BURO HAPPOLD

Local Energy Accelerator

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Glossary

Term	Definition
ASHP	Air Source Heat Pump
NHM	National heat map
EC	Energy centre
SSSi	Sites of special specific interest
SPA	Sites of protected areas
SAC	Sites of areas of conservation
Ramsar	Wetlands of international importance
WSHP	Water Source Heat Pump
RSHP	River Source Heat Pump
GLA	Greater London Authority
COP	Coefficient of Performance
CoL	City of London
PHA	London Port Health Authority
MHWS	Mean High Water Springs
LA	Local Authority
PLA	Port of London Authority
ERF	Energy Recovery Facility
EA	Environment Agency
MMO	Marine Management Organisation
DEFRA	Department for Environment, Food and Rural Affairs

1 Combined Cover Note

Two strategic studies have been completed by Buro Happold on behalf of the Greater London Authority (GLA) to assess the utilisation of heat source opportunities across London. These were:

- Waste Heat Study
- River Thames Study

The Waste Heat Study takes London's largest known recoverable waste heat sources and examines how they could catalyse the development of strategic multi-borough heat networks that can support the decarbonisation of heat supply in London. The study identified significant waste heat sources including but not exclusive to Energy from Waste (EfW) facilities, Waste Water Treatment Works (WWTW), industrial processes, and data centres. These sources and their relative waste heat potential, along with heat demands, were used to develop seven strategic areas:

- NLWA
- Beddington
- Royal Dock
- Mogden & Twickenham
- Hayes & West Drayton
- Crossness & South Bermondsey
- OPDC

Within these areas, heat source availability and heat demands (taken from the London Heat Map) have been used alongside constraints and existing heat networks to model potentially viable strategic heat networks. These networks are indicative and are intended to illustrate the opportunity that London's waste heat resource provides and give an indication of what heat networks using those waste heat sources could look like. The study found that the seven waste heat clusters and subsequent networks could:

- Cover 25 Boroughs
- Utilise over 10,000 GWh/yr of Rejected Waste Heat to meet up to 3700 GWh/yr of heat demands
- Save ~40 million tCO_2e over the next 40 years.

The River Thames Study assesses the opportunities around utilising heat from the River Thames to decarbonise both heating and cooling in areas close to its banks. The study identified that around 444MW of heat could be utilised from the river via Water Source Heat Pumps (WSHP), equating to 600MW once electrical input to these heat pumps has been accounted for. This would be capable of supplying circa 5% of London's annual heat demand. The study assessed the challenges and implications of abstracting heat from the river, and the steps needed to create a standardised process for assessing this heat.

Given that the river has a limited capacity as a heat source, it is suggested that heat networks in London that have access to alternative strategic waste heat sources should, where practical, prioritise these, although it is recognised that there are also various technical and commercial challenges to securing heat from these sources. From a strategic London context this would allow areas that have high heat loads but a lack of alternative waste heat sources, to maximise the available river capacity for heat networks in central locations. Those particular clusters of interest identified to benefit from the River Thames were located in:

- Wandsworth
- Richmond
- Lambeth
- Westminster
- Hammersmith and Fulham
- Kensington and Chelsea
- City of London
- Southwark

In total, both studies collectively identified a potential of ~ 5,230 GWh/yr of usable heat across London, of which 3,700 GWh/yr is from waste heat sources, and 1,530 GWh/yr is from the River Thames.

Figure 1-1 shows both the main outputs of the two studies. This graphic demonstrates a widespread heat network opportunity across London from these strategic heat sources.

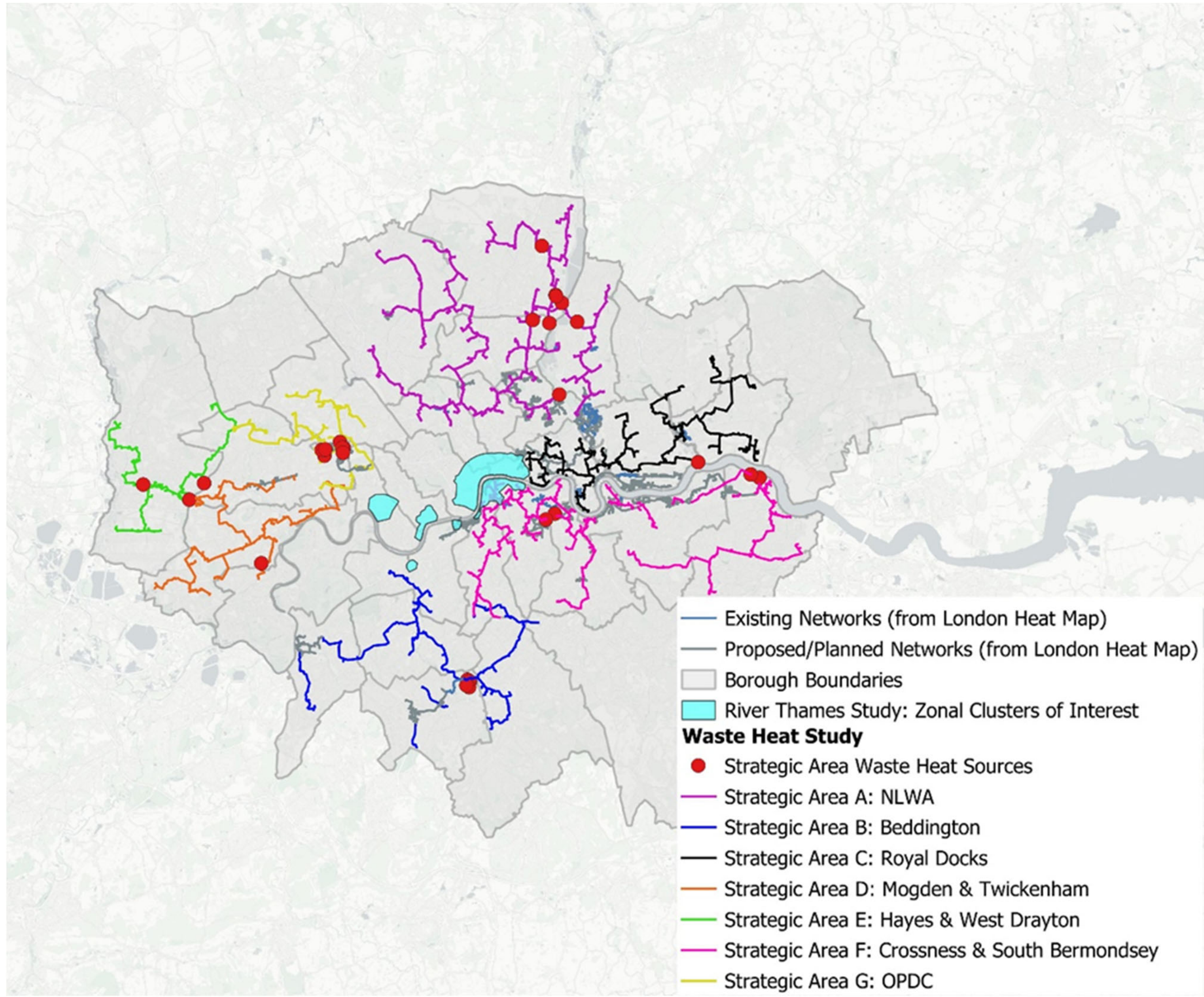


Figure 1-1 Waste heat and River Thames study key outputs

The individual reports outline recommended next steps to pursue these opportunities further - including further engagement and analysis within each strategic area.

2 Executive Summary

2.1 Introduction

This report complements the 'Waste Heat Strategic Areas' report also undertaken by Buro Happold as part of the strategic work undertaken for the GLA within the Local Energy Accelerator Programme. This report undertakes an initial assessment of the potential energy capacity of the River Thames, from Teddington Lock in the west to Dartford Creek in the east. It also looks at the licensing processes and permissions required for developing open-loop schemes. These two elements have been undertaken as a first step towards developing a coordinated and coherent strategy for utilising the River Thames as a low carbon heat source for supplying strategic multi-borough heat networks in London aimed at helping decarbonise heat supply in pursuit of London's Net Zero 2030 target. This study will also feed into the sub-regional Local Area Energy Plans (LAEP) that the GLA are undertaking in partnership with London Councils and London Boroughs. It will create additional intelligence and greater evidence for developing multi-borough heat networks across London.

This report has been produced to support the partnership working across London Government that is happening to identify and develop heat network opportunities as part of London's shared action to tackle the climate emergency. Some sections have been compiled into this report to support heat network developers and regulatory bodies work together to allow heat to be abstracted from the river to support heat network development whilst conforming with regulatory requirements.

2.2 Overview

As part of London's response to tackling the climate crisis the Mayor has set a 2030 Net Zero target and low carbon thermal energy networks have an important part to play in helping London to decarbonise heat supply and meet that target. Therefore, utilising waste and environmental heat sources to support the supply of affordable low-carbon networks is a priority for London.

The River Thames is a major feature of London and a potentially a considerable energy asset as well. Whilst it is a significant heat resource it is only capable of providing a fraction of London's overall heat demand and therefore, it is important that this heat resource is considered as a strategic resource within the context of London's other waste and environmental heat sources so that it can be used as part of a wider strategic approach to establishing a number of strategic multi-borough heat networks that optimise the use of low carbon heat sources across London.

Currently, the approach to utilising the River Thames as a low carbon heat source for decarbonising heating or cooling systems for buildings is carried out on an ad hoc individual project per project basis. There is the potential and need for a more strategic approach to using the river to supply heating and cooling to buildings and heat networks and that is why it is also informing the develook epment of the sub-regional LAEPs. This report has been developed both from a London Borough perspective and a regulatory perspective. This report aims to:

- Bring together previous works on quantifying the potential energy capacity of the River Thames
- Summarise the licensing processes of all regulatory bodies who have a role in open-loop water abstraction
- Identify and map existing and developing schemes, along with potential energy centre locations
- Provide an assessment of the overall opportunity that the River Thames offers for development of heat networks in London that can feed into the sub-regional LAEP process and suggest what next steps could be taken if London Boroughs along the river wanted to develop the opportunity further.

The objectives set at the outset of this study and the key findings / next steps are presented in Table 2-1.

2.3 Key Report Outputs

Table 2-1 - Study findings and next steps

No.	Objective Description	Key Findings	Next steps
1	Bring together previous works relating to water abstraction form the River Thames to provide an overall picture of the opportunity and identify existing or planned thermal energy networks that could utilise energy from the River Thames.	The River Thames has been previously evaluated to have 444MW of heat available (according to the National Heat Map) and by extrapolation the same can be assumed for the cooling capacity. Once the inclusion of the electrical input of a heat pump is included to elevate the heat, the river has over 600MW of heat potential. This amount of heat, if realised, is capable of supplying around 5% of London's overall heat demand. A total of 2 existing and over 10 potential river source schemes, at a range of scales, were identified adjacent to the Thames, with the majority being in Central London. The combined capacity of these schemes could consume up to 30% of the river's total heat capacity.	Carry out a dynamic model of the River Thames, to test the potential interferences of schemes with each other (for example whether a large scheme in Hammersmith and Fulham would have a downstream impact on a scheme in Westminster or Battersea) as well as possible schemes in tributaries of the main river. Integrating this into the sub-regional LAEP work will allow the GLA and London Boroughs to consider the river in the context of the wider strategic opportunity for London rather than in the context of their own sites or local needs. This may allow for the opportunity to look at fewer, but larger, projects along the river which support the development of strategic multi-borough heat networks.
2	Outline the implications of river abstraction and challenges of installing discharge infrastructure within the river.	Key constraints have been identified as follows: • Port of London Authority (PLA) permissions: Presence of abstraction and discharge infrastructure within marine traffic channels is not permitted by the PLA. Therefore, existing pier infrastructure should be utilised wherever possible. • Environment Agency (EA) consents: this relates to the threshold temperature deltas between abstraction and discharge which are typically 5 to 8ºC to avoid ecological impacts. These will limit abstraction flowrates from the Thames and could vary across the year. • Tidal range: the tidal range is considerable in the River Thames and the implications of this will need to be considered when assessing sites and locating abstraction plant. • Access for maintenance: maintenance and cleaning requirements including backwash cycles for filter screen cleaning, which will be required to avoid impact on system operation. • Siting of infrastructure: separation between abstraction (upstream) and discharge (downstream) infrastructure, which typically requires at least 100m to avoid thermal short circuiting. • Marine Management Organisation (MMO) consent and planning permission is also required.	Undertake further detailed analysis of potential in and on-river plant and equipment locations along the river. This could focus on the key strategic clusters that are identified as part of this report. The utilisation of existing in and on-river infrastructure that can host plant for a river source heat pump should be prioritised.

No.	Objective Description	Key Findings	Next steps
3	Assess the high level economic and carbon benefits of a typical or a range of representative large-scale WSHP-led heat networks compared to a counterfactual ASHP-led heat network.	A range of different scale scenarios were modelled to compare the spatial and cost impacts of a river source Water Source Heat Pump (WSHP) heat network project compared to an Air Source Heat Pump (ASHP) thermal network project. The modelling suggests that a WSHP scheme is expected to have a significantly greater capital cost but a lower running cost due to the higher efficiency of the heat pump plant – which also means higher carbon savings. The analysis shows that overall lifetime costs converge with ASHP-led schemes over a 40-year lifetime. The key benefit of a WSHP is that they are more deliverable at larger scale and have a significantly reduced spatial footprint compared to an equivalent ASHP scheme. This is particularly important in the urban London context where land opportunities for locating energy centres and rooftop spaces at sufficient scale are both likely to be limited. The benefits of WSHPs are particularly seen at larger scale. For ASHP schemes at scales over 5MW, projects are likely to be particularly challenging in a single location due to constraints posed by cold air dissipation and rooftop space. This makes large scale WSHP schemes more favourable and likely to be better able to support strategic multi-borough heat networks – there are operational examples of projects in Europe with heat networks with 20MW WSHPs as their primary heat source.	A high-level analysis has been conducted for this stage of the work. There are many variables that will impact on the costs. More detailed analysis could be carried out for one or two specific project(s) in London that are already exploring the river as a potential heat source to verify the report's findings. This next piece of work should include a more detailed cost and carbon comparison exercise for the projects being further developed, which should include a reference design and supply chain engagement.
4	Assess potential locations for WSHP Energy Centres (ECs) along the banks of the Thames and, if interest shown from London Boroughs, to suggest these areas are prioritised for further study after completion of this commission.	London has a number of potential waste heat supplies such as data centres, wastewater treatment plants and Energy Recovery Facilities (ERF). The location of these waste heat sources tends to be outside central London locations. Given that the river has a limited capacity as a heat source, it is suggested that thermal networks in London that have access to alternative strategic waste heat sources should, where practical, prioritise these, although it is recognised that there are also various technical and commercial challenges to securing heat from these sources. From a strategic London context this would allow areas that have high heat loads but a lack of alternative waste heat sources, to maximise the available river capacity for heat networks in central locations. Potential strategic zones were identified for river source heat, based on access to alternative heat sources, in the following riparian boroughs: - Wandsworth - Richmond - Lambeth - Westminster - Hammersmith and Fulham - Kensington and Chelsea - City of London - Southwark	The GLA and London Boroughs should continue to engage with major waste heat sources outside of the strategic zones identified in this report to encourage their uptake as part of a wider strategic approach to using low carbon heat sources for multi-borough heat network development across London. This will support the development of multi-borough heat networks that use local low carbon heat sources and will maximise the use of river heat in heat networks that need it most.

No.	Objective Description	Key Findings	Next steps
5	Outline the steps that are required for creating a standardised process for assessing the heat supply capacity of the Thames in the future. This should, importantly, include how to acquire the necessary planning and licensing permissions from the relevant authorities and set out how this would operate if WSHP's were to be developed at scale.	There are several regulatory bodies from which a project would require consent in order to implement a scheme – including the EA, PLA, MMO, as well as the Local Authority within which the scheme is located. In most cases, an Environmental Impact Assessment will be required as part of the process and this will require a suite of additional documents, as outlined in the main report, to inform the application and satisfy the regulators.	Currently schemes approach the regulators on a project-by-project basis. There is an opportunity to adopt a more strategic approach that could reduce the burden on both projects and regulators, whilst optimising the use of the available river energy. Understanding how this could work within existing Permitting Regulations is essential as currently their regulatory role is focussed on schemes presented to them as statutory consultees. Convening the regulatory bodies on completion of this report is recommended to maintain an on-going partnership and to explore this as an opportunity.

3 Study Definition

3.1 Introduction

This report complements the 'Waste Heat Strategic Areas' report also undertaken by Buro Happold as part of the strategic work undertaken for the GLA within the Local Energy Accelerator Programme. This report undertakes an initial assessment of the potential energy capacity of the River Thames, from Teddington Lock in the west to Dartford Creek in the east. It also looks at the licensing processes and permissions required for developing open-loop schemes. These two elements have been undertaken as a first step towards developing a coordinated and coherent strategy for utilising the River Thames as a low carbon heat source for supplying strategic multi-borough heat networks in London aimed at helping decarbonise heat supply in pursuit of London's Net Zero 2030 target. This study will also feed into the sub-regional Local Area Energy Plans (LAEP) that the GLA are undertaking in partnership with London Councils and London Boroughs. It will create additional intelligence and greater evidence for developing multi-borough heat networks across London.

This report has been produced to support the partnership working across London Government that is happening to identify and develop heat network opportunities as part of London's shared action to tackle the climate emergency. Some sections have been compiled into this report to support heat network developers and regulatory bodies work together to allow heat to be abstracted from the river to support heat network development whilst conforming with regulatory requirements.

3.2 Objectives

The study's main objectives are:

1. Bring together previous works relating to water abstraction form the River Thames to provide an overall picture of the opportunity and identify existing or planned thermal networks that could utilise energy from the River Thames.
2. Outline the implications of river abstraction and challenges of installing discharge infrastructure within the river.
3. Assess the high level economic and carbon benefits of a typical or a range of representative large-scale WSHP-led networks compared to a counterfactual ASHP-led network.
4. Assess potential locations for WSHP Energy Centres (ECs) along the banks of the Thames and, if interest shown from London Boroughs, to suggest these areas are prioritised for further study after completion of this commission.
5. Outline the steps that are required for creating a standardised process for assessing the thermal supply capacity of the Thames in the future. This should, importantly, include how to acquire the necessary planning and licensing permissions from the relevant authorities. Set out how this would operate if WSHP's were to be developed at scale.

The study is split into different work packages, as pictured below:

Figure 3-1 Study content

3.3 Report Structure

The report is structured as follows:

- **Case studies** – examples of large-scale heat pumps in the UK and Europe
- **River Thames energy capacity** – the potential volume of thermal energy recoverable from the Thames
- **Environmental and regulatory assessment** – the regulatory bodies involved in licensing activity on the river and the processes to consider when applying for permissions for a River Source Heat Pump (RSHP) scheme on the River Thames
- **Key technical considerations** – an overview of technical approaches and opportunities for RSHP schemes
- **Strategic opportunity areas** – where in London are organisations already considering RSHP schemes and along which parts of the river would a scheme benefit a heat network most
- **Counterfactual analysis** – comparing the economic and spatial differences of a RSHP against an air-source scheme
- **Conclusions and next steps** – study summary and suggestions for further work.

3.4 Study Boundary

The study focuses on the tidal River Thames itself and excludes tributaries and the estuary downstream of Dartford Creek. The boundary on the West side is Teddington Lock and on the East side is the Dartford Creek, as shown by the red pins in Figure 3-2.

In a larger and more detailed study, the thermal mixing between flows in the tributaries and the main river should be accounted for to understand it's impact on extractable heat capacity from the river. There may be reduced environmental impact using other waterbodies however this area was focussed on due to the proximity to heat demand.

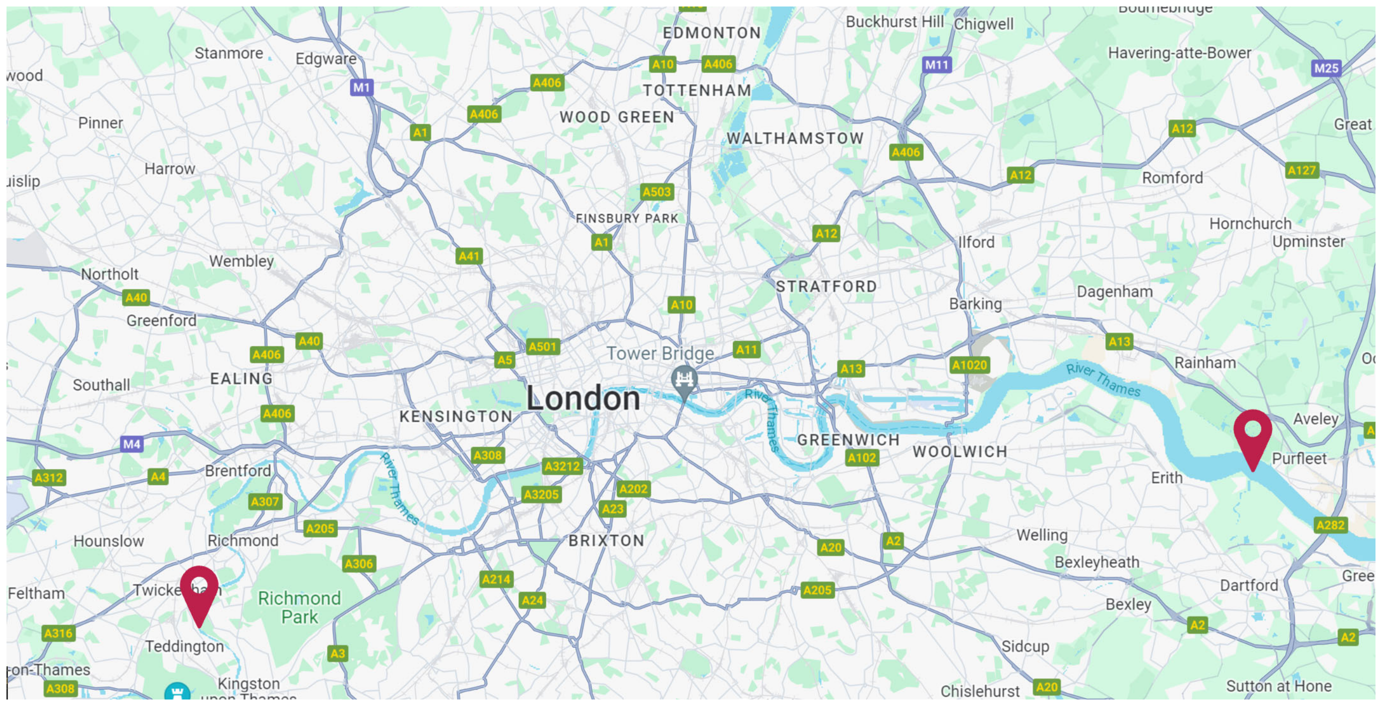


Figure 3-2 Teddington lock to Dartford creek river study boundary

3.5 Stakeholder Engagement

Stakeholders identified are:

- Riparian London Boroughs (LB) within the study boundary
- Regulatory bodies for water abstraction and infrastructure installation along the River Thames

3.5.1 Local Authority Engagement

There are 16 riparian London Boroughs on the River Thames within the study boundary, see Figure 3-3. All but Havering and Bexley have been contacted and requested further information on RSHP schemes in their boroughs. Bexley is unlikely to be a priority area for river source schemes due to large waste heat sources in its borough: an Energy Recovery Facility (ERF) at Cory Riverside and a Waste Water Treatment Plant (WWTP). Havering has not been investigated currently due to its relatively low heat density.

Table 3-1 sets out the stakeholders engaged and in what format. The information requested from the London Boroughs contacted included:

- Scheme name:
  - Relating to any RSHP studies within the Local Authority area that are in any process stage. Aimed to distinguish any RSHP schemes, blockers/opportunities within schemes, and identification of possible energy centre locations in adjacent land to the nearby river
- Total heating &/or cooling capacity of the scheme
- Project stage (ie: pre-feasibility, Outline Business Case, In operation etc.)
- Study Reports that are available

Figure 3-3 Riparian London Boroughs contacted

3.5.2 Regulatory Bodies

In respect to the regulatory bodies, the information gathered included:

- Boundary of their regulatory powers
- Understanding what licensing & documentation a water abstraction scheme would be required to provide
- The overall licensing process

Their vision for the challenges and opportunities of increasing the use of the River Thames as a thermal energy source for supplying multi-borough energy networks and helping to decarbonise thermal energy supply in London Boroughs

Table 3-1 Stakeholder engagement summary

Stakeholder	Stakeholder type	Engagement type	Response Received?	Data received	Key Outstanding Data
City of London	Local Authority	Meeting	Yes	Cross-borough energy masterplan received identifying various potential schemes	
Battersea / EQUANS	Project	Emails	Yes	Initial email	Technical details on the scheme
London Bridge & Southwark Council	Local Authority	Emails	Yes	Pre-feasibility study shared including technical and commercial details	Heat capacity per identified potential energy centre
Westminster	Local Authority	Emails	Yes	Feasibility study obtained for one scheme	Possible scheme at Millbank
Richmond & Wandsworth	Local Authority	Emails	Yes	Not identified relevant schemes besides EQUANs	
Tower Hamlets	Local Authority	Emails	Yes	Locations of opportunity areas to incorporate energy centre	
Newham	Local Authority	Emails	Yes	No identified relevant schemes. Previous feasibility work identified prioritised a nearby waste heat source	
Barking & Dagenham	Local Authority	Emails	Yes	No identified relevant schemes besides an existing abstraction site	
Greenwich	Local Authority	Emails	No	N/A	
Southwark	Local Authority	Emails	Yes	No other identified relevant schemes besides Team London Bridge Feasibility DHN study	N/A
Lambeth	Local Authority	Emails	Yes	No identified relevant schemes	
Southbank Employers Group	Project	Meeting	Yes	Existing abstraction from Shell Centre identified used for cooling	Technical details on the scheme
Kensington and Chelsea	Local Authority	Emails	Yes	Energy masterplan preferred locations for a WSHP	
Hammersmith and Fulham	Local Authority	Emails	Yes	Energy masterplan preferred locations for a WSHP	
Hounslow	Project	Emails	Yes	River Thames discounted in previous study due to technical difficulties in changing water levels	N/A
EA	Regulatory	Meeting	Yes	Abstraction heat and cooling licences	
PHA	Regulatory	Meeting	Yes	Discussion on regulatory requirements	“London Port of Health Order” boundary map
PLA	Regulatory	Meeting	Yes	Discussion on regulatory requirements. Quote for data also received	Technical data e.g. Navigational channels, Restricted zones, tidal height charts
Marine Management Organisation	Regulatory	Meeting	Yes	Discussion on regulatory requirements	

4 River Thames Energy Capacity

This section summarises the findings of the literature review of studies looking at quantifying the heat capacity of the River Thames.

4.1 Previous Works on the River Thames Capacity

Table 4-1 presents the three main documents which have been reviewed as part of this study. The National Heat Map document contained the most detailed analysis of the River Thames heat capacity, and therefore the remainder of this section focuses on extracting the Thames specific information from the document and validating the methodology.

Table 4-1 Literature review documents

Title	Publisher	Year	Relevant information
National Heat Map: water source heat pump layer	Department of Energy and Climate Change (DECC)	2015	Heat capacity of Thames estimated at 444MW – most complete study and methodology
Surface water source heat pumps: Code of Practice for the UK	Chartered institution of Building Services Engineers (CIBSE)	2016	Design guide for scheme technical consultant, construction, commissioning teams, and client.
UK Environmental standards and conditions	UK technical Advisory Group on the Water Framework Directive (WFD)	2008	Limited relevance to study

4.2 National Heat Map – Thames Focus

4.2.1 Introduction

An extensive water source heat map (WSHM) has been created and integrated into the larger National Heat Map, aiming to provide information around the potential for implementing heat pump technology-led energy centres for district heat networks using the natural resource of England's waterbodies.

The National Heat Map was developed by DECC and published in 2015 to illustrate heat demand and heat sources to encourage the development of low carbon heat projects. This additional water source heat layer provides a more in-depth analysis to assist local authorities, community groups and developers in exploring thermal potential within their geography before beginning any detailed feasibility studies.

The study highlights the estimated capacity of heat from waterbodies including rivers, canals, estuaries, and other coastal bodies by obtaining flow and temperature data mapped against existing geographical constraints. This was calculated by incorporating a variety of inputs such as, flow estimates and water temperature, and analysing them against environmental constraints to eliminate any areas unfit for heat pumps. Outcomes were inserted into a general heat pump model to obtain the overall capacity for each waterbody based on winter conditions only. A more detailed description of the general methodology and assumptions can be found in Appendix A.

4.2.2 Thames Capacity

The River Thames is noted as having a total heat capacity of 444 MW, as summarised in the screenshot of their table shown in Figure 4-1. It is assumed that the increased capacity is a result of including the non-tidal river and nearby waterbodies, such as reservoirs, tributaries and costal and/or estuarine waterbodies, for the whole of London. This assumption will need to be validated during any further analysis.

Rank	Urban Area (River)	Heat Cap. (MW)	Demand
1	Selby (Yorkshire Ouse)	505	Medium
2	Goole (Yorkshire Ouse)	505	Medium
3	Nottingham (Trent)	453	High
4	Newark-on-Trent (Trent)	452	Medium
5	London (Thames and tributaries) *	444	Very High

Figure 4-1 Urban areas and rivers ranked by river heat capacity taken from DECC "National Heat Map: Water source heat map layer"

The heat capacity of 444 MW is understood to equate to heat available from the Thames River and tributaries. rather than the potential heat output if water source heat pumps were to be used to upgrade the heat for distribution on heat networks.

In order to determine the heat output from heat pumps utilising the river water as a source, the COP and electrical energy input into the heat pump needs to be considered. Assuming an average COP of 3.5, this would translate to a total heat output of 621MW (not considering losses).

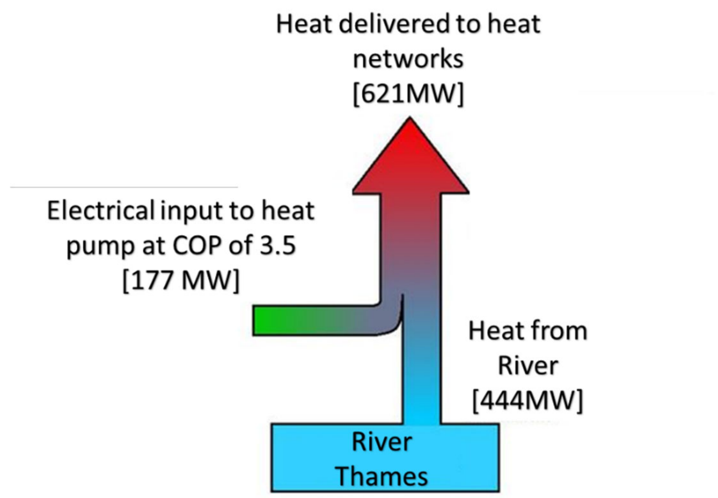


Figure 4-2 - Heat availability from river vs. heat output from heat pump

Given the 444MW is an estimate using a winter Q95 flow (i.e. the flow exceeded 95% of the time in winter and so can be considered to be reliably available), we can assume that this capacity might be available for the majority of the year although potentially less in the summer. Assuming a 60% availability peak factor over a typical year to account for varying heat requirements, as well as technical constraints (i.e. low river levels, system downtime, periods of river water temperature not being sufficient) this would translate to circa [(621*8760)*0.6]= **3.26 TWh** of heat delivered.

This would translate to up to 5% of the total 66TWh/yr heat demand in London, as estimated in the 2013 report "London's Zero Carbon Energy Resource – Secondary Heat".

The detailed methodology behind how the annual heat recovery potential for each river was calculated is uncertain from the information available in the National Heat Map. For this study's purpose we are assuming that the actual annual demand for heat recovery would be sufficient to cover the initial amount of heat required to supply the identified 'developing schemes' (currently much less than the theoretical maximum of 621 MW, as highlighted in Section 0). It is recommended that a further and more detailed study is undertaken to determine a more accurate heating and cooling capacity for the River Thames within the study boundary, from Teddington Lock to Dartford Creek.

This will be a complex analysis that requires input from a substantial amount of parameters and could be best displayed in a live model. Further examination of the impact that rejected/abstracted heat could have is essential using computational fluid dynamics modelling. This would allow for the assessment of the effects that existing projects could have on downstream capacity along the river, such as impacted river temperatures. If a substantially large abstraction and discharge flow rate is suggested for the open loop heat pump, then local factors will need to be reviewed as the current model assumes no water stress impacts from the installation of heat pumps.

Furthermore, due to the tidal nature of the River Thames there would be flow moving in either direction, as well as parts of the river where it becomes increasingly tidal which could impact the temperature profile. It is stated that the assumed flow for the waterbody is estimated as the outflow from it, implying the most downstream point was used in the model to evaluate the heat capacity. This could mean a possible over estimation in the heat capacities provided within the National Heat Map, and hence it is recommended to include a more detailed tidal model to understand the impact of multi-directional flow within the Thames.

4.3 Case Studies of river source schemes in UK and Europe

There are several examples of large WSHPs on rivers within the UK and Europe. Several examples are presented below.

Project name	Location	Capacity	Notes
Kingston Heights	London, UK	2.3 MW	• Designed to deliver heat to nearby residential developments and a hotel • An early version of a 5th Generation (ambient) network concept - after a two-stage filtration process, heat is transferred from the river water to a secondary circuit that links to a plant room in the apartment block. Water source heat pumps then increase the temperature of the low-grade heat before sending it to mini plant rooms, where the second part of the heat pump upgrades temperatures further. [1]
Castle Park	Bristol, UK	3.0 MW	• Installation of a 3MW water source heat pump which will contribute to the existing Bristol heat network. • Estimated coefficient of performance of 3.18 with heat supplied at 70-80ºC • The abstraction platform sits slightly above the water in the nearby floating harbour and supports the pipework which is submerged. This takes water from the harbour, filters it and pumps it into the main energy centre. [2]
Queens Quay	Scotland, UK	5.2 MW	• A twin 5.2MW water source heat pump as part of the £250m Queens Quay regeneration project in Clydebank • Abstracts water and heat from the River Clyde and generates energy to heat water up to 80°C, which is then pumped through 2.5km of district heating pipe connected to existing and new residential and commercial buildings. [3]
Mannheim	Mannheim, Germany	20MW	• Planned to use water from the River Rhine to heat some 3,500 households • With a capacity of 20MW, the heat pump, is one of the largest in Europe • Is capable of generating heat up to 99ºC. [4]

Figure 4-3 Heat pump installation at Queens Quay (source: Star-ref.co.uk)

Figure 4-4 Heat pump installation in Bristol (source: vitalenergi.co.uk)

[1] CIBSE Case Study Kingston Heights - Designing Buildings
[2] Castle Park Heat Network | Water Source Heat Pump Installation Project (vitalenergi.co.uk)
[3] Queens Quay | Star Refrigeration (star-ref.co.uk)
[4] Massive river heat pump launched to warm thousands of homes - Energy Live News

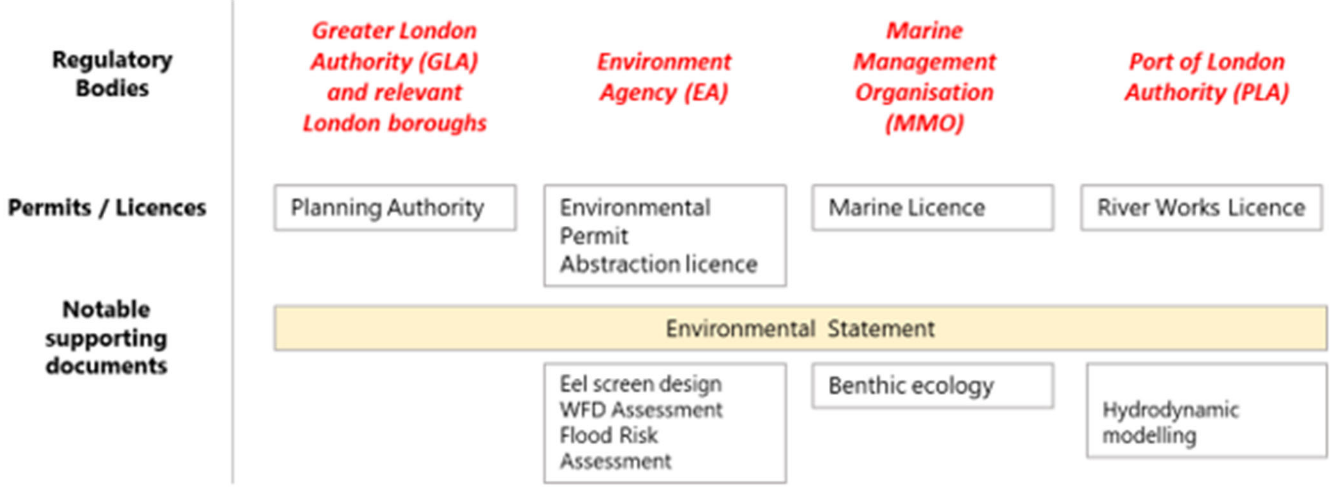
5 Environmental and Regulatory Assessment

This section provides an overview of the permitting and licensing process and requirements of the relevant regulatory bodies involved in open-loop RSHP schemes, where abstraction and discharge equipment is located in the tidal River Thames. The following assumptions have been made for the purposes of discussion with stakeholders:

- Open loop system, with water abstracted from the Thames in one location and discharged at a second location downstream of the abstraction, with an agreed minimum separation (understood to be ~100m).
- Community or district scale energy scheme, i.e. not an individual building.
- Abstraction and discharge points located below mean high water.
- The project includes in-river infrastructure, the construction of a land-based energy centre, and district heating pipework.

Note that the design and size of any heat pump scheme and the proposed construction methodology will have a significant impact on the assessments required by the regulatory bodies. This review is primarily based on Buro Happold experience working in and around the River Thames, any individual project being brought forward should engage a planning consultant in order to ensure all appropriate consultation is undertaken and relevant permissions are sought.

5.1 Summary Diagram



5.2 Licencing Requirements

The points below set out the interactions with the regulatory bodies through the lifecycle of a project. The following points consider the assumptions used within this study as well as further information required.

- The definition of the project under EIA regulations should be agreed at the outset (river infrastructure/energy centre/pipework, etc.) as this will impact the screening. If an EIA was screened out, it is likely that many of the assessments/documents listed as appendices to the EIA would still be required by the stakeholders, but as standalone documents.
- Note it should be assumed that all regulatory bodies will require plans/sections detailing the proposed solution, and a construction methodology will be required in order to inform the supplementary documents.
- The design of abstraction and discharge points (suspended / on the river bed) as well as the design of the network in terms of water flows required, temperatures and water plumes will all influence the potential environmental and navigational impacts on the River Thames and hence will influence the analysis required to inform the supporting documents and EIA.
- The usual Local Planning Authority requirements associated with land-based planning applications have not been listed.
- Associated documents are indicative based on previous experience but exact requirements for each agency will vary depending on the design of the inlet/outlet and will be confirmed through the consultation and EIA screening/scoping process.
- Associated documents may have an extended timeframe associated with their production – for example, ecological monitoring may require surveys over a variety of seasons – which may impact rate of implementation of a WSHP scheme.

Table 5-1 Regulatory body requirements

		Regulatory Body			
		Local Authority (Local Planning Authority)	**The Environmental Agency**	**The Port of London Authority**	**Marine Management Organisation**
Project Stage	**Consultation**	Pre-application consultation recommended.	Pre-application consultation (charged advice service) recommended.	Consultation not required but recommended on inlet/outlet location and design.	Pre-application consultation not required (the MMO are statutory consultees for the Local Authority and EA) but beneficial to ensure EIA includes relevant additional studies (it is a charged service).
Project Stage	**Planning Requirements**	Environmental Impact Assessment – (screening / scoping / assessment)			
Project Stage	*Associated documents or modelling requirements**	Requirements include: • Land Contamination Desk Study • Noise Assessment • Air Quality Assessment • Transport Assessment • Visual and Heritage Impact Assessment • Archaeological Desk Study *(Plus those adjacent)*	Requirements include: • Flood Risk Assessment. • Water Framework Directive Assessment (screening, scoping, assessment). • Biodiversity Assessment - including intertidal / benthic ecology. • River wall condition survey. • Flood defence consents would be required for certain infrastructure within proximity of the flood defences (usually the river wall/Embankment).	Requirements include: • Navigational risk assessment. • Hydrodynamic assessment. • Riparian life-saving equipment proposals. • Water Framework Directive Assessment.	Requirements include: • Scour modelling of riverbed. • Biodiversity Assessment - including intertidal / benthic ecology, underwater noise.
Project Stage	**Construction Permits**		Environmental Permit - Flood Risk	River works licence required for construction works including temporary works and dredging license if any bed disturbance.	Marine Licence for construction works including temporary works.
Project Stage	**Operation / ongoing permits or licences**		Abstraction Licence Discharge consent	River works licence and ongoing charge.	*None, unless requested as part of EIA.*
Decommissioning			Depending on the detail of the works, possible EIA and associated documents required.	River works licence and associated documents required for construction works to remove in-river structures; continue in perpetuity if structures remain under the bed.	Marine Licence for construction works to remove in-river structures.

*In the event that an EIA is found not to be required through the screening process, the supplementary documents suggested may still be required by the regulatory authorities, just as standalone documents rather than as appendices to the EIA

5.3 Roles and Responsibilities

5.3.1 The Environment Agency [EA]

The EA is an executive non-departmental public body, sponsored by the Department for Environment, Food and Rural Affairs (DEFRA). In relation to the potential for open loop heat pumps in the River Thames, the EA are the regulatory body responsible for water quality and resources, fisheries, ecology, and flood risk. The EA is a statutory consultee on planning applications this includes regulations for flooding, discharge and abstraction. Pre-application consultation with the EA is strongly recommended. The EA's areas of interest relevant to river WSHPs are flood risk, water quality, biodiversity and riverbed habitat, the condition of river walls / flood defence structures, and abstraction and discharge licencing.

As well as consulting on the planning application, the EA are the regulatory body responsible for licencing water abstraction and discharge. The EA's pre-application advice service should be consulted in order to ensure the correct information is provided which will smooth the process of applying for an abstraction licence; the following information is guidance based on an initial discussion with the EA however project specific criteria may vary.

An abstraction licence from the EA will be required if a project abstracts more than $20m^3$/day of water, and a water discharge permit may also be required. A $20m^3$/day abstraction corresponds to 4.8kW of heat capacity considering a temperature differential of 5°C. It can be assumed that all communal or district energy schemes would require more capacity than 4.8kW and therefore require licensing. Additionally, an 8°C maximum temperature differential allowed between abstraction and rejection usually applies, while being assessed on a case by case basis.

Discussion with the EA suggests that heating water (i.e. using the river for cooling rather than heating) is more of a concern from an ecology perspective than using it for heat and so cooling water.

An abstraction licence is typically granted for between 6 and 18 years, and renewals are generally for 12 years. The abstraction licence granted is likely to be a 'Hands off Flow' licence (HoF) which means there is no guarantee of supply, if river flows were to drop below a certain value abstraction would be stopped. In the tidal River Thames this could potentially mean abstraction may need to pause at extreme low tides and/or low river flow. A fish pass would not be required for the type of project envisaged, but safe passage for eels should be considered; an eel screen is likely to be required.

5.3.2 The Port of London Authority [PLA]

The PLA is the statutory harbour authority for the Port of London, with responsibility for maintaining safe access and managing the safety of vessels, the public and all users of the tidal River Thames. They are also responsible for consenting all works and dredging. The PLA own the majority of the riverbed of the tidal Thames. The PLA is not a statutory consultee on planning applications.

The PLA are likely to be primarily interested in the impacts of a project on navigation and safe use of the River Thames and also concerning scour/accretion and will be a key stakeholder to consult when considering locations for abstraction and discharge points, and the design of inlets and outlets. During construction and operation, the PLA are the regulatory body responsible for providing river works licences and notice to mariners (if required) to ensure that works on the river can be safely carried out without impeding the ongoing use of the river.

5.3.3 The Marine Management Organisation [MMO]

The MMO is an executive non-departmental public body of DEFRA. The MMO licence and regulate marine activities in the seas around England and Wales. In relation to the potential for open loop heat pumps in the River Thames, the MMO are responsible for planning and licencing for marine construction. The MMO is a statutory consultee on planning applications.

The MMO are responsible for regulation of marine activities from Mean High Water Springs (MHWS), therefore the design of the intake and outflow structures is relevant here. The MMO are likely to be primarily interested in the impacts of a project on the local ecological environment.

The EIA screening and scoping process should consider the MMO areas of interest and consult with them in order to ensure the additional documents required by the MMO are identified and produced to allow the MMO to understand the environmental impacts of the project, and for these to be identified and mitigated. It will be relevant to agree whether the MMO require EIA to be considered under their jurisdiction as a regulator, in addition to the local planning authority. This would not change the format or structure of the EIA, only the approvals process.

5.3.4 City of London Port Health Authority [PHA]

The City of PHA is the regulatory body relevant for port health matters such as infection control, and a regulator for environmental permitting. Following consultation with the PHA they are not a relevant regulatory body for this work. As a local authority the City of London are a key consultee as per other local authorities in the context of the Local Planning Authority, for example on mat

- Limitation on plant noise. The PHA is consulted in complaint mechanism with the LA.
- Construction works noise allowance. The PHA is involved through section 60 & 61 of the City of London (CoL) code.
- For pollutant emitting plant (ie: gas boiler emissions) an Industrial process permit from the PHA might be required.

5.4 Constraints for Abstraction and Rejection Infrastructure

Specific constraints have been provided by the EA and PLA which are outlined within section 6 of this report.

6 Key Technical Considerations

In this section the key technical considerations for developing a river water source scheme is explored. Please note that all indicative designs herein would need to be assessed in terms of their impact on the environment, scour, temperature, impact on flow, ecology, habitat etc.

6.1 Types of Abstraction

This study has assumed the typical arrangement seen for a river-based WSHP which follows an open loop abstraction and discharging method. This means that water is abstracted from the river using abstraction pumps, which then goes through a filtering process before being sent back to the energy centre, as shown in Figure 6-1. Whereas in a closed loop system there is no abstraction of the water but instead pipes or heat exchangers are submerged within the water where heat is transferred to the working fluid within the pipes / heat exchangers. Open loop systems typically have the capability of circulating larger water volumes than those of closed loop systems.

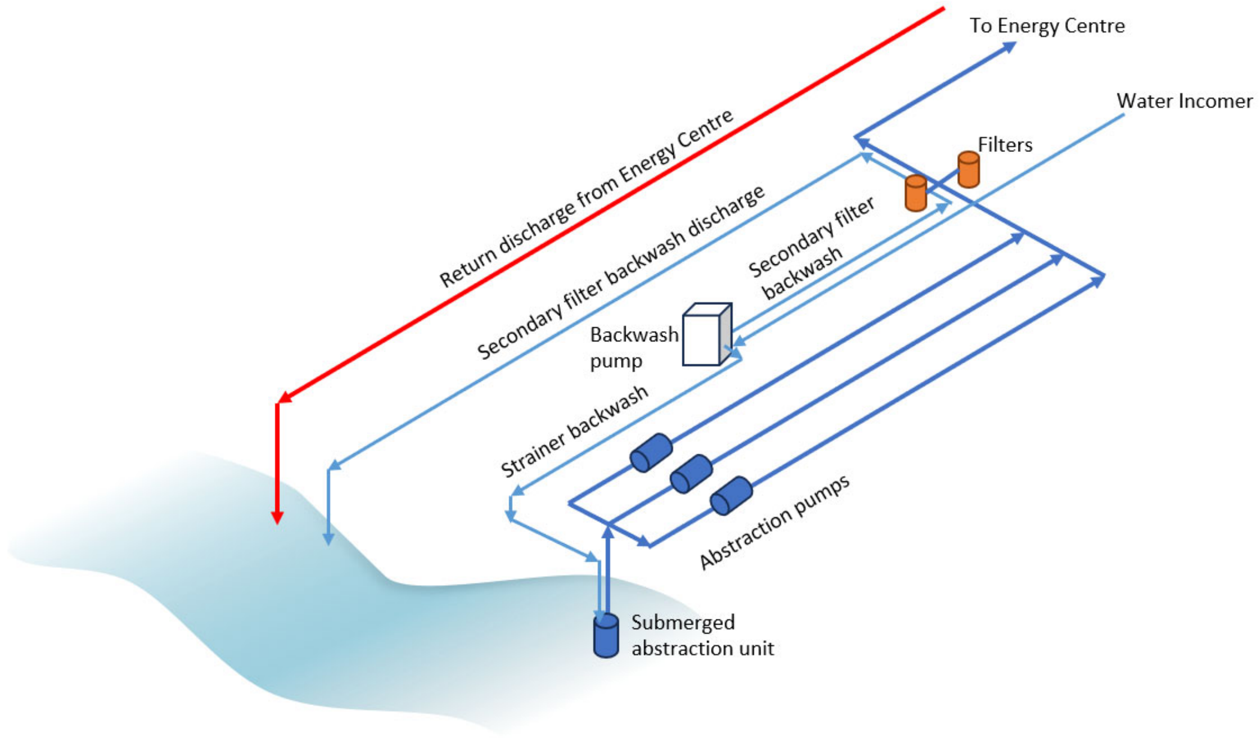


Figure 6-1 Typical open loop arrangement for a river based water source heat pump

6.1.1 Direct and Indirect Connection Systems

Within an open loop system the filtered water abstracted from the water source can be sent to the main energy centre in either a direct or indirect system. The key differences between both systems are shown in Table 6-1.

Table 6-1 Direct or indirect connection appraisal

Type	Description	Pros	Cons
Direct	Heat pump is connected directly to the water source, shown in Figure 6-2	• Heat pump will function with increased efficiency due to the lower temperature difference between the source and the load • Reduction in electricity consumption • Longer overall operational lifespan and prolonged running hours achieved during winter when the surface water temperature reaches freezing • Lower energy loss and pumping costs achieved due to the elimination of one heat exchanger • Lower CAPEX achieved as the additional cost required for filtration and cleaning the additional heat exchanger is not needed • Smaller plant room footprint without additional heat exchanger required	• More consideration of chemical and fouling of water required as the source water is passed directly through the heat pump • Potential damage to heat pumps and potential to reduce operational lifetime of heat pump and/or heat exchangers
Indirect	An intermediate hydraulic separation is installed between the water source and the heat pump, shown in Figure 6-3	• Water quality of the source is less of a concern when selecting the appropriate heat pump • Lifetime of energy centre pumps likely to increase due to higher control of water quality	• Further temperature and pressure drop incurred using intermediate heat exchangers which could lead to a reduction in winter operating hours when the water temperature falls below 3°C • Larger pressure drop seen due to the utilisation of two heat exchangers that the pumps will need to overcome • Lower efficiency due to the greater temperature difference between the source and the load

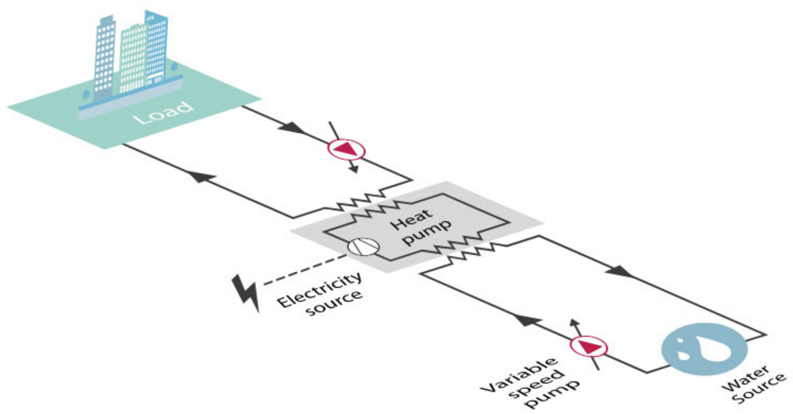


Figure 6-2 Direct connection to water source

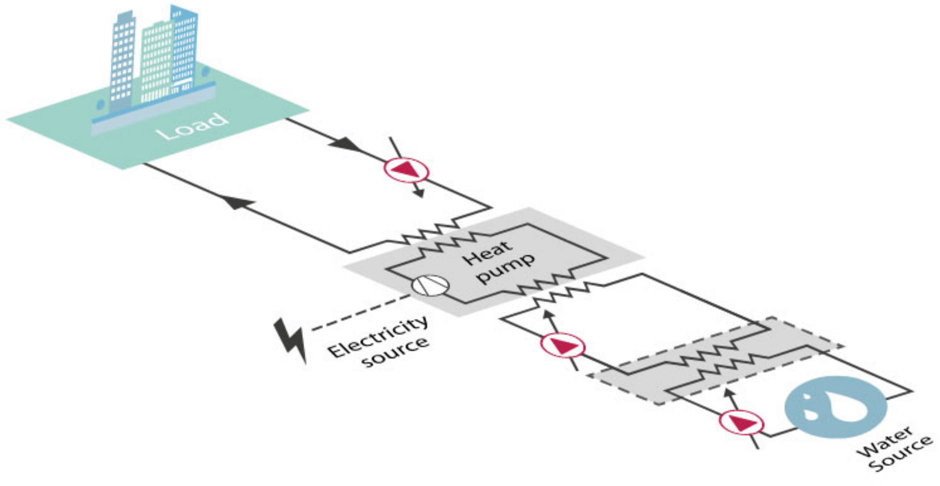


Figure 6-3 Indirect connection to water source

6.2 Stratification

The stratification within the water resource being examined could significantly influence the efficiency of the WSHP over its lifespan. Water reaches its maximum density at around 4°C, meaning that during winter, the lower layers of water may have higher temperatures than those near the surface. In the Thames, the intermingling of saltwater with freshwater can play a crucial role in stratification and impact the efficiency of the WSHP system. Due to saltwater's greater density, freshwater tends to remain atop the denser seawater.

Värtan Ropsten, one of the world's largest heat pump installations with a total heating capacity of 180MW, is situated on a barge anchored to the seabed. It has the capability to extract water from various depths below the sea surface depending on the season. During summer, extraction occurs near the sea surface to capitalize on higher temperatures, while in winter, extraction takes place at a depth of 13-15 meters. A comprehensive survey is essential for gaining insights into the watercourse's behaviour throughout the year.

6.3 Abstraction Pumping

6.3.1 Pump Losses and Material Selection

The pump is typically positioned above the liquid level when abstracting from a water source. When starting up it is essential to remove air from the suction line before initiating normal pumping operations. For such applications, a self-priming pump is necessary. The suction lift capability depends on factors such as friction, specific gravity, fluid temperature, system leakage, pump inefficiencies, and above sea level elevation. Typically, this lift is limited to a maximum of 7-8 metres.

Hence, to minimise suction losses, designers must reduce the number of bends and keep the pipe run length (i.e. the distance between the pump and the water) as short as possible. Calculating the Net Positive Suction Head (NPSH) available is critical; where it should exceed the NPSH required by the pump. In cases where this is not feasible, submersible pumps may be necessary.

Another important factor is the pump material. Marine-grade pumps become essential for consideration within the feasibility study if the pump is exposed to seawater. The selection of pump material involves balancing reliability and lifecycle cost, where super-austenitic and super-duplex stainless steels are well-suited for main reapplications as a result of their improved corrosion resistance at high velocities, favourable mechanical properties, and ease of fabrication. While various material options exist for seawater applications, a lifecycle cost analysis is necessary to determine the most appropriate material. Ultimately, the decision rests on the developer's willingness to initially invest in higher costing materials to allow for the reduction in total cost of ownership. The consideration will align with the long-term targets and interests of the developer, particularly regarding the operational and maintenance (O&M) responsibilities for the scheme.

6.4 Filtration Considerations

The filtration requirements for the WSHPs are influenced by water quality and site-specific variables. Consideration should be made to the volume of silt contained within the water in the Thames.The intake strainer must be designed to prevent the entry of aquatic life, which is commonly designed to have a mesh size less than 2mm. To ensure operational reliability of the WSHPs, a duty/standby intake strainer type of arrangement should be considered. This arrangement provides sufficient capacity in case debris like plastic bags adversely affects the operation.

Additionally, a secondary level of filtration might be necessary depending upon the water quality of the source. For example, implementing a combination of filters where the secondary filters have a dedicated water supply and a separate pump for the backwash process. Their primary purpose is to prevent the growth of zebra mussels within the water source side of the installed heat exchanger.

6.4.1 Abstraction Infrastructure and Plant

There are various methods of possible intake structures that can be adopted for a WSHP project. The three main considerations are outlined in Table 6-2.

Table 6-2 Intake structures

Type of intake structure	Description	Figure Reference
Using self-priming abstraction pumps	Follows a bank-side intake structure design that implements a self-cleaning primary intake filter, with secondary filtration and self-priming abstraction pumps are installed at the pump house. This type of set up can offer technical risks as a result of the pressure drop limitations on the suction-side.	Figure 6-4
Using vertical turbine pumps	Requires a bank-side sump chamber to be constructed where the water is abstracted using a vertical turbine pump. This arrangement has high capital and civil costs but avoids the technical risks seen with the use of self-priming pumps.	Figure 6-5
Using submerged intake	Design follows the application of running pipes along the river bed with an intake strainer situated on the intake pipe. There are a number of possible submerged intake designs that are shown in the three referenced figures. These configurations are better suited for schemes where the pump house is a greater distance away from the deep water.	Figure 6-6, Figure 6-7, Figure 6-8

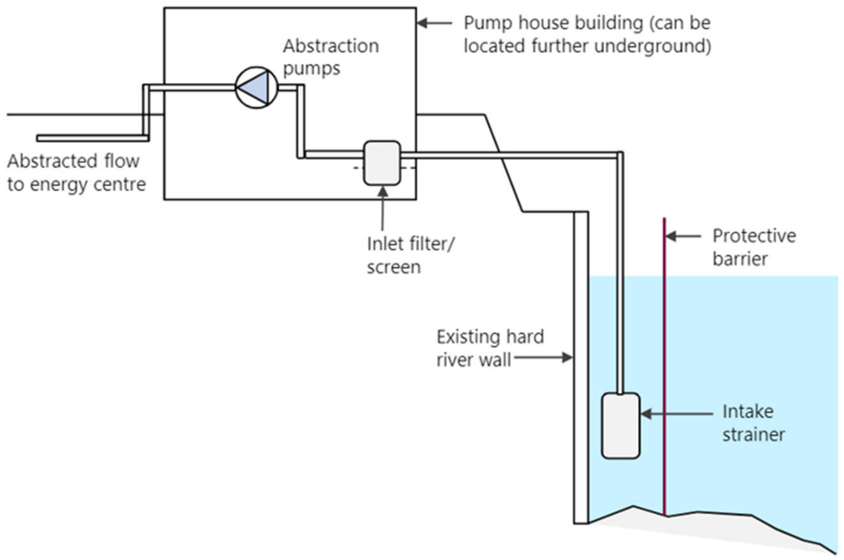


Figure 6-4 Intake structure option using self-priming abstraction pumps

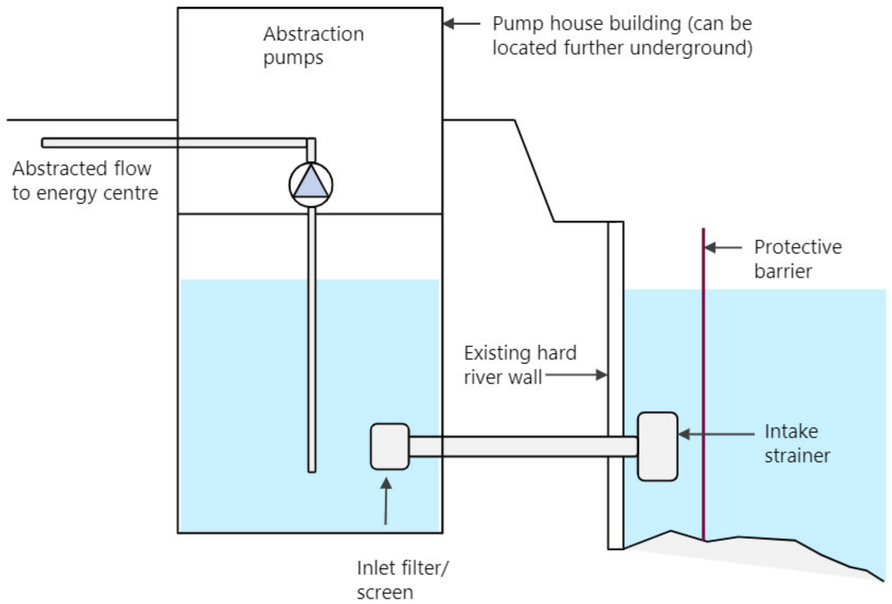


Figure 6-5 Intake structure option using vertical turbine pumps

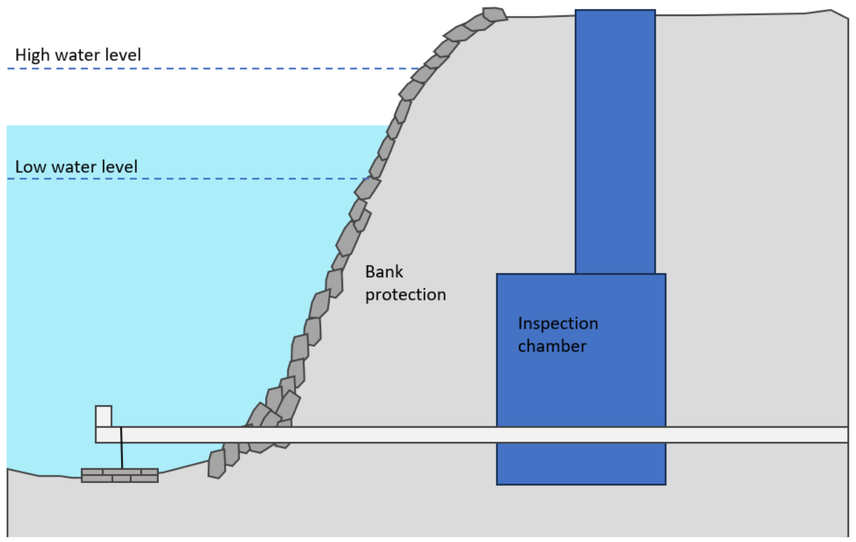


Figure 6-6 Intake structure option using a submerged intake with piping above bed – unprotected intake

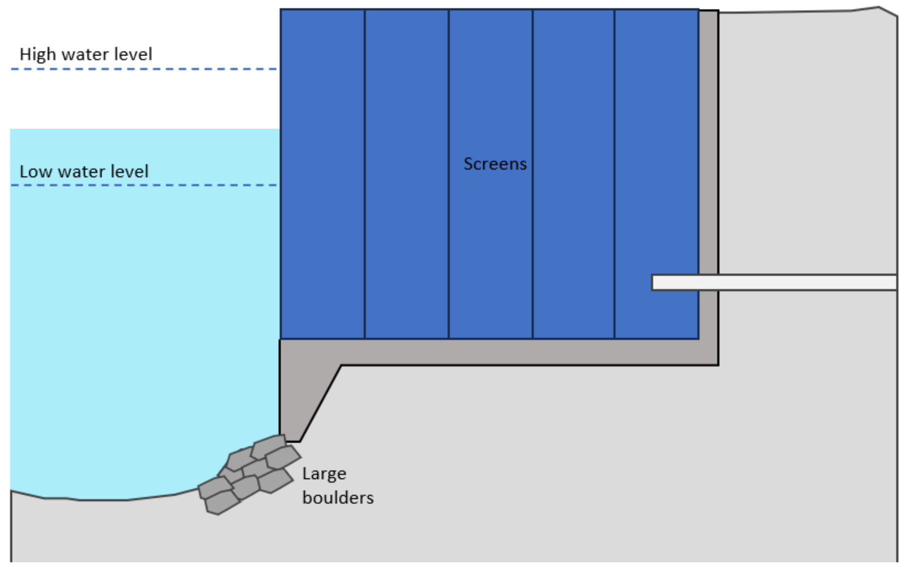


Figure 6-7 Intake structure option using a submerged intake with piping above bed – protected intake

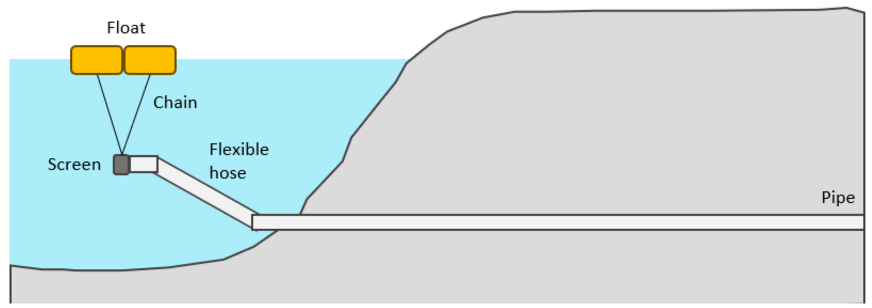


Figure 6-8 Intake structure option using a submerged intake with piping above bed – floating intake

Table 6-3 Key differences between the three typical configurations of a submerged intake structure

Type of submerged intake structure arrangement	Description
Unprotected intake	More suitable for locations where water levels are relatively stable and where the velocity and gravel loads of the water are small.
Protected intake	For sites that have higher river velocities the flow of water can be regulated by introducing a submerged weir or a partial/full dam, providing protection to the structure while simultaneously diminishing sediment load and stabilising water levels.
Floating intake	This application can offer several benefits, such as water being able to be extracted from the surface, which tends to have a lower turbidity, resulting in more consistent water treatment. Additionally, the intake can be easily obtained for cleaning. One disadvantage is their susceptibility to damage from floating debris.

For the purposes of this report a submerged intake design has been considered further, given the expected challenged of tidal variance of the Thames with alternative methods. Submerged intakes are generally utilised when the water depth near the shore is inadequate for extracting the necessary flow, or when constructing near the shoreline is deemed undesirable due to environmental or other considerations.

Figure 6-9 illustrated the abstraction and rejection infrastructure constraints, obtained through discussions with the EA and PLA. Constraints on the design include:

1. **Length from riverbed** - The pipes need to be long enough as to not scour the riverbed while also being short enough so as to not reside within the navigation channel. Additionally, to lay the pipe in its length, land needs to be available, or a directional drilling method employed. Certain areas on the riverbed are protected against those type of works by the local authorities or Historic England.

2. **Intake sufficient height above riverbed** – When positioning the intake strainer, it is crucial to account for the required clearances. These strainers will typically be needed to be submerged and impose a minimum operating head between the top of the strainer and the minimum water level. This assessment of the minimum water levels should be undertaken during the feasibility stage to guarantee that the minimum clearance between the two are maintained. Confirming this clearance or minimum operating head and the minimum clearance from the bottom of the seabed with the appropriate intake strainer manufacturer is essential.

   In watercourses such as rivers, lakes, and estuaries, sediment accumulation near the abstraction point will require careful examination, where the level of maintenance needed depends upon the material buildup. For effective removal of slit accumulations from the abstraction site, a diving team and combination tanker could be required (note that diving in the river is a specialised act and only undertaken at slack water). The use of sonar level instruments and telemetry offer detection of the slit buildup nearby the intake strainer.

   The approach for examining the abstraction pipework and intake strainer needs to be established. The removal of the strainer and pipework can be performed using a water-side maintenance platform and lifting equipment. Where removable platform panels on the water-side platform will facilitate easier access to the strainer and pipework.

3. **Mass flow rate of water abstraction or rejection** - The maximum abstraction rate is determined by the Environment Agency, depending on various factors including hydrometrics and species protections. For the latter, eel screens are likely to be necessary in the Thames. Additionally, there is a cap on the temperature differential between the abstracted and rejected water, usually of 8°C but sometimes lower. Plant/pipes and equipment which changes the temperature in the tidal (and non-tidal) river environment all have potential to have impact on flood defences, habitat and other elements, therefore detailed assessments will need to be carried out on site specific proposals. Flood defences will need to be raised/adapted in future so this needs to be taken into account for any specific proposal(s).

A minimum distance of 100 metres is typically needed to prevent thermal short circuiting between the abstraction (upstream) and discharge (downstream) infrastructure.

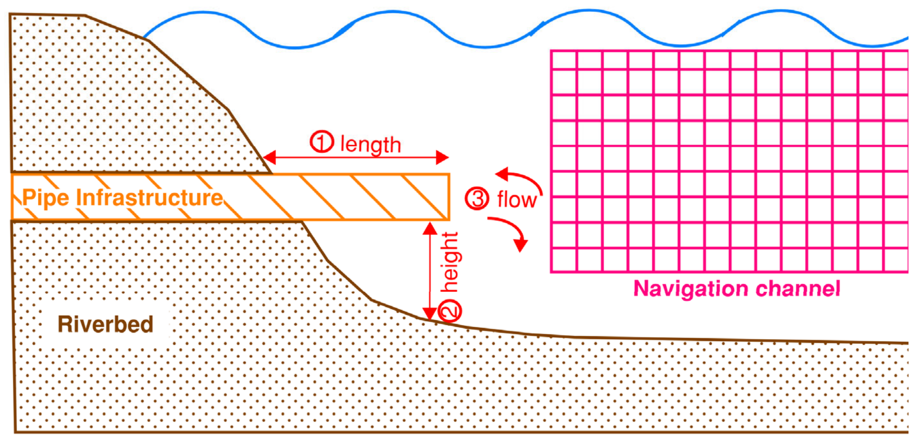


Figure 6-9 Diagram cross section of River Thames – Constraints

6.5 River Thames Temperature

Historic temperature data was reviewed at Runnymede (closest available monitoring point - for more accurate comparable temperature data for the tideway, additional monitoring may need to be undertaken) for years ranging from 2009-2017 outlined in Figure 6-10. This shows that temperatures fluctuate to as low as circa 1 degC in 2010 during the winter to highs of over 24 degC in 2017 during the summer. The lower temperatures suggest that there will be times of low / zero availability from the river as heat offtake will not be possible without approaching freezing temperatures. During this period there would be less possible heat output and heat pump deration.

Taking a full year's worth of data from September 2016- September 2017 as an example the lowest temperature was seen as circa 3degC, as shown in Figure 6-11. Taking 8degC as a minimum water temperature the period of low / zero availability could be up to 3.5 months or roughly 27% of the year.

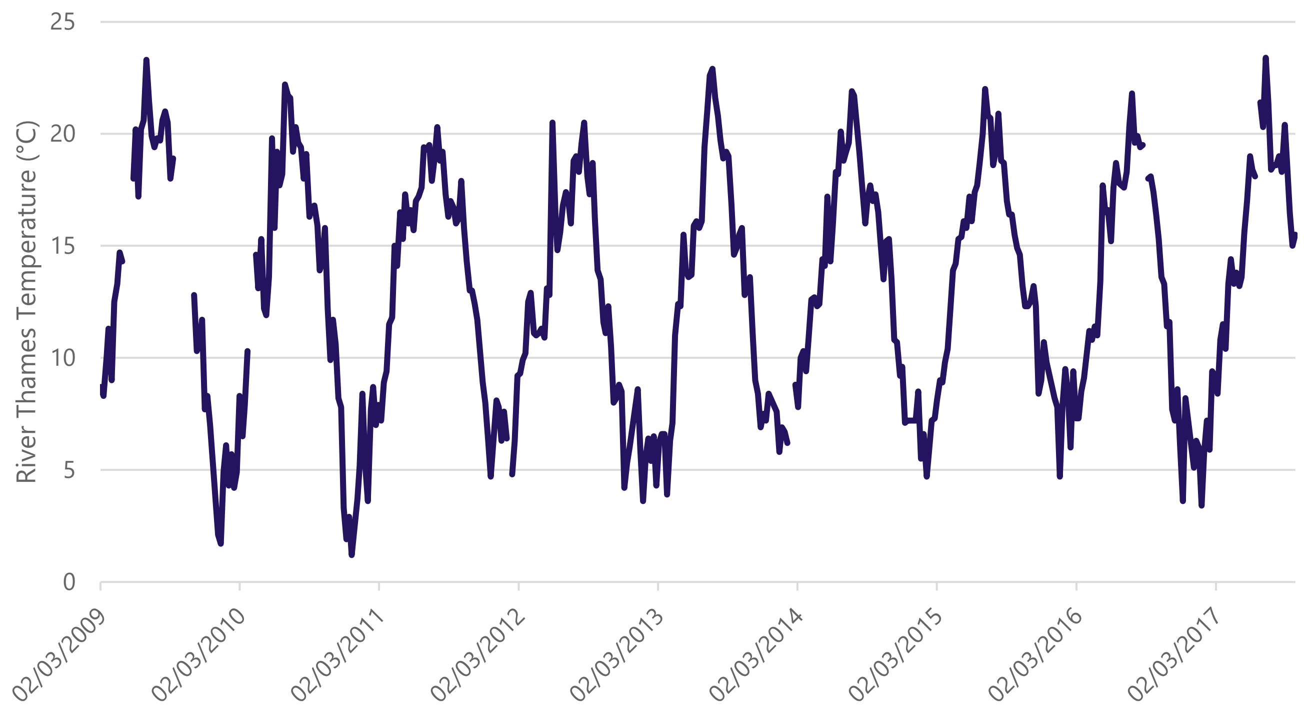


Figure 6-10 Historic temperature for the River Thames at Runnymede from 2009-2017

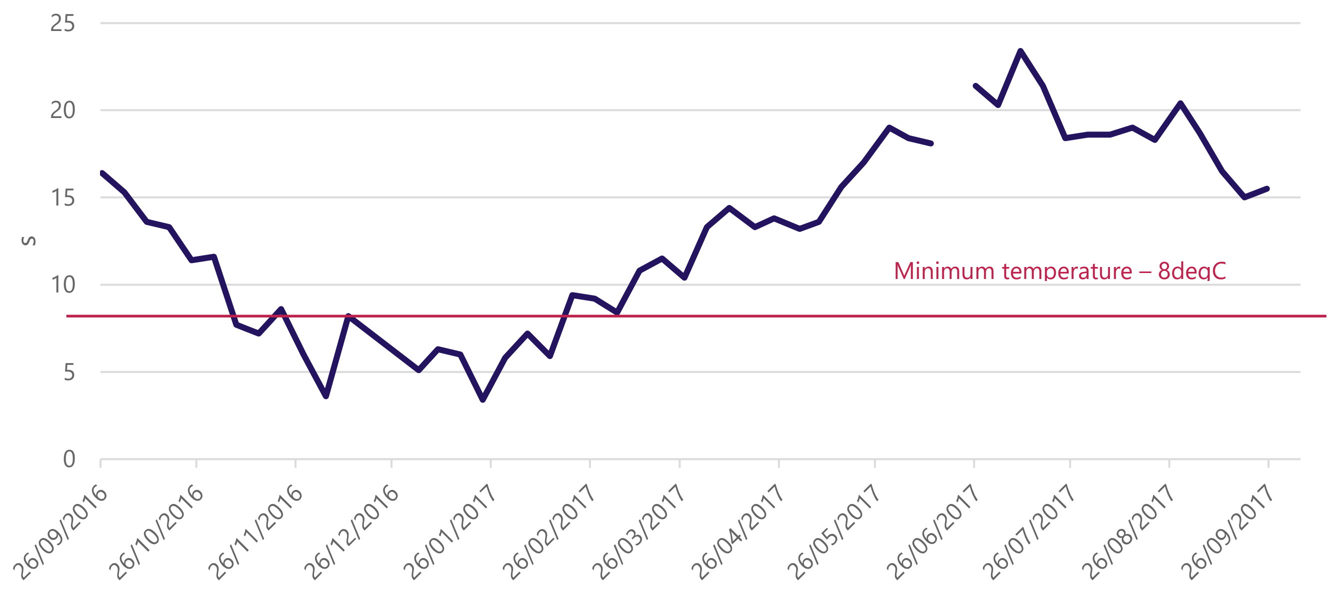


Figure 6-11 Temperatures seen at River Thames at Runnymede from 2016-2017

7 Strategic Areas for River Thames Heat Offtake

This section presents an initial appraisal of the main strategic areas where energy recovered from the Thames could be utilised in existing & potential heat networks. Strategic areas have been considered in line with availability and size of waste heat sources around London. Areas in close proximity to the river but with lower potential to utilise available waste heat sources, due to distance from the heat source, should be considered for prioritisation so that they are able to utilise energy from the Thames.

7.1 Existing and Developing Schemes

Information shared by stakeholders on WSHP schemes has been divided into four categories:

1. Historic abstraction and discharge sites: known existing pipe infrastructure in the Thames which is, to our best knowledge, not currently in use.
2. Interest area: areas identified by the London Boroughs for scoping study including WSHP options or high-level studies previously completed.
3. In development / feasibility: Feasibility study of a potential scheme.
4. Operational: A WSHP scheme which is currently understood to be operational.

These projects have been summarised in Table 7-1 and mapped with corresponding numbers in Figure 7-1. The cumulative capacity of the potential schemes is calculated at 172MW, which is equivalent to approximately 29% of the river capacity as estimated in the National Heat Map study.

The capacities for some existing operating schemes are not known and therefore the total heat required by all the schemes may be greater. In addition, there are some schemes that are under development where the capacity is not known along with an existing 8.8MW scheme on a tributary upstream of Central London[5].

[5] Ebtech install the UK's largest river source heat pump (ebtechenergy.co.uk)

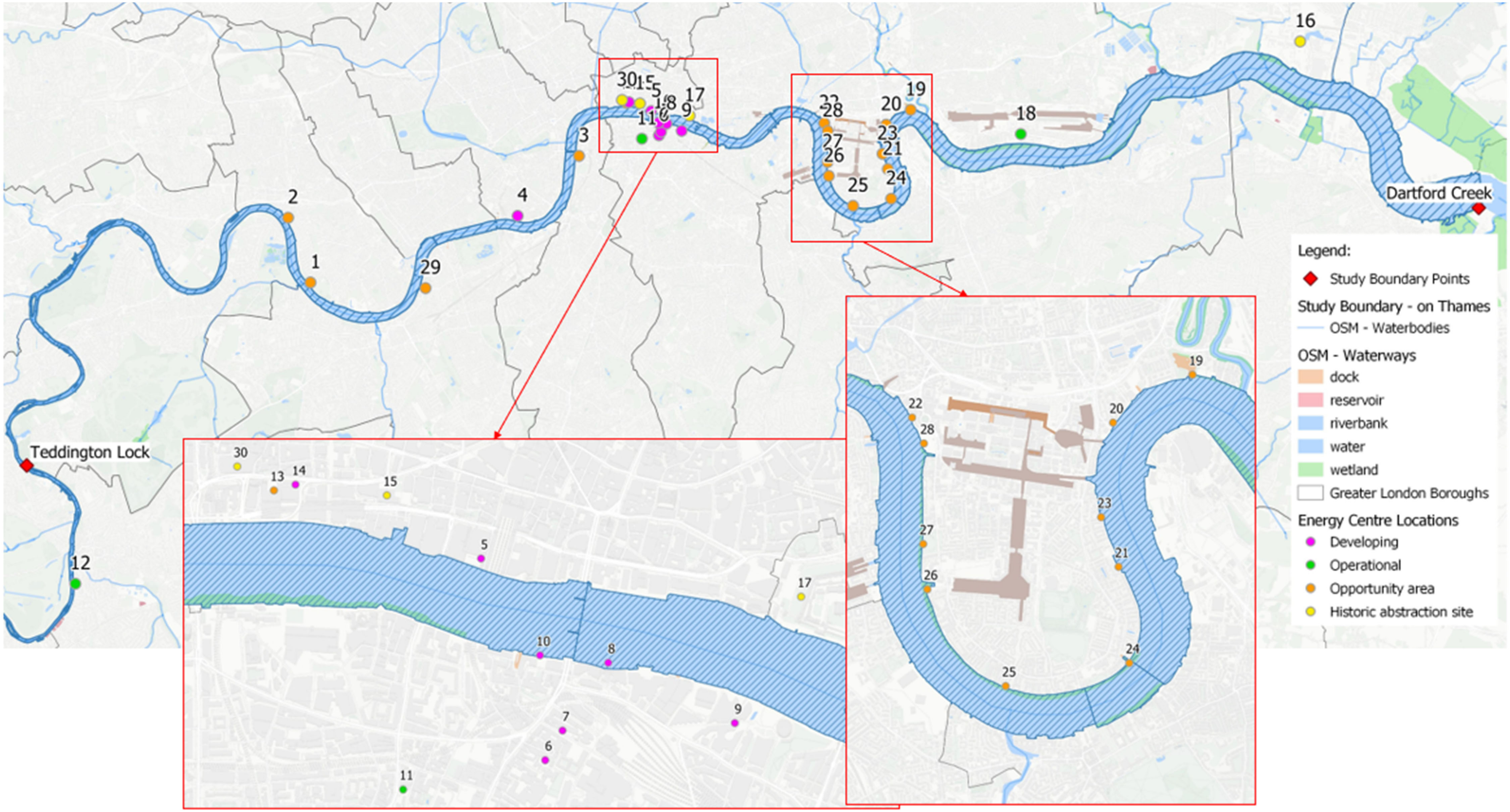


Figure 7-1 Existing and developing schemes identified through the study

Table 7-1 List of existing schemes and identified opportunities within the study boundary

ID	Study Name	Borough	Map Category	Potential Capacity (MW)	Description
1	Cross-Borough Energy Masterplan - Bishop's Park	City of London & Hammersmith and Fulham	Interest area	103	Provided masterplan identifies potential WSHP that can be installed during Phase 2 of construction programme, 2027-2030 to connect into the Hammersmith Town Centre and Olympia Network.
2	Cross-Borough Energy Masterplan - Manbre Wharf	City of London & Hammersmith and Fulham	Interest area	17	Provided masterplan identifies potential WSHP that can be installed during Phase 3 of the construction programme 2030-2033 to connect into the Earl's Court Network.
3	Waterloo and Southbank Strategy	Lambeth	Interest area	10	Identification of Southbank as a potential area for a heat network connecting large non-residential buildings to benefit from using local low carbon sources.
4	PDHU (Pimlico District Heat Undertaking)	Westminster	Developing	8	Feasibility study just completed outlining pumping station and river take off locations, including a techno-economic assessment across nine different scenarios.
5	Walbrook Wharf	City of London	Developing	6.6	Feasibility study completed analysing three different WSHP scenarios with possible energy centre locations. An indicative costing range for the scheme was produced at roughly £7-13m.
6-10	Team London Bridge DHN Feasibility Study	Southwark	Developing	20	Possible district network examined using WSHPs with 5 potential energy centre locations identified and an estimated capital expenditure of roughly £40m for the scheme, with target to secure 50% from GHNF.
11	Shell Centre	Lambeth	Operational	4	Capacity assumed from heat exchanger data . Existing abstraction license in area where Shell centre utilises water from Thames for cooling and heat rejection through filtration and pumping system.
12	Kingston Heights	Kingston Upon Thames	Operational	2.3	Scheme with an onsite water source heat pump, feeding an ambient loop system (outside of the tidal area).
13	City of London – Boy's School	City of London	Interest area	0.8	Feasibility study where a WSHP is mentioned as an option within study.
14	Puddle Dock	City of London	Developing	-	Existing energy strategy for ambient loop communal system leads to consideration of WSHP/ASHP. Existing river water cooling system not used but has assumed 7MW heating capacity.
15	Upper Thames Street	City of London	Historic abstraction site	-	Existing abstraction and rejection piping.
16	Barking Power Station	Barking and Dagenham	Historic abstraction site	-	Existing abstraction and rejection pipe, but possibility it has been filled in.
17	Tower Bridge	Tower Hamlets	Historic abstraction site	-	Existing decarbonisation strategy and existing abstraction & rejection pipe – exact details of site unknown but potential that this location served as a former river water intake system for the original steam-powered hydraulic bridge lift system.
18	Tate & Lyle	Newham	Operational	-	Existing abstraction and discharge site – still understood to be used for cooling.
19-22	Tower Hamlets Riverside Opportunity	Tower Hamlets	Interest area	-	Riverside site allocation - opportunity for energy centre to be part of site allocation.
23-28	Tower Hamlets Riverside Opportunities	Tower Hamlets	Interest area	-	Further opportunity sites from slipways/public spaces/dock entrances.
29	Battersea power station (EQUANS)	Wandsworth	Interest area	-	Exploration for potential use of River Thames for a WSHP scheme at Battersea.
30	Banyard House	City of London	Historic abstraction site	-	Heat rejection system installed previously to reject heat to Thames, system is no longer used as cooling demands has reduced.
			Total known potential sites	**172 MW**	

7.2 Strategic Zones

Strategic zones have been defined along the River Thames as areas which have:

- High heat density
- No or limited access to waste heat sources.

An initial exercise was performed to identify areas which have a lack of large, local waste heat sources that could support a heat network by using the waste heat dataset from the London Heat Map. The methodology applied is:

- London Heat Map dataset filtering to the River Thames surroundings, filtering out any waste heat source below 5GWh/yr and building demand below 100MWh/yr to reflect mandated buildings from upcoming Heat Network Zoning Policy (currently under consultation).
- Radial distribution from heat source to demand until 80% of supply exhausted (to allow for heat losses and unrecoverable heat).

Due to the limitations of this simplified modelling approach it is more than possible that the identified waste heat will potentially serve larger areas than shown here, as the waste heat sources may supply heat to meet demand that is more central where the demands are larger and heat networks are more likely to be viable. In addition, several waste heat sources overlap and if combined could serve a larger area. The areas shown for waste heat coverage are therefore potentially smaller than could be the case.

The radial distribution for connection of nearby heat demands is indicated on the map in Figure 7-2 and gives an indication of areas that are likely to benefit from other identified waste heat sources. Existing and proposed heat networks are also shown. Areas with significant waste heat availability may therefore be less reliant on the River Thames as a low carbon heat source for supporting their decarbonisation – although it is recognised that there are also various technical and commercial challenges to securing heat from these sources.

Several riparian London Boroughs have limited alternative waste heat sources, and therefore may be more reliant on the river as a low carbon heat source, and these include:

- Wandsworth
- Richmond
- Lambeth
- Westminster
- Hammersmith and Fulham
- Kensington and Chelsea
- City of London
- Southwark

An assumed buffer of 1.5km against the boundary of the River Thames has been taken to apply an assumed maximum distance in which buildings may most benefit from the river as a source, this may mean that boroughs such as Camden and Islington may also benefit from the river as a heat source.

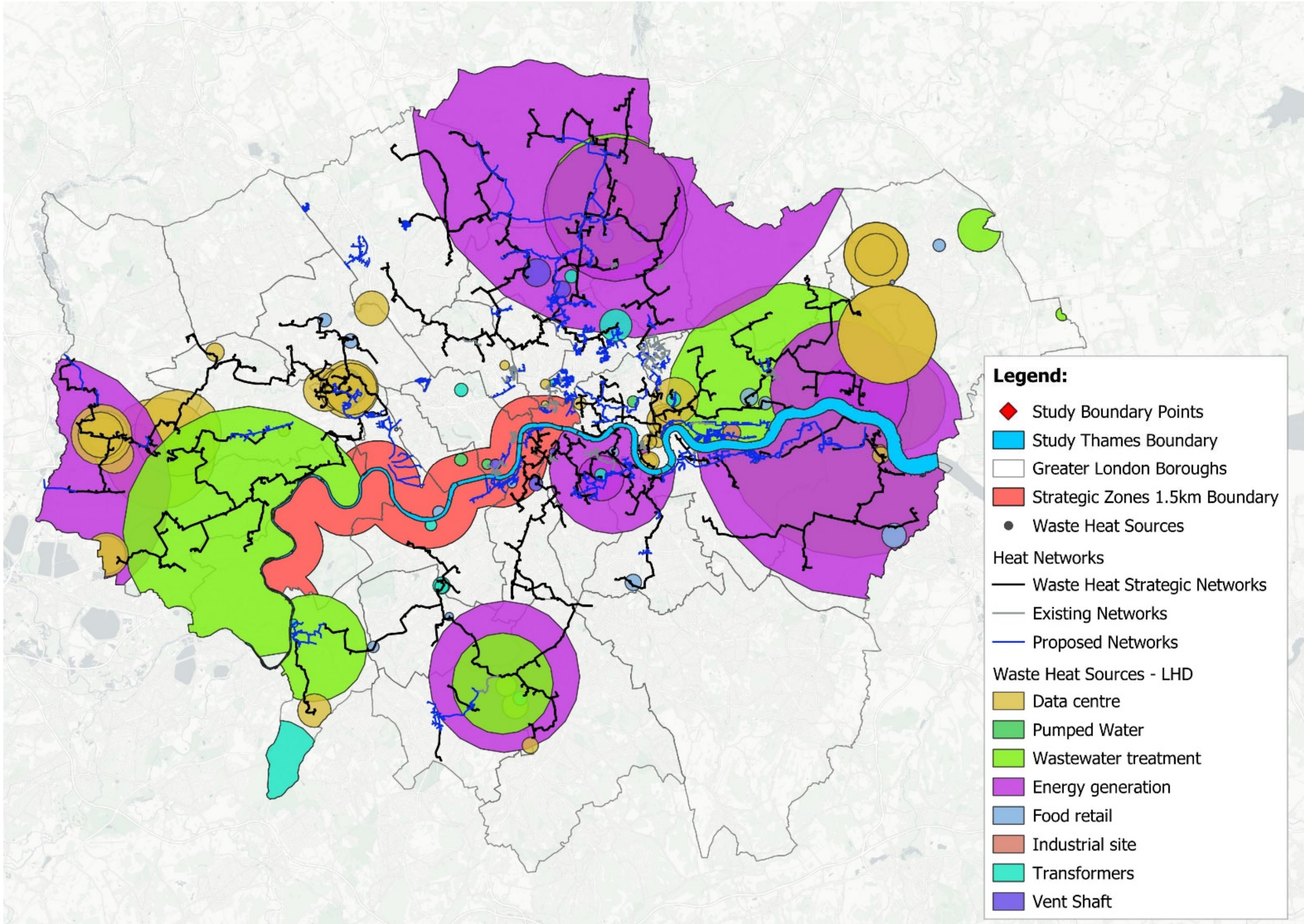


Figure 7-2 Strategic zones for large scale WSHP scheme when compared to waste heat availability and existing / proposed heat networks

7.2.1 Strategic Clusters Within Zones

A cluster analysis has been undertaken to highlight buildings within each of these strategic zones that offer a high potential for connection to a district heat network based off their heat demands.

These heat demands for existing developments were obtained from the London Heat Map dataset. This dataset should be regarded as indicative since it does not accurately represent realistic conditions.

To identify potential clusters for the heat demands, a 'buffered linear heat density (LHD) assessment' was undertaken. For this, the annual heat of each demand was divided by 16 MWh/m/yr to calculate a distance at which any demand closer than this could be connected and maintain a good linear heat density. An LHD of 16 MWh/m/yr was used for this assessment due to this criteria suiting the general density and size of the area. A buffer can then be drawn around each demand with a radius of this distance. Radiuses are limited to 250m to avoid buffers being generated around the largest demands consuming an unrealistic area.

A total of six clusters with a high potential for district networks have been identified where an indicative annual and peak heat demand has been summarised in Table 7-2 and outlined in Figure 7-3.

Note that the PLA have indicated that West London Boroughs may face more issues related to heat recovery from the Thames due to being able to get the sufficient depth of water required for abstraction and an increase in navigational safety issues.

Table 7-2 Annual and peak heat per cluster identified in Strategic Zones

Cluster ID	London Boroughs included	Annual heat (MWh)	Peak (undiversified) (MW)
1	Hammersmith & Fulham	116,000	70
2	Wandsworth	18,000	10
3	Hammersmith & Fulham and Kensington & Chelsea	121,000	70
4	Wandsworth	16,000	10
5	Westminster, Camden, Islington, and City of London	1,110,000	610
6	Lambeth and Southwark	221,000	120
Total		**1,598,000**	**870**

The annual demand of ~1.6TWh represents over 50% of the projected annual heat availability from the River Thames as noted in Section 4.

Aggregated peak demands in Table 7-2 are undiversified and would likely fall below the calculated peak generated heat output of 621MW as also noted in section 4, following a diversification exercise. Therefore, this initial analysis suggests that there is good alignment with heat availability from the Thames and that the 6 identified strategic zones each have good potential for supporting a viable heat network.

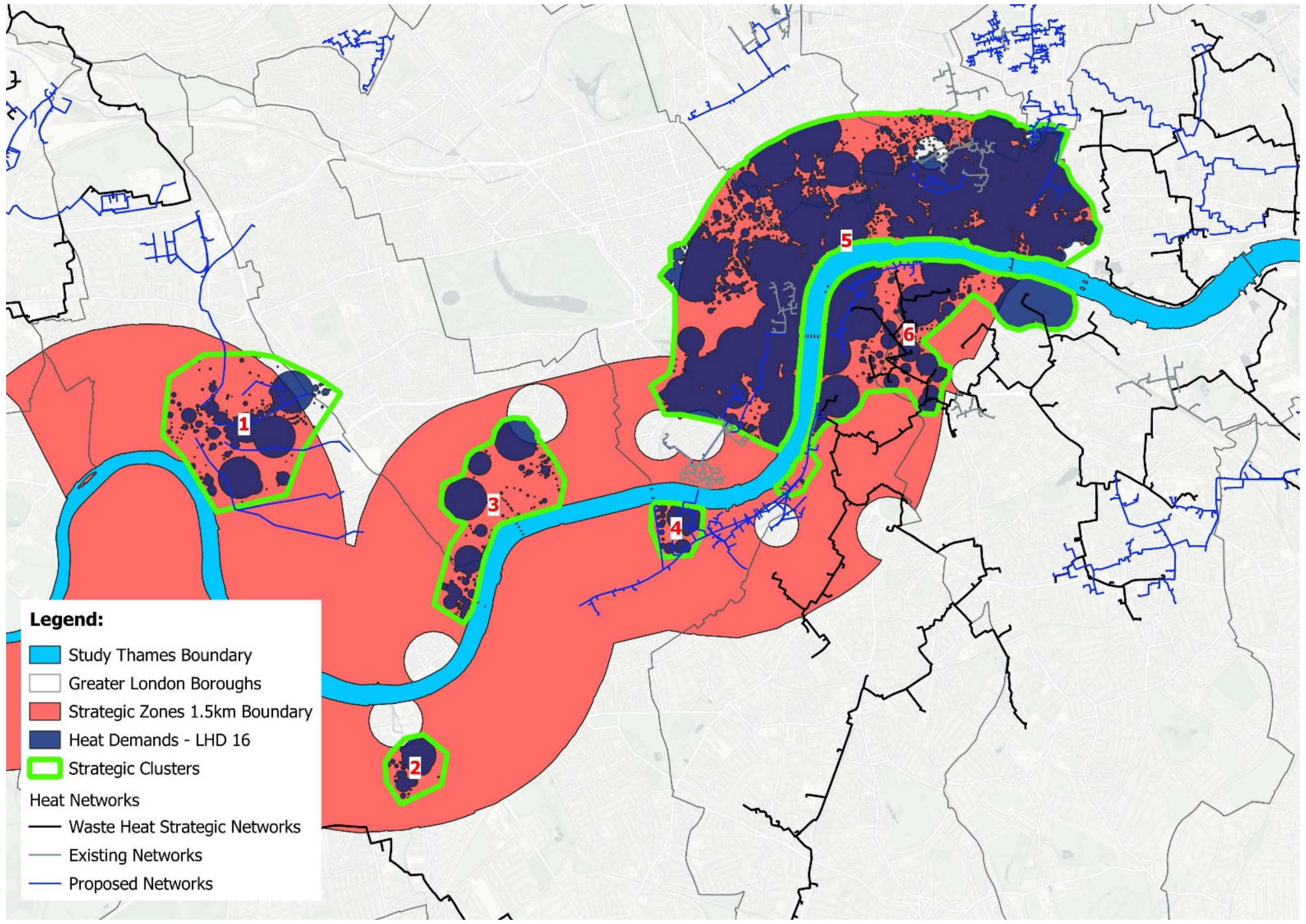


Figure 7-3 Strategic clusters identified within strategic zone

7.3 Identifying Suitable Sites for Large WSHP Schemes

When looking at these strategic zones to locate potential sites for large WSHP schemes there are a number of known constraints and considerations that need to be considered, which include:

1. **Tidal height** – This must be sufficient throughout the year (from PLA data)
2. **Existing Abstraction Infrastructure** - Is there already existing abstraction infrastructure in the river and what is the potential for it to be re-used/re-purposed (some of which is captured in our mapping and Table 7-1).
3. **Existing assets such as piers/jetties** – These may be able to be adapted to carry abstraction or discharge pipework whilst minimising risks of associated impacts such as impacting navigational channels. For example, one site under investigation is understood to be looking at the opportunity for using the existing HMS Belfast jetty.
4. **No navigation channel obstructions** - The PLA is the authority managing the navigation channel. Locating of on river infrastructure within the channel is understood to be forbidden. No detailed information was received around the precise location of the channel.
5. **River land and historical importance** – Avoid identifying river land with historical importance, such as heritage sites, for locating scheme.
6. **Publicly owned buildings on riverside** – Identify if there are publicly owned buildings, especially London Borough or GLA buildings, in the vicinity that have underutilised spaces that could house related energy centre plant.
7. **New development sites** – Space can be safeguarded on development and brownfield sites as well as in new developments to house energy centres. Some opportunities are identified as “opportunity area” in our mapping.

7.3.2 Additional Datasets for Locating Sites

Other datasets related to ownership of buildings in the study area could be useful to identify further potential sites for energy centres on public land. Other ownerships suggested to look at include:

- Map of publicly owned land[6]
- The Crown Estate Coastal Portal[7].

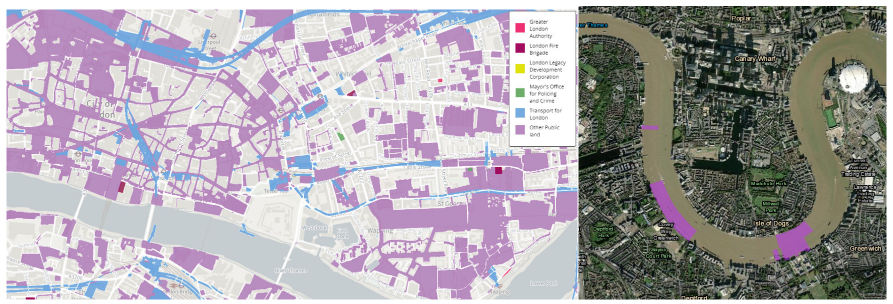


Figure 7-4 (Left) extract from Map of publicly owned land, (right) extract from Crown Estate Coastal portal

[6] https://apps.london.gov.uk/public-land/
[7] https://opendata-thecrownestate.opendata.arcgis.com/apps/0aac22685d2f4d78a2a3b0a5aa1660db/explore

Table 7-3 shows additional datasets which can be obtained from the PLA to help identify suitability of certain sites. They were quoted on January 26th 2024 and are valid for 90 days from that date, so these time-limited quoted prices may vary. The agreement of data is confidential to purchase.

Table 7-3 Port of London Authority Dataset Quotation

ID	Description	Refinement purpose	Quoted price (£)
1	Administration fee	Not applicable.	450
2	River Thames main channel shapefile	Official shapefile from boundary of River Thames used for defining start of riverbed, and therefore pipe length into the river.	0
3	River Thames Creeks line of max depth - extraction and shapefile deliverable	Very shallow (<0.5m*) to be excluded as suitable for a large WSHP schemes, as there is a risk for the abstraction pipe to not be always submerged.	0
4	River Thames Navigationally significant items constraints - extraction and shapefile deliverable	Exclude areas of significant constraint as it would be difficult to install infrastructure.	900
5	February 2023 – January 2024 inclusive, high and low water records for all River Thames tide gauges (Richmond Lock, Chelsea Bridge, London Bridge (Tower Pier), Charlton, North Woolwich (Silverton), Erith, Tilbury, Gravesend (Denton), Coryton (Thameshaven), Southend, Shivering Sands, Margate, Walton) – due to a change in systems data is not available for January 2023	Exclude areas with a low water record (<0.5m*) – there is a risk to exclude a large number of areas, even though the low water depth might happen only very rarely. It would be acceptable to occur rarely, as long as the WSHP heat network scheme is design with full supply resilience.	0
6	February 2023 – January 2024 inclusive, 60-minute tidal height data for all River Thames tide gauges (Richmond Lock, Chelsea Bridge, London Bridge (Tower Pier), Charlton, North Woolwich	The tidal height data would enable dismissing areas where the tidal heights is too low for a significant portion of the year, i.e. 20%*.	5,820
7	Total cost of item 1 to 6	Not applicable.	7,170

*arbitrary figure

7.3.3 Opportunities & challenges for river heat recovery identified by Stakeholders

Table 7-4 Stakeholder identified opportunities and challenges through the engagement process

Challenge identified	**Cited by**
Downplaying of risks around large-scale scheme and infrastructure for pushing decarbonisation agenda. Complexity of having structures in channel not to be underestimated; anything in the river could be hit and therefore navigation issues need to be mapped.	PLA
Thames is a silty river. Challenge of keeping abstraction equipment adequately maintained and implication of in-channel maintenance along with potentially regular disturbances.	PLA
Heritage buildings and their river frontages are no-go zones for any type of infrastructure.	PLA
Navigation docks and high navigation activity spots are no-go zones for infrastructure.	PLA
Challenge of decarbonising the City of London as they do not have any other obvious low-carbon source apart from the river. For example, they have no Energy from Waste facilities or Data centres and so could be the type of riparian borough that river heat makes the most sense for.	CoL
The main environmental concern in regard to river temperature is any activity that could lead to an increase.	EA
Fish and eel safety, adequate nets and infrastructure (eel regulation 2009).	EA
Concern over scouring (force of abstraction and discharge) and net loss of riverbed habitat.	EA
Accessing land from the side of the river is usually an underestimated challenge: ownership, construction, temporary infrastructure, traffic management etc.	EA
Concern over chemical pollutants and water treatment required for scheme.	EA
A big issue is linked to return temperatures and mixing zones, and that water can take several days to move down to the outer estuary. This impact will depend on the scale of the system, with greater impacts with larger systems (i.e. 20MW).	EA
The twice daily tides push the water upstream so fisheries colleagues have particular concerns about the general warming of the inter tidal Thames. There is a considerable amount of temperature data collected at various points, which is a useful starting point when considering such a scheme.	EA
Fish/eel screens and approach velocities of water being abstracted and keeping screens clear can be another challenge.	EA
Tidal mud flats are important conservation areas. Workings which can influence and/or affect any of our flood defence walls will also need to be considered.	EA
Noise of energy centre in river/riverbed or riverbank. Noise nuisance complaints from residents. If so, acoustic screening would be required, according to Pollution act section 60 & 61.	PHA
Poor communication to communities and residents around construction works and its impacts, work can be very disruptive.	PHA
Opportunities identified	**Cited by**
Numerous piers are owned by TfL and could have the required depths to be hosting water abstraction kit. Possible investment in bringing back to life older piers for purpose of large scale WSHP scheme and the associated benefits that this could provide for using the structures again for other types of activities or to create additional habitats as well.	PLA, GLA
City of London owned several buildings on the riverbed which could potentially host infrastructure.	CoL
CoL is aware of pre-application of riparian major developments, which will be interested in investigating WSHP for their energy strategy (ie: Bridge Foundation).	CoL
It is much easier to use an existing jetty rather than seeking permission to install abstraction pipes in the Thames, due to both sensibility and cost this can have.	EA
if the intention is for a heating-based scheme and returning cooler water then some of the above concerns do not necessarily become apparent. One-way flap-valves to prevent creatures from exploring such pipework when no discharge is occurring are useful.	EA

8 Counterfactual Analysis

This section summarises a high-level cost analysis which compares energy centres with different scales of either WSHP or ASHP driven plant as a baseload energy supply.

8.1 Definition and Methodology

A high-level assessment of the techno-economic performance of comparable size heat networks has been conducted. This is

1. ASHP driven energy centres.
2. WSHP driven energy centres abstracting water from the River Thames.

Three levels of capacities have been tested: 2MW, 10MW and 20MW where scenario references can be found in Table 8-1.

Elements of the system design which have been considered to reflect the differences between ASHP's and WSHP's include:

- Pumping/abstraction station house – for the WSHP
- Pumping cost of abstracting river water for the WSHP vs fan power for the ASHP
- WSHP vs. ASHP COP
- Cost of abstraction and discharge infrastructure for the WSHP
- Spatial requirement for the primary plant
- Downtime for maintenance:
  - i.e. backwash cycle for WSHP and clearing of the filtration system
  - Defrost cycles for ASHP's

Where elements are the same across the two options then these have been excluded from the analysis e.g.:

- Primary & secondary network
- Primary Distribution pumps
- Consumer substations
- Electrical infrastructure
- Thermal stores
- Mechanical ancillaries, controls

Table 8-1 Scenario references and descriptions

Reference Scenario	Description	Capacity (kW)
1	ASHP	2,000
2	ASHP	10,000
3	ASHP	20,000
4	WSHP	2,000
5	WSHP	10,000
6	WSHP	20,000

The following expenditures have been considered against the different scenarios for each technology:

- Capital Expenditure (CAPEX): costs related to upfront purchase of plant and equipment.
- Operating Expenditure (OPEX): costs related to the operation and maintenance plant and equipment as well as fuel consumption and ongoing business costs.
- Replacement Expenditure (REPEX): ongoing costs incurred as part of a sinking fund to replace plant and equipment at end of life.
- Fuel costs: combination of standing charge and variable fuel costs consumed by the plant.

This model compares the cost between the solutions on an annual basis, hence the total replacement costs for the product has been equally divided by its lifetime to obtain an annual figure. Indicative results are obtained for 2024 conditions and include additional typical uplifts for delivery, installation, plantroom design, and commissioning of equipment. Where possible, budget quotations were obtained for each level of capacity to allow for an informed comparison between the solutions.

Detailed assumptions which inform the analysis, such as assumed seasonal efficiencies and fuel tariffs, can be found in Appendix B.

8.2 Comparison Results

8.2.1 Energy and Carbon

Indicative carbon emissions are presented in Table 8-2 and Figure 8-1.

- Electricity consumption relates only to the power needed for the heating technology, including parasitic demands.
- Heat consumption is converted to electrical power by applying a typical SCOP of 2.5 for an ASHP and 3.5 for a WSHP for each technology. The increased efficiency observed in WSHP's results in a decrease in electricity consumption and, consequently, lower carbon emissions.
- Overall power carbon emissions are calculated per scenario using a carbon grid factor of 0.149 kgCO2/kWh obtained from Greenbook DESNZ datasheet.

Table 8-2 Annual carbon intensity of heat per scenario option

	ASHP	ASHP	ASHP	WSHP	WSHP	WSHP
	2 MW	10MW	20MW	2 MW	10MW	20MW
Carbon intensity of heat (kgCO2/kWh)	0.0656	0.0656	0.0656	0.0498	0.0498	0.0498

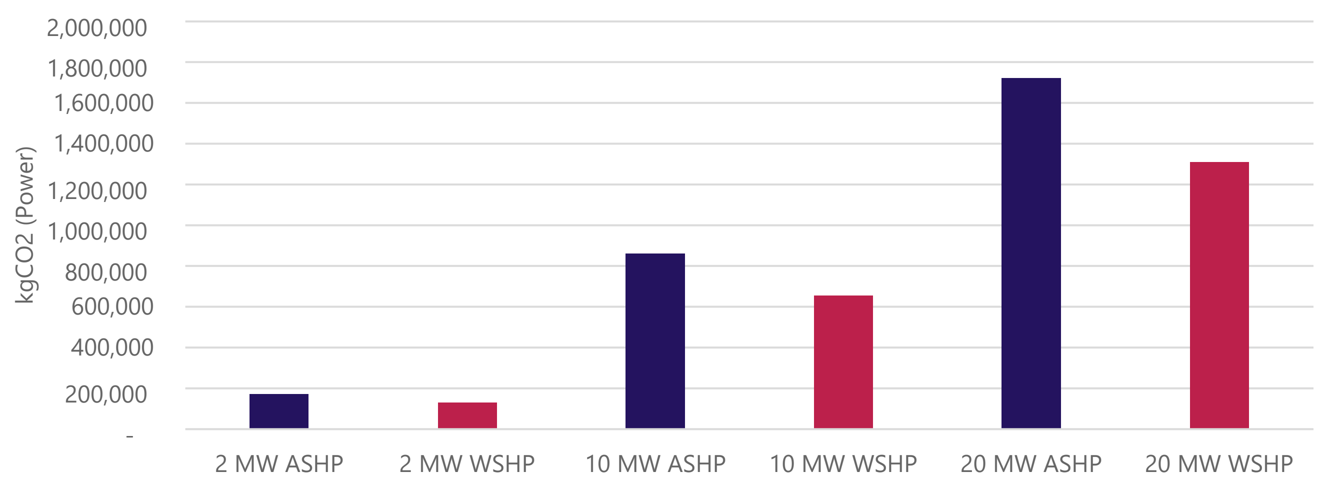


Figure 8-1 Annual power carbon emissions per scenario for each technology

8.2.2 Costing Comparison

Results are presented in Figure 8-2 and Table 8-3 In summary, it is evident that the capital costs associated with the implementation of a WSHP solution are likely to be considerably higher than those for an ASHP. This is primarily due to the additional equipment needed, despite the reduced operational, maintenance, and fuel costs associated with water source heat pumps resulting from their enhanced efficiency.

Total cost of installation and operation over a 20-year period are more comparable for each scenario, particularly with the 2MW systems.

Table 8-3 Capital, replacement, and operational expenditures comparison per scenario for each technology

	ASHP	ASHP	ASHP	WSHP	WSHP	WSHP
	2 MW	10 MW	20 MW	2 MW	10 MW	20 MW
CAPEX (£)	2,599,000	9,418,000	16,397,000	4,936,000	19,216,000	36,490,000
Annual REPEX (£/yr)	99,000	359,000	625,000	96,000	378,000	689,000
Annual OPEX (£/yr)	264,000	1,266,000	2,496,000	212,000	1,002,000	1,966,000
Undiscounted total costs during 20 year operation (£)	9,859,000	41,918,000	78,817,000	11,096,000	46,816,000	89,590,000

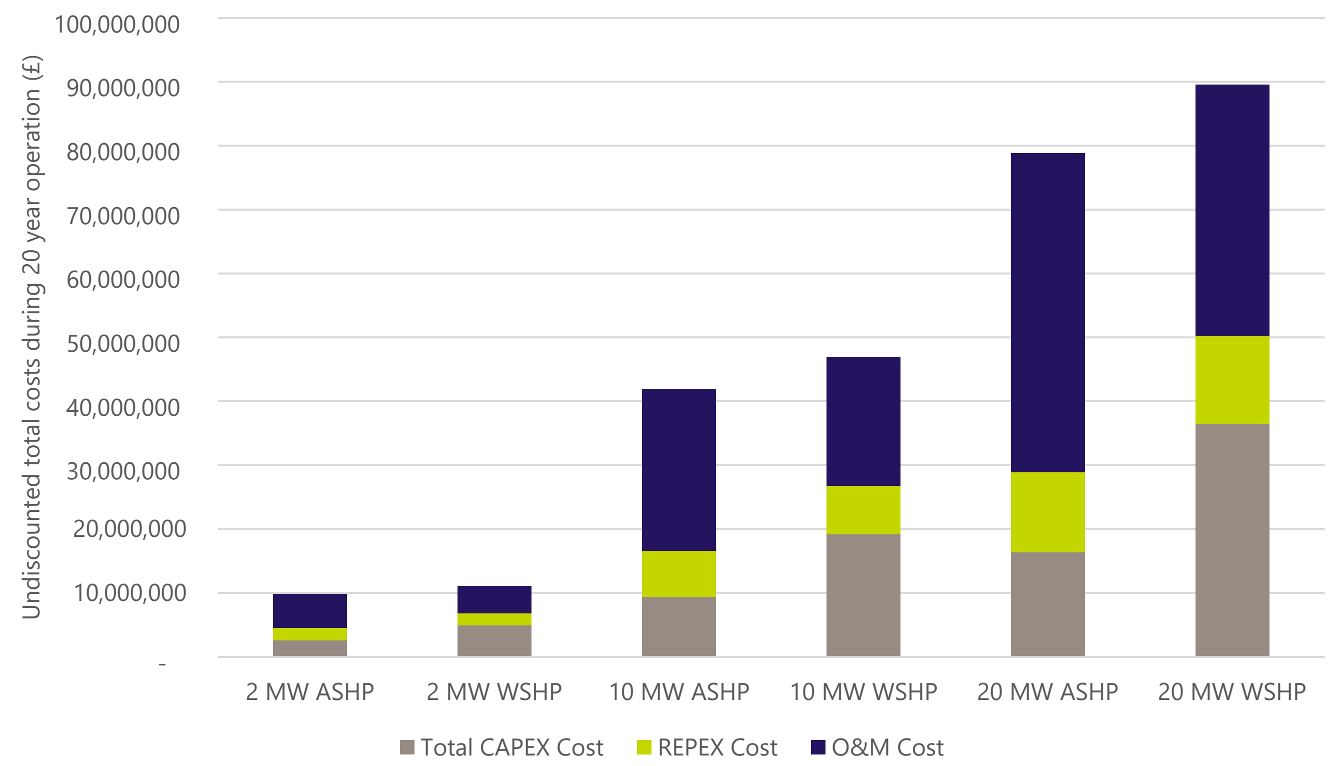


Figure 8-2 Estimated Counterfactual costing comparison over a 20 year operation between both solutions across three different sizes

A qualitative comparison for both technologies is displayed in Table 8-4.

Table 8-4 Costing comparison between both technologies

Expenditure Type	ASHP	WSHP
CAPEX	Lower due to minimal additional plant equipment required to operate	Higher due to the additional equipment required, such as abstraction screens, plate heat exchangers, pumps and more
REPEX	Same as above	Same as above
OPEX	Higher due to having a worse SCOP	Although the operational and maintenance costs required for a WSHP are higher, the overall OPEX is lower due to the improved efficiency which results in reduced fuel costs.

8.3 Spatial Requirement

An indicative layout has been produced to convey the key differences in spatial requirements between the ASHP and WSHP options. Similar to the counterfactual costing assessment, only plant and equipment which will vary for each solution has been considered.

An additional 20% area requirement has been factored in to accommodate network ancillaries. A 50% increase in area for the pumping and filtration equipment has been added to account for typical spacing required from pipework and general access.

Two scenarios of 2MW and 10MW have been investigated to provide comparisons between both solutions for a small scale and large scale development.

Components included within each scenario are shown in Table 8-5 Table 8-5.

It is assumed that all plant and equipment will be situated within the same energy centre, whereas in reality it would likely be required to be hosted across multiple energy centres for the larger sized schemes.

Table 8-5 Components included per scenario for both technology solutions

Component	ASHP (no. units)	ASHP (no. units)	WSHP (no. units)	WSHP (no. units)
	2 MW	**10 MW**	**2 MW**	**10 MW**
Evaporator beds	6 (3 per 1MW)	6 (3 per 1MW)	N/A	N/A
Compressor cabinets	30 (3 per 1MW)	30 (3 per 1MW)	6 (3 per 1MW)	30 (3 per 1MW)
Shunt pumps	N/A	N/A	1	5
Abstraction pumps	N/A	N/A	3 (1 x 95L/s + 2 x 85L/s)	6 x 100 L/s
Plate heat exchanger skids	N/A	N/A	3 x 1MW	3 x 3.6MW
Filters	N/A	N/A	2	5

Based on the sizing and component assumptions, the total area per technology solution and scenario size is summarised in Table 8-6. The subsequent figures show the indicative layouts for comparison.

Overall, the total footprint required for an ASHP solution comes out larger than that of a water-source heat pump solution, requiring 6% more space in the 2MW scheme and 53% more space in the 10MW scheme. This is a direct result of the large evaporator beds situated on the rooftop of the building.

However, when comparing ground floor space required the additional equipment and pump house required for the water-source heat pump solution the footprint is almost doubled for the ASHP solution. It is likely that a 10MW scheme for an WSHP would need to be located across several energy centres. Acquiring this space can be challenging in London due to the dense concentration of buildings as well as air dispersion issues around the evaporators which may dictate a practical size limit from the plant, even if it were possible to locate the plant spatially.

Table 8-6 Initial footprint comparison per technology solution for two different sizes

Technology Solution	Location	2 MW Scheme - Area (m^2)	10 MW Scheme - Area (m^2)
ASHP	Rooftop	250	1,090
	Energy centre (groundfloor)	170	720
	Total	**420**	**1,810**
WSHP	Pump and filtration house	80	130
	Energy centre (groundfloor)	315	1,060
	Total	**395**	**1,190**

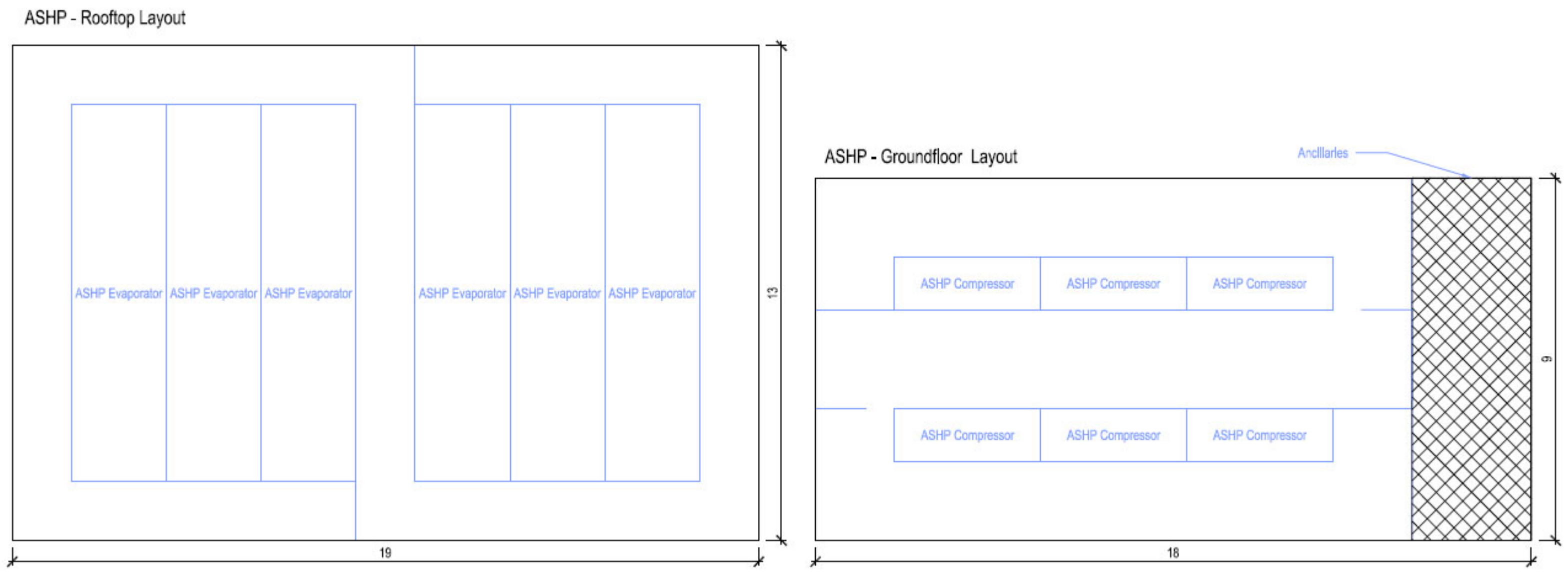


Figure 8-3 2 MW ASHP scheme rooftop and ground floor footprint

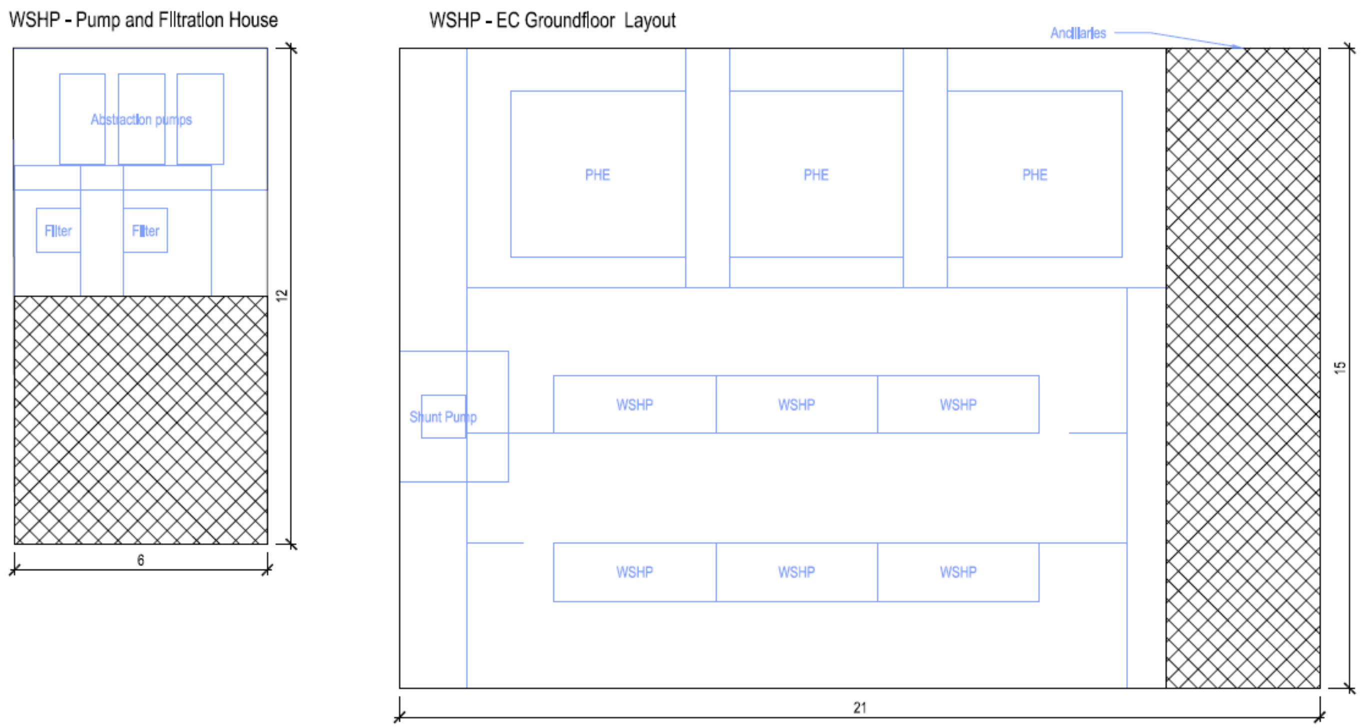


Figure 8-4 2 MW WSHP scheme energy centre and pump house footprint

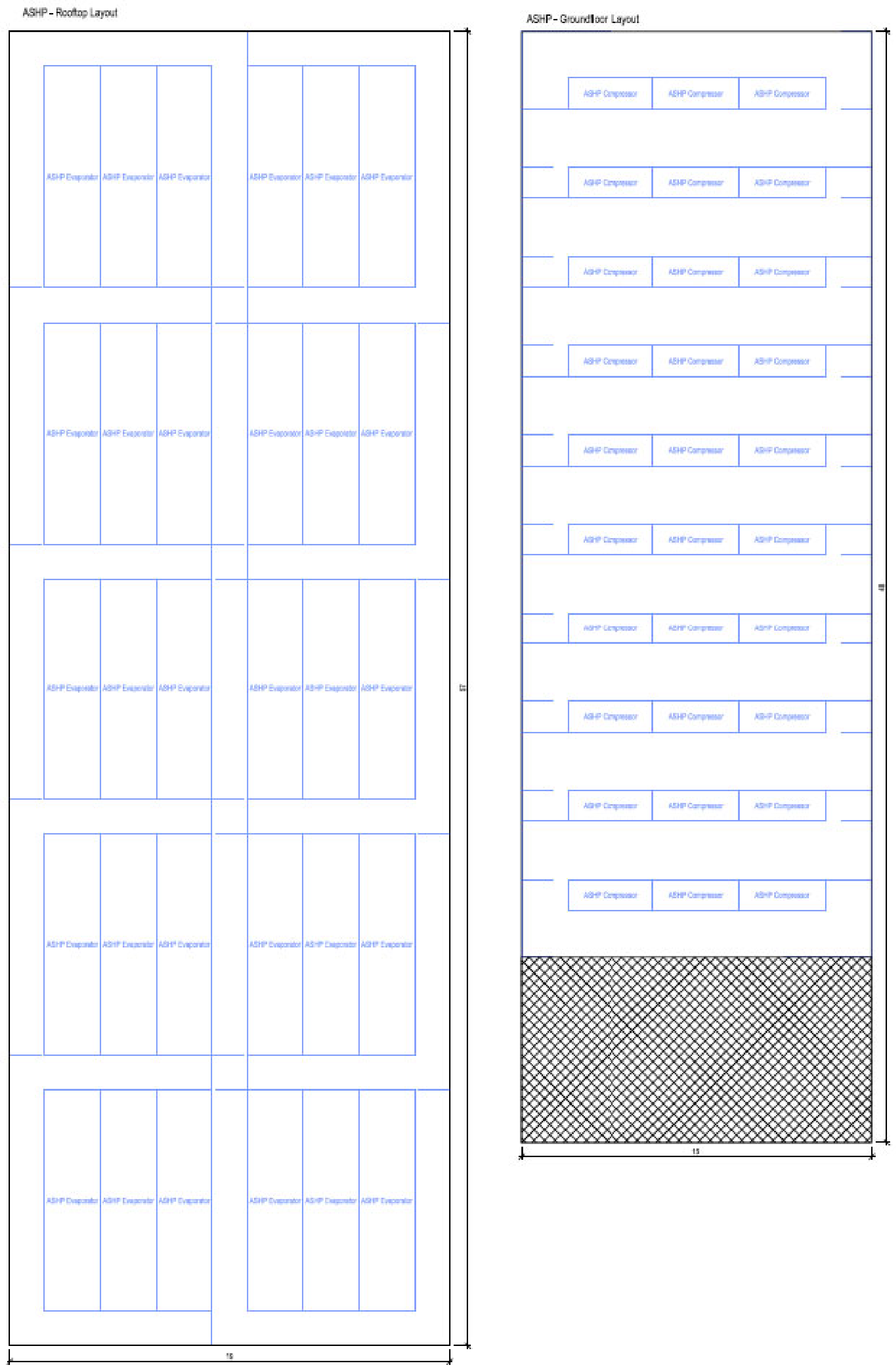


Figure 8-5 10 MW ASHP scheme rooftop and groundfloor footprint

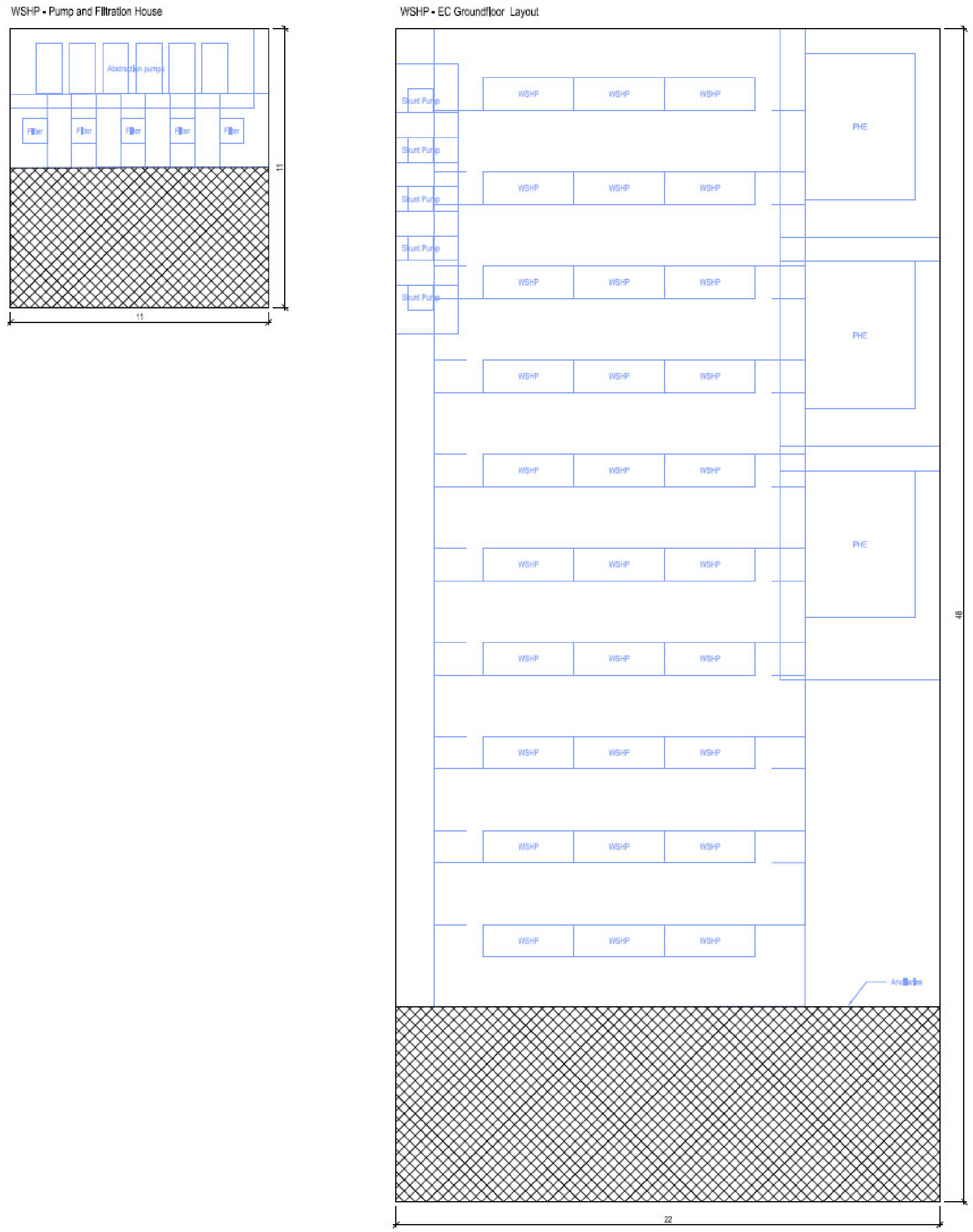


Figure 8-6 10 MW WSHP scheme energy centre and pump house footprint

9 Conclusions and Next Steps

The River Thames is a major feature of Greater London and a potentially significant energy asset. Whilst it is a significant resource for heat it is only capable of providing a fraction of London's overall heat demand and it is important to consider this opportunity within a strategic London-wide perspective. Therefore, taking a strategic approach to secondary heat utilisation and heat network development, looking at this heat source alongside other identified waste heat sources in London, allows heat utilisation and ultimately heat network coverage to be optimised in a way that supports London to meet its 2030 Net Zero ambition.

The river has a high potential to provide large scale water source heat pump-led heat network projects, provided regulatory requirements can be met, and using the approach suggested above would allow this heat source to be optimised for supporting heat networks along the river around inner London that have limited or no other secondary heat sources available to them. In many of these inner London riverside areas, the only alternative low carbon heat source is likely to be an ASHP scheme which, at the scales required, is likely to cause technical constraints including capacity from the grid, roof space and cold air dissipation. Based on findings from the counterfactual study ASHP schemes could have smaller costs primarily resulting from the lack of additional equipment, such as abstraction screens, pumps, etc, required, balancing out the higher OPEX requirements from having a reduced efficiency in comparison to a WSHP scheme. However, the improved efficiency allows for a reduced carbon intensity figure and overall carbon emissions associated with WSHP schemes. Overall footprint is larger for the ASHP solution associated with the required evaporator beds; however the counterfactual assessment shows higher ground floor footprints for the WSHP solution. It is possible that the difference between ground floor footprint required would be reduced when detailed sizing of the electrical items and infrastructure is taken into consideration. This is because the lower efficiency seen for the ASHP could equate to larger electrical demand and electrical infrastructure.

Currently, the approach for utilising the River Thames as a heat source for decarbonising heating or cooling supply to buildings is carried out on an individual project per project basis. There is potential for London Government - GLA, London Councils and London Boroughs - to play a co-ordinating role with the regulators and heat network developers for how best to utilise the heat from the River Thames as part of London's wider approach to decarbonising heat and getting to Net Zero.

There are a number of potential next steps to consider when thinking about how best to take this work forward:

- **Further technical work**
    - Unless there is already a model in existence (not identified as part of this study), develop and run a dynamic model of the River Thames, to test how potential schemes could impact on one another (for example whether a large scheme supplying a heat network in Hammersmith and Fulham would have a downstream impact on the amount of heat available for schemes in Westminster or Battersea) as well as any opportunities for schemes in tributaries or further down the estuary. This would also allow for testing the sensitivity of the river for using it for simultaneous cooling where demand is significant enough.
    - More detailed analysis of locations for installing on/in-river plant and equipment to recover heat and energy centres for elevating and distributing heat into the local heat network should be undertaken. And, if there is agreement with the suggested key strategic clusters identified as part of this report then these locations should be focussed on initially.
    - Further investigation of existing river infrastructure that could potentially be repurposed for supporting heat offtake infrastructure.
    - A more detailed analysis could be carried out on one or more of the projects in London which have been identified in this report and are already exploring the river as a potential heat source as this would help verify the techno-economic analysis that has been carried out as part of this study.
    - Further consideration of challenges raised by stakeholders, shown in section 7.3.3, and implementing means to combat these challenges. Such as:
        - Implementation of self-cleaning filtration systems and regular maintenance schedules to prevent silt buildup.
        - Monitoring river temperatures and using modelling to predict the impact of return temperatures and mixing zones by having multiple EC locations within a study and not just on a site by site basis.
        - Overall use of additional control measures to support these challenges.

- **Coordination of schemes**
    - London Government may wish to integrate this opportunity with the wider waste heat study that the Buro Happold-led Programme Development Unit (PDU) have also produced to help bring a more strategic approach to how heat networks and related partnerships are identified and developed, as part of a wider approach to decarbonising heat supply in London. This would also allow for engagement with the sub-regional Local Area Energy Plans (LAEPs) that London Boroughs are developing with the GLA and London Councils. And, by looking to create these strategic multi-borough heat networks it, of course, will allow London to be even better placed for the introduction of Heat Network Zoning regulation in 2025 and the activity that will flow from that.
    - Engage with potential network developers, new developments and building owners to encourage them to come together to look at the wider strategic opportunity of multi-borough heat networks rather than just their own site(s) or local needs. This would mean that there may be potential for fewer, larger projects that would realise the benefits of economies of scale in siting, construction and operation which would be able to better serve the need for large-scale decarbonisation of heat supply in London.
    - London Government should continue to support the engagement with major waste heat sources outside of the strategic zones in this study to support the development of multi-borough heat networks that maximise river heat availability and its use in riparian areas of London that need it most.
    - Currently individual schemes are approaching the regulators on a project-by-project basis and decisions are consequently being made on a project- by- project basis, there is an opportunity to develop a more joined up approach to optimising the low carbon heat potential of the River Thames that would also reduce the burden on projects and the regulator. Note that the regulators have indicated that existing permitting regulations only allow them, as a regulator, to permit, or otherwise, proposals as and when they are actually presented to them. Depending on support for a more strategic use of heat from the river and the impact of heat network zoning there may need to be a change in the legislation or the marine planning/land use planning regime to enable this strategic prioritisation to be carried out by a third party, for example the Zone Coordinator.

Appendix A River Thames Energy Capacity Research National Heat Map

A.1.1 Methodology

To determine the potential heat capacity from water source heat pump implementation across England a constraints map was produced in GIS (Geographic Information System) that allows for the analysis and integration of data within a spatial database.

The environmental constraints considered are shown in Figure 9-1, and allow for the exclusion of areas not suitable for WSHPs.

The primary focus of this study was on the requirement of space heating that occurs over the winter months.

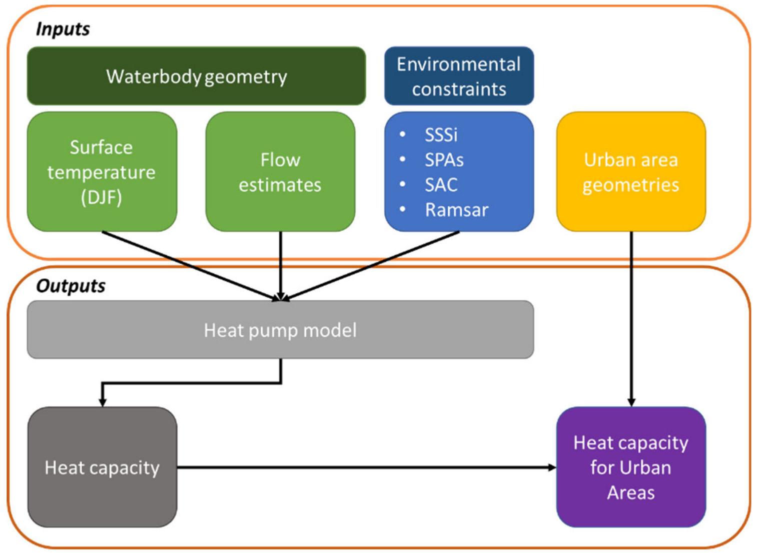


Figure 9-1 Overall flow chart of methodology (taken from the National Heat Map)

An exercise to obtain the raw data inputs such as surface water temperature and flow estimates was undertaken using various sources for to obtain this information for all the local waterbodies. If data was missing for a specific waterbody it was excluded from the analysis. Winter temperatures was interpolated to approximate the exact temperature seen at the points where flow data was also available.

A limitation on the quantity of river flow that can be abstracted is determined by the EA's use of the Environmental Flow Indicator (EFI), which set a threshold for annual flow exceedances where anything beyond could cause adverse ecological effects.

This information, along with the inclusion of the assumptions listed in the chapter below, was input into a basic heat pump model to determine available heat capacity.

Urban area geometries were then obtained based of Ordinance Survey Data to identify key areas of development. These areas were assessed to check if a river was situation within a 1km radius. In cases where a portion of the river intersected with the relevant area, the heat capacity was determined based on the furthest downstream point. In situations where multiple rivers were present, each one was individually assessed, and their respective heat capacities were combined.

Assumptions

The following assumptions were used within the methodology in various parts of the analysis.

Table 9-1 Assumptions used to support the generation of heat capacity from waterbodies within the National Heat Map study

Figure	Unit	Description
3	°C	Maximum allowable change to waterbody temperature set as an absolute limit to WSHP heat abstraction
N/A	°C	Average temperature changes used as detailed daily profiles not available at each location
3	°C	Winter mean temperatures should not be reduced below this figure, limiting the allowable waterbody temperature change
N/A	N/A	Open loop set up for heat pump model using a plate heat exchanger
3	°C	Minimum temperature that the plate heat exchanger (PHE) can operate at before ice crystal formation for freshwater
1	°C	PHE gradient for fresh and saltwater
-2	°C	Minimum temperature that the PHE can operate at before ice crystal formation for saltwater
N/A	N/A	Water availability use Q95 data from source model for rivers

Appendix B Counterfactual Analysis

B.1 Costing Comparison Assumptions

Table 9-2 Key assumptions made in counterfactual costing model

Component	Value	Unit	Description	Source
ASHP	2.5	kW/kW	SCOP	Solid Energy AWB HP
ASHP	950,000	£	Capital cost of ASHP of 1MW	Solid Energy AWB HP
ASHP	15	Yrs	Plant lifetime	CIBSE Guide M
ASHP	2	% CAPEX	O&M cost as a percentage of CAPEX	Solid Energy
ASHP	116,100	£	Acoustic housing cost for a 600 kW ASHP	Clade
WSHP	5	°C	Temperature differential for abstraction pumps	Buro Happold Experience
WSHP	3.5	kW/kW	SCOP	Solid Energy AWB HP
WSHP	750,000	£	Capital cost of ASHP of 1MW	Solid Energy AWB HP
WSHP	15	Yrs	Plant lifetime	CIBSE Guide M
WSHP	3	% CAPEX	O&M for WSHP	Buro Happold Experience
WSHP	1187	£/m^2	Water loop pump and filtration house	Average from previous BH projects
WSHP	35,991	£/#	Water loop abstraction screen	Average from previous BH projects
WSHP	600	£/kW	Water loop abstraction infrastructure	Average from previous BH projects
WSHP	20	£/kW	Water loop PHEX	Average from previous BH projects
WSHP	59	£/kW	Water loop filtration	Average from previous BH projects
WSHP	200	m	Water pipework to EC	Buro Happold Experience
WSHP	2,129	£/m	Water pipework to EC cost	Average from previous BH projects
WSHP	25	yrs	Water loop plate heat exchanger lifetime	CIBSE Guide M
WSHP	15	yrs	Abstraction pumps lifetime	CIBSE Guide M
WSHP	15	yrs	Water filtration and abstraction equipment	CIBSE Guide M
General	20	%	Commissioning & construction	Buro Happold Experience
General	5	%	Plantroom design	Buro Happold Experience
General	15	%	Contingency	Buro Happold Experience
General	80	%	REPEX as a % of CAPEX	Buro Happold Experience
General	19.56	p/kWh	Non-Domestic fuel tariff	DESNZ, Green Book supplementary guidance
General	63	p/day	Non-Domestic standing charges	Average of standing charges received from energy providers
General	0.149	kgCO2/kWh	Electricity carbon factor	2024 Prediction from Greenbook DESNZ figures published November 2023
General	19.9	%	Inflation 2020-2024	Office for National Statistics
General	18.7	%	Inflation 2021-2024	Office for National Statistics
General	16.1	%	Inflation 2022 – 2024	Office for National Statistics
General	7.0	%	Inflation 2023 – 2024	Office for National Statistics

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