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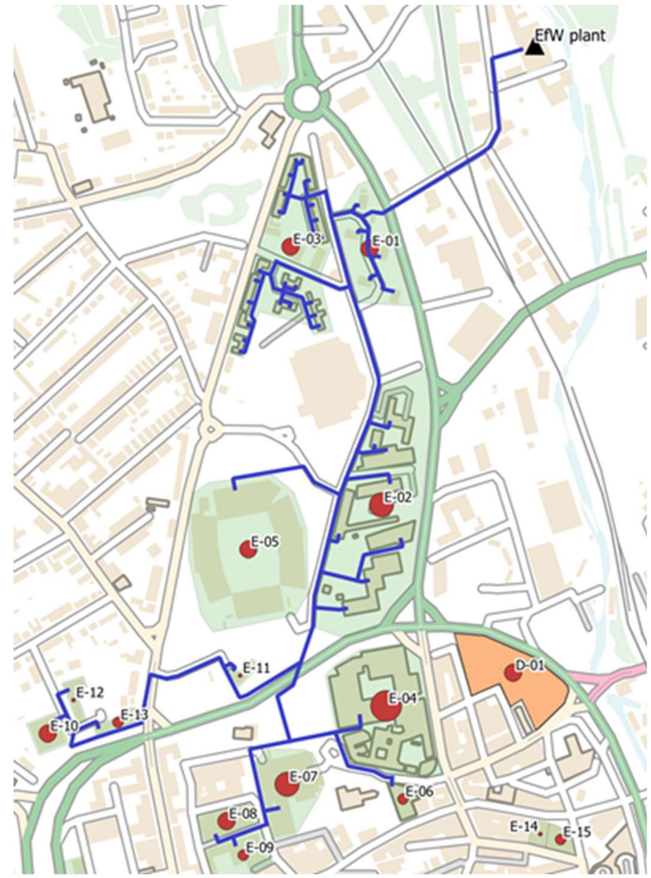

Wolverhampton City Heat Network/Detailed Feasibility

Final Report

July 2021

GREENFIELD

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Report information:

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Table of contents

Figures

Tables

Glossary

BEIS Department of Business, Energy and Industrial Strategy

CHP Combined Heat and Power

CO_2 Carbon dioxide (typically referring to CO_2 equivalent)

CWC City of Wolverhampton Council

DH District Heating

DHW Domestic Hot Water

DN Nominal diameter in mm (Diametre Nominal)

DNO Distribution Network Operator

EC Energy Centre

EED EU Energy Efficiency Directive

EfW Energy from Waste (waste combustion plant)

GIA Gross Internal Area (buildings floor area)

GCV (HHV) Gross Calorific Value (also referred to as Higher Heat Value)

GHNF Green Heat Network Fund

HIU Heat Interface Unit

HN Heat Network

HNDU Heat Network Delivery Unit (BEIS)

IRR Internal Rate of Return

LCOE Lifetime Cost of Energy

NPV Net Present Value

PHE Plate Heat Exchanger

PPA Power Purchase Agreement

QEP Quarterly Energy Prices (BEIS dataset)

SAP Standard Application Protocol (assessment approach for energy in buildings under Part L of Building Regulations)

UoW University of Wolverhampton

WH Wolverhampton Homes

1 Executive summary

1.1 Introduction

A Detailed Feasibility Study has been completed into the development of a heat network in the City of Wolverhampton. The study has sought to explore and develop a range of low carbon heat network solutions appropriate to the city. A feasibility study would typically be followed by a business planning exercise (Detailed Project Development) which would precede the commercialisation of a preferred project option. This work has been supported by BEIS through the Heat Network Delivery Unit (HNDU).

The work has been completed by Greenfield Nordic with support from Fichtner Consulting (related to heat offtake from the city's Energy from Waste plant).

Coral Tilling was the lead for the City of Wolverhampton Council (CWC) and was supported by Anna Spinks (CWC, Waste Management), with external project management support from Patrick Fleming (Midlands Energy Hub).

1.2 Strategic Drivers

CWC commissioned the work in response to the following objectives:

1/ Delivering significant carbon reduction in the city, as established by:

a. 'Future Generations: Our Climate Commitment, 2019' which set a target for a Net Zero council by 2028 and which was a response to the council's Climate Emergency Declaration in July 2019
b. 2019 Citizens' Assembly that set the target for Wolverhampton to become a net zero city by 2041

2/ Economic development: The corporate plan (Our Council Plan 2019-2024) maps out goals to develop and strengthen the city's economy in the longer term, attracting good-quality jobs and investment. The council is also committed to supporting businesses to develop local resilience in energy generation and distribution and to maximise the economic opportunities offered by the growth of a low carbon economy.

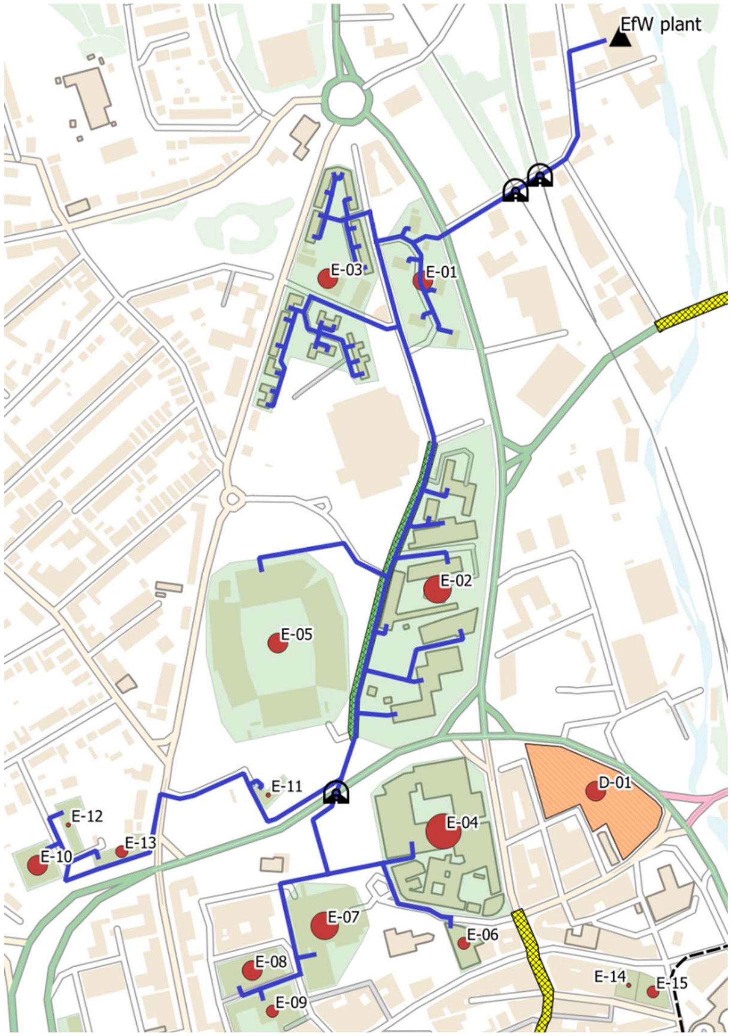
3/ Effective long-term use of the Wolverhampton Energy from Waste (EfW) facility which is an important low carbon 'asset' but which is only currently generating electricity that is exported to the 'grid'. Adaptation to enable heat export is identified as an important strategic opportunity.

4/ Alignment with national strategies and funding opportunities. The Council is actively pursuing a course of action that supports the national and international goals of climate change mitigation. As such, support including financial resources is anticipated over the coming months and years that can be harnessed to support local goals.

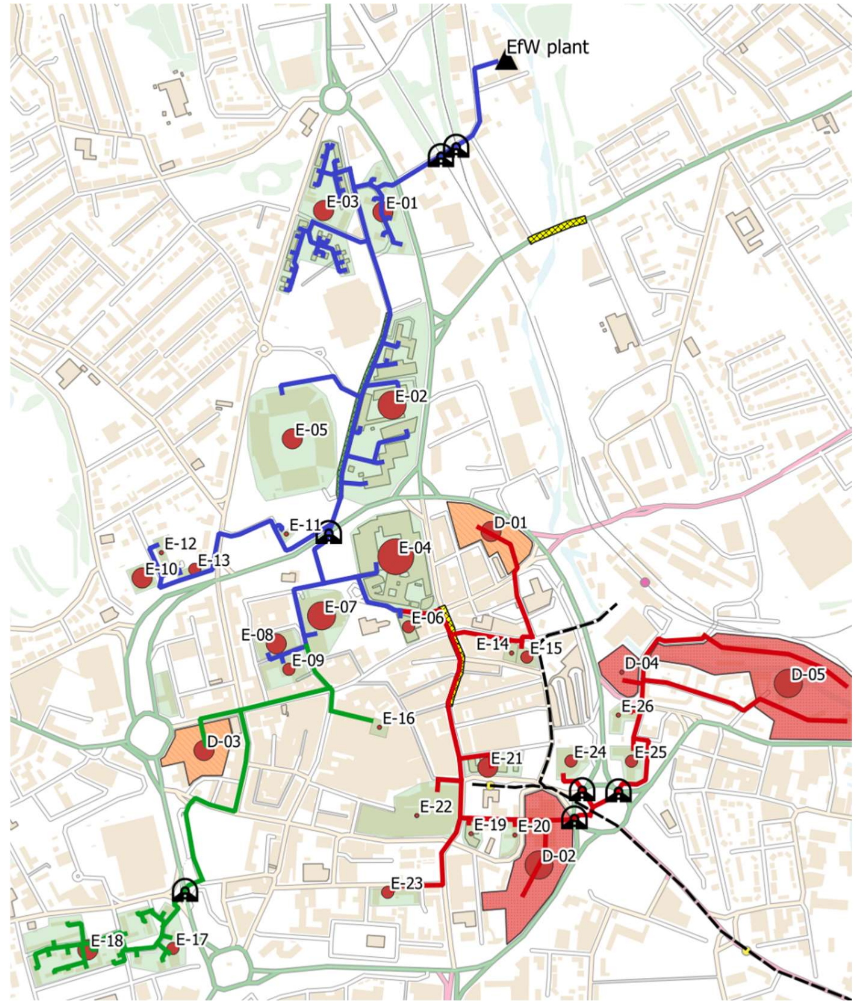
It should also be noted that many of the stakeholders within the project, especially the significant consumers are motivated to support the project because they see the implementation of a low carbon heat network scheme as a good opportunity to address their objectives around climate change mitigation/carbon reduction.

1.3 Heat Network option appraisal

Three primary network options were identified and developed. The first, shown below, is referred to as the Base network (or Network 1). This has been the primary focus of the study work based on the strategy that if the case for this can be established, then the other options, which are extensions of the Base network can be developed in subsequent stages of work.



The image below shows the extent of the East and West network extensions considered.



Within the Base network, there are only 6 consumers which represent 45 distinct buildings (including Boscobel flats which have 210 apartments). The heat consumption in the Base network is dominated by the University of Wolverhampton (UoW) at 61% and CWC at 27% with Wolverhampton

Homes and Wolverhampton Wanderers Football Club as the other two main consumers. As such, this is a small number of key stakeholders all of whom are generally supportive of the project and have clear motivations to connect, assuming the project can deliver significant carbon savings, is at least neutral in cost terms, and, can meet appropriate service standards. This represents a strong base from which to expand to a wider group of consumers (including new development) who are typically smaller and on their own would be less confident about connection to a heat network.

The project has explored the fundaments of a heat network scheme:

1/ energy supply (both heat and power) exported from a renewed EfW facility – considering availability, cost and carbon intensity. The current '2 line' arrangement was assessed as was a simplified scenario for an expanded '3 line' facility that would increase the potential energy supply capacity by 50%.

2/ route options for the insulated heat network pipework, which would typically be laid underground, including consideration of how best to navigate constraints such as rail lines and the city's Ring Road

3/ property connections, including consideration of access and space constraints for key property connections

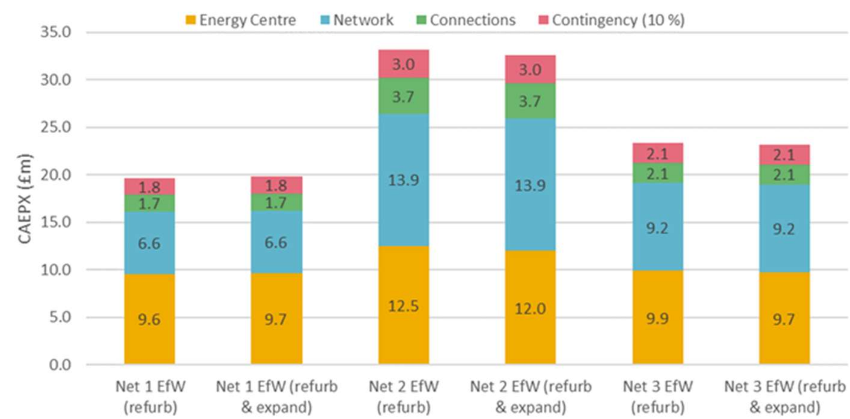
4/ economic viability.

Based on the network options identified, propositions for the establishment of an energy centre at the EfW facility, network routes (for appropriately sized pipework and property connections have been developed.

These propositions were costed and detailed economic models were developed and tested to examine the viability of the options.

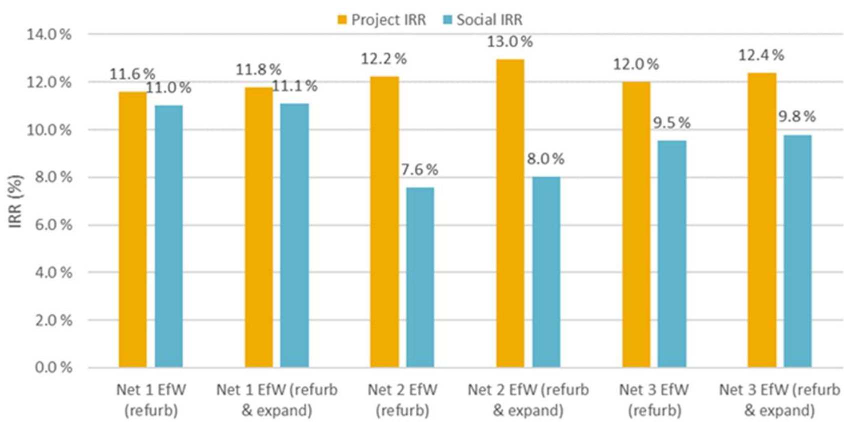
The table and bar chart below shows the range in the expected capital costs (£16.4m to £34.5m) across the options considered. These capital costs do not include the capital cost for renewal/replacement of the existing steam turbine plant that may be required. It is understood that the plant had a major overhaul within the past two years and so could be retained for a further period. For reference, a new steam turbine would cost in the region of £10m.

	Network:	Network 1 (Base)		Network 2 (East Extension)		Network 3 (West Exten-sion)	
	EfW refurb scenario:	2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
Total CAPEX	£m	19.7	19.8	33.2	32.6	23.4	23.2



It is assumed the investment case for a new turbine is covered by the general investment case for renewal of the EfW plant which would continue to generate power (as a major energy revenue stream (along with waste 'gate fees'). Heat and/or private wire power sales would then displace the revenue that would otherwise be achieved solely from 'grid' power sales, as is this the case today. It is worth noting that the benefit of power sale revenue currently goes to the EfW operator (WWS). It may also be possible to extract heat from other elements of the future EfW facility, e.g. Flue Gas heat recovery or recovery from the systems cooling circuit, but this has not been considered within the study as there is a lack of certainty over the design of the refurbished EfW facility, at this stage.

The economic modelling outputs, as summarised by the Internal Rates of Return (IRRs) in the graph below, has illustrated strong economic performance with project IRRs between 11.6-13% across the options. At the current stage of feasibility, this provides confidence that the project can support at least public sector financing. Where gap financing is needed, e.g. if funded by the private sector then funding may be available from the £280m Green Heat Network Fund which will support low carbon heat network through grant support from Spring 2022. This initial 'transition' phase of the fund launched in July 2021, which has proved early guidance on the funding mechanism and priorities.



For each network option, the following economic results were identified:

1/ Network 1: Base:

- IRRs sit at around 10 % for the two supply scenarios
- NPVs sit between £19m - £20m
- Small uplift in both when accounting for social value

2/ Network 2: East extension:

- IRRs sit at between 11 % and 12 % for the two supply scenarios
- NPVs sit between £32m – £35
- Significant reduction both when accounting for social value, which is understood to be caused by a combination of increased carbon emissions and capital costs

3/ Network 3: West extension:

- IRRs sit at between 10 % and 11 % for the two supply scenarios
- NPVs sit at around £25m
- Small reduction when accounting for social value
- NPVs sit at around £17m
- Small IRR reduction when accounting for social value

The resulting estimated carbon emission reduction for delivered heat as shown in the table below is in the region of 65-90%. This excludes the carbon savings associated to power supplied which is uncertain since various carbon accounting methodologies could be used that would lead to different results.

The figures for the East network extension are lower because this network assumes the connection of a large quantity of new development which largely has the counterfactual assumption of using building-level heat pump systems. Heat pump systems (combined with recently lowered carbon factor grid electricity) will mean that a heat network solution is likely to increase carbon emissions when compared to this counterfactual (when compared to conventional gas boilers, for example, the heat network would be seen as very low). This dilutes the overall impact of the carbon saving on the entire network.

	Network:	Network 1 (Base)		Network 2 (East Extension)		Network 3 (West Extension)	
	EfW scenario:	2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
15 yr.							
CO_2 emission savings	$kTCO_2$/yr	3.8	4.1	3.6	4.3	3.9	4.4
	%	83%	9 0%	65%	78%	78%	87%

The report also reviews:

- the key sensitivities to the economic results
- consumer benefits (particularly to the UoW and CWC as the principal consumers in the base network)
- key development risks as well as opportunities for improving performance.

The most significant risks identified are as follows:

1/ Not being able to access the assumed heat or power from the EfW at the assumed pricing. Either has a significant impact on IRR.

2/ Losing private wire electricity sales. This would have a large negative impact on IRR. In addition, changes to the (national) electricity pricing regime could have an impact on the revenue/cost balance which may negatively affect economic performance.

3/ Losing anticipated consumers / reducing heat load density. All prospective consumers will need to formally enter into contract. Losing a large proportion of the estimated demand will have a significant impact on viability.

4/ Negatives changes in the cost metrics (capital cost, operating cost, revenue).

1.4 Conclusions

Based on the analysis conducted and the broader context of the possible heat network project, the following conclusions have been drawn:

1. **Reviewed against Critical Success Factors, all of the 3 network options essentially meet the stated objectives.**
2. **All network solutions considered will deliver significant carbon reduction of between 65% and 90%**. These figures are calculated with the 'private wire' power sales excluded; depending on the methodology used the overall carbon savings could increase or decrease. It should be noted that the carbon reduction for heat supply is driven by the proportion of energy delivered by the EfW facility but also the assumed counterfactual energy supply (that it is assumed the network replaces). Where this includes future new development, the reduction in the carbon emissions is calculated to be lower because future property standards are expected to result in lower counterfactual emissions. The carbon factor for the heat from the EFW facility will also vary depending on the offtake arrangements of the steam turbine.
3. **All network solutions show a strong return on investment** and appear investable (IRRs between 11.6-13.0% - assumes private wire power sales).
4. **All network solutions developed are expected to deliver significant wider socio-economic benefits**, such as reduced energy costs, inward investment, employment (construction and O&M) and related education, research and training opportunities.
5. **Network 2 (Base+East) performs best out of all options in terms of return on investment**. The differences are relatively marginal, suggesting that the decision regarding the preferred network option to pursue should rest on deliverability, noting that the larger networks present greater delivery risks.

6. **The assumed optimised EfW/steam turbine plant provides 'headroom' for expansion beyond the 3 network options considered.** Within the analysis conducted it is important to note that the cost of new turbine capacity is assumed to be covered within the EfW refurbishment costs, i.e. only offtake costs are considered within this analysis.
7. **The EfW plant provides 'headroom' for expansion beyond the 3 network options considered.**
8. **Expanding the EfW plant's heat production capacity** (the 3-line option) has a small positive impact on project viability and a positive impact on carbon savings as well as providing greater future flexibility to expand the heat networks served by the EfW plant. It would also provide greater resilience since two lines could be taken out of operation whilst still enable energy generation.
9. **Numerous techno-economic risks need to be addressed.** These include:
    a. finalising the plans for the EfW plant
    b. securing key consumers (particularly UoW and CWC)
    c. the sale of power (private wire network)
10. **Opportunity for grant support.** At the levels of economic performance shown it is highly likely that a Special Purpose Vehicle, perhaps a joint venture between the Council and UoW, could finance the project with a blend of council and university funding. Where there is a funding gap or where there is a wish for the network to be funded by a private heat network business then grant funding from the Green Heat Network Funding may be appropriate to draw down. This £280m government programme is due to launch in 2022 and is intended to provide capital support for low carbon networks, including those using the EfW as the primary supply technology. Further details regarding the programme are anticipated later in summer 2021.

1.5 Recommendations

The following recommendations are made to support the further development of the project:

1. **Commission a Detailed Project Development (DPD) phase of work**

   This should result in the development of a Treasury standard business case and resolve project structuring and financing solutions to suit key stakeholder needs**.** This work shows that there is a good case for a heat network project assuming the EfW plant is renewed (with or without expansion). The indicative economic performance is strong, there are few stakeholders (particularly in the Base network) and all are motivated to connect. There are numerous delivery risks, but these are considered typical for a heat network project and can be addressed through a systematic development process, using appropriate expert support.

   Assuming a DPD process can start in Q3 2021 it could be complete by Q2/3 2022, giving time to address key uncertainties around the supply, consumers (including the identified network extensions) and network (through a 'route proving exercise').

   As well as developing the evidence base for the project and addressing the key risk items (as discussed previously), the principal output of this stage is an Outline Business Case (OBC). The OBC will capture key decisions around the nature of the preferred network scheme but also establish the preferred project structure and financing options.

   On the basis formalised in the OBC, the council (assuming they lead the development) with stakeholders/partners would commercialise the scheme, resolve project financing, establish the necessary organisations and then let the key contracts for design, construction and operation on the network.

   Until specific plans for the EfW plant and a delivery programme is in place, the programme for the post-DPD development stages for the heat network cannot be programmed. Certainty over the renewal/expansion of the EfW plant is essential post-DPD.

2. **Finalise plans for the EfW plant.** The DPD process will require greater certainty over the EfW options being considered.

   Simplified scenarios have been developed in this study to enable review of the possible options but this will not be sufficient to support an Outline Business Case and it will likely undermine the confidence of key stakeholders and prospective consumers unless resolved. It is therefore essential for CWC to rapidly complete the examination of options.

   It is strongly recommended that the EfW plant is renewed and an optimised steam turbine arrangement (to limit power generation losses) is installed as this would support the delivery of a major long term decarbonisation project which will have a profound impact on carbon emissions with the city in the short term. It will also support the development of infrastructure (hard and soft) that will enable sustained decarbonisation since it will provide the capacity for new supply technologies to integrate into the distribution infrastructure established.

   An expanded 3 line facility is recommended this will significantly increase the headroom for the expansion of the heat network well beyond the 3 options identified within this study.

   The review of the EfW options should also consider the possibility of locating the primary heat network energy centre on the EfW facility site. Where this is not the case, the DPD work should include a review of other viable locations.

3. **Planning policy (zoning) and development control**. It is recommended that CWC explores the introduction of planning policy that would seek to encourage and facilitate connection to the heat network to both new development and existing properties (for example, when they seek to renew existing boiler plant). This could include establishing a 'heat hierarchy' policy, with low carbon heat network connections being prioritised, possibly limited to specific zones. It is understood that the draft Black Country Plan (which is intended to operate as a Local Plan for each of the four boroughs of the Black Country) includes such policies. This is due to be issued for consultation in summer 2021 and is anticipated to be adopted between 2024 and 2026. Supplementary planning policy or guidance may be required to address locally specific issues associated with this project, including giving general permission for the implementation of heat network infrastructure. For reference, the Government is intending to run a consultation on 'heat zoning' policies in summer 2021 which will support the implementation of supportive policies nationally.

4. **Plan for connection of council buildings**. CWC buildings are a significant proportion of the loads proposed particularly in the Base network. This should include addressing the uncertainties with the City Hall (Base network) and the other properties identified for the network extensions (Library, Job Centre, Grand Theatre, Adult Education College).

   Also, by publicly committing to connect its properties (and the development it plans to bring forward), CWC would both directly support the development of the network and encourage others to connect.

5. **Investigate the connection of the identified property development schemes that CWC is leading or is a party to, e.g. as landowner, and encourage other developers to do the same.**

6. **Maintain engagement with key consumer stakeholders** particularly for the Base network (UoW, Wolverhampton Homes, Wolverhampton Wanderers and the development sites identified). In particular, the following will likely be important:

UoW: understanding changes to estate plans that may materially affect the prospective heat network connections, including (a) building-level decarbonisation investment, (b) decisions around the existing gas CHP at Wulfruna, e.g. contract renewal, (c) development plans for Springfield Campus which may influence a connection decision, (d) decisions around the future provision of on-site residential accommodation

WH: progression of plans for cladding of the Boscobel flats and the establishment of a local heat network and substation which should be designed to be compatible for later connection to the city heat network

Wolverhampton Wanderers: request that sub-metering is installed (could be temporary) to improve certainty over thermal demands that could be supplied by a heat network

Other consumers: For the other consumers in Network 2 and 3, uncertainty over demand estimates, the likelihood of connection and connection timing constraints are greater than for the Base network. Whilst it will be important to review these consumers in the DPD stage CWC could consider some engagement measures such as an email campaign and online workshops. This will help to address the programme risks of re-initiating consumer engagement if there is a hiatus as background work progresses.

2 Introduction & strategic drivers

2.1 Introduction

This report records the Detailed Feasibility Study conducted into options for the development of a low carbon heat network within the city of Wolverhampton.

It builds on elements of an earlier Heat Mapping and Masterplanning exercise but draws distinct conclusions, particularly by focusing on the export of heat from the city Energy from Waste (EfW) plant which is owned by the City of Wolverhampton Council (CWC) and is operated under licence by MES Environmental Limited (MESE). The MESE operational licence is due to end in 2023 and the future of the plant is currently being considered by CWC.

The primary purpose of the study was to assess the viability of a heat network primarily fuelled by the EfW plant and to determine how such as scheme could be brought forward by CWC and other stakeholders.

2.2 Strategic drivers

CWC has identified the following and strategic drivers relevant to the development of a low carbon heat network in the city:

(1) Local carbon targets, which have been formalised by the following plans/actions:

- Corporate plan[1]: to promote a greener and more sustainable city, lessen its environmental impact and maximise carbon reduction
- Climate emergency declared by full Council on 17th July 2019, which has then been used as the basis for a 2019 climate change strategy[2]
- Membership of the UK100 network of local government leaders
- Citizens' Assembly and public consultation in 2020

The above sets the following targets for the city and council:

- To shift Wolverhampton to 100% clean energy by 2050
- To become a Net Zero Carbon Council by 2028
- To work with others to achieve a Net Zero city by 2041 (as defined by Citizens' Assembly and subsequently adopted by Council members

(2) Economic development: The corporate plan maps out goals to develop and strengthen the city's economy in the longer term, attracting good-quality jobs and investment. With the growth in the low carbon sector internationally, nationally and locally there are growing opportunities for investment, employment, training, education and energy costs. The council is also committed to supporting businesses to develop local resilience in energy generation and distribution, to maximise the economic opportunities offered by the growth of a low carbon economy.

(3) The Wolverhampton EfW is an important, long term low carbon asset[3] that is currently producing and exporting electricity. Where this can be adapted (and potentially expanded) to enable both heat and power export if carbon-reduction value can be maximised.

[1] Our Council Plan 2019-2024, 2019

[2] Future Generations: Our Climate Commitment, City of Wolverhampton Council, 2019

[3] The facility is owned by the Council but is operated under licence, with the current contract due to expire in 2023

(4) Alignment with national strategies and funding opportunities. The Council is actively pursuing a course of action that supports the national and international goals of climate change mitigation. As such support, including financial resources, is anticipated over the coming months and years that can be harnessed to support local goals.

The Council is also committed to following related actions:

- Enhance and invest in improving sustainability within the city.
- Working with partners to develop low carbon measures including low carbon renewable energy sources.
- Change how the council uses its assets to enable transformation in our communities and identify renewable and low carbon energy opportunities
- Alleviate fuel poverty

2.3 Critical Success Factors

To assess potential heat network opportunities the following Critical Success Factors were identified by CWC:

1/ EFW waste heat is fully utilised

2/ Reduction of the carbon intensity of heat to assets (properties)

3/ Provision of viable heat network both technically and economically

4/ City-wide decrease in carbon emissions

5/ Implementation is affordable for consumers

6/ Electricity generation is maximised

3 Energy Network options

3.1 Spatial overview

The mapping and pie charts in this section summarise the consumers identified and their estimated energy consumption. Section 4 provides further detail on individual consumers/properties. Figure 3-1 and Figure 3-2 summarises the heat (heating and hot water) and power consumption estimates for all consumers identified, which are also shown in Figure 3-3. Figure 3-4 shows the consumers zones that were then identified after exploring consumer distribution and potential primary network routes.

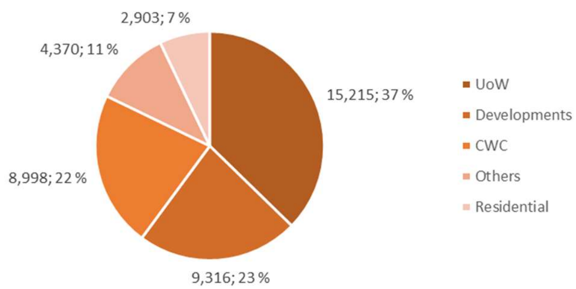


Figure 3-1. Heat demand (MWh/yr) across all consumers

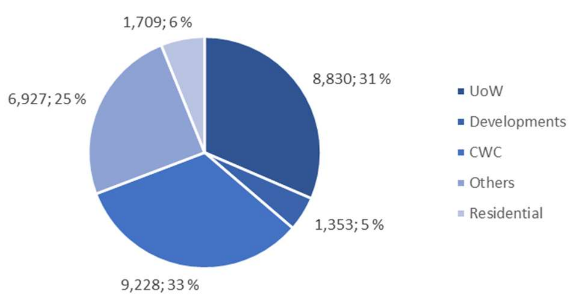


Figure 3-2. Electricity demand (MWh/yr) across all consumers

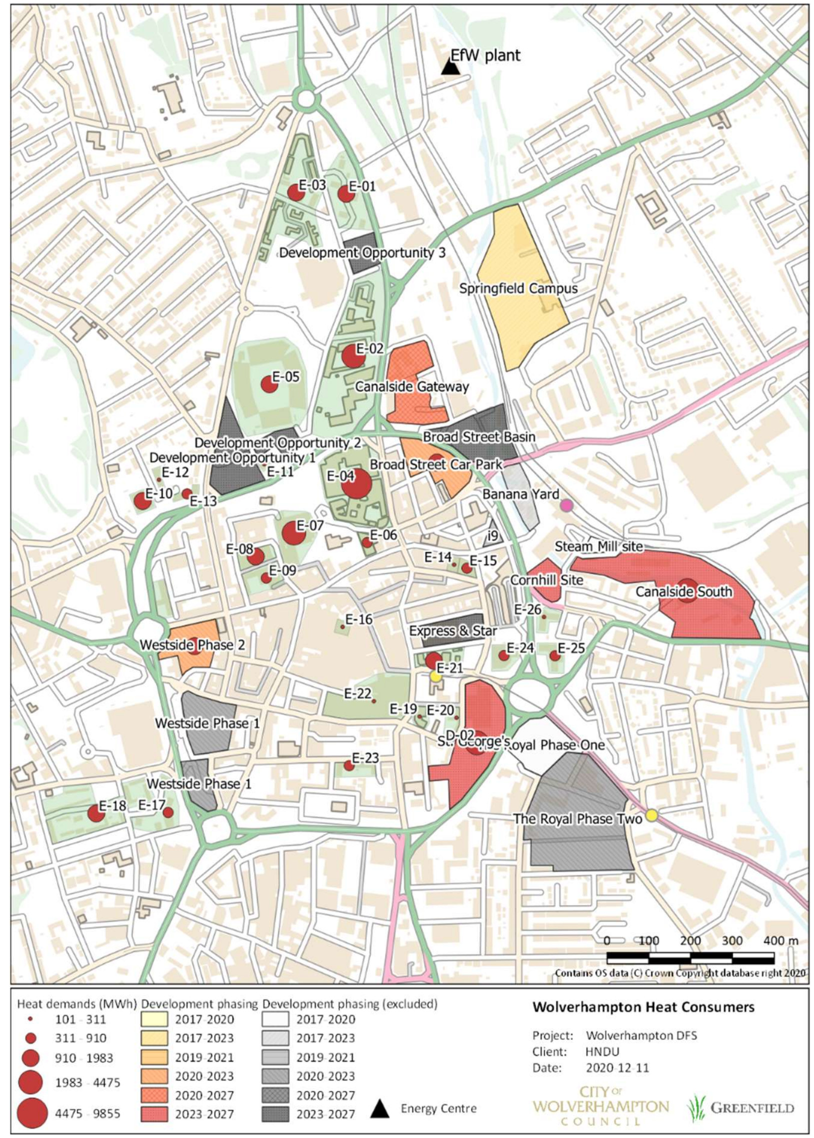


Figure 3-3. Wolverhampton heat consumers (all)

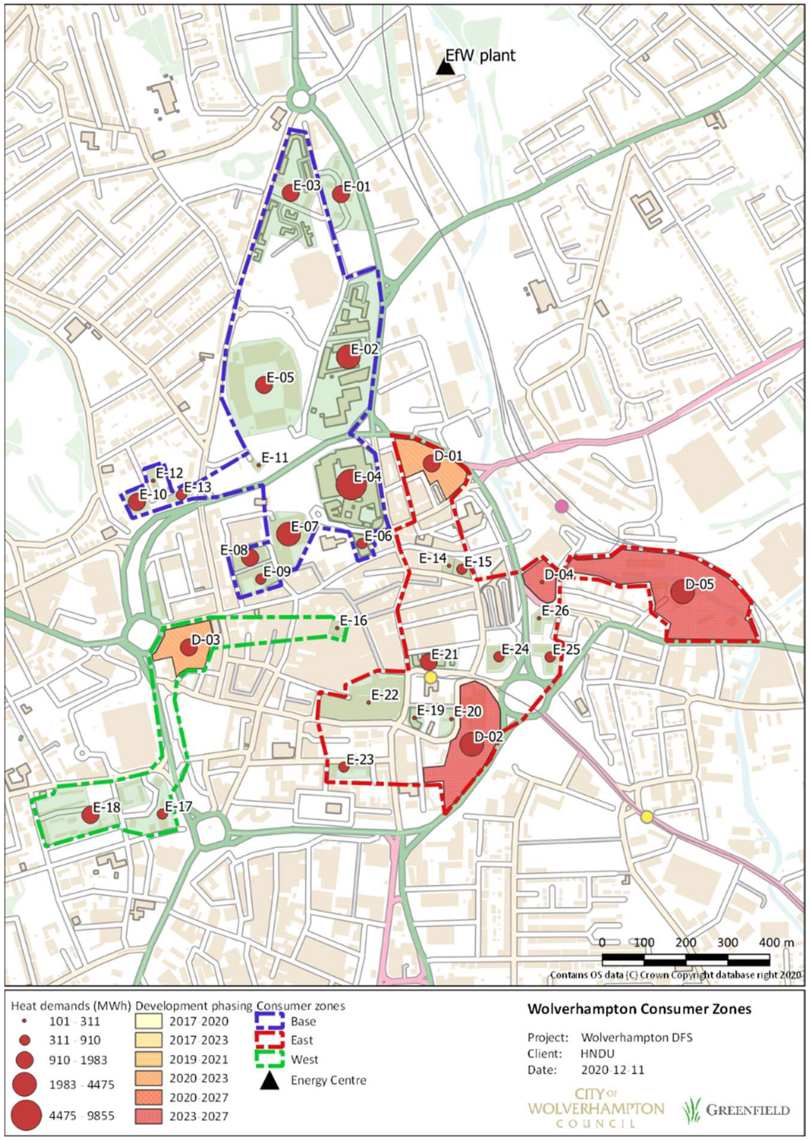


Figure 3-4. Wolverhampton consumer zones.

Table 3-1 summarises the heat consumption estimates for all consumers and by each demand zone: Base, Base + East and Base + West. It shows the change in the scale of heat demand between the zones and the consumer make-up in each zone across. The selection of consumers has been led by the location of the presumed primary energy source: the EfW facility on Crown Street. The implementation of heat networks involves the laying of heat pipe infrastructure (often underground), which is expensive. To improve viability, minimising distances between consumers and avoiding 'high constraint' routes is important. Put into other words, to improve commercial viability for a heat network maximising the density of demand (kWh per length of pipework) is important.

All consumer scenarios considered hereafter include the 'Base' zone. This is a "gateway" consumer zone which is: a) close to the EfW facility and b) made up of a relatively small number of consumers dominated by the University of Wolverhampton and the City of Wolverhampton Council. Base + East and Base + West are essentially extensions to the Base zone.

	Units	All	Base	Base +East	Base +West
Heat demand	GWh/yr	40.8	24.5	36.0	29.3
UoW	%	37 %	45 %	42 %	52 %
CWC	%	22 %	36 %	25 %	23 %
Development	%	23 %	0 %	19 %	8 %
Other	%	18 %	19 %	13 %	16 %

Table 3-1. Consumption zones (all and by demand zone)

It should be noted that the identification of prospective consumers is not exhaustive. Whilst those shown are representative of larger consumers, most likely to connect, others will exist. Once a heat network scheme is formalised as 'live', e.g. financing is in place, then it would be important to locate additional consumers to support the project's viability and maximise carbon reduction. Of course, until contracts are in place, prospective consumers could also be lost. Figure 3-5 to Figure 3-10 summarise the demand of the various zones identified.

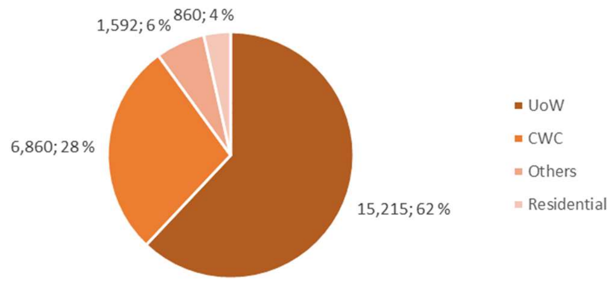


Figure 3-5. ***Base zone*** *heat demand (MWh/yr)*

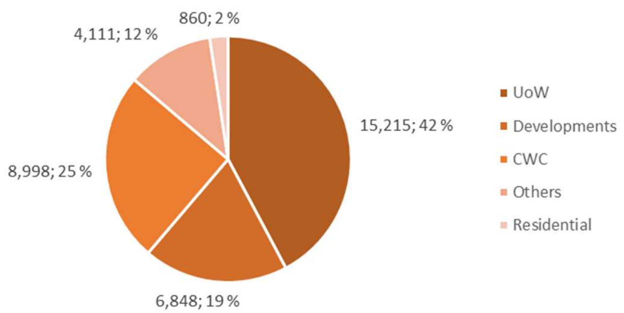


Figure 3-6. ***Base + East zones*** *heat demand (MWh/yr)*

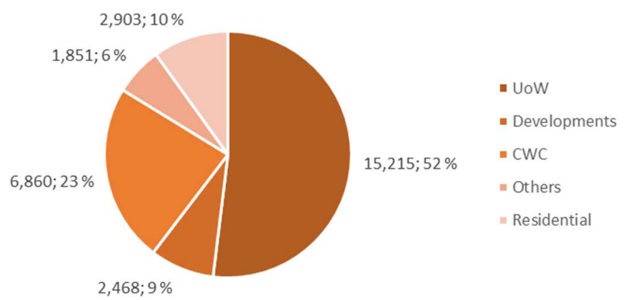


Figure 3-7. ***Base + West zones*** *heat demand (MWh/yr)*

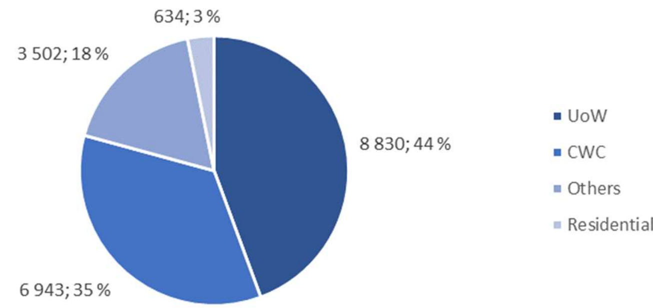


Figure 3-8. ***Base zone*** *electricity demand (MWh/yr)*

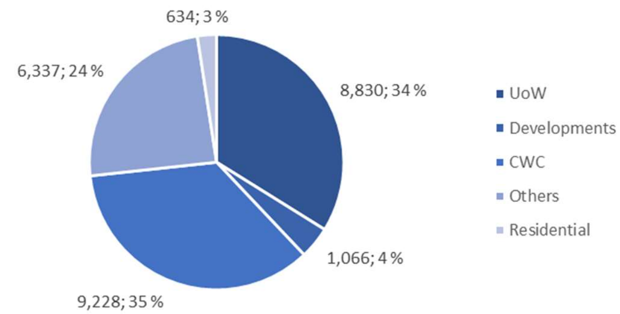


Figure 3-9. ***Base + East zones*** *electricity demand (MWh/yr)*

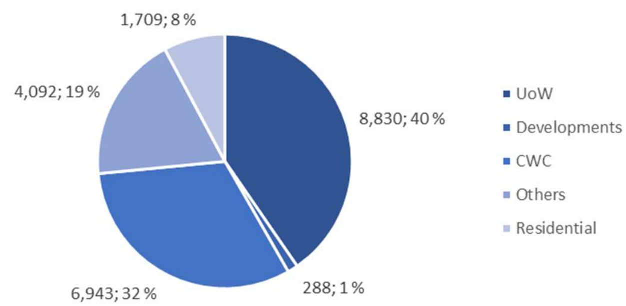


Figure 3-10. ***Base + West zones*** *electricity demand (MWh/yr)*

3.2 Network scenarios

Based on the three demand zones, three heat network options were developed for the city:

- Network 1: Base
- Network 2: Base + East
- Network 3: Base + West

The Base network is shown in
Figure *3-11* and the extension to the East and West are shown in Figure 3-12.

The base network, and the east and west extensions are shown in different colours. Network 1 (Base) encompasses consumers in the northern part of Wolverhampton City Centre as follows:

E-01/Boscobel high-rise flats (Wolverhampton Homes)

E-02/Molineux Campus (UoW)

E-03/student accommodation (UoW)

E-04/Wulfruna Campus (UoW)

E-05/Molineux Stadium

E-06/Wolverhampton Art Gallery (CWC)

E-07/Civic Centre (CWC)

E-08/Civic Hall (CWC)

E-09/Magistrates Courts (CWC)

E-10/Central Baths (leisure centre) (CWC)

E-11/Molineux Hotel (city archive) (CWC)

E-12/Regents House (private office)

E-13/Redwings Lodge Hotel (private hotel).

Network 2 expands to the east to pick up a variety of other prospective consumers, which are largely a mix of existing private sector properties and several major (mixed and commercial and residential) property development sites. The development sites are being directly or indirectly supported by the council through their regeneration strategy and most are included within the 2019 City Centre Investment Prospectus.

Network 3 expands to the west ultimately to connect high and medium-rise flats (Wolverhampton Homes, again) in the Graiseley area with a major regeneration site. This network extension also potentially provides a link to Marstons brewery site which has a large and specific industrial energy demand (high temperature / periodic demand) which is unlikely to see value from import heat from a heat network but could potentially be an additional heat source, if the other sources available are not sufficient.

During the second part of the feasibility study (aimed at refining the network solutions and address key risks) effort has largely focused on the connections proposed in Network 1 (Base). Except for E-13 (Redwings Lodge), primary consumption data were obtained and detailed discussions were held with the property owners/operators (particularly the university, council and Wolverhampton Homes) to refine connection data and explore key connections risks (see section 4). Connection surveys were also conducted on the majority of the CWC and UoW properties.

3.3 Network routes

The route of the network connections from the Crown Street EfW facility to individual consumers has been developed after investigation of both constraints and opportunities, including railway bridges, busy roads, planned highway renewal and use of subways, particularly to facilitate access beyond the city's central ring-road. Whilst mitigation measures have been proposed for the key issues, it will be necessary to explore these issues in much further detail to developed engineering proposals for approval and detailed costing. This would need to be done in concert with the council's highways team, Midland Metro (regarding the existing tram line) and owners of underground utilities.

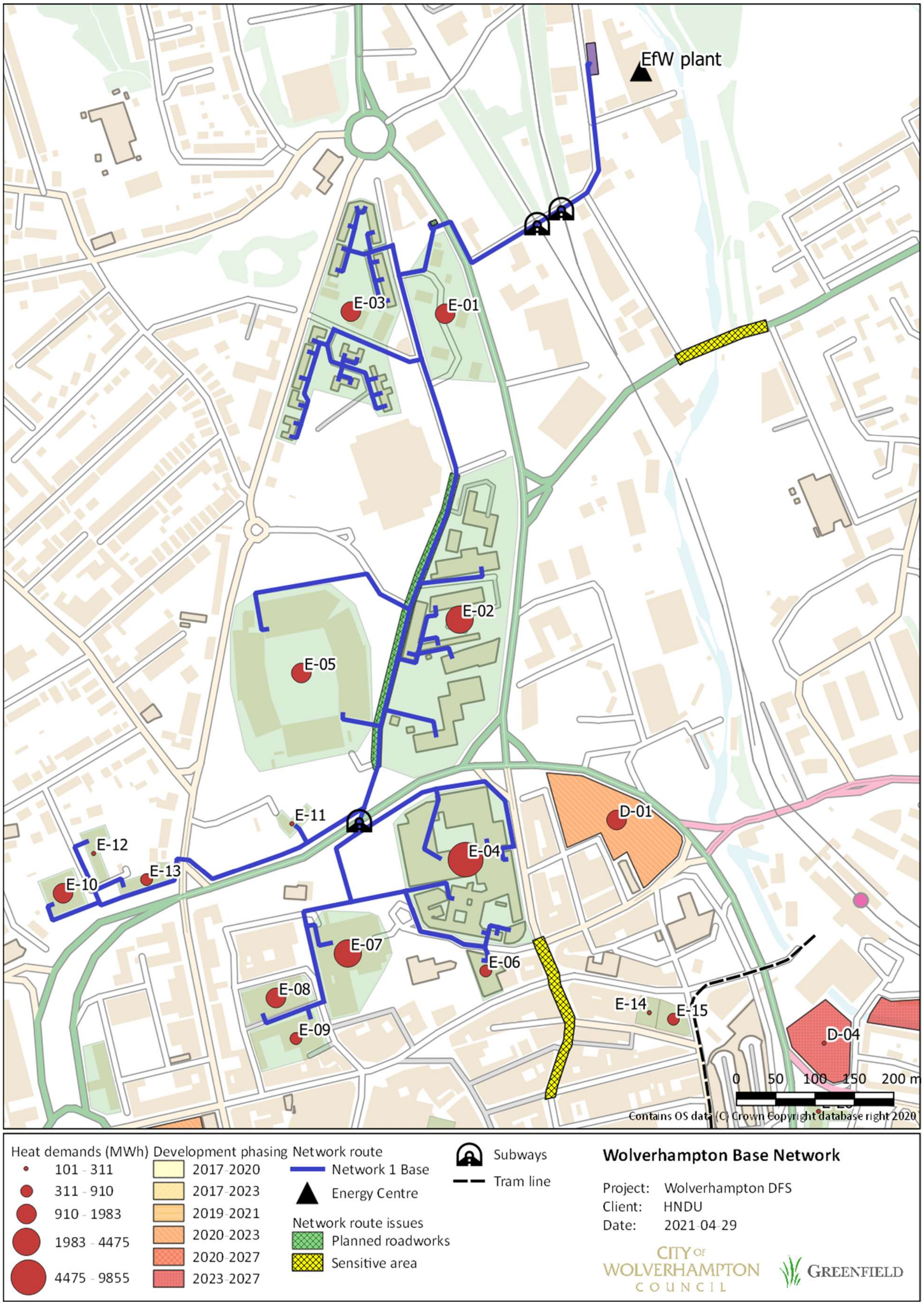


Figure 3-11. Base Network: route & key constraints

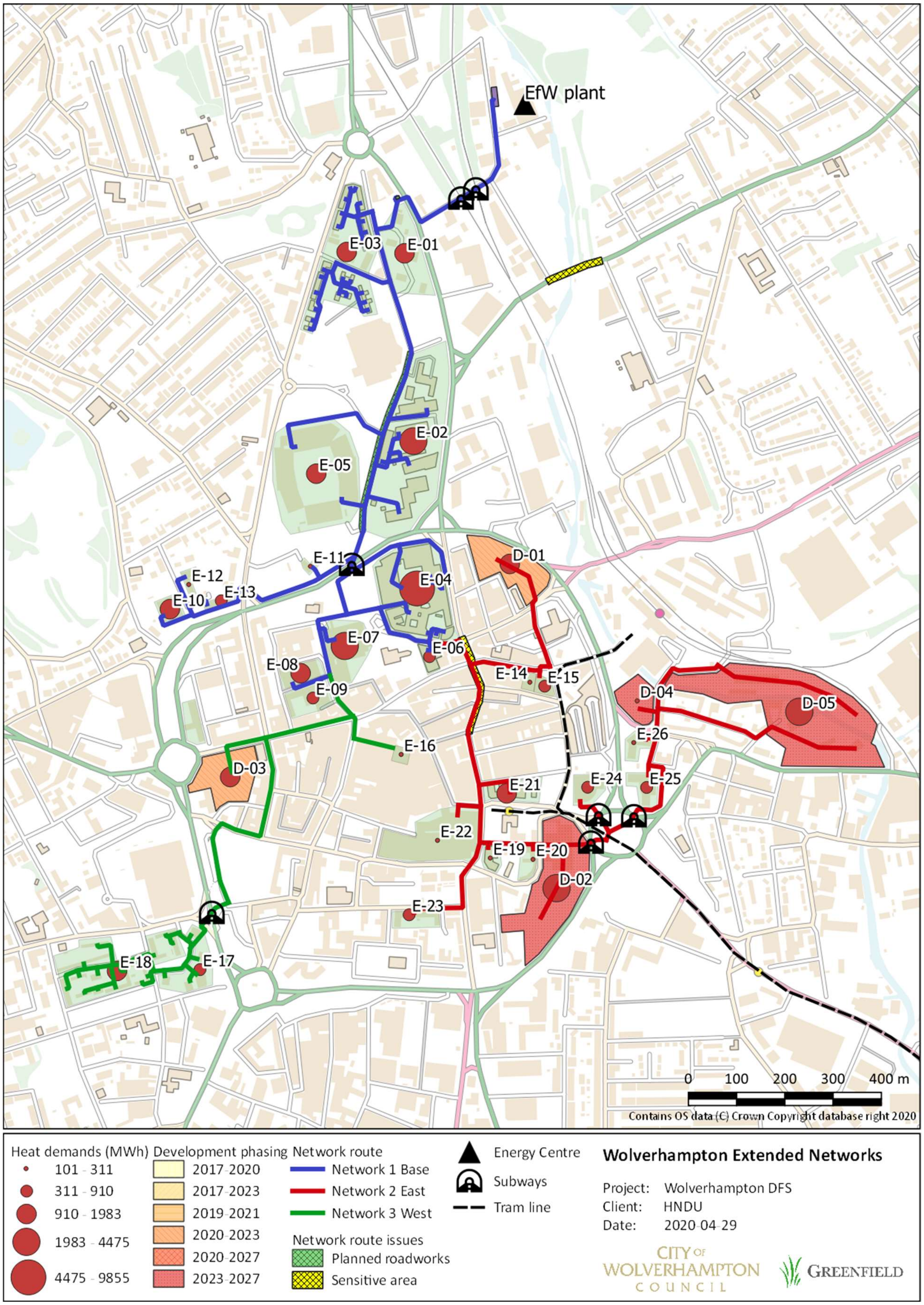


Figure 3-12. Extended Networks: route & key constraints

The following specific network constraint issues were identified:

1/ **Rail Crossing / Bone Mill Lane:** The main route into City Centre is proposed to be through Bone Mill Lane using existing tunnels.

Figure 3-13. Rail tunnels at Bone Mill Lane

2/ **Use of North Road and Molineux Street:** Rather than using Stafford Street (the main highway to the city centre from the north), the network is proposed to be routed through Molineux St which passes through the UoW Molyneux between many of the key (base) consumers. It is understood that this route is likely to be adapted to further facilitate pedestrian and bicycle use in future. This potentially offers the opportunity to install energy infrastructure (or at least trenching) at the same time.

3/ **Crossing the city ring-road at UoW:** The network is proposed to be routed via the road network, avoiding the busier main streets, particularly the Ring Road, which is crossed using existing subways to avoid impacting traffic during network construction and maintenance. Figure 3-14 and Figure 3-15 shows the subway at the south end of Molineux St which is proposed to cross the Ring Road to connect the UoW Molineux Campus with the UoW Wulfruna Campus. Whilst this provides a convenient crossing it will be important to explore the engineering issues of locating pipework underground. Locating pipes on the wall or ceiling may be an option but could limit pedestrian flow – the subway is heavily used on match days (for the nearby Molineux Stadium).

Figure 3-14. Subway entrance (Molineux St.)

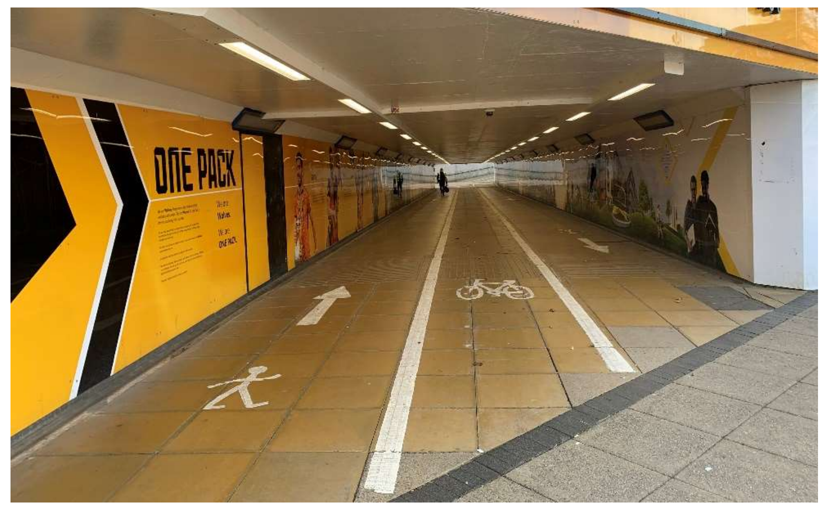


Figure 3-15. Subway (Molineux St.)

4/ **Princess Street SuDS:** In Network 2 (Base + East), Princess Street (highlighted in Figure 3-12) is shown to be used for the network, south from Wulfruna Campus (UoW). Princess Street was selected to avoid the tramline on Pipers Row. The CWC Highways team advised that Princess Street (which is pedestrianised) has a complex sustainable urban drainage system. Whilst this does not prevent using the route, it will need specific consideration to identify how drainage infrastructure can remain unaffected. Solutions avoiding Princess Street would be possible where this proves to be problematic.

5/ **Crossing Ring Road and tramline at Bilston Street Island (Network 2):** to reach consumers to the east of the city centre, it is necessary to cross the city's ring road and the recently built tramline. After discussion with the council's highway department, the use of existing pedestrian subways was identified as the preferred solution, avoiding highway disruption of the ring road and limiting costs. Figure 3-16 shows the general routes proposed with the network approaching from the West – yellow line - and accessing the Crown Court (to North West of the roundabout) - red line - and the Novotel and other eastern consumers (to the North West of the roundabout) – green line. This would avoid the need for sub-surface drilling under the city's recently built tram network. This is technically possible and Highways advised it should be considered an exceptional constraint. However, it would require a detailed engineering investigation and permitting (including the investigative fieldwork) with Midland Metro and the council's highways team. This option is only recommended should the underpass options prove challenging or expensive.

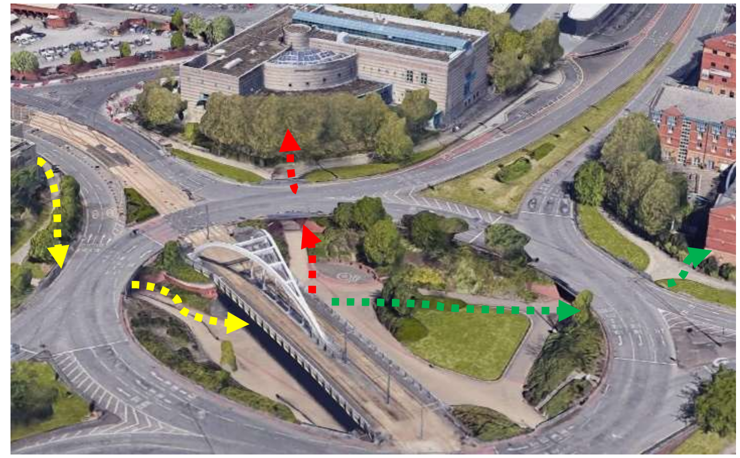


Figure 3-16. Three subways at Bilston St Island

Figure 3-17 shows the nature of the road underpass, where pipework could be potentially located on the angled wall sections and Figure 3-18, which shows the general arrangement under the tram bridge and illustrates scope for the location of pipework.

Figure 3-17. Bilston Island underpass approach from West

Figure 3-18. Bilston Island tram bridge

6/ **Crossing Ring Road to reach Graiseley flats (Network 3):** to reach consumers to the west of the city centre for Network 3, it is necessary to cross the city's ring road. Adjacent to the first Graiseley tower block (as shown in Figure 3-19 is Peel Street car park (surface level) between the two ring road highways. Several plausible crossing options exist:

- via the existing footway (approximate route show in red)
- the roadway from Peel Street using the car park underpass. It is assumed directional drilling would be used to cross the western highway from the car park entrance ramp – see yellow line.

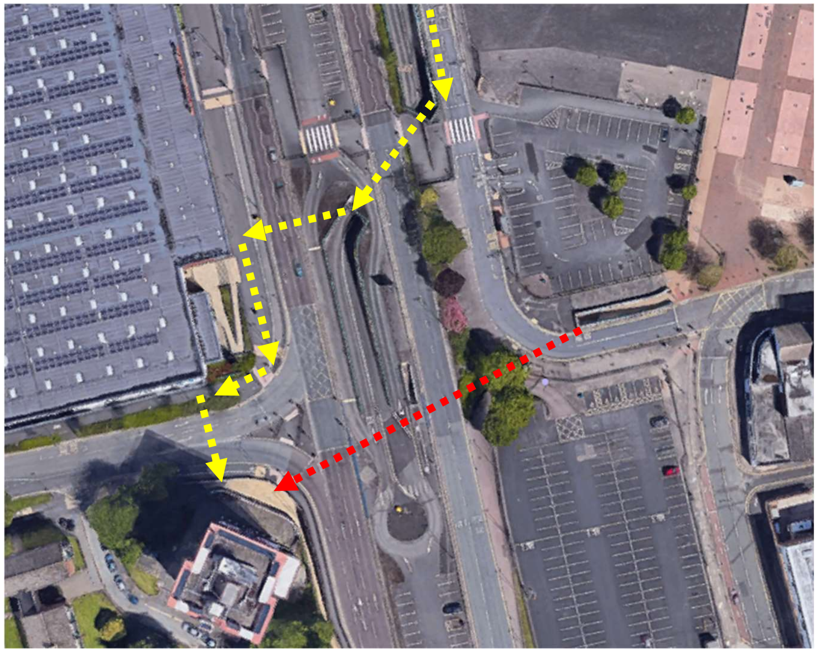


Figure 3-19. Ring Road crossing area (Peel St. to Great Brickkiln St.)

Both pedestrian and roadway underpasses are relatively narrow, making hanging pipework unlikely. Figure 3-20 shows the road underpass which is used to access the Peel Street car park and Figure 3-21 shows the pedestrian underpass. The latter would be the preferred solution as it is a more direct route and would likely avoid the need for directional drilling. The use of this route would need to be proved by exploring existing underground utilities.

Figure 3-20. Road underpass to be Peel Street car park

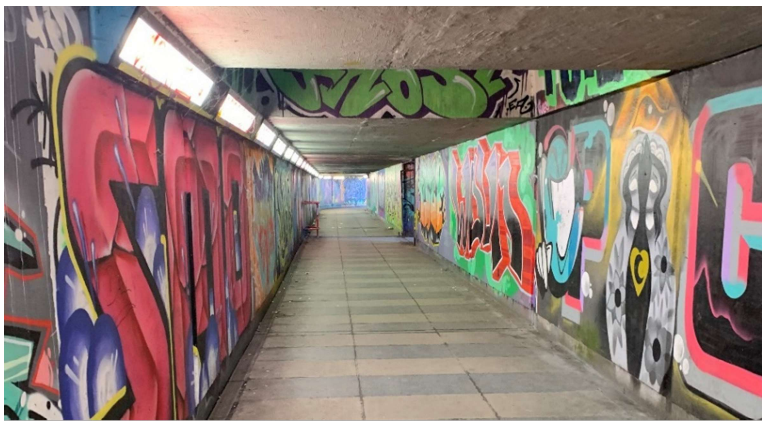


Figure 3-21. Pedestrian subway to Graiseley Flats

3.4 UoW Springfield Campus and use of the canal

The UoW Springfield Campus is a possible future addition to the Base network. It was excluded from the network options at this stage due to uncertainty regarding the nature and timing of the development. The network could be routed via Cross St North but is understood that there are underground utility constraints along Cannock Road, making the alternative of using the canal network appealing. This is also likely to reduce construction costs. Both options are shown in Figure 3-22 and a high-level cost assessment is shown in Table 3-2.

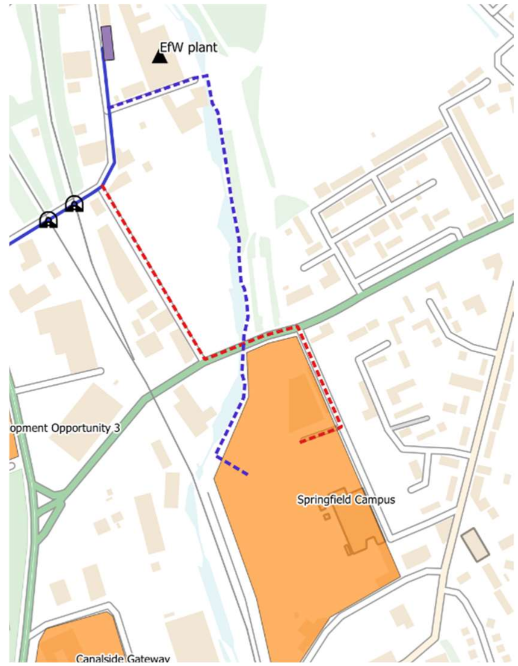


Figure 3-22. Possible connections to Springfield Campus (UoW)

Route	Canal	Road
Length (m)	633	537
Pipe size	DN100	DN100
Estimated network cost – pre-survey (£000s)	627	768

Table 3-2. High-level comparison of route costs to Springfield Campus (UoW)

A series of images follow that show the nature of the route between the EfW plant and the Springfield Campus. Figure 3-23 shows the proposed access to the Canal network at Jordan's Bridge.

Figure 3-23. Jordan's Bridge (looking north) – entrance point to canal

Figure 3-24 shows a typical cross-section of the canal showing a relatively wide thoroughfare (the route is part of National Cycle Route 81) but also one of the three locks between the EfW plant and the Cannock Road Bridge (there is a further lock immediately to the south of the bridge also).

Figure 3-24. Typical canal section (one of three locks)

Figure 3-25 shows Cannock Road bridge which the heat network would pass under.

Figure 3-25. Cannock Road bridge (north side)

Figure 3-26 shows the canal to the south of the bridge with the UoW Springfield Campus immediately to the left of the shot.

Figure 3-26. South of Cannock Bridge (UoW Springfield Campus to left)

It has also been suggested that connecting the East extension of the heat network to the EfW could also be achieved using the same canal network, as indicated in Figure 3-27. Whilst this would doubtless reduce cost for the pipework (compared to highways construction) it also would mean, if this were the primary network, that access to some of the key consumers including UoW and CWC buildings would be lost. If it were then to become a second connection this would add significant additional cost which would then depress the viability of the project. Hence, at this point, the use of the canal other than as an option to connect to Springfield Campus, is not recommended. Finally, to prove the viability of using the canal network it will be necessary to commission the Canal and Rivers Trust to survey the relevant sections.

A high-level cost estimate is shown in Table 3-3 for the routing, as shown. It is important to note that the pipe sizing used for the cost estimate assumes that this in the main pipeline to the town centre.

Route	Canal
Length (m)	1,821
Pipe size	DN300
Network cost estimate (£m)	2.45

Table 3-3. Cost estimate for network routing via canal to Canalside

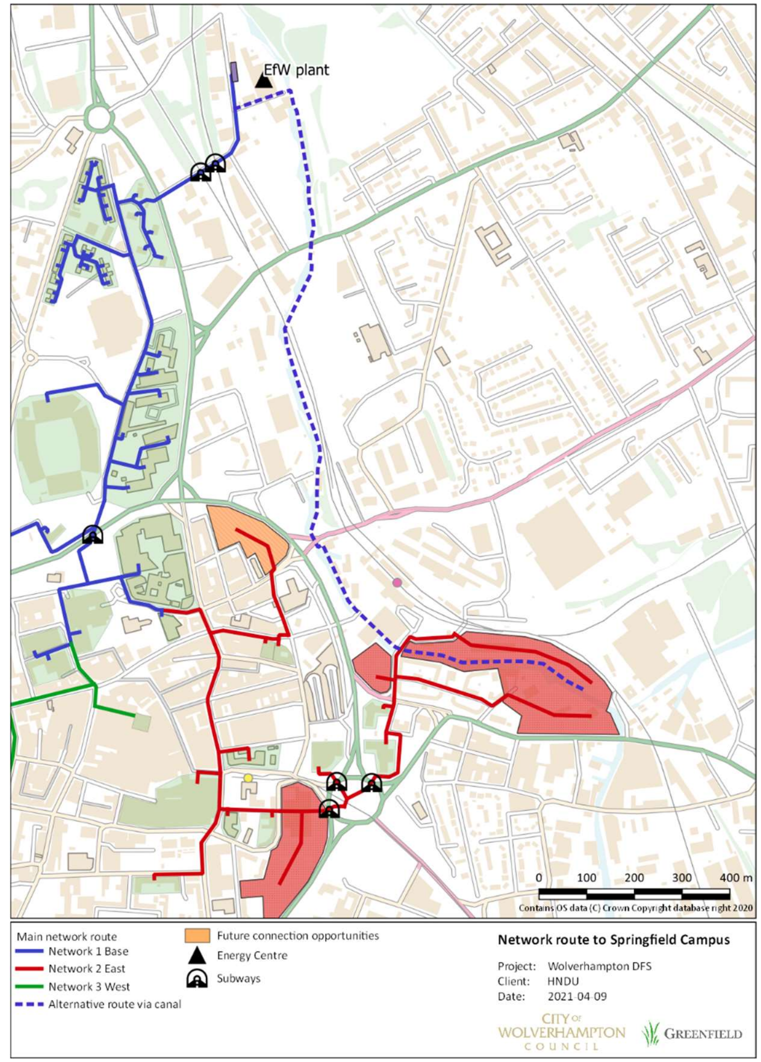


Figure 3-27. Possible connection to Canalside development site

4 Prospective Consumers

4.1 Introduction

As shown in section 3, a wide range of consumers has been considered across the city to support the development of heat network scenarios. As heat networks progress through the development stages (masterplanning, feasibility, business planning and commercialisation) consumer certainty will improve. The next stage of work would seek to formalise intentions to connect, for example, through establishing 'heads of terms'. Uncertainties for the key consumers in the Base network are well understood. Whilst further data and assumption adjustments are anticipated, the changes are not expected to materially affect the commercial viability of the network.

Specific uncertainties worth noting are:

- UoW is due to make decisions regarding its on-campus residential accommodation. This could see the existing (circa 800) bed spaces decommissioned and replaced with a purpose-built facility close to the Molineux Campus
- The Civic Hall (CWC) is currently being refurbished under a design-build-operate arrangement and it has not been possible to determine the expected change to future energy consumption
- The Boscobel tower blocks are likely to be clad before 2025 to improve their 'thermal envelopes' which is likely to significantly reduce thermal energy demand
- The UoW Springfield Campus, which is partially built, is excluded at this stage but could be added later after decisions relating to the development of the remainder of the site have been made.

For the other consumers in Network 2 and 3, uncertainty over demand estimates, the likelihood of connection and connection timing constraints are greater – this relates to both existing and new-build consumers. It will be important to review these consumers as the project progresses.

4.2 Connection timing

As discussed in section 1, the development programme of the city heat network is largely dependent on the timing of the renewal or expansion of the EfW facility. The current operational contract is due to end in 2023. At present, there is uncertainty about when the renewal/expansion would happen (unlikely to be available before 2025 and possibly several years after this point). Consequently, some of the existing and planned consumers may need to take an alternative path as there are numerous time-bound objectives, including:

- UoW wish to significantly decarbonise the university estate during the mid-2020s
- CWC has a net zero corporate target for 2028
- Wolverhampton Homes need to replace obsolete energy systems at the Boscobel flats within the next few years
- Some of the planned property development schemes earmarked for connection are expected to be completed before 2025

Once a fixed programme for the EfW facility is established, consumer connection dates should be reconciled and actions explored to retain them including the implementation of temporary solutions to enable retrospective connection to the heat network. At this stage, the analysis reported here has assumed an EfW plant capable of heat export is available from 2025 and that consumer connections could be implemented from this time.

4.3 Consumer recruitment

Presently there is no way to oblige connections to a heat network without locally-specific planning policy. The UK government is, however, exploring the establishment of heat network Zoning policies, which may introduce regulatory and market measures within 'heat network zones'. Zoning would aim to encourage the connection of appropriate consumers in areas where heat networks exist or are planned.

CWC could consider the introduction of planning policy that would seek to encourage and facilitate connection to the heat network (whilst giving general permission for the implementation of heat network infrastructure), as has been done by other Local Authorities. It is understood the Black Country Plan (which will operate as a Local Plan in Wolverhampton) is intended to incorporate related policies. CWC should review this and consider additional local policies to support their objectives around this project. Finally, by committing to connect its own properties and development sites, CWC would directly encourage others to connect.

Without an obligation to connect, it will be necessary to directly recruit consumers. This requires the presentation of connection offers that deliver consumer benefit. In this respect, a well-designed heat network in Wolverhampton would offer the following general benefits:

- **Carbon reduction.** The carbon reduction benefit is significantly affected by the carbon intensity of the primary energy source(s) used and the efficiency of the network (degree of heat loss). As discussed later, the development network options are estimated to deliver energy at a very low carbon intensity. It is important to note that consumers will compare this to their existing (or planned – especially for new development) energy supply arrangements. This 'counterfactual' supply arrangement for most consumers, is a modern gas boiler but there is an array of other possibilities. Over time, consumers are likely to increasingly switch to low carbon solutions such as electric heat pumps, which would lead to a lower aggregate counterfactual carbon perfromance for the network.
- **Energy Cost.** Delivery of energy will typically need to cost no more than the counterfactual. Within the modelling conducted in this study, revenue has assumed to be 5% less than the counterfactual.
- **Provision of service.** Counterfactual options are typically based on a conventional model of consumers owning and managing their own energy supply plant/equipment. A heat network will replace this with a contracted energy service. Heat (potentially cooling and power too) would be delivered through a Heat Interface Unit (HIU) or Sub-station. Consumers would no longer need to pay for maintenance or operation of on-site plant (although some may wish to retain this to provide additional resilience).

At the present feasibility stage, an assumed 'offer' for each consumer has been developed and benefit summaries for key consumers have been developed - see section 6.

4.4 Summary of prospective consumers

Table 4-1 shows the summary of the number of consumers across the network options considered.

Network	Consumers *see note (1)*	Connections (grouped) *see note (2)*	Connections (individual) *see note (3)*
Base	6	45	238
Base + East	20	745	1,554
Base + West	9	71	776
Base + East + West *(see note 4)*	23	771	2,092
Total Demand			

Table 4-1. Consumer summary by network

Table notes for Table 4-1: (1) Development sites and residential operators, e.g. Wolverhampton Homes are considered single consumers; (2) Apartment blocks considered as one + Includes large number of new single houses at Canalside and Westside Phase 2; (3) apartments considered as one, (4) Shown for reference – not modelled as an option

Table 4-2, Table 4-3 and Table 4-4 summarises the estimated consumption data by consumer for the Base network and the two extensions. Only heat and power demands assumed to be connected are shown. Further information on methodology and the data sources are included in Appendix 1 and further consumption data is included in Appendix 2.

Ref	Site	Building type	Counterfactual heating system[4]	Peak Heat (MW)	Heat demand (MWh/yr)	Electricity demand[5] (MWh/yr)	Connect year
E-01	Boscobel - Residential, existing	Flats	ESH / EI	0.55	860	-	3
E-02	WU - Molineux Campus	University	GB	2.23	3,377	2,507	3
E-03	WU - Student Accommodation	Student Residential	GB	1.23	1,983	-	3
E-04	WU - Wulfruna Campus (aka South Campus)	University	GB & CHP	6.53	9,855	5,695	3
E-05	Wolverhampton Wanderers FC	Football Stadium	GB	0.74	1,083	-	3
E-06	Wolverhampton Art Gallery	Art Gallery	GB	0.48	656	-	3
E-07	Civic Centre	Office	GB	2.87	2,795	4,345	3
E-08	Civic Hall	Venue	GB	0.71	1,331	887	3
E-09	Magistrate Courts (old Town Hall building)	Court	GB	0.55	634	452	3
E-10	Leisure Centre ("Baths")	Leisure	GB	0.84	1,343	452	3
E-11	Molineux Hotel (city archive)	Office	GB	0.14	101	116	3
E-12	Regents House	Office	GB	0.03	28	-	3
E-13	Redwings Lodge Hotel	Hotel	GB	0.27	481	-	3
	Total Demand			**17.18**	**24,527**	**14,454**	

Table 4-2. Demand data summary – Base network

[4] *ESH – Electric Storage Heater / Electric Immersion heaters; GB – Gas Boiler; CHP – Combined Heat and Power (Gas)*
[5] *Shows only those buildings assumed to be connected to Private Wire*

Ref	Site	Building type	Counterfactual heating system[6]	Zone	Peak Heat (MW)	Heat demand (MWh/yr)	Connect year
E-14	Wolverhampton Britannia Hotel	Hotel	GB	East	0.47	463	3
E-15	Grand Theatre	Theatre	GB	East	0.87	309	3
E-19	Central Library	Library	GB	East	0.17	152	3
E-20	Adult Education College	Education	GB	East	0.32	173	3
E-21	Police Station	Police Station	GB	East	0.30	965	3
E-22	Wulfrun Shopping Centre	Retail	GB	East	0.23	130	3
E-23	Job Centre	Office	GB	East	0.40	540	3
E-24	Crown Court	Office	GB	East	0.61	704	3
E-25	Novotel	Hotel	GB	East	0.52	910	3
E-26	St Davids Court	Office	GB	East	0.32	311	3
D-01	Broad Street Car Park	Mixed	GB & ASHP	East	1.45	1,546	3
D-02	St George's	Flats	GB & ASHP	East	1.12	1,221	3-5
D-04	Cornhill site	Offices	ASHP	East	0.09	103	5-8
D-05	Canalside South	Houses	GB & ASHP	East	2.97	3,978	3-7
	Total Demand				**9.82**	**11,505**	

Table 4-3. Demand data summary – East extension

Ref	Site	Building type	Counterfactual heating system[7]	Zone	Peak Heat (MW)	Heat demand (MWh/yr)	Connect year
E-16	Mander House	Office	GB	West	0.27	259	3
E-17	Graiseley High Rise	Flats	GB	West	0.42	742	3
E-18	Graiseley Low Rise	Flats	GB	West	0.65	1,301	3
D-03	Westside Phase 2	Flats & Hotel	GB & ASHP	West	1.20	2,468	3
	Total Demand				**2.54**	**4,770**	

Table 4-4. Demand data summary – West extension

[6] *GB – Gas Boiler; ASHP – Air Sourced Heat Pumps (building leve)*
[7] *GB – Gas Boiler; ASHP – Air Sourced Heat Pumps (building leve)*

4.5 Notes on principal ("Anchor") consumers

4.5.1 *University of Wolverhampton (UoW)*

Discussions with UoW confirmed a strong interest in connecting to a low carbon heat network (and private wire network) to support its ambitions of becoming carbon neutral by 2030.

The university contains four principal opportunities for connection to a heat network:

- Molineux Campus (E-02)
- Wulfruna Campus (E-04)
- Student Halls: on Lomas Street and North Road Residences (E-03)
- Springfield Campus

The Wulfruna and Molineux Campuses, which are separated by the Ring Road, are the most significant opportunities within the estate for connection. Hot water circuits typically operate on an 80/60 (flow/return) temperature basis.

01 Molineux Campus

This part of the university estate is made up of 10 individual teaching/administration buildings (see Figure 4-1), which operate on a stand-alone basis, with individual plant rooms. The biggest of these MK, ML, MN, MU, MH and MX. All teaching/office buildings on the Molineux campus use gas boilers/water heaters for the provision of heating and hot water except for ML which uses radiant heaters because of the nature of the workshop space.

Direct heat network connections are proposed, except for the buildings MU and MN which due to limited space within plant rooms is assumed to be supplied from a substation located within the MH plant room in an external heat station building. Figure 4-1 shows an indicative route for the connecting pipework. MU and MX buildings have top floor or roof level plant rooms and so will need vertical pipework either located internally in existing risers spaces or externally fixed to the buildings.

Circa 800 student residential properties are located to the northeast of the MX building and heating and hot water is supplied by gas boilers. There is some uncertainty regarding their future with a suggestion that the university will replace them with new accommodation in close proximity to the Molineux and Wulfruna Campuses. The existing residential properties, except for RMR (hall of residence which is no longer in use), have been included within the analysis as a reasonable proxy for future provision.

02 Wulfruna Campus

Wulfruna Campus is a complex of individual buildings which have an array of plant rooms as shown in Figure 4-2. The campus has an existing 580 kW_e CHP engine which distributes 'base load' heat all but three of the plant rooms (shown as green diamond icons), which supply three smaller buildings[8]. The CHP plant is some 10 years old and so has only 2-5 years of viable operation. It has therefore been assumed that the plant will be decommissioned before the campus is connected to the city heat network.

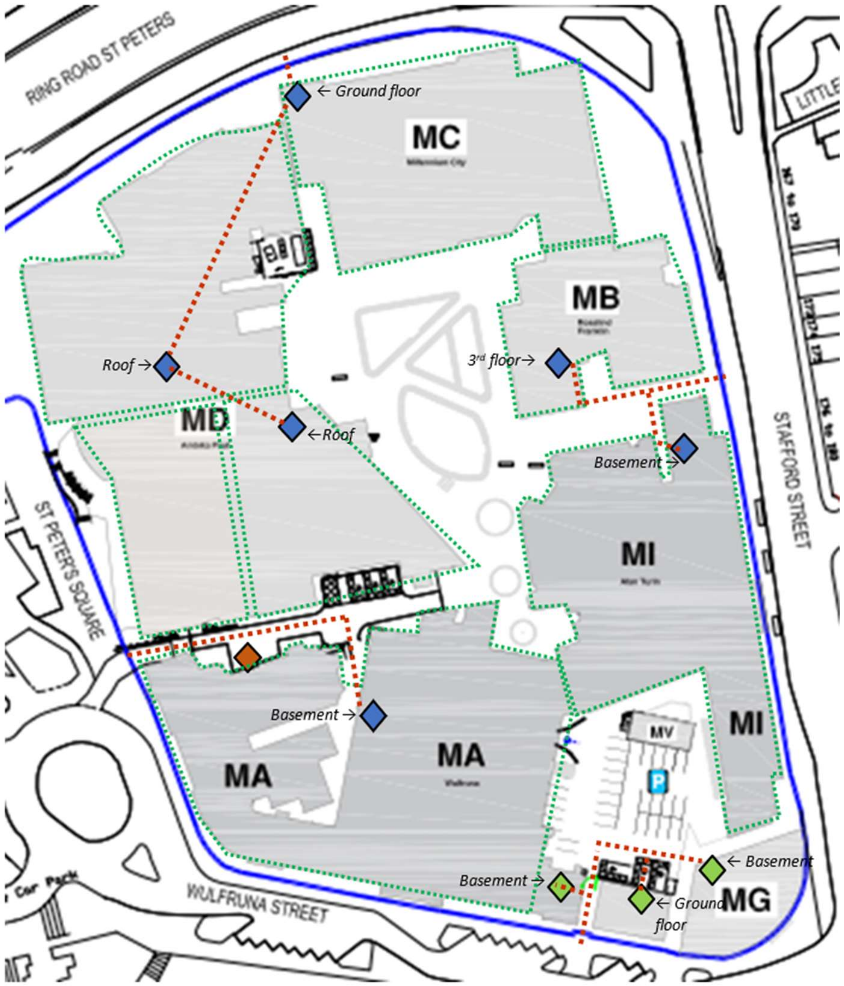
In 2019, the Wulfruna Campus CHP plant generated 6.7 GWh of heat (out of total heat demand of 9.9 GWh) and 4.7 GWh of power (out of a total power demand of 5.7 GWh) with 8,472 hours of operation. The levelised cost of energy for Wulfruna Campus was estimated based on the University's energy costs to be 55.64 £/MWh for heat and 73.48 £/MWh for power.

[8] *Building MB has an indirect connection via MI (as back-up only).*

Legend: Plant Rm (Ground flr.) Plant Rm (Roof or top flr)
Indicative connection route from MH substation

Figure 4-1. Molineux Campus plan

Figure 4-2 shows indicative connection points to the heat network to reach the principal plant rooms. Four principal entry points to the campus are proposed, with some interconnection between plant rooms, as the most cost-efficient and least disruptive solution. This avoids installing pipework through the site which it is understood would be costly due to the nature of the underlying ground at the centre of the site.



Legend: Existing CHP   Plant Rm with CHP connection   Stand-alone boilers
Indicative Heat Network connection route

Figure 4-2. Wulfruna Campus plan

03 Springfield Campus

This campus has been excluded from the analysis due to uncertainty over future development, but it can be added at a later stage. As discussed in section 3.4 use of the canal network from the EfW facility would appear to be a feasible solution but this will need to be proved through a route survey with the Canals and Rivers Trust.

4.5.2 City of Wolverhampton Council (CWC)

The strategic drivers for connection to a low carbon heat network (and private wire network) are discussed in section 2.2. The following properties are proposed to be connected for both heat and power supply:

E-06: Wolverhampton Art Gallery
E-07: Civic Centre
E-08: Civic Hall
E-09: Magistrate Courts (old Town Hall building)
E-10: Leisure Centre ("Baths")
E-11: Molineux Hotel (City Archive)

Each is ‘stand-alone’ with existing gas boiler plant. Primary hot water circuits typical operate on an 80/60 (flow/return) temperature basis. The properties were surveyed to identify the location of the principal plant rooms and to identify the preferred entry routes into the buildings as illustrated in Figure 4-3 through to Figure 4-10. Each plant room is located either on the ground floor or basement of the properties and no major constraints to entry were identified. Property drawings for the Civic Hall were not provided and it was not possible to access the building due to ongoing construction, so it has not been possible to locate the plant room or determine a preferred entry route.

Subsequent discussion with CWC regeneration planners concluded that routeing the network behind the Civic Hall and Magistrates Court (along Paternoster Row and Red Lion Street) would be preferred to avoiding using North Street which is due to be re-paved. Also, in other areas of the city centre, such as Stafford Street where significant street works are planned it was suggested that pipework could be installed during this work, avoiding the possibility of re-digging. This should be considered once consumer connections are more certain (particularly in the city centre) and route-proving is conducted.

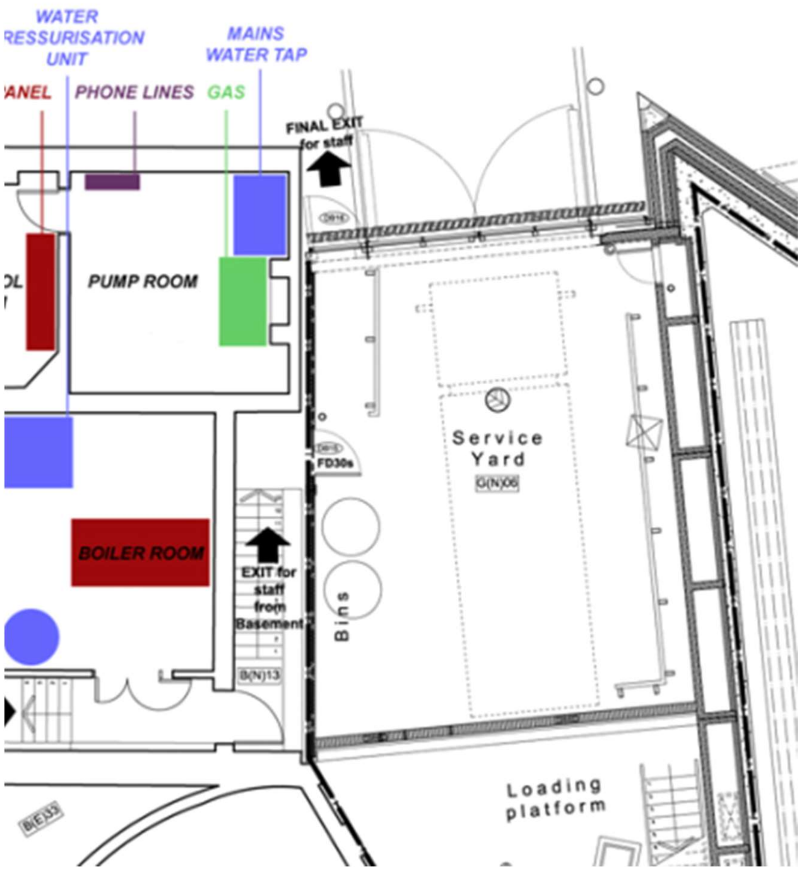


Figure 4-3. Art Gallery boiler room – service access from Wulfruna St.

Figure 4-4. Civic Centre connection route via Paternoster Row

Figure 4-5. Civic Centre – entry to plant room via service access

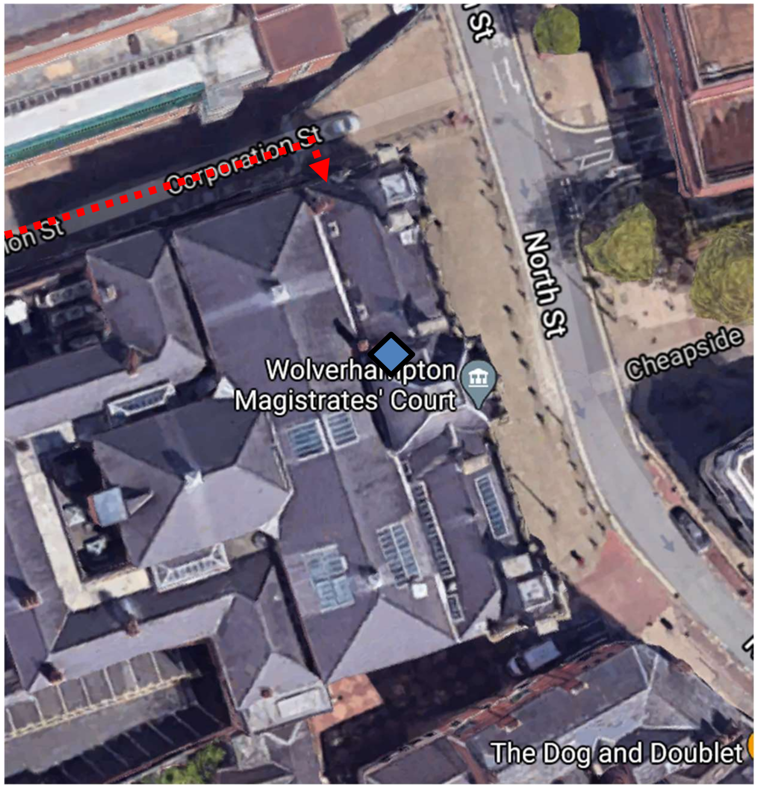


Figure 4-6. Magistrates Court – access route options

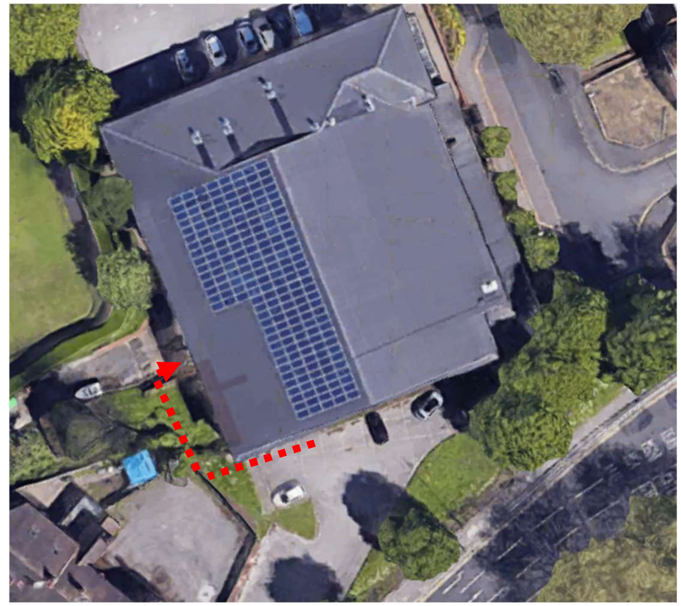


Figure 4-7. Baths – proposed access route to basement plant room

Figure 4-8. Baths – service access to basement plant room

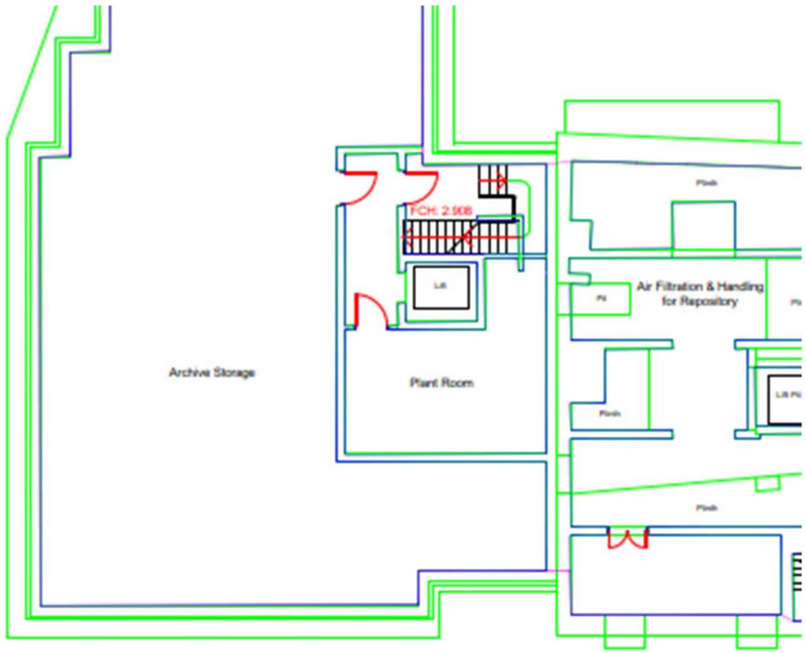


Figure 4-9. Molineux Hotel plan (southwest corner) with basement plant room

Figure 4-10. Molineux Hotel – possible entry through street-level air vents

4.5.3 Wolverhampton Homes (WH) – Boscobel flats

Five blocks of flats owned by Wolverhampton Homes are located just to the north of the UoW Molineux Campus on Boscobel Crescent:

- Tong Court
- Weston Court
- Birch Court
- Lane Court
- Kilsall Court

Figure 4-11 shows a view from the roof of the UoW MX building.

Figure 4-11. Boscobel flats (Wolverhampton Homes)

Each block has 11 floors with 2 ground floor flats and 4 flats on all other floors giving a total of 42 flats per block and 210 flats in total. Analysis of EPC data suggests average flat demand of 3,750 kWh/year for space heating and 2,634 kWh/year for hot water.

WH would like to connect to the city heat network to support their agenda of decarbonising their estate but also address fuel poverty for tenants. There is a time-critical need for these blocks since the existing electric storage heaters units installed are obsolete. WH wish to avoid a piecemeal replacement over time (at £2-£3,000 per flat) and favour a local heat network solution, which would also limit fire risks within the blocks. With no basements and limited free space on the ground floors, the individual blocks could not accommodate supply plant within them.

WH also plans to clad the external surfaces (walls and roof) of the blocks and replace the glazing to improve the 'thermal envelope' and address the current poor energy efficiency (many are classified as 'D' and 'E' within Energy Performance Certificates). This would also have the impact of significantly decreasing heat demands by an estimated 50-70%.

WH anticipate refurbishment of the blocks could start in 2022/24, which is likely to be in advance of the build-out of the city heat network hence it is proposed a WH construct a local network (using gas boilers) which would then switch over to the city heat network, when available. It is assumed WH would be responsible for the connection of individual flats to an internal network with the use of external riser pipework to overcome the lack of internal riser column space. This could be included in the planned cladding works.

Potential locations for a substation have been considered with the green coloured zone in Figure 4-12 providing the preferred location from the perspective of space and proximity to the proposed city network route, where it crosses Stafford Street from the EfW plant via Bone Mill Lane.

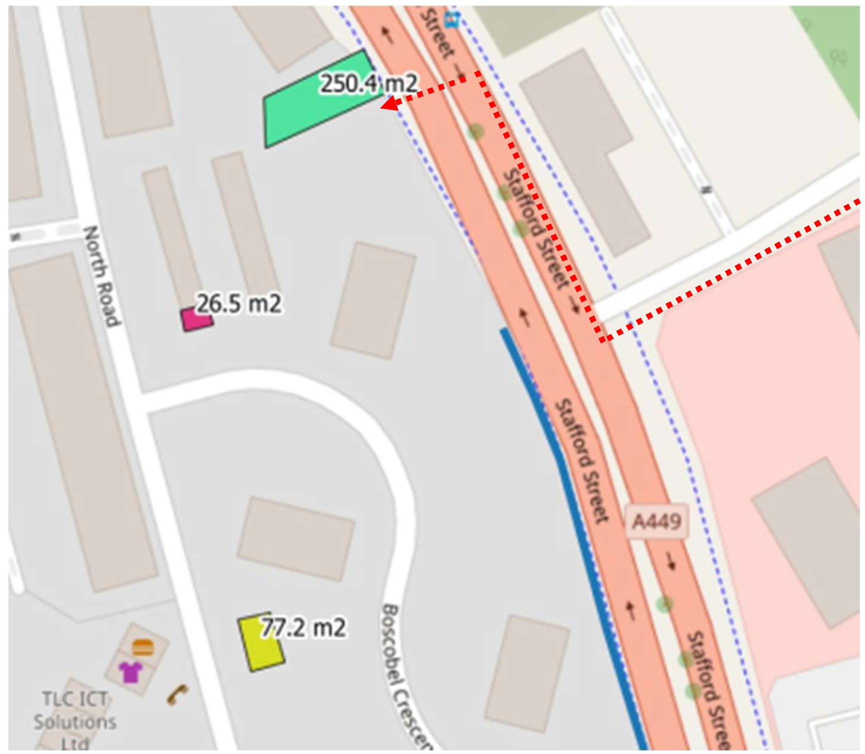


Figure 4-12. Potential Boscobel flats substation locations

An indicative substation layout has been developed and is shown in Appendix 3.

4.6 Other prospective consumers

4.6.1 Base network

Owners of the following properties have also expressed a wish to connect to the city heat network:

E-05/Molineux Stadium. The Wolverhampton Wanders Football Club stadium would be an iconic connection to a city heat network and the club would be interested in connection if it can deliver carbon savings and be broadly cost-neutral. The stadium has an average annual gas demand in the region of 2.5 GWh which is understood to be largely used for underground pitch heat, office/visitor area space heat, and, catering. Numerous buildings on site have electrical heating (resistive). From discussions with the club, it is apparent that there is limited gas sub-metering but they provided a working assumption that 50% of the gas demand is due to catering. It is recommended that this is verified through the installation of sub-metering.

E-12/Regents House. This is a private office adjacent to the Leisure Centre. It is a relatively small consumer but has ageing basement level boiler plant supply space heat. The owner, UK Land, is anticipating replacing the existing plant and would be interested in a heat connection for this reason

E-13/Redwings Lodge Hotel. The hotel is owned by Redwings Lodge Ltd. It has centralised boiler plant that supplies hot water to the accommodation areas with electric storage heaters used for space heating. The owner has expressed their interest in connecting to the heat network if it can deliver carbon savings and be broadly cost-neutral.

In addition, the Canalside Gateway development in the area around Stafford St and Cannock Road (see Figure 4-13) could become a connection to the base network. This is a mixed-use development that is currently at feasibility stage, and hence does not present sufficient certainty for inclusion at this point. The development is anticipated to include offices, residential and leisure uses. Some of the land is owned by CWC, e.g. The Maltings. A development of 210 dwellings and 26,000m^2 of non-residential development is envisaged.

4.7 Other consumers

4.7.1 New-build

Table 4-5 summarises the new development schemes proposed as connections to the heat network. A number of the development sites were excluded at this stage because they are currently under development (or will be shortly) or are likely to present limited demands compatible with a heat network. However, the following are possible future development sites (see Figure 4-13) that could be considered for connection as their plans further develop:

- Canalside Gateway – as discussed above
- Express & Star - no plans known
- Pipers Row - no plans known
- 3 x development opportunities around Molineux Stadium - no plans known
- Springfield Campus – discussed earlier in section 3.4

	Build date	Residential		Non-domestic	
		Number	GIA (m^2)	use type	GIA (m^2)
East Network extension					
D-01 Broad Street Car Park	Summary: Public sector hub-led development. Developer: mixed (includes CWC)				
	2023-25 (single phase assumed)	Unknown	12,270	Public Sector Hub Pharmacy Nursery Dentist Gym	6,315 100 130 70 500
D-02 St George's	Summary: Residential-led mixed-use (at feasibility stage) Developer/landowner: CWC				
	2023-27	450	Unknown	Unknown	Unknown
D-04 Cornhill Site	Summary: Planned extension to the Interchange commercial district of three office buildings. Developer: 3rd party under development agreement with Ion Developments				
	2027-30	NA	NA	Office	14,000
D-05 Canalside South	Summary: Residential-led mixed-use. The 1st development ('Horseley' site) is excluded due to timing. The remaining land parcels are at feasibility stage. Developer: CWC-led				
'British Steel'	2025-27	300	Unknown	NA	NA
'Qualcast'	2027-29	200	Unknown	NA	NA
'Crane Foundry'	2024-26	250	Unknown	NA	NA
West network extension					
D-03 Westside Phase 2	Summary: Hotel with some residential. Developer: CWC				
	23-25 (one phase assumed)	200	Unknown	Hotel	170 (beds)

Table 4-5 Proposed new development connections (heat only)

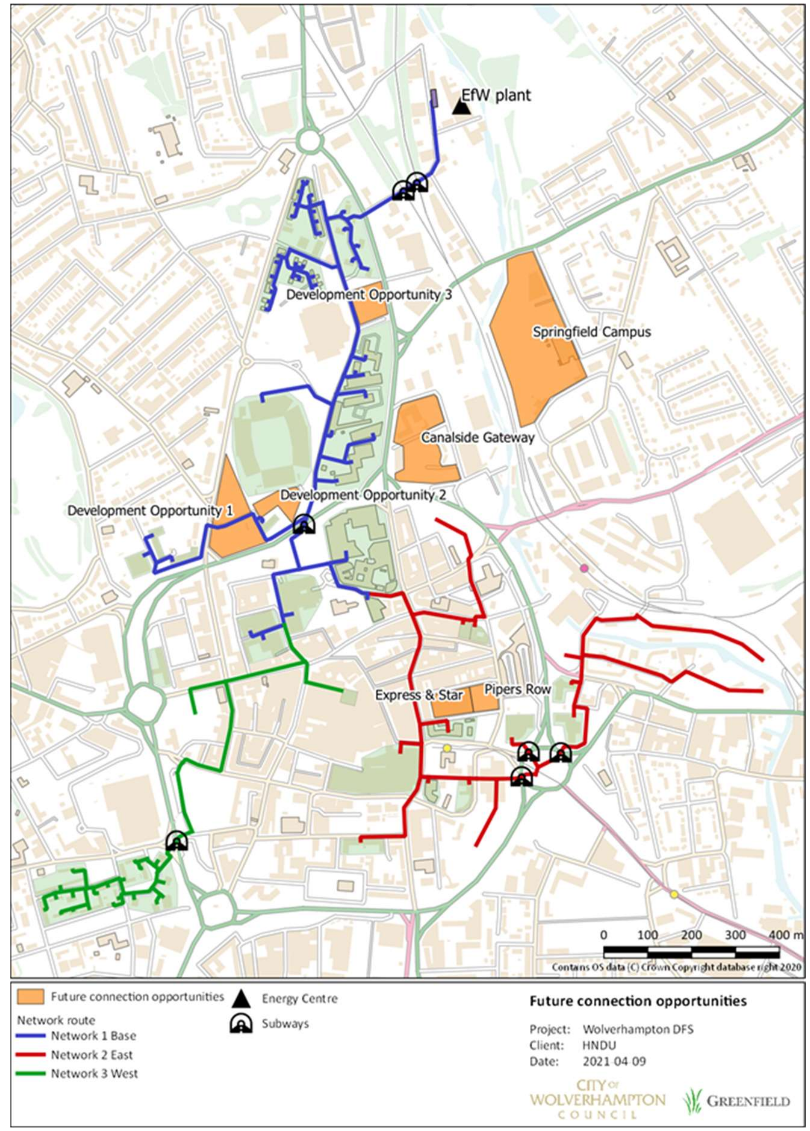


Figure 4-13. Prospective future new build consumers

4.7.2 Existing consumers

Based on the scale of demand, proximity to proposed network routes, compatibility of loads they are included as proposed additional consumers. It has not been possible to collate data beyond basic fuel consumption and confirmation of the type of existing heating/hot water systems since the study has focused on the viability of the Base network. However, discussions have been held with most (see notes below) and where this has occurred owners/operators have confirmed a general willingness to connect. All properties are understood to have gas boilers for heating and hot water except where noted below.

Demand data was sense-checked and time-profiled to enable inclusion in the network modelling. Broad assumptions have been made regarding connection costs. The timing of connection is assumed to coincide with the build-out of the heat network. As such, it is anticipated that some consumer data will change in future.

West network extension

E-14 Wolverhampton Britannia Hotel: data from prior masterplanning study

E-15 Grand Theatre: data from prior masterplanning study

E-19 Central Library (owned/managed by CWC

E-20 Adult Education College: owned/managed by CWC

E-21 Police Station: Data from DEC provided. It is understood that a major refurbishment is planned in 2023)

E-22 Wulfrun Shopping Centre: Discussion with LPC Properties led to the exclusion of the shopping except for the specific connection to a single water-based HVAC supply point which provides are condition to part of the shopping centre

E-23 Job Centre: owned/managed by CWC

E-24 Crown Court: data supplied by the HMCTS

E-25 Novotel: Uses centralised gas boiler for hot air distribution and the hot water – consumption is benchmarked based on DEC data

E-26 St Davids Court: Serviced office complex, consumption has been benchmarked based on DEC data

East network extension

E-16 Mander House: Only partial engagement due to "lock-down" constraints but it is understood this multi-storey office property has a water-based heating system fed by the gas boilers which are approximately 18 years old. Some uncertainty over its future use, in part because it is need of updating

E-17 & E-18 Graiseley High Rise & Low Rise flats: The blocks are owned by the Wolverhampton Homes and as with the Boscobel flats (Base Network) WH would be keen to connect these properties. Consumption has been estimated through a review of EPC data. The High Rose blocks (2 of) have been re-clad in recent years which would present some challenges for the installation of riser pipework. As with Boscobel, it is assumed this would fall to the responsibility of WH and the heat network would supply heat to a substation (or several substations) which would then supply heat to a local network connected to each flat.

4.8 Modelling of counterfactual supply & tariffs

Counterfactual energy supply has been modelled for each building proposed to be connected. This represents the supply solutions that are currently installed (generally gas boiler or with some incidences of electrical (resistive) heating) or are likely to be installed in new development if a heat network solution were not available. For the new development, it is anticipated that most will be built after 2025. After this point, gas boilers are expected to be prohibited in new housing under revisions to Building Regulations (in response to the 'Future Homes Standard'). Whilst it cannot be predicted how new developments will achieve these standards, Air Source Heat Pumps (ASHPs) have been assumed to be the defacto solution.

The counterfactual analysis is used to generate tariffs for the heat network alternative and a 'base case' for carbon emissions to enable the estimation of relative carbon performance. Tariffs (counterfactual and heat network) are split into three components:

1) unit rate for heat (£/kWh)
2) annual maintenance cost (£/yr)
3) annualised replacement cost (£/yr)

The counterfactual analysis uses reported or estimated local energy costs, applying BEIS retail price projections to account for change over time. Annual maintenance costs and annualised replacement costs have been estimated based and assumed installation costs divided by assumed equipment/system lifetimes.

The heat network tariff is assumed to be equivalent to 95% of the counterfactual heat production cost, representing a small, direct financial incentive to consumers. In practice, savings could be greater but will depend on the overall financial performance of the heat network and the pricing strategy, which will be influenced by the overall commercial strategy, e.g. ownership (public or private) and whether the scheme is 'for profit' or not. A worked example is shown below:

Heat tariff (Civic Centre)

Unit rate for heat:

Unit rate for gas = £23.6/MWh
Assumed seasonal efficiency of gas boiler = 85 %
Unit rate for heat = 23.6 / 85 % = £26.3/MWh

Annual maintenance cost[9]:

Assumed at 11 % of boiler investment = 11 % * £90/kW = £9.9/kW

Boiler capacity = 5,740 kW
Cost of boiler maintenance per year =5,740 kW * £9.9/kW = £56,826
Cost of boiler maintenance per MWh = £56,826 / 2 795 MWh = £20.3/MWh

Annualised replacement cost:

Boiler capacity required (incl. reserve) = 5,740 kW
Cost of boilers = 5,740 kW * £90/kW = £516,600
Cost of boilers per year = £516,600/ 15 yrs = £34,440
Cost of boilers per MWh = £34,440/ 2 795 MWh = £12.3/MWh

Total cost of heat (counterfactual): 26.3 + 20.3 + 12.3 = £58.9/MWh

Total heat network tariff: (26.3 + 20.3 + 12.3) * 95% = 56.0 £/MWh

[9] *Methodology and input data taken from NERA/ AEA cost modelling for DECC (2009)*

5 Energy Supply - Wolverhampton Energy from Waste plant

5.1 Review of key issues

Baseload supply for all reviewed network options is based on heat exported from the Energy from Waste (EfW) plant on Crown Street. This is owned by CWC and operated under contract MES Environmental (MESE) via Wolverhampton Waste Services (WWS). The EfW facility is designed and currently operated as a power generation facility, but CWC is currently reviewing future options for the facility ahead of the close of the existing operational contract in 2023. Council officers are committed to providing an Energy from Waste facility to manage its future waste needs and are actively pursuing all appropriate options concerning the facility post the 2023 contract end date, in addition to considering whether the existing contract could be extended for an interim period. It should be noted that formal approval and adoption of the preferred option for the facility will still need council approval.

Amongst the long-term future options being considered are:

a) major refurbishment of the facility
b) expansion from a “2-line” to a “3-line” facility which is assumed to increase energy generation capacity by 50%.

A primary heat network Energy Centre would ideally be located on the EfW facility site. This would house the EfW plant steam turbine offtake equipment, heat network export plant, circulation pumps, peak/reserve gas boilers[10], water management plant, control equipment, potentially thermal stores (depending on detailed design decisions). This may require the council to explore the use of neighbouring sites to support this.

The EfW offtake plant consists of a plate heat exchanger which is used to extract heat from the turbine offtake to the district heat network water, and it should be located close to the actual turbine offtake to minimise heat losses from the offtake steam. The offtake is assumed to be available in perpetuity (nb. 40+ years used in modelling) as part of the Council’s waste management strategy.

Indicative layouts for the Heat Network energy centre and EfW offtake are included in Appendix 3

A private wire power substation would need to be installed as part of the EfW operator’s equipment since power will need to be sold directly from the “generator” rather than the network operator due to electricity supply licencing restrictions. To avoid a requirement to be licensed, the “generator” would also be limited to a maximum supply of 5 MW. Based on a 24/7 operation and a generator availability of 90% this would equate to power generation of 39.4 GWh/year. Private Wire demand in the energy calculations is 13.3 GWh/year and the combined peak power demand is approximately 4.14 MW, which means that licensing restrictions are assumed not to apply.

The EfW heat export connection portion of the Energy Centre is relatively small, estimated at 10 m x 12.5 m floor area, and it appears that it can be

[10] *After completion of techno-economic modelling a delayed quotation for gas connection (from Cadent) was received. This is indicated a high cost of connection (due to upstream reinforcement) which will require re-assessment of the use of gas boilers as the peak/reserve supply solution. This is further discussed as a risk issues in section 6.2.6.*

located on the western side of the site under the current EfW design but also if the facility is expanded and a 3rd line is added.

The full Energy Centre including peak boilers and thermal stores has an estimated total floor area of 40 m x 12.5 m which may be more difficult to fit on the EfW site. It is impossible to be certain at this point since there is no design for an expanded EfW facility which may need to accommodate the waste handling and combustion elements of a 3rd line but will also likely require significant updating of the waste and pollution control measures since regulatory requirements will have changed significantly from those of the early 1990s when the current plant was designed.

The site is constrained and whilst it appears that there is sufficient space on the western side of the site for such a building (see Figure 5-1) this needs to be investigated in further detail as options for the EfW itself are explored. It cannot currently be confirmed that this area would be available for development, as this area is heavily used for maintenance of the plant, particularly during the annual outage periods. Where space cannot be found for the energy centre on the EfW site, other nearby options could be considered, these could also include ancillary infrastructure to support the EfW and Heat Network schemes close to the site, or the wider waste service portfolio if the council required. Land immediately to the south) could be a possible option.

A further option would be to locate only the EfW heat offtake plant on the EfW site with the main Heat Network energy centre plant being located elsewhere. This would require identifying a potential new site for the secondary Energy Centre somewhere along the heat network. Separating the plant in this way would have some implications on the HN pipe sizing and will increase building and auxiliary equipment costs. Whilst it would not be ideal to separate the facilities there are few operational risks involved but at this point no suitable locations have been identified.

Figure 5-1. Indicative primary Energy Centre location & footprint

Technical aspects of the EfW plant's current and potential future operation and the impact of 'off-taking' heat (to supply a heat network) from the facility were assessed by Fichtner Consulting. Four heat offtake scenarios were developed and assessed. They are:

1/ **Current/HP bleed:** off-taking from only the high-pressure bleed of the current turbine. The maximum heat export capacity is estimated at 2.6 MW.

2/ **Current/both bleeds:** off-taking from both bleeds for heat export of the current turbine. The maximum heat export capacity is estimated at 3.5 MW.

3/ **Refurbished/3-line:** off-taking from a refurbished and expanded EfW facility with a new "heat-optimised[11]" steam turbine arrangement – assumed 50% additional waste (and steam input). The maximum heat export capacity is estimated to be 9.4 MW.

4/ **Refurbished/2-line:** off-taking from a refurbished facility with a new "heat-optimised[11]" steam turbine arrangement using steam generated from the same quantity of waste as assumed in Options 1 and 2, i.e. 2-line. The maximum heat export capacity is estimated to be 6.3 MW.

The maximum power export capacity of the turbine in options 1, 2 and 4 is estimated to be 8.24 MW_e (with no heat export). With the expanded turbine option, option 3, the maximum power export capacity is increased to 12.36 MW_e as the additional 3rd waste processing line allows for an increase in energy output. It has been assumed that the 3rd line is identical to the existing two lines, thus increasing waste processing and subsequent power export capacity by 50%.

The power export capacity of the existing turbine has been determined by Fichtner Consulting based on actual turbine characteristics data and process flow charts available for the existing facility. This data has also been used in determining the characteristics of the new optimised turbine. The new turbine in option 4 has the same maximum power export capacity as the existing turbine since it is essentially limited by the number of waste processing lines rather than the turbine itself. A new turbine may have marginally better efficiency (i.e. smaller losses) but based on the turbine characteristics data the existing turbine already has an efficiency of over 95 % so there is very small potential for improvement.

A key design factor for the turbine when considering heat offtake is the z-factor, which is the ratio of heat generation to lost power generation. The z-factor is dynamic, depending on the operating circumstances of the turbine. The average z-factor for the four options is summarised in Table 5-1.

Offtake option	
1 - Current/HP bleed	6.14
2 - Current/both bleeds	6.70
3 - Refurbished/3-line	7.40
4 - Refurbished/2-line	7.96

Table 5-1 Estimated average z-factor variance

The z-factor has a significant influence on the price of exportable heat. Lower z-factors result in a greater quantity of lost power generation which will be a more significant revenue opportunity than the sale of heat. Thus, lower z-factors result in higher heat prices and vice versa. At this stage simplified assumptions have been made around the design of the turbine plant (the offtake arrangement) – it is likely to be possible to improve z-factors through the selection of adaptable plant and design optimisation.

Currently, WWS (the CWC EfW contract counterparty) sells power under a Power Purchase Agreement (PPA) at a fixed value of £48/MWh. Whilst this figure has been used in the current analysis to estimate heat cost, a new power purchase agreement will be required and so the price is likely to be different. It is also likely to be affected by any separate Private Wire power purchase agreements established between the future EfW operator[12] and 3rd parties, e.g. CWC and UoW. This will require further review at a later stage.

Heat export price is also affected by the total annual heat export, thus changing slightly with different network options.

[11] *Assumes steam bleeds designed to enable low pressure steam export*

[12] *This could also be CWC as the EfW owners or EfW contract counterparty*

The optimised turbine arrangement is anticipated to improve the carbon performance of the EfW plant (essentially more of the available energy is harvested), resulting in lowering the carbon intensity of the exported heat.

Table 5-2 shows a summary of the EfW turbine options, covering the capital cost (heat offtake modifications only, i.e. excluding any turbine renovation or replacement), maximum heat export capacity, initially modelled heat export price and heat export carbon intensity[13].

	Capex	Max heat export	Min heat price	Carbon intensity
	£000s	*MW_{th}*	*£ / MWh*	*gCO_2 / kWh*
1 – Current/HP bleed	810	2.6	25.46	17
2 – Current/both bleeds	830	3.5	20.58	15
3 – Refurbished/3-line	880	9.4	11.49	14
4 – Refurbished/2-line	960	6.3	14.07	13

Table 5-2. Summary of EfW heat export options.

This illustrates that exporting heat from the current turbine arrangement has a much greater cost, much smaller supply capacity and will lead to greater carbon emissions. Heat price is affected by the low z-factor of the existing turbine but also the fact that the capital costs required to enable heat export do not vary significantly between the options. The low z-factor of the existing turbine is due to the turbine being designed exclusively for power export whereas the new turbine can be optimised to take into account both power and heat export, maximising the overall efficiency.

The results illustrate that a heat-optimised solution (a new turbine) will provide better value to the heat network both in terms of the proportion of energy available from the EfW and its cost. The existing turbine may offer a transitional solution but at a high cost since the heat-offtake modifications will be required for both solutions over time although some elements of the offtake installation could be reused to limit the overall costs. Based on these results, the optimised turbine scenarios 3 and 4 were chosen as the baseload supply assumptions when developing and testing the subsequent heat networks solutions. It should be noted that the case for replacement of the existing steam turbine will also depend on the business case for the EfW refurbishment, with or without expansion, which will largely sit on the revenue from power sales (which would be boosted through direct consumer sales through a Private Wire Network).

Supply optimisation and thermal storage

Heat supply optimisation and unit sizing was conducted for the heat network options identified using EfW scenarios 3 and 4 (Refurbished/3-line and Refurbished/2-line).

As shown later, the EfW alone can meet a high percentage of the total heat demand of the networks considered. However, to meet the assumed highest peaks in demand and to provide reserve capacity to allow for maintenance shutdown periods, significant gas boiler capacity and thermal storage are assumed to be integrated within an energy centre close (ideally on-site) to the EfW facility.

According to the EfW analysis, the current turbine plant has a typical availability of 7,972 hours per year, which is a reasonable and conservative long term availability assumption in new steam turbine scenarios. The following other assumptions are made:

1/ The turbine capacity operates at full capacity 24/7

[13] *Carbon emissions are calculated based on a displaced power methodology as per Green Heat Network Fund Transition Scheme Guidance for applicants (v1.1) and uses an average of 2025-41 'Long-run marginal emission factors' for electricity*

2/ The turbine capacity operates in either power and heat mode, or, if there is no heat demand in the network, in a power-only mode

3/ During periods of non-availability, the turbine is completely out of operation (as opposed to at part-operation)

4/ Peak boiler plant is sized to meet the full heat demand of the heat network options. From a heat export point of view, it would be optimal to schedule annual maintenance during the summer. Should it occur during winter, or in case of unexpected shutdowns, the boiler plant is sized to meet the full load, ensuring security of supply.

Regarding power sales/export two scenarios have been considered:

1/ Exporting power via a Private Wire network connected to the UoW Molineux and Wulfruna campuses and CWC buildings with the remainder being exported to the 'grid'. When in operation, the power export capacity of the optimised turbine options exceeds the estimated demand of the Private Wire network at all times.

2/ Power is only exported to the 'grid'.

Heat storage was considered as part of the supply optimisation analysis. Heat storage was found not to add significant value in most scenarios as a very high percentage of the network heat demand can be supplied by the EfW plant already without including storage in the system. Storage also does not bring significant value in terms of optimising the timing of power export capacity as it is generally higher than the power demand of the Private Wire network.

It is important to note that this is a simplified analysis since the 'grid' export value is fixed as is the price of consumer power purchase. Accounting for 'time of day' variability (for both) could result in more value from increased storage capacity. In addition, variation in power (e.g. adding other properties and overnight transport charging) or heat loads (and their time-profile) could lead to changes in these conclusions.

The viability of heat storage is affected by the fact that off-taking more heat results in less power generation/exported and reduces power sale revenue. In practice, the cost of heat from thermal storage (which includes loss of power and the capital cost of the storage systems) will balance against the costs of heat provided by gas boilers, which is inherently low. Marginal additional carbon savings could be achieved with the addition of thermal storage as gas use decreases. However, the impact is small since EfW-based heat production also has a small but non-negligible carbon factor. This is the main limiting factor for available carbon savings for this scheme.

In conclusion, for this particular case, heat storage becomes more viable when there is a greater need for gas boiler supply. In the largest network (Network 2 – East Extension expansion) with the refurbished/2-line turbine arrangement, a small 100 m³ store was found to be cost-effective (decreasing Lifetime Cost of Energy (LCoE)), which also leads to a small increase in carbon savings.

5.2 Resulting heat export conclusions

Table 5-3 shows total annual heat exports, final heat export prices and carbon factors for the network & supply option combinations.

	Network:	**Network 1 (Base)**		**Network 2 (East Extension)**		**Network 3 (West Extension)**	
	EfW refurb scenario:	2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
	Unit						
Heat export	GWh	23.6	25.7	30.4	35.0	27.3	30.0
Heat export price	£/MWh	10.4	9.8	9.2	8.7	9.8	9.3
Heat carbon factor	gCO_2/kWh	14	13	14	13	14	13

Table 5-3. Heat export (from EfW) - prices and carbon factors by network

Figure 5-2 shows annual heat production (GWh) from EfW and gas boilers for the different (fully built-out) network/supply scenarios. Figure 5-3 shows heat production shares from EfW and gas boilers as a percentage of total annual heat demand.

Load duration curves for all reviewed network and supply options are also shown in Figure 5-4 to Figure 5-9. These graphs show output from the hourly demand/supply modelling. They illustrate the consumer demand (the curve) and the proportion supplied for the various supply options (EfW, gas boiler and thermal storage).

As can be seen, the share of EfW heat in all networks is very high, ranging from 77% in Network 2 to over 96% in Network 1. A small 100 m³ thermal store is introduced in both Network 2 and Network 3 in the '2-line' supply scenario.

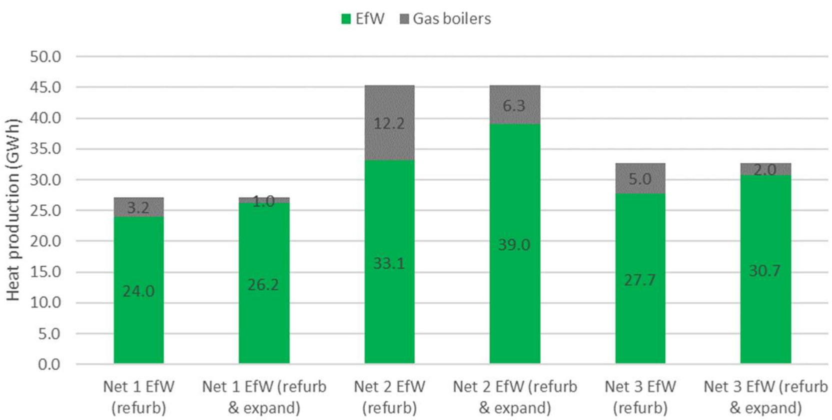


Figure 5-2 Heat production – all options

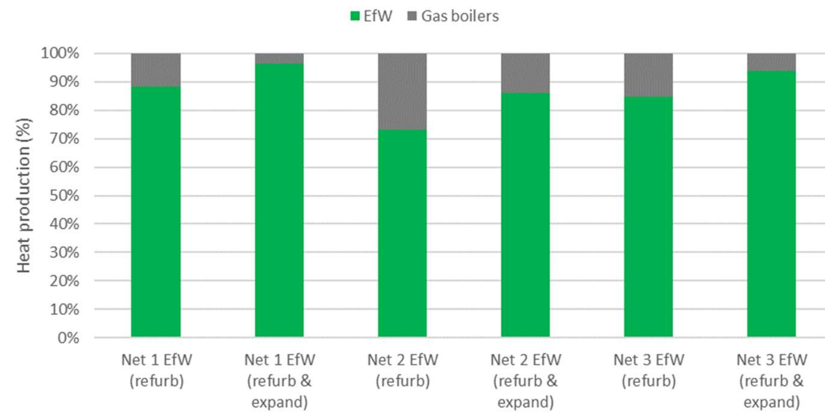


Figure 5-3 Heat production share – all options

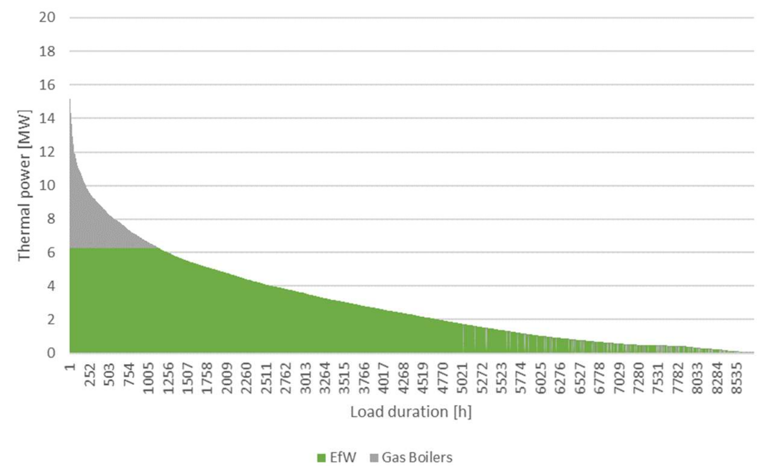


Figure 5-4. Load duration curve for Net 1 EfW refurb option

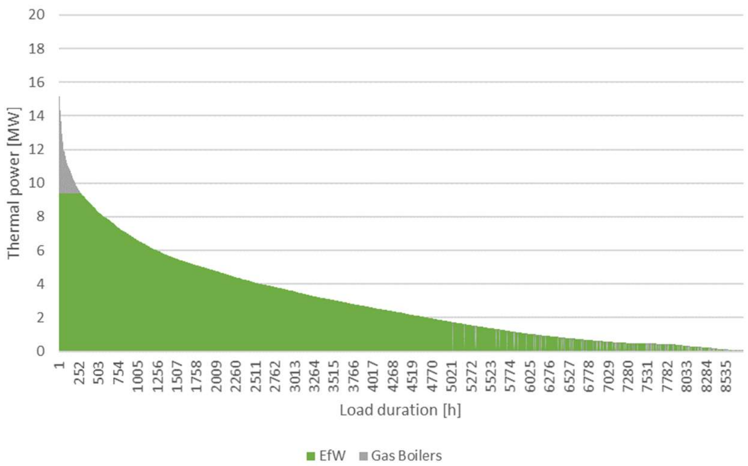


Figure 5-5. Load duration curve for Net 1 EfW refurb + expansion option

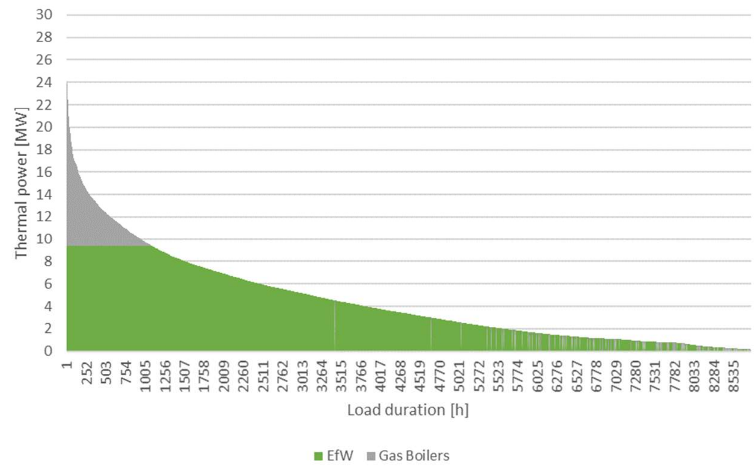


Figure 5-7. Load duration curve for Net 2 East refurb + expansion option

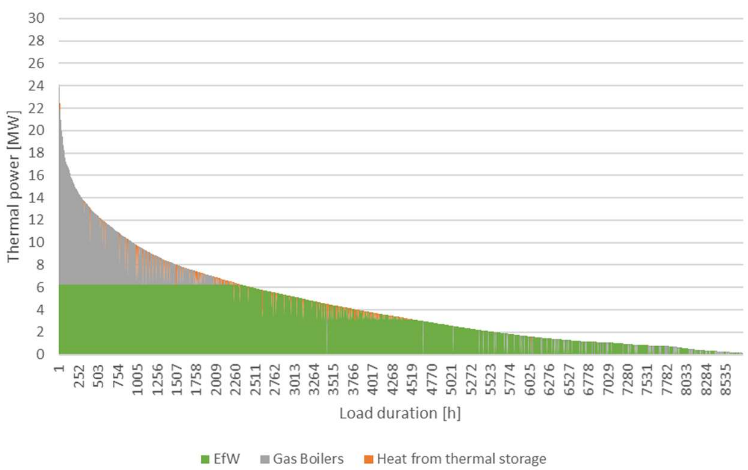


Figure 5-6. Load duration curve for Net 2 East refurb option

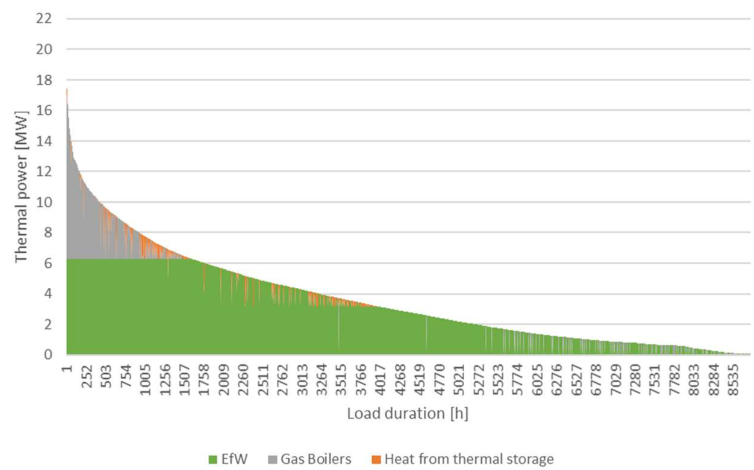


Figure 5-8. Load duration curve for Net 2 West refurb option

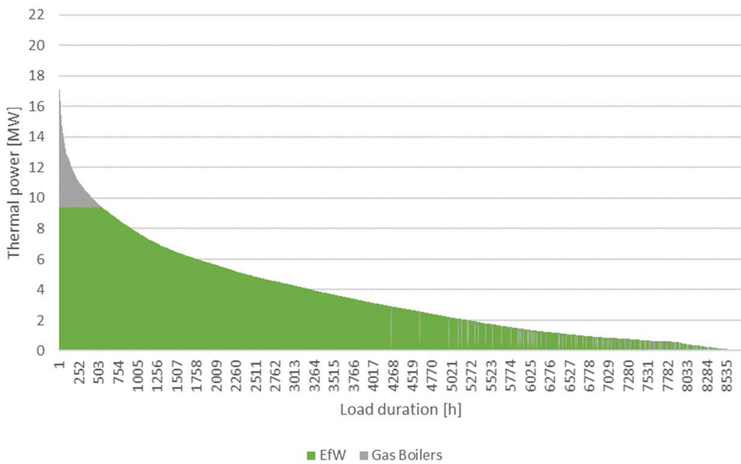


Figure 5-9. Load duration curve for Net 2 West refurb + expansion option

Table 5-4 shows the energy balances for all reviewed network & supply combinations and Table 5-5 shows the equivalent thermal capacities required.

	Network:	Network 1 (Base)		Network 2 (Base + East Extension)		Network 3 (Base + West Extension)	
	EfW refurb scenario:	2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
Heat Generation							
Heat production	GWh/yr	26.6	26.6	39.6	39.6	31.8	31.8
EfW	GWh/yr	23.6	25.7	30.4	35.0	27.3	30.0
	%	89%	97%	77%	88%	86%	95%
Gas boilers	GWh/yr	3.0	0.9	9.2	4.6	4.5	1.8
	%	11%	4%	23%	12%	14%	6%
Gas consumption	GWh/yr	3.3	1.0	10.2	5.1	5.0	2.0
Electricity consumption	GWh/yr	0.7	0.7	1.0	1.0	0.8	0.8
Electricity							
EfW electricity production	GWh	62.7	95.0	61.9	93.8	62.2	94.5
To Private Wire	GWh	13.3	13.3	13.3	13.3	13.3	13.3
	%	21%	14%	22%	14%	21%	14%
To EC own use	GWh	0.7	0.7	1.0	1.0	0.8	0.8
	%	1%	1%	2%	1%	1%	1%
To grid	GWh	48.7	81.1	47.6	79.5	48.2	80.4
	%	78 %	85 %	77 %	85 %	77 %	76 %

Table 5-4. Energy balance for all network/supply scenarios

Network:		Network 1 (Base)		Network 2 (Base + East)		Network 3 (Base + West)	
EfW scenario:		2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
EfW - heat	MW	6.3	9.4	6.3	9.4	6.3	9.4
Gas boilers	MW	21.0	21.0	29.2	28.0	21.0	21.0
Thermal storage	m^3	-	-	100	-	100	-
EfW - Private Wire	MW	3.7	3.7	3.7	3.7	3.7	3.7

Table 5-5. Supply plant sizing for all network/supply scenarios

6 Network options appraisal

6.1 Network design and key assumptions

This section appraises the various heat network options identified. Supporting information is also included in the following Appendices:

- Appendix 4. Heat network infrastructure
- Appendix 5. Pipe sizing analysis
- Appendix 6. Carbon reduction analysis
- Appendix 7. Costings and financial assumptions
- Appendix 8. Detailed financial modelling results

Following a review of consumer operating conditions (particularly secondary system temperatures), many of the existing properties operate on the basis of 80/60 °C flow/return temperatures. With audits and rebalancing of heating systems, it is assumed that all existing consumers will be able to achieve an 80/60 °C regime. Based on this, the primary heating network pipework has been dimensioned on a 90/65 °C basis. Whilst these temperatures are used for dimensioning (at peak load conditions), the network is proposed to operate on a variable temperature, variable flow basis such that it can efficiently respond to the ambient temperatures (and subsequent variation in consumer demands).

For the new developments, heat emitters are recommended to be sized to operate at low return temperatures at peak load conditions, i.e. no more than an average 40 °C return temperature (secondary side). Based on this, the primary district heat network connections to the new developments are dimensioned with a 45 °C return temperature.

Property connections would be configured with Duplex Duty-Duty Heating Plate Exchanger (PHE) systems, using Low-Temperature Hot Water (LTHW) on the primary side to provide heat to the building-level heating systems (secondary side). A single PHE option is proposed as a standard solution for buildings with a heat load below 600 kW since these do not require the resiliency of a twin-plate solution.

PHE substations would be installed in plant rooms of each building, as existing gas boilers would be decommissioned. In residential apartment buildings, Heat Interface Units (HIUs) would serve end-use heat emitters (radiators or underfloor heating).

The heat network is proposed to utilise Class 2 steel, pre-insulated pipework to minimize heat losses whilst limiting capital costs – this could be upgraded to Class 1 to further reduce losses with the drawback of slightly higher network capital costs.

The EfW plant heat offtake would allow for the potential future expansion of the scheme. The total heat production potential (if running at full capacity year-round) is estimated at circa 50 GWh/yr (2 line) and at circa 75 GWh/yr (3 line) and the total demand in the three network options sits between 27-45GWh/yr.

A private wire connection is proposed from the EfW plant to the largest Network 1 Base consumers, University of Wolverhampton Wulfruna and Molineux campuses and City of Wolverhampton Council properties. The private wire would distribute power from the EfW plant to the properties via an 11 kV connection. The private wire network follows the route of the heat network and is assumed to be installed at the same time as the heat network to avoid unnecessary infrastructure works.

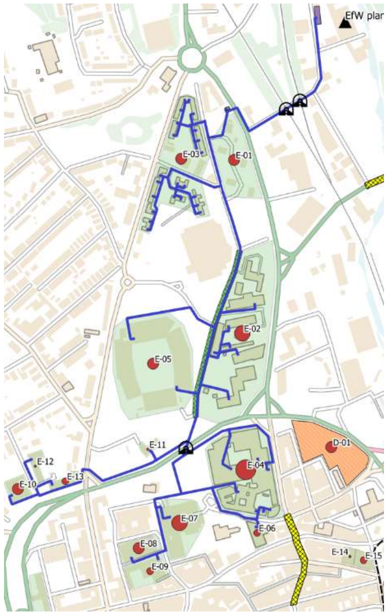
At this point, until plans around the future of the EfW plant the date at which heat from the plant will be available is not known. A provisional assumption has been made that it would be available by 2025.

6.1.1 Network 1: Base

Network 1 (Base) would connect a core set of anchor consumers mainly consisting of University of Wolverhampton and City of Wolverhampton Council properties. A private wire network would provide power to the key anchor consumers improving the economic performance of the network while providing the consumers with savings on power costs.

Based on consumer loads and the scheme development strategy, key design parameters for the network are shown in Table 6-1. Corresponding capital costs are summarised in Table 6-2.

Full network maps with pipe sizing are presented in Appendix 5, along with more detail on network and connection costs.



	Units	
Heat demand	GWh/yr	24.8
Peak demand (diversified)	MW	17.2
Full load hours	h	1,428
Number of connections Non-residential (includes UoW student accom.) Residential (buildings) Residential (dwellings)	 No. No. No.	 45 5 198
Network trench length	km	4.7
Linear heat density	GWh/yr/km	5.3
Main pipe size	DN	300
Heat losses	%	8 %
Design temperatures	°C	90 / 65-45 (flow/return)
Soft dig / Hard dig	%	4 / 96

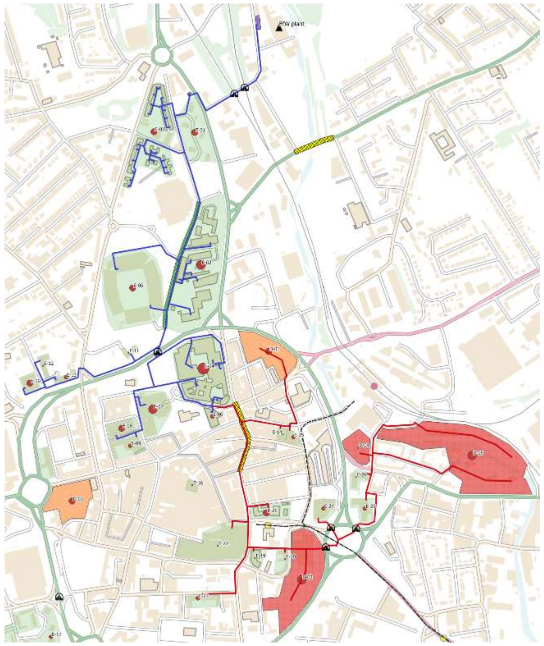
Table 6-1. Network 1: Base – key parameters

Heat network - Pipe only supply and installation - Trenching and civils	 £k £k	 2,001 3,487
Heat substations, HIUs and metering	£k	779
Private wire network	£k	1,081
Private wire connections	£k	954
Total	£k	8,302
Contingency (10 %)	£k	830
Grand total	**£k**	**9,132**

Table 6-2. Network 1: Base – network capital costs

6.1.2 Network 2: East Extension

Network 2 East Extension builds on Network 1 Base and adds an extension to consumers found in the Town Centre area and new developments beyond.



Based on consumer loads and the scheme development strategy, key design parameters for the network are shown in Table 6-3 and capital costs are summarised in Table 6-4.

Full network maps with pipe sizing are presented in Appendix 5, along with more detail on network and connection costs.

	Units	
Heat demand	GWh/yr	36.0
Peak demand (diversified)	MW	27.3
Full load hours	h	1,321
Number of connections Non-residential (includes UoW student accom.) Residential (buildings) Residential (dwellings)	 No. No. No.	 69 676 1,485
Network trench length	km	14.4
Linear heat density	GWh/yr/km	2.5
Main pipe size	DN	400
Heat losses	%	10 %
Design temperatures	°C	90 / 65-45 (flow/return)
Soft dig / Hard dig	%	53 / 47

Table 6-3. Network 2: East Extension – key parameters.

Heat network - Pipe only supply and installation - Trenching and civils	 £k £k	 4,779 8,055
Heat substations, HIUs and metering	£k	2,795
Private wire network	£k	1,081
Private wire connections	£k	954
Total	£k	17,664
Contingency (10 %)	£k	1,766
Grand total	**£k**	**19,430**

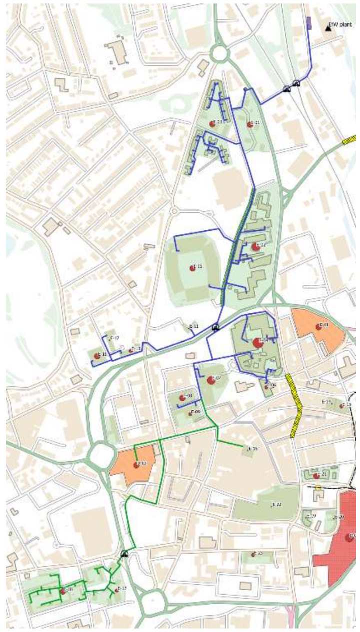
Table 6-4. Network 2: East Extension – network capital costs.

6.1.3 Network 3: West Extension

Network 3 West Extension also builds on Network 1 Base while adding an extension to developments in the western parts of Town Centre and council-owned housing at Graisley.

Based on consumer loads and the scheme development strategy, key design parameters for the network are shown in Table 6-5 and capital costs are summarised in Table 6-6.

Full network maps with pipe sizing are presented in Appendix 4, along with more detail on network and connection costs.



	Units	
Heat demand	GWh/yr	29.3
Peak demand (diversified)	MW	19.5
Full load hours	h	1,506
Number of connections Non-residential (includes UoW student accom.) Residential (buildings) Residential (dwellings)	 No. No. No.	 42 29 734
Network trench length	km	7.7
Linear heat density	GWh/yr/km	3.8
Main pipe size	DN	400
Heat losses	%	9 %
Design temperatures	°C	90 / 65-45 (flow/return)
Soft dig / Hard dig	%	22 / 78

Table 6-5. Network 3: West Extension – key parameters

Heat network - Pipe only supply and installation - Trenching and civils	 £k £k	 2,950 5,217
Heat substations, HIUs and metering	£k	1,143
Private wire network	£k	1,081
Private wire connections	£k	954
Total	£k	11,345
Contingency (10 %)	£k	1,135
Grand total	**£k**	**12,480**

Table 6-6. Network 3: West Extension – network capital costs

6.2 Economic and Carbon performance appraisal – network

This section reviews the economic analysis conducted for the various heat network options.

6.2.1 Capital costs

Estimated capital costs, ranging from £16.4m for Network 1 (EfW refurb/2-line) to £34.5m for Network 2 East (EfW refurb/2-line), are shown in Figure 6-1 and Table 6-7.

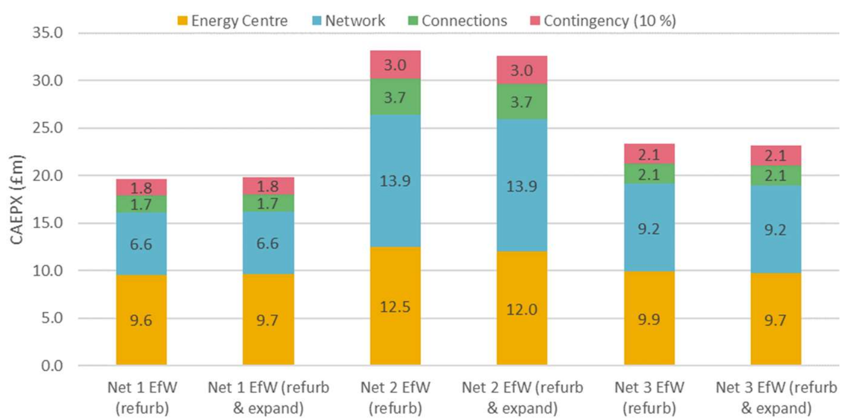


Figure 6-1. Summary of capital costs

Network:		Network 1 (Base)		Network 2 (East Extension)		Network 3 (West Extension)	
EfW refurb scenario:		2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
Heat network *(Incl. connections)*	£m	6.3	6.3	15.6	15.6	9.3	9.3
Power network *(Incl. connections)*	£m	2.0	2.0	2.0	2.0	2.0	2.0
Energy Centre *(Incl. thermal store & utility connections)* [14]	£m	6.8	6.8	9.1	8.6	7.0	6.8
EfW offtake	£m	0.9	1.0	0.9	1.0	0.9	1.0
Development costs +contingency	£m	3.7	3.8	5.5	5.4	4.1	4.1
Total CAPEX	£m	19.7	19.8	33.2	32.6	23.4	23.2

Table 6-7. Capital cost summary (full build)

6.2.2 Energy tariffs, other revenue and operating costs

In terms of revenues for the heat network, consumer tariffs are based on a 5% reduction of a calculated counterfactual cost as described in section 4.8. Tariffs vary between consumer types based on reported costs or regional estimates. Further details on tariff assumptions are presented in Appendix 7.

Key operating costs assumptions have been developed for each of the network options, covering key issues such as fuel/electricity costs (which are inflated based on BEIS projections), plant lifetimes (used to calculate

[14] *Following completion of modelling using estimated gas connection costs a delayed indicative quotation was received from Cadent which suggests cost would be £1.7m higher than shown. This is highlighted as a risk issue in section 6.2.6 but it is recommended that alternatives solutions are considered to mitigate this issue.*

replacement costs) and plant/equipment maintenance. Details are included in Appendix 7.

6.2.3 Economic analysis

Economic analysis has been conducted with a bespoke discounted cashflow model covering time periods of 25, 30 and 40 years. This long-term modelling illustrates the long-term nature of heat network infrastructure and its investment. Modelling has been developed for each network scenario and has enabled sensitivity-testing of key parameters.

Outputs from the modelling include a range of financial parameters including Internal Rate of Return (IRR) and Net Present Value (NPV). The results of the base-case economic model (including private wire) for a 25-year period are summarised in Figure 6-2 (full year opex and revenue by scenario), Figure 6-3 (IRRs by scenario) and Figure 6-4 (NPVs by scenario).

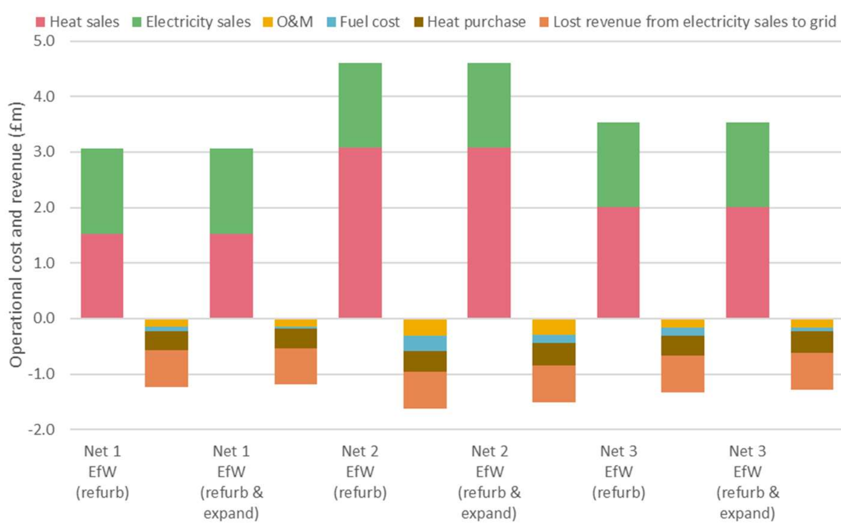


Figure 6-2. Summary of operational costs and revenues

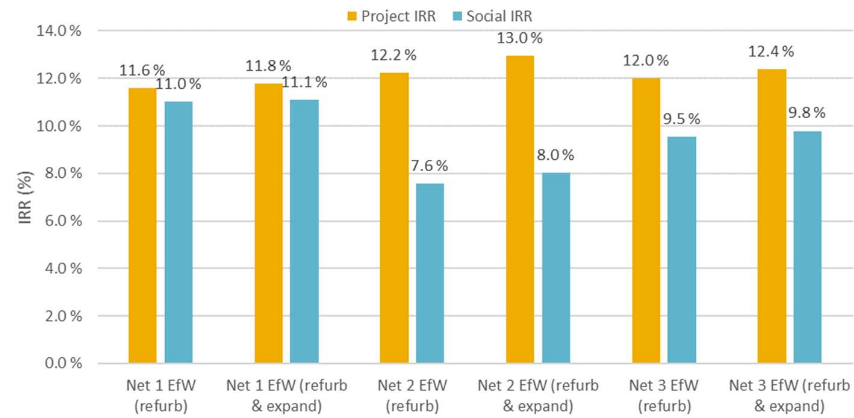


Figure 6-3. IRR and Social IRR (25 years)

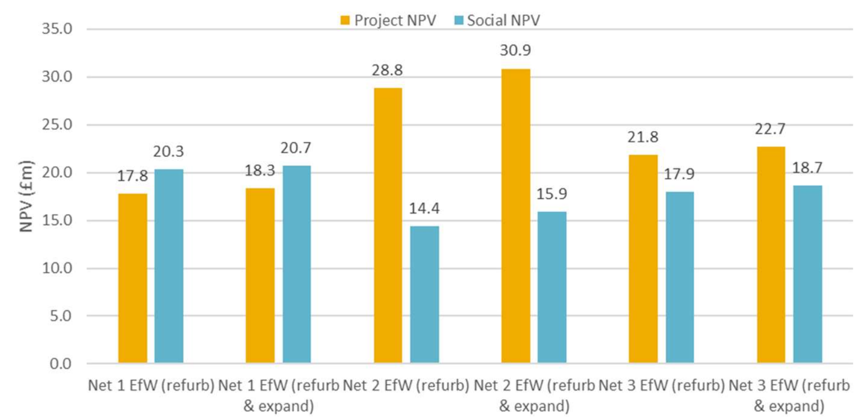


Figure 6-4. NPV and Social NPV (25 years)

Further detail on the economic performance is given in **Error! Reference source not found.**.

Network:		Network 1 (Base)		Network 2 (East Extension)		Network 3 (West Extension)	
EfW refurb scenario:		2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
Total CAPEX	£m	19.7	19.8	33.2	32.6	23.4	23.2
Total REPEX	£m	6.0	6.0	9.8	9.5	6.4	6.4
Total OPEX	£m/yr	1.2	1.2	1.6	1.5	1.3	1.3
Annual revenue	£m/yr	3.3	3.3	4.9	4.9	3.8	3.8
Gross margin	£m/yr	2.1	2.1	3.3	3.4	2.5	2.5
Consumer heat tariff costs[15]	£/MWh	73.6	73.6	102.7	102.7	81.9	81.9
Total connection fees	£m	3.1	3.1	10.9	10.9	4.6	4.6
Economic viability including private wire network							
IRR (25 yr)	%	11.6 %	11.8 %	12.2 %	13.0 %	12.0 %	12.4 %
NPV (3.5 %, 40yr)	£m	25.0	25.8	38.2	40.9	29.9	31.1
Social NPV (3.5 %, 40yr)[16]	£m	38.5	39.1	21.6	23.9	32.4	33.6
LCOE, heat (25 yr)	£/MWh	22.1	20.7	43.0	39.3	27.1	25.2
Economic viability excluding private wire network							
IRR (25 yr)	**%**	-0.6 %	-0.2 %	4.8 %	5.5 %	2.0 %	2.5 %
NPV (3.5 %, 40yr)	£m	-8.7	-7.9	4.5	7.2	-3.8	-2.6
Social NPV (3.5 %, 40yr)[16]	£m	-3.1	-2.4	-20.0	-17.6	-9.2	-8.0
LCOE, heat (25 yr)	£/MWh	86.5	85.1	86.8	83.2	81.0	79.1

Table 6-8 Economic modelling results

Table 6-8 also shows the discounted cash flow graphs, without RHI incomes, on an annual basis, illustrating the balance of revenue and costs throughout the period. Full results for all calculated calculation periods (25, 30, and 40 years) are presented in Appendix 8.

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15 *Average across all consumers.*

16 *Accounts for monetised costs of carbon emissions, air quality damage and heating costs. Based on guidance from: Valuation of energy use and greenhouse gas – Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government, DBEIS, April 2019.*

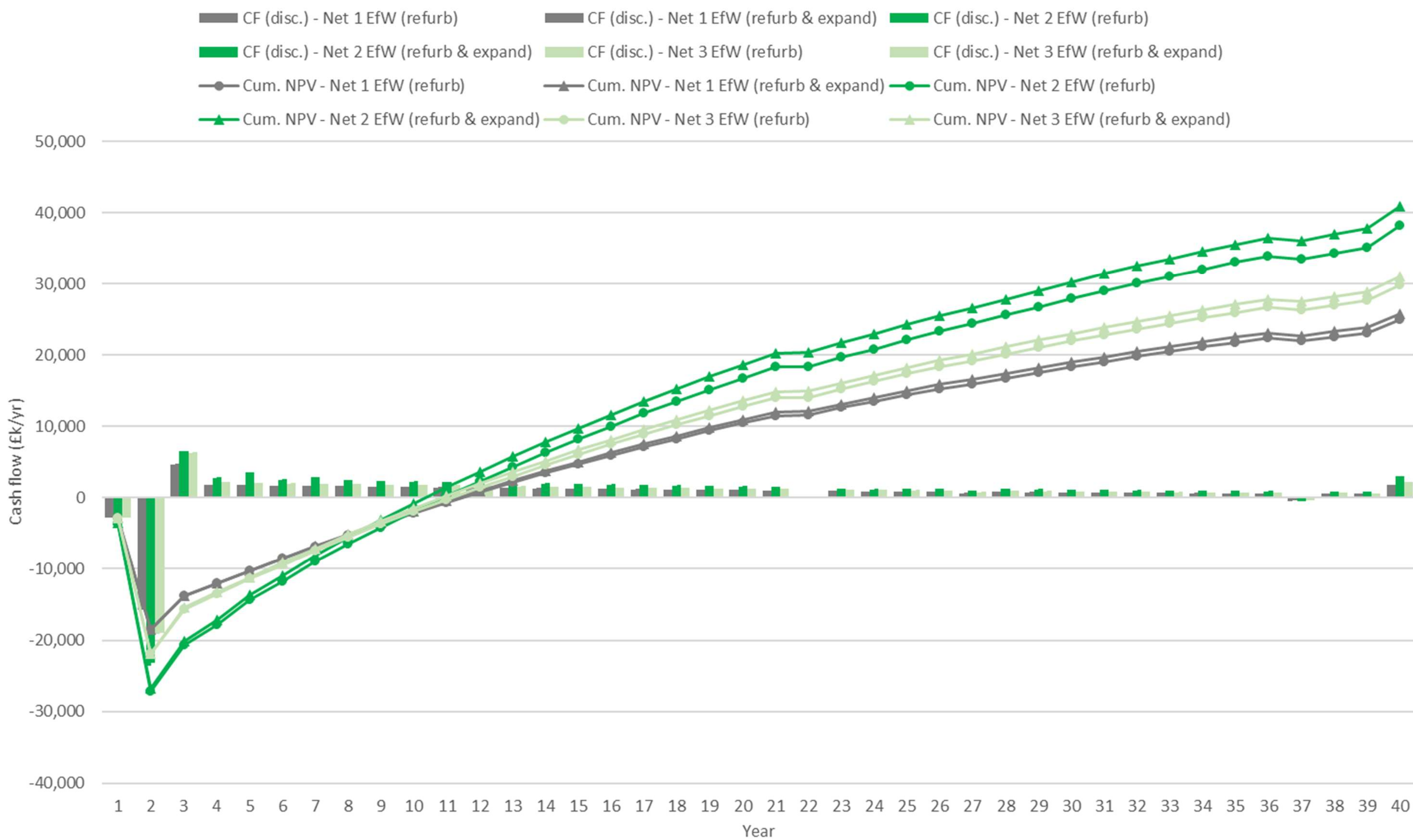


Figure 6-5. Cash flows for Wolverhampton network options

6.2.4 Key results from economic analysis

From the economic modelling the following key results were identified:

1/ Network 1: Base:

- IRRs sit at around 11-12% for the two supply scenarios
- NPVs sit between £25-26m (against capex of £20m)
- Strong uplift in both when accounting for social value

2/ Network 2: East extension:

- IRRs sit at between 12-13% for the two supply scenarios
- NPVs sit between £30-31m (against capex of £33m)
- Both are significantly reduced when accounting for social value (caused by a combination of increased carbon emissions and capital costs)

3/ Network 3: West extension:

- IRRs sit at between 12-12.5% for the two supply scenarios
- NPVs sit at around £30-31m (against capex of £23m)
- Small reduction when accounting for social value

At these levels of economic performance, it is highly likely that a Special Purpose Vehicle, perhaps a joint venture between the Council and UoW, could finance the project with a blend of council and university funding.

Where there is a funding gap or where there is a wish for the network to be funded by a private heat network business then grant funding from the Green Heat Network Funding may be appropriate to drawdown. This £280m government programme is due to launch in 2022 and is intended to provide capital support for low carbon networks, including those using the EfW as the primary supply technology. Further details regarding the programme are anticipated later in 2021.

6.2.5 Carbon performance

Carbon Dioxide emission savings for delivered heat have been estimated against the assumed counterfactual (existing or planned) energy supply arrangements (see section 4). Appendix 6 for further information on the methodology and carbon factors used together with a discussion regarding the accounting of carbon emission of power supplied via the private wire network. Figure 6-6 and Figure 6-7 show, respectively, annual and cumulative results over 40 years. Table 6-9 shows the estimated annual carbon emission reductions over both 15 and 40 years.

In summary, carbon emissions have been estimated based on a ‘displaced power’ methodology, rather than allocating a proportion of the combustion emissions of the EfW operation to the heat produced. This is the same methodology required for Green Heat Network Fund (GHNF) applications and under future iterations of SAP under Part L of Building Regulations (for new dwellings). The methodology assumes heat recovered from the EfW plant is assumed to be a waste product and therefore has zero emissions, however, since the extraction of heat results in some loss of power generation, the carbon associated to the grid-sourced power required to replace this loss is attributed to the heat. The carbon factor for the extracted heat is therefore affected by the design of the offtake from the EfW steam turbine. Design optimisation of the offtake, maximising the ‘z-factor’, would reduce emissions by reducing loss of power generation; it would also reduce heat costs.

For reference, whilst the proportion of biogenic material in the waste used in the EfW plant is a significant factor when accounting for the carbon emissions of combustion (since the biogenic component would be accounted to be zero carbon), the ‘displaced power’ method is not affected by this. As such, a reduction in the biogenic component, for example, through the introduction of food waste recycling, would not lead to an increase in the attributed carbon emissions.

The carbon calculations for delivered heat also takes into account the emissions associated to the peak/backup boilers and network losses.

Network 1/Base heat carbon reduction: estimated at 83-90% (3,800-4,100 Tonnes CO_2 per year on average).

Network 2/East extension heat carbon reduction: estimated at 65-78% (3,600-4,300 Tonnes CO_2 per year on average). This reduction in performance is due to:

- A larger overall heat demand lowering the estimated proportion of heat supplied by the EfW plant
- Lower counterfactual carbon emission associated with a greater proportion of new-build development which uses a general assumption that Heat Pumps would be the counterfactual comparator

Network 3/West extension: sees a small decrease in carbon savings compared to Network 1 to between 78-86% (3,900-4,400 Tonnes CO_2 per year on average). Again, the larger heat demand dilutes the proportion of heat supplied by the EfW plant resulting in higher emissions from the gas boilers used for backup and peak supply.

All of the options considered deliver heat at a carbon intensity of between 20 and 50 gCO_2/kWh which is far below the 100 gCO_2/kWh 'carbon gate' threshold of the Green Heat Network Fund (transition phase).

Finally, it is worth noting that once heat network infrastructure is in place it enables the connection of other low carbon supply technologies over time. Without a network solution, carbon reduction would need to be tackled on a building-by-building basis.

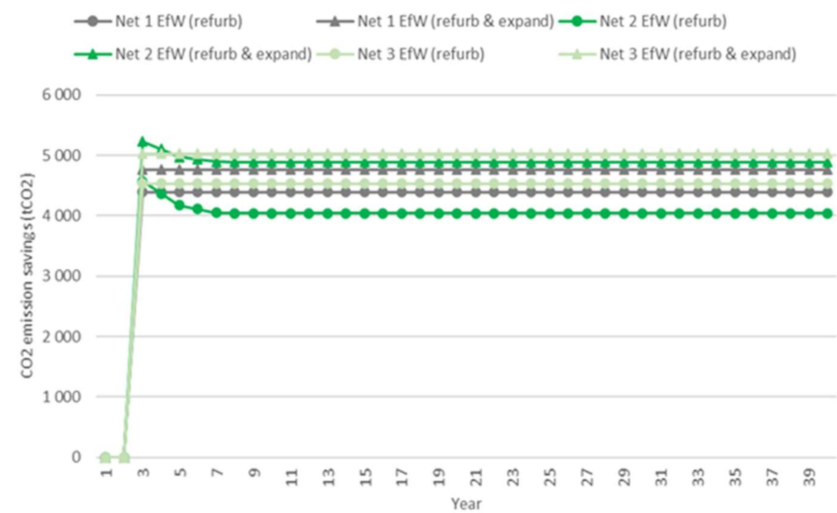


Figure 6-6. Annual CO_2 savings vs. counterfactual (heat only)

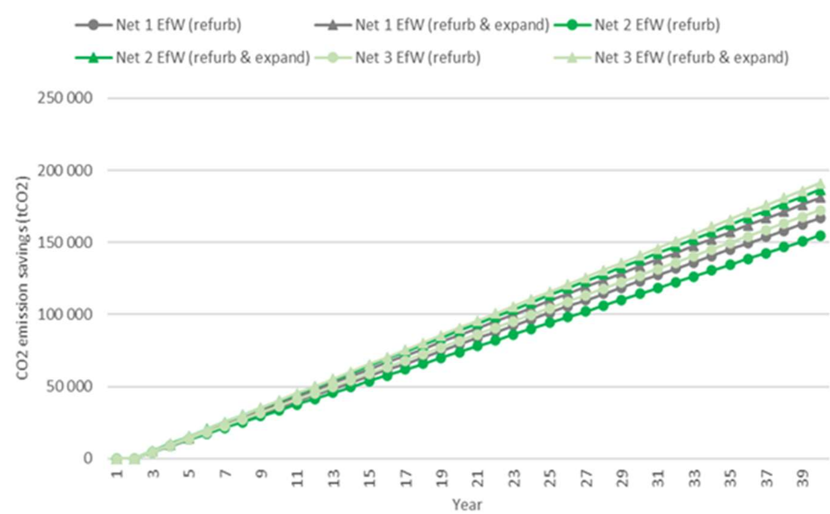


Figure 6-7. Cumulative CO_2 savings vs. counterfactual (heat only)

	Network:	**Network 1 (Base)**		**Network 2 (East Extension)**		**Network 3 (West Extension)**	
	EfW refurb scenario:	2 Line	3 Line	2 Line	3 Line	2 Line	3 Line
15 yr.							
CO_2 emission savings	$kTCO_2$/yr	3.8	4.1	3.6	4.3	3.9	4.4
	%	83%	90%	65%	78%	78%	87%
CO_2 intensity	gCO_2 /kWh	34	20	56	35	40	24
40 yr.							
CO_2 emission savings	$kTCO_2$/yr	4.2	4.5	3.9	4.7	4.3	4.8
	%	83%	90%	65%	78%	78%	87%
CO_2 intensity	gCO_2 /kWh	34	20	57	36	40	24

Table 6-9. Carbon emission savings vs. counterfactual (heat only)

6.2.6 Performance variance (opportunities and risks)

It is important to recognise at this stage of project development, numerous conservative assumptions have been used to counter optimism-bias. This means that improvements in economic performance are possible after further design development. Equally, changes to assumptions could worsen economic performance. Also, changes can happen concurrently, compounding the impact on economic performance.

The following opportunities for improvement and key risks for worsening (of performance) have been initially identified:

Improvement opportunities

1/ **Securing additional consumers.** There will be opportunities for including additional consumer, particularly for the network extensions, especially once the project become a firm proposition and connection can be marketed. Loss of consumers is also possible (see risks table).

2/ **Increasing tariffs and connection costs (revenue).** Presently tariffs are discounted (by 5%) against estimated counterfactual costs. This could be removed, accounting for the added-value of the HN 'service' offering, limiting on-site liabilities, and/or the social value.

3/ **Higher demands, particularly for new-build consumers.** Simple estimates of energy demand have been used for some consumers, particularly for the extensions. There can be significant differences between estimates and actual performance. Lower demand is also possible particular as consumer are likely to implement energy saving measures in existing building and building regulations will seek to limit demand of new development (see risks table).

4/ **Value engineering and design optimisation.** Development of scheme designs may yield cost savings such that budget tolerances and contingency can be reduced. This covers both capital and project development costs, which are significant. Technical improvements may also boost performance, e.g. increased energy yields and lower operating costs.

Risks
1/ **Not being able to access the assumed heat or power from the EfW at the assumed pricing.** Either has a significant impact on IRR.
2/ **Losing private wire electricity sales** has a large negative impact on IRR. The review of sensitivities below shows the impact of a total loss of power sales (includes removal of capital costs), which could occur if consumers did not wish to buy power through a private network. Changes from the estimated revenues and costs for 'private wire', which could be a result of possible changes to the regulation of network pricing, may result in a worsening of the cost/revenue balance for private wires sales but not to the extent of a total loss of power sales. This could reduce project returns but, at this point, it is not possible to estimate the impact.
3/ **Losing anticipated consumers / reducing heat load density.** All prospective consumers will need to formally enter into a contract. Losing a large proportion of the estimated demand will have a significant impact on viability.
4/ **Increasing capital costs** e.g. unknown/uncertain cost issues become apparent or macro-economic changes increase costs. Presently the analysis suggests even quite large variations will not significantly change the economic outcomes
5/ **Higher operating costs**, particularly the purchase of fuels/electricity which - largely dictated by market pricing (nb. heat and power are primarily purchased from the EfW facility)
6/ **Decreased tariffs and connection costs**, for example, further discounting to help secure consumers
7/ **Carbon emission savings** could be restricted where EfW is non-operational for an extended period. In addition, there is some uncertainty as to how carbon emissions for 'private wire' power sales should be allocated which could negatively affect the environmental credentials of the project – see Appendix 6 note.

Risks
8/ **Peak/reserve supply solution.** After completion of the economic modelling, an indicative quotation for a gas connection for the proposed energy centre gas boiler plant was returned at a price circa £1.7m higher than estimated. This higher cost relates to probable upstream network reinforcement. Whilst the change is significant at an item level, it is not anticipated to have a significant impact on IRR (of the order of -1%). Various solutions should be explored including: a) agreeing an alternative pricing model (with Cadent) to take account of the reduction in the peak gas requirement elsewhere on the gas network since those consumers supplied by the heat network, in principle, no longer need the gas supply capacity of existing boiler plant b) adjusting consumer demand and storage arrangements to reduce peak heat demands c) utilise other peak/reserve solutions such as: i) electric boiler plant - this would require a large power network connection and energy costs will increases, although this could be limited through a PPA with the EfW generator ii) site-stored oil (could be bio-oil to limit carbon emissions) iii) use of retained boiler plant at large consumer points (distributed through the network) d) a combination of the above

Table 6-10 Possible negative change to economic performance

Figure 6-8 illustrates IRR sensitivities to various economic risks for the Network 1: Base (EfW refurbishment / '2-line'). The impact on the base IRR shown here is largely repeated in the graphs for each of the network scenarios.

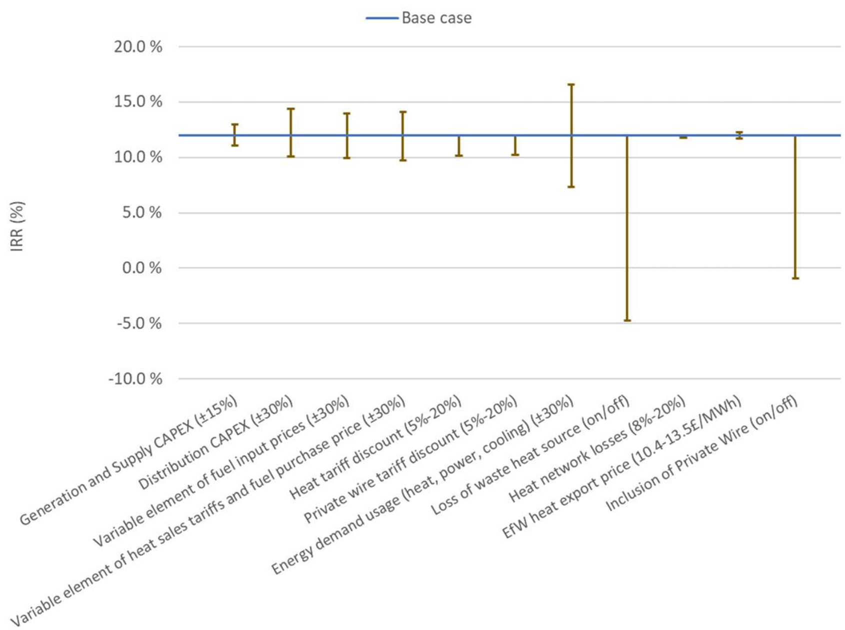


Figure 6-8. IRR sensitivities – Network 1: Base (EfW refurb)

Conclusions from sensitivity analysis

1/ The loss of the EfW supply, i.e. switching to gas boiler only supply leads to a collapse in financial returns from circa 13% IRR to -5% IRR

2/ Total loss of the private wire sales (and associated operating costs) also has a significant impact taking the IRR to below 0% if there is no Private Wire revenue. Figure 6-9 shows the impact in terms of annual cash flow.

3/ Energy demand is the next biggest sensitivity. Whilst this can have a significant impact: (a) it could be positive or negative and (b) where change happens the network would be redesigned/re-sized, mitigating the impact

4/ The other sensitivities tested are (a) not untypical for the heat network scheme, (b) not that significant in comparison with the base IRR, and, (c) could be managed/mitigated as the network designs are developed.

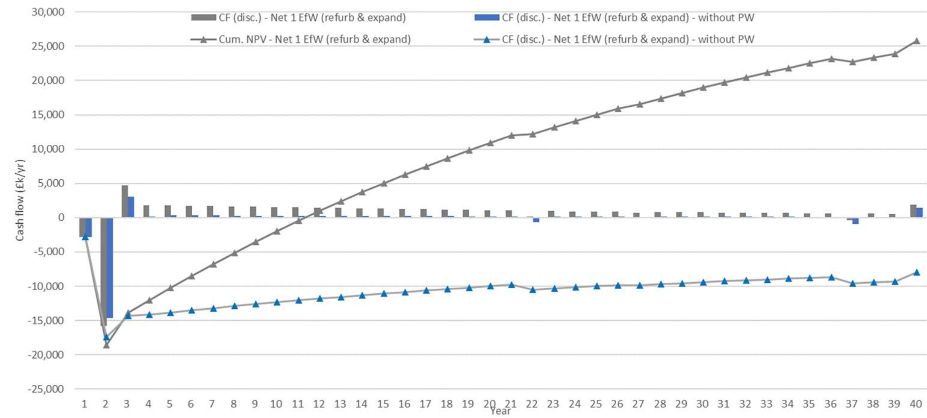


Figure 6-9. Cash flow:Network 1 EfW (refurb/3-line) with/without 'private wire'

University of Wolverhampton and CHP

The Wulfruna Campus currently has a 580kWp gas-fired CHP plant, which is anticipated to reach the end of its useful life around 2025. The heat and power tariffs for Wulfruna Campus for supply from the heat network are calculated based on gas boiler and grid electricity counterfactual, i.e. assuming the CHP is not replaced. For reference, a sensitivity test was run for Network 1 to examine using heat and private wire tariffs designed to compete with a CHP solution. Network 1 was selected because the effect will be most pronounced here. The results of the sensitivity test are presented in Table 6-11 and this shows only a minor downward impact on IRR.

	Network 1 (Base)	
EfW refurb scenario	2 Line	3 Line
Wulfruna Campus BaU: Gas boilers and grid electricity		
IRR (%)	11.6 %	11.8 %
NPV (£m)	25.0	25.8
Wulfruna Campus BaU: Gas CHP, gas boilers and grid electricity top-up		
IRR (%)	11.0 %	11.2 %
NPV (£m)	22.0	22.8

Table 6-11. Wulfruna Campus BaU scenario sensitivity

6.2.7 Consumer benefits

The consumer benefits from the city heat network will motivate individual consumers to commit to connecting to the network. Consumers are generally looking for the same thing: carbon reduction at a cost that is no more (and ideally less) than their current situation. They would compare the heat network offer against a counterfactual, i.e. their current heat (and possibly power) arrangements or their future arrangements if there are plans to upgrade existing systems or they are new build consumers.

Consumers are likely to have differing opinions and different interpretations of their counterfactual energy arrangement, for example, accounting for the long-term cost of operation, maintenance and replacement of on-site supply plant is often overlooked. They may also not have a good understanding of energy-related emissions nor have a good understanding of the how costs of energy supply might change over time.

It is also important to note that connection to a heat network (not the case for private wire power sales) involves the transition from a self-generation and supply model to an external heat supply service model. Instead of generating heat from imported fuel or power they would purchase heat under specific operational terms, covering temperature pressure, availability etc). They will also do away with the need for on-site maintenance, operation and replacement of equipment such as boilers.

Some consumers will also ascribe value to other 'social' benefits such as addressing fuel poverty, local economic development and innovation.

Consumers will also consider both real and perceived disbenefits of a heat network connection such as:

- reliability of supply (including the risk of the supply disruption)
- variability of supply e.g. changing temperatures, pressures and carbon intensity
- disruption during installation, which can be considerable, particularly in properties requiring internal conversion
- uncertainty, particularly during development phases
- commercial risks such as increasing costs (heat supply is currently unregulated)

All of these can be addressed by technical and contractual means as proved in the many successful examples of operational heat networks both in the UK and elsewhere. Where consumers are unfamiliar with heat networks there is a 'learning curve' to go through. It is also important that these issues are addressed through the development of a solution that is appropriately designed and constructed and that is structured (in operational and organisational terms) to addresses the risks that exist.

To support the case for connection for individual consumers it will be important to present each with the basis of an offer that will meet their objectives.

At this stage 'in principle' benefits have been assessed for the two major consumers (>25% of heat demand) in the Base network, UoW and CWC. These are shown in Table 6-12 and Table 6-14.

The consumer tariffs and counterfactual (BAU) costs presented below are based on a 5% reduction of a calculated counterfactual cost, i.e. cost of the current energy supply solution. Tariffs will vary between consumer types, with domestic consumers paying more (per unit of energy delivered) than commercial properties, as per counterfactual costs. This approach aims to represent the economic benefits of the scheme. In practice, tariffs will be a matter of negotiation between the heat supplier and consumers. Various arrangements can be made, e.g. the connection fee can be waived or a larger portion of the cost can be allocated to fixed or variable tariffs.

LCOE outputs are separated for heat and electricity to allow easier comparison between the counterfactual (BAU) case and the networked solution.

The carbon performance of heat supplied by the heat network compared against the counterfactual (BAU) case is also shown.

Consumer	University of Wolverhampton			
Consumer information	Molineux Campus (E-02), Wulfruna Campus (E-04), Student Accommodation (E-03). See connection/access points in section 1.1. Heat supply to all properties Power supply to Molineux and Wulfruna campuses Gas boiler counterfactual in all buildings (Wulfruna CHP assumed to be decommissioned by 2025)			
Energy consumption	**MWh/yr**		**% of network total consumption**	
Heat	15,215		62 %	
Electricity	8,202		57 %	
Costs	**BAU**	**HN (inc. PW)**		
Capital outlay / connection fees	£1.80m	£1.71m		
Operating costs	£2.03m	£1.93m		
Heat tariff, fixed (p/kWh)	£1.4	£1.4		
Heat tariff, variable (p/kWh)	£4.9	£4.7		
Annual heat cost per building (avg.)	£240k	£228k		
LCOE (£/MWh) – heat and power	**BAU - heat**	**HN - heat**	**BAU - electricity**	**PW - electricity**
LCOE, 15 yr	85.6	81.3	133.7	127.0
LCOE, 25 yr	82.2	78.1	133.6	126.9
LCOE, 30 yr	81.5	77.4	133.6	126.9
LCOE, 40 yr	80.6	76.6	133.6	126.9
Carbon (TCO_2) – heat only	**BAU**	**HN**	**Savings**	**Savings-%**
15 yr	42,787	6,793	35,993	84 %
25 yr	75,700	12,019	63,681	84 %
30 yr	92,156	14,632	77,524	84 %
40 yr	125,069	19,858	105,211	84 %
Carbon intensity - heat only (gCO_2/kWh)	**BAU**	**HN**		
15 yr	216	34		
25 yr	216	34		
30 yr	216	34		
40 yr	216	34		

Table 6-12. Consumer benefits – UoW (gas boiler counterfactual)

Note: if power carbon savings are added to the carbon savings calculation this affects carbon savings but there is uncertainty about how this should be attributed (see Appendix 6). Based on two methods of allocating combustion emissions this could change the 15-year emissions savings to between 64% and 25%, with variations over time, since power carbon factors will vary over time. It is also plausible to account for the carbon emission savings of EfW as an alternative to other waste management options, such as, landfill which could be further (and significantly) reduce the carbon emissions attributable to power supply, but this has not been accounted for in this study.

Consumer	University of Wolverhampton			
Consumer information	Molineux Campus (E-02), Wulfruna Campus (E-04), Student Accommodation (E-03). See connection/access points in section 1.1. Heat supply to all properties Power supply to Molineux and Wulfruna campuses Gas boiler counterfactual at Molineux and Student accommodation Gas CHP counterfactual at Wulfruna			
Energy consumption	**MWh/yr**		**% of network total consumption**	
Heat	15,215		62 %	
Electricity	8,202		57 %	
Costs	**BAU**	**HN (inc. PW)**		
Capital outlay / connection fees	£1.80m	£1.71m		
Operating costs	£1.84m	£1.75m		
Heat tariff, fixed (p/kWh)	£1.4	£1.4		
Heat tariff, variable (p/kWh)	£6.0	£5.7		
Annual heat cost per building (avg.)	£244k	£232k		
LCOE (£/MWh) – heat and power	**BAU - heat**	**HN - heat**	**BAU - electricity**	**PW - electricity**
LCOE, 15 yr	98.3	93.4	90.0	85.5
LCOE, 25 yr	95.1	90.3	90.0	85.5
LCOE, 30 yr	94.4	89.6	90.0	85.5
LCOE, 40 yr	93.5	88.8	89.9	85.4
Carbon (TCO_2) – heat only	**BAU**	**HN**	**Savings**	**Savings-%**
15 yr	63,957	6,793	40,352	86 %
25 yr	111,733	12,019	71,392	86 %
30 yr	135,446	14,632	86,913	86 %
40 yr	182,839	19,858	117,953	86 %
Carbon intensity – heat only (gCO_2/kWh)	**BAU (inc. PW)**	**HN**		
15 yr	210	34		
25 yr	207	34		
30 yr	207	34		
40 yr	205	34		

Table 6-13. Consumer benefits – UoW (with Wulfruna Gas CHP)

Note: if power carbon savings are added to the carbon savings calculation this affects carbon savings but there is uncertainty about how this should be attributed (see Appendix 6). Based on two methods of allocating combustion emissions this could change the 15-year emissions savings to between 69% and 36%, with variations over time, since power carbon factors will vary over time. It is also plausible to account for the carbon emission savings of EfW as an alternative to other waste management options, such as, landfill which could be further (and significantly) reduce the carbon emissions attributable to power supply, but this has not been accounted for in this study.

Consumer	City of Wolverhampton Council			
Consumer information	Wolverhampton Art Gallery (E-06), Civic Centre (E-07), Civic Hall (E-08), Magistrate Courts (old Town Hall building) (E-09), Leisure Centre ("Baths") (E-10), Molineux Hotel (E-11). See connection/access points in section 1.1. Heat and power supplied to all consumers			
Energy consumption	**MWh/yr**		**% of network total consumption**	
Heat	6,860		28 %	
Electricity	6,251		43 %	
Costs	**BAU**	**HN (inc. PW)**		
Capital outlay / connection fees	£1.01m	0.96m		
Operating costs	£1.11m	£1.06m		
Heat tariff, fixed (p/kWh)	£1.8	£1.7		
Heat tariff, variable (p/kWh)	£3.1	£2.9		
Annual heat cost per building (avg.)	£158k	£150k		
LCOE (£/MWh) – heat and power	**BAU - heat**	**HN - heat**	**BAU - electricity**	**PW - electricity**
LCOE, 15 yr	69.1	65.6	129.1	122.6
LCOE, 25 yr	64.7	61.4	129.0	122.6
LCOE, 30 yr	63.7	60.5	129.0	122.6
LCOE, 40 yr	62.5	59.4	129.0	122.6
Carbon (TCO_2) - heat only	**BAU**	**HN**	**Savings**	**Savings-%**
15 yr	19,291	3,063	16,228	84 %
25 yr	34,130	5,419	28,711	84 %
30 yr	41,549	6,597	34,952	84 %
40 yr	56,388	8,953	47,435	84 %
Carbon intensity - heat only (gCO_2/kWh)	**BAU**	**HN**		
15 yr	216	34		
25 yr	216	34		
30 yr	216	34		
40 yr	216	34		

Table 6-14. Consumer benefits - CWC

Note: if power carbon savings are added to the carbon savings calculation this affects carbon savings but there is uncertainty about how this should be attributed (see Appendix 6). Based on two methods of allocating combustion emissions this could change the 15-year emissions savings to between 69% and 35%, with variations over time, since power carbon factors will vary over time. It is also plausible to account for the carbon emission savings of EfW as an alternative to other waste management options, such as, landfill which could be further (and significantly) reduce the carbon emissions attributable to power supply, but this has not been accounted for in this study.

7 Conclusions & Recommendations

7.1 Conclusions

The previous section describes the modelled performance of the various networks considered, together with a review of potential variance due to a variety of risk factors, including changes in heat and power revenues and capital costs.

Based on this analysis and the broader context of the possible heat network project, the following conclusions have been identified:

1. **Reviewed against Critical Success Factors, all of the 3 network options essentially meet the stated objectives.**
2. **All network solutions deliver significant carbon reduction** for heat supply of between 65-90%. These figures are calculated with the exclusion of 'private wire' power sales may depress the savings achieved, depending on the carbon accounting methodology used. It should be noted that the carbon reduction for heat supply is driven by the proportion of energy delivered by the EfW facility but also the assumed counterfactual energy supply (that it is assumed the network replaces). Where this includes future new development, carbon reduction is calculated to be lower because future property standards are expected to result in lower counterfactual carbon emissions. The carbon factor for the heat from the EFW facility will also vary depending on the offtake arrangements of the steam turbine.
3. **All network solutions show a strong return on investment** and appear investable (IRRs between 11.6-13.0% - assumes private wire power sales).
4. **All network solutions offer significant wider socio-economic benefits**. Although these wider benefits have not been quantified within this project, they would include reduced energy costs for consumers (which can be adjusted depending on the project objectives), inward investment, employment (construction and O&M) and related education, research and training opportunities.
5. **Network 2 (Base+East) performs best out of all options in terms of return on investment**. The differences are relatively marginal suggesting that decisions around the preferred network option to be pursued should focus on deliverability, noting that the larger networks present greater delivery risks.
6. **Extending the network has a small positive impact on viability.** This applies to both the East or West extension options.
7. **The assumed optimised EfW/steam turbine plant provides 'headroom' for expansion beyond the 3 network options considered.** Within the analysis conducted it is important to note that the cost of new turbine capacity is assumed to be covered within the EfW refurbishment costs, i.e. only offtake costs are considered within this analysis.
8. **The EfW plant provides 'headroom' for expansion beyond the 3 network options considered.** The total heat production potential is estimated at circa 50 GWh/yr (2 line) and circa 75 GWh/yr (3 line) whilst the total demand of the three network options sits between 27-45GWh/yr.
9. **Expanding the EfW plant's heat production capacity** (the 3 line option) has a small positive impact on project viability and a positive impact on carbon savings as well as providing greater future flexibility to expand the heat networks served by the EfW plant. It would also provide greater resilience since two lines could be taken out of operation whilst still enable energy generation.
10. **Numerous techno-economic risks need to be addressed.** The following are of particular importance:

a. finalising the plans for the EfW plant (without which there is no economic case for the heat network as envisaged – although other heat network solutions are plausible where alternative primary low carbon energy supply can be identified)

b. securing key consumers (particularly UoW and CWC)

c. the sale of power (private wire network).

11. **Opportunity for grant support.** At the levels of economic performance shown it is highly likely that a Special Purpose Vehicle, perhaps a joint venture between the Council and UoW, could finance the project with a blend of council and university funding. Where there is a funding gap or where there is a wish for the network to be funded by a private heat network business then grant funding from the Green Heat Network Funding may be appropriate to drawdown. This £280m government programme is due to launch in 2022 and is intended to provide capital support for low carbon networks, including those using the EfW as the primary supply technology. Further details regarding the programme are anticipated in summer 2021.

7.2 Recommendations

The following recommendations are made:

1. **Commission Detailed Project Development (DPD) phase of work.** This should result in the development of a Treasury standard business case and resolve project structuring and financing solutions to suit key stakeholder needs**.** There is a good case for a heat network project assuming the EfW plant is renewed (with or without expansion). The indicative economic performance is strong and there are few consumer stakeholders (particularly in the Base network) and all are motivated to connect to a centralised heat network scheme. There are numerous delivery risks but these are considered typical for a heat network project and can be addressed through a systematic development process, using appropriate expert support.

   Assuming a DPD process can start in Q3 2021 it would likely be complete by the end of Q2/3 2022, giving time to address key uncertainties around the supply, consumers (including the identified network extensions) and network (through a 'route proving exercise').

   As well as developing the evidence base for the project and addressing the key risk items (as discussed previously), the principal output of this stage is an Outline Business Case (OBC). The OBC will capture key decisions around the nature of the preferred network scheme but also establish the preferred project structure and financing options.

   On the basis formalised in the OBC, the council (assuming they lead the development) with stakeholders/partners would commercialise the scheme, resolving project finance, establishing the necessary organisations and then let the key contracts for design, construction and operation of the network.

   Until specific plans for the EfW plant and a delivery programme is in place, the programme for the post-DPD development stages for the heat network is not certain.

2. **Finalise plans for the EfW plant.** The DPD process will require greater certainty over the EfW options being considered.

   Simplified scenarios have been developed to enable review of possible options, but this will not be sufficient to support an Outline Business Case and it will likely undermine the confidence of key stakeholders and prospective consumers unless resolved. It is therefore essential for CWC to rapidly complete the examination of options.

   It is recommended that:

(1) the EfW plant is renewed and an optimised steam turbine arrangement (to limit power generation losses) is installed as this would support the delivery of a major long term decarbonisation project which will have a profound impact on carbon emissions with the city in the short term and support the establishment of infrastructure (hard and soft) that will enable sustained decarbonisation over time

(2) An expanded 3 line facility is constructed. This will significantly increase the headroom for the expansion of the heat network well beyond the 3 options identified within this study it will also increase the carbon reduction potential.

(3) Examine the possibility of locating the primary heat network energy centre on the EfW facility site at Crown Street. Where this is not possible, the DPD work should include a review of other viable locations.

3. **Planning policy (zoning) and development control**. It is recommended that CWC explores the introduction of planning policy that would seek to encourage and facilitate connection to the heat network to both new development and existing properties (for example, when they seek to renew existing boiler plant). This could include establishing a 'heat hierarchy' policy, with low carbon heat network connections being prioritised, possibly limited to specific zones. It is understood that the draft Black Country Plan (which is intended to operate as a Local Plan for each of the four boroughs of the Black Country) includes such policies. A draft of this is due to be issued for consultation in summer 2021 and it is anticipated to be adopted between 2024 and 2026. Subsequent local planning policy and/or guidance may be required to address locally specific issues associated with this project, including giving general permission for the implementation of heat network infrastructure. For reference, the Government is intending to run a consultation on 'heat zoning' policies, in summer 2021, which will support the implementation of supportive policies nationally.

4. **Plan for connection of council buildings**. CWC buildings are a significant proportion of the loads proposed particularly in the Base network. This should include addressing the uncertainties with the City Hall (Base network) and the other properties identified for the network extensions (Library, Job Centre, Grand Theatre, Adult Education College).

   Also, by publicly committing to connect its properties (and the development it plans to bring forward), CWC would both directly support the development of the network and encourage others to connect.

5. **Investigate the connection of the identified property development schemes that CWC is leading or is a party to, e.g. as landowner, and encourage other developers to do the same.**

   Other than the Canalside Gateway, CWC influenced developments are associated with the two network extensions options.

   It will be important that expert assessment is made regarding the design and commercial impacts of heat network connections for these schemes.

   Issues that should be considered include:

   (1) location of development-wide heat substation and network infrastructure

   (2) property design to operate at appropriate temperatures (ideally underfloor heating) and to accommodate heat interface units

   (3) temporary provision of supply plant on-site if a heat network connection is not available before construction

   (4) commercial and legal issues associated with the localised sale of heat (and possibly power), including how sale and tenancy agreements need to account for these issues.

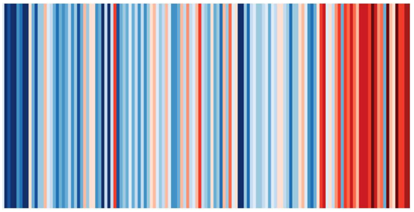
6. **Maintain engagement with key consumer stakeholders** particularly for the Base network (UoW, Wolverhampton Homes, Wolverhampton Wanderers and the development sites identified). In particular, the following will likely be important:

    UoW: understanding changes to estate plans that may materially affect the prospective heat network connections, including (a) building-level decarbonisation investment, (b) decisions around the existing gas CHP at Wulfruna, e.g. contract renewal, (c) development plans for Springfield Campus which may influence a connection decision, (d) decisions around the future provision of on-site residential accommodation

    WH: progression of plans for cladding of the Boscobel flats and the establishment of a local heat network and substation which should be designed to be compatible for later connection to the city heat network

    Wolverhampton Wanderers: request that sub-metering is installed (could be temporary) to improve certainty over thermal demands that could be supplied by a heat network

    Other consumers: For the other consumers in Network 2 and 3, uncertainty over demand estimates, the likelihood of connection and connection timing constraints are greater than for the Base network. Whilst it will be important to review these consumers in the DPD stage CWC could consider some engagement measures such as an email campaign and online workshops. This will help to address the programme risks of re-initiating consumer engagement if there is a hiatus as background work progresses.



Annual UK temperatures 1884-2018

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