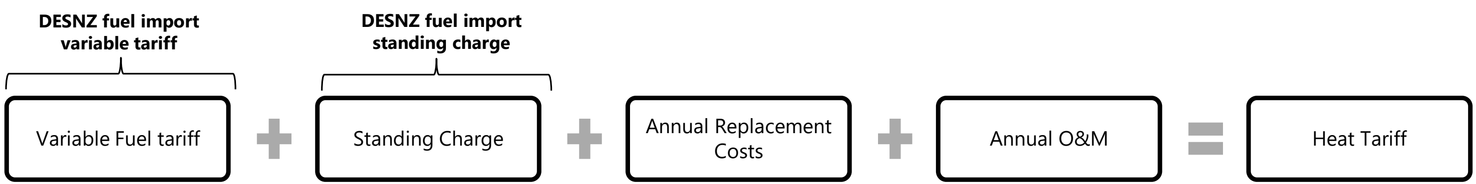
The counterfactual heating and cooling scenarios was used as the basis for establishing heat sales price and standing charges for AZP modelling. The counterfactual scenario represents the alternative heating solution for customers if the proposed scenarios were not instated.

The counterfactual scenario is modelled as gas boilers for PCH Commercial Place and UoP Marine Station, and the NMA as ASHPs for heating and cooling charges.

The below presents a breakdown of the initial calculation process.

Table 15: Heat sales price rates

Heat sale price item	Applied to	Rate
Existing Buildings – Heat (variable)	The NMA and UoP Marine Station	12.92 p/kWh
Social Housing – Heat (variable)	PCH Commercial Place	11.1 p/kWh
Cooling (variable)	The NMA	11.6 p/kWh
Standing charge - Heat	All Sutton Harbour connections	53.5 £/kW
Standing charge - Cooling	The NMA	20 £/kW



Sensitivity Analysis

Scenario 1 – 5G AZP connection

The impact of changing NPV at 40 years is shown in the following figures including changes to key financial inputs.

- **Connection charge** – The upfront cost paid to the ESCo for connection to the network.
- **Standing charge** – The £/kW charge paid by each connection to the ESCo per year. **Cooling variable price** – The p/KWh price of cooling paid by the building owner to the ESCo.
- **Heat variable price-** The p/KWh price of cooling paid by the building owner to the ESCo.
- **Capital cost** – The cost of capital infrastructure to deliver the network

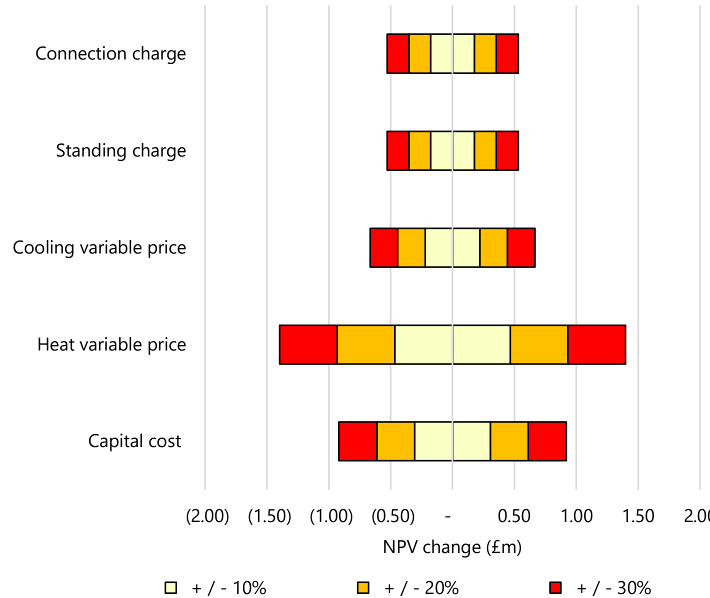


Figure 47: Sutton Harbour Scenario 1 - AZP 5G Connection Sensitivity Testing

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Sensitivity Testing

Scenario 2 – 4G AZP connection

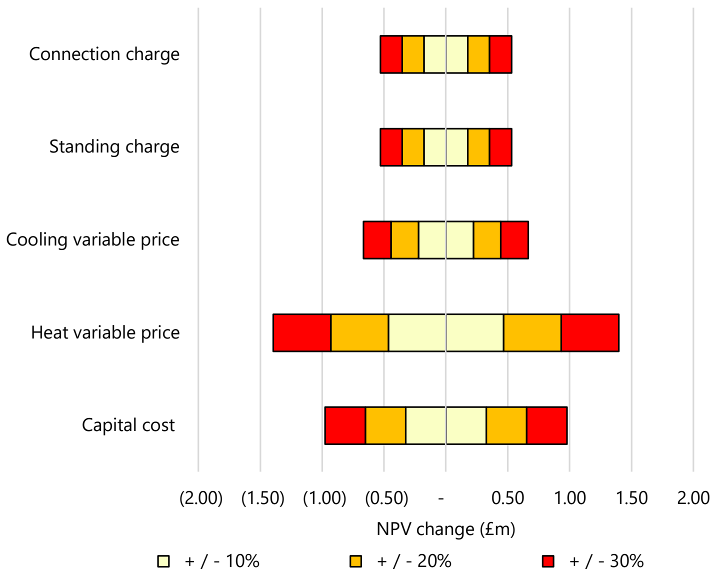


Figure 48: Sutton Harbour Scenario 2- AZP 4G Connection Sensitivity Testing

Sensitivity Testing

Scenario 3a and 3b – Individual network solutions

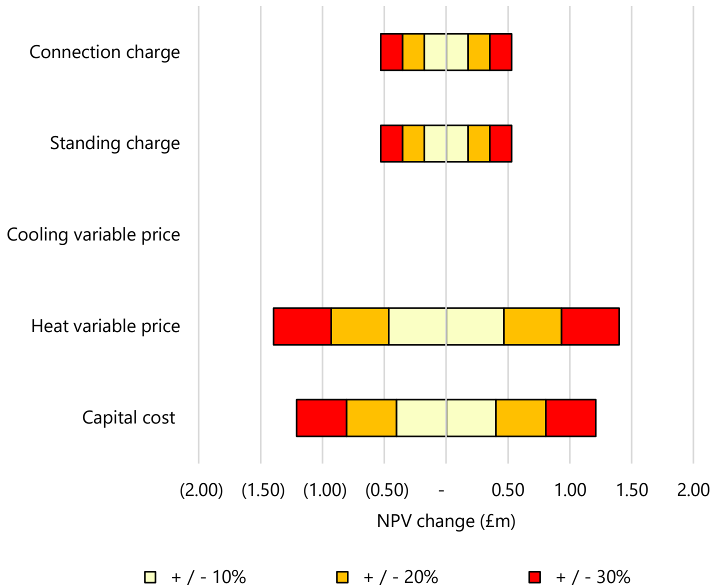


Figure 49: Sutton Harbour Scenario 3a- Standalone connection sensitivity testing

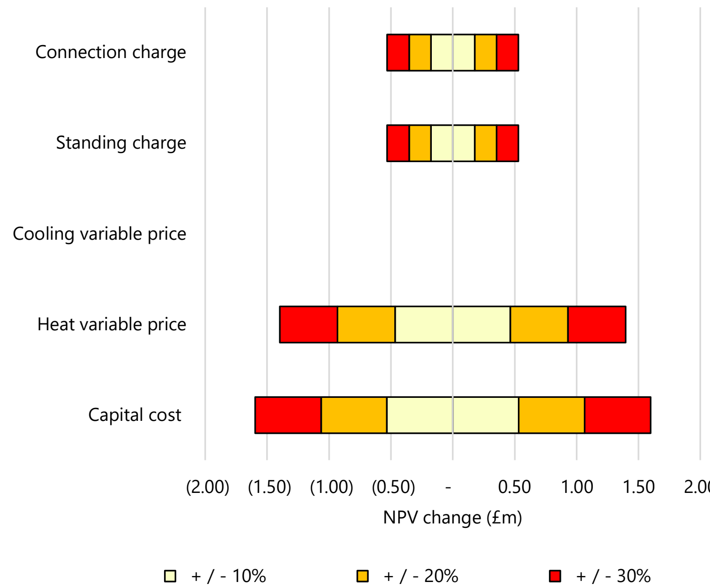


Figure 50: Sutton Harbour Scenario 3b- Standalone connection with heat recovery at the NMA sensitivity testing

9

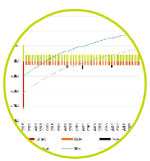
SUMMARY AND NEXT STEPS

Summary and Key Next Steps

Sutton Harbour cluster sits on the main branch into the city centre from SWW Prince Rock heat extraction site. The cluster is a pinch point on the AZP network, with potential to supply revenue and reduce operating cost per connection in phase 1 of the AZP network through heat and cooling sales to the network energy service company (ESCo). An opportunity to supply heat to the cluster either by local energy centres or directly to buildings through a AZP 4G/5G network that could provide heat and cooling was identified.

Various heat sources across the Sutton Harbour area were investigated and prioritized based on risk. Connection to the AZP network was deemed to be the lowest risk for connections. Potential for an open loop ground source system was assessed and established possibility to yield adequate heat to meet demand, this could be pursued by PCC as an additional low-carbon heat source feeding into the Sutton Harbour cluster or AZP ambient loop network.

An NMA interface plantroom is required for installation for heat plant, as there is insufficient space within the building. This could be installed on Fish Market land, with land agreements potentially easier to facilitate with the same landowner for both buildings. An interface energy centre located on PCC owned land would allow for heat upgrade from the AZP ambient loop network, to meet the operating temperatures required by PCH Commercial Place and UoP Marine Station. This would also reduce land take at PCH Commercial Place (only a heat substation installed) and in the UoP Marine Station main plantroom (insufficient space for a WSHP).



TEM results show a **4G connection to the AZP network for PCH Commercial Place and UoP Marine Station, along with 5G connection of the NMA (providing heating and cooling sales) as the best economic solution** of the scenarios evaluated. A greater heat load on the network could increase viability of an open loop borehole scheme, by providing a greater revenue to operational cost ratio.

Table 16: Sutton Harbour Techno-economic modelling summary

Techno-economic Metric	Unit	AZP 4G connection
Total CAPEX – not including inflation	£m	3.08
Total Connection Charge (£m)	£m	1.42
Unfunded IRR @ 40 years (%)	%	N/A
Unfunded NPV @ 40 years (£m)	£m	0.83
Average annual operating costs (£m)	£m	0.093
Funding gap for 10% IRR	£m	1.12
Funding gap for 10% IRR as % of CAPEX	%	36

Key considerations and proposed next steps

The AZP ambient loop network is the recommended primary heat source for the Sutton Harbour cluster. Should PCC wish to pursue this solution the following next steps should be taken:

- **Continue discussion with AZP key connections** on requirements for connection to the network, system arrangements, network routing to the area, and the progress of the design of the AZP network
- **Communicate timelines for AZP connection** to all stakeholders and how this could facilitate decarbonisation of heating and cooling
- **Undertake a DPD of the proposed scheme** to technically de-risk the opportunity and develop a more detailed techno-economic model
- **Establish the proposed commercial arrangement** for different connections/costumer types
- **Undertake further stakeholder engagement with NMA** to confirm preferred technical connection arrangement, confirm modelled heat and cooling demands, and operating temperatures
- **Establish land use agreements with** NMA/Fish Market landowner for installation of NMA AZP interface plantroom
- **PCC confirm land PCC owned green open areas land use** for installation of an AZP interface plantroom (shared between PCH Commercial Place and UoP Marine Station)

APPENDIX A – GROUND HEAT SOURCES STUDY AND CONNECTIONS

Open Loop Ground Source Feasibility Study

Please refer to the open loop ground source feasibility study for the Sutton Harbour, developed by Worley Consulting.
This has been issued in parallel with this report as supporting information.

Other Additional Connections

Potential additional connections in close proximity to Sutton Harbour have been identified and are shown in Figure A1.

These connections are identified based on size and greater likelihood of singular ownership.

In the next stage further stakeholder engagement could be carried out as part to establish potential connection and estimated loads.

Figure A1: Core and additional connection options for the Sutton Harbour area

Table 17: Additional connection summary

Additional Connection List
Royal Western Yacht Club
Rockfish Restaurant
Lockyer's Quay
Premier Inn Buildings
Barbican Leisure

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APPENDIX B – SCENARIOS INDICATIVE LAYOUTS & LOCATIONS

Scenario 1 & 2 – AZP 5G connection NMA interface plantroom

The proposed NMA interface plant room layout and location is presented in Figure B1 and Figure B2, respectively. Energy modelling and equipment sizing was carried out, allowing for an indicative layout and space take of the plant room to be developed. The following assumptions were made:

- Power supply is to be provided by the dedicated electrical substation installed at the NMA
- Land usage is to be agreed with the owner to confirm the location of the interface plant room

Figure B1: Proposed NMA interface plant room location based on indicative layout

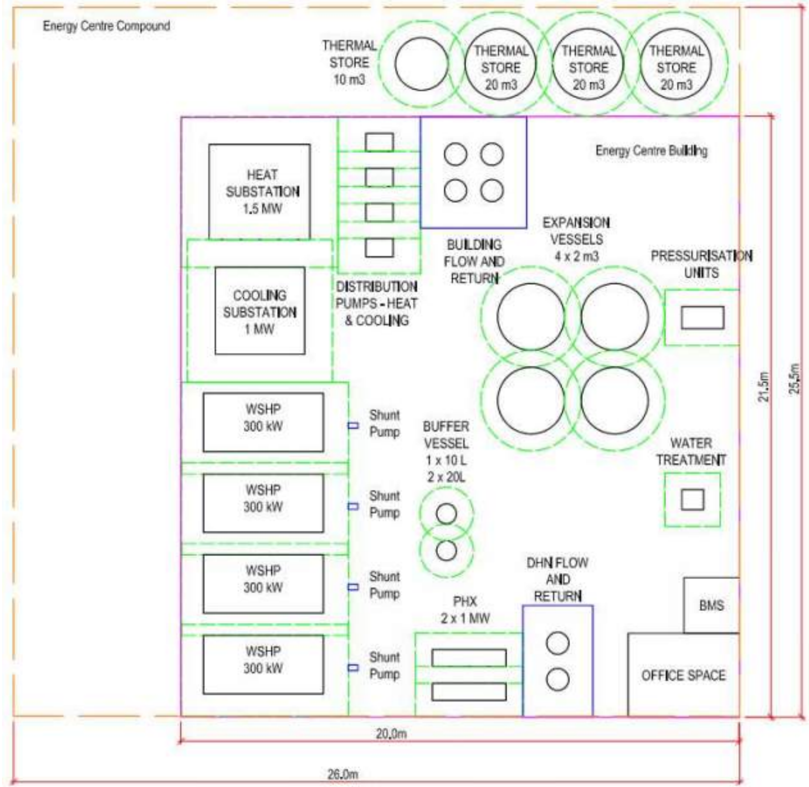

Figure B2: Proposed NMA interface plant room layout

Scenario 1 – AZP 5G connection
PCH Commercial Place interface plantroom

The proposed PCH Commercial Place interface plant room layout and location is presented in Figure B3 and Figure B4, respectively. Energy modelling and equipment sizing was carried out, allowing for an indicative layout and space take of the plant room to be developed.

Power supply is to be provided via the local electrical substation (TBC location). A dedicated transformer room is to be installed near the interface plantroom, the sizing and location are to be confirmed at the next stage.

Figure B3: Proposed PCH Commercial Place interface plant room location based on indicative layout

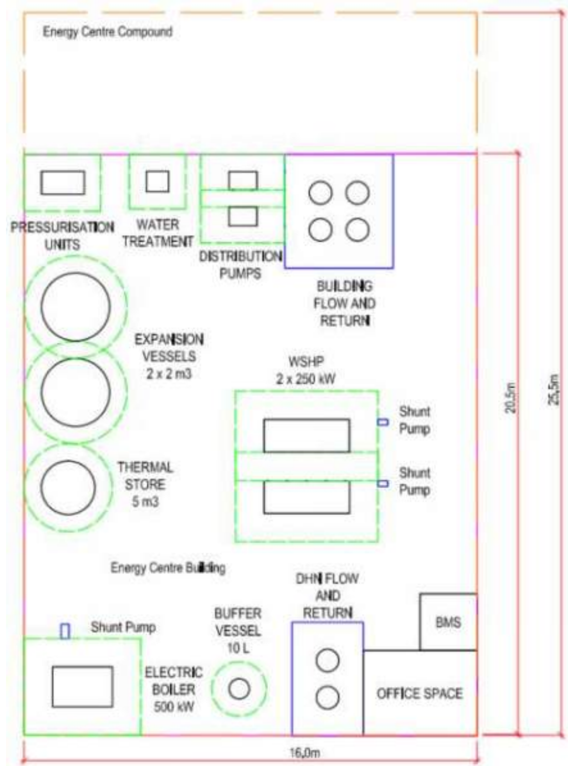

Figure B4: Proposed PCH Commercial Place interface plant room layout

Scenario 1 – AZP 5G connection UoP Marine Station main plantroom

The proposed location the UoP Marine Station main plant room is presented in Figure B5, a mark-up of the proposed WSHP installation footprint is presented in Figure B6. Energy modelling and equipment sizing was carried out, allowing for space take in the plant room to be confirmed. The mark-up shows the space take of the WSHP to be greater than available space in the plant room. In addition the maintenance access area (~1m around) is not included.

Power supply is to be provided via the electrical connection to the building, confirmation is required in the next stage of any upgrade works and increases to connection agreements required.

Figure B5: Proposed UoP Marine Station main plant room location

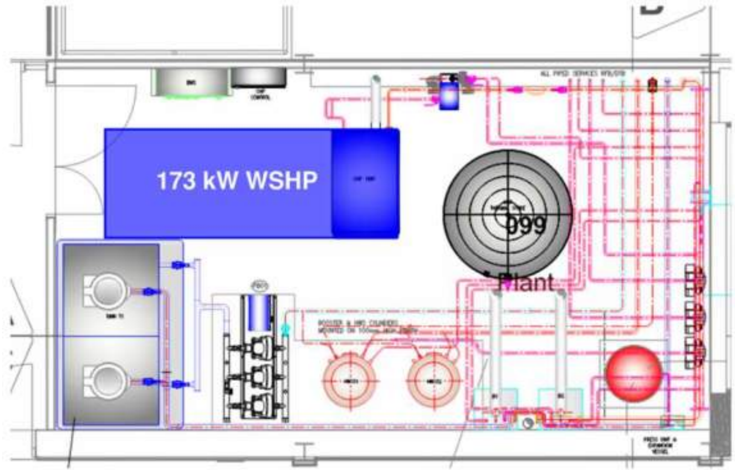

Figure B6: Proposed UoP Marine Station WSHP (blue) installation in main plant room

Scenario 2 – AZP 4G connection
PCH Commercial Place & UoP Marine Station interface plantroom

The proposed PCH Commercial Place & UoP Marine Station interface plant room layout and location is presented in Figure B7 and Figure B8, respectively. The heat substation for PCH Commercial Place substation (2 x 260kW) are presented alongside. Energy modelling and equipment sizing was carried out, allowing for an indicative layout and space take of the plant room to be developed.

Power supply is to be provided via the local electrical substation (TBC location). A dedicated transformer room is to be installed near the interface plantroom, the sizing and location are to be confirmed at the next stage.

Figure B7: Proposed PCH Commercial Place & UoP Marine Station interface plant room location based on indicative layout. Shown PCH Commercial Place heat substation (pink)

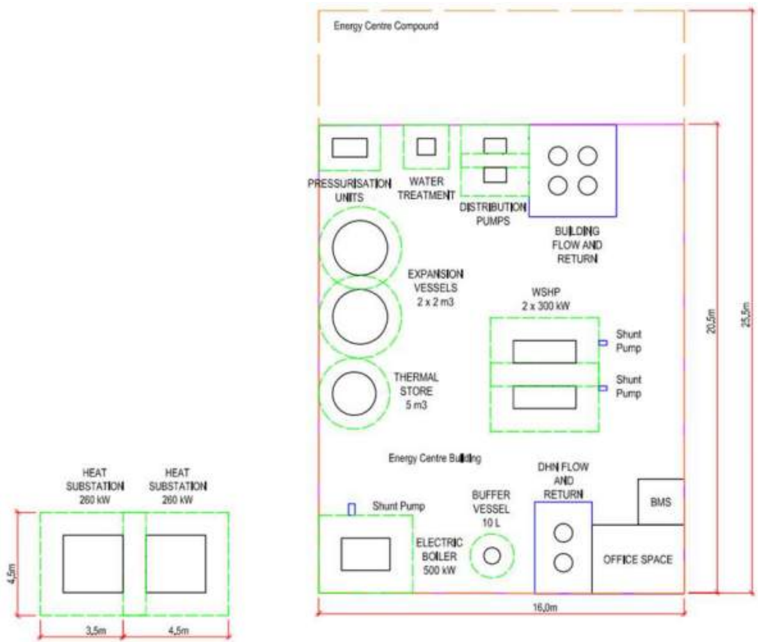

Figure B8: Proposed PCH Commercial Place & UoP Marine Station interface plant room layout

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Scenario 2 – AZP 4G connection
UoP Marine Station main plantroom

The proposed location the UoP Marine Station main plant room is presented in Figure B9, a mark-up of the proposed HIU (70 kW) installation footprint is presented in Figure B10. This shows the space take to be minimal in comparison to the existing CHP and near the building heating system connection point.

Figure B9: Proposed UoP Marine Station main plant room location

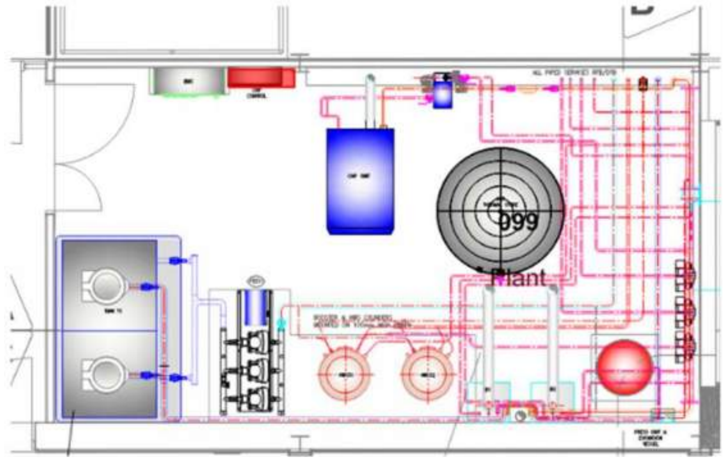

Figure B10: Proposed UoP Marine Station HIU (red) installation in main plant room

Scenario 3a - Open Loop Ground Source 4G network main plantroom

The proposed open loop ground source 4G network main plant room layout and location is presented in Figure B11 and Figure B12, respectively. The heat substations for the NMA (1.5 MW) and the PCH Commercial Place substation (2 x 260kW) are presented alongside. Energy modelling and equipment sizing was carried out, allowing for an indicative layout and space take of the plant room to be developed.

Power supply is to be provided via the local electrical substation (TBC location). A dedicated transformer room is to be installed near the interface plantroom, the sizing and location are to be confirmed at the next stage.

Figure B11: Proposed open loop ground source 4G network main plant room location based on indicative layout

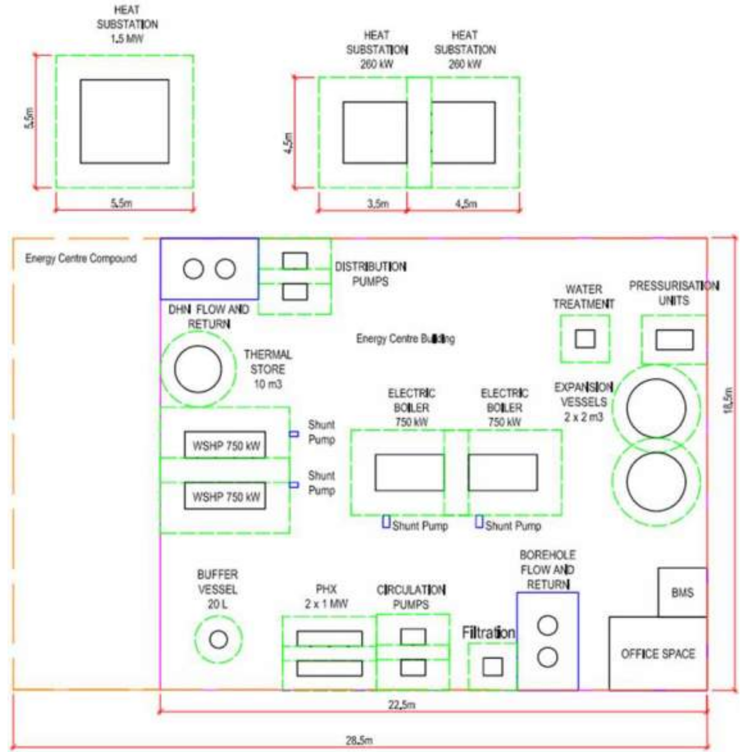

Figure B12: Proposed open loop ground source 4G network main plant room layout

Scenario 3b - Open Loop Ground Source 4G network NMA interface plantroom

The proposed NMA interface plant room layout and location is presented in Figure B13 and Figure B14, respectively. Energy modelling and equipment sizing was carried out, allowing for an indicative layout and space take of the plant room to be developed. The following assumptions were made:

- Power supply is to be provided by the dedicated electrical substation installed at the NMA
- Land usage is to be agreed with the owner to confirm the location of the interface plant room

Figure B13: Proposed open loop ground source 4G network NMA interface plant room location based on indicative layout

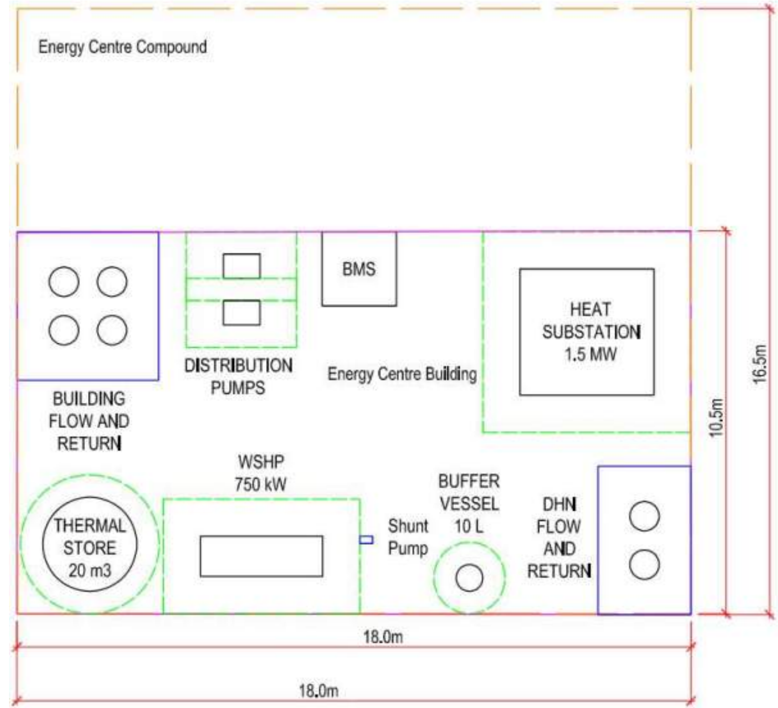

Figure B14: Proposed open loop ground source 4G network NMA interface plant room layout

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APPENDIX C – TEM SCENARIO REVENUE MODELS

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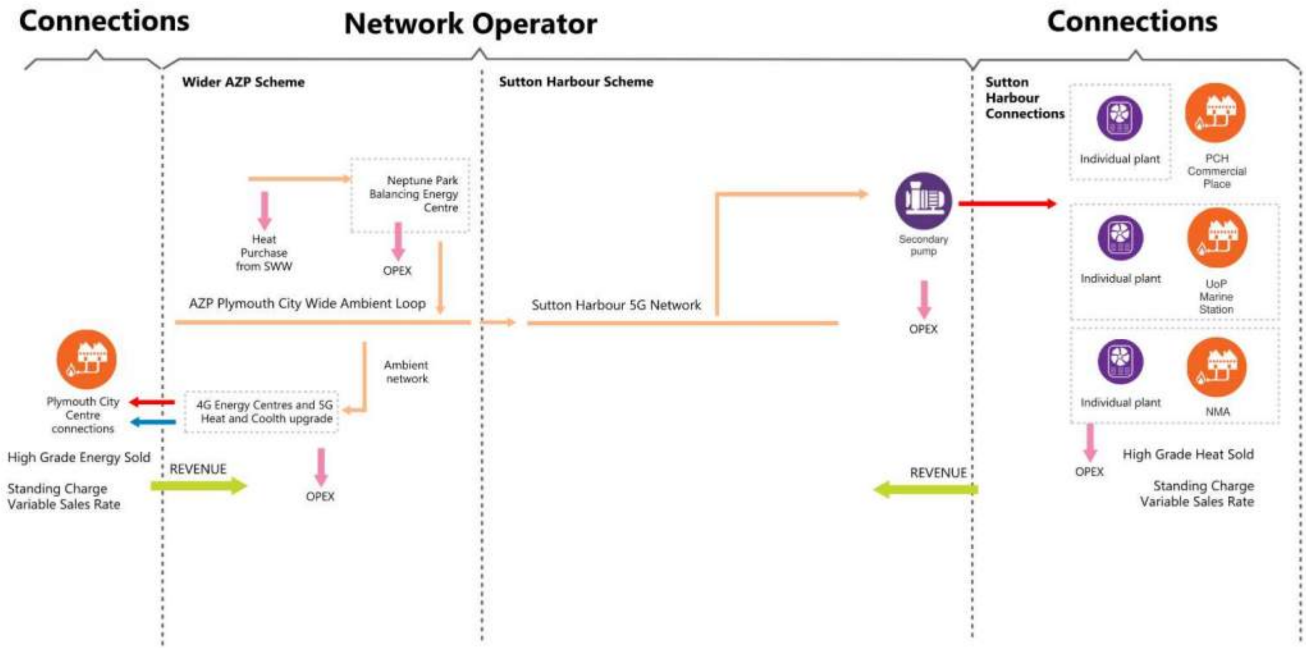
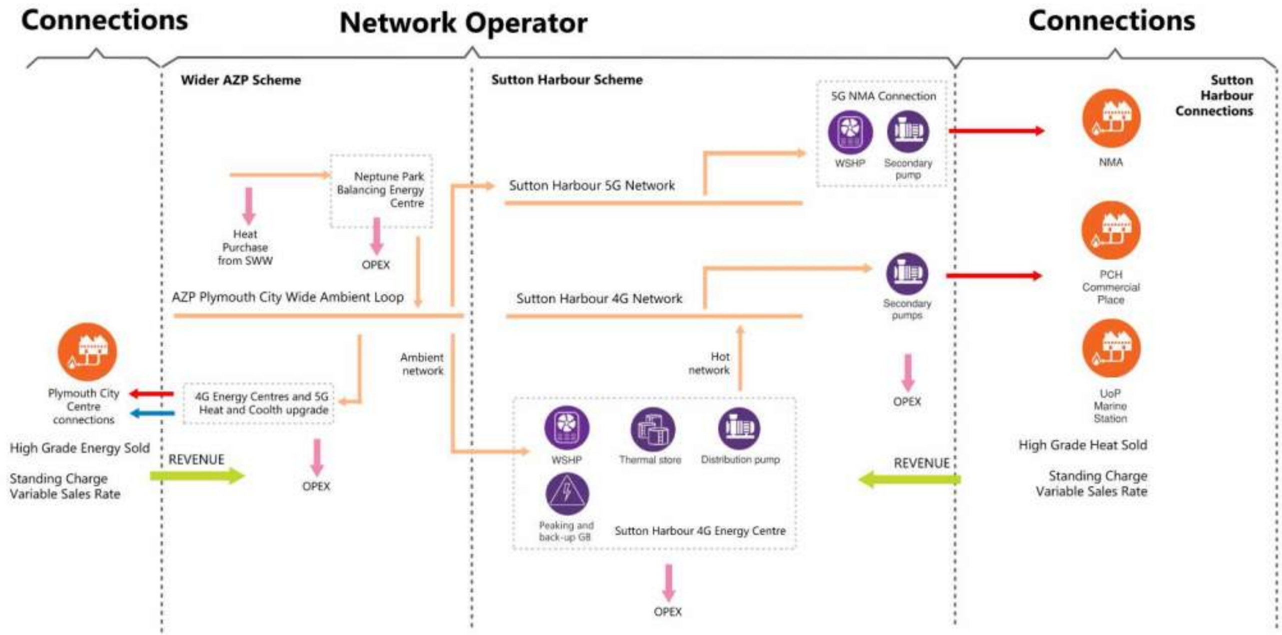
Cost and revenue model

Scenario 1 – AZP connection 5G network



Cost and revenue model

Scenario 2 – AZP connection 4G network



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Cost and revenue model
Scenario 3 – GSHP 4G network