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VALE OF GLAMORGAN COUNCIL

RENEWABLE ENERGY ASSESSMENT

OPPORTUNITIES FOR A DISTRICT HEAT NETWORK IN BARRY

MARCH 2023

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OPPORTUNITIES FOR A DISTRICT HEAT NETWORK IN BARRY

MARCH 2023

FINAL

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CONTENTS

FIGURES

EXECUTIVE SUMMARY

This report investigates the opportunity for a district heat network to be deployed in the town of Barry as part of the Renewable Energy Assessment prepared by Wardell Armstrong. Greenfield completed a feasibility study investigating the implementation of a heat network in the town of Barry in 2019. This report provides a summary of the Greenfield report and comments on it in the context of policy and economic changes since 2019.

The report presents the benefits of a low temperature districting heating scheme, which include reduced heat losses in the network, reduced costs and additional flexibility of heat delivery to consumers. Key risks of deploying a district heat network include the longevity of a reliable heat source, economic feasibility and volatile energy prices. There could be opportunity for waste heat from the proposed green energy hub at Aberthaw Power Station to be input into a district heat network and piped into Barry. There could also be an opportunity for waste heat from the production of hydrogen to supply a district heat network in Barry.

1 INTRODUCTION

1.1 Background

1.1.1 This report is an additional output from the Renewable Energy Assessment carried out by Wardell Armstrong (WA) for the Vale of Glamorgan Council (VOGC). We understand these reports will be used as part of the evidence base informing the upcoming Local Development Plan and will sit alongside our existing study examining the decarbonisation of the Vale of Glamorgan (also known as 'The Vale' and referred to as this from now on).

1.1.2 Greenfield Group[1] completed a feasibility study investigating the implementation of a heat network in the town of Barry in 2019 (Appendix 1). This report aims to provide a summary of the Greenfield report and comment on it in context of policy and economic changes since 2019.

1.2 Location and Environment

1.2.1 The Vale is a county borough in the southeast of Wales. It borders the counties of Rhondda Cynon Taf to the north, Cardiff which is directly to the east, and Bridgend to the west. The Bristol Channel is directly to the south and forms a coastal boundary for the county, with the beautiful Glamorgan Heritage Coast stretching for 14 miles from Aberthaw to Porthcawl.

1.2.2 The town of Barry is one of the largest industrial towns in Wales. It has a population of 53,353 and spans over 18.59km[2]. Figure 1.1 shows a satellite image of Barry from Google Earth.

[1] Greenfield Group (June 2019) 'Barry Heat Network Masterplanning: Draft Report'. Electric Works, Shefield.

[2] City Population (2023) *Barry.* Available from: https://citypopulation.de/en/uk/wales/admin/the_vale_of_glamorgan/W04000650__barry/ [Accessed 24 March 2023].

Figure 1.1: Town of Barry. Source: Google 2023, TerraMetrics, Data SIO, NOAA, U.S Navy, NGA, GEBCO

2 POLICY CONTEXT

2.1 Vale of Glamorgan Local Development Plan 2011 – 2026 (2017)

2.1.1 Policy MD19 relates to Low Carbon and Renewable Energy Generation within The Vale. This policy suggests that favourable consideration will be given to development proposals that involve the use of energy and/or heat from renewable or low carbon generation. This could relate to the establishment of a District Heat Network (DHN)[3].

[3] Vale of Glamorgan Council (2017) *Local Development Plan: Written Statement.* Available from: https://www.valeofglamorgan.gov.uk/Documents/Living/Planning/Policy/LDP/LDP-Adoption/Adopted-LDP-Written-Statement-June-2017-final-interactive-web-version.pdf [Accessed 08 February 2023].

3 METHODOLOGY

3.1 General Approach

3.1.1 The Greenfield 2019 report demonstrates the techno-economic feasibility of a heat network in Barry. This report aims not to replicate the previous study but to add value by identifying relevant policy and economic changes since this report was produced that would affect a DHN project in Barry. The benefits of a low temperature scheme will be considered, as well as key risks and opportunities.

4 POLICY REVIEW

4.1.1 Since the 2019 Barry Heat Network study there have been some key policy updates which are summarised below.

4.2 Future Wales: The National Plan 2040

4.2.1 Policy 16 relates to Heat Networks. The Plan highlights priority areas for heat networks, which includes Barry. It states that planning authorities should identify opportunities for DHNs and plan positively for their implementation. It suggests large mixed-use developments should, where feasible, have a heat network with renewable/low carbon or waste heat as the energy source[4].

4.3 Local Authorities and the Sixth Carbon Budget (2020)

4.3.1 This report by the Climate Change Committee suggests local authorities need to identify areas suitable for heat networks which are effective in providing low-carbon heat to dense areas. It also suggests '*public buildings can form anchor loads for heat network investments*.[5]' This report suggests DHNs can be key to decarbonising council buildings.

4.4 Net Zero Wales Carbon Budget 2 (2021 – 2025)

4.4.1 This plan focuses on the second carbon budget (2021 – 2025) for Wales. It sets out pathways for each emissions sector. Policy 28 – *Scope out the challenges and opportunities around low-carbon heat* and Policy 29 – *Increase the use of waste heat and low carbon heat sources* set out the high level policy requirements for exploring opportunities for developing heat networks within Wales.

[4] Welsh Government (2021) Future Wales: The National Plan 2040. WG, Cardiff.
[5] Climate Change Committee (2020) *Local Authorities and the Sixth Carbon Budget.* CCC, London.

5 SUMMARY OF GREENFIELD HEAT NETWORK REPORT

5.1 Energy Supply Options

5.1.1 The report identified five supply options:

- Water Source Heat Pumps
- Hybrid WSHP / Gas CHP
- Heat recovery from Dow Chemicals principal heat rejection plant (using WSHP)
- AVIVA Biomass power station: heat recovery from steam cycle
- AVIVA Biomass power station: heat recovery from heat rejection unit (using WSHP)

5.2 Heat Network Options

5.2.1 The report identified two heat network opportunities. The first option connects prospective consumers around the dock area and south part of the town centre. Key consumers include Barry Waterfront Development, Barry Leisure Centre and council offices. Figure 5.1 shows the network route in option one.

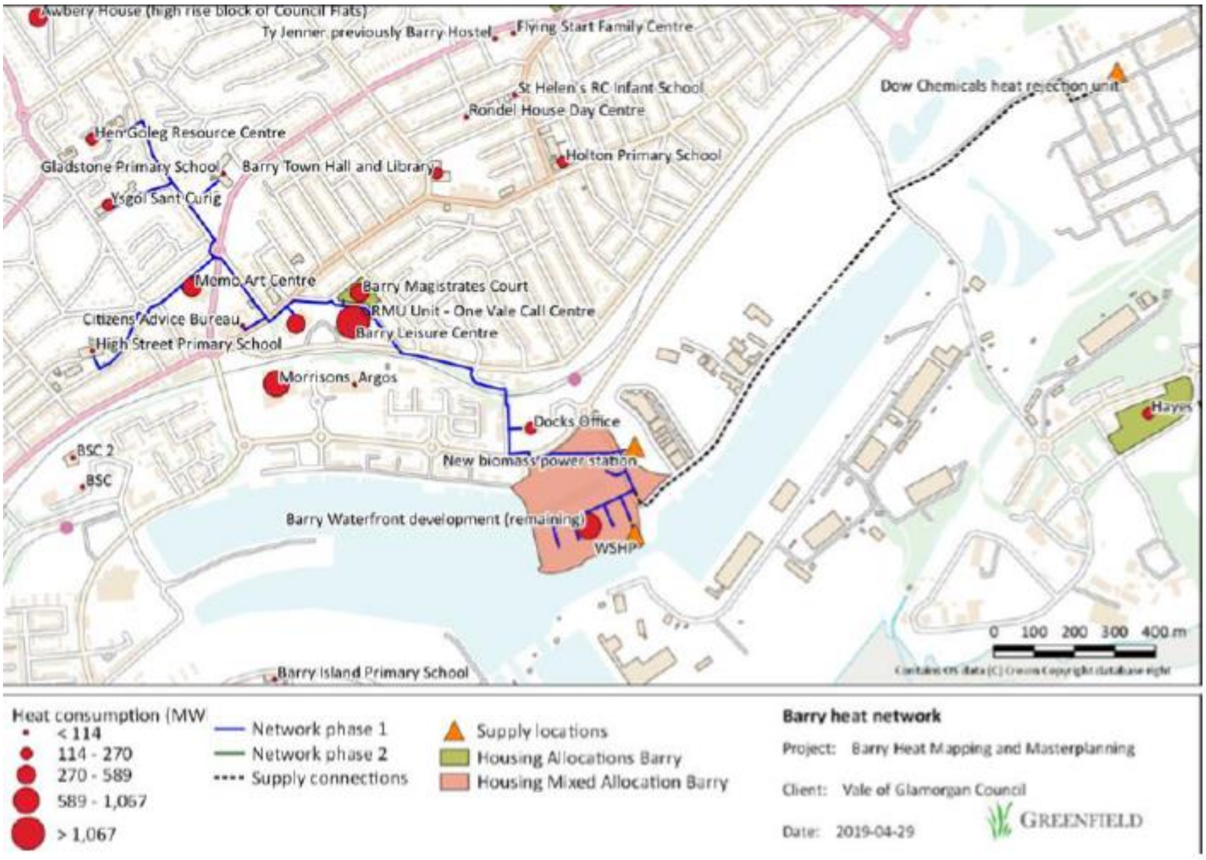


Figure 5.1: Heat Network Option One. Source: Greenfield Report

5.2.2 The second option is an extension of the first option and would include some relatively large consumers in the east of Barry including Barry Hospital, Cardiff and Vale College, and Awbery House. Figure 5.2 shows the network route in option two.

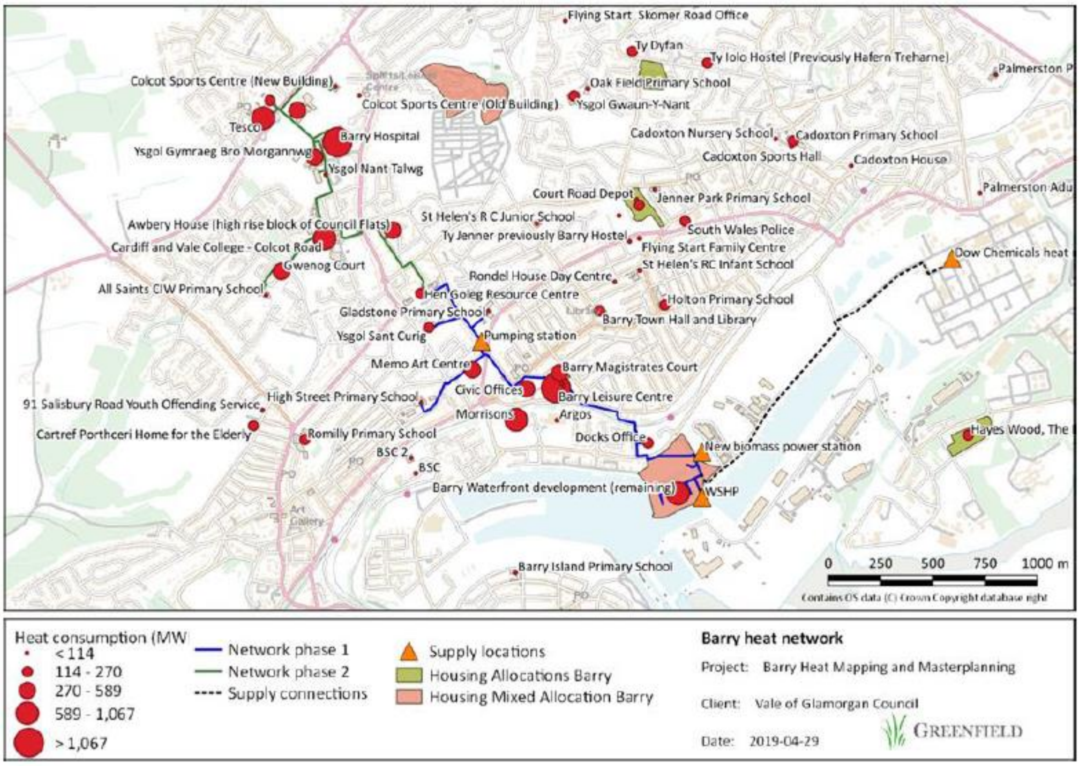


Figure 5.2: Heat Network Option Two. Source: Greenfield Report

5.3 Economic performance

5.3.1 The IRR & NPV 25-year figures show negative or marginal performance on all options.

5.3.2 There is negligible difference in economic performance of the two networks.

6 LOW TEMPERATURE HEAT NETWORK

6.1.1 The 2019 report identified two design changes which could present opportunities. The first was to design a low temperature scheme. There are various types of heat networks that have evolved in different 'generations' of design. Third generation designs originated in the 1970's and involve high temperature networks. Fourth generation designs operate at much lower temperatures providing efficiency gains and can be integrated into smart energy systems. Fifth generation networks have the ability to provide heating and cooling and operate at near ambient temperatures.

6.1.2 High temperature networks are the more common variant currently and tend to be sourced by gas CHP, Biomass CHP, energy from waste plants or other surplus industrial heat. They operate at temperatures that can be used directly for heating and domestic hot water in residential developments, usually via a heat interface unit.

6.1.3 Low Temperature Heat Networks (LTHN) operate at much lower temperatures and are generally a two-stage system with heat pumps, solar or low-grade waste heat providing the initial ambient heat usually circulating water at temperatures of 10-25 degrees Celsius lower. They then also use a further water to water source heat pump in each property or building to elevate the ambient temperatures to more useful heating temperatures once inside.

6.1.4 A LTHN could be a more attractive option to the high temperature scheme considered in the Greenfield report. Potential benefits from a low temperature scheme:

- Reduces heat losses through transportation in the pipelines
- Reduces operating costs and plant costs
- Adds flexibility to the network
- Ability to use save costs using plastic pipes instead of steel pipes

6.1.5 The efficiency gains are the primary driver for LTHN schemes. The reduced heat losses will also result in reduced distribution costs.

6.1.6 An example of the nominal heat loss in a high temperature and low temperature scheme is demonstrated from the extract in Figure 6.1.

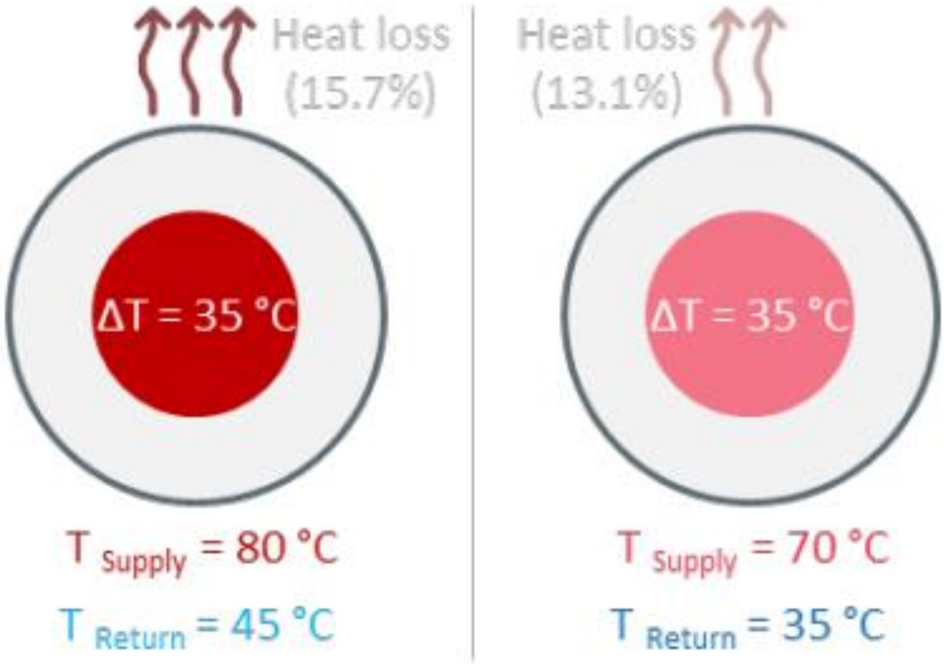


Figure 16. Example of heat loss in a district heating network for design system temperatures (80/45 °C, left) and reduced system temperatures (70/35 °C, right)

Figure 6.1: Difference between heat losses in a high and low temperature scheme. Source: Low-temperature District Heating Implementation Guidebook (2021)

7 RISK

7.1.1 The success of a district heating plan relies on the longevity of a reliable heat source. VOGC have taken enforcement action over planning concerns at Barry Biomass[6]. As there is some uncertainty around the future of Barry Biomass, this adds considerable risk to using the plant as a source waste heat. Any DHN would need to include a reliable source of waste heat for the lifespan of the network.

7.1.2 Economic performance is considered to be the overarching risk of the project. Since the invasion of Ukraine in February 2022, energy prices have increased dramatically and remain volatile. This price volatility exacerbates this economic risk.

[6] Vale of Glamorgan Council (2021) *Council takes enforcement action over Barry Biomass Plant*. Available from: https://www.valeofglamorgan.gov.uk/en/our_council/press_and_communications/latest_news/2021/August/Council-takes-enforcement-action-over-Barry-Biomass-Plant.aspx [Accessed 27 March 2023].

8 OPPORTUNITIES

8.1.1 In 2022, the Cardiff Capital Region which represents the 10 local authorities in South East Wales have agreed to acquire the Aberthaw Power Station with ambitious plans to transform it to a green energy hub. This masterplan for the redevelopment if built will seek to deliver renewable and green energy projects and a zero-carbon manufacturing cluster that would include green hydrogen production facilities.

8.1.2 There could be opportunity for waste heat from these operations to be input into a DHN and piped into Barry. This would require high infrastructure costs as the power station is circa 5.3 miles from Barry Docks.

8.1.3 In February 2021, The South Wales Industrial Cluster (SWIC), led by CR Plus and Costain was established focusing on developing the infrastructure to enable large scale industrial decarbonisation across Wales and beyond. There could be an opportunity for waste heat from the production of hydrogen to supply a DHN in Barry. Figure 8.1 displays the location of the key features of the planned SWIC infrastructure in the southwest Wales region.

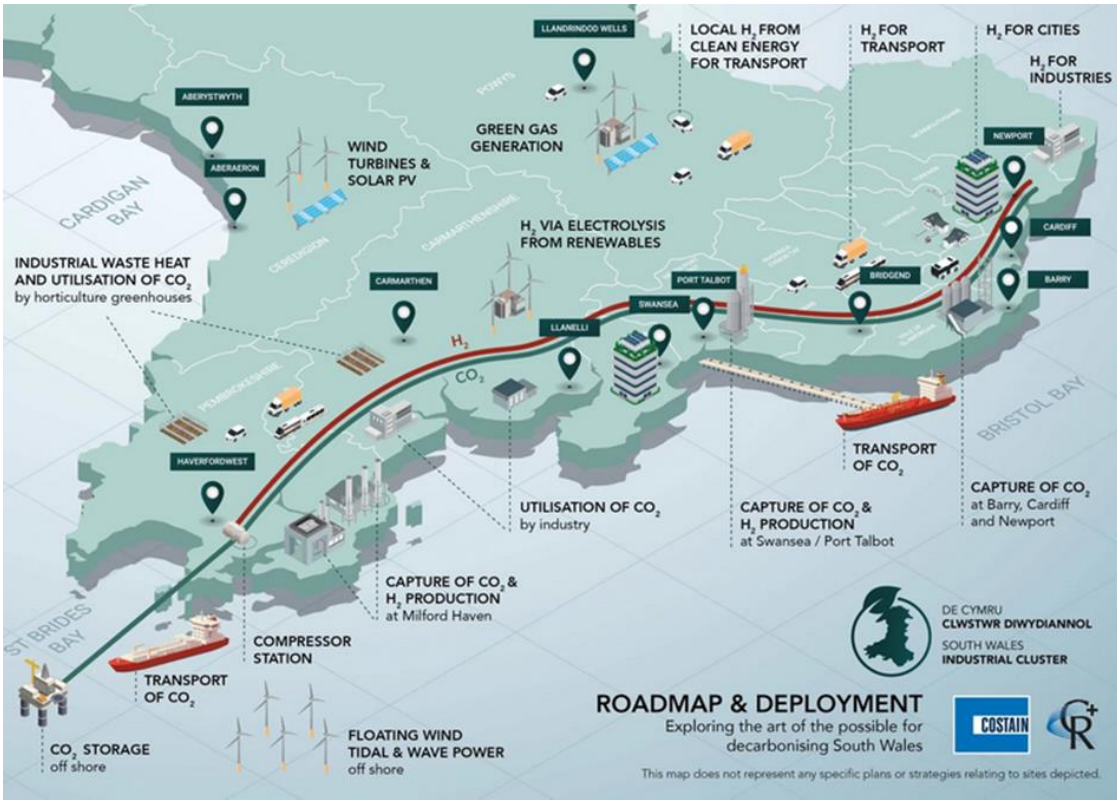


Figure 8.1: Decarbonising South Wales with deployment of hydrogen and CCUS infrastructure

9 CONCLUSION

9.1.1 The economic case for a DHN was weak in 2019. Due to the current fluctuations in global energy prices, the economic case for a DHN in Barry will be less stable. For a DHN project to be viable in Barry it would likely need to be subsidised.

9.1.2 The Greenfield Report investigated the possibility of a high temperature DHN. However, it recognised designing the network as a low temperature scheme could deliver significant benefits. The flexibility, higher efficiency and reduced costs from a low temperature network might make this option more feasible. Although the economic case will likely remain unattractive.

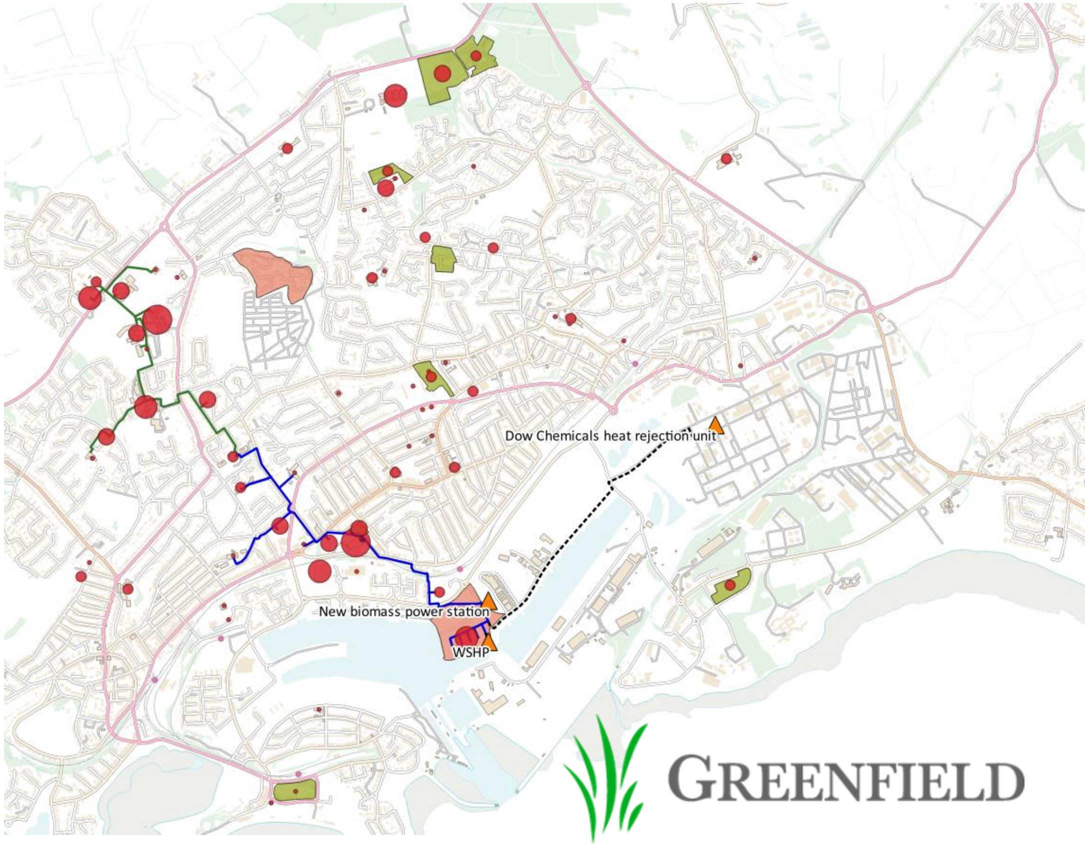
9.1.3 There could be other sources of waste heat in future as the SWIC and the Aberthaw Power Station green hub develops. These should be investigated as plans progress to assess to feasibility of supplying a DHN in Barry.

Appendix 1: Greenfield Barry Heat Network Masterplanning Report

BARRY HEAT NETWORK MASTERPLANNING

Draft report

June 2019



REPORT DETAILS

Report	Barry heat network masterplanning		
Version	0.1	1st Draft report	06 June 2019
Author(s)	Robert Clark, Oskari Fagerstrom, Sami Sihvonen		
Contributors	NA		
Contract Reference	NA		

The information provided in this report is for general information only and should not be relied on to inform investment decisions or technical design specifications.

It is not intended that the content and analysis in this report should be relied upon as the basis for commercial bids; bidders are expected to carry out their own due diligence and form their own technical and commercial solutions.

GREENFIELD

Table of Contents (with section hyperlinks)

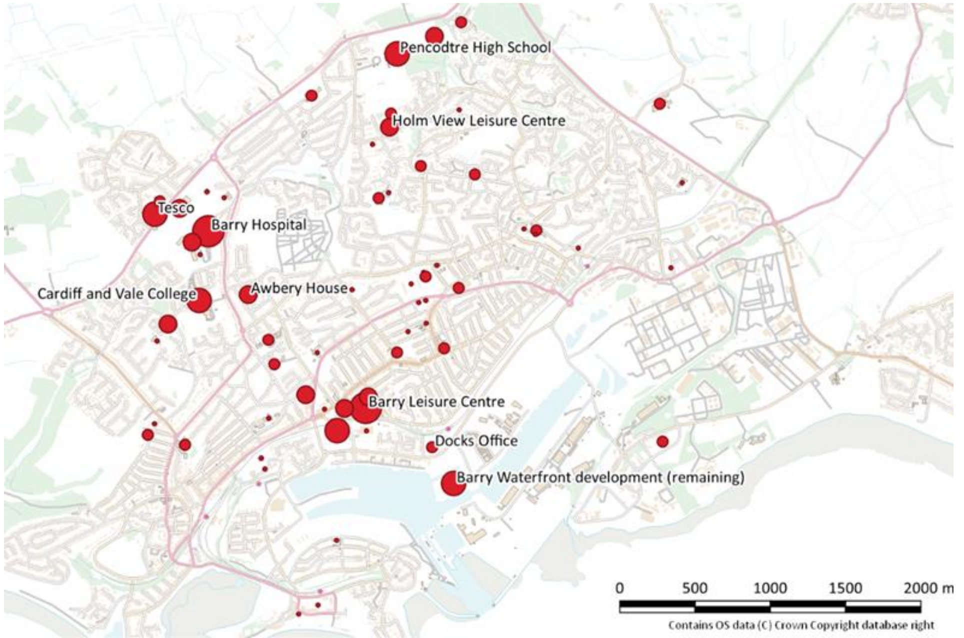
GREENFIELD

Executive Summary

This study has examined the feasibility of implementing a heat network within the town of Barry. The investigation is described as a Mapping and Masterplanning exercise, which would typically be followed by a Detailed Feasibility study, where viable heat networks have been identified. The report shows the stages of work from collection and estimation of energy demand, assessment of supply opportunities, the identification of heat network scenarios (consumers and supply options) and the subsequent concept design development and techno-economic testing of these.

Identifying consumers

A range of prospective consumers were identified, primarily by Vale of Glamorgan Council. They prospective consumers are primary existing buildings but some new development is also included. Energy consumption data was received from the council and where required independent estimates of energy consumption where made – see demand map.



Energy supply options

Three principal energy technologies where identified: heat recovery of the Aviva biomass power plant (located near to the Dock area), Heat recovery from the Dow Chemicals facility and the use of the heat pumps extracting heat from the docks. In all five supply options were analysed:

- Water-source heat pumps (WSHP)
- Hybrid WSHP / Gas CHP
- Heat recovery from Dow Chemicals principal heat rejection plant (using water sourced heat pumps)
- AVIVA Biomass power station: heat recovery from steam cycle
- AVIVA Biomass power station: heat recovery from heat rejection unit (using water sourced heat pumps)

GREENFIELD

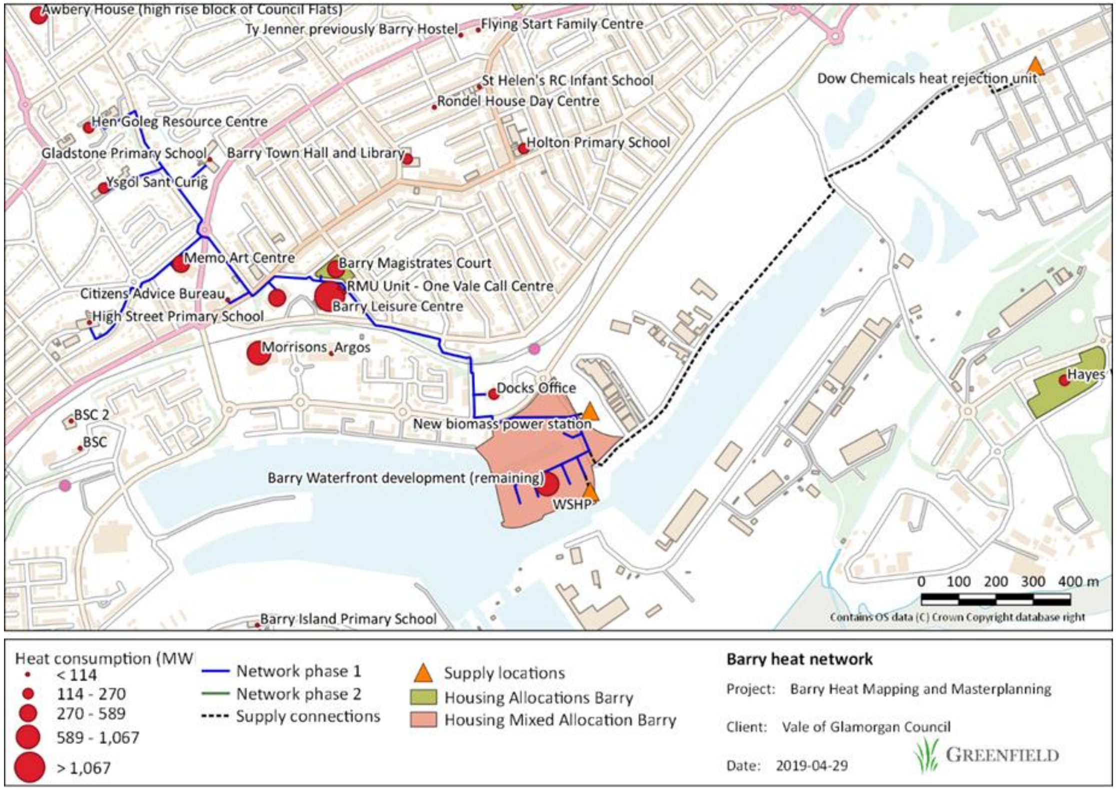
Executive Summary

Heat network options

Spatial examination of the prospective consumers and potential supply point lead to the identification of the two distinction heat network opportunities for which initial design solution were developed. The first option was to connect consumers around the dock area and the south part of the town centre as shown by the blue in the map.

Key consumers in this network include the Barry Waterfront development, Barry Leisure Centre and council offices. To access the town centre will be necessary to cross the rail line, the preferred solution for which would to use the Subway Road crossing, although there are other options.

Subway Road tunnel



The network has a low linear heat density (annual energy demand per length of connecting pipe) in region of 1.3 GWh/km.

The WSHP and Aviva supply location are in close proximity to the Barry Waterfront, whereas use of the Dow heat recovery options would require a long heat pipe connection across the dock area (shown by dotted black line)

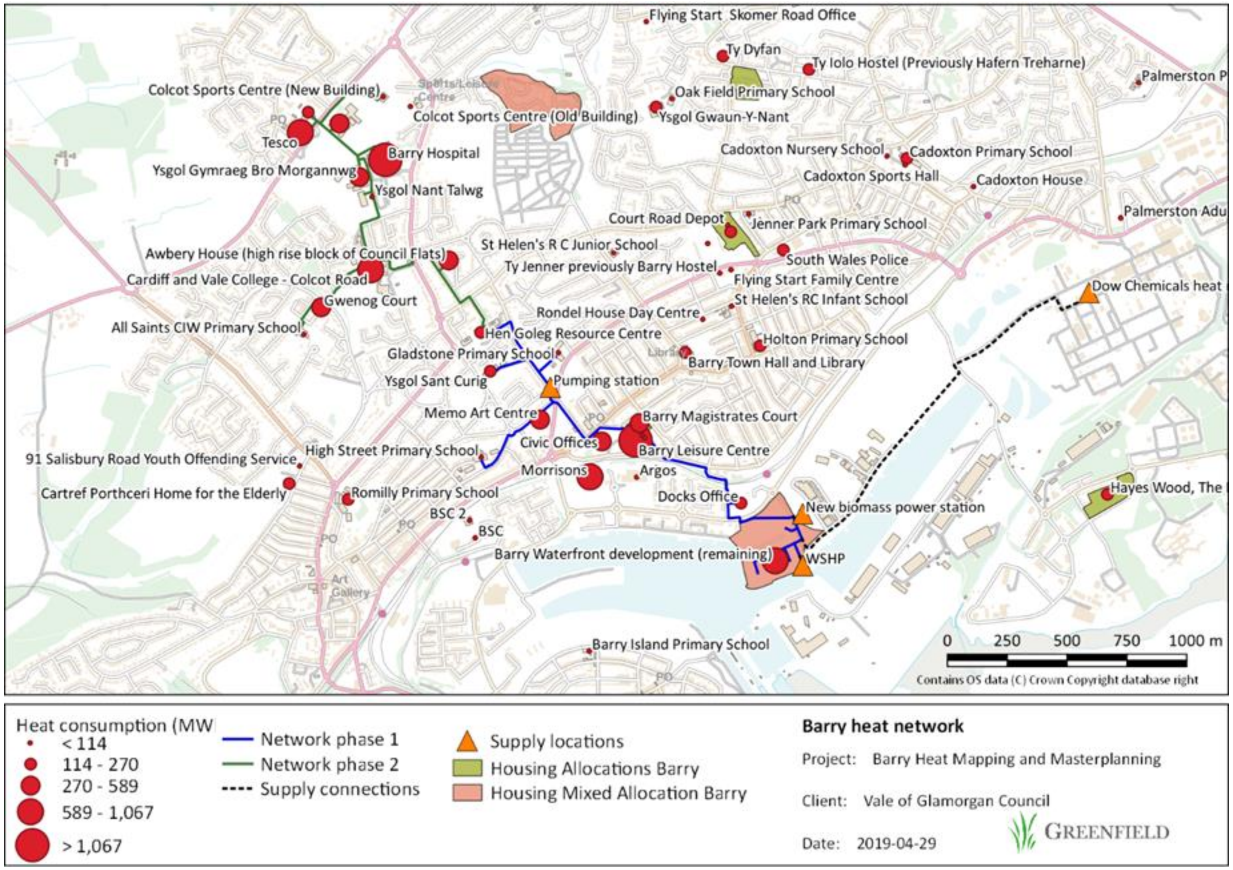
GREENFIELD

Executive Summary

The second network option is proposed as an extension of the Docks/Town Centre network, shown as a green line on the map. This would pick up a number of relatively large consumers in the east of Barry including Barry Hospital, Cardiff and Vale College, and, Awbery House (apartments). The change in elevation of the extended network will require the installation of a pumping close to Memo Arts Centre, to minimise pressures throughout the network.

The linear heat density of the full network is in the region of 1.7 GWh/km which whilst still low as significant improvement on the Docks/Town Centre network.

Whilst additional relatively large consumers are located in the north-east of the town, few prospective large consumers where identified through the centre of the town. Considering an branch connection to the north-east is only considered plausible if more consumers were identified in the central area.



Executive Summary

Economic / carbon performance of the networks identified

Designs for the heat network options were developed, including sizing of energy supply plant/energy centres, sizing of the required heat pipe infrastructure. Capital costs were estimated and detailed techno-economic models were developed to estimate economic performance and the carbon reduction benefits. The table below summarises the outcomes of the analysis.

Barry Docks and Town Centre						
		WSHP	Gas CHP + WSHP	Dow Chemicals HR	Aviva Biomass 'high-grade'	AvivaBiomass low-grade
Capital costs	£m	7.3	7.9	9.2	6.5	7.6
IRR-25yr	%	-1.2 %	0.2 %	-0.4 %	-1.9 %	2.1 %
NPV-25yr	£m	-3.6	-2.7	-3.8	-3.3	-1.1
CO_2 savings over 25 yr	%	39%	33%	45%	48%	73%
Extension to Colcot Rd Area						
Capital costs	£m	13.5	14.2	15.3	11.8	14.2
IRR-25yr	%	-1.7 %	0.1%	0.2%	-2.2%	2.2%
NPV-25yr	£m	-7.2	-5.0	-5.3	-6.2	-1.8
CO_2 savings over 25 yr	%	39 %	30%	51%	48%	72%

Key findings:

- The IRR & NPV figures (25-year) show negative or marginal performance on all options - largely driven by low heat density
- There is a negligible difference in economic performance of the two networks
- The best performing supply solution is the ‘low-grade’ heat supply from the Aviva plant which is driven by the assumed relatively low cost (of waste heat) and low power prices (to run the heat pumps and energy centre).
- The data shows that that the hybrid WSHP/CHP should be selected on economic grounds in favour of the options with WSHP on its own.
- The analysis also shows that Aviva ‘low-grade’ option out performs the ‘high-grade’ option in economic and carbon terms
- A sensitivity analysis also showed that there are opportunities to improve the economic case through further design iterations. The following would be of particular value: reducing capital costs, increase the scale of the demand (in close proximity to identified consumers) and exploring lower energy costs particularly with the Aviva or Dow heat recovery options.

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Executive Summary

Grant support

- Assuming no further improvements are made to the economic case, the grant support required is shown below to take the project options to an IRR of either 5% or 7%. The results highlighted in grey identify the technology options and IRR outcome combination that likely to be achieve-able, i.e. not been ineligible due to state aid rules (assumed to be 50% of capital costs), although this would need to be verified.
- Hence:
  - the Aviva 'low-grade' option and should be eligible in up to and beyond 7% (in fact as shown early IRRs of over 10% could still be eligible – taking the project into the realm of being privately fund-able)
  - the Dow and WSHP/CHP hybrid options are only possible to an IRR of between 5% and 7%

Barry Docks and Town Centre						
		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass 'high-grade'	AVIVA Biomass 'low-grade'
IRR 5.0 %	£m	4.1	3.4	4.5	3.6	1.9
	%	56.1 %	43.2 %	49.0 %	55.2 %	25.2 %
IRR 7.0 %	£m	4.4	4.0	5.1	3.8	2.7
	%	61.1 %	50.5 %	55.4 %	59.1 %	35.3 %
Extension to Colcot Rd Area						
IRR 5.0 %	£m	8.0	6.2	6.6	6.7	3.4
	%	59.3 %	43.6 %	42.9 %	57.2 %	23.9 %
IRR 7.0 %	£m	8.5	7.2	7.7	7.1	4.8
	%	63.3 %	50.4 %	50.0 %	60.4 %	34.1 %

GREENFIELD

Executive Summary

Heat Network benefits

There are a range of economic and environmental benefits that would be derived from these heat network options, assuming they were developed. In summary they are:

- A general 5% reduction in consumer energy costs (the basis for revenue modelling) and mitigation of future energy cost increases. This value can be varied to, each to support fuel poverty goals or encourage consumer connections, but it would have an impact on the rates of return for investors.
- Operational benefits for consumers including reduced plant liability and releasing property floor space
- Reduction in short term carbon emissions of between 30% and 73% for connected consumers – (depending on supply technology)
- Potential to deliver deep and sustained carbon reduction through expansion across the other parts of the town, over time
- Inward investment into the town of between £6m to £16m, depending on option
- Development of a local energy generation / supply entity
- Encourage commercial/residential tenant retention in the town

Project risks

In addition to the overarching risks of not being able to achieve the required economic performance (as discussed previously) there are a number of addition risks. Many risks are typical of a heat network scheme within an urban area like Barry and the following are identified that the most important ones:

- Securing already identified and new consumers.
- Securing heat supply arrangements: WSHPs and heat recovery (with Dow and/or Aviva), including a location of required energy centre.
- Development Governance: assuming the council leads the development process it will be important to developed capacity and capabilities.
- Potential network construction and servicing risks, primarily: crossing the rail line and laying infrastructure within the highways.
- Renewable Heat Incentive revenues: RHI is due to close in quarter 1, 2021 if it nor an alternative is not available the renewable heat options will be difficult to justify or require greater grant support.

GREENFIELD

Executive Summary

Recommendations / next steps

At this early stage of investigation, the heat network options, as conceived, appear to be deliverable (with several significant risks) but not capable of achieving reasonable commercial performance unless there are further design improvements or grant support is accessed. If delivered, a heat network would provide benefits to consumers and to the town in terms of reducing energy costs, economic development and providing a solution to long term decarbonisation of heat consumption, which would otherwise be very difficult to deliver.

It is recommended that the council conducts a detailed feasibility study into a heat network solution within Barry, focusing on opportunities to improve the case for investment, including identifying new consumers, value engineering, securing the preferred supply options and addressing key risks. It is recommended that three supply options are considered from which to select a preferred solution, whilst retaining others as fallback options, should the preferred solution prove not to be deliverable. The WSHP without CHP and the Aviva 'high-grade' solutions should be excluded from further consideration as they are not likely to meet the economic performance requirements.

Key improvement opportunities should be considered: adding addition consumers, seeking market equipment and construction costs, refining input assumptions over the bulk heat and power costs from Dow and Aviva and addressing design and development risks.

It is recommended that a detailed feasibility should also consider how best the council could develop its skills and capabilities to manage the development of a heat network project and also explore ownership and governance options.

1. Introduction

The scope of this study was to examine the feasibility of implementing a heat network within the town of Barry. The investigation is described as a Mapping and Masterplanning exercise, which would typically be followed by a Detailed Feasibility study, where viable heat networks have been identified. The work covered here designed to be compliant with UK Heat Network Code of Practice (CP1).

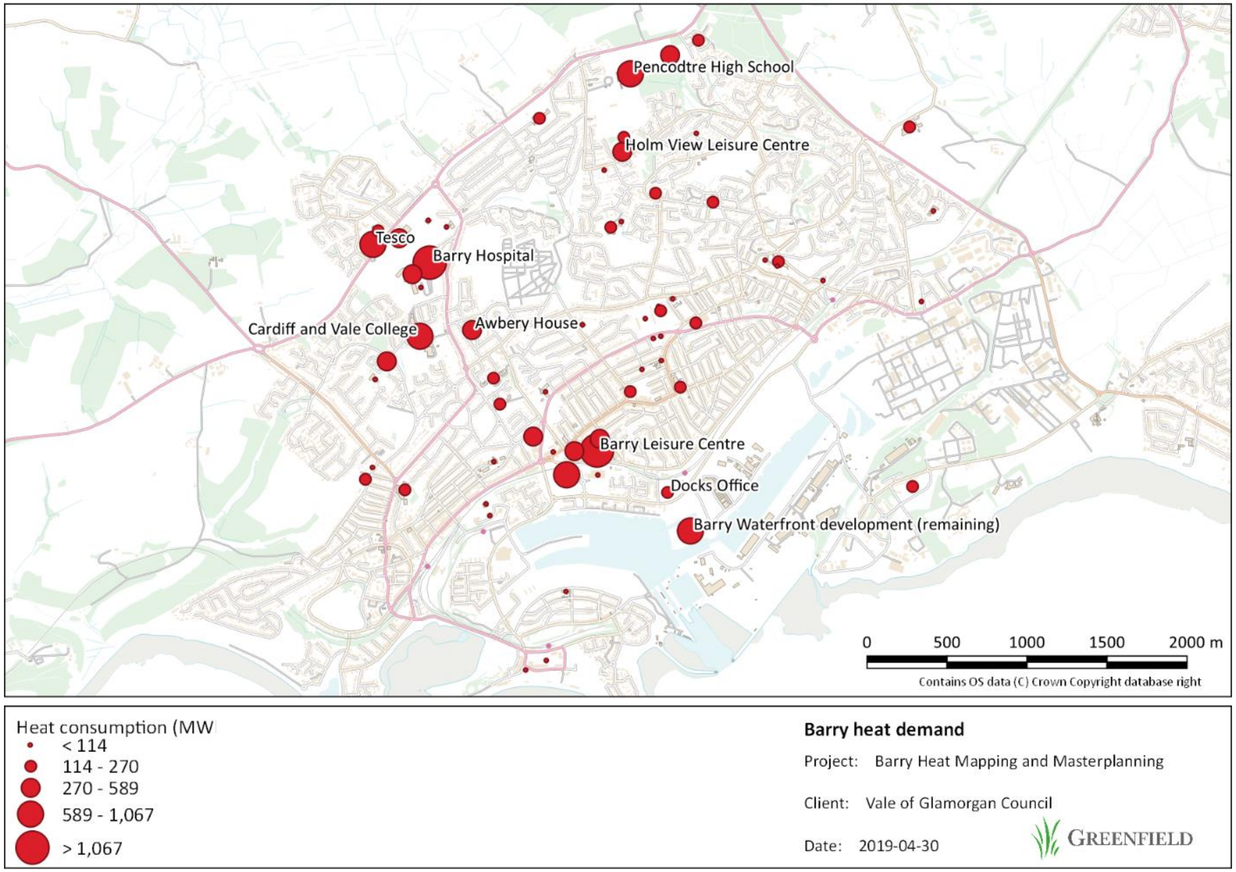
The report shows the stages of work from collection and estimation of energy demand, assessment of supply opportunities, the identification of heat network scenarios (consumers and supply options) and the subsequent concept design development and techno-economic testing of these.

The analysis conducted is shown in the following pages which should be read in conjunction with the separate appendices that provide further detail. Information included in the main report and the appendices is a follows:

- The report summarises the key consumers included in the analysis of heat network opportunities. Appendix 1 provides background on the methodology of assessing demand and Appendix 2 schedules all prospective consumers.
- The report reviews the heat network design solutions developed for each option assessed. Summary descriptions of the energy supply technologies included in Appendix 3 and general notes on key heat network design issues are included in Appendix 4.
- The report highlights the heat network arrangements developed whilst Appendix 5 for includes further detail on pipe dimensions, operational parameters and capital costs.
- Preliminary Energy Centre designs are shown in Appendix 6.
- Supporting information used within the financial modelling in the shown in Appendices 7, 8 and 9 (capital costs, operating costs and revenue, respectively). Results of the financial model are shown in the main report with additional information included in Appendix 10.
- The carbon reduction benefits of the each network option consider as part of the techno-economic analysis sections, with further detail included in Appendix 11.
- For each network project risks are explored in the main report with an initial risk register shown in Appendix 12

2. Energy Mapping and Heat Network Opportunity Areas

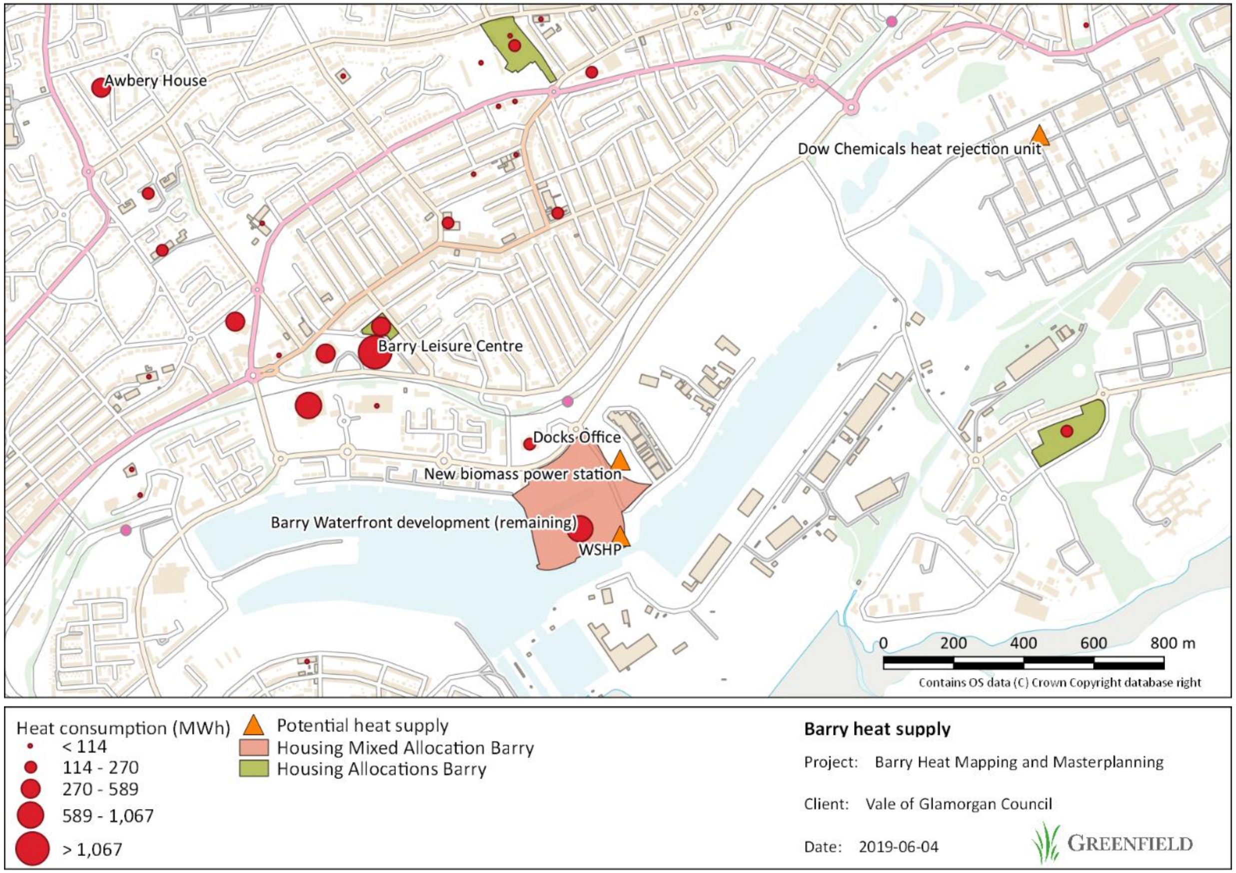
Heat mapping



- Energy demands for a wide range of consumer were identified and mapped – Appendix 1 describes method and data sources
- This list is not exhaustive (there will be other consumers). Anticipated that a significant proportion of large consumers are included.
- The map shows heat loads – the size of each bubble represents the approximate quantum of demand.
- Demand data for all potential consumers is shown in Appendix 2

2. Energy Mapping and Heat Network Opportunity Areas

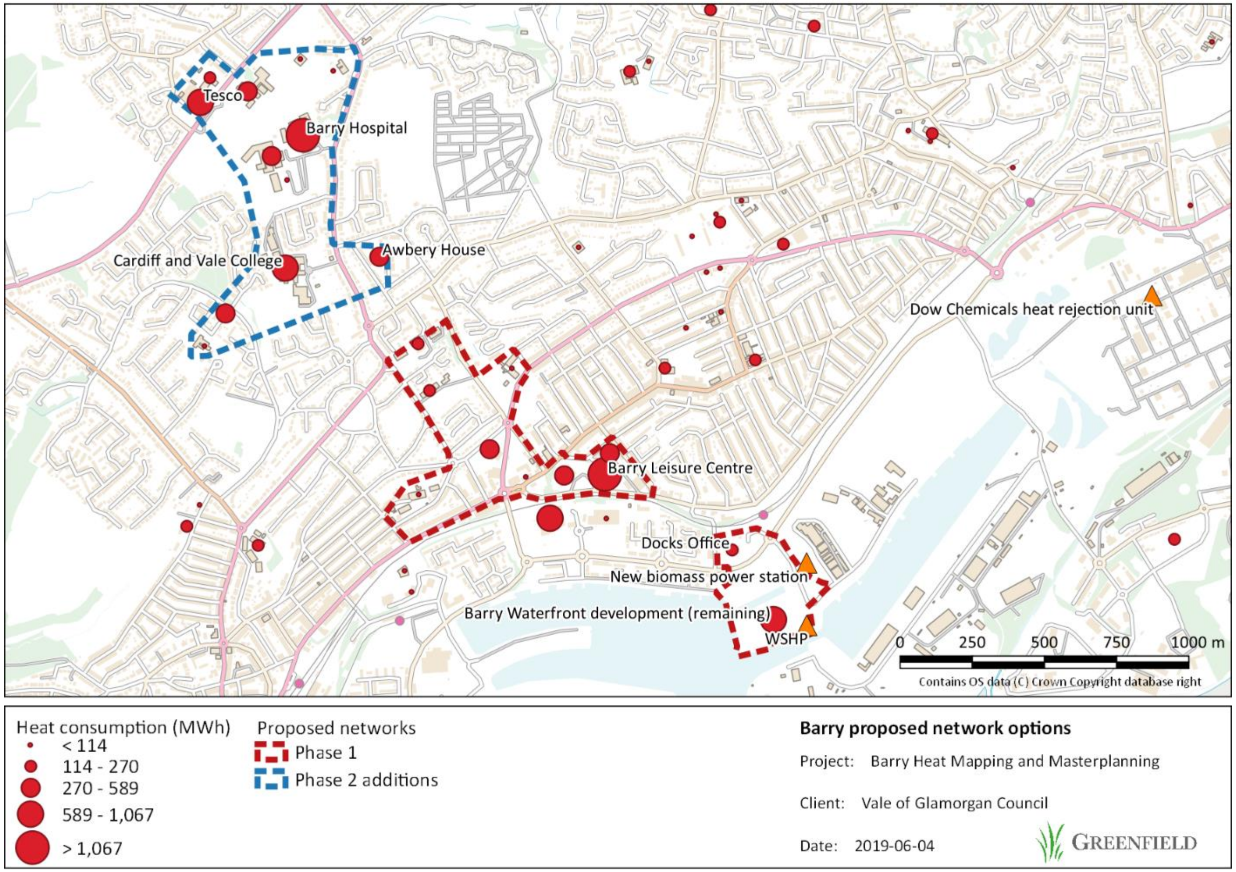
Identified supply opportunities



- Existing and new heat supply opportunities in Barry have been mapped.
- Orange triangle icons identify locations within context of the key demand points.
- Three primary / baseload heat source options were identified:
  - AVIVA biomass power station (heat recovery)
  - Dow Chemicals heat rejection unit (heat recovery)
  - Barry Docks (Water Source Heat Pump (WSHP))
- Notes on supply options included in Appendix 3, with key information included in the supply sections below.

2. Energy Mapping and Heat Network Opportunity Areas

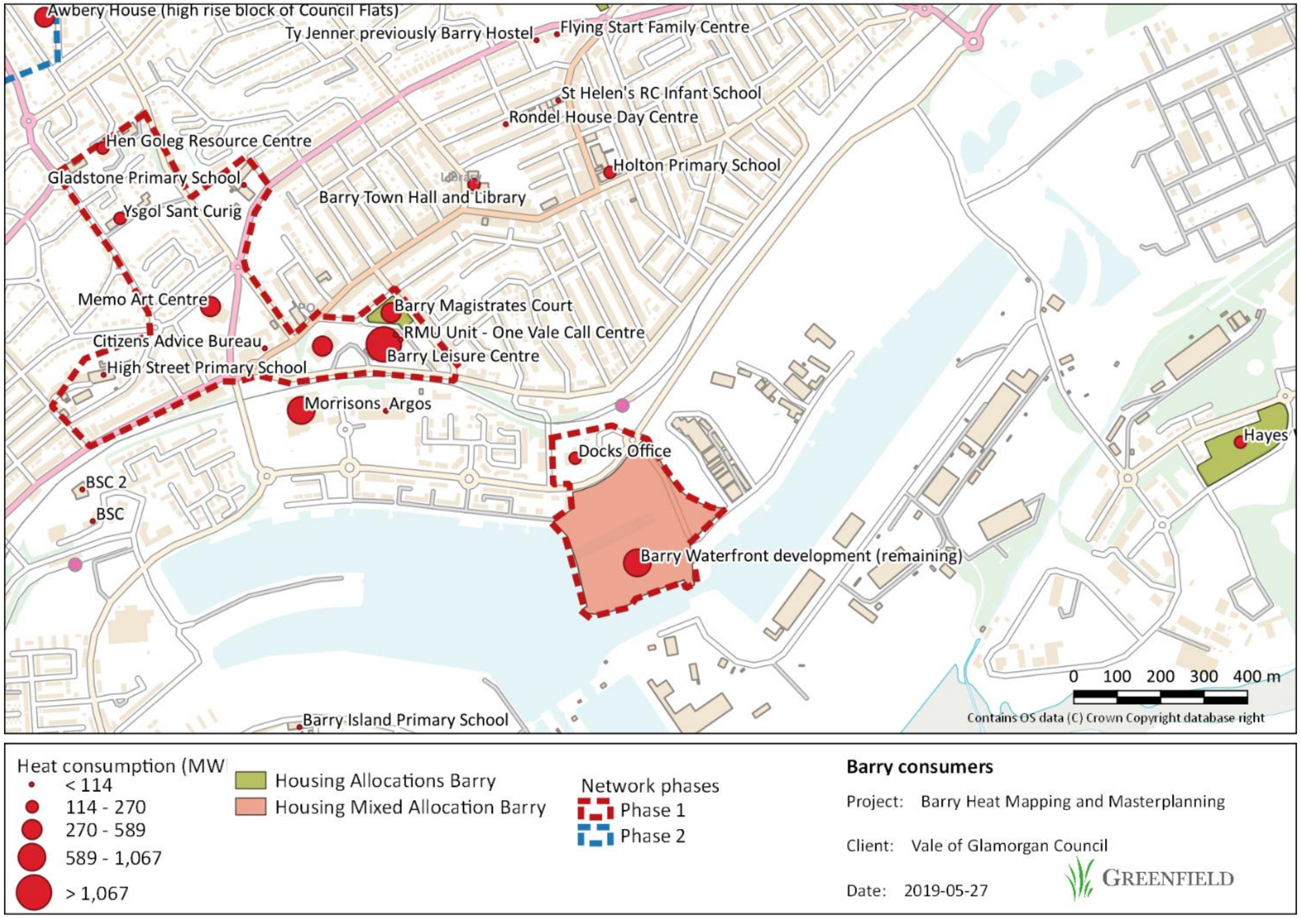
Identified heat network zones



- Spatial review of demand and supply identified to 2 consumer zones and following considered less favaourable:
  - Central are (low demand)
  - North-east area (poor proximity to main supply points)
- The consumer zones used as focus for development of heat network solutions
- Location of supply points mean these network solutions would develop from south
- Phase 1 is proposed to connect the Barry Waterfront development and southern town centre
- Phase 2 expands Phase 1 to Colcot Rd area
- All supply options are considered for both phases

3. Barry Docks and Town Centre network

Heat network (1/6) – Consumers



Barry Docks / Town Centre network consumers

- This heat network provides a heat connections between Barry Waterfront (new development) and southern part of town centre
- Major consumer include:
  - Barry Waterfront development
  - Barry Leisure Centre
  - Barry Magistrates Court
  - Memo Art Centre
  - Ysgol Sant Curig
  - Docks Office (VoG Council)
- Total heat consumption of 4.5 GWh/yr.

GREENFIELD

3. Barry Docks and Town Centre heat network

Heat network (2/6) – Consumers

Site	Phase	Type	Peak heat (MW)	Annual Heat Load (MWh)	Data Source
Barry Leisure Centre	1	Leisure Centre	0.71	1,795	Metering (council)
Barry Waterfront development (remaining)[1]	1	Residential development	1.25	760	New development benchmarking
Barry Town Council / Memo Art Centre	1	Offices / Theatre	0.35	590	Estimate based on gas cost
Civic Offices	1	Offices	0.29	529	Metering (council)
VoG Magistrates Court	1	Courthouse	0.15	279	DEC
Ysgol Sant Curig	1	Education	0.08	150	Metering (council)
Docks Office	1	Offices	0.08	146	Metering (council)
Hen Goleg Resource Centre	1	Community	0.07	128	Metering (council)
High Street Primary School	1	Education	0.05	86	Metering (council)
Gladstone Primary School	1	Education	0.04	77	Metering (council)
C1V Call Centre	1	Offices	0.04	67	Metering (council)
RMU Unit - One Vale Call Centre	1	Offices	0.04	67	Metering (council)
Citizens Advice Bureau	1	Offices	0.02	27	EPC
			3.20	**4,538**	

Barry Docks / Town Centre network consumers

[1] *344 dwellings from 2021-23 (source JHLAS housing allocations 2018)*

3. Barry Docks and Town Centre heat network

Heat network (3/6) – Supply scenarios

Five supply scenarios examined for Barry Docks / Town Centre network:

1. Water-source heat pumps (WSHP)
    - Energy centre located at Barry Waterfront development site, allows access to Barry Docks for water abstraction
2. Gas CHP and WSHP
    - Energy centre located at Barry Waterfront development site, allows access to Barry Docks for water abstraction
    - Gas CHP feeding power to the WSHP units
3. Heat recovery from Dow Chemicals (using heat pumps)
    - Heat recovered from Dow Chemicals plant heat rejection unit
    - Heat pump plant and backup gas boilers located on site
4. 'high-grade' heat from AVIVA Biomass power station
    - Steam extraction from Aviva power station process
    - Backup boilers located on site
5. 'low-grade' heat from AVIVA Biomass power station (using heat pumps)
    - Heat pump plant and backup gas boilers located on site

General description of these technologies are included in the Appendix 3

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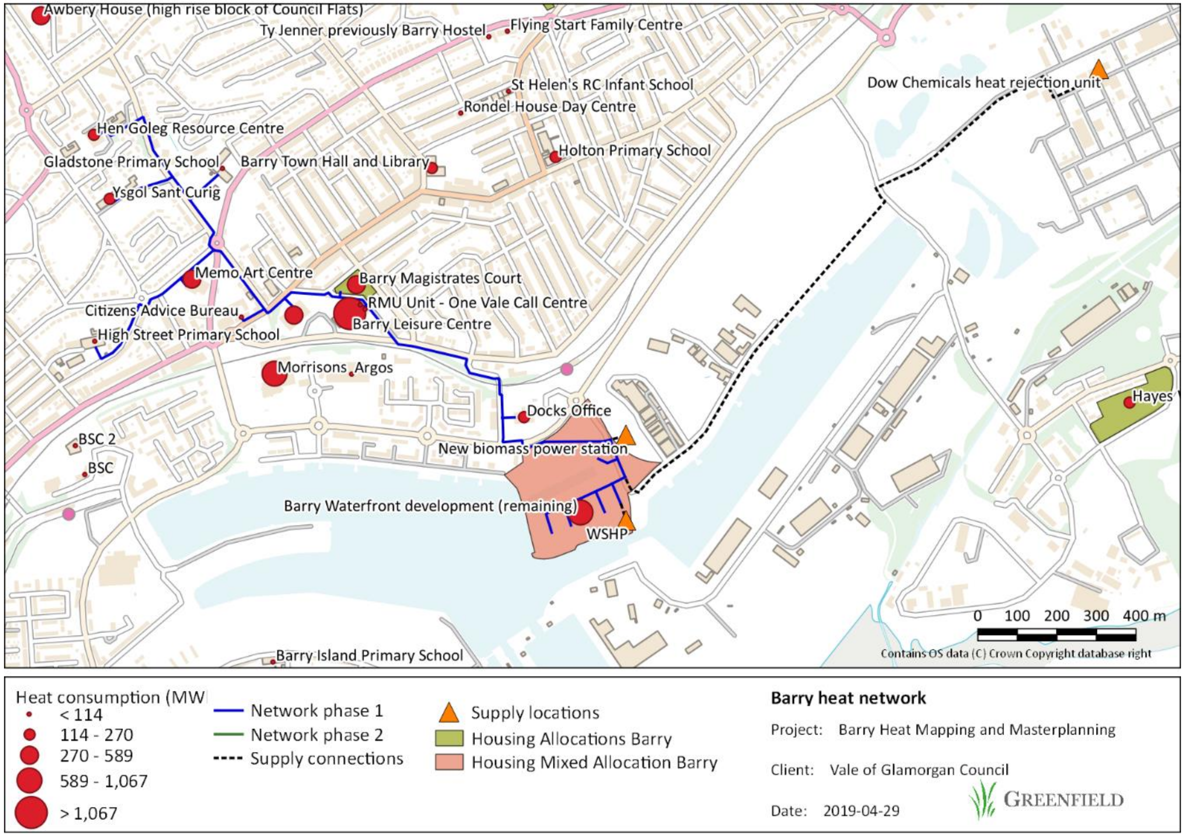
3. Barry Docks and Town Centre heat network

Heat network (4/6) – Route and constraints

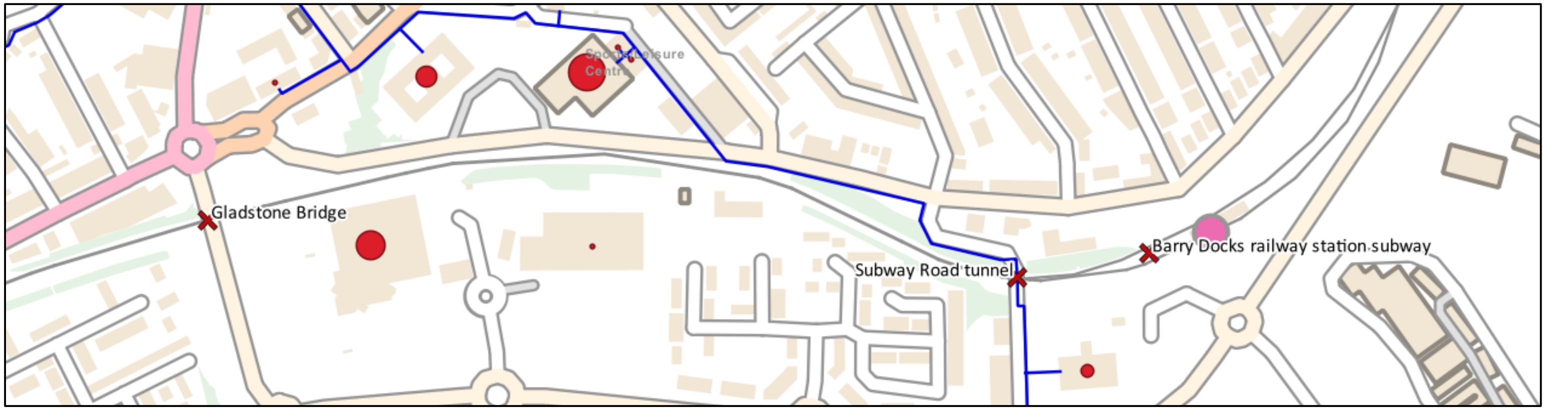


Barry Docks / Town Centre network heat network route

- Heat network route takes advantage of "soft-dig" land where possible
  - Particularly within Barry Waterfront development site (network installed as the site is built-out)
  - Soft-dig land is scarce in town centre, but used where possible
  - Otherwise route follows highway network
- A pumping station is required to avoid excessive pressures (and vapourisation) due to topography
  - Hydraulic simulations suggest pumping station should be located near Buttrills Road/Llandinam Road intersection (c. 35m elevation from ASL).
  - Downstream of the Buttrills Road/Llandinam Road intersection the elevation changes rapidly from 30 m to 70 m.
  - The pumping station could non-invasive if installed underground (service pit)

3. Barry Docks and Town Centre heat network

Heat network (5/6) – Route and constraints



Heat network constraints

- Main network constraint is the Vale of Glamorgan rail line near Docks area
  - Preferred solution: road tunnel on Subway Road
  - If not possible: (1) directional drilling through railway embankment, (2) existing walk/cycle subway at Barry Docks railway station, (3) Gladstone Bridge further west (requires significantly re-routing the network), but also offers advantage of picking up additional consumers, e.g. Morrissons
- Network constraints are considered typical for an urban location in the Barry town centre area.

Subway Road tunnel

GREENFIELD

3. Barry Docks and Town Centre heat network

Heat network (6/6) – Key parameters of heat network

Heat network key parameters					
	Unit	WSHP	Biomass 'high-grade'	Biomass 'low-grade'	Dow Chemicals HR
Demand					
Heat demand	GWh/yr	4.5	4.5	4.5	4.5
Peak demand	MW	3.2	3.2	3.2	3.2
Number of connections Non-residential Residential (dwellings) Total	 No. No. No.	 12 344 356	 12 344 356	 12 344 356	 12 344 356
Network					
Network trench length	km	3.5	3.5	3.5	5.3
Linear heat density	GWh/yr/km	1.3	1.3	1.3	0.9
Main pipe size	DN	200	150	200	200
Heat losses	%	10 %	10 %	10 %	10 %
Design temperatures Flow Return	 °C °C	 80 45-55	 90 45-55	 80 45-55	 80 45-55
Soft dig Hard dig	% %	40 % 60 %	40 % 60 %	40 % 60 %	55 % 45 %

Heat network key parameters

- Further detail included in Appendix 4
- Linear heat density figures illustrate low density of heat demand

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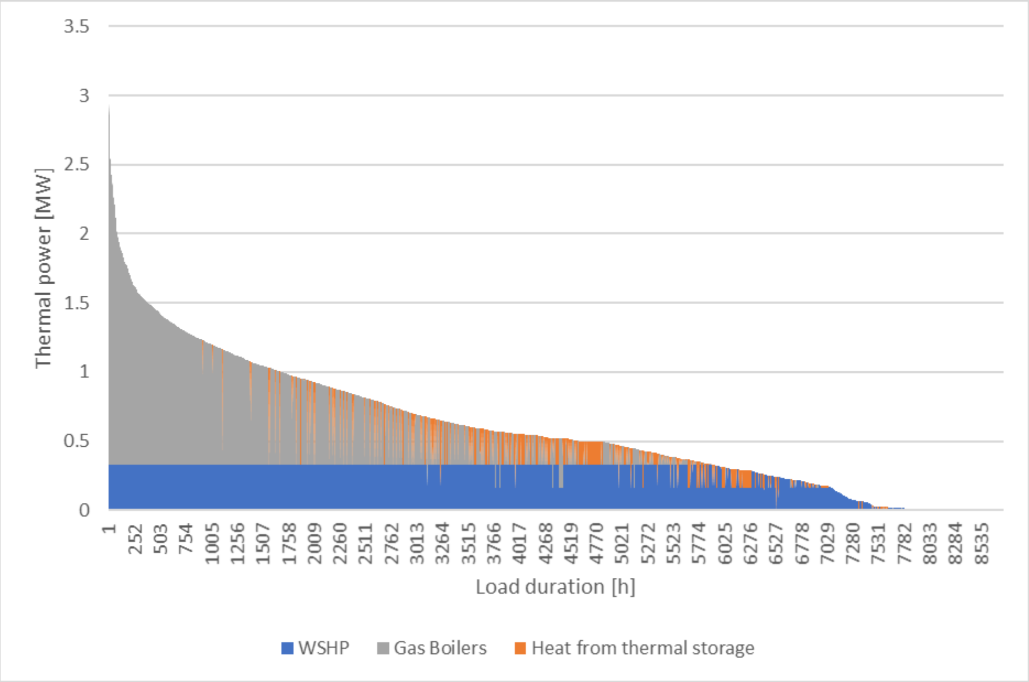
3. Barry Docks and Town Centre heat network

Supply analysis (1/6) – Water-Source Heat Pumps (WSHP)



Load duration curve - 330 kW WSHP

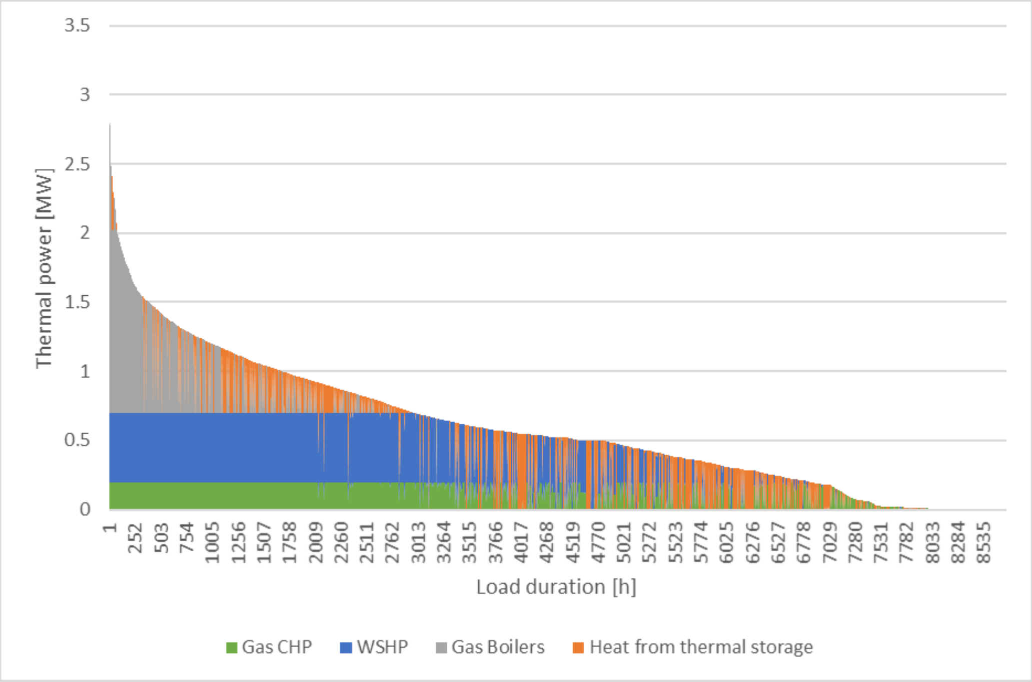
Note on WSHP analysis: Flow rate data for the Docks was not available but approximations of the Docks' dimensions were given by ABPorts. Total volume of water at the Docks area is estimated as 5,367,000 m³ with a 1,226,000 m³ monthly rate of change due to vessel locking operations and replacing water that is gradually lost from the docks. Based on this information and the temperature data received, it was estimated that the Docks have significant heat supply potential. Further analysis requires more detailed knowledge of flow characteristics and temperature fluctuations at the Docks to ensure sufficient flow of water at the proposed EC location. WSHP's abstraction and extraction pipes would need to be located taking into account these flow characteristics to minimise risk of thermal interference.

- Optimised supply capacities:
  - 330 kW WSHP
  - 3,720 kW Gas Boilers
  - 50 m³ thermal storage
- WSHP Energy Centre is proposed to be located at the Barry Waterfront Development site at the Docks (see earlier map).
- Availability of WSHP units is assumed 8,592 h/a (accounting for annual one-week maintenance during summer). Maintenance of the units is sequential (multiple units are proposed)
- Heat pump operation is calculated with a delta T of 3°C between inlet and outlet heat source flows (could be higher)
- The Coefficient of Performance of the heat pumps varies based on water temperatures at condenser and evaporator. Annual average CoP based on modelling results is 3.13 (above RHI requirement of 2.8)
- Water temperature data (half-hourly data from 01/2019 to 02/2019) for the Docks received from AB Ports UK indicates that annual lowest temperatures are in the range of 5-6°C, i.e. no restriction to availability across year

GREENFIELD

3. Barry Docks and Town Centre heat network

Supply analysis (2/6) – Hybrid WSHP / Gas CHP

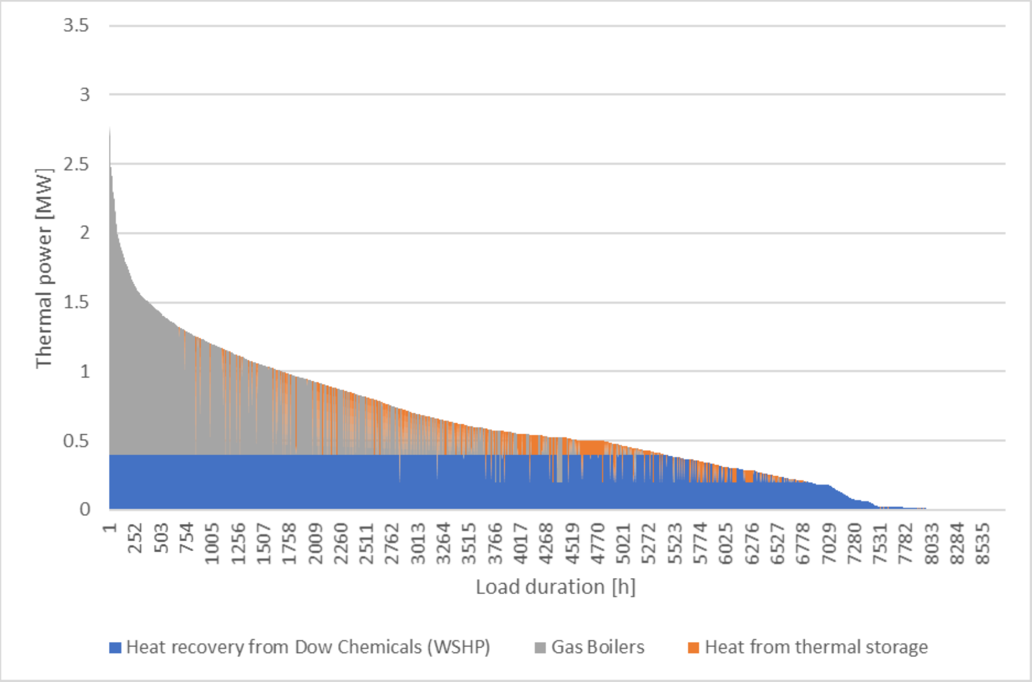


Load duration curve - 500 kW WSHP / 200 kW Gas CHP

- Optimised supply capacities:
  - 500 kW WSHP
  - 200 kW Gas CHP
  - 3,350 kW Gas Boilers
  - 100 m³ thermal storage
- WSHP operation is modelled with same assumptions as per WSHP-only
- The Coefficient of Performance: 3.05 (annual average)
- Gas CHP availability assumed: 8,592 h/a (accounting for annual one-week maintenance period during summer). Maintenance is assumed sequential (multiple units proposed)
- CHP is modelled to produce heat and electricity with a power to heat ratio of 0.93 and efficiency of 83 %
- Electricity from CHP is used in WSHP units and excess is exported to ‘grid’
- The Energy Centre including both WSHP and CHP units is proposed to be located at the Barry Waterfront development site

3. Barry Docks and Town Centre heat network

Supply analysis (3/6) – Heat recovery from Dow Chemicals

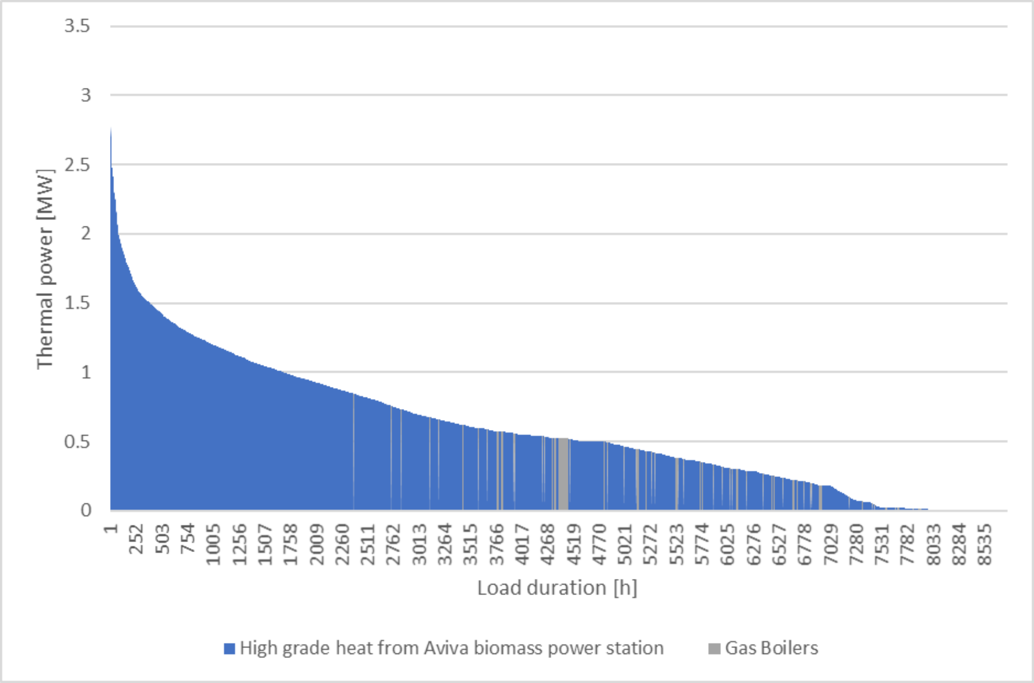


Load duration curve - 400 kW WSHP (at Dow)

- Optimised supply capacities:
  - 400 kW WSHP (at Dow)
  - 3,650 kW Gas Boilers
  - 50 m^3 thermal storage
- Heat recovered from Dow assumed constant 22°C, from the site's primary heat rejection plant. 22°C identified as the minimum available (by Dow).
- WSHP boost temperatures meet heat network requirements
- It is assumed that constant flow rate of 60 m^3/hr is available 24/7 around the year
- WSHP CoP will vary based on water temperatures at condenser as evaporator inlet temperature is constant 22°C. Estimated annual average CoP based estimated at 3.46
- Availability of Dow heat and WSHPs is assumed 8,592 h/a (accounting for annual one-week maintenance period during summer for the WSHP units). Maintenance is sequential (multiple units are proposed).
- The Energy Centre including heat pumps and gas boiler units is proposed to be located at the Dow Chemicals industrial site in close proximity to the heat rejection units (see earlier map).

3. Barry Docks and Town Centre heat network

Supply analysis (4/6) – 'high-grade' heat from AVIVA biomass power station



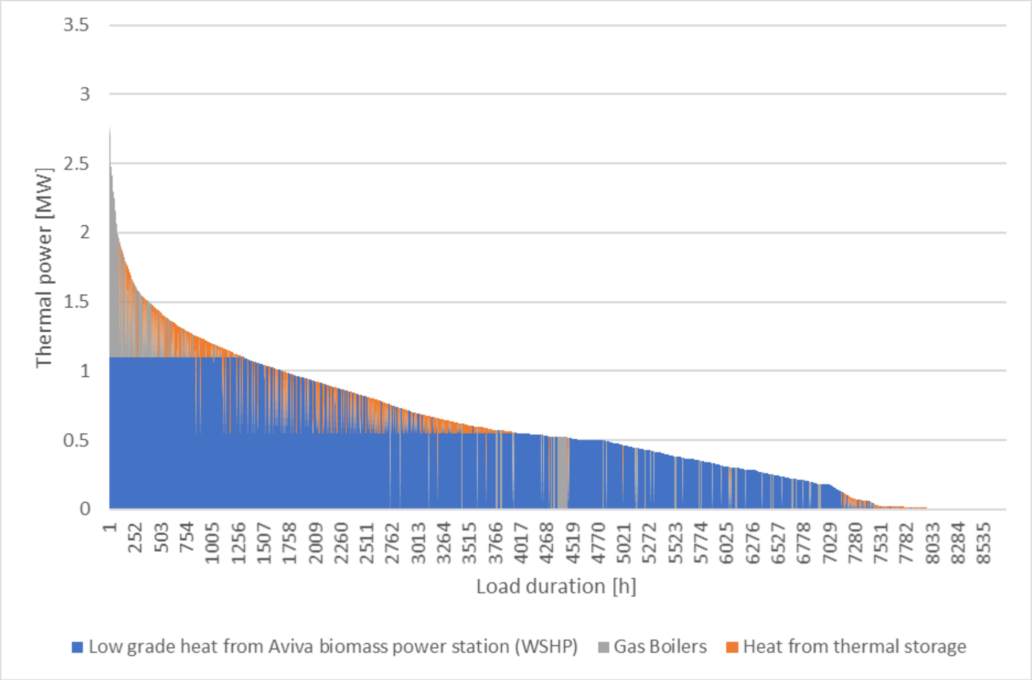
Load duration curve - 3,110 kW 'high-grade' heat from Aviva

- Optimised supply capacities:
  - 3,110 kW 'high-grade' heat import
  - 3,110 kW Gas Boilers
  - No thermal storage
- Aviva 'high-grade' heat: steam at 45 bar / 400°C temperature. According to Aviva, up to 13.2 kg/s steam is available. Assuming imported steam can be returned as condensate water, capacity (over 20 MW) far exceeds need for this network (or Colcot Road extension).
- It is assumed: (1) existing plant at Aviva are power generation-only and need to be retrofitted to enable heat/steam export, (2) standard heat exchanger equipment is installed to extract heat, (3) Energy centre plant is located on Aviva site.
- Availability assumed as 8000 h/a, taking into account a 30-day maintenance period during summertime for the biomass plant.
- NB. Backup gas boiler capacity is dimensioned to cover full heat demand of the network to ensure security of supply if heat import is unexpectedly cut off or if scheduled maintenance occurs during winter.

GREENFIELD

3. Barry Docks and Town Centre heat network

Supply analysis (5/6) – 'Low-grade' heat from AVIVA biomass power station



Load duration curve - 1,100 kW WSHP ('low-grade' heat from Aviva)

- Optimised supply capacities:
  - 1,100 kW WSHP (at Aviva)
  - 3,110 kW Gas Boilers
  - 50 m³ thermal storage
- 'Low-grade' heat recovery from Aviva biomass power station uses constant 35°C excess heat from the site's power generation units
- WSHPs used to boost temperatures
- WSHP CoP varies based on water temperatures at condenser as evaporator inlet temperature is constant 35°C. Annual average CoP estimated at 4.33
- Availability of 'low-grade' heat import is assumed 8000 h/a, taking into account a 30-day maintenance period during summertime for the biomass plant. WSHP units' annual maintenance is performed during the same period.
- Assumed that energy centre plant is located on Aviva site and that low cost power from Aviva is used to operate WSHPs

3. Barry Docks and Town Centre heat network

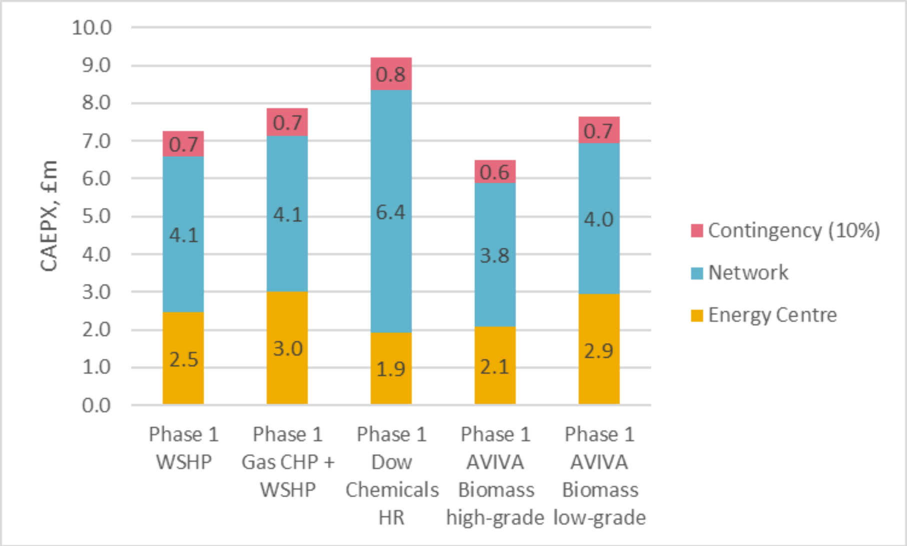
Supply analysis (6/6) – Summary

Heat and electricity production						
Supply option		WSHP	WSHP + Gas CHP	Heat recovery from Dow (WSHP)	'high-grade' heat from Aviva	'low-grade' heat from Aviva (WSHP)
Supply capacity						
WSHP	kW	330	500	400	-	1,100
Gas CHP	kW	-	200	-	-	-
Steam connection	kW	-	-	-	3,110	-
Gas Boiler	kW	3,720	3,350	3,650	3,110	3,110
Thermal storage	m³	50	100	50	-	50
Heat production share						
Heat production	GWh/yr	5.2	5.2	5.2	5.2	5.2
WSHP	%	50.2 %	59.3 %	57.6 %	-	90.0 %
Gas CHP	%	-	22.2 %	-	-	-
Heat purchase	%	-	-	-	95.9 %	-
Gas boilers	%	49.8 %	18.5 %	42.4 %	4.1 %	10.0 %
CHP electricity						
CHP electricity production	GWh/yr	-	1.1	-	-	-
Consumed by EC site	%	-	4.8 %	-	-	-
To WSHPs	%	-	89.5 %	-	-	-
To grid	%	-	5.7 %	-	-	-

Heat and electricity production

3. Barry Docks and Town Centre heat network

Techno-economic analysis (1/8) – Capital costs



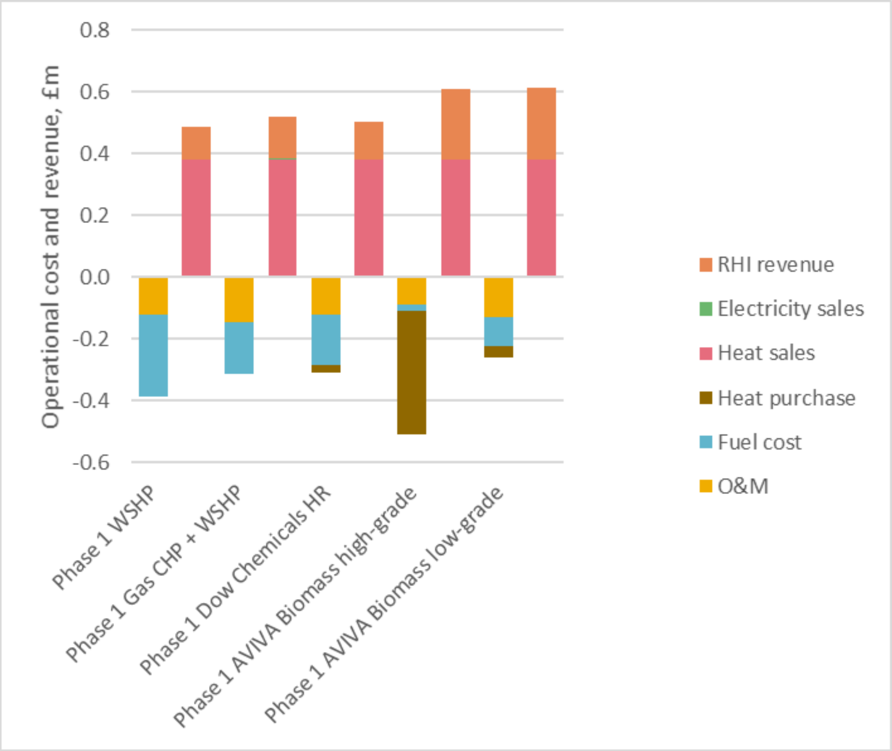
Capital costs

- In total the costs are estimated at:
  - £7.3m for the WSHP option
  - £7.9m for the Gas CHP + WSHP hybrid option
  - £9.2m for Dow Chemicals heat recovery (using heat pumps)
  - £6.5m for AVIVA biomass 'high-grade' heat recovery
  - £7.6m for AVIVA biomass 'low-grade' heat recovery (using heat pumps)
- Further details of costs are shown in Appendix 7.
- With Dow Chemicals, the proportion of network costs is c 50% higher than other options due to the long network connection required
- At this stage where costings rely on a range of assumptions, the tolerance on capital costs applied is ±20 %.

GREENFIELD

3. Barry Docks and Town Centre heat network

Techno-economic analysis (2/8) – Operational costs and revenue



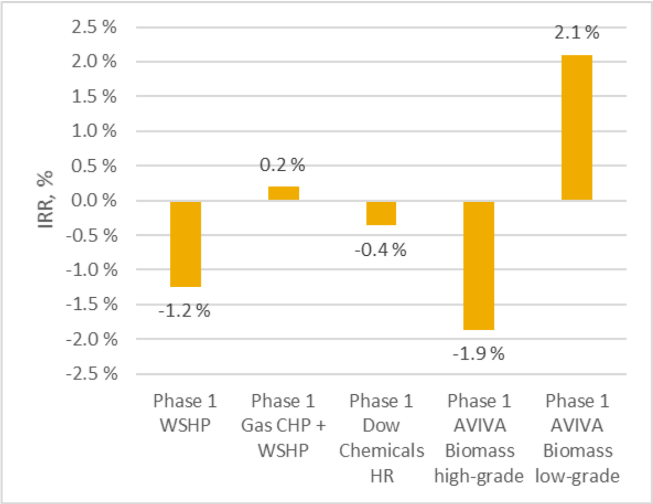
Operational costs and revenue

- A summary of operational costs and revenues at full build-out is shown in graph
- More detail is shown in Appendix 8 and Appendix 9
- Operational costs range from £260k with AVIVA 'low-grade' heat recovery to £506k with AVIVA 'high-grade' heat recovery.
  - The latter is driven by the high bulk heat purchase cost (£50/MWh) which results from a relatively low z-factor and high value of power sales to Aviva due to their grandfathered ROC contract. See sensitivity for further review.
- Electricity cost for operation heat pumps used in the Dow and Aviva ('low-grade' heat) options is assumed to be lower than typical (BEIS wholesale/grid export reference point used). This presumes power is supplied directly from the host organisations' on-site power generation.
- Revenues range from £486k with WSHP to £613k with AVIVA 'low-grade' heat recovery. Where the source of the energy renewable (Aviva & WSHP), RHI income is assumed – see sensitivity.

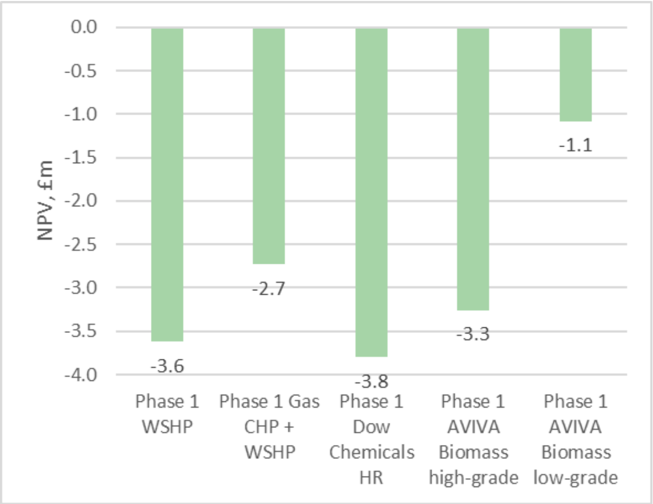
GREENFIELD

3. Barry Docks and Town Centre heat network

Techno-economic analysis (3/8) – IRR and NPV



IRR (25 years)



NPV (25 years @ 3.5 %)

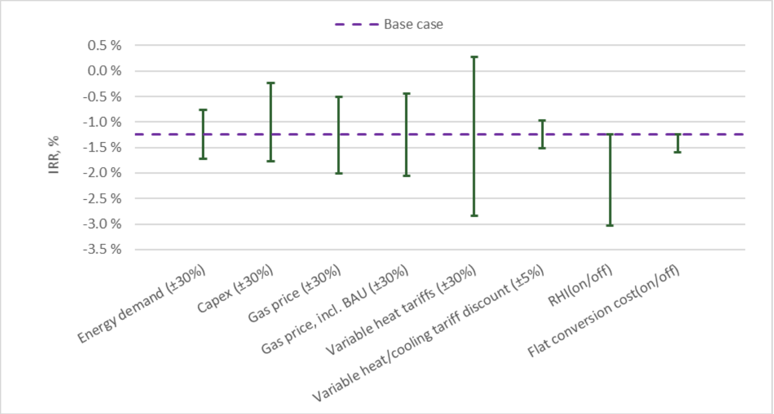
- The figures above show the IRRs and NPVs of the various options. Full schedule of financial performance results are presented in Appendix 10
- AVIVA Biomass 'low-grade' heat recovery shows the strongest IRR at 2.1 %
  - Largely due to high COP available from the temperature of recovered heat and assumed power costs
- Adding CHP to the water-source heat pump option to power the heat pumps increases IRR by 1.4 %
- AVIVA Biomass 'high-grade' heat recovery performs poorly at -1.9 % IRR
  - Explained by the high bulk heat purchase cost resulting from the z-factor / ROC contract

GREENFIELD

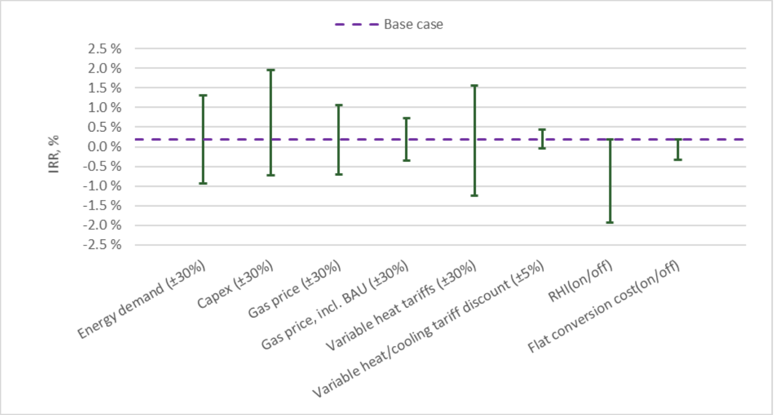
3. Barry Docks and Town Centre heat network

Techno-economic analysis (4/8) – Sensitivities

- Within the financial modelling, sensitivities of key parameters have assessed to examine the strength of the economic case for each option.
- Parameters have been considered independently although, in reality, parameters could change together and have a compound impact (positive or negative); this should be considered in any subsequent investigations.
- The figures highlight the impact on IRR (25-year) of the variation of key parameters. The impact varies across the options, making it complex to succinctly interpret the results, however, the following appear most significant:
  - Exclusion of RHI revenue (WSHP and Aviva options only) – presently RHI is due to close by Q1 2021. Although no plans to replace / extend RHI, is anticipated that some form of support programme will be forthcoming.
  - Change in gas prices (particularly for those with gas CHP), although the impact is likely to be mitigated since heat tariffs will typically, in part, be linked to gas prices.
  - Variable component of heat tariff (unlikely to vary significantly in practice)
  - Capital cost change has a significant impact. Cost reductions also appear to have a more significant (positive) impact than cost increases (negative). Value engineering and specification adjustment as well removing contingency and risk items (as the design develops) could deliver savings
  - Energy demand with increases (e.g. new consumers) have similar impact to reduction, e.g. revising consumption estimates downwards from initial assessment and similar affect all options. In this options performing least well it have less impact and as costs are already high relative to revenues
  - Heat purchase prices from Dow Chemicals and AVIVA ('high-grade' and 'low-grade'). This is more impactful for the 'high-grade' Aviva options because the cost of others are assumed to be a relatively low value in the base model.



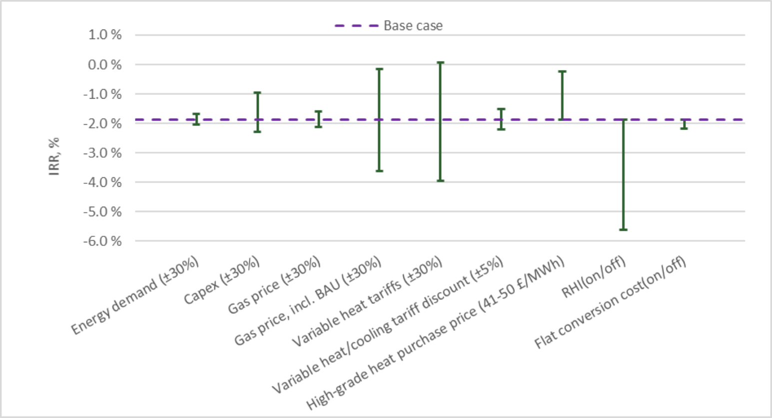
Sensitivities for Barry Docks / Town Centre network WSHP



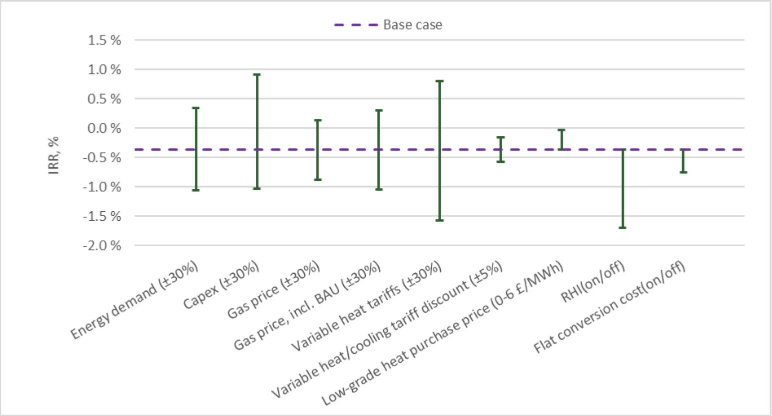
Sensitivities for Barry Docks / Town Centre network Gas CHP + WSHP

3. Barry Docks and Town Centre heat network

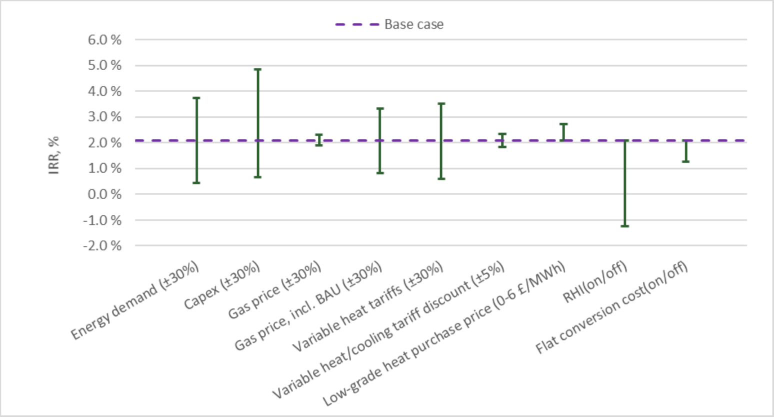
Techno-economic analysis (5/8) – Sensitivities



Sensitivities for Barry Docks / Town Centre network AVIVA 'high-grade' heat recovery



Sensitivities for Barry Docks / Town Centre network Dow Chemicals HR



Sensitivities for Barry Docks / Town Centre network AVIVA 'low-grade' heat recovery

3. Barry Docks and Town Centre heat network

Techno-economic analysis (6/8) – Analysis results

Techno-economic analysis results						
	Unit	WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass 'high-grade'	AVIVA Biomass 'low-grade'
Financial						
Total CAPEX (to full build out)	£m	7.3	7.9	9.2	6.5	7.6
Total REPEX (full scheme)	£m	2.0	2.6	1.7	2.0	2.5
Total OPEX (full scheme)	£m/yr.	0.4	0.3	0.3	0.5	0.3
NPV (25 yr @ 3.5 %)	£m	-3.6	-2.7	-3.8	-3.3	-1.1
IRR (25 yr)	%	-1.2 %	0.2 %	-0.4 %	-1.9 %	2.1 %
Social IRR (25 yr)	%	-1.2 %	0.0 %	-0.3 %	-1.7 %	2.7 %
LCOE (25 yr)	£/MWh	139.6	126.6	142.2	134.3	102.5
Minimum grant to achieve 6 % IRR	£m	4.3	3.7	4.8	3.7	2.3
Carbon						
CO_2 savings over 25 yr	$ktCO_2$/yr.	10.1	8.7	11.8	12.5	18.9
CO_2 savings over 25 yr	%	38.8 %	33.5 %	45.4 %	48.0 %	72.6 %
CO_2 savings per £1,000 grant	tCO_2/£1,000	2.4	2.4	2.4	3.4	8.1
Cost of CO_2 savings	£/tCO_2	1,493	1,565	1,300	1,160	585

Techno-economic analysis results

- Key economic output parameters are shown in the table with further detail shown in Appendix 10
- All options provide significant carbon savings ranging from 34 % (Gas CHP + WSHP) to 73 % (AVIVA 'low-grade' heat recovery)
- In absolute terms carbon savings range from 8.7 ktCO2/yr (Gas CHP + WSHP) to 18.9 ktCO2/yr (AVIVA 'low-grade' heat recovery)
- Conclusions regarding the performance of the options is discussed in section 5 (both networks)

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3. Barry Docks and Town Centre heat network

Techno-economic analysis (7/8) – Grant support

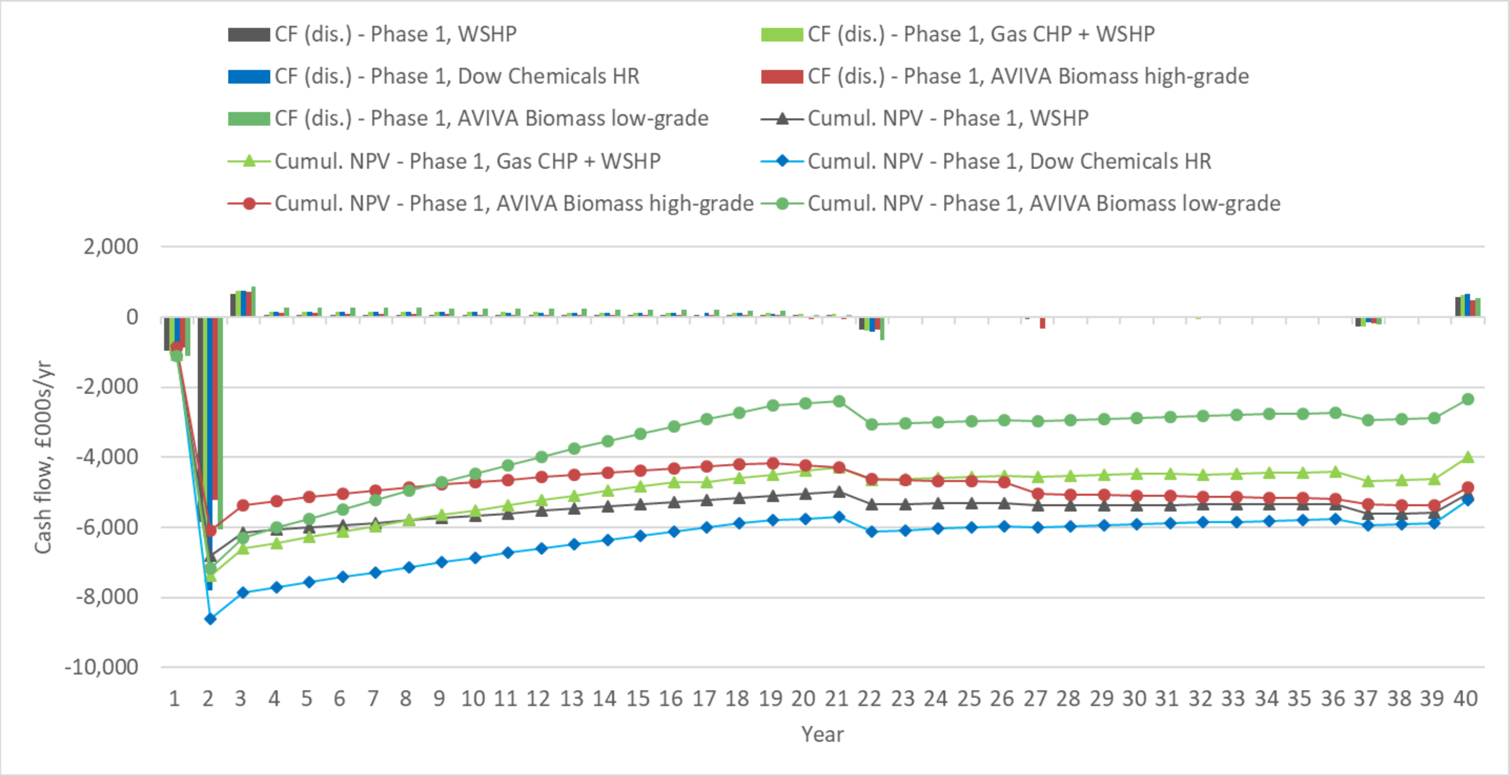
Grant support requirements						
		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass 'high-grade'	AVIVA Biomass 'low-grade'
IRR 5.0 %	£m	4.1	3.4	4.5	3.6	1.9
	% capex	56.1 %	43.2 %	49.0 %	55.2 %	25.2 %
IRR 7.0 %	£m	4.4	4.0	5.1	3.8	2.7
	% capex	61.1 %	50.5 %	55.4 %	59.1 %	35.3 %
IRR 10.0 %	£m	4.7	4.4	5.5	4.0	3.4
	% capex	64.3 %	56.2 %	60.0 %	61.6 %	44.2 %

Grant support requirements

- The table above shows the level of grant support (e.g. HNIP) that would be required to achieve specific rates of return
- A 3-7 % rate of return is assumed to be required for a wholly public funded project and above 10-12% is assumed to be required for a wholly privately funded project
- It should be noted that all options achieve the required % of heat supply from a renewable / CHP source to be eligible for HNIP
- Only AVIVA Biomass 'low-grade' heat recovery appears to be able to reach a 10 % IRR level without requiring >50 % of capex, which is a reasonable starting assumption for the maximum limit set by state-aid rules
- All options need fairly significant grant support even to achieve 5%, with WSHP and Aviva ('high-grade' heat) exceeding the requirement for more than 50% capex to achieve this.
- Where public funding requirements for returns are below this then there may be no need for grant support at all.

3. Barry Docks and Town Centre heat network

Techno-economic analysis (8/8) – Cash flow and net present value

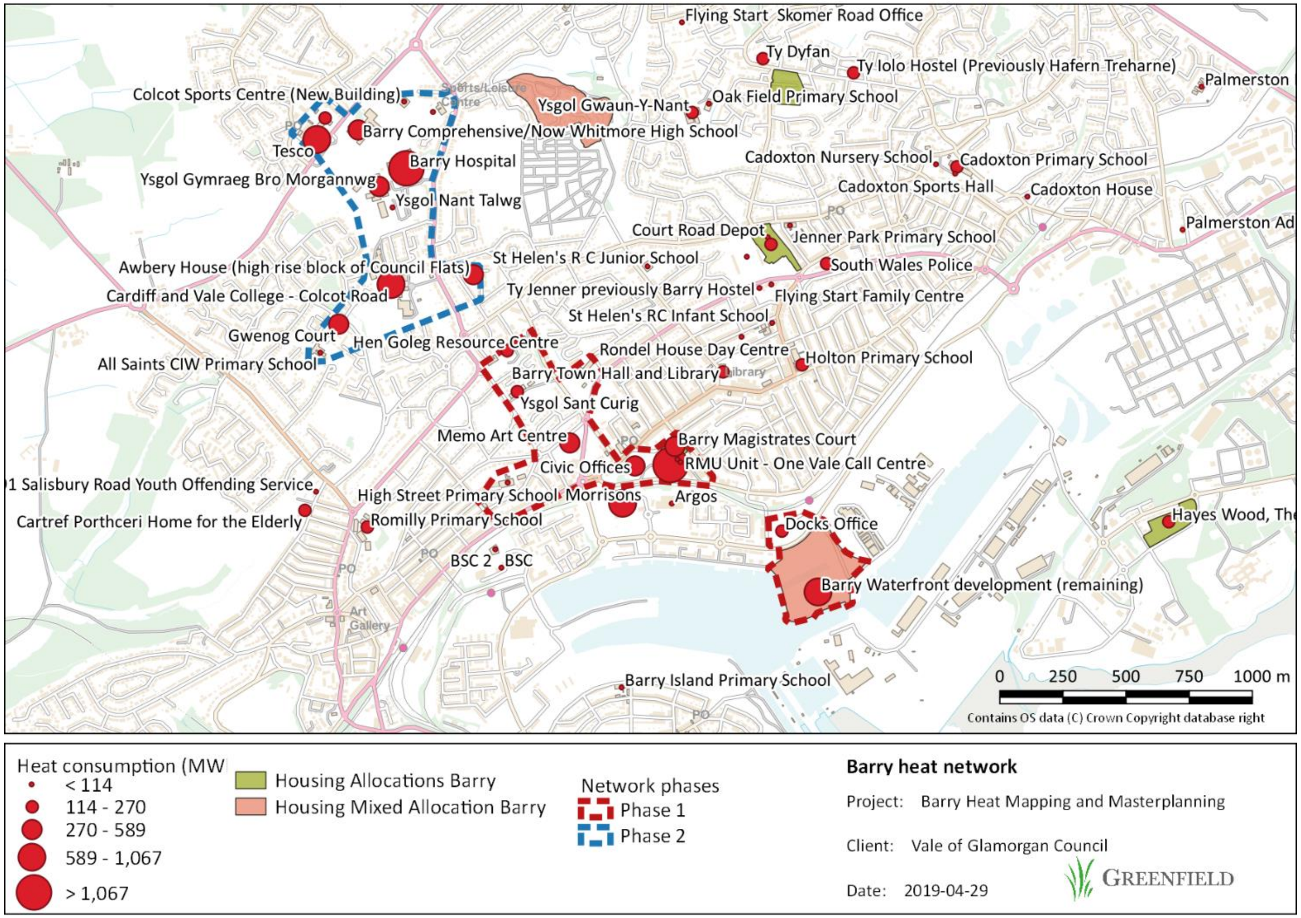


Discounted cash flow – Barry Docks / Town Centre network

- Discounted cash flow graphs shows general weak performance overall with poor balance between operating costs and revenues (shallow graphs)

4. Extension to Colcot Rd Area

Heat network (1/5) – Consumers



Colcot Road extension consumers

- This networks connects the Barry Docks / Town Centre network network to the Colcot Rd area
- Major new consumers:
  - Barry Hospital
  - Cardiff and Vale College
  - Tesco
  - Ysgol Gymraeg Bro Morgannwg
  - Gwenog Court
  - Whitmore High School
- Total heat consumption of 10.4 GWh/yr (more than 2x Barry Docks / Town Centre network)

4. Extension to Colcot Rd Area

Heat network (2/5) – Consumers

Site	Phase	Type	Peak heat (MW)	Heat Load (MWh)	Data Source
Network 1 consumers	1	Various	3.20	4,538	Various
Barry Hospital	2	Hospital	0.94	2,317	BEES
Tesco	2	Retail	0.31	805	Metering (HH)
Cardiff and Vale College - Colcot Road	2	Education	0.37	662	DEC
Barry Comprehensive/Now Whitmore High School	2	Education	0.22	400	Metering (council)
Ysgol Gymraeg Bro Morgannwg	2	Education	0.21	368	Metering (council)
Gwenog Court	2	Residential	0.15	362	Metering (council)
Awbery House (high rise block of Council Flats)	2	Residential	0.13	310	EPC / NEED
Barry Emergency Services Station	2	Emergency services	0.11	204	Metering (annual)
Ysgol Nant Talwg	2	Education	0.06	115	Metering (council)
Colcot Sports Centre (New Building)	2	Leisure	0.04	90	Metering (council)
All Saints CIW Primary School	2	Education	0.04	79	Metering (council)
TOTAL (ALL)			**5.75**	**10,414**	

Colcot Road extension consumers

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4. Extension to Colcot Rd Area

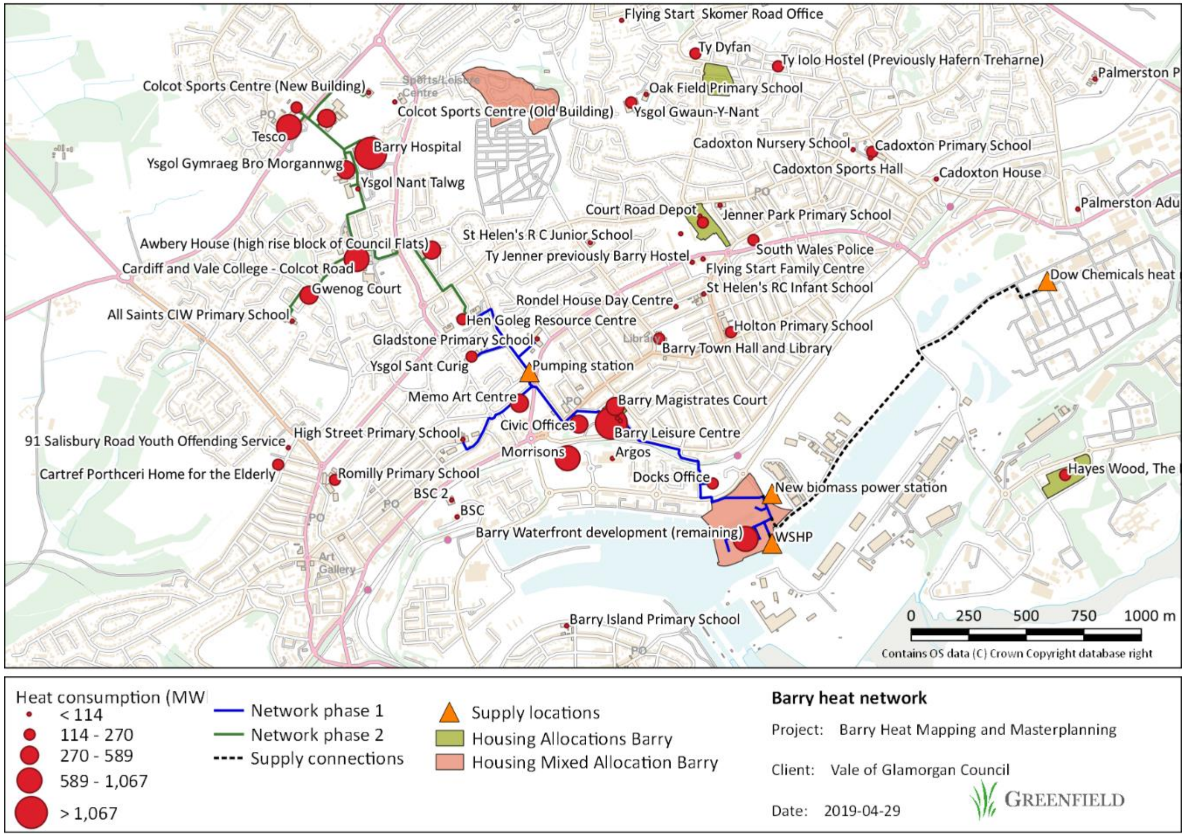
Heat network (3/5) – Supply scenarios

Five supply scenarios examined for Colcot Road extension:

1. Water-source heat pumps (WSHP)
   - Energy centre located at Barry Waterfront development site, allows access to Barry Docks for water abstraction
2. Gas CHP and WSHP
   - Energy centre located at Barry Waterfront development site, allows access to Barry Docks for water abstraction
   - Gas CHP feeding power to the WSHP units
3. Heat recovery from Dow Chemicals (using heat pumps)
   - Heat recovered from Dow Chemicals plant heat rejection unit
   - Heat pump plant and backup gas boilers located on site
4. 'high-grade' heat from AVIVA Biomass power station
   - Steam extraction from Aviva power station process
   - Backup boilers located on site
5. 'low-grade' heat from AVIVA Biomass power station (using heat pumps)
   - Steam extraction from Aviva power station process
   - Heat pump plant and backup gas boilers located on site

4. Extension to Colcot Rd Area

Heat network (4/5) – Route and constraints



Colcot Road extension network route

- Heat network route takes advantage of "soft-dig" land where possible
  - The extension to Colcot Rd area allows extensive use of soft dig land around Cardiff and Vale College, Ysgol Gymraeg Bro Morgannwg , Barry Hospital, Whitmore High School and Colcot Sports Centre, as the sites are surrounded by greenspace
  - Using the greenspace to route the network also allows for the shortest connection routes between the buildings
- As with network 1, a pumping station is required to address high pressure resulting from topography

4. Extension to Colcot Rd Area

Heat network (5/5) – Key parameters

Heat network key parameters					
	Unit	WSHP	Aviva 'high-grade'	Aviva 'low-grade'	Dow Chemicals HR
Demand					
Heat demand	GWh/yr	10.4	10.4	10.4	10.4
Peak demand	MW	5.8	5.8	5.8	5.8
Number of connections					
Non-residential	No.	21	21	21	21
Residential (dwellings)	No.	344	344	344	344
Total	No.	365	365	365	365
Network					
Network trench length	km	6.2	6.2	6.2	8.0
Linear heat density	GWh/yr/km	1.7	1.7	1.7	1.3
Main pipe size	DN	200	200	200	200
Heat losses	%	10 %	10 %	10 %	10 %
Operating temperatures					
Flow	°C	80	90	80	80
Return	°C	45-55	45-55	45-55	45-55
Soft dig	%	42 %	42 %	42 %	52 %
Hard dig	%	58 %	58 %	58 %	48 %

Heat network key parameters

- See Appendix 4 for further detail
- Linear heat density figures illustrate low density of heat demand

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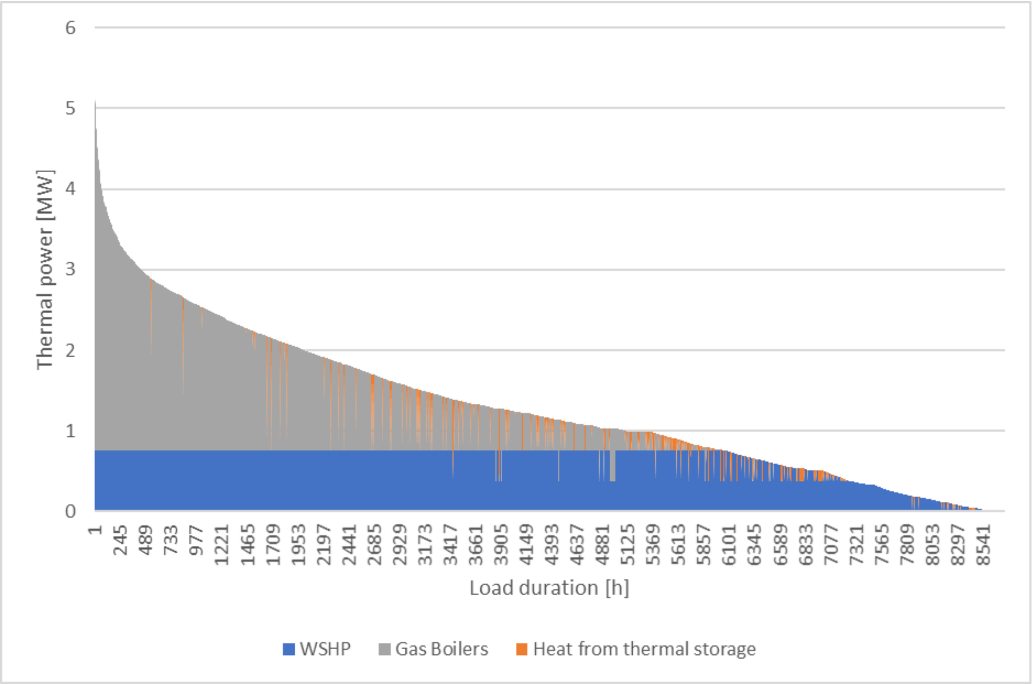
4. Extension to Colcot Rd Area

Supply analysis (1/6) – Water-Source Heat Pumps

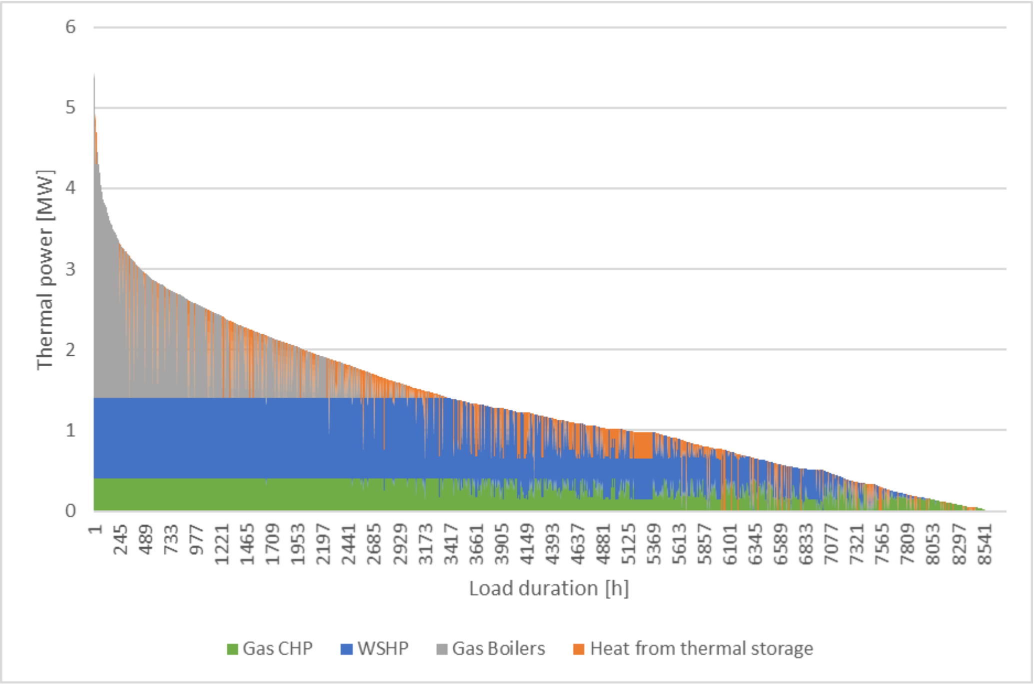


Load duration curve - 750 kW WSHP

- Optimised supply capacities:
  - 750 kW WSHP
  - 6,450 kW Gas Boilers
  - 50 m³ thermal storage
- Notes / for Barry Docks / Town Centre network network as apply here

4. Extension to Colcot Rd Area

Supply analysis (2/6) – Hybrid Water-Source Heat Pumps (WSHP) + Gas CHP

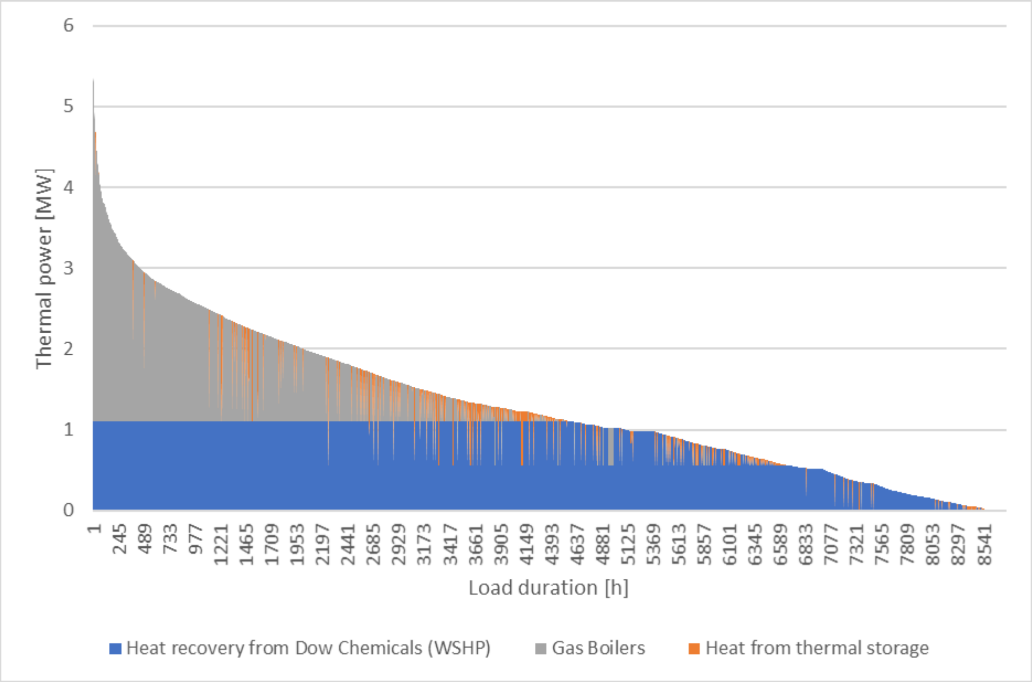


Load duration curve - 1,000 kW WSHP and 400 kW Gas CHP

- Optimised supply capacities:
  - 1,000 kW WSHP
  - 400 kW Gas CHP
  - 5,800 kW Gas Boilers
  - 100 m³ thermal storage
- Notes / for Barry Docks / Town Centre network network as apply here

4. Extension to Colcot Rd Area

Supply analysis (3/6) – Heat recovery from Dow Chemicals



Load duration curve - 1,100 kW WSHP (at Dow)

- Optimised supply capacities:
  - 1,100 kW WSHP (at Dow)
  - 6,100 kW Gas Boilers
  - 50 m^3 thermal storage
- Notes / for Barry Docks / Town Centre network network as apply here
- Annual average CoP is estimated at 3.09

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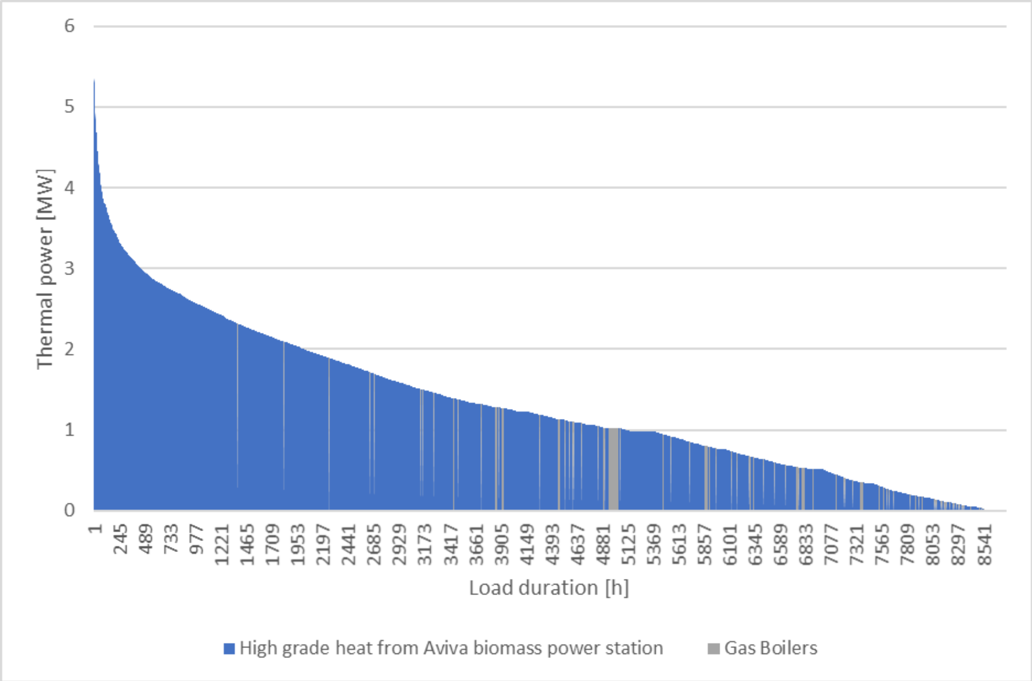
4. Extension to Colcot Rd Area

Supply analysis (4/6) – 'high-grade' heat from AVIVA biomass power station



Load duration curve - 5,540 kW 'high-grade' heat import from Aviva

- Optimised supply capacities:
  - 5,540 kW 'high-grade' heat import
  - 5,540 kW Gas Boilers
  - No thermal storage
- Notes / for Barry Docks / Town Centre network network as apply here

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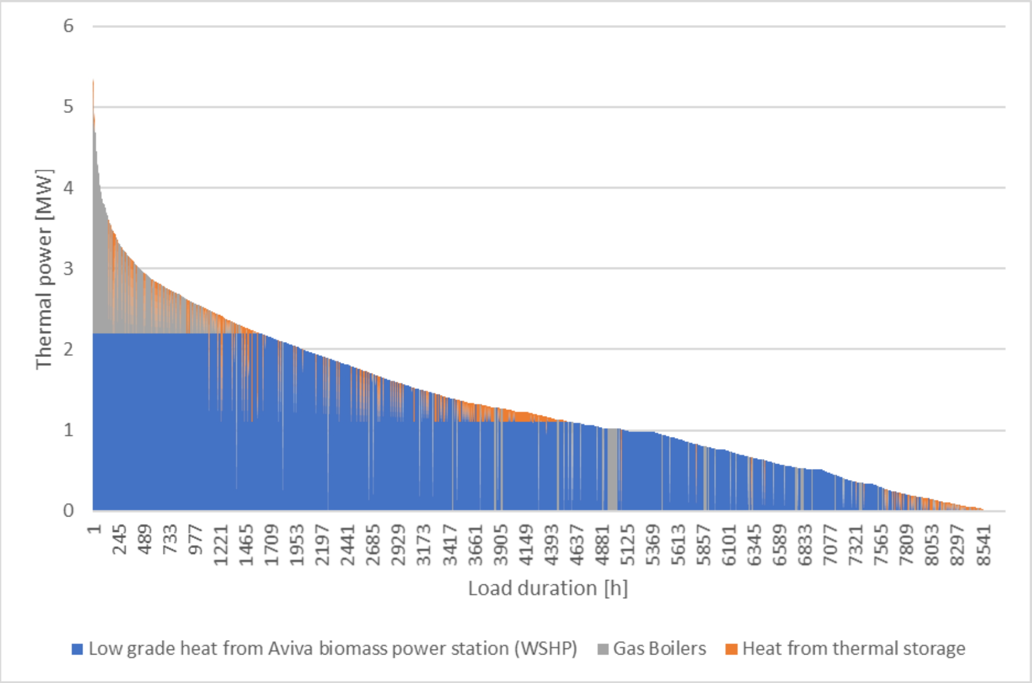
4. Extension to Colcot Rd Area

Supply analysis (5/6) – 'low-grade' heat from AVIVA biomass power station



Load duration curve - 2,200 kW WSHP ('low-grade' heat from Aviva)

- Optimised supply capacities:
  - 2,200 kW WSHP (at Aviva)
  - 5,540 kW Gas Boilers
  - 50 m³ thermal storage
- Notes / for Barry Docks / Town Centre network network as apply here

4. Extension to Colcot Rd Area

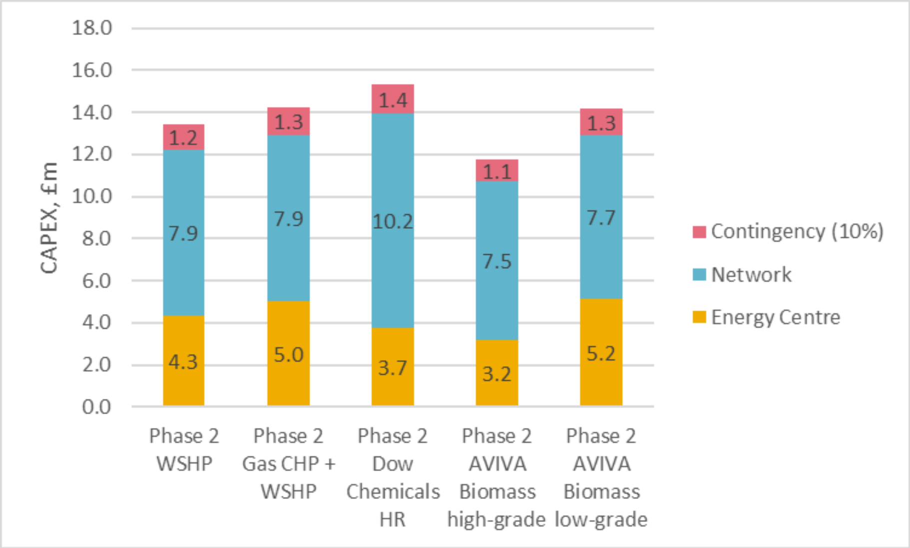
Supply analysis (6/6) – Summary

Heat and electricity production						
Supply option		WSHP	WSHP + Gas CHP	Heat recovery from Dow (WSHP)	'high-grade' heat from Aviva	'low-grade' heat from Aviva (WSHP)
Supply capacity						
WSHP	kW	750	1,000	1,100	-	2,200
Gas CHP	kW	-	400	-	-	-
Steam connection	kW	-	-	-	5,540	-
Gas Boiler	kW	6,450	5,800	6,100	5,540	5,540
Thermal storage	m³	50	100	50	-	50
Heat production share						
Heat production	GWh/yr	11.6	11.6	11.6	11.6	11.6
WSHP	%	50.1 %	57.1 %	66.3 %	-	88.9 %
Gas CHP	%	-	21.4 %	-	-	-
Heat purchase	%	-	-	-	95.8 %	-
Gas boilers	%	49.9 %	21.5 %	33.7 %	4.3 %	11.1 %
CHP electricity						
CHP electricity production	GWh/yr	-	2.3	-	-	-
Consumed by EC site	%	-	5.0 %	-	-	-
To WSHPs	%	-	90.3 %	-	-	-
To grid	%	-	4.7 %	-	-	-

Heat and electricity production

4. Extension to Colcot Rd Area

Techno-economic analysis (1/8) – Capital costs

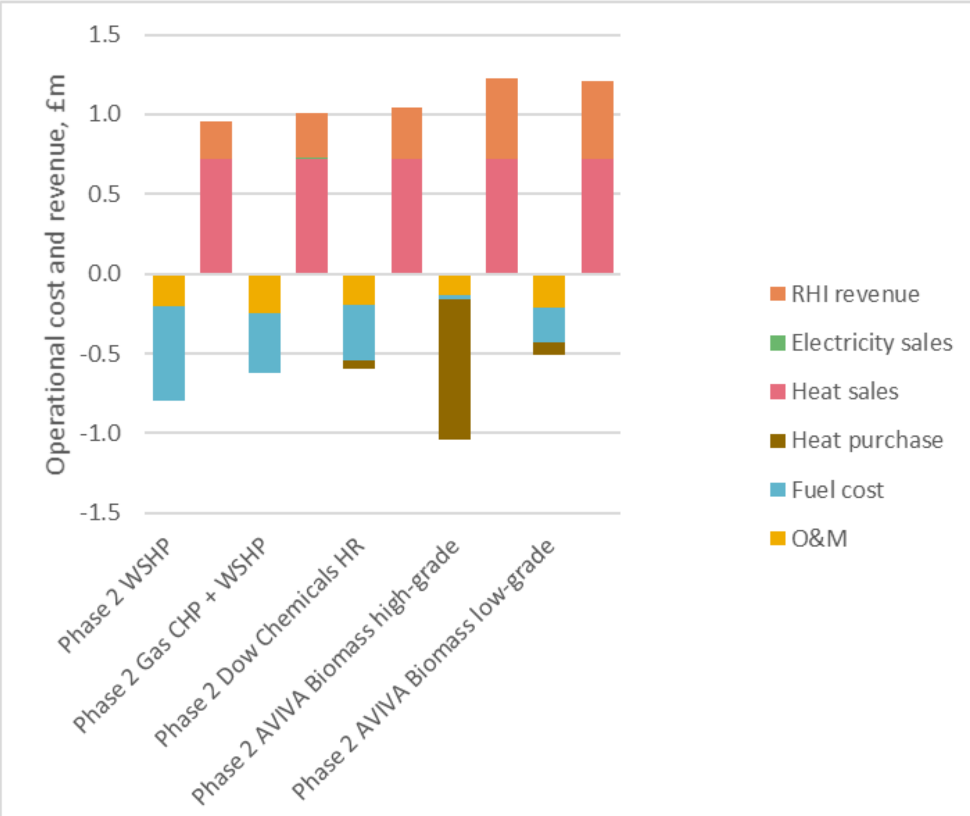


Capital costs

- In total the costs are estimated at:
  - £13.5m for the WSHP option
  - £14.2m for the Gas CHP + WSHP hybrid option
  - £15.3m for Dow Chemicals heat recovery (using heat pumps)
  - £11.8m for AVIVA biomass 'high-grade' heat recovery
  - £14.2m for AVIVA biomass 'low-grade' heat recovery (using heat pumps)
- Further details of costs are shown in Appendix 7.
- With Dow Chemicals, the proportion of network costs is c.50% higher than other options due to the long network connection required
- At this stage where costings rely on a range of assumptions, the tolerance on capital costs applied is ±20 %.

4. Extension to Colcot Rd Area

Techno-economic analysis (2/8) – Operational costs and revenue



Operational costs and revenue

- A summary of operational costs and revenues at full build-out is shown in graph with further detail in Appendix 8 and Appendix 9
- Operational costs range from £510k with AVIVA 'low-grade' heat recovery to £1,040k with AVIVA 'high-grade' heat recovery.
  - The latter is driven by the high bulk heat purchase cost (£50/MWh) which results from a relatively low z-factor and high value of power sales to Aviva due to their grandfathered ROC contract. See sensitivity for further review of this figure
- Electricity cost for operation of the Dow and Aviva ('low-grade' heat) options is assumed to be lower than typical (BEIS wholesale/grid export reference point used). This presumes power is supplied directly from the host organisations' on-site power generation.
- Revenues range from £954k with WSHP to £1,223k with AVIVA 'high-grade' heat recovery. Where the source of the energy renewable (Aviva & WSHP), RHI income is assumed.

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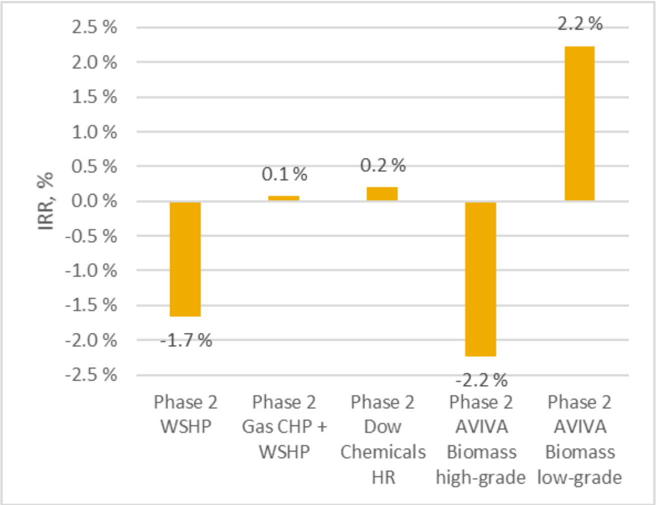
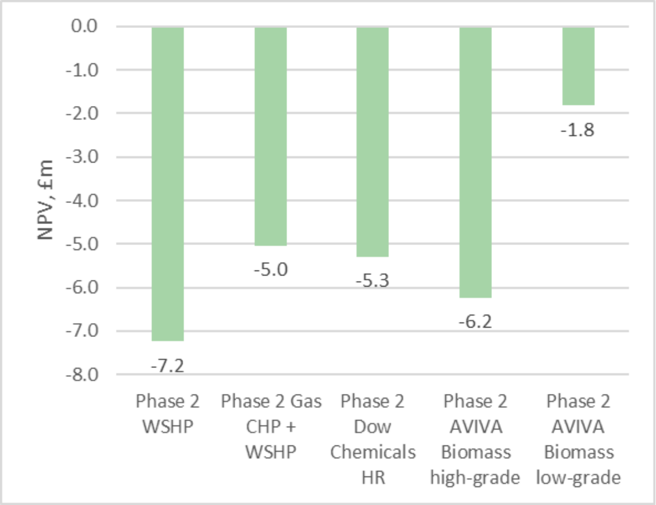
4. Extension to Colcot Rd Area

Techno-economic analysis (3/8) – IRR and NPV



IRR (25 years)



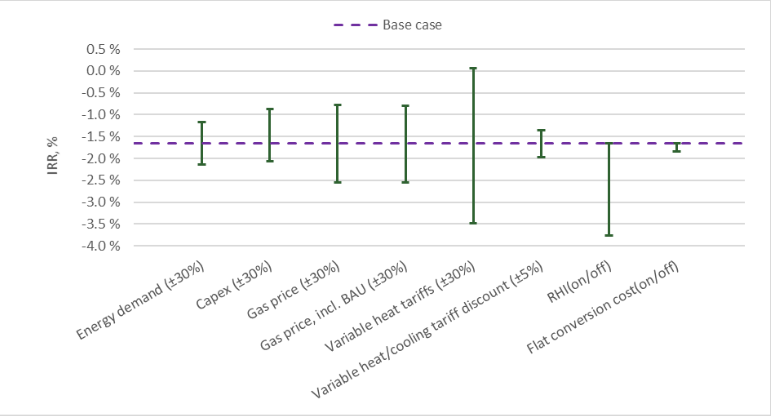
NPV (25 years @ 3.5 %)

- The figures above show the IRRs and NPVs of the various options with further data tables included in Appendix 10.
- AVIVA Biomass 'low-grade' heat recovery shows the strongest IRR at 2.2 %.
  - Largely due to high COP available from the temperature of recovered heat and assumed power costs
- Adding CHP to the water-source heat pump option to power the heat pumps increases IRR by 1.8 %.
- AVIVA Biomass 'high-grade' heat recovery performs poorly at -2.2 % IRR.
  - Explained by the high bulk heat purchase cost resulting from the z-factor / ROC contract

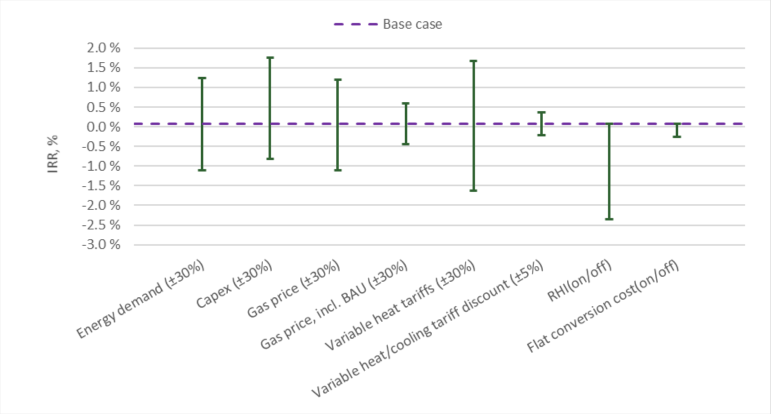
4. Extension to Colcot Rd Area

Techno-economic analysis (4/8) – Sensitivities

- Within the financial modelling, sensitivities of key parameters have assessed to examine the strength of the economic case for each option.
- Parameters have been considered independently although, in reality, parameters could change together and have a compound impact (positive or negative); this should be considered in any subsequent investigations.
- The figures highlight the impact on IRR (25-year) of the variation of key parameters. The impact varies across the options, making it complex to succinctly interpret the results, however, the following appear most significant:
  - Exclusion of RHI revenue (WSHP and Aviva options only) – presently RHI is due to close by Q1 2021. Although no plans to replace / extend RHI, is anticipated that some form of support programme will be forthcoming.
  - Change in gas prices (particularly for those with gas CHP), although the impact is likely to be mitigated since heat tariffs will typically, in part, be linked to gas prices.
  - Variable component of heat tariff (unlikely to vary significantly in practice)
  - Capital cost change has a significant impact. Cost reductions also appear to have a more significant (positive) impact than cost increases (negative). Value engineering and specification adjustment as well removing contingency and risk items (as the design develops) could deliver savings
  - Energy demand with increases (e.g. new consumers) have similar impact to reduction, e.g. revising consumption estimates downwards from initial assessment and similar affect all options. In this options performing least well it have less impact and as costs are already high relative to revenues
  - Heat purchase prices from Dow Chemicals and AVIVA ('high-grade' and 'low-grade'). This is more impactful for the 'high-grade' Aviva options because the cost of others are assumed to be a relatively low value in the base model.



Sensitivities for Colcot Road extension WSHP



Sensitivities for Colcot Road extension Gas CHP + WSHP

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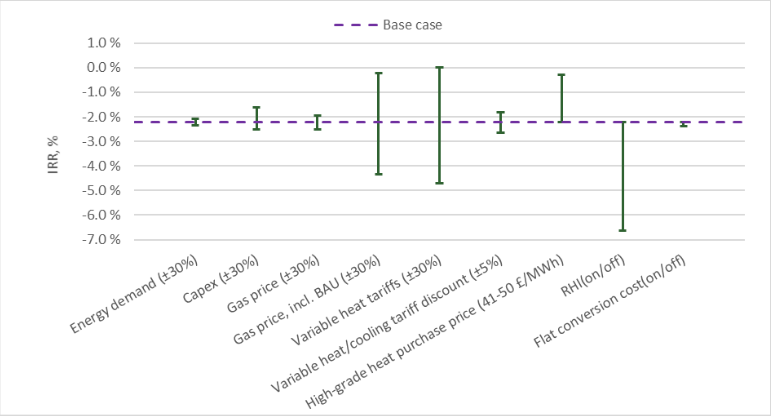
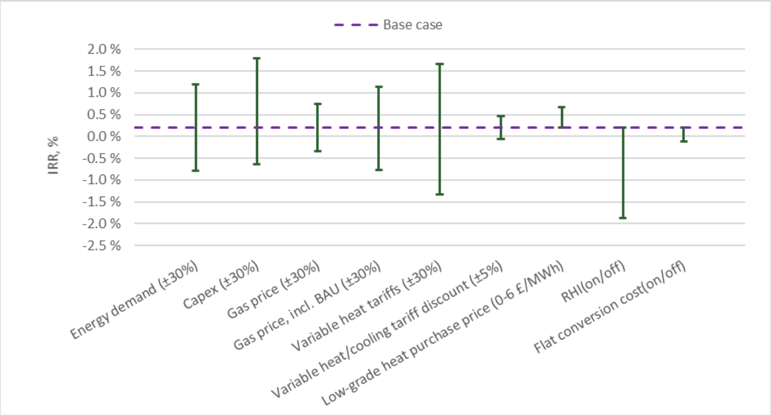
4. Extension to Colcot Rd Area

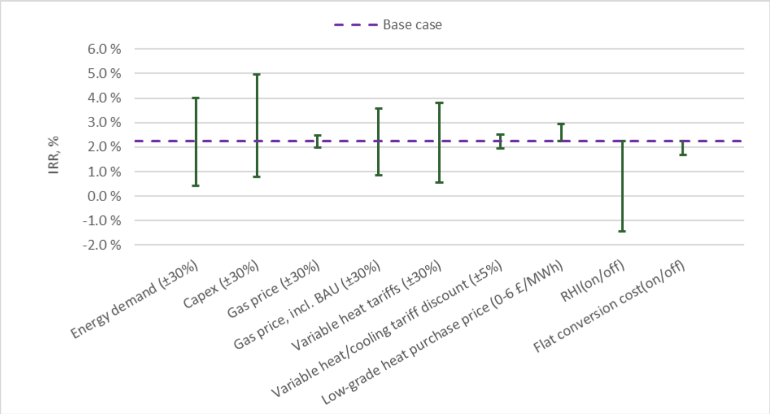
Techno-economic analysis (5/8) – Sensitivities



Sensitivities for Colcot Road extension AVIVA 'high-grade' heat recovery



Sensitivities for Colcot Road extension Dow Chemicals HR



Sensitivities for Colcot Road extension AVIVA 'low-grade' heat recovery

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4. Extension to Colcot Rd Area

Techno-economic analysis (6/8) – Analysis results

Techno-economic analysis results						
	Unit	WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass 'high-grade'	AVIVA Biomass 'low-grade'
Financial						
Total CAPEX (to full build out)	£m	13.5	14.2	15.3	11.8	14.2
Total REPEX (full scheme)	£m	3.7	4.7	3.3	3.2	4.5
Total OPEX (full scheme)	£m/yr.	0.8	0.6	0.6	1.0	0.5
NPV (25 yr @ 3.5 %)	£m	-7.2	-5.0	-5.3	-6.2	-1.8
IRR (25 yr)	%	-1.7 %	0.1 %	0.2 %	-2.2 %	2.2 %
Social IRR (25 yr)	%	-1.2 %	0.2 %	0.9 %	-1.4 %	3.4 %
LCOE (25 yr)	£/MWh	122.2	107.2	108.9	115.3	85.2
Minimum grant to achieve 6 % IRR	£m	8.3	6.7	7.2	7.0	4.2
Carbon						
CO_2 savings over 25 yr	$ktCO_2$/yr.	22.0	17.1	28.7	27.0	40.9
CO_2 savings over 25 yr	%	39.0 %	30.3 %	50.9 %	47.8 %	72.5 %
CO_2 savings per £1,000 grant	tCO_2/£1,000	2.6	2.5	4.0	3.9	9.7
Cost of CO_2 savings	£/tCO_2	1,299	1,469	887	999	487

Techno-economic analysis results

- A summary of key economic outputs of the financial modelling is presented in the table with further detail in Appendix 10.
- All options provide significant carbon savings ranging from 30 % (Gas CHP + WSHP) to 73 % (AVIVA 'low-grade' heat recovery).
- In absolute terms carbon savings range from 17.1 ktCO2/yr (Gas CHP + WSHP) to 40.9 ktCO2/yr (AVIVA 'low-grade' heat recovery).
- Conclusions regarding the performance of the options is discussed in section 5 (both networks).

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4. Extension to Colcot Rd Area

Techno-economic analysis (7/8) – Grant support

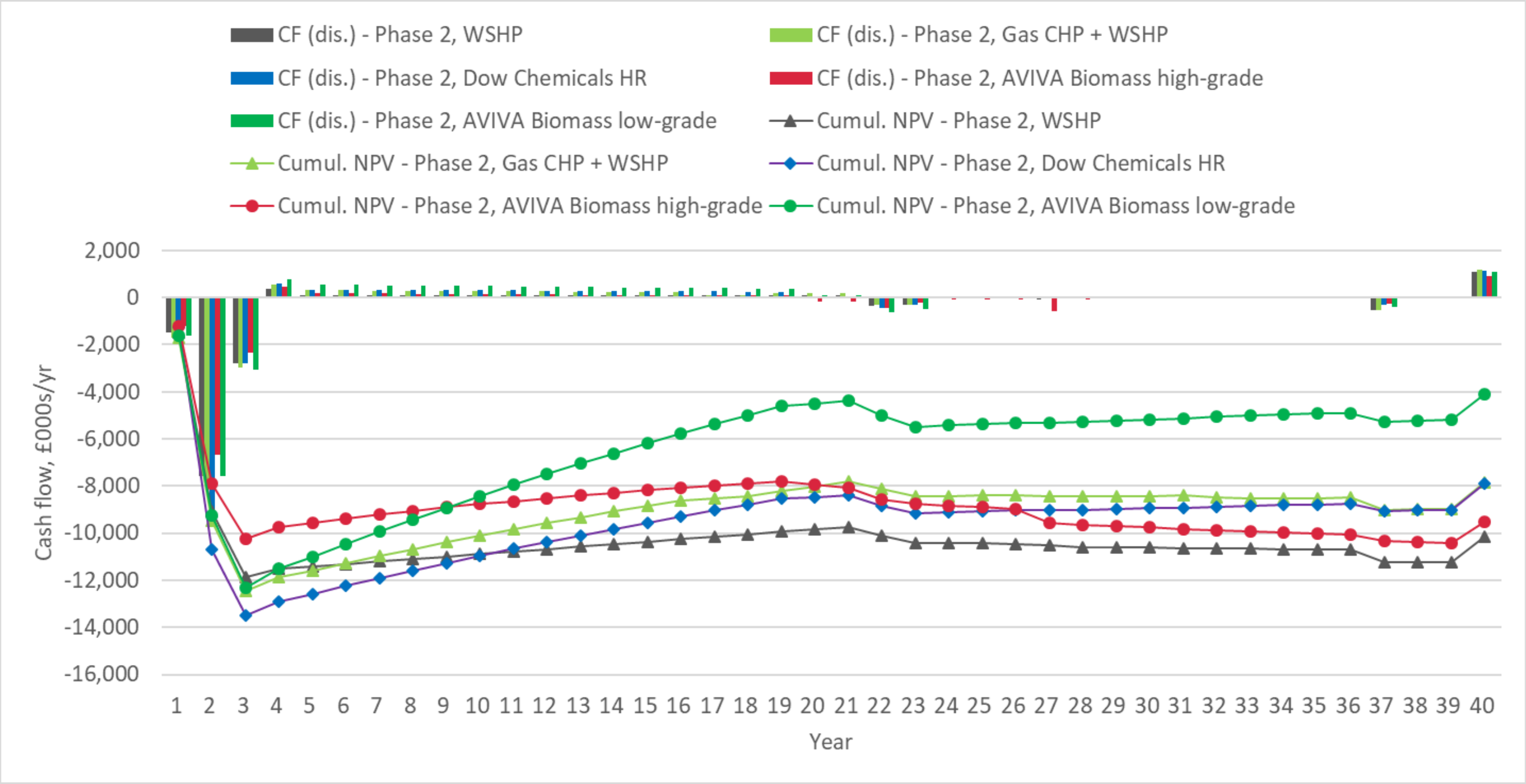
Grant support requirements						
		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass 'high-grade'	AVIVA Biomass 'low-grade'
IRR 5.0 %	£m	8.0	6.2	6.6	6.7	3.4
	% capex	59.3 %	43.6 %	42.9 %	57.2 %	23.9 %
IRR 7.0 %	£m	8.5	7.2	7.7	7.1	4.8
	% capex	63.3 %	50.4 %	50.0 %	60.4 %	34.1 %
IRR 10.0 %	£m	8.8	7.9	8.5	7.3	6.1
	% capex	65.4 %	55.5 %	55.3 %	61.9 %	42.9 %

Grant support requirements

- The table above shows the level of grant support (e.g. HNIP) that would be required to achieve specific rates of return
- All options achieve the HNIP criteria for funding regarding plant sizing
- Only AVIVA Biomass 'low-grade' heat recovery appears to be able to reach a 10 % IRR level without going above the requirement for 50 % of capex, which is a reasonable starting assumption for the maximum limit set by state-aid rules
- All options need fairly significant grant support even to achieve 5%, with WSHP, Hybrid WSHP/CHP, Dow Chemicals heat recovery and Aviva 'high-grade' heat option exceeding the requirement for more than 50% capex to achieve this

4. Extension to Colcot Rd Area

Techno-economic analysis (8/8) – Cash flow and net present value



Discounted cash flow – Colcot Road extension

- Discounted cash flow graphs shows general weak performance overall with poor balance between operating costs and revenues (shallow graphs)

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5. Techno-economic conclusions (Both networks)

		WSHP	Gas CHP + WSHP	Dow Chemicals HR	Aviva Biomass 'high-grade'	AvivaBiomass low-grade
Barry Docks / Town Centre network						
Capital costs	£m	7.3	7.9	9.2	6.5	7.6
IRR-25yr	%	-1.2 %	0.2 %	-0.4 %	-1.9 %	2.1 %
NPV-25yr	£m	-3.6	-2.7	-3.8	-3.3	-1.1
CO_2 savings over 25 yr	%	39%	33%	45%	48%	73%
Colcot Road extension						
Capital costs	£m	13.5	14.2	15.3	11.8	14.2
IRR-25yr	%	-1.7 %	0.1%	0.2%	-2.2%	2.2%
NPV-25yr	£m	-7.2	-5.0	-5.3	-6.2	-1.8
CO_2 savings over 25 yr	%	39 %	30%	51%	48%	72%

Key points:

- The IRR & NPV figures (25-year) show negative or marginal performance on all options. This is largely driven by the low heat density of assumed consumers which can only be addressed by adding additional consumers that have not be identified to date
- There is a negligible difference in economic performance of the two networks
- The best performing supply solution is the 'low-grade' heat supply from the Aviva plant which is driven by the assumed relatively low cost (of waste heat) and low power prices (to run the heat pumps and energy centre). The Dow option adds additional heat network capital cost and for this reason does not perform as well as the Aviva 'low-grade' option.
- The analysis also shows that that the hybrid WSHP/CHP should be selected on economic grounds in favour of the options with WSHP on its own. This will add some complexity and reduce carbon emission reduction but a better financial performance is more important at this stage.
- The analysis also shows that Aviva 'low-grade' option out performs the 'high-grade' option in economic and carbon terms and so it is recommended the latter is not further considered unless Aviva is able to significantly reduce the bulk heat cost
- The sensitivity analysis shows that there are opportunities to improve the economic case through design iterations. Particular areas of interest include reducing capital costs, increasing scale of demand (in close proximity to identified consumers) and exploring lower operating costs particularly with the Aviva or Dow heat recovery options.

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5. Techno-economic conclusions (Both networks)

Grant support

- Assuming no further improvements are made to the economic case, the grant support required is shown below to take the project options to an IRR of either 5% or 7%. The results highlighted in grey identify the technology options and IRR outcome combination that likely to be achieve-able, i.e. not been ineligible due to state aid rules (assumed to be 50% of capital costs), although this would need to be verified.
- Hence:
  - the Aviva "low-grade" option and should be eligible in up to and beyond 7% (in fact as shown early IRRs of over 10% could still be eligible – taking the project into the realm of being privately fund-able)
  - the Dow and WSHP/CHP hybrid options are only possible to an IRR of between 5% and 7%

Barry Docks / Town Centre network						
		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass 'high-grade'	AVIVA Biomass low-grade
IRR 5.0 %	£m	4.1	3.4	4.5	3.6	1.9
	%	56.1 %	43.2 %	49.0 %	55.2 %	25.2 %
IRR 7.0 %	£m	4.4	4.0	5.1	3.8	2.7
	%	61.1 %	50.5 %	55.4 %	59.1 %	35.3 %
Colcot Road extension						
IRR 5.0 %	£m	8.0	6.2	6.6	6.7	3.4
	%	59.3 %	43.6 %	42.9 %	57.2 %	23.9 %
IRR 7.0 %	£m	8.5	7.2	7.7	7.1	4.8
	%	63.3 %	50.4 %	50.0 %	60.4 %	34.1 %

5. Techno-economic conclusions (Both networks)

Heat Network benefits

There are a range of economic and environmental benefits that would be derived from these heat network options, assuming they were developed. In summary they are:

- A general 5% reduction in consumer energy costs (the basis for revenue modelling) and mitigation of future energy cost increases. This value can be varied to, each to support fuel poverty goals or encourage consumer connections, but it would have an impact on the rates of return for investors.
- Operational benefits for consumers including reduced plant liability and releasing property floor space
- Reduction in short term carbon emissions of between 30% and 73% for connected consumers – (depending on supply technology)
- Potential to deliver deep and sustained carbon reduction through expansion across the other parts of the town, over time
- Inward investment into the town of between £6m to £16m, depending on option
- Development of a local energy generation / supply entity
- Encourage commercial/residential tenant retention in the town

Techno-economic improvement opportunities

As discussed earlier that there are opportunities to improve the investment case for the all the project options considered. Improvement opportunities include incremental adjustments, such as adding new consumers to increase revenue, reduce capital costs through value engineering and specification changes, and, reduce operating cost. Reducing operating costs particularly relates to the Aviva and Dow options which are driven by the cost of bulk heat and power (for operation of the heat pumps), which would need to negotiated. In addition, regarding the Dow option there is a low certainty over the available water temperatures and hence a worst case of the 24 degC has been used – where this is higher it will reduce operating costs.

Other more significant design changes could also be considered which could deliver more significant benefits. These include: (1) designing the network as a low temperature scheme which can reduce heat losses, operating costs and plant costs (as well as increasing carbon savings). However, it may add some capital costs for the network and is likely to require property adaptations (other than for the new-build properties); (2) exclusion of heat interface units that (standard property connections), i.e. “direct connection”. Whilst this can reduce costs significantly is does present higher operational risks.

5. Techno-economic conclusions (Both networks)

Project risks

In addition to the overarching risks of not being able to achieve the required economic performance (as discussed previously) there are a number of addition risk. These are scheduled in the initial risk register shown in Appendix 12. This briefly describes the risks, provides a risk value (likelihood x impact) and suggested risk mitigation actions. Many risks are typical of a heat network scheme within an urban area like Barry. The following are the key ones identified:

- Securing consumers: this risk will require a lead agency, presumably Vale of Glamorgan Council, with external support to identify new consumers and the engage with both these and the consumers already identified in a bid to secure them
- Securing heat supply: the Dow and Aviva options rely on access to ‘waste heat’ with the necessary engineering arrangement and under a suitable commercial agreement. These issues will need to be agreed in principal prior to commissioning detailed engineering design and negotiation of terms. The WSHP option would also need to go through a detailed design process approvals for the water abstraction and, presumably, planning permission.
- Energy Centre location: securing land for the preferred supply options with the Aviva or Dow site or close to the docks for the WSHP options is critical. For the Dow and Aviva options the likelihood of securing land within the curtilage sites is thought to be high.
- Development Governance: it is anticipated that the council would need to lead development and so the primary risk resides around their ability to bring forward the resources and capability to implement.
- Potential network construction and servicing risks: the primary specific risks here is the need to cross the rail line and laying infrastructure within the highways which will need to be discussed with highways engineers to plan an optimal solution from both a construction and servicing perspective.
- Renewable Heat Incentive revenues: RHI is due to close in quarter 1, 2021 and no extension/replacement currently planned. In any case, where a project relies on the RHI income this will expire after year 20, which is the standard contract term applicable. As shown in the sensitivity analyses, having no-RHI would remove any case for investment into the WSHP and Aviva options. It would be important to further consider the availability of RHI (or replacement) and develop solutions address it not being available, e.g. achieving economic improvements elsewhere, or bringing in additional grant support.

5. Recommendations / next steps

At this early stage of investigation, the heat network options, as conceived, appear to be deliverable (with several significant risks) but not capable of achieving reasonable commercial performance unless there are further design improvements or grant support is accessed.

If delivered, a heat network it would provide benefits to consumers and to the town in terms of reducing energy costs, economic development and provide a solution to long-term decarbonisation of heat consumption, which would otherwise be very difficult to deliver.

It is recommended that the council conducts a detailed feasibility study into a heat network solution in Barry, focusing on opportunities to improve the case for investment, including identifying new consumers, value engineering, securing the preferred supply options and addressing key risks.

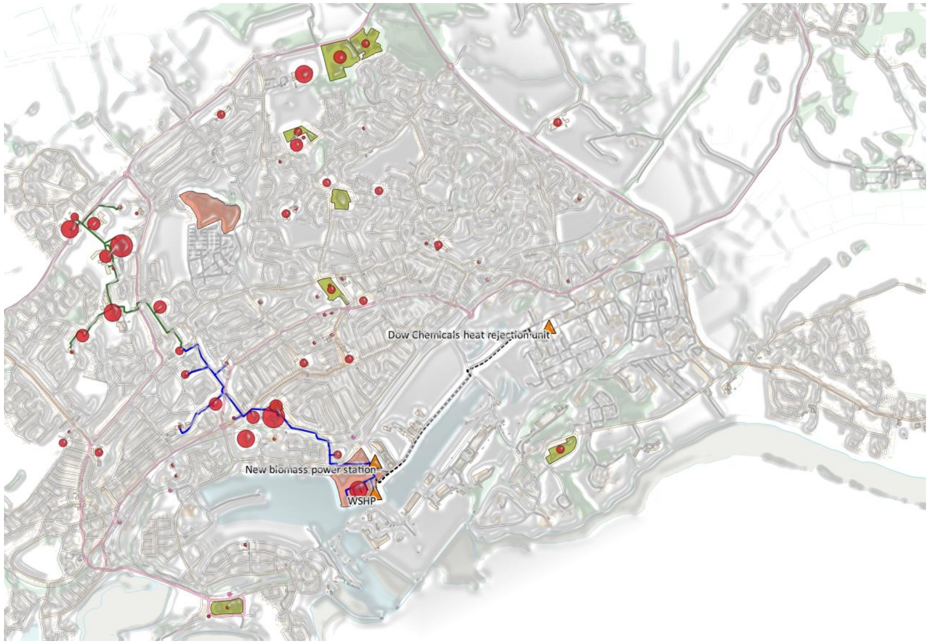
It is recommended that three supply options are considered from which to select a preferred solution, whilst retaining others as fallback options should the preferred solution prove not to be deliverable. The WSHP without CHP and the Aviva 'high-grade' solutions should be excluded from any further consideration as they are not likely to meet the economic performance requirements.

Key improvement opportunities should be considered: adding addition consumers, seeking market equipment and construction costs, refining input assumptions over bulk heat and power costs from Dow and Aviva and addressing design and development risks.

It is recommended that a detailed feasibility should also consider how best the council could develop its skills and capabilities to manage the development of a heat network project and also explore ownership and governance options.

Appendices (see separate document)

- Appendix 1. Energy Mapping
- Appendix 2. Prospective Consumers
- Appendix 3. Supply Technology Descriptions
- Appendix 4. Heat Network Infrastructure – General Notes
- Appendix 5. Heat Network Design Parameter, Pipe Sizing and Capital Costs
- Appendix 6. Preliminary Energy Centre Layouts
- Appendix 7. Capital Costs (whole system)
- Appendix 8. Operational Cost Assumptions
- Appendix 9. Revenue Assumptions
- Appendix 10. Detailed Financial Modelling Results
- Appendix 11. Carbon Reduction Analysis
- Appendix 12. Initial Risk Register



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Barry heat network masterplanning

Draft report – Appendices

June 2019

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The information provided in this report is for general information only and should not be relied on to inform investment decisions or technical design specifications.

It is not intended that the content and analysis in this report should be relied upon as the basis for commercial bids; bidders are expected to carry out their own due diligence and form their own technical and commercial solutions.

Table of contents

Appendix 1. Energy mapping

Heat mapping methodology

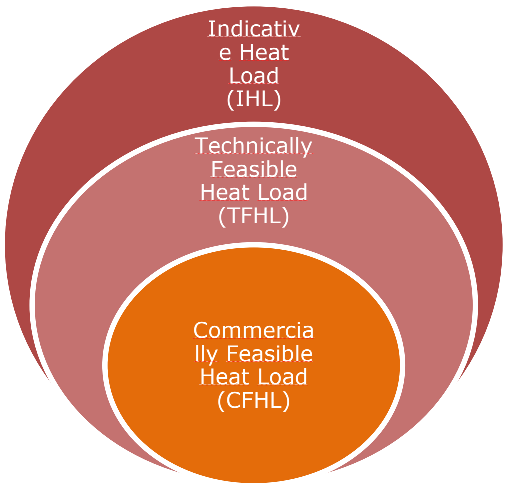
The heat mapping is conducted by utilizing data from various sources including:

- Primary consumption data for existing consumers (replacing benchmarked data), where it was made available by stakeholders
- Filed EPC and DEC records
- Barry Housing Allocations data
- Barry Employment Land data
- Barry Waterfront development masterplan
- Open source information (e.g. Google Maps)

Additional demands were identified in the area by engagement with the local authority. Where actual metered data or filed EPC and DEC records were not available, benchmarking analysis was used to estimate heat, electricity and cooling loads. The benchmarking methodology is described in the sections below.

Identifying appropriate loads

The figure below illustrates the various classifications of the energy load assessments that are used. Typically, the first, Indicative Heat Load (IHL) is determined from current energy use to provide heat, e.g. gas used in a boiler to provide heat. Where available, actual consumption information is used to determine the heat load. If actual consumption information is not available, then benchmarking is conducted, or where this is not possible, then other secondary data such as data from Energy Performance Certificates (EPCs) or Display Energy Certificates (DECs) could be used. Benchmarking and use of secondary data brings inaccuracies and uncertainty, and so metered data is always preferable but is frequently unavailable, particularly during early stage investigations.



The second classification is Technically Feasible Heat Load (TFHL) which is arrived at by adjusting IHL to account for non-displaceable loads, i.e. those that cannot be substituted by a heat network using hot water. Reasons could include that energy is required in the form of steam or at temperatures that are unsuited to a hot water network. At an early stage of analysis, this level of detail would typically only be considered for major consumers.

The final classification is Commercially Feasible Heat Load (CFHL), which is determined by excluding those loads for which supply from a heat network supply is unlikely to be commercially viable, e.g. an existing low-cost supply is available, or the cost of the transmission pipework required would be excessive. Commercial issues might also include phasing of the replacement of existing plant, the relative cost of connection, the loss of other potential revenues, e.g. from power generation where local CHP is being considered. CFHL is the thermal load that would ideally be modelled to determine the overall load required within a heat network. It is not always possible, for all prospective consumers, particularly at early stages of feasibility, to arrive at reasonable estimates for CFHL and this can subsequently be dealt with through risk and sensitivity analyses.

The methodologies used to analyse the heat loads of different building categories are presented in the following sections.

Existing buildings

Metered consumption

Where available, actual consumption information is used to determine the heat load. Actual consumption data varies from half-hourly/hourly, monthly or annual level data.

The consumption data, typically gas consumption data, was used to calculate the heat demand under the assumption of thermal efficiency of 80% for traditional Heat-Only-Boiler (HOB) systems across the whole data set.

If the consumption data was available at monthly or annual level, the data was time-profiled against assumed building occupation hours and heating degree days, to arrive at hourly consumption profiles.

Benchmarking

Annual consumption for all energy consumption is estimated through benchmarks based on property use, type of building, estimated internal floor area and number of dwellings. In order to reflect the energy performance of modern buildings, where applicable, good practice values from published benchmarks such as BEES and NEED for existing properties. Benchmark assessments are weather-corrected against local degree-days to match the number of annual heating degree days in the local area.

The BEES benchmarks define heating, hot water, cooling and electricity demands. NEED benchmarks define gas and electricity consumption per dwelling (the data can be sorted to by e.g. property type and property age). A typical boiler efficiency of 80% is then applied to arrive at a heat consumption estimate.

Annual heating demand was then also time-profiled against assumed building occupation hours and heating degree days based on external temperature variations in the local area. For occupied periods a heating degree day reference temperature of 15.5°C is assumed and during unoccupied hours 10.5°C. The analysis is used to generate estimated peak demands and consumption profiles for hot water and heating.

Hourly electricity demand is generally calculated by allocating standard winter (October-April) and summer (May-September) billing profiles for non-domestic buildings to the annual consumption data. Where electricity consumption demand profiles for a particular type of building is available then these were applied.

New development

Future energy demand has been estimated and profiled (on an hourly basis) for new development. A variety of planning, master planning and design-stage information has been used. The methodology for the analysis is as follows:

1. Sites have been split out into the different building use types (space types), so that each consumption type may be modelled separately.
2. Energy consumption benchmarks have been applied to each space type, using an appropriate benchmark. This calculation is done within an in-house energy demand modelling tool.
3. The total heat and electricity demand for the site are then mapped onto an hourly energy demand profile, using an energy profiling tool which incorporates energy demand profiles for different use types.
4. The total demand and demand profiles have been adjusted to account for degree day variations.

The following energy consumption benchmarks have been utilised:

1. BEES benchmark data was used to model the energy demand of the commercial use areas.
2. Building Regulations 2013 standards were applied to model benchmark data used to examine residential development.
3. NEED provides primary heat benchmarks for dwellings. A boiler efficiency of 80% was assumed to convert this figure into heat demand.
4. Existing hourly energy demand profiles have been used based on space type.
5. Heating benchmarks were adjusted according to any variation in Degree Days between the site and the UK average. A base temperature of 15.5°C was assumed for heating.

Appendix 2. Prospective consumers

Schedule of prospective consumers

Site	Phase	Type	Peak heat (MW)	Annual Heat Load (MWh)	Data Source
Barry Leisure Centre	1	Leisure Centre	0.71	1,795	Metering (council)
Barry Waterfront development (remaining)	1	Residential development	1.25	760	New development benchmarking
Barry Town Council / Memo Art Centre	1	Offices / Theatre	0.35	590	Estimate based on gas cost
Civic Offices	1	Offices	0.29	529	Metering (council)
VoG Magistrates Court	1	Courthouse	0.15	279	DEC
Ysgol Sant Curig	1	Education	0.08	150	Metering (council)
Docks Office	1	Offices	0.08	146	Metering (council)
Hen Goleg Resource Centre	1	Community	0.07	128	Metering (council)
High Street Primary School	1	Education	0.05	86	Metering (council)
Gladstone Primary School	1	Education	0.04	77	Metering (council)
C1V Call Centre	1	Offices	0.04	67	Metering (council)
RMU Unit - One Vale Call Centre	1	Offices	0.04	67	Metering (council)
Citizens Advice Bureau	1	Offices	0.02	27	EPC
Barry Hospital	2	Hospital	0.94	2,317	BEES
Tesco	2	Retail	0.31	805	Metering (HH)
Cardiff and Vale College - Colcot Road	2	Education	0.37	662	DEC
Barry Comprehensive/Now Whitmore High School	2	Education	0.22	400	Metering (council)
Ysgol Gymraeg Bro Morgannwg	2	Education	0.21	368	Metering (council)
Gwenog Court	2	Residential	0.15	362	Metering (council)
Awbery House (high rise block of Council Flats)	2	Residential	0.13	310	EPC / NEED
Barry Emergency Services Station	2	Emergency services	0.11	204	Metering (annual)
Ysgol Nant Talwg	2	Education	0.06	115	Metering (council)
Colcot Sports Centre (New Building)	2	Leisure	0.04	90	Metering (council)
All Saints CIW Primary School	2	Education	0.04	79	Metering (council)
Total			**5.75**	**10,414**	

Appendix 3. Supply technology descriptions

Included in appendix: Gas CHP; Water-Source Heat Pumps; Heat recovery from Aviva biomass power station; Heat recovery from Dow Chemical cooling towers; Gas Boilers; Heat Storage Systems; Air quality note

Gas CHP

Combined heat and power (CHP) systems capture the heat released during power generation, resulting in reduced energy losses and increased energy efficiency. Typical technology in small mixed used heating systems (<5 MW) and medium size (<20 MW) district heating systems are reciprocating gas-fired engine CHP systems. Overall efficiency in such systems is in the range of 80 to 90% with power to heat factor at 90 to 110%.

Gas fired CHP is a proven low carbon technology that can provide heat to district networks with additional revenue generated from power sales. Electricity can be distributed via a grid connection or by private wire to local customers. Key to good economic performance is identifying private wire opportunities to enable power to be sold at (near to) the retail electricity price (rather than the grid wholesale price).

Another aspect of achieving good economic performance is ensuring the gas CHP capacity is appropriately dimensioned. Capital and operating costs are relatively high and CHP plant is not suited to modulation (turning down) and as a consequence, utilisation (or load factor) needs to high to generate sufficient value from energy supply whilst minimising maintenance costs. Typically, gas CHP will met a baseload supply, operating for a minimum of 5,000 hours per year, with gas boilers/thermal storage are providing top up and back up.

Energy centre location and utility connections (gas and electricity) is also important factor as utility connections can add significant capital costs.

A well-designed gas CHP can modestly reduce carbon emissions due to its higher efficiency compared to the alternative case of conventional gas boiler and grid electricity produced mostly by large distant “power only” power stations. District heating CHP technology is appropriate today from a carbon perspective but would deliver reduced savings if the grid sourced electricity decarbonises in the future (as predicted), which leads to the need to replace or supplement the technology overtime with lower carbon technologies, if carbon saving is a primary objective.

Water-Source Heat Pumps

Water source heat pumps operate by taking heat from the water, upgrading to useable temperatures through an electrically driven heat pump system so that it can be fed into a building or local heat networks. The WSHP system will include a heat pump unit (or units) and a water pumping system which might be integrated in the WSHP heat pump energy centre or be a separate pumping station close to the water source. Water abstraction and discharge pipes are required in both cases.

COP (Coefficient of Performance) of the heat pump is mainly dependent on the temperature difference between the lowest and highest temperature in the system. If abstracted water temperature is 10 degrees and it is discharged at 5 °C and district heating flow temperature is 75 °C the highest temperature difference in the system is 70 °C. In above case COP might reach the level of 2.5 to 3.0. If assuming that COP is 2.75 it means that one (1) part of electricity is consumed to produce 2.75 parts of thermal energy.

Using water source heat pumps would achieve savings in CO_2 emissions and also gain financial support in the form of Renewable Heat Incentive (RHI); current rates for all capacities for WSHP and GSHPs are: tier 1, 95.6 £/MWh and tier 2, 28.5 £/MWh.

Technically, when looking at the feasibility of implementing a heat pump into a specific river or canal the two most important characteristics are water temperature and flow rates.

Heat recovery from Aviva biomass power station

The option refers to heat import from a nearby Aviva biomass power station. Two different types of heat import are possible according to Aviva; high grade heat from a tapping point in the power generation unit or low grade heat from an additional water-cooled condenser.

High grade heat would be available in the form of HP steam at 45 bar and 400°C temperature with potential 13.2 kg/s availability. Imported steam would be used to generate hot water for the heat network with heat exchangers. Exporting HP steam energy from the power generation process reduces electricity output by one third based on Aviva initial estimate and to a heat sales price of 50 £/MWh for the steam. Modifying the power generation units into biomass CHP unit would mean that financial support in the form of RHI could potentially be available if the system complies with other requirements set for biomass CHP installations (subject to further investigation). Current RHI rate for all biomass CHP capacities is 45.1 £/MWh.

There is also the option of low grade heat import, which could be available in the form of 35°C hot water from an additional condenser installation (subject to confirmation of feasibility by a condenser manufacturer/or Aviva ACC supplier). Aviva has estimated that up to 25 MW of low grade waste heat would be available for export. Water-source heat pumps would be required to upgrade the low temperature excess heat to temperature levels required in the heat network. Major benefit of WSHP systems using industrial waste heat compared to WSHP's using natural water sources (sea, river etc.) as a source of heat is higher and less varying heat source temperature. With higher source temperatures the heat pumps are able to operate more efficiently and achieve higher CoP values.

Heat recovery from Dow Chemical cooling towers

The option refers to extraction of heat from Dow Chemical's excess heat generated in the site's cooling processes. Cooling water between 22°C and 35°C returns from process users to the cooling towers where the water is cooled down to 24°C or below with air and recirculated into the cooling processes. Dow has estimated a constant 60 m^3/hr flow rate of water into the cooling towers.

This excess heat can be extracted from the cooling water with a water-source heat pump system and upgraded to useful temperatures with an electrically driven heat pumps similarly as in any other water-source heat pump installation. Major benefit of WSHP systems using industrial waste heat compared to WSHP's using natural water sources (sea, river etc.) as a source of heat is higher and less varying heat source temperature. With higher source temperatures the heat pumps are able to operate more efficiently and achieve higher CoP values.

Gas Boilers

Gas fired boilers are common generation plant for individual heating systems as well as for centralised district heating. Gas is a fossil-based energy source that has low capital costs and flexibility to be used at different operating temperatures and it reacts quickly in load variations. Gas boilers are often used as back-up and peak boilers in district heating systems alongside combined heat and power baseload generation plants.

Heat Storage Systems

In addition to the energy supply options considered above, heat storage can be a useful addition to a heat network. The optimum use of the capacity mix can be enhanced by including heat storage which is used to even out momentary demand variations and most importantly, can increase the use of base load capacity, maximising carbon reduction and use of the least-cost supply option. During periods of low heat demand (e.g. during night periods and at weekends) the excess base-load capacity can be used to ‘charge’ the heat storage and correspondingly, during high heat demand the storage ‘discharges’ partially replacing peak supply plant (gas boilers).

In addition, heat storage brings other operational benefits by reducing the need of short-term modulation of heat production from CHP, heat pumps or boiler systems; this helps to ensure higher efficiency and will also reduce the maintenance needs. Other operational benefits also include production optimisation with energy price hourly variations. This concerns mainly on Gas CHPs and heat pumps; CHP electricity generation can be scheduled at the times when electricity price is high and WSHP when electricity price is low, respectively.

Air quality note

All heat generation technologies that utilise combustion present a localised air pollution risk particularly in terms of NOx and particulates. This can be mitigated through the use of modern boiler technology (which is likely be required under Medium Combustion Directive licensing) and appropriate siting of the boiler plant/energy centre. Where energy centres are to be developed, evidence would need to be prepared, including flue gas dispersal modelling, to enable licencing by the Environment Agency.

There are currently no Aire Quality Management Areas declared in the study area and as such there are no known specific air pollution concerns in any of the locations proposed for energy centres.

A heat network would displace existing or planned (in the case of new development) property-level boilers. The impact of a heat network will therefore be to reduce the total volume of combustion gases entering the atmosphere and to reduce air pollution overall. This benefit is compounded by that fact that the displaced boilers will be less efficient and more polluting than the highly managed energy plant within a heat network energy centre.

Where gas CHP is used within a heat network energy supply strategy it may lead to an increase in overall air pollution since this would use gas locally to generate power (as well as heat), which would otherwise be delivered via the ‘grid’ utilises a diverse range of generation technologies outside of the study area.

Appendix 4. Heat network infrastructure – general notes

Included in appendix: Heat network pipework; Trenches; Testing and commissioning of pipe welds; Valves and valve chambers; Routing Principles and Key Constraints; Heat Interface Units (HIUs); Electrical network

Heat network pipework

It is assumed the network would constructed with pre-insulate steel pipework. The pipe assemblies will consist of a steel service pipe, rigid polyurethane foam insulation and an outer casing of polyethylene. The pipe assembly would also include the following additional elements: measuring wires, spacers and diffusion barriers. Measuring wires are used to monitor moisture inside the polyurethane insulation to predict corrosion. An upper limit for thermal conductivity is typically set at 0.033W/mK but modern applications often reach a level of 0.026-0.029 W/mK.

The steel heat network is typically designed to withstand a maximum operating temperature of ≤120 °C (flow), however 100 °C is rarely exceeded and flow will typically vary between 80-85°C most of the year. The standard maximum nominal design pressure for the pipes is 16 bar or 25 bar (typical shown as PN16 or PN25). Actual pressure level will typically vary between 5-10 bar (including static and dynamic pressure), depending on operating conditions in the network.

Recommended pipe material for the underground DH pipeline is carbon steel P235GH for pressure level of PN 16 and for the pipe dimensions less than DN 500. P265GH is recommended for PN 25 (typically used in deep underground tunnels or areas with high topographic difference) and where pipe diameters are greater than DN 500.

DH circulation water is demineralised water with oxygen removal; hydrazine (oxygen removal chemical) is fed into the DH network to prevent corrosion.

Properties of pre-insulated polyurethane bonded district heating pipes are governed by the following European standards:

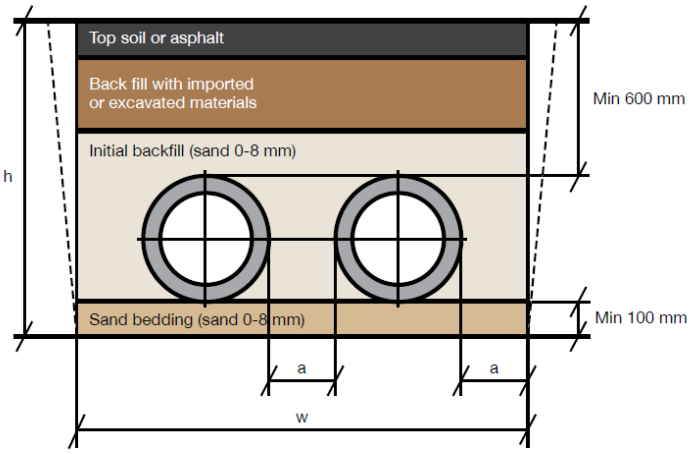
- EN 253 for pipe assemblies
- EN 448 for fitting assemblies
- EN 488 for valve assemblies
- EN 489 for joint assemblies
- EN 13941 for design and installation
- EN 14419 for surveillance systems.

Trenches

The figure below shows a typical construction detail for a heat network mains pipe trench in the public highway, using a pair of pipes for flow and return; this is the recommended pipe system in this case. The minimum distance from the top of the pipes to ground level is 600mm. Pipes can be located within road structures as defined under NRSWA[1], but care should be taken with design and construction. The dimensions of the excavation depth (d) and width (w) and the separation distance between pipes (a) and from the excavation edge (b) depend on the size of pipe and the highway construction. **Error! Reference source not found.** provides the suggested relevant trench dimensions

[1] New Roads and Street Works Act

for typical pipe diameters. Additional space at welding points, corners, valve locations and spurs will be required.



Typical installation arrangement for separate flow and return pipes (source: London Heat Network Manual, GLA, 2014).

DN (carrier/ casing)	a (mm)	b (mm)	w (mm)	h (mm)
DN80/160	150	150	770	860
DN80/160	150	150	770	860
DN100/200	150	150	850	900
DN125/225	150	150	900	925
DN150/250	150	150	950	950
DN250/400	200	200	1400	1100
DN300/450	200	200	1500	1150
DN400/560	200	200	1720	1260
DN500/630	200	250	1910	1330
DN600/800	250	300	2400	1500
DN700/900	250	300	2600	1600

Table 1. Trench minimum dimensions.

When the trench is located within the public highway the depth, surround, backfill and reinstatement of the trench must comply with the NRSWA (New Roads and Street Works Act 1991) specification for the reinstatement of openings in roads. When backfilling, the initial surround (a minimum of 100mm) above the heat network pipes should use specified, imported and screened sand.

The excavated trenches should be surveyed to determine high and low spots of the installed bonded pipe network. This information should be used to inform where the optimum positions for air release valves and drainage valves are to be located.

Where a heat network is installed in proximity to other existing utility and service apparatus, the installation of the heat pipes should endeavour to comply with the principles of separation from other apparatus. Separation will depend upon the congestion of the area and consultation with owners of the existing apparatus is recommended.

Where a heat network is installed in new developments where no other apparatus exists, the installation should endeavour to comply with the principles within the National Joint Utilities Group Guidelines on the Positioning of Underground Utilities Apparatus for New Development Sites.

Testing and commissioning of pipe welds

Pipe work should be tested as detailed in EN 13941. Typical requirements which should be included in the works specification are:

- All steel pipe welding is to be undertaken by certified coded welders. Certification must be in compliance with current British and European Standards. Welders may be subjected to a welding test with at least the same acceptance criteria as the criteria for the finished work, with reference to EN 25817;
- A testing regime must be established for welded joints e.g. non-destructive testing of 10% of welds as detailed in EN 13941. Visual inspection of welds is required;
- All pipe work installations should be hydrostatically pressure tested, witnessed, and signed off by a competent engineer. All equipment used for testing should be fully calibrated and the test procedures and monitoring proposals must be agreed before the tests commence;
- Following completion of a satisfactory pressure test the site closures must be made in strict accordance with the pipe work manufacturer's specification;
- The leak detection system must be tested and certified; and
  Systems must be flushed and treated prior to being put to service.

In terms of case joint welds, typical requirements to be included in the works specification are:

- Joint assemblies for the steel pipe systems, polyurethane thermal insulation and outer casing of polyethylene shall comply with BS EN 489. The joint assemblies shall be installed by specially trained personnel according to the instructions given by the manufacturer. Fusion welded insulation joints shall be implemented to join the pre-insulated steel pipe systems;
- All joint assemblies must be manufactured by same manufacturer as the steel pipe systems and/or approved by the steel pipes systems' manufacturer for use with their pipes;
- The joint should be pressure tested to confirm it is air tight;
- Polyethylene welders shall possess evidence of valid qualifications, which document their ability to perform reproductive welding of the quality specified.

Valves and valve chambers

All valves on a heat network should be pre-insulated and of the same manufacture as the pre-insulated pipe system. Where necessary spindle extensions must be provided to enable operation of the valves buried at depth or located within manholes where it is otherwise unnecessary to enter.

Where valves are housed in specific chambers then these chambers should be sized to accommodate the apparatus within them and to enable easy operation of the valves. The valve chambers and associated items must be designed to withstand the likely traffic loads applicable to their location. Valve chambers should be clearly marked such that the location and contents of the pipes are easily identifiable.

Routing Principles and Key Constraints

Heat network routing has been developed to connect key heat loads efficiently (shortest distances) and has been influenced by constraints identified during site inspections (route walk-throughs). Where possible, the network route takes advantage of 'soft dig' land, to minimise installation costs (e.g. removing and reinstalling pavement/roadways). Pre-insulated pipes would be directly buried, thermal expansion being accommodated by the friction between the surrounding compacted soil and the outer polyethylene casing of the heat network pipeline. Where land constraints are an issue, e.g. contamination, then over-ground sections could be considered. No compensators are proposed because they are prone to leakage and breakages over time.

Where possible, it is recommended that construction of the heat network be integrated into other construction works to deliver savings in construction costs and ensure in-building costs, such as boilers, are fully displaced and correctly accounted for.

Heat network heat losses

Heat conduction is directly proportional temperature difference. In district heating pipelines, heat is conducted from the pipeline to ground and consequently to the environment. A portion of the heat is conducted from flow pipe to return pipe. This portion is not counted as losses, as it is returned to the energy centre.

Heat loss calculations have been performed for each month of operation, taking account of estimated variations of heat demand, flow, return, and ground temperatures. The heat loss percentage is calculated for the whole year and presented in the report.

The heat networks code of practice advises network-side heat losses not to exceed 15% of the heat supplied up to the point of connection of each building, while the losses are typically expected to be less than 10%. Heat losses from a secondary heat distribution system within a multi-residential building shall not exceed 10% while losses less than 10% would constitute best practice.

Heat Interface Units (HIUs)

Heat consumers (individual buildings) are connected to the district heating network indirectly using prefabricated heat interface units (HIUs). Generally, the use of HIUs (a separate heat exchanger between the heat network and consumer circuits) is an additional cost component compared to direct connection. It is not an evident that the total costs of the installation are higher, considering that the primary temperature and differential pressure should be adjusted to the level of the secondary systems. Drawbacks with a direct connection are as follows:

- The risk of a leak in the heating system having large consequences
- It can be difficult to handle large pressure variations in networks with significant differences in height (not an issue in this project)
- Unless a heat network keeps relatively low pressure and temperature levels, it must be reduced in some way to match the internal systems of a building

HIUs comprise of heat metering equipment and isolation valves on the supply side, and heat exchangers, and circulation pumps on the consumer's side. For small building (e.g. individual residential consumers), these usually come packaged in a single unit, some of which are a similar size to wall-hung boilers. For larger buildings, the equipment is larger but is easily accommodated in existing boiler rooms. If the consumer has existing gas-fired boilers, these can usually be replaced directly with the district heating HIU, providing the operating temperatures are compatible. In comparison with boiler plant, HIUs require a smaller space, are quicker and easier to install and are easier to maintain.

Details of connections for each building will need to be developed in due course but the diagram below shows a typical connection and metering arrangement. A heat exchanger unit and arrangements for domestic hot water off-take will also need included on the consumer side of the connection.

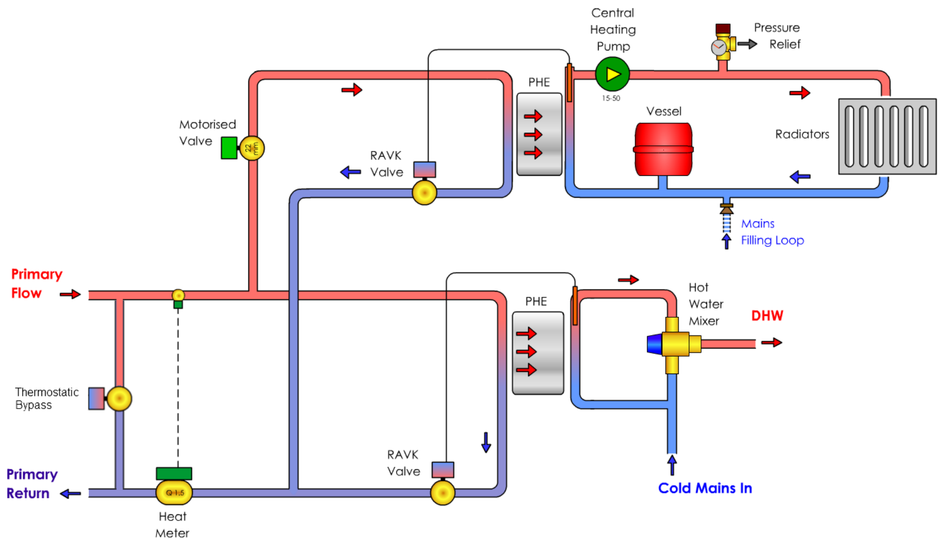


Diagram illustrating a DH Consumer's Heat Metering Equipment and Heat Interface Unit (HIU).

Typical modern units have automatic temperature controls such that the heating circuit is adjusted in relation to outdoor temperature and the required indoor temperatures via a thermostatic control, outdoor sensor and/or indoor sensor; this enables optimisation of water flow and temperatures which will improve system efficiency.

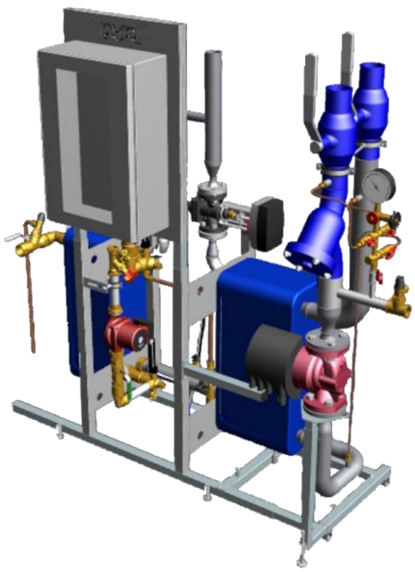
The HIU/property connections used in larger buildings are typically free-standing units (opposed to wall mounted for smaller buildings), as is the case with the unit shown below. HIUs are typically delivered as ready-to-install packages and as such are easy to install.

Modern units can be controlled and monitored remotely using a standard PC with an internet connection or by an operator panel.

Sufficient space around the HIU is required to enable installation and maintenance. The height of the plant space should be at least 2m. The HIU typically requires 80 cm of space in front and 60 cm on either side. The total space requirement will typically be:

- Length: 300.0 cm – 329.0 cm
- Width: 218.0 cm – 249.0 cm
- Height: 134.0 cm – 212.0 cm

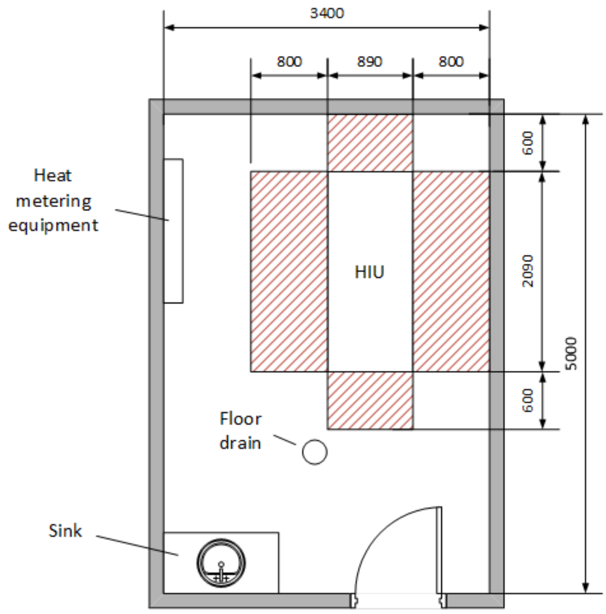
An indicative layout drawing of a plant space with the largest HIU (1000/700, as presented above) installed is shown below.



Typical modern heat interface unit (HIU) suitable for larger consumers.

The space should be equipped with a faucet and a floor drain. The temperature of the plant room may vary between 5-35°C, and a heating element must be installed if the plant room temperature can fall below 5°C.

Technical and commercial data concerning typical and modern HIUs for large buildings is presented in the table below. Cost estimates are based on consultant's previous experience on similar projects and on budget proposals requested for this case.



Indicative plant space layout drawing, shown with the 1000/700 unit installed.

HIUs for large buildings				
Unit		**300/300**	**600/450**	**1000/700**
Rating, heating	kW	300	600	1000
Rating, DHW	kW	300	450	700
Temperature, heating primary	°C	100-52	100-55	100-54
Temperature, heating secondary	°C	50-70	50-70	50-70
Temperature, DHW primary	°C	65-21	65-19	65-18
Temperature, DHW secondary	°C	10-55	10-55	10-55
Length	cm	185	180	209
Width	cm	58	73	89
Height	cm	134	155	212

Technical and example commercial data for large HIUs.

Installation costs can be estimated to amount to 50% of the substation cost if the building is newly built, and 100% of the substation cost if the substation is installed in an existing building, requiring removal of existing gas boilers from the plant space and renovation of the plant space.

Electrical network

An important revenue opportunity for heat networks is the possibility to introduce Combined Heat and Power (CHP) systems. The total efficiency of a CHP heat network system is much higher (about 85%) compared with separate heat and power production (ranging between 55-65%), with commensurate fuel savings and environmental benefits.

From a financial viability point of view, it is important that the revenue from power generation can be maximised as this will contribute to the payback of the network investment. The value of CHP electricity depends on the trading arrangements and the degree to which power generated can be consumed on site, where it will command the greatest value. Electricity exported to the 'grid' yields significantly lower value compared to utilising it on site (end consumer or as an input for heat pump systems) or selling it through a private wire network, both of which can achieve values close to retail tariffs, which will vary between £95/MWh to £125/MWh for non-domestic consumers[2]. Sale or 'spill' to the 'grid' will typically achieve a value below the wholesale electricity market price which is dynamic but will typically be in region of £45/MWh to £50/MWh.

Minimising export to 'grid' is achieved by correct sizing of CHP plant and effective generation scheduling. Since the heat demand profile will not be truly known until the heat network is fully operational and "bedded-in" it is important to be conservative, since additional CHP could be added at a later stage, whereas oversized plant will lead inefficient operation with increased modulation and periods of shut down. On-site power storage (via batteries) or diversion to other uses such as vehicle charging could also be considered.

Power will also still be required to be purchased via the regional power network to fill the gap between demand and the CHP supply.

The operational power demands for the main energy centre, which would be located with the CHP plant, would be covered from the CHP generation or, during non-operating periods, from the grid.

The CHP plant arrangement would also include a step-up transformer and switching equipment for the generator and a grid connection facility, assuming the regional power network is able to accept the exported power.

Approvals for connections on to regional power network for the proposed CHP plan is a key issue. In some locations, regional electricity networks need reinforcement to allow new generation to connect on to them and this can be exacerbated by other new generation being developed, such as solar farms, seeking to connect on to the same network. Minimising export capacity through appropriate sizing and operation of CHP plant can mitigate this risk. In addition, Distributed Network Operators (the organisations operating regional electricity networks) are actively considering dynamic grid connection arrangements would prevent export when the network is constrained, and therefore potentially allow larger capacities able to export at unconstrained times.

[2] Quarterly energy prices, BEIS

Appendix 5. Heat network design parameters, pipe sizes and capital costs

Operational parameters

In this study, the district heating network layout and pipework has been optimised and dimensioned using TERMIS district heating/cooling hydraulic modelling software. The design parameters used for dimensioning are presented in the table below.

Parameter	Value	Source
Maximum design temperature Maximum operating temperature	140°C 120°C	HVAC TR/20, 2003
Upper dimensioning supply temperature – Flow (plant outlet)	90°C 80°C (heat pumps)	HNCP[3], BEIS report: Assessment of the costs and performance of HNs (Bulk schemes, max value), supplier data
Lower dimensioning temperature – Return (consumer HIU)	55°C 45°C (new developments)	HNCP
Maximum design gauge pressure	16.0 bar	HVAC TR/20, 2003
Static return pressure	3.0 bar	Greenfield experience from prior projects
Pressure loss guideline to be used in design Main lines Branches	 100 Pa/m 250 Pa/m	 London Heat Network Manual London Heat Network Manual
Minimum pressure difference at consumer HIU	60 kPa	HNCP
Pipe series	2	Greenfield analysis

Design parameter assumptions used for hydraulic modelling of the heat network.

The Heat Networks proposed are dimensioned with a source (or flow) temperature of 90°C at peak demand. It is proposed that the network would operate on a variable flow and variable temperature basis, with changes in both responding to the instantaneous consumption needs. Higher loads will require greater water flow (controlled at the 'consumer substations' or 'Heat Interface Unit') and higher source (often called 'flow') temperatures.

The flow temperature would typically reside around 80-85°C (70-75°C with heat pumps) until an outdoor temperature of below 0-5°C occurs. With colder weather, the flow temperature is gradually increased towards the maximum temperature. Return temperature is dependent on correct/optimum design and operation of consumer substations and building heating systems, varying normally between 45-55°C.

Pipe dimensions and capital costs

Pipe dimensions (shown in map form and tables) and capital cost breakdowns are presented in the below for the network options considered.

[3] *Heat Networks Code of Practice*

Phase 1 Barry Docks and Town Centre (WSHP & Gas CHP + WSHP) pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	125	23.1	63.1	86.2
DN32	821	153.5	424.6	578.1
DN40	-	-	-	-
DN50	422	98.8	205.6	304.4
DN65	379	95.3	266.9	362.2
DN80	53	16.8	28.2	45.0
DN100	478	205.7	334.5	540.2
DN125	74	37.7	55.4	93.0
DN150	1,082	705.1	710.5	1,415.5
DN200	41	31.3	23.1	54.4
DN250	-	-	-	-
Subtotal	3,540	1,379.2	2,144.3	3,523.5
Constraint mitigation				-
Contingency (10%)		137.9	214.4	352.4
Total	3,540	1,517.1	2,358.7	3,875.9

Phase 1 Barry Docks and Town Centre (WSHP & Gas CHP + WSHP) pipe dimensions and capital costs.

Phase 1 Barry Docks and Town Centre (Dow Chemicals heat recovery) pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	125	23.1	63.1	86.2
DN32	821	153.5	424.6	578.1
DN40	-	-	-	-
DN50	481	112.5	232.0	344.5
DN65	380	95.4	267.3	362.6
DN80	53	16.8	28.2	45.0
DN100	516	221.8	355.6	577.4
DN125	74	37.7	55.4	93.0
DN150	985	642.4	656.4	1,298.8
DN200	1,782	1,356.0	1,053.1	2,409.1
DN250	-	-	-	-
Subtotal	5,281	2,671.1	3,168.1	5,839.3
Constraint mitigation				-
Contingency (10%)		267.1	316.8	583.9
Total	5,281	2,938.2	3,485.0	6,423.2

Phase 1 Barry Docks and Town Centre (Dow Chemicals heat recovery) pipe dimensions and capital costs.

Phase 1 Barry Docks and Town Centre (AVIVA high-grade heat recovery) pipe dimensions.

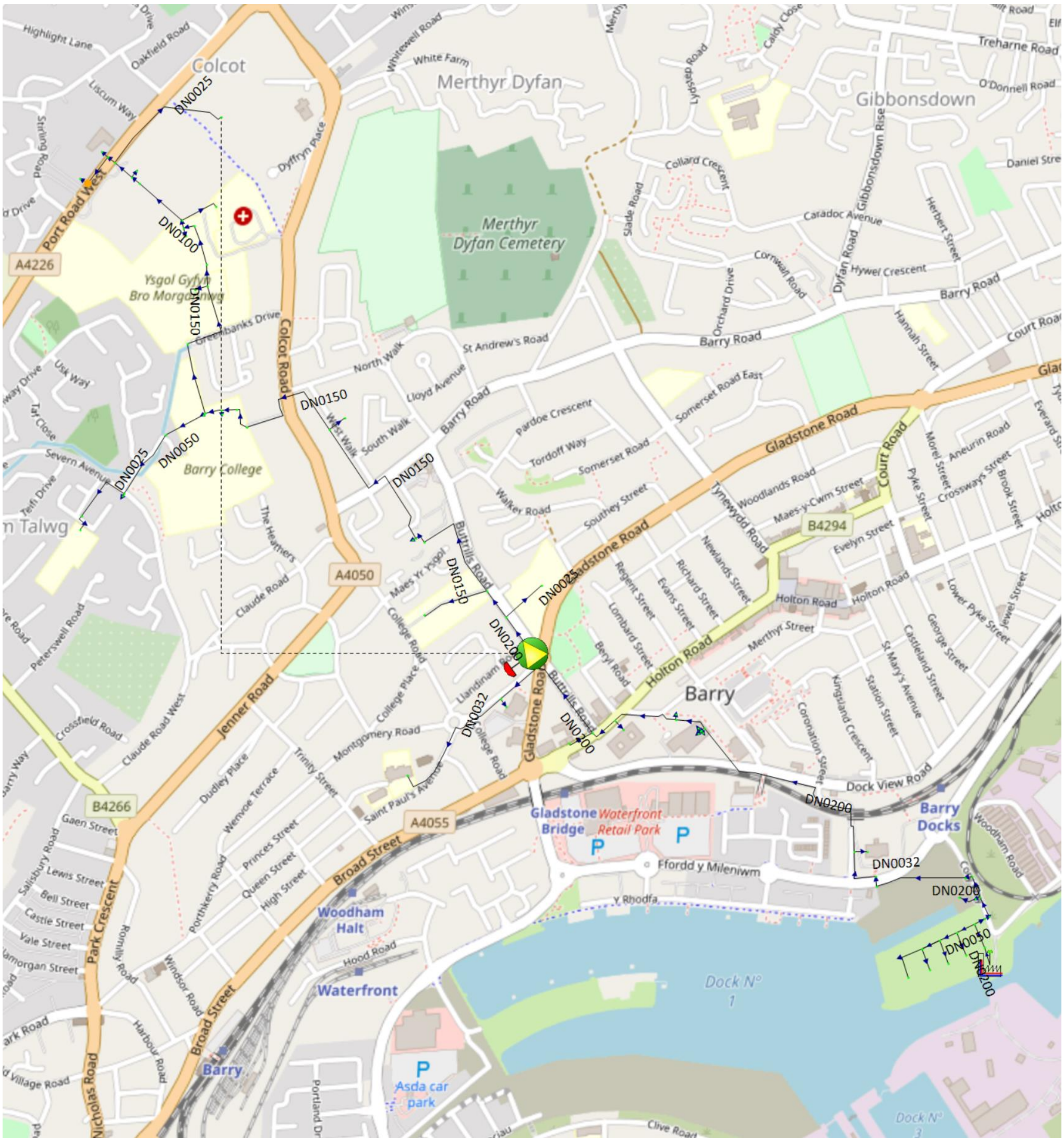
	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	461	85.0	231.7	316.7
DN32	485	90.8	213.2	304.0
DN40	13	2.7	8.3	11.0
DN50	738	172.5	406.0	578.5
DN65	110	27.7	77.7	105.4
DN80	380	120.3	251.5	371.7
DN100	363	156.1	232.6	388.7
DN125	885	451.9	590.1	1,042.0
DN150	36	23.5	19.2	42.7
DN200	-	-	-	-
DN250	-	-	-	-
Subtotal	3,535	1,142.3	2,063.0	3,205.3
Constraint mitigation				-
Contingency (10%)		114.2	206.3	320.5
Total	3,535	1,256.6	2,269.2	3,525.8

Phase 1 Barry Docks and Town Centre (AVIVA high-grade heat recovery) pipe dimensions and capital costs.

Phase 1 Barry Docks and Town Centre (AVIVA low-grade heat recovery) pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	461	85.0	231.7	316.7
DN32	485	90.8	213.2	304.0
DN40	13	2.7	8.3	11.0
DN50	519	121.3	257.4	378.7
DN65	329	82.8	231.9	314.7
DN80	62	19.6	34.5	54.1
DN100	607	261.3	398.5	659.8
DN125	74	37.7	55.4	93.0
DN150	885	576.8	602.8	1,179.6
DN200	36	27.4	20.2	47.6
DN250	-	-	-	-
Subtotal	3,535	1,317.3	2,086.5	3,403.7
Constraint mitigation				-
Contingency (10%)		131.7	208.6	340.4
Total	3,535	1,449.0	2,295.1	3,744.1

Phase 1 Barry Docks and Town Centre (AVIVA low-grade heat recovery) pipe dimensions and capital costs.



Phase 2 Barry Docks and Town Centre (WSHP & Gas CHP + WSHP) pipe dimensions.

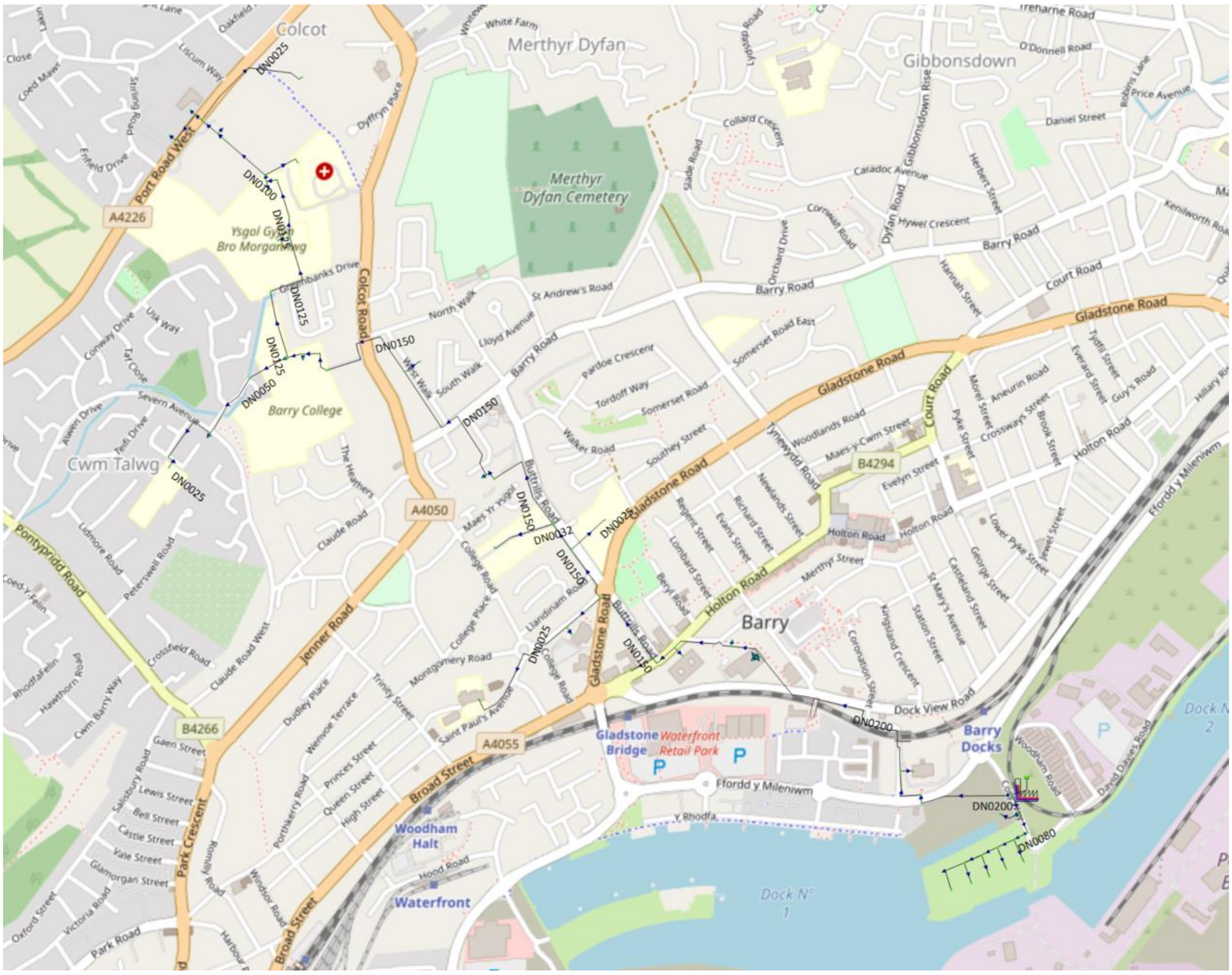
	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	627	115.6	232.2	347.8
DN32	567	106.0	321.4	427.5
DN40	63	13.4	41.3	54.7
DN50	734	171.5	387.9	559.4
DN65	273	68.6	174.2	242.8
DN80	125	39.6	79.7	119.3
DN100	301	129.3	154.6	283.9
DN125	-	-	-	-
DN150	1,631	1,063.2	1,108.8	2,171.9
DN200	1,838	1,399.2	1,339.7	2,738.9
DN250	-	-	-	-
Subtotal	6,223	3,118.3	3,872.2	6,990.5
Constraint mitigation				-
Contingency (10%)		311.8	387.2	699.1
Total	6,223	3,430.1	4,259.4	7,689.6

Phase 2 Barry Docks and Town Centre (WSHP & Gas CHP + WSHP) pipe dimensions and capital costs.

Phase 2 Barry Docks and Town Centre (Dow Chemicals heat recovery) pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	627	115.6	232.2	347.8
DN32	567	106.0	321.4	427.5
DN40	63	13.4	41.3	54.7
DN50	775	181.2	402.4	583.6
DN65	290	73.0	186.4	259.4
DN80	125	39.6	79.7	119.3
DN100	338	145.4	175.7	321.1
DN125	-	-	-	-
DN150	1,631	1,063.2	1,108.8	2,171.9
DN200	3,483	2,651.0	2,313.5	4,964.5
DN250	-	-	-	-
Subtotal	7,964	4,400.3	4,893.9	9,294.1
Constraint mitigation				-
Contingency (10%)		440.0	489.4	929.4
Total	7,964	4,840.3	5,383.3	10,223.6

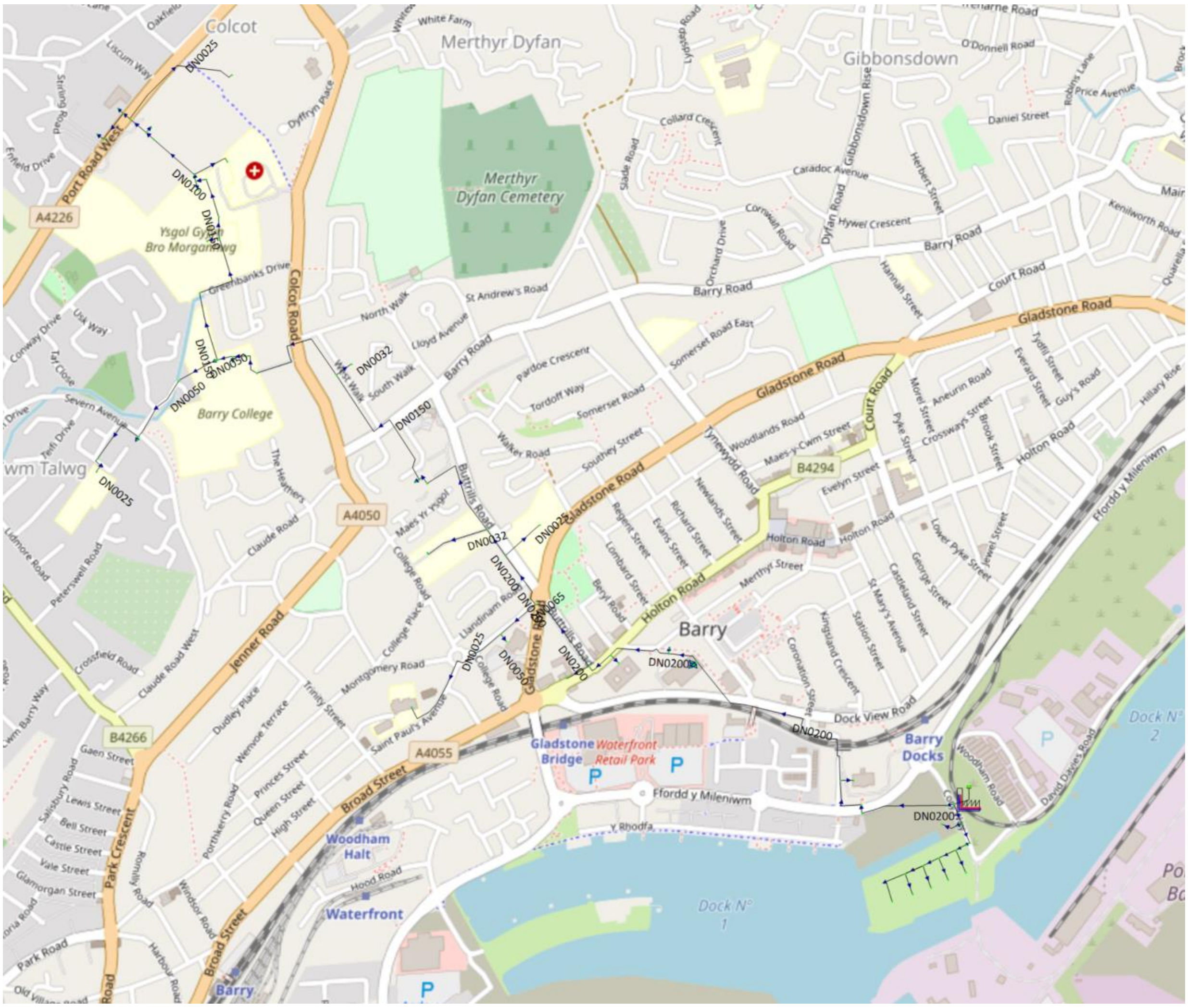
Phase 2 Barry Docks and Town Centre (Dow Chemicals heat recovery) pipe dimensions and capital costs.



Phase 2 Barry Docks and Town Centre (AVIVA high-grade heat recovery) pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	993	183.2	416.3	599.5
DN32	264	49.3	130.5	179.9
DN40	19	4.1	11.2	15.3
DN50	927	216.6	489.1	705.7
DN65	139	34.8	97.6	132.4
DN80	254	80.3	139.4	219.7
DN100	291	125.0	150.4	275.4
DN125	584	298.4	372.6	670.9
DN150	1,763	1,149.0	1,275.8	2,424.8
DN200	921	700.9	651.3	1,352.2
DN250	-	-	-	-
Subtotal	6,218	2,853.6	3,766.7	6,620.3
Constraint mitigation				-
Contingency (10%)		285.4	376.7	662.0
Total	6,218	3,139.0	4,143.4	7,282.4

Phase 2 Barry Docks and Town Centre (AVIVA high-grade heat recovery) pipe dimensions and capital costs.

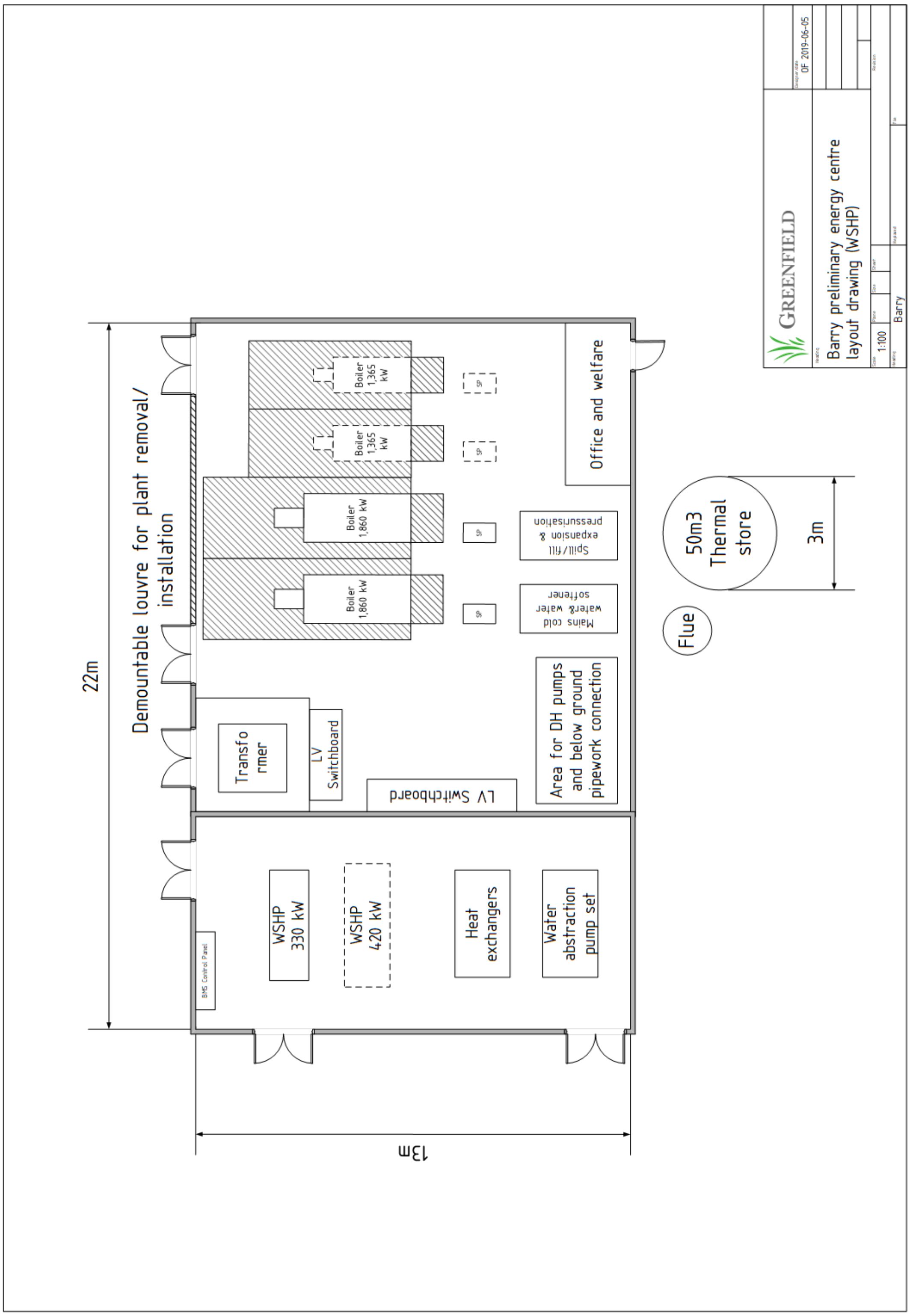


Phase 2 Barry Docks and Town Centre (AVIVA low-grade heat recovery) pipe dimensions.

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	64	11.9	32.6	44.5
DN25	993	183.2	416.3	599.5
DN32	264	49.3	130.5	179.9
DN40	19	4.1	11.2	15.3
DN50	921	215.3	485.3	700.5
DN65	125	31.4	87.9	119.3
DN80	227	71.8	131.0	202.8
DN100	337	144.8	173.0	317.8
DN125	17	8.8	8.9	17.7
DN150	1,614	1,051.9	1,099.6	2,151.5
DN200	1,637	1,245.9	1,224.1	2,470.0
DN250	-	-	-	-
Subtotal	6,218	3,018.5	3,800.4	6,818.9
Constraint mitigation				-
Contingency (10%)		301.9	380.0	681.9
Total	6,218	3,320.4	4,180.4	7,500.8

Phase 2 Barry Docks and Town Centre (AVIVA low-grade heat recovery) pipe dimensions and capital costs.

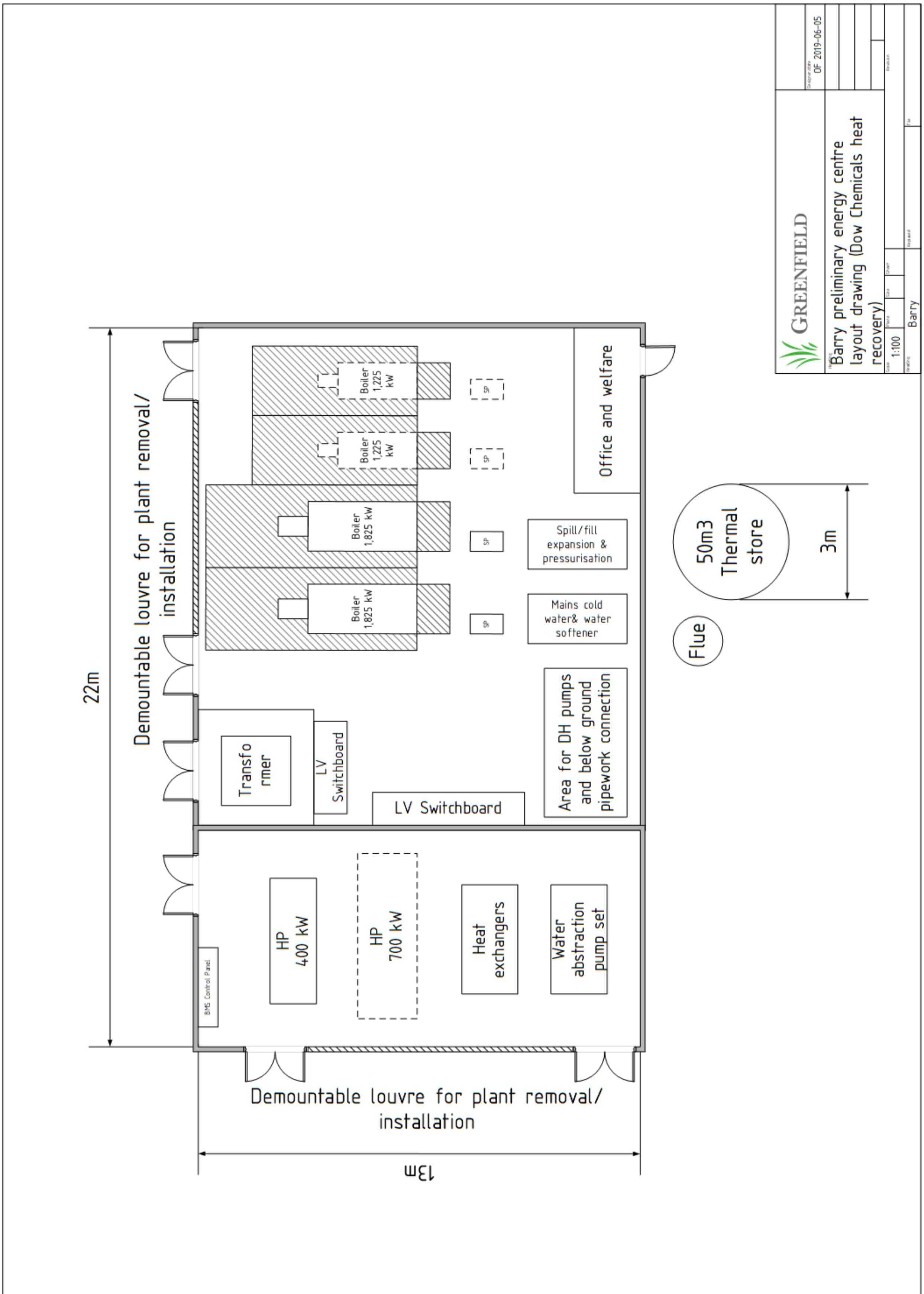
Appendix 6. Preliminary Energy Centre layouts



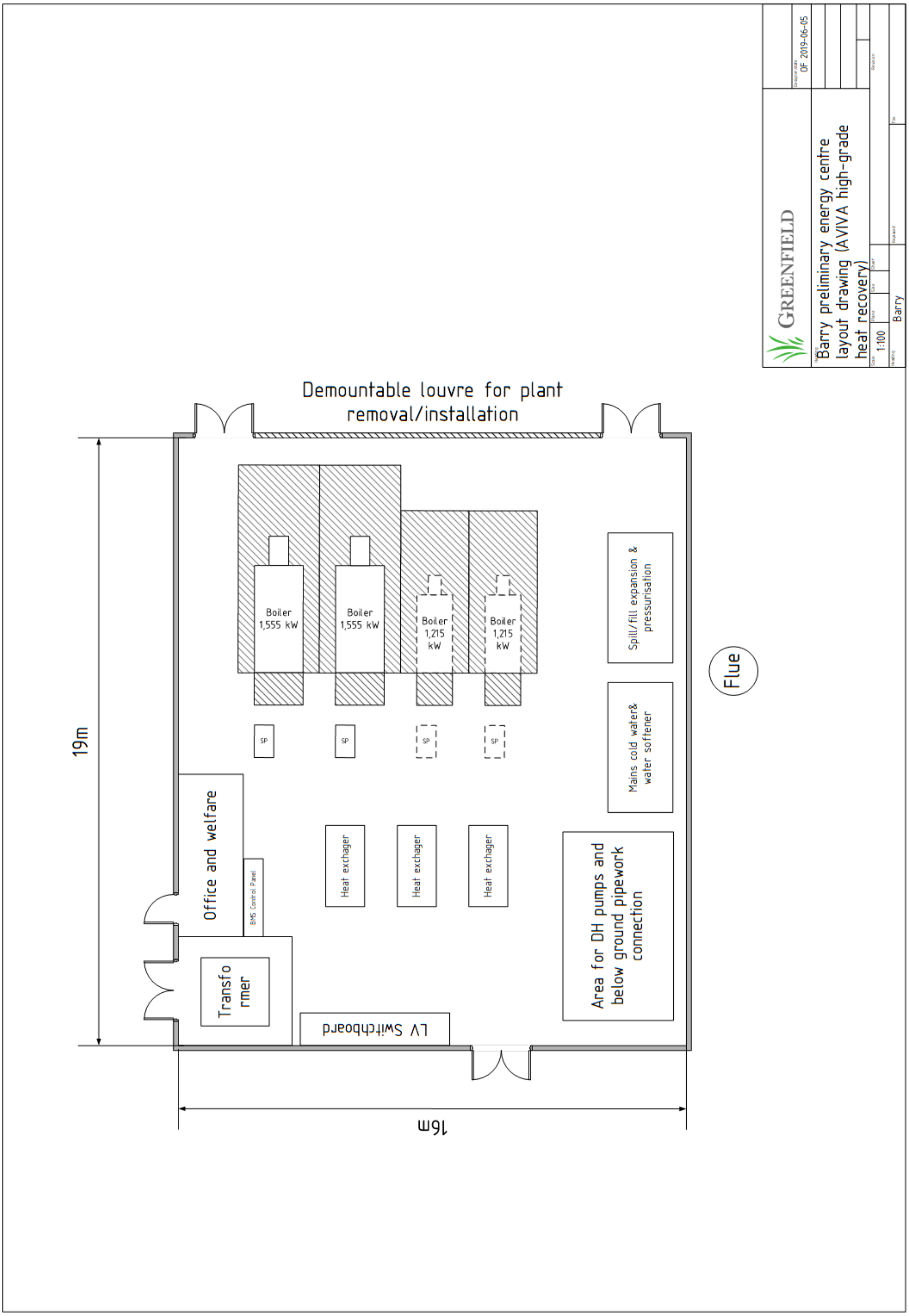
Preliminary layout drawing for the WSHP energy centre.[4]

[4] Dashed line marks space reservation for production units required in Phase 2.

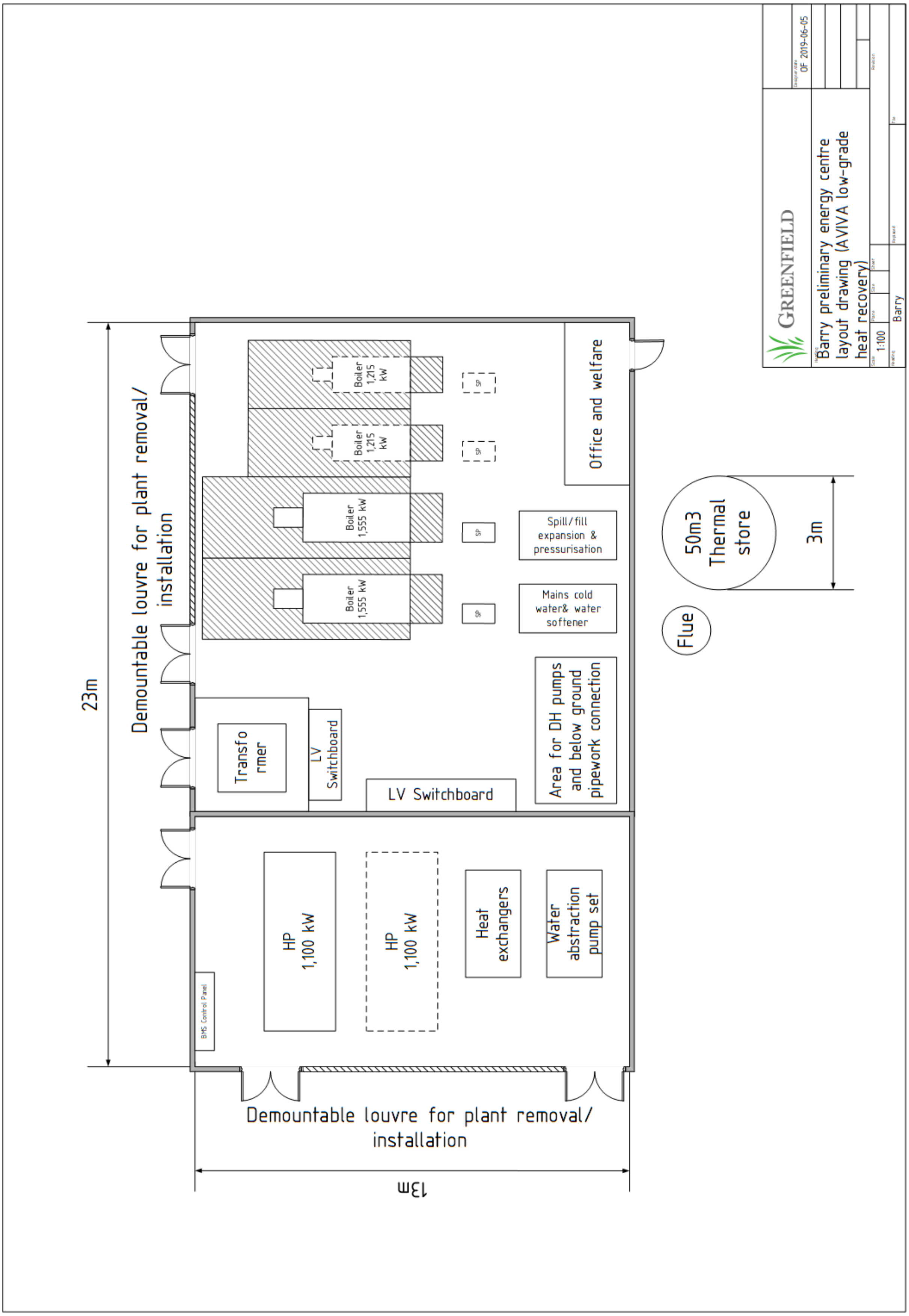
Preliminary layout drawing for the Gas CHP + WSHP energy centre.



Preliminary layout drawing for the Dow Chemicals low-grade heat recovery connection and peak/reserve boiler plant.



Preliminary layout drawing for the AVIVA plant high-grade heat recovery connection and peak/reserve boiler plant.



Preliminary layout drawing for the AVIVA plant low-grade heat recovery connection and peak/reserve boiler plant.

Appendix 7. Capital costs (whole system)

Network Phase 1

Investment costs						
Phase		1	1	1	1	1
Baseload supply technology		WSHP	WSHP + CHP	Heat recovery from Dow (WSHP)	High grade heat from Aviva	Low grade heat from Aviva (WSHP)
Total investment costs	£k	7,259	7,859	9,202	6,486	7,634
DH Network (steel)	£k	3,524	3,524	5,839	3,205	3,404
Heat substations, HIUs & metering		423	423	423	423	423
Energy Centres		1,605	1,997	1,272	1,427	1,980
Utility connections (gas, power, water, drainage, telecoms)		107	107	107	107	107
Pumping station		175	175	175	175	175
Heat Store		139	260	0	5	139
Development costs[5]		626	659	549	553	712
Contingency (10%)		660	714	837	590	694

Capital costs breakdown – Network Phase 1.

[5] *Including detailed engineering costs, professional fees, project management, and project development*

Energy Centre cost breakdown						
Network		**1**	**1**	**1**	**1**	**1**
Baseload supply technology		**WSHP**	**WSHP + CHP**	**Heat recovery from Dow (WSHP)**	**High grade heat from Aviva**	**Low grade heat from Aviva (WSHP)**
Land	£k	-	-	-	-	-
Energy Centre Building (shell and core) plus civils	£k	482	482	482	370	501
Energy generating technology costs	£k	380	689	430	731	940
CHP units	£k	-	194	-	-	-
Water-Source Heat Pumps	£k	249	378	302	-	832
Steam connection/CHP retrofit	£k	-	-	-	622	-
Gas Boilers	£k	130	117	128	109	109
Energy Centre items, or refurbishment of existing plant areas, as applicable	£k	-	-	-	-	-
Thermal storage	£k	139	260	139	-	139
Electrical export switchgear and transformers	£k	80	190	96	-	265
Gas connection	£k	45	45	45	45	45
Electrical connections (export by Private Wire or export to grid)	£k	-	-	-	-	-
Water connection	£k	30	30	30	30	30
Drainage connection	£k	30	30	30	30	30
Telecoms connection	£k	2	2	2	2	2
Other Energy Centre capex (e.g. piping, valves, pumps, water treatment, cabling, electrical panels, etc.)	£k	664	635	263	327	274
Energy centre subtotal (exc. thermal store and connections)	**£k**	**1,605**	**1,997**	**1,272**	**1,427**	**1,980**
Energy centre subtotal (inc. thermal store and connections)	**£k**	**1,852**	**2,364**	**1,518**	**1,535**	**2,226**
Detailed engineering costs	£k	278	355	228	230	334
Professional fees	£k	93	118	76	77	111
Project Management	£k	56	71	46	46	67
Project Development	£k	200	200	200	200	200
Contingency (10%)	£k	248	311	207	209	294
Energy Centre total	**£k**	**2,725**	**3,418**	**2,274**	**2,297**	**3,232**

Energy Centre cost breakdown for Network Phase 1.

Network Phase 2

Investment costs						
Phase		2	2	2	2	2
Baseload supply technology		WSHP	WSHP + CHP	Heat recovery from Dow (WSHP)	High grade heat from Aviva	Low grade heat from Aviva (WSHP)
Total investment costs	£k	13,457	14,211	15,338	11,784	14,189
DH Network (steel)	£k	6,991	6,991	9,294	6,620	6,819
Heat substations, HIUs & metering		680	680	680	680	680
Energy Centres		3,164	3,765	2,635	2,321	3,811
Utility connections (gas, power, water, drainage, telecoms)		107	107	107	107	107
Pumping station		225	225	225	225	225
Heat Store		139	0	139	0	122
Development costs[6]		928	1,150	863	759	1,133
Contingency (10%)		1,223	1,292	1,394	1,071	1,290

Capital costs breakdown – Network Phase 2.

[6] *Including detailed engineering costs, professional fees, project management, and project development*

Energy Centre cost breakdown						
Network		**2**	**2**	**2**	**2**	**2**
Baseload supply technology		**WSHP**	**WSHP + CHP**	**Heat recovery from Dow (WSHP)**	**High grade heat from Aviva**	**Low grade heat from Aviva (WSHP)**
Land	£k	-	-	-	-	-
Energy Centre Building (shell and core) plus civils	£k	857	857	857	659	921
Energy generating technology costs	£k	793	1,347	1,045	1,302	1,857
CHP units	£k	-	388	-	-	-
Water-Source Heat Pumps	£k	567	756	832	-	1,663
Steam connection/CHP retrofit	£k	-	-	-	1,108	-
Gas Boilers	£k	226	203	214	194	194
Energy Centre items, or refurbishment of existing plant areas, as applicable	£k	-	-	-	-	-
Thermal storage	£k	139	260	139	-	139
Electrical export switchgear and transformers	£k	181	381	265	-	530
Gas connection	£k	45	45	45	45	45
Electrical connections (export by Private Wire or export to grid)	£k	-	-	-	-	-
Water connection	£k	30	30	30	30	30
Drainage connection	£k	30	30	30	30	30
Telecoms connection	£k	2	2	2	2	2
Other Energy Centre capex (e.g. piping, valves, pumps, water treatment, cabling, electrical panels, etc.)	£k	1,181	1,181	468	360	503
Energy centre subtotal (exc. thermal store and connections)	**£k**	**3,011**	**3,765**	**2,635**	**2,321**	**3,811**
Energy centre subtotal (inc. thermal store and connections)	**£k**	**3,257**	**4,132**	**2,881**	**2,429**	**4,058**
Detailed engineering costs	£k	489	620	432	364	609
Professional fees	£k	163	207	144	121	203
Project Management	£k	98	124	86	73	122
Project Development	£k	200	200	200	200	200
Contingency (10%)	£k	421	528	374	319	519
Energy Centre total	**£k**	**4,627**	**5,811**	**4,118**	**3,506**	**5,710**

Energy Centre cost breakdown for Network Phase 2.

Appendix 8. Operational cost assumptions

			Source:
Fuel costs – gas	£/MWh	24.9–42.1	BEIS QEP: Tables Annex, September 2018, non-domestic, very small to medium, excl. VAT, incl. CCL
Fuel costs – electricity (for heat pumps and energy centre)	£/MWh	113.8–144.4	BEIS QEP: Tables Annex, September 2018, non-domestic, small to large, excl. VAT, incl. CCL
Fuel costs – electricity (for heat recovery (Aviva & Dow) heat pumps and energy centre)	£/MWh	45.7	Alternative revenue for Dow/AVIVA electricity export to grid (BEIS (electricity wholesale, reference scenario)
Heat purchase price from Dow Chemicals	£/MWh	6.0	Research report on district heating and local approaches to heat decarbonisation, Element Energy, 2015
Heat purchase price from AVIVA (high-grade)	£/MWh	50.0[7]	AVIVA
Heat purchase price from AVIVA (high-grade)	£/MWh	6.0	Research report on district heating and local approaches to heat decarbonisation, Element Energy, 2015
Metering and billing cost	£/consumer/yr	90	Quote from heat network operator
Network management ("Account Manager")	£/yr	18,000	Quote from heat network operator
Utility costs and overheads (water, data, etc.)	£/yr	1,500	Greenfield experience from prior projects
Insurance		0.1% of CAPEX	Quote from heat network operator
Heat Trust	£/dwelling	4.5	Quote from heat network operator

Operational cost assumptions.

[7] The price is based on a relatively low z-factor of 3. A sensitivity is explored where the z-factor is increased by 20 %, resulting in a bulk heat purchase price of 41.11 £/MWh.

			Source:
Variable costs			
Gas CHP variable	£/MWh$_{fuel}$	2.43	Analysis based on plant maintenance costs based on operating hours
WSHP variable	£/MWh$_{fuel}$	3.00	
Gas boiler variable	£/MWh$_{fuel}$	1.25	
Annual fixed costs			
Gas CHP		3.5 % of CAPEX	Analysis based on plant maintenance costs based on operating hours
WSHP		3.5 % of CAPEX	
Gas boiler		2.0 % of CAPEX	
Other energy centre equipment		1.0 % of CAPEX	
Heat network fixed maintenance	£/m, trench	1.3	Greenfield experience from prior projects
Heat network replacement/repair	%-of HN capex/yr	0.5%	
Substation & HIU servicing	£/unit/yr	50	Quote from heat network operator

Maintenance cost assumptions.

			Source:
Gas boilers lifetime	*yrs*	25	Greenfield experience from prior projects
Gas CHP lifetime	*yrs*	15	
WSHP lifetime	*yrs*	20	
Other energy centre equipment lifetime	*yrs*	35	
Heat network, steel lifetime	*yrs*	50	
Substations & HIUs lifetime	*yrs*	20	
REPEX		70% of Balance of Plant original CAPEX	

REPEX / lifetime assumptions.

Appendix 9. Revenue assumptions

In terms of revenues (or income) for the heat network, consumer tariffs are based on a 5% reduction of a calculated counterfactual cost, i.e. cost of the alternative energy supply solution (assumed to be building-level gas boilers in all properties and grid supplied power). Tariffs will vary between consumer types, with domestic consumers paying more (per unit of energy delivered) than commercial properties, as per counterfactual costs. Connection fees would also be levied against each property when it connects to the network and this is assumed to be a 5% reduction of the calculated counterfactual cost of installing gas boilers. On this basis, connection fees would vary based on the heat capacity required by each consumer. In total connection fees are estimated that just over £500k.

Revenue is assumed to be available from the Renewable Heat Incentive (RHI) for the renewable energy options (heat pumps), although it should be noted that the current RHI programme is due to close in Q1 2021 and a replacement or extension has yet to be proposed (a financial sensitivity has been modelled with the exclusion of RHI).

All heat and power sales prices to consumers are based on the consumers' counterfactual energy costs. Heat and power sales tariff components include a 5% discount to incentivise the consumers to connect to the heat network.

The heat sales tariff has been split to three components; energy fee, fixed annual fee, and connection fee. The energy fee is estimated based on counterfactual gas cost and applying the appropriate BEIS retail gas price projection. The fixed annual fee accounts for counterfactual boiler O&M costs, replacements and residual value.

Boiler maintenance costs, life expectancy, and replacement costs reflect the centralised gas boiler solution and are based on the Heat Trust Heat Cost Calculator and boiler manufacturer data.

	Unit rate for gas	Annual boiler O&M costs	Annual boiler replacement costs (based on 15 yrs)	Variable heat tariff (inc. 5% discount)	Fixed heat tariff inc. (5% discount)	Connection fee (inc. 5% discount)
	£/MWh	£/kW	£/kW	£/MWh	£/kW	£/kW
Barry Hospital	24.9	9.9	2.9	30.9	12.3	85.5
Non-residential consumers	25.6	9.9	2.9	31.8	12.3	85.5

Heat sales tariffs non-residential consumers.

	Unit rate for gas	Annual boiler O&M costs	Annual boiler replacement costs (based on 15 yrs)	Variable heat tariff (inc. 5% discount)	Fixed heat tariff inc. (5% discount)	Connection fee (inc. 5% discount)
	£/MWh	£/dwelling	£/dwelling	£/MWh	£/dwelling	£/dwelling
Residential, flats	43.0	205.3	78.1	53.4	273.2	1,451.6

Heat sales tariffs residential consumers.

Power revenues, within gas CHP options, is based upon sales of power to the consumers at a 5% discount to their recently billed costs, accounting time-of-day changes in their tariff.

			Source
Electricity sales (grid)	£/MWh	45.7	BEIS (electricity wholesale, reference scenario) Price is inflated annually according to BEIS predictions

Power revenue assumptions.

Details on RHI revenue assumptions are shown in the table below.

		Rate	Term	Source
Heat pumps Tier 1 (15 % of heat load) Tier 2 (85 % of heat load)	 £/MWh £/MWh	 95.6 28.5	20 years	Office of Gas and Electricity Markets: Tariffs and payments: Non-Domestic RHI
Biomass CHP	£/MWh	45.1		

RHI revenue assumptions.

Appendix 10. Detailed financial modelling results

Phase 1

Project viability		**WSHP**	**Gas CHP + WSHP**	**Dow Chemicals HR**	**AVIVA Biomass high-grade**	**AVIVA Biomass low-grade**
NPV @ Discount rate:	3.5 %					
25 yr	£k	-3,619	-2,729	-3,799	-3,257	-1,080
30 yr		-4,223	-3,276	-4,423	-3,925	-1,630
40 yr		-5,036	-3,999	-5,232	-4,875	-2,339
LCOE (heat consumption) @ Discount rate:	3.5 %					
25 yr	£/MWh	139.6	126.6	142.2	134.3	102.5
30 yr		133.4	120.3	133.9	133.4	98.9
40 yr		127.9	115.7	125.3	128.6	96.2
IRR						
25 yr	%	-1.2 %	0.2 %	-0.4 %	-1.9 %	2.1 %
30 yr		-1.9 %	-0.4 %	-0.8 %	-2.9 %	1.4 %
40 yr		-3.4 %	-1.4 %	-1.7 %	-5.5 %	0.2 %
MIRR						
25 yr	%	0.4 %	1.6 %	1.1 %	0.5 %	2.7 %
30 yr		0.3 %	1.5 %	1.1 %	0.5 %	2.6 %
40 yr		0.5 %	1.6 %	1.2 %	0.5 %	2.5 %
Simple Payback (yr)	yr	NA	NA	NA	NA	NA
Discounted Payback (yr) @ Discount rate:	3.5 %	NA	NA	NA	NA	NA
Economic viability (including socio-economic benefits)						
NPV @ Discount rate:	3.5 %					
25 yr	£k	-3,673	-2,909	-3,750	-3,195	-605
30 yr		-3,639	-2,794	-3,573	-3,602	-437
40 yr		-3,486	-2,625	-3,127	-3,668	-50
IRR						
25 yr	%	-1.2 %	0.0 %	-0.3 %	-1.7 %	2.7 %
30 yr		-1.3 %	0.2 %	0.0 %	-18.8 %	3.0 %
40 yr		-14.0 %	-16.2 %	0.7 %	NA	-22.0 %
Simple Payback (yr)	yr	NA	NA	NA	NA	32.4

Detailed financial modelling results.

Gap funding required to reach		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass high-grade	AVIVA Biomass low-grade
IRR 5.0 %	£m	4.1	3.4	4.5	3.6	1.9
	% capex	56.1 %	43.2 %	49.0 %	55.2 %	25.2 %
IRR 7.0 %	£m	4.4	4.0	5.1	3.8	2.7
	% capex	61.1 %	50.5 %	55.4 %	59.1 %	35.3 %
IRR 10.0 %	£m	4.7	4.4	5.5	4.0	3.4
	% capex	64.3 %	56.2 %	60.0 %	61.6 %	44.2 %

Gap funding required to reach investment thresholds set out by HNDU.

Phase 2

Project viability		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass high-grade	AVIVA Biomass low-grade
NPV @ Discount rate:	3.5 %					
25 yr	£k	-7,244	-5,043	-5,293	-6,233	-1,815
30 yr		-8,477	-6,222	-6,414	-7,585	-2,820
40 yr		-10,165	-7,828	-7,885	-9,525	-4,115
LCOE (heat consumption) @ Discount rate:	3.5 %					
25 yr	£/MWh	122.2	107.2	108.9	115.3	85.2
30 yr		117.0	102.8	103.6	115.0	82.1
40 yr		112.7	100.4	98.4	111.4	80.1
IRR						
25 yr	%	-1.7 %	0.1 %	0.2 %	-2.2 %	2.2 %
30 yr		-2.4 %	-0.7 %	-0.4 %	-3.5 %	1.5 %
40 yr		-4.4 %	-2.3 %	-1.5 %	-6.9 %	0.4 %
MIRR						
25 yr	%	-0.3 %	1.3 %	1.4 %	0.0 %	2.8 %
30 yr		-0.4 %	1.2 %	1.3 %	-0.1 %	2.6 %
40 yr		-0.4 %	1.2 %	1.4 %	-0.2 %	2.5 %
Simple Payback (yr)	yr	NA	NA	NA	NA	NA
Discounted Payback (yr) @ Discount rate:	3.5 %	NA	NA	NA	NA	NA
Economic viability (including socio-economic benefits)						
NPV @ Discount rate:	3.5 %					
25 yr	£k	-6,702	-4,886	-4,336	-5,447	-150
30 yr		-6,590	-4,824	-3,948	-6,195	371
40 yr		-6,357	-4,956	-3,128	-6,385	1,317
IRR						
25 yr	%	-1.2 %	0.2 %	0.9 %	-1.4 %	3.4 %
30 yr		-1.1 %	0.2 %	1.2 %	-21.7 %	3.7 %
40 yr		-16.5 %	-12.6 %	1.9 %	NA	4.3 %
Simple Payback (yr)	yr	NA	NA	NA	NA	18.8

Detailed financial modelling results.

Gap funding required to reach		WSHP	Gas CHP + WSHP	Dow Chemicals HR	AVIVA Biomass high-grade	AVIVA Biomass low-grade
IRR 5.0 %	£m	8.0	6.2	6.6	6.7	3.4
	% capex	59.3 %	43.6 %	42.9 %	57.2 %	23.9 %
IRR 7.0 %	£m	8.5	7.2	7.7	7.1	4.8
	% capex	63.3 %	50.4 %	50.0 %	60.4 %	34.1 %
IRR 10.0 %	£m	8.8	7.9	8.5	7.3	6.1
	% capex	65.4 %	55.5 %	55.3 %	61.9 %	42.9 %

Gap funding required to reach investment thresholds set out by HNDU.

Appendix 11. Carbon reduction analysis

CO_2 emissions have been calculated for the preferred energy supply solutions taking account of the efficacy of the various supply plant, system losses and parasitic consumption, e.g. pumping and the impact of displacing grid supplied power in the CHP options. Carbon factors have been applied to each supply option and then this has been compared against a 'business as usual' scenario for each property that assumed to be connected to the network. The 'business as usual' scenario assumes gas boilers supply all existing and new buildings. Typical assumptions for boiler efficiencies have been applied. All buildings are assumed to be supplied with grid power. Where power generation is included in the supply mix, e.g. with CHP plant, carbon savings associated to power supply is attributed to the heat supply to enable comparison between heat networks. The emission factors for gas, biomass and grid supplied electricity shown in the table below have been used.

Emission Factors		
Gas[8]	tCO_2 / MWh	0.205
Biomass	tCO_2 / MWh	0.039
Grid Electricity (2018)[9]	tCO_2 / MWh	0.313

CO_2 emissions for each heat network option and for the 'business as usual' solution is calculated based on static 2018 factors. Subsequently the report goes on to show the impact of accounting for future projections for carbon emissions as estimated by HM Treasury[10], whilst also taking account of the specific carbon reductions that can be attributed to decentralised power generation from CHP as estimated by BEIS[11]. It is important to account for this since the carbon factor for electricity is forecast to significantly change over coming decades as the UK government seeks to decarbonise power supply, which would reduce the carbon benefits of locally generated electricity (when relative to grid power). The changes in electricity carbon factor predicted requires significant transformation of the UK power supply system which relies on major investment into new nuclear power, renewables and other low carbon technologies. Whilst it cannot be said with certainty that the rate of change predicted will be achieved it is a risk for a heat network scheme using CHP (whether gas, fuel cell or biomass) for baseload supply. Where carbon reduction is a key objective and stakeholders wish to apply the government's future grid carbon factors projections then the lower figures should be utilised to interpret the analysis results.

From a long-term perspective, it should be noted that supply technology can vary within a heat network; this is one of its key advantage. This may mean it acceptable for stakeholders to initially adopt more cost-effective technologies even where they do not deliver significant carbon savings because the implementation of the network infrastructure then enables lower carbon technologies to be introduced at later, perhaps at which point they will be more cost effective.

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[8] BEIS: "Government emission conversion factors for greenhouse gas company reporting" (August 2017)
[9] BEIS: "Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal" (January 2018)
[10] "Grid Average, consumption-based" emission factor for electricity has been used from Valuation of energy use and greenhouse gas (GHG) emissions - supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government, HM Treasury, January 2018.
[11] "CHP exporting" and "CHP onsite" emission factors have been used from Emission factors for electricity displaced by gas CHP, Bespoke natural gas CHP analysis, Department of Energy & Climate Change, December 2015.

Appendix 12. Initial risk register

Version	Date	Notes
0.1	28/5/19	First issue

Key: Risk phase	
Project Development (PD)	Risks occurring prior to construction
Construction (C)	Risks occurring during construction
Operational & Mngt (O)	Risks occurring during operation period
Key: Risk theme	
Project Development	Risks associated due to scheme management (project development and construction phases)
Demand	Risk of loads to materialise or loads are lost over time, e.g. construction delays, efficiency programme, errors in initial analysis
Supply	Risk of out of insufficient generation and other EC and network failures/limitations of the required supply of energy
Financial/Commercial	Risks of increases in operational costs and depressed revenues beyond business case modelling assumptions, e.g. interest rate hike, inflation, reduced reference fuel costs
Regulatory	Risk with of legislative change (during development and operation), e.g. change in planning requirements, emissions standards, customer protection

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Demand	**PD, C**	**All**	**Demand for heat and power is lower than expected due to not being able to sign up consumers**	At this stage there is limited certainty over consumers connections (no MOUs/HOTs/contracts in place). The impact of losing consumers can be significant but some are more important than others (scales and proximity to others). Loss of consumers could be for a range of reasons, including (1) the scheme not being able to provide an attractive offer to stakeholders (site operators, end-consumers, developers) or (2) because the scheme is not available when required (although few require early connection)	4	4	16	1. Identify additional consumer opportunities 2. Liaise with key stakeholders as scheme move through feasibility to investable proposition 3. Ideally establish MoU/HoTs with key consumers in near future 4. Refine understanding of programme / milestone issues and adjust scheme phasing and consider temporary solutions, where necessary 5. Revise scheme design based on secured consumers (allowing for expansion capacity)
Supply	**PD**	**All**	**Energy Centre location**	Location options are dependent on supply technology (WSHP, heat recovery or combination) and the access to land/building facilities. Without securing this, the project will not proceed. Space would need to be found on the Barry Waterfront development to house the WSHP plant. In case of heat recovery from Dow Chemicals or Aviva, space would need to be found on the sites to house an energy centre or integrate into existing plant. A particular issue is the bulk heat purchase price which will vary based on displaced electricity production (z-factor). A sensitivity is explored relating to the bulk heat purchase price.	4	4	16	1. Explore site options with stakeholders (including Dow Chemicals, Aviva, and Council) 2. Develop solutions for all options to provide fall-back solutions until such as point as its necessary to make a decision of the supply option
Supply	**PD**	**All**	**Supply from Aviva biomass power station**	Obvious potential exists for the export of thermal energy from the Aviva biomass power station but the economic case for investment in the on-site upgrades would need to be made based on secure incomes from heat (and possibly power) sales. Presently there is little certainty around this.	5	3	15	1. Explore business case with Aviva

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
				Also, mutually beneficial terms would need to be struck between Aviva and (future) heat network operators.				
Supply	**PD**	**All**	**Supply from Dow Chemicals**	Obvious potential exists for the export of thermal energy from the Dow Chemicals heat rejection unit but the economic case for investment in the on-site upgrades would need to be made based on secure incomes from heat sales. Mutually beneficial terms would need to be struck between Dow Chemicals and (future) heat network operators.	5	3	15	1. Explore business case with Dow Chemicals
Project Development	**PD, C**	**All**	**Development skills / resources (to deal with feasibility investment planning, project/contract management, technical appraisal)**	There is limited present capacity and capability to act as an informed client to contract to market (feasibility, install & operate). Not resolving this will lead to the non-delivery and/or unintended consequences of poor delivery where it is attempted without sufficient resource.	4	3	12	Once there is a "live" project with good stakeholder support and appointed lead entity: 1. Formalise / Initiate project and establish project management structure and agreements between project champion and key stakeholders 2. Conduct skills audit 3. Work with / secure funding from HNDU for the follow-on investigation work 3. Recruit key resources (some will be external) 4. Up-skill decision makers and internal managers
Regulatory	**PD, C**	**All**	**Planning + consenting**	Energy Centres will need to planning permission and regulatory approvals	4	3	12	Once indicative scheme is established liaise with planners to review key information required and adaptations that may support a positive outcome
Supply	**O**	**All**	**Poor reliability and performance**	Poor design, construction or operational standards leading to poor service and/or non-service at times and a loss of trust in the system which could result in disconnections. The masterplanning stage has developed early-stage	4	3	12	1. Apply best practice design, construction and operational standards, e.g. UK Code of Practice 2. Ensure specification meets longevity

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
			of consumer heat supply	indicative design solutions but care will need to be taken to conduct design, installation and operation in compliance with the National Heat Code of Practice (and subsidiary guidance).				standards required 3. Ensure scheme revenues are sufficient to support O&M and meeting re-investment requirements 4. Transfer risks and incentives to operator to maintain optimal performance 5. Give careful consideration for interfaces between design, build and operation
Supply	**PD**	**All - Renewable supply options only**	**No access to RHI**	RHI is due to close by end of Q1 2021 and as such these heat network options will not be able to access it. It may be replaced or extended but this has not been confirmed by government	4	3	12	1 Develop solutions (technical/financial) in subsequent work that limit reliance on RHI
Demand	**PD**	**Phase 1**	**Heat connections to new developments**	The developments included in the heat network are currently in a planning stage where final scales and timescales may still change before and during the sites are built out. Demands and timescales have been estimated based on currently available plans.	4	3	12	1. Engage with developers to ascertain final scale and timescale of development 2. Redesign network solution as needed
Demand	**PD, C**	**All**	**Loss of any of the large consumers (hospital, Barry Leisure Centre, Cardiff and Vale College)**	Either due to lack of the engagement or commercial/technical reasons, e.g. existing contract arrangement or lacking commercial justification, the consumers may choose not to connect, in which case the conceived network would be very different and possibly nothing to commercially support it within this location	5	2	10	1. Hold discussions with consumers to explore rationale and constraints to involvement 2. Explore alternative consumers to replace them if they are to be excluded
Supply	**PD**	**All**	**Access to water abstraction from Barry Docks**	Potential exists for water abstraction and heat recovery from the Barry Docks using heat pumps but the commercial basis of that needs to be explored with the owner. Mutually beneficial terms would need to be struck between the site operator and (future) heat network operators. Hydraulic modelling may need to be undertaken in the	3	3	9	1. Explore business case with Associated British Ports

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
				design stage to ensure proper operation of the WHSP system.				
Demand	**PD, O**	**All**	**Demand for heat is lower than expected, due to poor data or change in consumption profiles**	Heat demand data for most properties is based on metered consumption data so provide high confidence. Other data, particularly in the new developments, is based on benchmarking and realised energy demand could be lower or higher than expected. Energy demands may also change over time as buildings are updated / operated differently. For example, refurbishment.	4	2	8	1. Highlight data weaknesses and seek to improve over time 2. Update consumption estimates (and update scheme design) as new data becomes available (at least at key decision points during the scheme development process) 3. Use new data to revise scheme design prior to project investment 4. Address consumption changes through operational management
Supply	**PD**	**All**	**Energy Centre utility constraints**	Technical or commercial constraint to connect energy centre servicing infrastructure, e.g. gas and power connections	4	2	8	1. examine connection issues with DNOs once EC sizing is completed
Financial /Commercial	**C**	**All**	**Overspend on capital budget**	Failure to deliver project within the estimated capital costs and contingency. Likelihood is low since costs have been benchmarked against major UK suppliers and a 10% contingency is added. However, there are risks such as greater construction and construction management costs for the network infrastructure and energy centre options.	4	2	8	1. Use effective project management framework/process 2. Produce clear specification of requirements and systematically de-risk 3. Use PM and advisers with experience of heat networks 4. Pass on risks, e.g. Design, Build & Operate council 5. Manage budget, making adjustments to capital allocation and finding balancing cost reduction, as necessary

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**C, O**	**All**	**Energy Centre & network: Poor end-consumer service delivery**	Poor service provision leads to user dissatisfaction and in worst case to disconnection	4	2	8	1. Ensure design, construction and commissioning are of a high standard and at least compliance against Code of Practice 2. Provide effective operational management, including annual consumer satisfaction surveys 3. Structure incomes/profits to management performance 4. Establish arbitration solution, e.g. Heat Trust or council operated scheme
Supply	**O**	**All**	**Energy Centre and network: Inadequate maintenance**	Poor maintenance could lead to system failures which will cause dissatisfaction and increased costs	4	2	8	1. Ensure design, construction and commissioning are of a high standard and at least compliance against the Heat Network Code of Practice 2. Design in effective monitoring and management capabilities 3. Provide effective asset management and ensure sufficient budget (O&M and repex) for planned and un-planned maintenance / replacement 4. Structure O&M contracts to performance
Demand	**C**	**All**	**Construction delays**	This refers to delays once a detailed construction plan is resolved which is likely to be linked to consumer and/or supply plant milestones. Delays may cause commercial impact but in the worst-case result in loss of supply option and/or consumers	3	2	6	1. Develop realistic programme 2. Implement effective project management and risk appraisal to predict constraints 3. Explore risks with stakeholders and development joint mitigation plans
Financial /Commercial	**PD**	**All**	**Availability of appropriate investment**	A heat network scheme involves significant capital expenditure, which will be compensated by long term returns. Funding is required to be secured from amongst key stakeholders or external investors. At this early stage investment strategies are not in place; this is a task that will require further investigation as it proceeds through subsequent development stages. Options include 3rd party	2	3	6	1.Explore options as the specific network schemes develop

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
				network ownership, public debt (PWLB, soft loan or grant support (e.g. HNIP, LEP/EU funds)) and private debt/equity and will depend on the nature of the project structure.				
Financial /Commercial	**O**	**All**	**Operating costs and revenues outside business case tolerances**	O&M costs exceed and/or revenues fall short, of the modelling tolerances. Modelling has been conducted on a conservative basis and so as are considered reasonable at this point.	3	2	6	1. Conduct independent due diligence 2. Monitoring costs and revenues during operation and develop operational responses 3. Pass risks on to operators, where possible
Financial /Commercial	**PD, O**	**All**	**Energy prices (general) vary on the medium/long-terms basis**	The financial modelling uses long terms price forecasts from BEIS and so retain inherent uncertainty, although there is a clear trend towards increasing energy costs over time. Changing energy prices will both affect costs of energy supply and the operation of the heat network, e.g. pumping and operation of heat pumps, but will also affect consumer tariffs since these will either be linked to UK energy or consumer price indices. These will typically act against one another to mitigate overall impact.	3	2	6	1. Carefully negotiate energy centre fuel/electricity contracts 2. Establish heat supply contracts that link tariffs to energy/consumer indices 3. Adjust business case accordingly
Supply	**PD, C**	**All**	**General network route constraints**	Various highway and junction constraints and existing buried services will present route constraint issues. These are likely to be surmountable but solutions will need to be developed.	2	3	6	1. Liaise with owner/operators of existing utility infrastructure 2. Survey other network constraints 3. Develop engineering solutions and examine capital costs impact
Supply	**C**	**All**	**Runs beyond programme**	Construction delays leading to possible cost increases and potentially missing deadlines for the new consumer connections and/or supply	3	2	6	1. Use project management framework/process 2. Use experienced PM
Supply	**PD, C**	**Phase 1**	**Network route constraints - crossing railway line**	All of the examined supply options are located on the south side of the railway line while the majority of the consumers are located on the north side of the railway. A crossing is required and suggested to be undertaken via the Subway Road tunnel. Should this not be possible, directional drilling (under rail line) or using an alternative route would be	2	3	6	1. Liaise with owner/operators of land and existing utility infrastructure, including Canals and Rivers Trust and council highways department 2. Identify options and complete review to identify preferred solution (with fall-back)

Risk theme	Phase: PD, C, O	Network / option relevance	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
				possible alternatives. Each will add additional cost, although this will be relatively small in the context of the full network cost.				3. Use this to inform the design of the proposed network such that it is future-proofed for future expansion
Supply	**O**	**All**	**Future proofing network capacity**	A decision will need to be made regarding the sizing of the network infrastructure and the energy centre(s) based on a assumed demand, which clearly could increase overtime. Whilst there is significant capacity within the proposed network to allow for expansion, it is finite and major demand growth could exceed capacity. However, it important to avoid oversizing as this results in greater construction costs and if underutilised it will limit system efficiency (greater losses) and higher supply costs.	2	2	4	1. Make decision for initial network sizing based on reasoned opinion of future expansion strategies. 2. Continue to review as network design evolves
Regulatory	**PD, O**	**All**	**National legislation introduces new costs, e.g. taxation**	New carbon taxation of the heat network may add additional costs.	2	2	4	1. Due diligence against the possible changes 2. Make operational adjustments as required
Regulatory	**PD, O**	**All**	**Heat supply becomes regulated**	Currently unregulated, the supply of heat can be treated as any unregulated services. This is unlikely to be a major issue since heat sales are internal or to as part of the tenant arrangements.	2	2	4	1. Review implications in further detail as scheme progresses
Supply	**PD**	**All**	**Air quality impacts of energy centre(s) (perceived and real)**	Air quality impact may lead to regulatory constraints or may create public concern against development. Careful site selection and selection of appropriate plant with NOx and other emission mitigation systems are likely to address concerns, particularly as a heat network will displace emission relative to less efficient building-level boiler plant. However, with the heat pump solutions, this is not a concern.	3	1	3	1 On next iteration of energy centre design, review this issue further

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