TEED Green Energy Innovation Quarter

District Heating Scheme – Tyseley, Birmingham

for National Grid Electricity Distribution (NGED)

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1 About Us

1.1 Investor in city scale heat decarbonisation

Pinnacle Power are an experienced heat networks developer and investor. We have been involved in over 100 projects, all over the UK, since our inception in 2011. We have a newly announced fund and plan to invest £1bn into heat networks between now and 2030 - the fund places Pinnacle Power at the forefront of the district heating market in the UK and put us in an unrivalled position to deliver low carbon heat into cities right across the country, making us a leading player in the decarbonisation of UK heat. We will be both an investor in and a contractor for heat networks. We are investing in towns and cities now, so that homes and buildings can connect to our heat networks as gas is phased out.

We provide end-to-end solutions for district energy networks, employing experienced and specialised personnel across every phase of District Energy; funding, design and build, operation and maintenance, customer services and metering and billing, **all of which are delivered in-house**. We offer these services as a package or as individual elements and have extensive experience running these services under multiple contract structures.

We are a friendly, approachable, and innovative team, based around the UK and in Denmark. We understand the complex challenges that accompany heat decarbonisation, and we think that by working with local authorities and communities, we can decarbonise towns and cities with low-carbon district heating.

Heat networks are proven to have the lowest levelised cost of heat in dense urban environments like Birmingham. They are highly efficient, low carbon and the only way to give consumers access to the abundant, cheap waste heat at scale.

By 2050 the Committee on Climate Change predicts that most towns and cities will be supplied by district heating. Heat networks take waste heat and other low carbon heat from around the neighbourhood and provide it to homes and buildings through a network of underground pipes.

We believe our added value stems from the positive feedback loop shown below. Our design engineering team work closely with our commercial team so that our heat network design solutions can be technically and commercially into the final design, to deliver best whole life value.

Figure 1: 'The feedback loop' – Pinnacle provide all of these services in-house, with each team encouraged to share lessons learnt and feedback, to speed up development of our offering.

1.2 Pinnacle Power Way

Collaborative working is at the heart of our approach. While we recognise the importance of contractual process and commercial imperatives, we firmly believe that a cooperative, polite, and open approach to service delivery is essential. The key to this approach is frequent honest and clear communication between all parties, both through face-to-face meetings and regular structured reporting and event communication, all in combination with coordinated planning, effective functional systems, clear understanding of responsibilities and a positive “can do” attitude.

Most importantly Pinnacle Power are committed to always questioning whether the established way of ‘doing things’ is the best way and improving through experience and innovation to provide better performance and better value for our Clients and Customers.

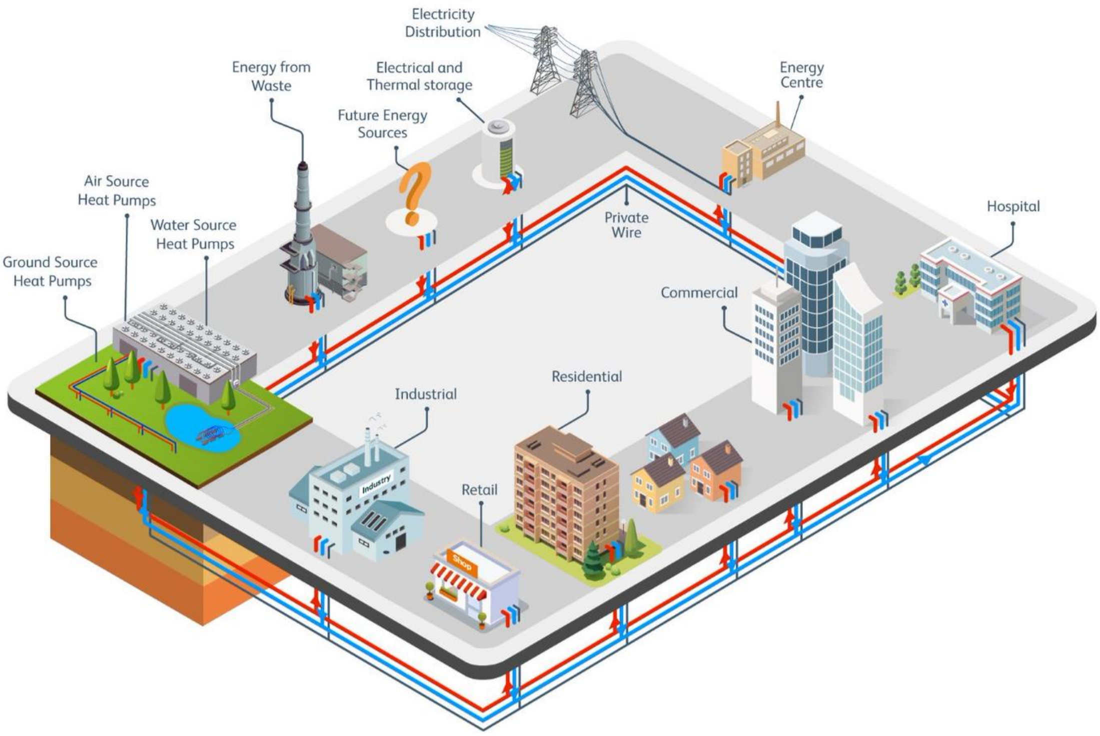

Figure 2: Pinnacle Power philosophy - flexible energy sources feeding community networks

2 Introduction

Pinnacle Power (PP) have been asked to produce a report investigating the feasibility of a district heating scheme, fed from local industrial activities and utilising waste heat, within the Tyseley area.

It should be noted that this report is a high-level feasibility report and the information available to the author is as per that of a 'discovery phase' and therefore the values provided should be seen as high-level estimates. The information in this report is to be refined at future project phases however Pinnacle Power judges the conclusions of this report to be indicative.

2.1 Project Background

Tyseley Area

Tyseley is located south-east of the Birmingham city centre as per Figure 3. The project focuses on the Tyseley Environmental Enterprise District (TEED) area, as pictures below in purple. TEED consists of approximately 250 mixed-use business and 8,000 residents and the area suffers from fuel poverty. The TEED area is home to Birmingham Bio Power Limited (BBPL) and the Tyseley Energy from Waste (EfW) plant; with planning permission grated for an EfW plant at the Hay Hall Road brownfield site. These generation assets presently only deliver electricity.

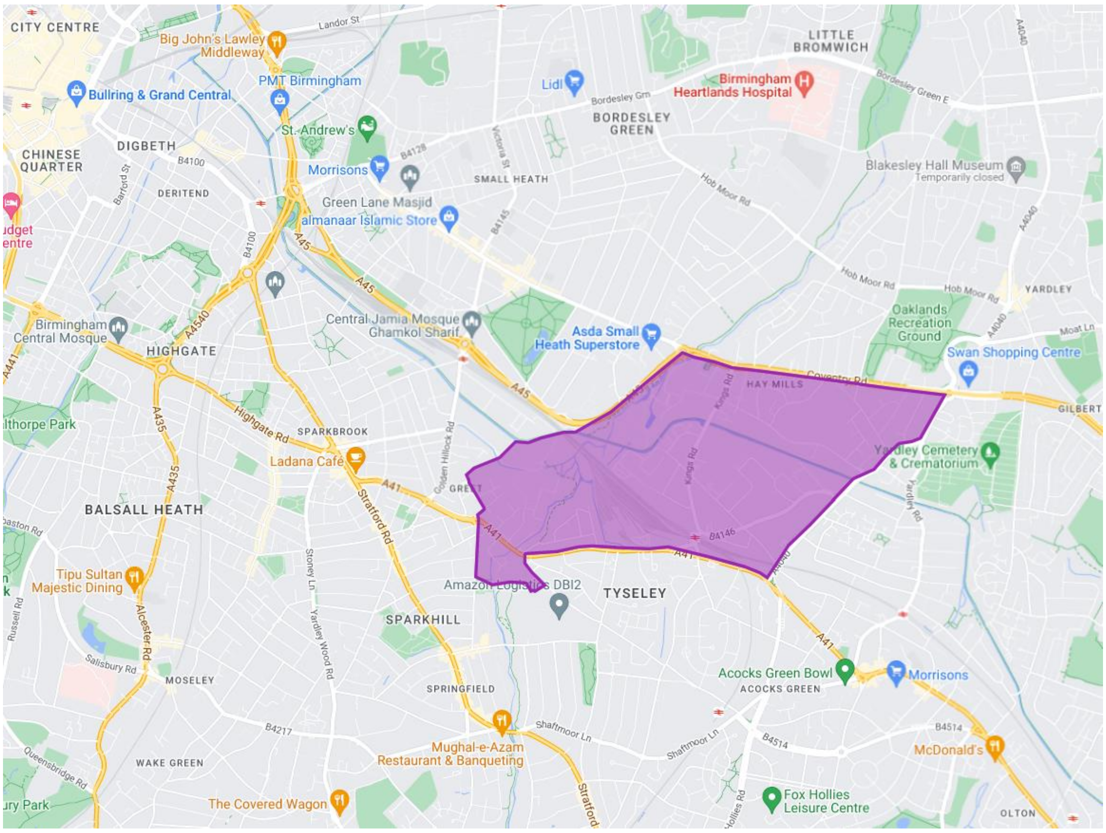

Figure 3: The TEED area shown on a map of Birmingham.

Scope

The scope of this report is to assess the feasibility of utilising the waste heat from the electrical generation plant to provide a district heating network (DHN) to supply space heating and hot water to the Tyseley area. Key performance indicators are carbon emissions, cost to customer, CAPEX and technical feasibility. These are presented in the conclusion Section 7 alongside future scopes of work and recommendations.

3 Heat Network Inputs

3.1 Energy Sources

There are various energy sources in the Tyseley area which may be utilised for the proposed heat network (see Figure 4 for reference) and these are discussed in detail in the following sections. Note the values provided for power outputs in the following sections are preliminary high-level values that would require verification in future design phases. These are intended to provide indicative values to allow progression of this feasibility phase.

Figure 4: Potential energy source locations in the TEED area.

Veolia Energy from Waste (EfW)

The Veolia Energy Recovery Facility (ERF) is an Energy from Waste (EfW) plant located in the TEED area as per Figure 4. The plant entered operation in 1996 and processes waste from the local Birmingham area providing 25 MW_e to the national grid. Power is generated from the incineration of non-recyclable waste, and this also provides waste heat that may be recovered for the purposes of a heat network. Preliminary modelling by Veolia indicates that a heat offtake solution via a steam offtake from the Low Pressure (LP) header supplying a heat exchanger is feasible. The estimated peak thermal power output is 6-7 MW_{th} as per the Environmental Services Association (ESA) Heat Network Directory and it is estimated by Veolia that this would also result in a reduction of electrical power output of approximately 1.5 MW_e. This method of heat extraction is preferred as there is existing infrastructure (decommissioned boiler feed connection to the LP header) available which can be utilised, reducing capital costs and technical risk. It is anticipated that due to the age of the Veolia plant it shall only be operational until 2035 and this needs to be considered when assessing the lifetime feasibility of the heat network.

Hay Hall Road EfW

A new EfW plant is currently being designed to be located at the Hay Hall Road brownfield site as per Figure 4. Due to the early phases of the design process for the new plant, information on the feasibility of a heat offtake system is not available. It is understood from conversations with key stakeholders that it is valid to assume that the Hay Hall Road plant shall generate heat in lieu of the Veolia plant after its closure. However, the validity of this assumption depends on the following points:

- **Integration of a heat offtake** – if the Hay Hall Road plant will be Combined Heat and Power (CHP) ready it will allow for simpler integration of a heat offtake system, increasing efficiency and reducing technical risk and cost. It is currently unknown whether the plant will be CHP-ready.

- **Power generating capacity and available wate heat** – the available and utilisable waste heat from the Hay Hall Road plant will need to be equal to or greater than that assumed in the section above for the Veolia plant otherwise an alternative supplementary energy source would be required.
- **Financial and environmental metrics (£/MWh and kg CO_{2eq}/MWh)** – the cost of the heat and the carbon emissions associated with generating this heat shall need to be equal to or lower than that assumed for the Veolia plant.

For the purposes of this feasibility assessment the values for the Veolia plant are assumed to be applicable to those for the Hay Hall Road plant in lieu of further information. However, the CAPEX associated with installing a heat offtake system for the Veolia plant followed by a new heat offtake system for the Hay Hall Road plant is notable.

Birmingham Bio Power Ltd. (BBPL)

The Birmingham Bio Power Ltd. (BBPL) plant is a biomass renewable energy power plant located as per Figure 4 above which entered operation in 2016. The plant uses waste wood feedstock sourced primarily from the local area and a gasification process to generate heat and then electrical power. During this process, waste low-grade heat is produced which is not suitable for power generation but is suitable for use in heating applications. The nominal power output is 10.3 MW_e. It should be noted that it is understood from discussions with plant operators that the steam turbine at this plant is not CHP-ready. The following options are considered for utilising this low-grade heat, with key considerations provided in Table 1:

Option 1. Steam turbine direct heat extraction – low pressure steam is extracted from the existing steam cycle to supply a new district heating heat exchanger.

Option 2. Steam turbine exhaust heat extraction (utilising a heat pump) – the steam turbine exhaust is condensed with the resulting heat passed into a heat pump for utilisation in the new district heating network.

Table 1: Key considerations for the heat offtake solutions for the BBPL biomass plant. Note this table is not exhaustive and future design phases would need to address the feasibility of these options in full.

Consideration	Option 1 – Direct Steam Extraction	Option 2 – Exhaust Heat Utilisation
Heat extraction feasibility	The full technical feasibility of this approach is unknown at this phase. The quality of the extracted steam (temperature, pressure moisture content etc.) would need to be considered when designing the offtake and heat exchanger. The extent of the required modifications to the existing steam turbine at the plant is unknown and may be significant. Considerations include the changes to the loads on the turbine, effects on the steam bleed points (notably with regards to noise, flow rate and corrosion limits) and integration with the steam turbine control systems. There is a risk that there is significant design and interfacing with the steam turbine manufacturer required to ensure feasibility.	The full technical feasibility of this approach is unknown at this phase. The exhaust from the steam turbine is low absolute pressure (< 1 bara) and the back pressure provided to the steam turbine is important in its function. The effects on adding such a heat offtake system on to the steam turbine would need to be investigated. Considerations include the changes to the loads on the turbine, effects on the exhaust back pressure and integration with the steam turbine control systems. There is a risk that there is significant design and interfacing with the steam turbine manufacturer required to ensure feasibility. The design of this system would include a steam condenser unit and heat pump that adds complexity, design effort and system integration risk.
Effects on existing plant performance	A drop in electrical output due to the reduced amount of steam flowing through the turbine is expected. Feedwater temperatures to the steam generator may be slightly reduced.	As above, the effects on the steam turbine performance need to be considered, notably the back pressure on the steam turbine.

Consideration	Option 1 – Direct Steam Extraction	Option 2 – Exhaust Heat Utilisation
Auxiliary loads	Very low auxiliary loads required.	Significant auxiliary electrical load required to power the heat pump. Options to supply this directly from the plant or through an independent connection to the national grid.
Combined power output	Small decrease in electrical power produced however thermal power is lower than Option 2.	Large decrease in electrical power produced (when considering auxiliary load of heat pump) however the quantity of thermal power produced is significantly higher compared to Option 1.

Table 2: Estimated power outputs of BBPL biomass plant per option – note this does not consider availability of plant.

All P in kW	Base Case	Option 1	Option 2
Electrical Power Output[1]	9,833	8,285	3,668
Thermal Power Output	-	12,945	27,335
Total Useful Power	9,833	21,230	31,003
Z-factor ($P_{th}/P_{e,\ lost}$)	-	8.4	4.4[2]
Electrical Power vs. Base Case	-	84%	37%
Total Power Output Increase vs. Base Case	-	116%	215%

(1) Note, the electrical power output here accounts for the auxiliary electrical load associated with the heat pump.
(2) Note, this is lower than the CoP assumed below of 4.6 due to other auxiliary loads.

Although there are key benefits and risks of both options, for the purpose of this reports assessment, Option 1 has been selected as preferred with a thermal power capacity of 12.9 MW_{th}. This is due to the following key points:

- Greater uncertainties associated with the technical feasibility of Option 2 as per Table 1.
- The reduced impact on the electrical output of the plant compared to Option 2 as per Table 2.
- From a high-level assessment, significantly lower CAPEX and therefore a shorter payback period for the installation of the plant when compared to Option 2.

It should be noted this report does not rule out Option 2 and both options should be subject to further analysis at the next stage of project development.

Centralised Heat Pump

Centralised heat pumps may be used in the TEED area to provide the heat required or supplement other systems or before other systems come online. This would be a standalone system connected to the national grid and would be specified to provide the required power in conjunction with thermal storage. These systems are scalable, and it is anticipated that a suitably sized system for the required demand is theoretically feasible, although further technical feasibility studies are required considering the local context to confirm buildability. This is a well-understood option that is a common approach used for heat networks and therefore carries low technical risk when compared to utilising heat offtakes from the EfW and/or biomass plants.

The following options are considered potentially viable:

- Air Source Heat Pump (ASHP) – utilising heat from the air. In brief, if a suitable location for mounting the heat pumps and associated Dry Air Coolers (DAC)/Evaporators, then the heat can be extracted from the air. The fans will need to be elevated on a frame to allow free movement of air beneath them. Cold plume dispersion and noise breakout modelling would need to be progressed to ascertain that the cold plume of air and noise produced from the fans could be managed to prevent any unacceptable impacts on local receptors.
- Water Source Heat Pump (WSHP) – utilising heat from the canal. Further feasibility studies are required to confirm this option is viable considering the following for example:

- How intake and discharge pipework would access the canal – or a simple heat exchange methodology
- What the sustainable heat extraction is without unacceptably impacting on the temperature of the canal
- Impacts associated with biodiversity
- Impacts associated with water quality
- Filtration/Cleaning In Place (CIP) requirements to ensure heat exchangers do not foul
- Relevant permissions/permits such as from the Canal and Rivers Trust etc.

These heat pumps would be used in conjunction with thermal stores to allow for demand smoothing and to prevent short cycling of the heat pumps. This would provide a benefit to the national grid through a reduced peak electrical demand and smoother demand curve compared to localised ASHPs (i.e., one per building with no heat network). In addition, through a combination of centralised electric heat pumps and EfW, grid balancing services could be incorporated into the scheme - i.e., when there is overgeneration into the grid the heat pumps can be run as priority charging the thermal stores and if there is under generation the EfW would be prioritised.

For simplicity the CoP of a centralised ASHP is used in this report (CoP of 2.8) however this could be substituted with a WSHP depending on the results of further feasibility studies. It should be noted that a WSHP would provide a larger CoP (approximately 3+) due to lower seasonal temperature fluctuations.

Carbon Intensity

The Government's Standard Assessment Procedure for Energy Rating of Dwellings (SAP 10.2 11-04-2023) considers the emissions associated with heat generation for a heat network. For the above heat offtake approaches the following guidance is provided or an alternative is used but broadly this considers the carbon emissions of the lost electrical output from a power plant, the energy required to run heat pumps or the emissions from burning fuel such as in a gas-fired boiler:

- **EfW plant** – such as the Veolia and Hay Hall Road plants. EfW plants are treated separately to conventional power plants or CHP plants in SAP 10.2. As per Figure 6, SAP 10.2 considers the lost electricity generating capacity of the EfW plant due to the reduction of steam flowing through the turbine or the addition of auxiliary loads which are noted in the section above. Therefore, as per Figure 6, the emissions associated with the heat taken from the EfW plants is <u>0.015 kg CO_2/kWh</u>. However, it should be noted that this assumes a Z-factor of 9-10 and, depending on the method of heat extraction, this assumption may require validation. The mix of the fuel or waste that is burned to generate heat should be noted but is not currently considered in SAP 10.2. However, the mix of wate that is used can have a significant effect on the carbon emissions of the EfW plant.
- **Biomass plant** – such as the BBPL plant. SAP 10.2 considers heat recovered from power stations however this is only for those over 30 MW capacity and should otherwise be considered as follows:
  - **High grade heat recovery (Option 1)** – this approach considers the heat to be free except for the reduction in electrical output that is experienced by the biomass plant due to auxiliary loads and reduced steam flow. This gives <u>0.011 kg CO_2/kWh</u> as per Figure 6.
  - **Low grade heat recovery (Option 2)** – this approach considers the heat to be free other than the emissions associated with the heat pump raising the temperature to useful levels for a heat network. In SAP 10.2 this is given as 0.136 kg CO_2/kWh which is the same as that for electricity from the national grid and therefore does not account for the coefficient of performance (COP) of the heat pump (i.e., *X* units of electricity generates *Y* units of heat where *Y/X* is the COP). Therefore, this report considers the emissions of the low-grade heat recovery approach to be as per Figure 5 with an assumed COP of 4.6[1] and considering the reduced carbon emissions of the national grid as per the Government's Green Book Supplementary Guidance data tables 1 – 19. For reference, the emissions as per Figure 5 for a COP of 4.6 in 2025 give <u>0.045 kg CO_2/kWh</u> and for 2035 give <u>0.009 kg CO_2/kWh</u>.

[1] It should be noted that the COPs have been assumed to be 4.6 and 2.8; this is judged to be reasonable based upon available technology in the market for the proposed operating conditions although actual performance will vary depending on the detailed design phase of work.

- **Centralised heat pump** – SAP 10.2 gives this as 0.136 kg CO_2/kWh because the electricity used is from the national grid however, as above, this does not consider the COP of the heat pump. Therefore, this report uses the approach in Figure 5 considering the decreasing carbon factor of the national grid with an assumed COP of 2.8[1]. For reference, the emissions as per Figure 5 for a COP of 2.8 in 2025 give 0.075 kg CO_2/kWh and for 2035 give 0.014 kg CO_2/kWh.

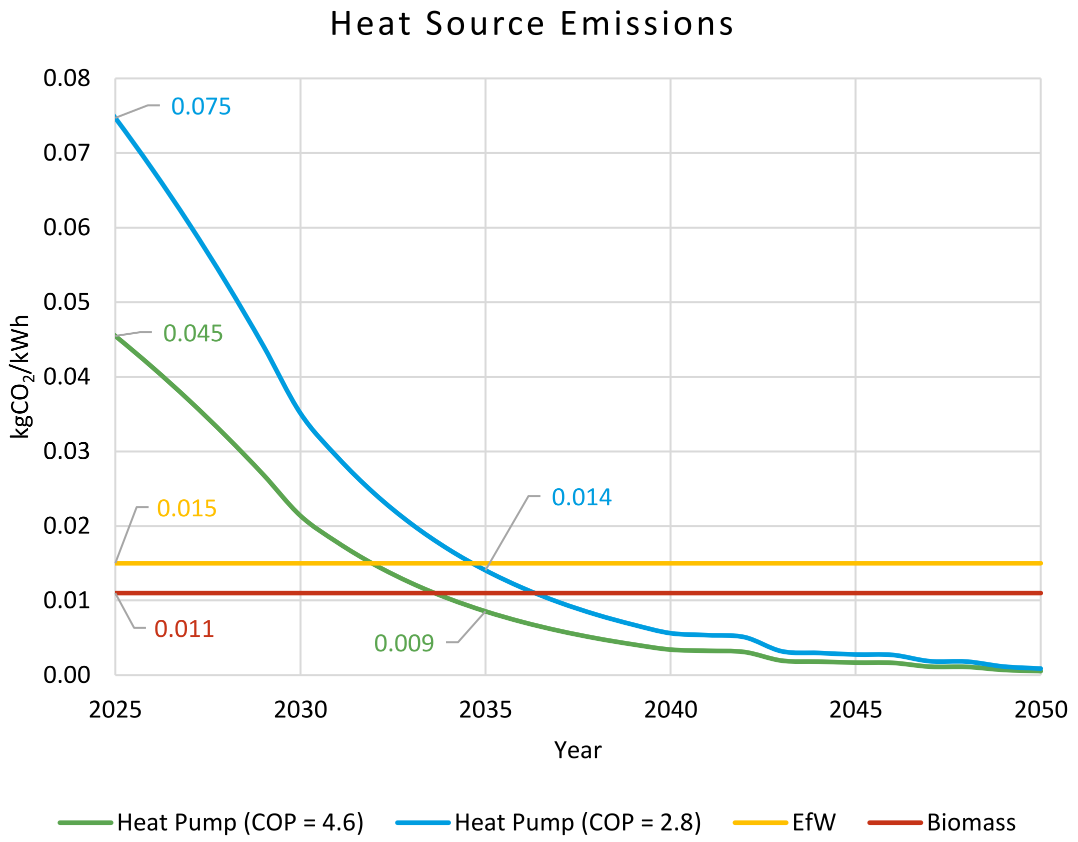

Figure 5: Carbon emissions of the national grid and electric heat pumps from 2010 to 2050 (data from Government's Green Book Supplementary Guidance data tables 1 – 19).

Heat networks: (k)	92 (l)		
heat from boilers – mains gas		4.44	0.210
heat from boilers – LPG		4.44	0.241
heat from boilers – oil (assumes 'gas oil')		4.44	0.335
heat from boilers that can use mineral oil or biodiesel		4.44	0.335
heat from boilers using HVO from used cooking oil		4.44	0.036
heat from boilers FAME from animal/vegetable oils (e)		4.44	0.018
heat from boilers – B30D (f)		4.44	0.269
heat from boilers – coal		4.44	0.375
heat from electric heat pump		4.44	0.136 (s)
heat recovered from waste combustion		4.44	0.015 (p)
heat from boilers – biomass		4.44	0.029
heat from boilers – biogas (landfill or sewage gas)		4.44	0.024
heat recovered from power station		3.11	0.015 (p)
high grade heat recovered from process (Appendix C4.3)		3.11	0.011
low grade heat recovered from process (Appendix C4.4)		3.11	0.136 (s)(v)
heat recovered from geothermal or other natural processes		3.11	0.011
heat from CHP		3.11	as above(q)

Figure 6: SAP 10.2 method for assessing the carbon emissions for heat offtake solutions and energy sources.

It should be noted that the above calculations use a mixture of methodologies, and this does not consider any future decreases in emissions from the EfW or Biomass plants – these are assumed to be constant. Future phases should agree a unified emissions calculation approach to allow for like-for-like comparisons.

Heat Source CAPEX

CAPEX estimates for the installation of the heat offtake solutions and the centralised heat pumps are provided below however it should be noted that these are high-level estimates that are subject to further feasibility studies and concept design development. It is difficult to provide accurate estimates at this phase however, utilising experience and comparisons to similar projects, Pinnacle Power judges the below estimates to be indicative of the relative costs.

- **EfW plant** – unknown CAPEX to install heat offtake solution however expected to be comparable to that for the BBPL biomass plant **Option 1** below.
- **Biomass plant**:
  - **High grade heat recovery (Option 1)** – it is estimated that the cost of plant (not including design or installation) for this option is £0.7m. Therefore, a high-level estimate for the overall CAPEX costs for this option are £2.1m. This assumes that the heat offtake solution is housed in an existing building.
  - **Low grade heat recovery (Option 2)** – it is estimated that the cost of plant (not including design or installation) for this option is £6.4m. Therefore, a high-level estimate for the overall CAPEX costs for this option are £19.2m (this includes a new heat-offtake building, mechanical and electrical plant, design, procurement and installation etc.)
- **Centralised heat pump** – using comparisons across other heat networks and centralised heat pump solutions that Pinnacle Power have provided gives an estimate for the CAPEX of £34.5m.

Cost of Heat (£/kWh)

It should be noted that a full commercial model has not been built for this project and therefore the heat charges stated below are preliminary and subject to change in future design phases and as commercial modelling is progressed to ensure the project can be delivered in a commercially viable manner at the stated heat charges. Table 3 gives the estimated costs of heat per energy source however this does not account for losses and non-energy costs, these are discussed in Section 6. It is assumed that the cost of electricity is 29 p/kWh.

Table 3: Estimated unit cost per heat source, note this does not account for losses and non-energy costs, these are discussed in Section 6.

Heat Source	Energy Input	Input Cost (p/kWh)	Non-energy input cost (p/kWh)	Z-factor/ CoP	Unit cost (p/kWh)
Veolia/Hay Hall	Compensation for loss of electricity generation	29	2[1]	4.7	8.21
BBPL Option 1	Compensation for loss of electricity generation	29	2[1]	8.4	5.45
BBPL Option 2	Electricity input for heat pump	29	2[1]	4.4[2]	8.59
Centralised Heat Pump	Electricity input for heat pump	29	n/a	2.8	10.36

(1) This cost is to allow for an incentive or profit for the EfW and biomass plants to provide heat, the input cost is simply replacing the lost revenue due to the reduction in electricity production. These are assumed at this stage, further engagement with the plant owners will be required to negotiate the heat tariffs from each site.

(2) Note, this is lower than the CoP assumed below of 4.6 due to other auxiliary loads.

Summary

In conclusion, due to significant amounts of potential heat and the opportunity to increase the overall efficiency of both plants, it is recommended that heat offtake solutions are investigated for the Veolia plant (with the expectation that the Hay Hall Road plant will take over heat production after closure) and also the BBPL plant. It should be noted that there are significant questions that require addressing in future phases regarding the feasibility of these heat offtake approaches noting the requirement for integration into the complex systems involved in steam turbines. The emissions as per Table 4 for these plants are initially lower than the alternative of a centralised ASHP however the power available is limited; the implications of this is discussed in later sections of this report.

Table 4: Power outputs of the energy sources used in this report and the associated carbon intensity.

Energy Source	Thermal Power (MW_{th})	Carbon Intensity (kg CO_{2eq}/kWh)	Z-factor / COP	Heat Cost (p/kWh)
Veolia (EfW)	7	0.015	*Z-factor* 4.7	10.21
Hay Hall Road (EfW) *assumed*	7	0.015	*Z-factor* 4.7	10.21
BBPL (Biomass) – Option 1	12.9	0.011	*Z-factor* 8.4	7.45
BBPL (Biomass) – Option 2	27.3	*Year 2025* 0.045[1] *Year 2035* 0.009[1]	*Z-factor* 4.4[2]	10.59
Centralised ASHP	As required	*Year 2025* 0.075[1] *Year 2035* 0.014[1]	*CoP* 2.8	10.36

(1) Values quoted for the year 2025 and then 2035 from Figure 5 due to decreasing emissions of the national grid.
(2) Note, this is lower than the CoP assumed below of 4.6 due to other auxiliary loads.

3.2 Demand / Supply Points

The below building data was collated by the University of Birmingham for the Tyseley area as depicted in Figure 3.

In Table 5, references to 'HNZ data' are taken from the Heat Network Zoning (HNZ) data. Where HNZ data was not available, benchmarks were derived from the CIBSE kW/m^2 benchmark data and multiplied by the building floor area and number of floors; this is referred to as 'benchmark data'.

Diversification is applied to the peak heat demand data to account for the demand profiles of a large number of connections. This has been undertaken as per guidance in CP1. This provides a peak diversified demand in the Tyseley area of 40.13 MW.

Table 5: Heat demands and annual consumption used for DHN modelling.

Peak Heat Demands			
Building Category	**HNZ Data (kW)**	**Benchmark Data (kW)**	**Total (kW)**
Educational	837	0	837
Industrial	22,779	10,899	33,678
Office	8,663	2,014	10,677
Residential	220	8,513	8,733
Retail	11,987	0	11987
	TOTAL - Undiversified Peak Load (kW)		**65,912**
	TOTAL - Diversified Peak Load (kW)		**40,130**

Annual Consumption			
Building Category	**UoB Data (kWh)**	**Benchmark Data (kWh)**	**Total (kWh)**
Educational	1,313,462	0	1,313,462
Industrial	36,919,190	17,430,918	54,350,108
Office	13,250,006	270,859	13,520,865
Residential	299,161	3,828,505	4,127,666
Retail	20,978,178	0	20,978,178
	TOTAL - Annual Consumption (kWh)		**94,290,279**
	TOTAL - Annual Consumption (GWh)		**94.3**

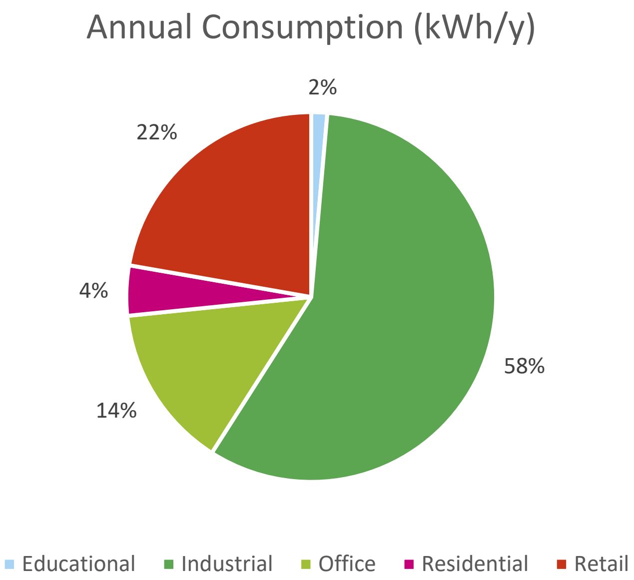

Figure 7: Annual consumption distribution by category for the Tyseley DHN model.

The following are key assumptions regarding the input data:

- All peak heat data includes space heating and domestic hot water demand
- Industrial process heat has not been accounted for in peak heat demand data
- Floor heights are assumed to be 2.5 m, except those classed by HNZ as Industrial Buildings
- Industrial buildings are assumed to have 1 floor
- Building with a floor area less than 25m^2 and no unique property reference number (UPRN) are assumed to have no heat demand
- Heat data from HNZ takes primacy over demands calculated from benchmarks
- The benchmarks used for the purpose of analysing building with no HNZ data are shown in Table 10.

Table 6: Benchmarks used in DHN modelling where HNZ data was not available.

Building category	**Peak heat demands per floor area (kW/m^2)**	**Annual heat demands per floor area (kWh/y/m^2)**
Educational	0.0824	122.8
Industrial	0.1501	244.2
Office	0.0643	94.0
Residential	0.0760	88.8
Retail	0.0756	130.6

4 Modelling

4.1 Proposed Heat Sources

Table 4 gives the available heat sources in the TEED area and as per the Section 3.2 it is evident that the BBPL and EfW plants will not be sufficient to supply the whole of the TEED area. Therefore, it is proposed that these plants are used to their full capacity with the remaining demand supplied by a centralised heat pump as per Figure 8. However, it is possible that some of the industrial spaces such as warehouses may not be heated so the heat fraction that could be supplied by the EfW plants may be higher than shown below. This also assumes full build out of the network whereas in reality the scheme will be built out over phases and therefore initially a much higher percentage of the total heat demand is likely to be able to be provided by the EfW/biomass heat sources.

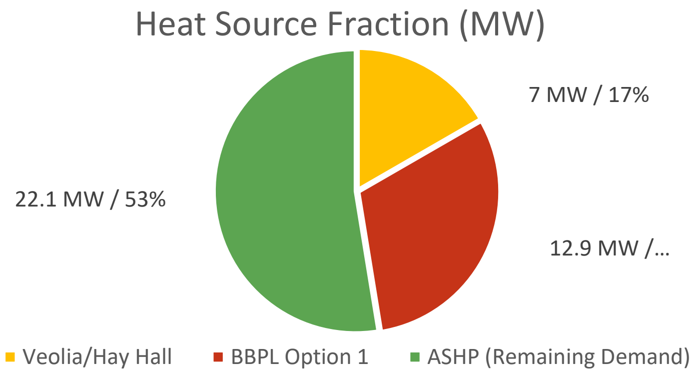

Figure 8: Heat source fraction for the proposed DHN.

4.2 Proposed Network

The proposed DHN includes the majority of buildings within the TEED area and is phased to connect commercial buildings first followed by residential buildings. The phases also consider the railway line that runs through the TEED area and connect to the North part of the TEED area prior to the South area. Figure 9 and Figure 10 show the proposed network with phasing, indicative pipe sizes and a satellite overlay respectively.

Base: Connections to commercial offtakers north of the railway line.

Phase 1: Connections to residential offtakers north of the railway line.

Phase 2: Connections to commercial and residential offtakers to the south of the railway line.

Phase 3: Connection to the network in the Birmingham city centre. Note, this connection is indicative, and the figures used for the expected demand (2,000 kW) and annual consumption (250,000 kWh/y) are likely to be low however were included to show the future connection in principal.

The connections shown in the above phases are dependent on the engagement process with offtakers and are subject to change. If the offtakers shown do not all connect then a larger connection to the Birmingham city centre may be feasible, utilising the spare capacity in the network.

Table 7: Key outputs from the DHN modelling including losses and network density per phase.

	Base	Phase 1	Phase 2	Phase 3
Network distance (km)	13.7	14.8	22.3	23.6
Heat demand (MWh/y)	65,624	69,737	94,040	94,290
Heat losses (MWh/y)	2,388	2,555	3,847	4,113
Heat losses (%)	3.5%	3.5%	3.9%	4.2%
Network density (MWh/y/m)	4.8	4.7	4.2	4.0

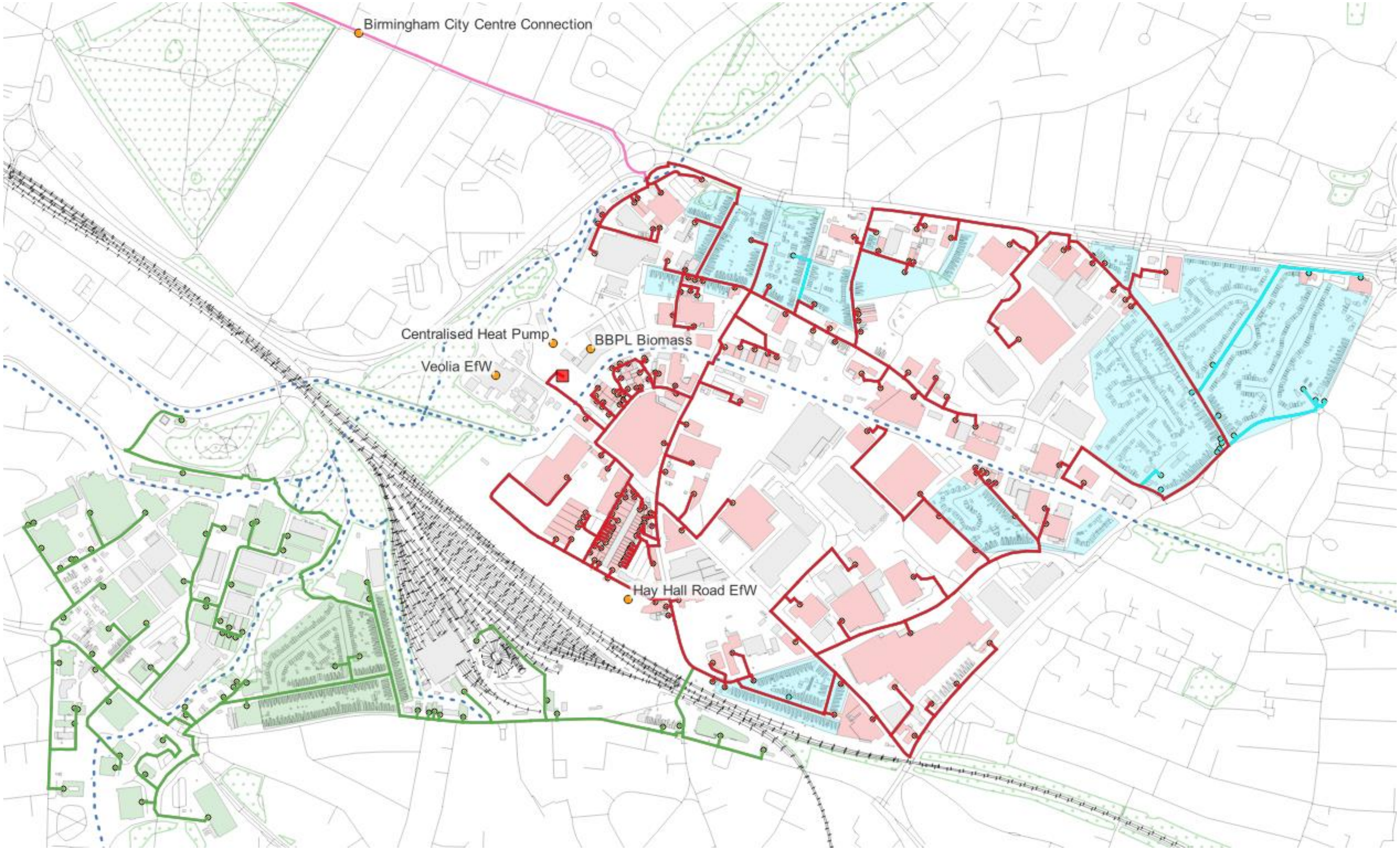

Figure 9: Proposed DHN phases with Base in red, Phase 1 in blue, Phase 2 in green and Phase 3 in pink (dashed blue represents waterways).

Figure 10: Proposed DHN layout with indicative pipe sizes.

5 Carbon

Significant CO_2 savings are expected through the utilisation of waste heat and heat pump led heat networks and these are calculated for the proposed network here. The energy sources proposed for this network either draw electrical energy from the grid or reduce the associated power plants output to the grid and therefore the emissions of the national grid need to be considered. These are expected to decrease over the next 20 years as the national grid decarbonises as per Figure 5. The network as described above in Section 4 is a combination of heat sources and the results presented below weight the emissions of each energy source by their contribution to the heat network. At this stage we have assumed the heat fractions are as per full build out of the scheme from day one which is a simplification. In the next stage of the project, possible phasing of connections should be considered with the changing heat fraction by heat source over time. To update this analysis, the carbon factor of the part-developed network will be lower than shown in Figure 11 due to a higher fraction from EfW/Biomass therefore it is likely that the carbon savings from the heat network are being underestimated in this initial assessment.

Figure 11 shows the annual CO_2 emissions of the proposed DHN and the alternatives of the gas boiler and localised ASHP. This shows the decreasing emissions of the DHN and the localised ASHP due to the decreasing emissions of the grid with the DHN initially having lower emissions due to the heat supplied by the EfW and biomass plants (carbon emissions discussed in Section 3.1). Once the national grid has decarbonised (approximately 2040-2045) the emissions of the localised ASHP option is lower due to the now relatively higher emissions of the EfW and biomass plants however it should be noted that this difference is minimal and both options are low-carbon at this point.

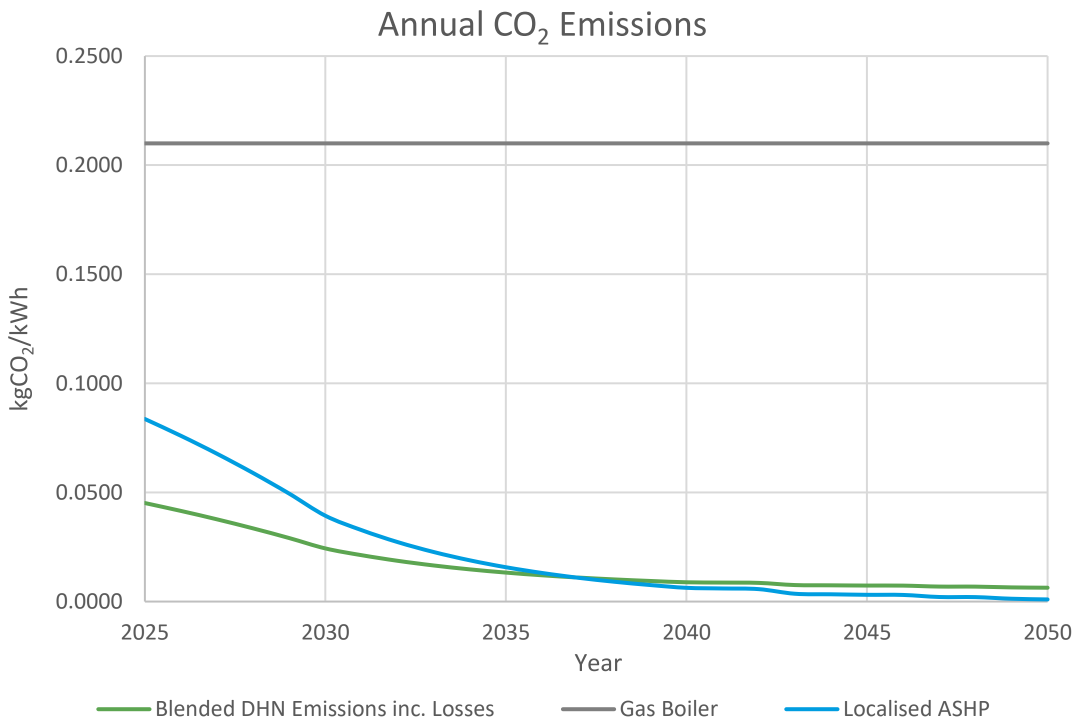

Figure 11: Annual CO_2 emissions for the proposed DHN and the alternatives of a gas boiler and localised ASHP (CoP of 2.5).

Figure 12 shows the cumulative emissions which reflects the benefits of utilising the heat from the EfW and biomass plants (which have lower emissions than the grid initially). Over the course of 25 years **the DHN option provides a net saving of 26% or 13,500 tonnes of CO2 compared to the localised ASHP comparator**. The savings compared to the gas boiler alternative are significant 92% or 456,000 tonnes.

As noted above the carbon emissions here assume that the network is fully installed and adopted in the TEED area from day one, in reality the network would be phased, and emission savings would cumulate at a slower rate. Gas boiler heat CO_2 intensity assumes a gas carbon factor of 0.21 $kgCO_2/kWh$ and boiler efficiency of 80%. National grid carbon emissions are taken from the Government's Green Book Supplementary Guidance data table 1 (long-run marginal, consumption-based, commercial/public sector).

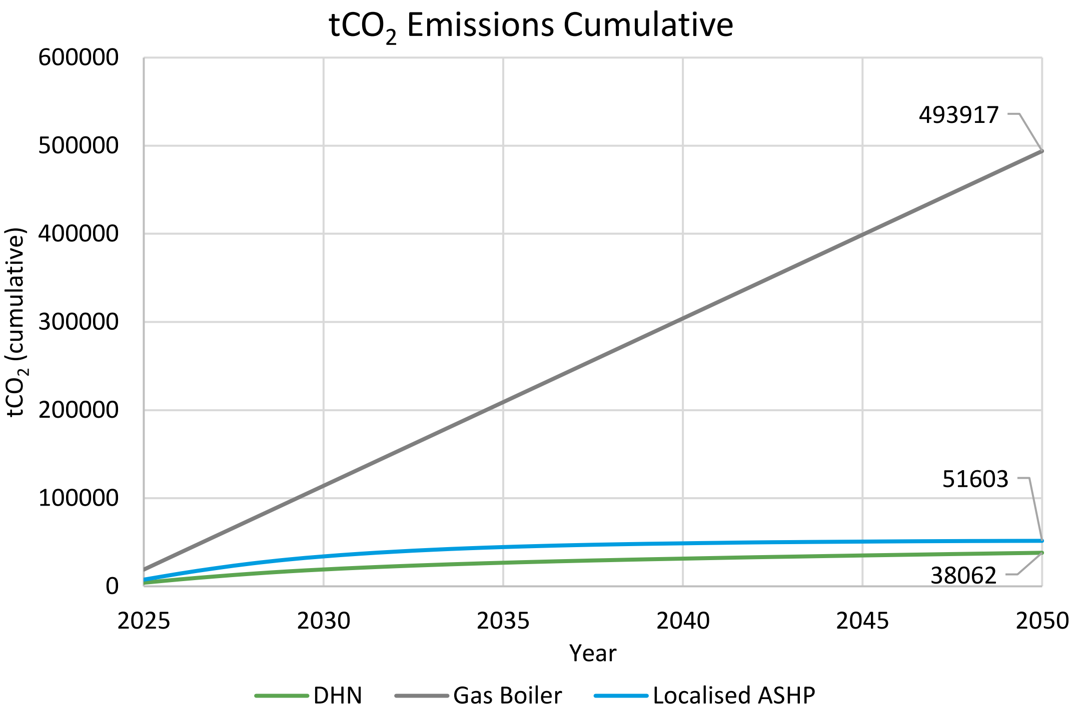

Figure 12: CO_2 emissions (cumulative) for the proposed DHN and the alternatives of gas boiler and localised ASHP.

Table 8: Total cumulative emissions of the DHN and the alternative options from 2025 to 2050.

Option	CO_2 Emissions (tCO2)
DHN	38,062
Gas Boiler	493,917
Localised ASHP	51,603

6 Financial & Commercial

The below figures are based on a full build out of all phases of the proposed district heating network.

6.1 Cost of Heat

Section 3.1 gives the cost of heat per heat source however as per Figure 8 this needs to be weighted by the heat sources' contribution to the overall network. In addition, the following needs to be considered when estimating the final unit cost of heat for the consumer:

- DHN losses and the associated cost
- Financial factors such as cost of finance, payment transaction charges and a bad debt risk allowance
- Overhead Profit for the DHN operator and owner

Preliminary high-level variable heat tariff calculations are provided in Appendix A in Table 10 giving a heat unit charge of 4.97p/kWh assuming an electricity price of 13p/kWh. Table 9 shows the heat unit charges depending on electricity price.

At this stage, to give an indication of the level of fixed charge that could be set to give a saving vs an ASHP counterfactual (which tends to be the accepted comparator and cost capping mechanism on a levelized cost of heat basis in most new low carbon heat network ESCO contracts), a counterfactual calculator has been considered in Table 11 and Table 12 in Appendix A and the fixed charge adjusted to **achieve a circa 5% saving versus the counterfactual. This results in a fixed charge of £158.25/kW for residential and £131.40/kW for commercial when considering a heat unit charge of 4.97p/kWh at an electricity price of 13p/kWh.** Electricity prices are highly variable due to recent and ongoing geopolitical events and therefore the below calculations have been repeated at a variety of electricity input prices as per Table 9.

These values contain significant assumptions, and it should be noted that a full commercial model has not been generated for this report, which is required to confirm the stated charges are suitable and commercially viable for the scheme.

Table 9: Sensitivity analysis of heat unit and fixed charges depending on electricity input prices.

Electricity price (p/kWh)	Unit heat charge (p/kWh)	Fixed charge - residential (£/kW)	Fixed charge - commercial (£/kW)
13	4.97	158.25	131.40
18	6.40	163.90	155.00
25	8.40	171.90	188.00
30	9.83	177.50	211.50

6.2 Capital Expenditure (CAPEX)

The proposed DHN CAPEX is estimated below however these numbers are preliminary estimates based on rules of thumb and industry experience. An all-in rate for the ASHP comparator is indicatively assumed to be £1,400/kW however this would require refinement during future design phases.

DHN		
Heat sources		
Centralised heat pump & plant CAPEX (£/MW)	£	444,444.44
Centralised heat pump CAPEX total[1]	£	9,802,042.23
EfW/Biomass heat offtake (each)	£	2,100,000.00
EfW/Biomass heat offtake (total)	£	6,300,000.00
Energy centre	£	5,000,000.00
Sub-total	£	21,102,042.23
Heat network		
Pipework, trenching, component costs etc.	£	43,297,159.86
Substations	£	19,310,906.81
Sub-total	£	62,608,066.67
TOTAL	**£**	**83,710,108.90**
ASHP		
ASHP cost commercial (£/kW) [2]		1,200
ASHP cost residential (£/connection)		8,000
TOTAL	**£**	**81,375,043.60**

(1) This budget considers an allowance for the building to house the plant, mechanical and electrical, design and procurement etc.
(2) There is not currently a good pool of referenceable cost data for large scale building level ASHPs as would be required for the buildings in the TEED area. Therefore, at this stage we have used £1,200/kW as per the Green Heat Network Fund counterfactual calculation for new heat networks. Pinnacle Power are actively engaging in industry association development of this area to make comparative pricing of heat networks more standardised and would look to utilise the outputs of this exercise when available for this project.

To deliver decarbonised heat to the TEED area the total required CAPEX over the course of the full DHN build-out would be **£83.7m**. The comparator of domestic ASHPs would require **£81.4m**. Neither number considers inflation. It should be noted that the cost of heat is also cheaper from the DHN.

Importantly, this comparator **does not** include the extensive grid upgrade/reinforcement that would be required to meet the increased electrical demand and the funding required to decarbonise the national grid; this is considered in Section 6.3.

Further this does not consider the grid benefits of peak lopping or wider grid management benefits. We can show analysis of peak flattening using the heat network, as well as using electric boilers and thermal stores to better link grid fluctuations to heat price.

6.3 National Grid Loading

It is important to note the benefits provided by a DHN to the national grid through the reduction in overall consumption from the grid and the reduction in peak demand. These benefits are significant and will translate to significant cost reductions for the national grid. It is estimated that the implementation of the full build-out proposed DHN would give a **reduction in peak demand on the national grid of 57% and a reduction in annual consumption drawn from the grid of 26%.**

Domestic ASHP comparator	
Peak demand	
Peak demand (MW_{th})[1]	63.9
Domestic ASHP CoP	2.5
Peak demand (MW_e)	25.6
Annual consumption	
Annual consumption (GWh_{th}/y)	90.5
Domestic ASHP CoP	2.5
Annual consumption (GWh_e/y)	36.2
DHN	
Peak demand	
Peak demand supplied by heat pump (MW_{th})	22.1
Centralised heat pump CoP	2.8
Peak demand supplied by heat pump (MW_e)	7.9
Veolia/Hay Hall Road power generation reduction (MW_e)	1.5
BBPL power generation reduction (MW_e)	1.55
Total demand on the grid (loss of supply and additional demand)	10.9
Annual consumption	
Annual consumption provided by heat pump (GWh_{th}/y)	49.7
Centralised heat pump CoP	2.5
Annual consumption provided by heat pump (GWh_e/y)	19.9
Veolia/Hay Hall Road power generation reduction (GWh_e/y)	3.4
BBPL power generation reduction (GWh_e/y)	3.5
Total demand on the grid (loss of supply and additional consumption)	26.7
Comparison	
Peak demand	
Reduction in peak grid demand (MW_e)	14.6
Reduction in peak grid demand (%)	57%
Annual consumption	
Reduction in grid annual consumption (GWh_e/y)	9.5
Reduction in grid annual consumption (%)	26%

(1) Note, this value is the undiversified peak load of the localised heat pumps.

7 Conclusion and Recommendations

7.1 Conclusion

The DHN proposed through this report can be judged by the following key factors:

- Carbon emissions savings
- Price of heat for the consumer
- CAPEX required
- Utilisation of local low-carbon waste heat
- Reduced demand on the national grid

In all of the above categories the proposed DHN is superior to both the existing gas boiler fed heat approach (with the exclusion of cost as this comparator has not been completed in this report) and the alternative of domestic/localised ASHPs. The technical and commercial feasibility of this heat network is not fully understood due to this being a preliminary feasibility report however this report highlights key risks and areas for future work in the subsequent design phases. Through the use of the heat offtakes from the BBPL biomass plant and the EfW plants (Veolia and Hay Hall Road) in conjunction with a centralized heat pump (either ASHP or WSHP), it is possible to supply the whole of the TEED area with low-carbon affordable heat.

The following key benefits of the proposed DHN are summarised from this report:

- Significant CO_2 savings:
  - Net saving of 26% or 13,500 tonnes of CO2 compared to the localised ASHP comparator
  - 92% or 456,000 tonnes of CO_2 reduction compared to the gas boiler alternative
- Consumer price of heat:
  - DHN achieves a circa 5% saving versus the localized ASHP counterfactual – this could be increased.
  - This results in a fixed charge of £158.25/kW for residential and £131.40/kW for commercial when considering a heat unit charge of 4.97p/kWh at an electricity price of 13p/kWh.
- CAPEX:
  - Required CAPEX over the course of the full DHN build-out would be £83.7m
  - Comparator of domestic ASHPs would require £81.4m
  - Higher CAPEX expected for the ASHP comparator when accounting for the reinforcement of the national grid and increased demand
- Low carbon waste heat utilisation:
  - Utilises waste heat available from Veolia and in the future Hay Hall Road EfW plants, increasing overall plant efficiency whilst minimizing cost of reduced electrical output
  - Utilises waste heat from the BBPL biomass plant increasing plant efficiency whilst minimizing cost of reduced electrical output
- Reduced demand on national grid:
  - DHN would give a reduction in peak demand on the national grid of 57% compared to the ASHP comparator
  - DHN would provide a reduction in annual consumption drawn from the grid of 26% compared to the ASHP comparator
  - The installed capacity of the localised heat pumps would be significantly higher than that of the diversified heat network because they would need to cover the peak demand compared to the DHN which would cover the diversified peak.

7.2 Recommendations and future work

In order to develop the TEED DHN further it is recommended that Pinnacle Power undertake the following exercises in future work programmes:

- Development of a full commercial model to ensure commercial feasibility
- Further studies to investigate the technical feasibility of heat offtake solutions for the EfW and Biomass plants as discussed in Section 3.1
- Further studies to investigate the technical feasibility of air and water source heat pump options
- Engagement with potential heat offtakers to further quantify demand profiles and likelihood of connection to a DHN – this will likely guide phasing plans
- Further development of DHN route and refinement of pipe sizing and route plans including assessment of existing services that will need to be coordinated with, traffic management requirements for the installation works and other site specific considerations such as how to bring pipework across the highway/railways lines.
- Exploring grant funding opportunities that may be available for the heat network scheme.

Figure 13: Proposed DHN phases with satellite imagery overlay with Base in red, Phase 1 in blue, Phase 2 in green and Phase 3 in pink (dashed blue represents waterways).

Appendix A. Tariff Calculations

Table 10: DHN tariff calculation for unit charge.

Electric unit rate	*p/kWh*	13
Z-factors/CoP		
Veolia (EfW) Z-factor	-	4.7
Hay Hall Road (EfW) Z-factor	-	4.7
BBPL (Biomass) – Option 1 Z-factor	-	8.4
BBPL (Biomass) – Option 2 Z-factor	-	4.4
Centralised ASHP CoP	-	2.8
Localised ASHP CoP	-	2.5
Heat source fraction		
Veolia/Hay Hall	-	17%
BBPL Option 1	-	31%
BBPL Option 2	-	0%
Centralised HP	-	53%
Heat source cost (electricity)		
Veolia/Hay Hall	*p/kWh*	2.79
BBPL Option 1	*p/kWh*	1.55
BBPL Option 2	*p/kWh*	2.95
Centralised HP	*p/kWh*	4.64
Heat source cost (other)		
Veolia/Hay Hall (EfW profit rate)	*p/kWh*	0.50
BBPL Option 1 (BBPL profit rate)	*p/kWh*	0.50
BBPL Option 2 (BBPL profit rate)	*p/kWh*	0.50
Heat source cost (total)		
Veolia/Hay Hall	*p/kWh*	3.29
BBPL Option 1	*p/kWh*	2.05
BBPL Option 2	*p/kWh*	3.45
Centralised HP	*p/kWh*	4.64
Blended DHN Rate	*p/kWh*	3.62
Losses		
DHN losses	*kWh/y*	4113000
Cost of loss	*£/y*	148827
Loss allowance	*p/kWh*	0.16
TOTAL		
Blended DHN Rate	*p/kWh*	3.62
Loss allowance	*p/kWh*	0.16
Payment transaction charges		2.50%
Bad Debt risk allowance		2.50%
Non-Energy Costs	*p/kWh*	1.00
Retail charge	*p/kWh*	4.97

Table 11: Residential ASHP comparator calculation

Site Inputs		
Residential Counterfactuals		
Domestic heat load	*kW*	8
Domestic heat consumption	*kWh*	6,000
Variable electricity tariff	*p/kWh*	13.00
Fixed electricity charge	*p/day*	46.00
Worthing District Heat Network		
Domestic heat load	*kW*	8
Domestic heat consumption	*kWh*	6,000
Variable heat tariff	*p/kWh*	4.97
Fixed heat charge	*£/kW*	158.25
Air Source Heat Pump (ASHP) Counterfactual Comparison		
Dwelling ASHP with Thermal Store / DHW Cylinder		
Calculations		
Heat loss from store	*% heat*	15%
Heat loss from store	*kWh*	900
Seasonal efficiency of ASHP	*sCoP*	2.50
Electrical consumption	*kWh*	2,760
Total variable electricity cost	*£ / yr*	359
Total fixed electricity cost	*£ / yr*	168
Replacement cost for ASHP	*£ / kW*	1,200
Expected life of ASHP	*years*	15
Average cost per year for replacement	*£ / yr*	640
Annual Maintenance Cost	*% Repex*	5%
Maintenance and repair cover (Inclusive, no excess)	*£ / yr*	480
Total cost of counterfactual heat		
Total Cost of heating system	*£ / yr*	1,647
Levelised Cost of Heat	*p/kWh of heat*	27.45
Worthing District Heat Network		
Calculations		
Total variable heat cost	*£ / yr*	298
Total fixed heat cost	*£ / kW / yr*	1,266
Total cost of District Heat		
Total Cost of heating system	*£ / yr*	1,564
Levelised Cost of Heat	*p/kWh of heat*	26.07
Cost saving District Heating vs ASHP System		**5.00%**

Table 12: Commercial ASHP comparator calculation

Energy Input costs		
Electric		
Customer Projected Electricity Price	*£/kWh*	0.1300
Est heat consumption	*kWh/yr.*	500,000
Heat Generation Cost		
Seasonal Coefficient of Performance	*%*	250%
Cost of heat from HP	*£/kWh*	0.0520
Building Details		
Customer Substation Thermal Capacity	*kW*	1,000
Customer Annual Average Energy Demand	*kWh/yr.*	5,000,000
Replacement Cost	*£/kW*	1,200
Expected Life		15
Annual Maintenance Cost	*% Repex*	5%
Comparator		
Unit Cost of Heat	*£/kWh*	0.0520
Replacement Cost	*£/kWh*	0.0160
Maintenance Cost	*£/kWh*	0.0120
Gross Average Charge Levelized Heat Tariff	*£/kWh*	0.0800
Gross Average Charge Levelized Heat Tariff	***p/kWh***	**8.00**
Total Customer Comparator cost	*£/yr*	400,000
Tariff vs Counterfactual		
Heat Fixed Charge Rate	*£/kW*	131.40
Heat Unit Charge Rate	*p/kWh*	4.97
Heat Fixed Charge	*£/yr*	131,400
Heat Unit Charge	*£/yr*	248,606
Total Tariff Charges	*£/yr*	380,006
Tariff GACLHT	*£/kWh*	0.0760
Tariff GACLHT	***p/kWh***	**7.600**
Tariff saving vs Counterfactual	*p/kWh*	0.400
		5.00%