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THAMESMEAD & BELVEDERE

HEAT NETWORK FEASIBILITY STUDY: WORK PACKAGE 2

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HEAT NETWORK FEASIBILITY STUDY: WORK PACKAGE 2

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EXECUTIVE SUMMARY

This report presents the findings from the second stage ("Work Package 2") of a detailed techno-economic feasibility study for a new District Energy (DE) network linked to the Cory Energy-from-Waste plant and delivering heat to the Thamesmead & Belvedere area of Bexley.

The broad requirements for this stage of the study were to:

1. Revisit and update previous energy demand assessment work.
2. Refine selection of heat supply plant and infrastructure sizing and routing.
3. Reflect requirements / recommendations for elements of network future-proofing.
4. Produce concept design information for proposed plant and network.
5. Determine network commercial performance and test key sensitivities.
6. Produce supporting techno-economic discounted cashflow model.

As part of this work, additional supporting information was gathered and meetings held with the following key project stakeholders:

- London Borough of Bexley
- Cory (plus commercial and technical advisors)
- Peabody Housing Association
- Great London Authority (GLA)

The key updates reflected beyond previous Work Package 1 works are as follows:

1. Reflecting Cory modelling and guidance, a heat offtake availability of 90% per annum was reflected within the concept design and techno-economic modelling of the network, accounted for by provision of limited backup gas-fired boiler plant and thermal storage.

2. Network CAPEX build-up was refined to allow for greater resolution of costs, including; design costs and consultancy fees, Planning support costs, Contractor preliminaries, builders work in connection plus system testing and commissioning.

3. Information was gathered on location and types of existing buried utilities present within the proposed extent of the Core Scheme network.

4. Modelling undertaken to determine heat offtake pricing was refined to reflect the more detailed information discussed with and shared by Cory and their partners, including a split to include fixed and variable components.

5. Customer heat pricing was similarly refined and split between fixed and variable components, comprising annual standing charges and heat tariffs, whilst still retaining a 10% discount versus counterfactual provision of heat determined via heat price comparators calculations.

6. Previous assumptions on network transmission and distribution heat losses were replaced with figures determined by hydraulic modelling.

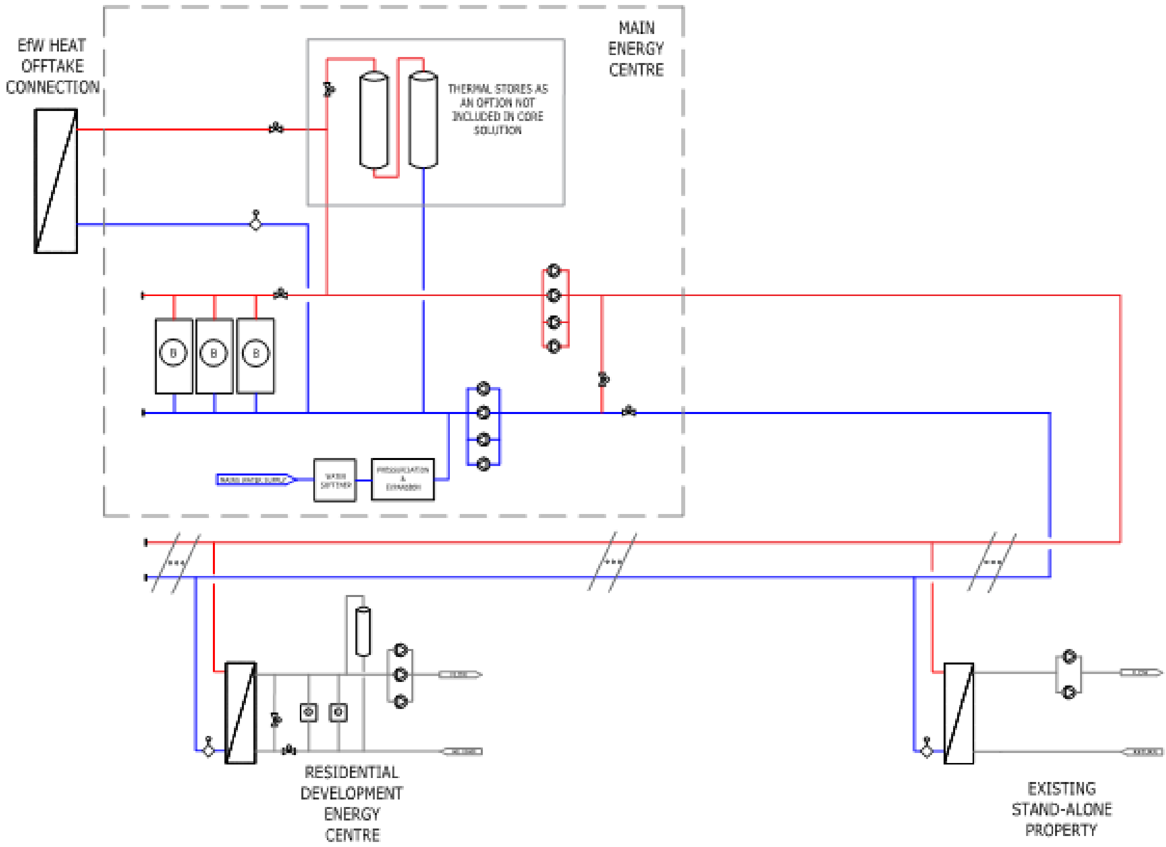


Figure 1: Outline heat network schematic

The key findings from Work Package 2 are as follows:

1. The total level of heat demand and annual consumption determined for all loads modelled for connection to an initial "Core Scheme" network, comprising the Belvedere, Thamesmead and Abbey Wood redevelopment areas (plus limited adjacent existing buildings/sites) can be met via heat offtake from the Cory EfW plant.

2. In line with Cory's proposed annual availability of 90% for heat offtake, the provision of supplementary heat generation and storage is required to meet year-round demand and is proposed to comprise a mix of centralised and distributed plant.

3. The techno-economic modelling undertaken indicates that delivery and operation of a full Core Scheme network could achieve IRRs in the region of 7.5% – 11.1% (depending upon inclusion of its extension into Erith) and positive NPVs, whilst providing competitively priced heat to all connected customers. Additional analysis has tested the sensitivity of these metrics to a range of key parameters, both in isolation and combined.

4. The predicted commercial performance of the project upon full build-out has improved since the earlier Work Package 1 work for the following reasons:
    a. The previous (conservative) assumption that a network operator would make adoption payments in relation to developers' secondary distribution has been replaced with receipt of connection charges, calculated as the avoided costs to developers of installing the low-carbon heating plant otherwise required.

b. Figures of gas tariffs and standing charges previously used to determine counterfactual costs have been updated using latest Uswitch data specific to the Borough of Bexley – this has resulted in an increase to base case cost, and therefore also to network heat charges, of 18% whilst retaining provision of a 10% discount.

5. The utilising of heat generated from the Cory plant, at the point of full Core Scheme buildout, could deliver an overall CO_2 saving of 3,970 tonnes/annum against a counterfactual case of new Air-Source Heat Pump plant, adhering to projected new London Plan requirements, or 14,900 tonnes/annum against a case of gas-fired CHP led communal heating schemes.

6. If a more aggressive build-out scenarios were considered for the Core Scheme and additional sites further afield in Bexley and particularly Greenwich, where build-out is closely linked to potential new transport links, further improvement would be seen tot eh network commercial case. It is also likely that a further heat source(s) beyond the existing Cory plant would be required to meet any significant increases to total heat demands.

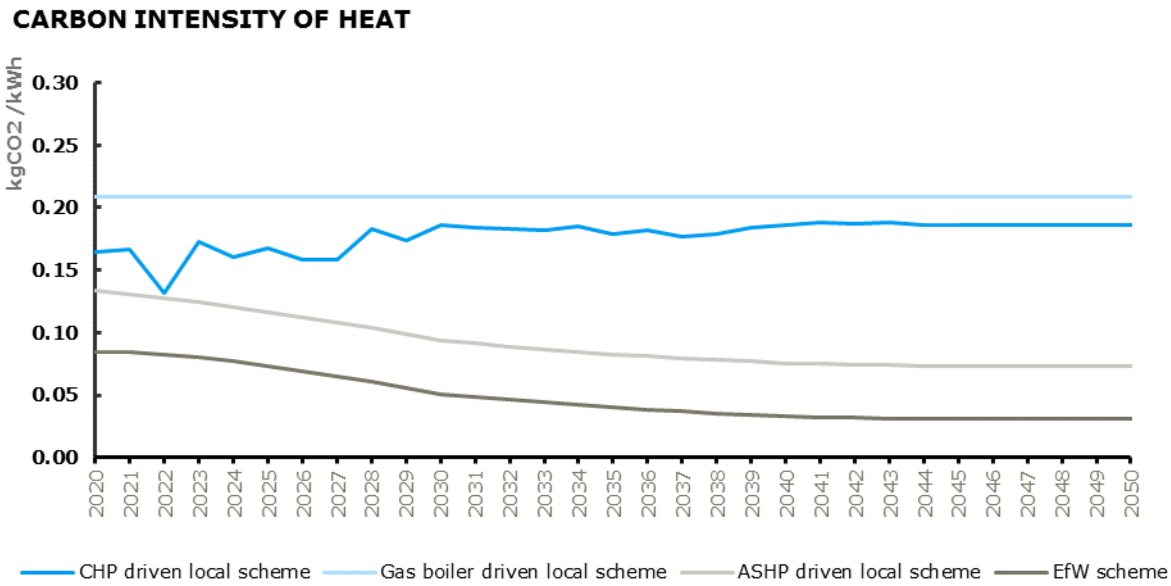


Figure 2: Carbon intensity of DH network heat versus counterfactual scenarios

The recommended next steps for the project are as follows:

A. Project to be taken forward to the stage of developing an Outline Business Case.

B. LBB to progress early discussions with Cory over the principles and arrangements for heat offtake pricing (with meetings in this regard already planned).

C. Engagement with other LBB development partners to be sought to the level already in place with Peabody, with Orbit Homes identified as one such key party.

D. LBB to consider and determine its key objectives and goals for the network and with this its preferred role and level of engagement going forward in development and delivery of the scheme, as part of wider discussions with known and potential partners.

E. LBB to continue close working with the GLA, given the strategic importance of the project, to maintain and maximise their support and added value going forward.

F. Seeking of advice and support from appropriate Commercial and Legal partners to develop draft agreed Heat of Terms for heat sale agreements, expected to involve (at least) Cory and Peabody.

G. Consider in more detail the option of seeking project capital funding via the Government's HNIP scheme, including identifying the best time during project development to apply for this support.

1. INTRODUCTION

1.1 Background

Ramboll were appointed by the London Borough of Bexley (LBB) in April 2018, under the Greater London Authority (GLA)'s Decentralised Energy Enabling Project (DEEP), to undertake a detailed techno-economic feasibility study for a new District Energy (DE) network linked to the Cory Energy-from-Waste plant and delivering heat to the Thamesmead & Belvedere area of Bexley.

This DE network was initially proposed within the previous Energy Masterplan (EMP) study, undertaken in 2015, following earlier heat mapping work carried out for LBB by Ramboll in 2011.

This study is being carried out across two discrete Work Packages as follows:

- Work Package 1 (WP1): comprising a review and update of previous energy mapping and masterplanning work.
- Work Package 2 (WP2): comprising a detailed techno-economic feasibility study.

This report summarises the works undertaken and findings of **Work Package 2**.

1.2 Work Package 2 Scope

The primary scope items for Work Package 2 were defined as follows:

1. Scheme design and economics should be optimised and include consideration of UK best practice options.
2. Energy demand and assessment work to include:
    a. Define core demand and supply energy data, including peak and annual loads.
    b. Split of demands by customer type.
    c. Undertake site surveys for existing buildings planned for network connection.
3. Energy centre / central plant work to include:
    a. Determine CO_2 emissions against counterfactual technology case.
    b. Determine requirements and location for backup/temporary boilers and thermal storage plant.
    c. Identify plant phasing and associated future-proofing requirements.
    d. Assess existing utilities infrastructure.
    e. Produce outline design for recommended scheme, including layouts, schematics, key criteria or outline specifications and GIS representation.
4. Energy distribution systems work to include:
    a. Hydraulic modelling, optimisation and sizing/selection of heat pipe network for recommended scheme.
    b. Identification of route constraints and mitigation recommendations.
    c. Provision of design/operating parameters and an outline network schematic.
5. Techno-economic cashflow modelling to include:
    a. Provision of costs and income for recommended scheme within a discounted cashflow model, considering a 25, 30 and 40-year life cycle.
    b. Accompanying documentation of assumptions underpinning cashflow model.
    c. Short user guide for cashflow model.
    d. Model outputs to include calculated NPV and IRR across required life cycles.

    e. Inclusion of future phasing options capable of being switched on or off.
6. Provision of a Risk & Issues register.

This report has been structured in line with these scope items and also to document how previous work under Work Package 1 has been progressed and developed further.

2. ENERGY DEMAND ASSESSMENT

SUMMARY OF WORK PACKAGE 1 FINDINGS (for full details, refer to WP1 report)

Works during Work Package 1 derived a combined heat load for all planned developments and selected existing buildings within the study area totals of 139 GWh/year, at the time of full build-out.

Within this, redevelopment areas in/around Belvedere comprised the largest single heat load cluster with buildout commencing in 2020 and continuing for 35 years, as shown in Figure 3.

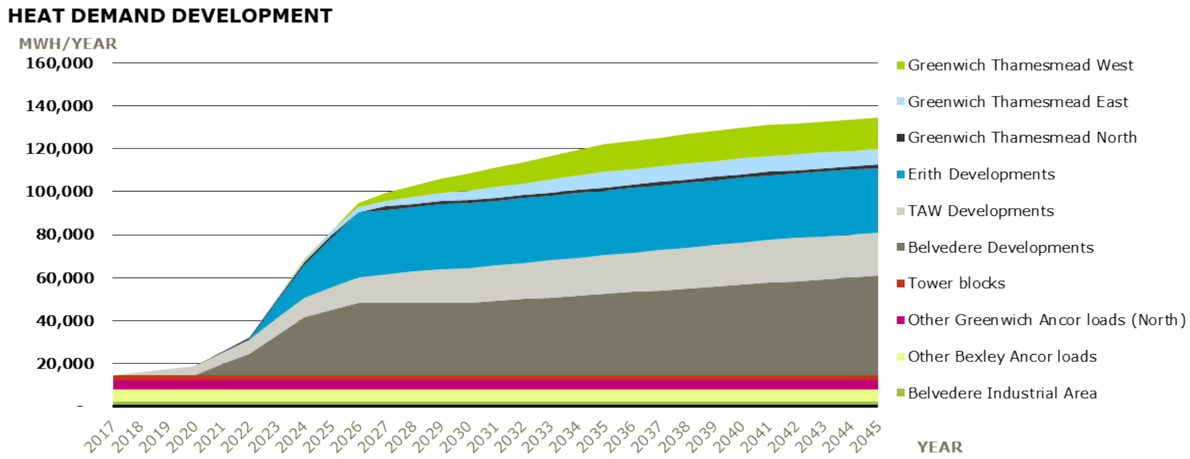


Figure 3: Overall heat demand development

The location, scale and timing of all assessed loads was also assessed, as displayed in Figure 4, with indications given for radial distance of all identified loads from the Cory EfW plant.

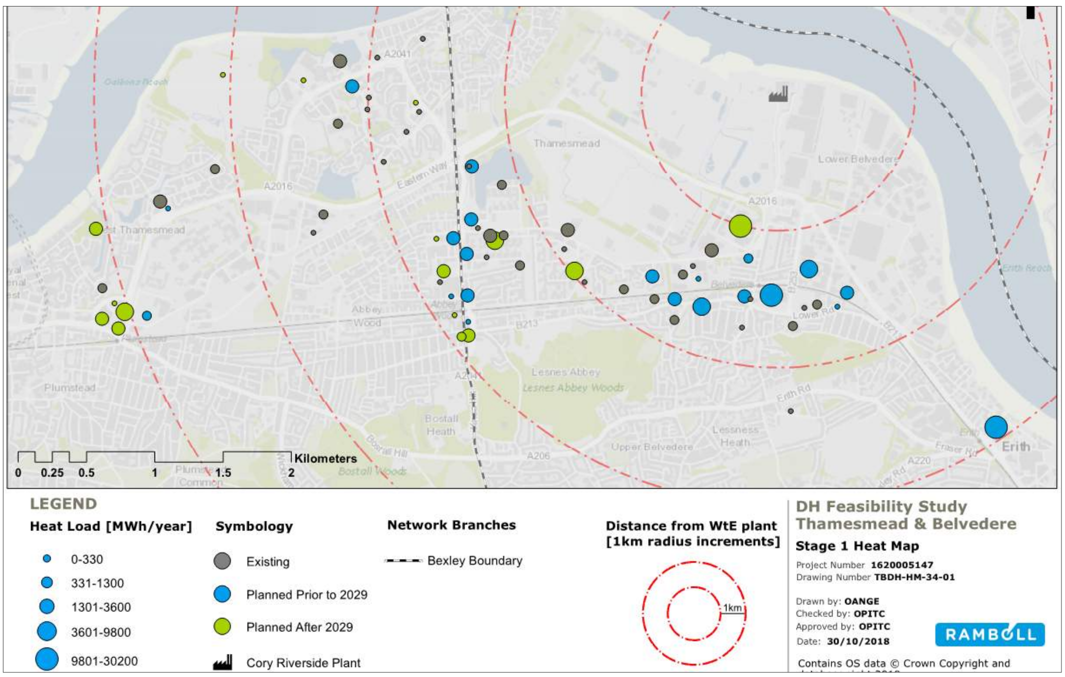


Figure 4: Full assessment area heat map

The following next steps were identified to be undertaken during Work Package 2, to refine and confirm details of energy demand initially modelled:

i. Further granularity of new residential development quanta to be sought and applied in relation to the Erith area.
ii. Any energy consumption data available for the retained/refurbished South mere and Parkview residential towers to be sought and applied.
iii. The status and load information for existing non-residential loads considered for connection to be confirmed and updated as required.
iv. Any information on existing infrastructure and data available for energy consumption of largest industrial sites within Burt's Wharf to be sought and applied.

WORK PACKAGE 2 REFINEMENT

2.1 Erith Development Areas

As part of work under WP2, a meeting was held with LBB Planners to share the latest details of development intentions and quanta associated with the Erith area. The extent and layout of the development areas for which data was supplied are shown in Figure 5.

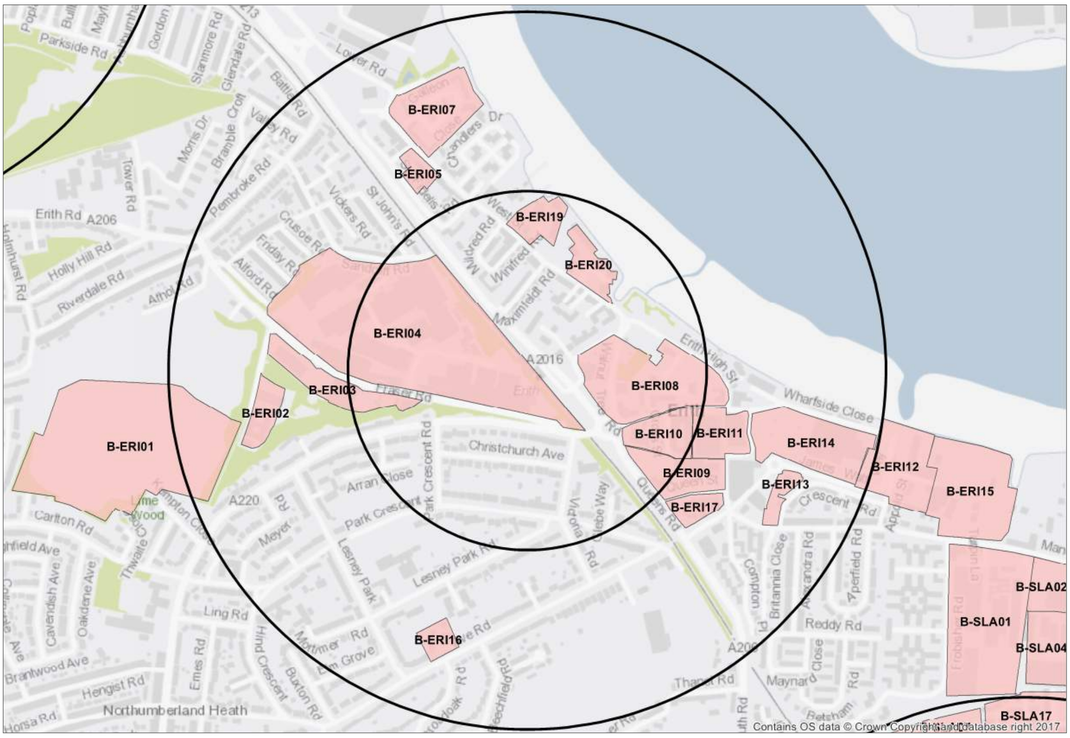


Figure 5: Erith development areas

With a variety of differing development buildout scenarios developed by LBB, it was agreed to reflect and apply the quanta involved with the "2017 SHLAA" figures, being those developed agreed with the GLA.

The provided figures for residential units within each defined development area were used to determine associated heat loads, as displayed within Table 1.

Site ID	SHLAA residential units	Estimated start date	Estimated build-out duration (years)	Heat Demand (on completion)
B-ERI01	514	2016	13	3,335
B-ERI02	39	2029	12	253
B-ERI03	96	2029	12	625
B-ERI04	602	2029	12	3,908
B-ERI05	42	2019	5	272
B-ERI08	410	2019	10	2,659
B-ERI09	201	2024	10	1,302
B-ERI10	111	2024	10	723
B-ERI11	71	2034	7	462
B-ERI12	0	-	-	-
B-ERI13	57	2024	10	369
B-ERI14	286	2024	10	1,854
B-ERI15	0	-	-	-
B-ERI16	31	2016	3	198
B-ERI19	26	2029	12	166
B-ERI20	110	2034	7	717
B-ERI07	-	-	-	-
B-ERI17	-	-	-	-

Table 1: Heat demand for Erith development areas (based on 2017 SHLAA growth scenario)

These figures were used to refine the previous energy demand assessment modelling, replacing the earlier assumptions previously applied around quanta and geography.

2.2 Retained Southmere & Parkview Towers

2.2.1 Site Visit

A site visit was held on 5th March 2019 to the residential tower blocks being retained as part of redevelopment works in the Thamesmead/Abbey Wood area. This visit was facilitated and accompanied by Hugo Buchanan of Peabody and included limited access provision to ground floor plant areas of the towers.

2.2.1.1 Southmere Towers

The Southmere towers were originally served by a district heating network, prior to its replacement with gas supplies to individual flats for local boilers.

Figure 6: Visible external gas distribution pipework to individual flats

During the site visit, evidence of the previous DH arrangement was seen via a combination of access points within roadways and also remaining above-ground sections of pipework.

Figure 7: Manhole access points approaching tower plant room

Figure 8: Defunct DH pipework running with car park area

As with all blocks in the area, the Southmere towers were designed with no flats at ground level in order to accommodate communal and plant spaces. The tower ground floor plates currently accommodate the following rooms, all of which were identified from the outside:

- Electrical equipment room.
- Bin store.
- Gas meter (and possibly booster) room.
- Staff toilet.

In addition to defined areas, instances were noted of previous doorways to other unknown ground floor spaces being sealed up, possibly as a result of removal of plant previously associated with incoming DH connections.

Figure 9: Southmere ground floor spaces

Access was possible to the ground floor level of one of the Southmere towers, Osney House. Within the SE corner of the building's footprint, a room was inspected that appeared to be the point at which the previous DH network entered the building, as shown in Figure 10

Figure 10: Capped DH pipework entering Osney House

Also located within this room was the shell of a previous item of DH plant, suspected to be either a DHW storage tank or heat exchanger, shown in Figure 11 .

Figure 11: Previous DH plant

Finally, onward pipework could be seen leaving the room, either running internally to serve Osney House or potentially beyond to distribute to all the Southmere towers.

Figure 12: Disconnected distribution pipework

With the design and layout of all towers believed to be the same, it is likely that each features a now redundant plant room at ground floor level which could potentially be reused as a location for a primary heat substation to serve the buildings.

2.2.1.2 Parkview Towers

Similar to the Southmere site, all existing residential towers on the Parkview Estate were linked to a district heating network at the time of their construction but have since had all flats fitted with individual boilers and according gas supplies installed.

Figure 13: Parkview flats viewed from podium walkway

Unlike Southmere, however, the majority of major distribution pipework involved with the previous heating network were routed above ground, with large extents still visible alongside the estate.

Figure 14: Examples of above-ground defunct DH pipework

Though no access was possible at the time of the visit to ground floor plant rooms and spaces within the Parkview towers, the design and layout are believed to match that of the Southmere towers.

2.2.2 Revision of Energy Consumption Data

Following the visits held to the existing towers to be retained and form part of the developed Thamesmead/Abbey Wood estate, updates were made to the assumptions applied in determining current heat loads for all buildings in recognition of confirmed number of flats and typical floor areas.

Also requested of Peabody were any records of metered gas consumption for all or a representative proportion of the flats/buildings in place.

At the time of reporting, this information had not been collated or provided but could be made available to inform further heat network design development work.

2.3 Revisions to Existing Building Loads

A high-level exercise was undertaken with LBB to test the data previously gathered for existing non-residential Council buildings considered for connection to the network.

This work revealed a number of known changes to buildings, including planned or enacted vacating of these with unconfirmed plans in place to redevelop the sites.

On this basis, it was agreed with LBB that the identified sites would be named within this study but that no loads or modelling of their connection would be included, with further consideration and investigation of this potential to follow at a later stage of the project.

2.4 Updated Demand Assessment Results

Following the findings identified in the preceding sections, the heat demand assessment was updated resulting in a revised total figure of 141 GWh/year for all potential connections at the time of full build out.

The core scheme accounts for 97 GWh/year of this, with Erith adding a further 17 GWh/year as is shown in Figure 15.

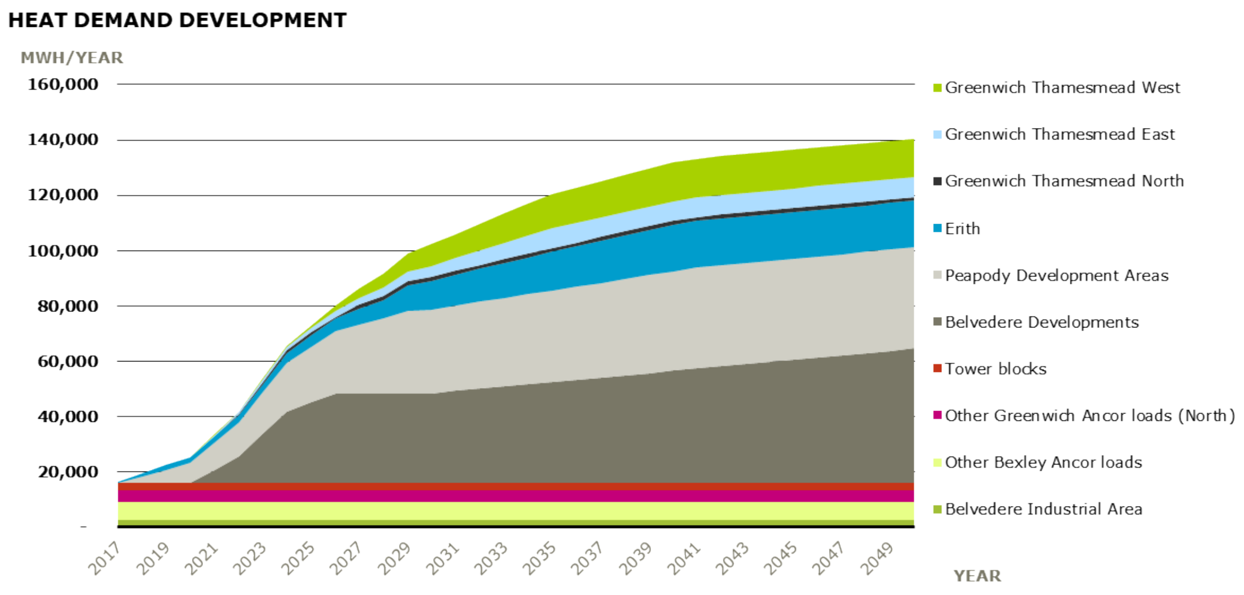


Figure 15: Overall heat demand development WP2

The network routing with scale and timing of all assessed loads for the core network plus the Erith extension is shown in Figure 16, with indications given for radial distance of all identified loads from the Cory EfW plant.

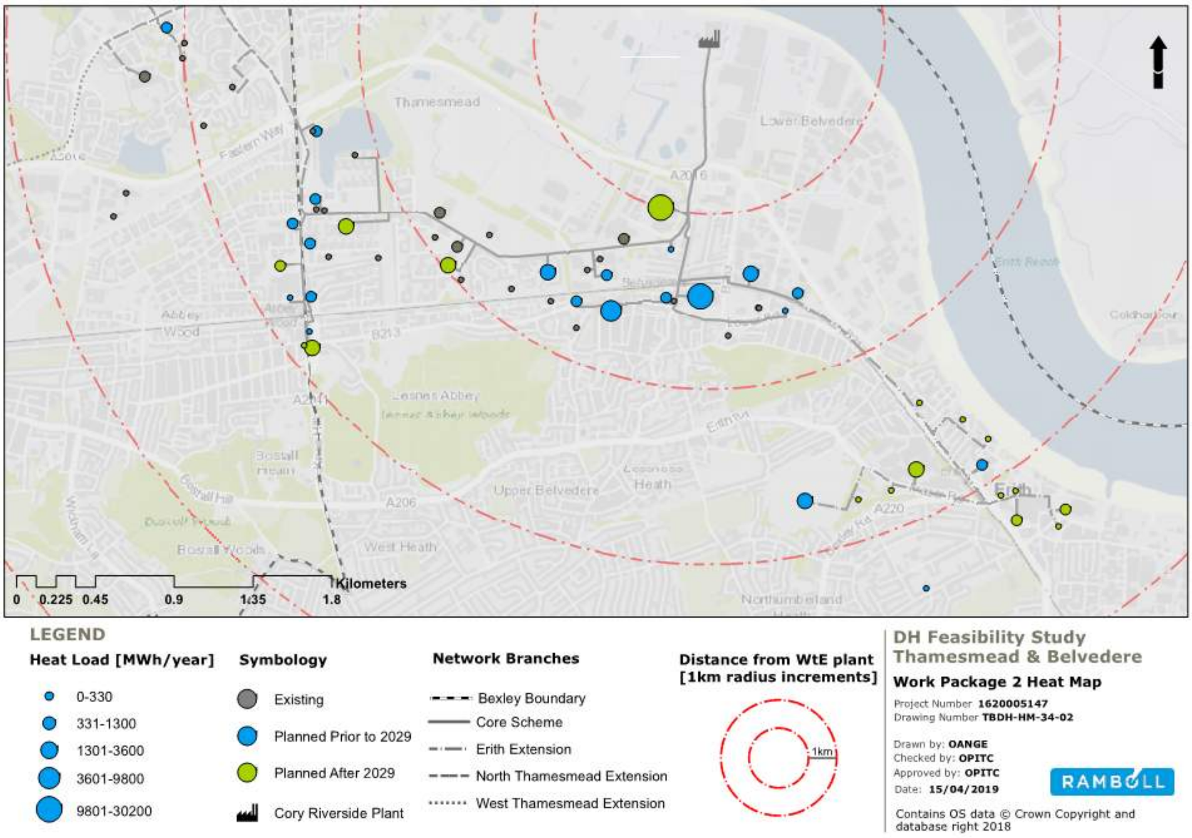


Figure 16: Full assessment area heat map

The opportunity and impact of extending the Core Scheme to incorporate connections and supply to the Erith development area has been further assessed with results provided later within this report.

3. ENERGY SUPPLY ASSESSMENT

SUMMARY OF WORK PACKAGE 1 FINDINGS (for full details, refer to WP1 report)

Works during Work Package 1 identified a peak heat offtake capacity available from the Cory EfW plant of 28.6 MW, leading to a maximum annual supply capability of up to 200,000 MWH/year.

This annual capacity was plotted against the extent of assessed heat loads with potential to connect to a new DH network, considering the linear distance of these from the plant, with results as shown in Figure 17.

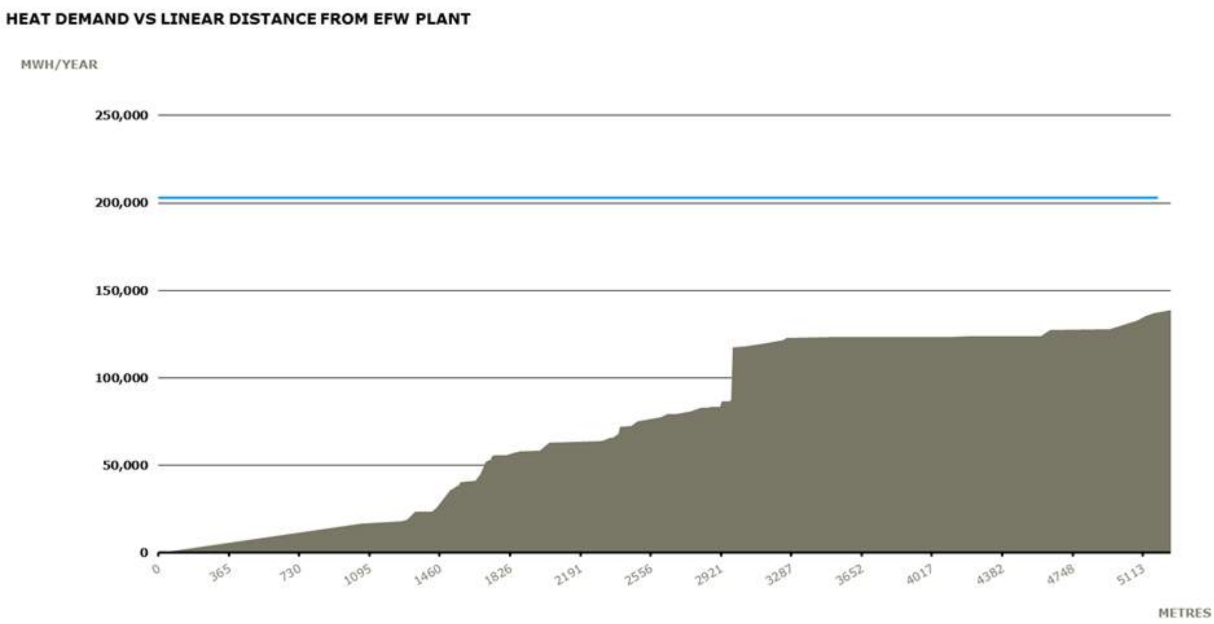


Figure 17: Modelled scheme heat demand by distance from Cory plant

To inform the WP1 high-level assessment of heat supply options, early information was also sought from Cory in terms of key technical and commercial parameters associated with a new heat offtake connection from the existing plant, with those supplied indicated in Table 2.

Table 2: Early plant operation data from Cory

Data Requested of Cory	*Data Provided*
Current Z-Factor	4.3
Current Electrical Export Prices (£/MWh)	61 in summer 65 in winter

The following next steps were identified to be undertaken during Work Package 2, to refine and confirm details of heat offtake arrangements from the Cory plant:

i. Liaising with Cory and their technical advisors on requirements and costs involved with achieving required heat offtake from plant.

ii. Liaising with Cory and their commercial advisors on methodology and metrics to be applied in derivation of assumed bulk heat purchase pricing.

WORK PACKAGE 2 REFINEMENT

3.1 Cory Engagement

A meeting was held with Cory and their technical & commercial advisors (Fichtner and Inventa respectively) on 22nd February 2019, in order to gain an appreciation for the work already undertaken with regard to plans for facilitating heat offtake from the EfW plant.

3.1.1 Heat Offtake: Technical Arrangements

Works have been undertaken by Fichtner to assess the technical arrangements and spatial requirements to achieve the maximum intended heat offtake capacity from the Cory plant of 28 MWth when operating in combined heat and power (CHP) mode.

Based upon heat provision via 2 no. shell and tube steam to water heat exchangers, with selected capacities of 20 MW and 5 MW respectively, this assessment determined the following spatial arrangements to accommodate plant associated with heat transfer for export from site:

1. Total footprint area of approx. 150m^2.
2. Split of plant across 3 no. levels (ground & first floor plus roof).
3. Floor-to-floor heights of 4m, to align with existing facility floor levels.

It is proposed that this new plant space be located adjacent to the existing turbine hall, in order to minimise lengths and associated costs of connecting steam and condensate pipework, with an arrangement as shown within Figure 18.

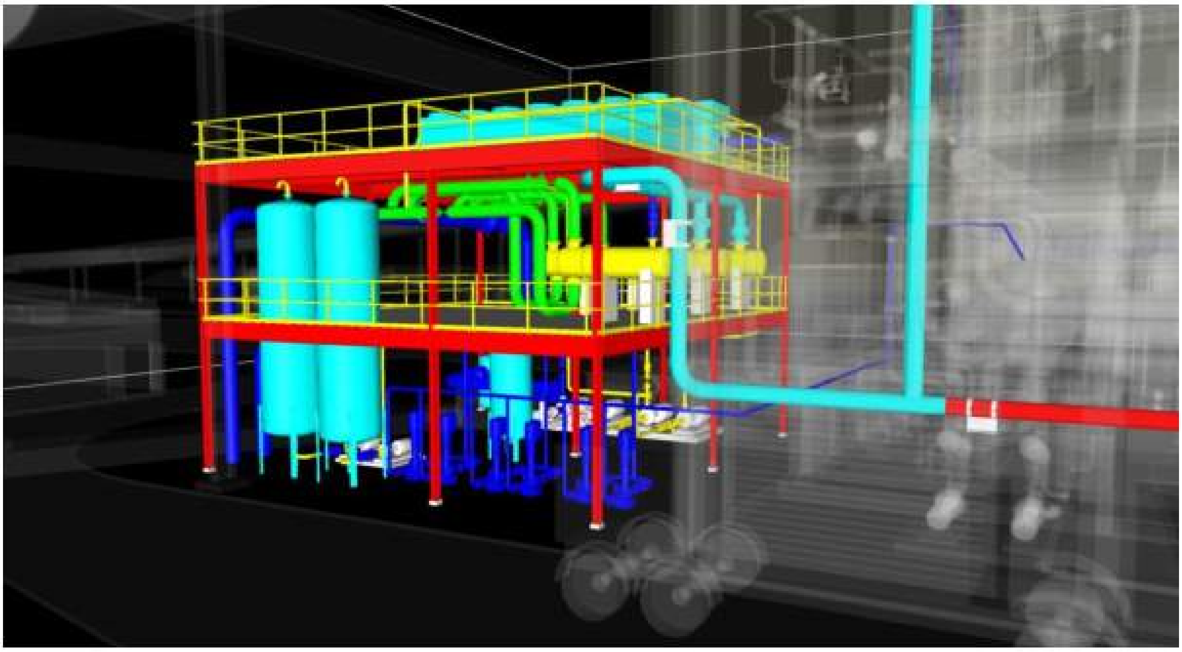


Figure 18: Cory EfW heat exchange plant arrangement (© Fichtner)

Further detail was also shared around operational of the EfW plant and its primary heat generating components as follows:

- Steam turbine undergoes a statutory inspection period of 3 days every 2 years.
- Turbine extended outage for full maintenance occurs every 8 years.
- Boiler plant continues to operate during turbine offline periods, feeding the LP header (from which is it intended steam offtake would occur for heat exchange).
- Annual boiler outages typically comprise 10-12 days (major works) or 5-7 days (minor works) downtime.
- Such outages are staggered to allow continued plant operation.

Reflecting the above, Cory indicated an expected annual availability of 90% for heat offtake from the plant.

3.1.2 Heat Offtake: Commercial Arrangements

The techno-economic analysis undertaken within Work Package 2, and resulting in a proposed heat offtake pricing structure, has reflected a range of updated capital and operating costs discussed and validated with Cory.

Full details of these have been included within sections 5.2 and 5.3 of this report.

3.2 Supplementary Heat Generation & Storage

In recognition of the annual heat availability factor from the Cory plant, it is necessary to provide additional heat generation plant in order to meet the demand of the network throughout the year. The prefeed strategy assumes that the majority of back up plants and thermal stores will be located at the end of distribution network around the new development areas.

This will reduce space requirements and extensive capital investment in the main distribution plant room. Instead, new residential developments will retain satellite energy centres with back up plants and thermal stores, as they connect along the network.

3.2.1 Centralised Heat Generation

It is proposed to provide supplementary heating plant via a mix of centralised and distributed/local gas-fired boilers, with centralised plant comprising the following:

- Total centralised boiler plant of 2.7 MW.

This capacity of plant has been determined not to provide full backup to all buildings connected to the DH network but rather to those which would not feature their own localised boilers, such as existing sites where connections are made via removal of current plant (either for space requirements or due to boilers reaching end of life).

An outline floor area required in which to accommodate this capacity, split between 3 no. boiler modules, has been determined as approx. 300 m^2 as shown in Figure 19.

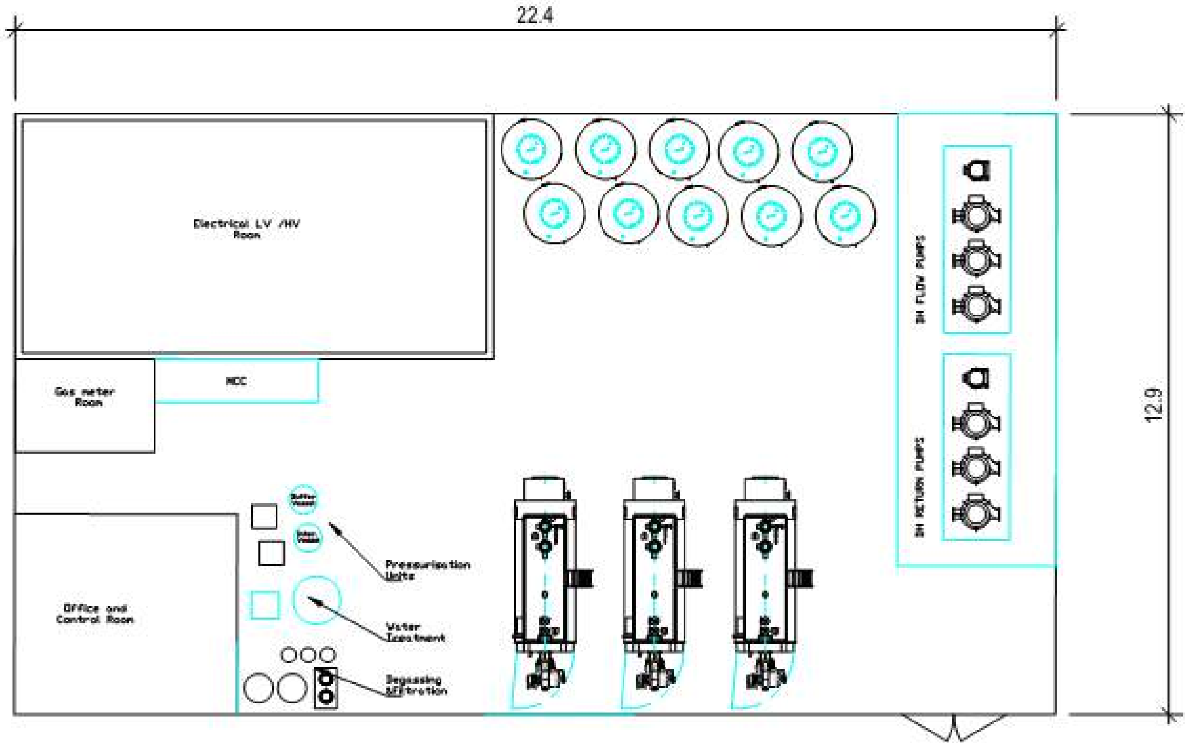


Figure 19: Outline DH network distribution plant/control room layout

In practice, it may be possible (and preferable) to integrate boiler plant within the same area and footprint as the heat exchange arrangement, via introduction of an additional two storeys, based on the current intended 150 m^2 building footprint.

3.2.2 Heat Storage

The use of heat storage serves to help balance fluctuation between instantaneous heat offtake and consumption within the network, as well as to allow extended offtake during periods of low demand and subsequent increase in supply when demand increases.

Following reassessment and reduction of the number of existing buildings and loads to be served by the DH network, the provision of centralised thermal storage during initial buildout of the scheme is not deemed necessary, with balancing of heat supply to be manded via control interfaces between the DH distribution and Cory plant. However, an investment on 15m^3 of thermal store is included in the cashflow for contingency purposes.

Centralised thermal store is not included in the layout of Figure 19 but, if necessary, this could be located externally adjacent to the facility. Instead, the bulk of storage used to balance heat supply and demand is proposed to be provided via thermal stores installed in the satellite energy centres.

The current investigation concluded to 2.7 MW peak of standalone heat demand, which is less than 10% of Cory's heat offtake capacity. If extended standalone heat loads connect, central thermal store options should be considered.

3.2.3 Distributed Heat Generation

In addition to the proposed inclusion of limited centralised supplementary heating plant, the presence and use of discrete distributed plant in the form of boiler.

When allocating costs for supplementary distributed boiler plant, costs breakdown for boiler plantrooms of similar capacity from previous projects were referenced.

Within subsequent techno-economic modelling, it was assumed that this associated boiler CAPEX sits with each site developer, meaning that this represents a proportion of their avoided cost in installing plant of sufficient capacity to serve the full peak load of their site.

The peak demand figures determined at full build-out for each main site developments are illustrated in Figure 20.

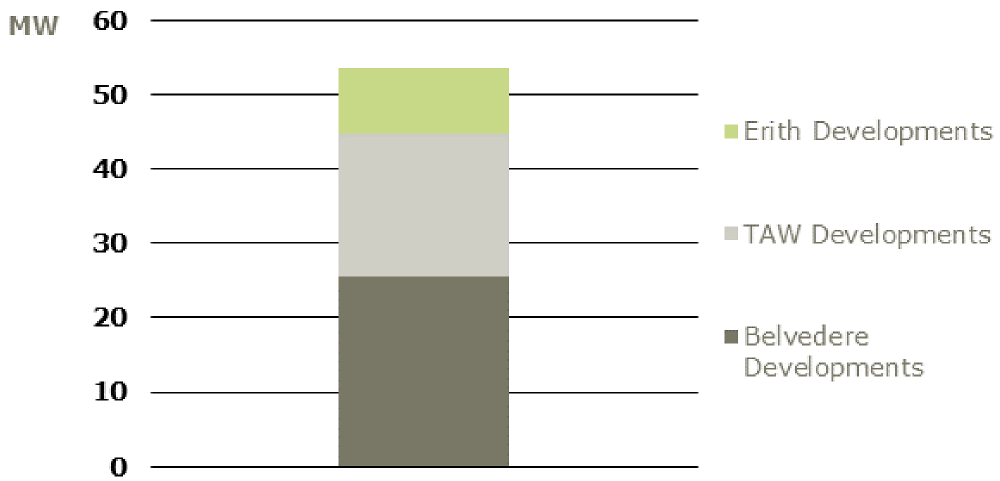


Figure 20: Peak heat demand for new development (at full build-out)

3.2.3.1 Distributed Heat Storage

The selection of distributed storage volumes has been based on the capacity to store heat associated with 30 minutes of peak demand of each discrete development. This capacity is determined based on a high-level energy model indicating an EfW share of heat fluctuating between 90%-97%.

This size of thermal storing is comparable with the counterfactual case of decentralised low carbon heat plant with adequate thermal store cylinders.

4. ENERGY DISTRIBUTION SYSTEMS

SUMMARY OF WORK PACKAGE 1 FINDINGS (for full details, refer to WP1 report)

Works during Work Package 1 identified the proposed sequence of plant and infrastructure envisaged to form the entirety of the heat network arrangement, from initial heat offtake within the Cory plant through to individual dwelling/building systems, as shown in Figure 21.

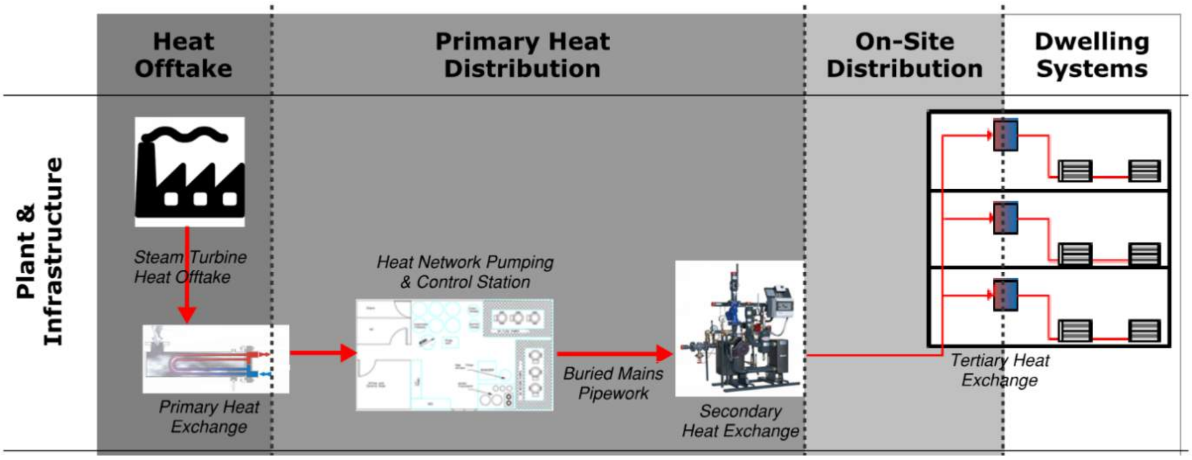


Figure 21: Plant & infrastructure elements comprising heat network

Also determined and quantified was a proposed route and pipework split to comprise the "Core Scheme" DH network, linking the Cory plant to intended connecting loads, as described within Figure 22 and Table 3.

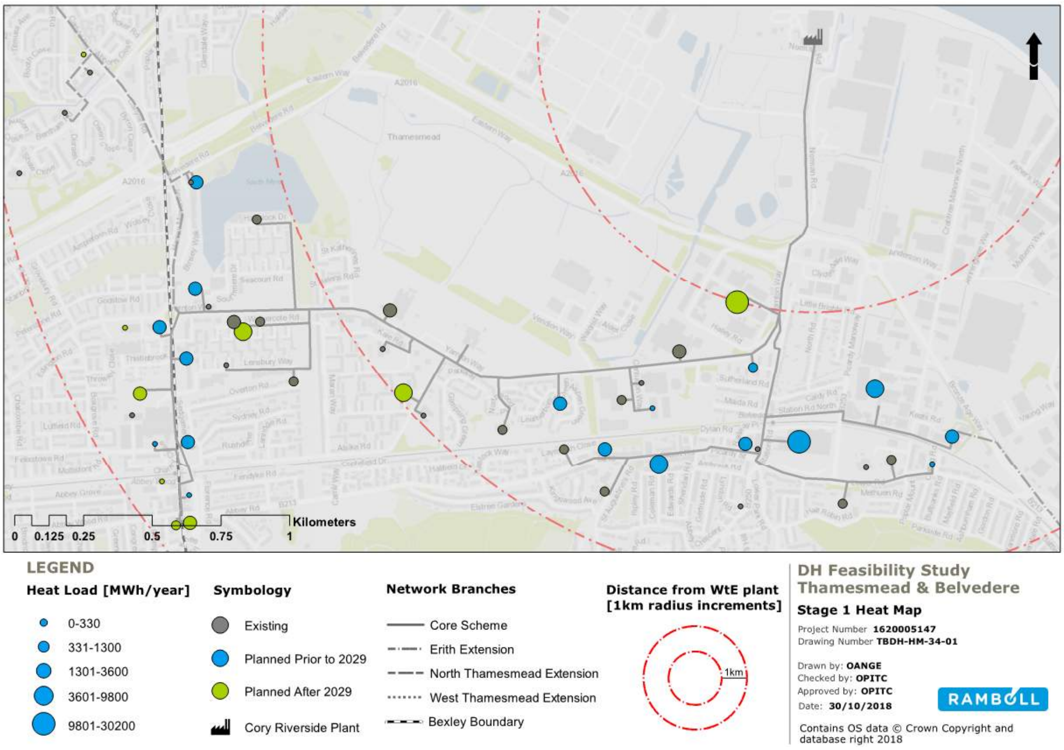


Figure 22: Core scheme heat network route

Table 3: Breakdown of heat network pipe lengths

	Main Spine (m)	Branches (m)	Total length (m)
Core Scheme	3,960	7,112	11,072
Erith extension	1,617	1,169	2,786
North Thamesmead extension	2,052	1,484	3,536
West Thamesmead extension	2,143	2,140	4,066

The following next steps were identified to be undertaken during Work Package 2, to refine and develop further detail in relation to heat distribution infrastructure:

i. Information to be gathered on existing major buried infrastructure present within roads and areas proposed for heat network routing.
ii. Assessment of alternative primary heat network main routing, adjacent to Crossness Nature Reserve.
iii. Completion of detailed hydraulic and heat loss assessment of proposed heat network routing.
iv. Assessment to be undertaken to determine thermal store sizing options.
v. Options for network pumping station and thermal store locations to be assessed with Cory.
vi. Details of existing heating systems (or though planned following refurbishment) to be sought for major retained buildings considered for heat network connection.
vii. Acceptability of direct dwelling/building connections from bulk heat substations to be tested with site developer stakeholders.

WORK PACKAGE 2 REFINEMENT

4.1 Existing Buried Infrastructure

In order to assess further the viability of the new DH network between the Cory plant and the intended connecting buildings and sites, a third part company ("Groundwise") were employed to undertake a search of all existing utilities and other buried services across the extent of the proposed route.

In keeping with the route determined during WP1 for the Core Scheme, the outline of the services search area is shown in Figure 23.

Figure 23: Extent of buried services search area

4.1.1 Utilities and Network Operators

Table 4 indicates the full list of utility and other network owners/operators who were approached for details of existing services and identifies those who have assets in the area.

Table 4: List of all utility & network operators contacted

Type	Data Supplier
Electricity	Energetics
Electricity	UK Power Networks
Electricity	Utility Assets Ltd
Electricity	National Grid
Gas	GTC
Gas	Southern Gas Networks
Mobile Phone Masts	Mast Data
Telecom	BskyB Telecommunications Services Ltd
Telecom	BT
Telecom	C.A. Telecom - Colt
Telecom	CityFibre
Telecom	euNetworks
Telecom	Instalcom Ltd
Telecom	GTT (Formerly Interoute Vtesse Networks Ltd)
Telecom	KPN
Telecom	MBNL
Telecom	Plancast
Telecom	Telent
Telecom	Trafficmaster
Telecom	Verizon
Telecom	Virgin Media
Telecom	Vodafone
Transport	Crossrail
Transport	HS1 / HS2
Transport	London Overground
Transport	London Underground HV Power Assets
Transport	London Underground
Transport	LUL TFL Streetworks
Transport	Network Rail
Transport	Transport for London
Tunnels	MOD
Tunnels	Thames Tideway Tunnel
Various	HSE *[client should contact HSE directly for further information]*
Various	LinesearchbeforeUdig – ESP
Various	SSE
Mains	Thames Water
Sewers	Thames Water
District Energy	ENGIE
Various	Local Council **

The maps received indicating services within and adjacent to the intended route for new DH pipework were reviewed and, with the key risks identified comprising the presence of high voltage cables, extra high voltage cables and gas pipework within Norman Road, running toward the Cory plant.

The resulting changes required to network routing were minor and limited to lateral shifts of pipe location in order to maximise distance from existing services running directly parallel. It was not necessary to divert or otherwise alter the basic intended routing for the network.

With the combined total of drawings and information provided exceeding 1,600 pages (across some 600+MB), the full Groundwise report and appendices will be issued to LBB as a separate accompanying document to this report.

It is recommended that, as designs for the DH network progress, the Groundwise report is referenced and used identify specific parties within whom early discussions should be sought in order to:

a) Confirm that services information remains up-to-date and valid.
b) Confirm accuracy offered for services line and levels.
c) Understand specific requirements around permissible proximity of other services.
d) Make any arrangements required for trial-holing or other investigations.

4.2 Primary Heat Network Routing

4.2.1 Route Assessment

Depending upon the diameter and material of pipework involved, the costs of civil trenching and reinstatement works associated with installation of DH networks can be equal or even exceed those of the pipes themselves. This is especially true when installing within hard-dig areas requiring the breaking out of existing road or pavement surfaces.

For this reason, it is generally preferable to pursue a route for new DH pipework which utilises soft-dig area characterised by unmade ground.

The Core Scheme network route was derived during WP1 with the priority of minimising the distance travelled by primary transmission pipes between the largest load centres, as well as avoiding the need to cross major obstacles (either natural or manmade).

The result of this was a route which utilises a combination of Norman Road and Yarnton way to travel from the Cory plant to the Bexley area and beyond to the Thamesmead/Abbey Wood area respectively.

In practice, it may be possible to minimise the hard-dig elements involved with the Norman Road element of the route via the laying of pipes within grass verges to one (or both) sides of the road itself.

A visit was undertaken to the Abbey Wood area on 18th February 2019 in order to walk the intended route of primary network pipework, from Thamesmead/Abbey Wood to Belvedere.

During this route walk, ongoing enabling works were seen associated with Phase 1 of Peabody’s redevelopment works on the Southmere Village and Binsey Walk sites (north of Yarnton Way). These works should serve to provide greater clarity of the existing buried services in the area.

Figure 24: Ongoing enabling works within Yarnton Way (east of A2041 roundabout)

Also clearly visible alongside Yarnton Way, adjacent to the Parkview Estate, were large sections of the previous (no defunct) district heating pipes which once serves the residential towers in this area.

Figure 25: Example of above-ground DH pipework, mounted on side of Parkview Estate podium walkway

Though not as common in the UK, such an approach to above-ground pipework distribution is seen in cities elsewhere in the world and can serve as a viable option should it offer significant savings in pipe length, for example if significant buried obstructions are identified.

Heading east along Yarnton Way, beyond the Parkview Estate, options were identified for potential use of soft dig and verge spaces alongside the road towards Belvedere, in order to reduce costs of installation.

Figure 26: Yarnton Way (east of Alsike Road roundabout)

A critical and likely most challenging part of the proposed network link to the redevelopment areas in and around Belvedere is the requirement to cross the railway line in the vicinity for the station.

Whilst only 2 tracks wide, the only existing crossing point is a pedestrian footbridge, as pictured in Figure 27.

Figure 27: Pedestrian footbridge at Belvedere station

It is felt unlikely that this lightweight steel bridge and decking could support the addition of new DH pipework. For this reason, CAPEX allowance has been made within the techno-economic modelling for the network for the introduction of a new crossing, either comprising a dedicated pipework bridge or micro-tunnelling under the lines.

An alternative approach would be to increase pipework length and network distance via the routing of pipework to the existing B253 road bridge of the railway, approx. 300m east of Belvedere station.

Figure 28: Belvedere area railway crossing options

4.2.2 Alternative Primary Route Options

A significant extent of green space exists between the Cory plant and Thamesmead, comprised mainly of the Crossness Nature Reserve and the Erith Marshes as shown in Figure 29.

Figure 29: Green space and primary roadways between Cory and Thamesmead

With the nature reserve sitting adjacent to the Thames Water WWTW site, it is understood than an existing easement corridor exists just within the edge of Thames Water's land in which HV cabling connecting from the Cory plant currently runs.

Beyond here, the dual carriageway comprising Eastern Way separates land to the north from Erith Marshes then Southmere Park further south.

Whilst an opportunity may exist for a pipework route to utilise some or all of the soft-dig options present between Cory and Thamesmead, the following further investigation would be required in order to test and confirm this potential:

- Determine acceptability of running DH pipework in parallel with HV cabling in existing easement corridor.
- Confirm rights of access to install pipework within Crossness Nature Reserve.
- Consider crossing option for Eastern Way (either bridging over or micro-tunnelling under).
- Understand permissibility of routing through Erith Marshes, plus assess outline ground conditions with a view to stability, depth and ground-water.

In addition, such routing would need to consider how and where to run a major transmission branch toward the Belvedere area.

At the current feasibility stage, it was determined to be a lower risk (and more readily quantifiable) option to propose a route following existing roadways, less major than Eastern Way, and to respect presence and extents of existing services therein.

4.3 Network Hydraulic Modelling

With network routing refined Ramboll's in-house hydraulic modelling software System Rørnet, developed over 30 years' experience in Danish heat network design and operation, was used to develop an overall network operating strategy and to calculate the required pipe sizes for the proposed heat network route.

The key inputs to this modelling work were:

- Pipe lengths
- Topography along route
- Network operating temperatures
- Network operating pressure
- Peak load conditions

Table 5 presents the assumptions regarding network temperatures. In designing a district heating network, it is common practice to maximise the temperature differential (ΔT) between the flow and return system as the greater the ΔT, the smaller the pipes can be and therefore the lower the capital cost.

Table 5: Heat Network Temperature Design Parameters

Design Parameter	Value	Comment
Existing buildings – Secondary side – Flow and return	80/60°C	Refer to CP1
New buildings – Secondary side – Flow and return	65/35°C	Refer to CP1
Difference between primary return temperature and the secondary return temperature	5°C	Across heat exchanger
Primary flow temperature at design condition	105°C	At maximum capacity requirements, the operational will aim at 85°C, especially until all the loads are connected.
Primary return temperature range for new developments at design condition	40-55°C	Assumes design return temperature that can be achieved
Primary return temperature range for existing buildings at design condition	55-65°C	Assuming design return temperature that can be achieved from an existing building with retrofitting and rebalancing of existing systems when required.

The network flow temperature was calculated from the exhaust heat capacity information supplied by Cory, while the temperatures of the secondary side of the buildings are unknown at this stage so were assumed to be in line with those indicated/recommended within the CIBSE Heat Networks Code of Practice for the UK (CP1).

CP1 guidance for existing buildings at a feasibility stage advises that existing radiator circuits designed for 82°C flow and 71°C return can be rebalanced to achieve lower return temperatures (such as 80°C flow and 60°C return), as radiators are often oversized, especially where fabric improvements have been made subsequently to the original heating installation.

For the hydraulic modelling, a flow-return temperature differential (delta-T) of 50°C was assumed (105-55°C) for the primary transmission pipes to ensure minimising of cost whilst also providing future proofing of capacity.

As specified in WP1, this way the network has the flexibility to operate at lower temperatures (85/55), as will likely be required by the mix of existing and new-build loads intended to connect, until full build-out occurs whilst still providing adequate capacity to meet future peak load conditions.

A nominal pipe diameter of DN300 has been determined as a trade-off between oversizing and associated increased investment and futureproofing of network spine capacity. For the majority of the year, a network operating at 85/55°C can supply the full EfW heat capacity.

The associated large volume flow rates involved, however, impose a maximum velocity of 3.3 m/s within the network. It is therefore recommended that in winter peak conditions (or following future extensions) the DN300 spine should be designed to operate at 105/55 °C, thereby allowing transmittance of up to 42 MW.

An oversized spine of DN300 has been allowed for those highlighted in blue within the Core Scheme, being the branches leading to the Erith extension, in order to guarantee capacity for future connection.

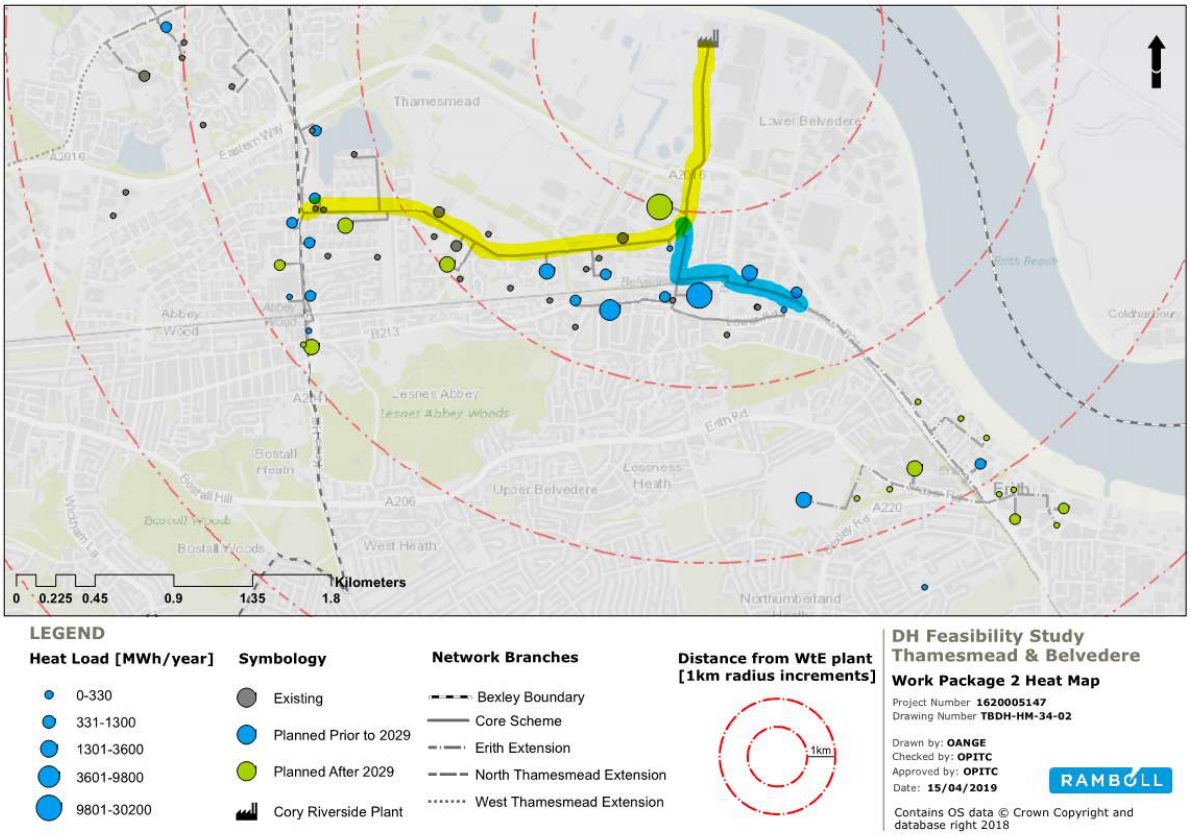


Figure 30: Core Scheme network with main transmission (yellow) and Erith extension (blue) highlighted

4.3.1 Heat Losses

The heat losses of the network were modelled using a proprietary software produced by one of the largest DH pipework suppliers, Logstor[1], considering 3 no. flow and return temperature differential as indicated in Table 6.

Insulation at series 2 thickness and steel material were selected and modelled.

[1] http://calc.logstor.com/en/energitab

Table 6: Heat Loss cases

Pipe size Nominal diameter (mm)	Heat Loss 1	Heat Loss 2	Heat Loss 3
	105-55 for 90 days of year, 85-55 for rest) MWh/year/m	**105-55 for 245 days of year, 85-55 for rest) MWh/year/m**	**(85-55 for all year) MWh/year/m**
25	0.13	0.14	0.12
32	0.14	0.14	0.13
40	0.15	0.17	0.15
50	0.18	0.18	0.17
65	0.19	0.21	0.19
80	0.21	0.23	0.2
100	0.22	0.23	0.21
125	0.25	0.26	0.23
150	0.28	0.3	0.27
200	0.32	0.34	0.3
250	0.32	0.33	0.3
300	0.36	0.38	0.34

Heat Loss case 2 was selected and modelled in the financial analysis with a 20% safety margin.

4.3.2 Network Layouts

The pipe layouts and schedules derived for the Core Scheme, plus inclusion of the Erith extension, have been provided in this section.

4.3.2.1 Core Scheme

The pipe schedule for the Core Scheme is shown in Table 7, with Figure 31 showing the related network layout generated by System Rørnet.

Table 7: Core Scheme cluster pipe schedule

Pipe Diameter (mm nominal bore)	Total pipe length (m)
25	722
32	55
40	185
50	104
65	906
80	359
100	402
125	1,362
150	84
200	1,240
250	837

Pipe Diameter (mm nominal bore)	Total pipe length (m)
300	3,252
Total	**9,507**

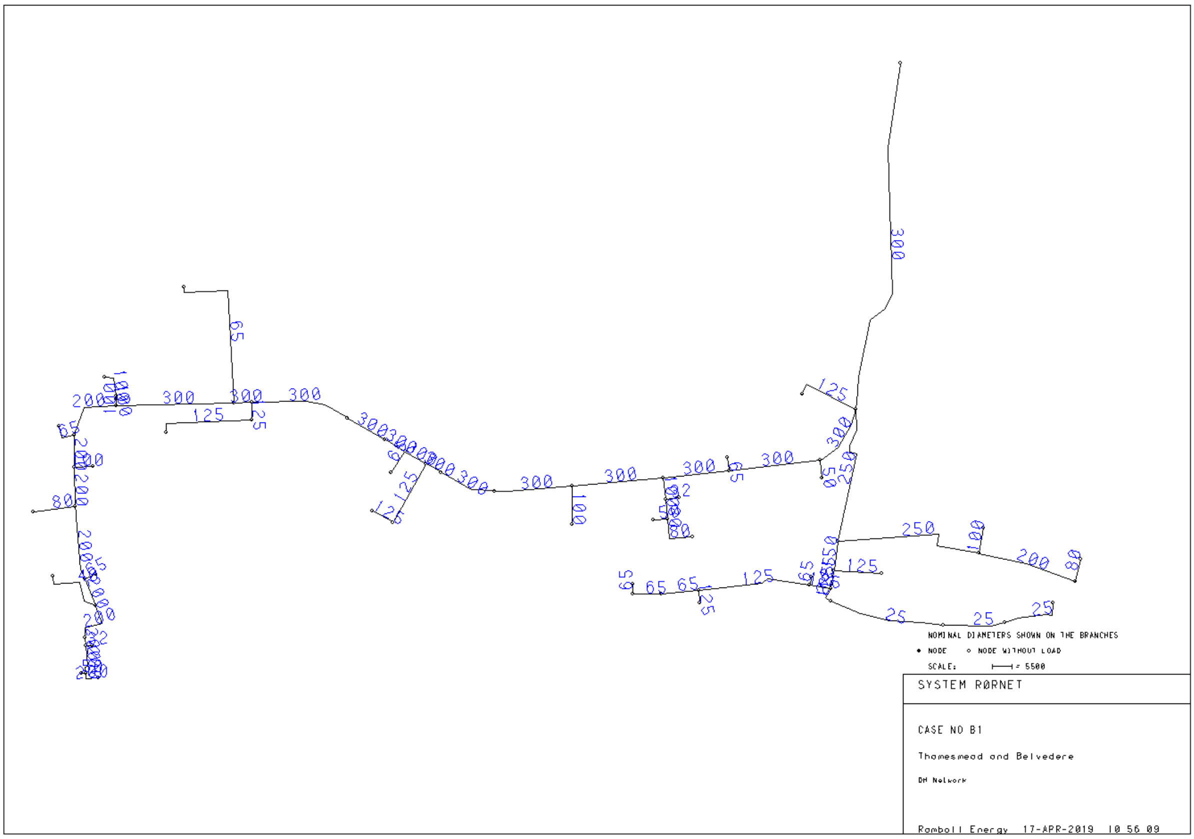


Figure 31: Core Scheme SR layout output

4.3.2.2 Core & Erith

The pipe schedule for the Core Scheme plus Erith extension is shown in Table 8, with Figure 32 showing the related network layout as generated by System Rørnet.

Table 8: Core & Erith cluster pipe schedule

Pipe Diameter (mm nominal bore)	Total pipe length (m)
25	772
32	140
40	323
50	1,062
65	811
80	605

Pipe Diameter (mm nominal bore)	Total pipe length (m)
100	1,514
125	1,362
150	874
200	2,925
250	-
300	3,649
Total	**14,037**

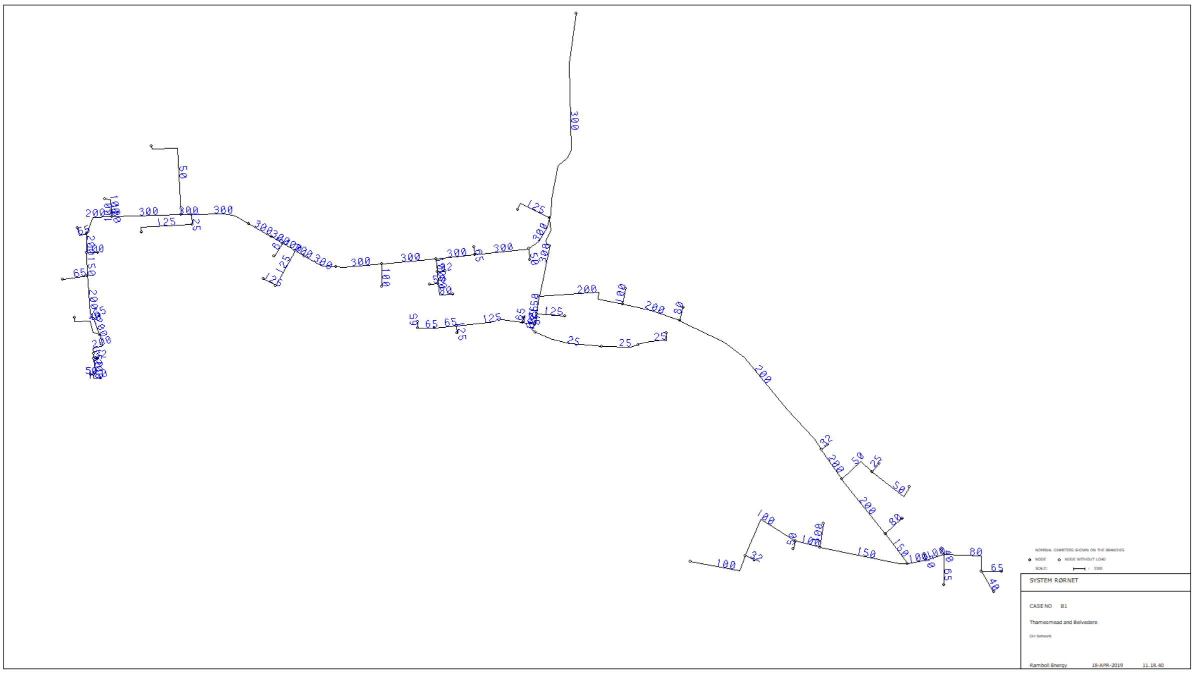


Figure 32: Core Scheme & Erith extension SR layout output

4.4 Existing Buildings to Connect

The largest single existing buildings and loads proposed for connection to the DH network comprise the retained Southmere and Parkview Towers. As is detailed earlier within section 2.2, these buildings have been identified as having their original communal heating systems replaced with gas supplies to individual boilers.

4.4.1 Previous Incoming DH Services

Spaces still exist at ground floor level within the buildings visited (and are suspected to be present in all) where previous DH pipework entered, and associated plant was located for subsequent distribution within the towers.

Though likely requiring some intrusive works, a next step in determining potential routing for new internal would include access to the previous risers used by DH pipework.

4.5 Development Connection Arrangements

In keeping with the approach identified during Work Package, it is proposed that an initial point of hydraulic separation be provided between the incoming transmission pipework and the subsequent distribution network on discrete developments via use of a heat exchanger located in the premises of residential developments plantrooms.

For new residentially-led developments, further hydraulic separation would be introduced via the use of heat interface units (HIUs) within or local to individual flats/properties.

5. TECHNO-ECONOMIC ASSESSMENT

SUMMARY OF WORK PACKAGE 1 FINDINGS (for full details, refer to WP1 report)

As part of the initial economic assessment completed as part of Work Package 1, the anticipated roles and interactions between main parties involved with the design, delivery and ultimate operation of the scheme were defined, as shown in Figure 33 (with the previously named "Pipe Co." now termed "Network Operator" for clarity).

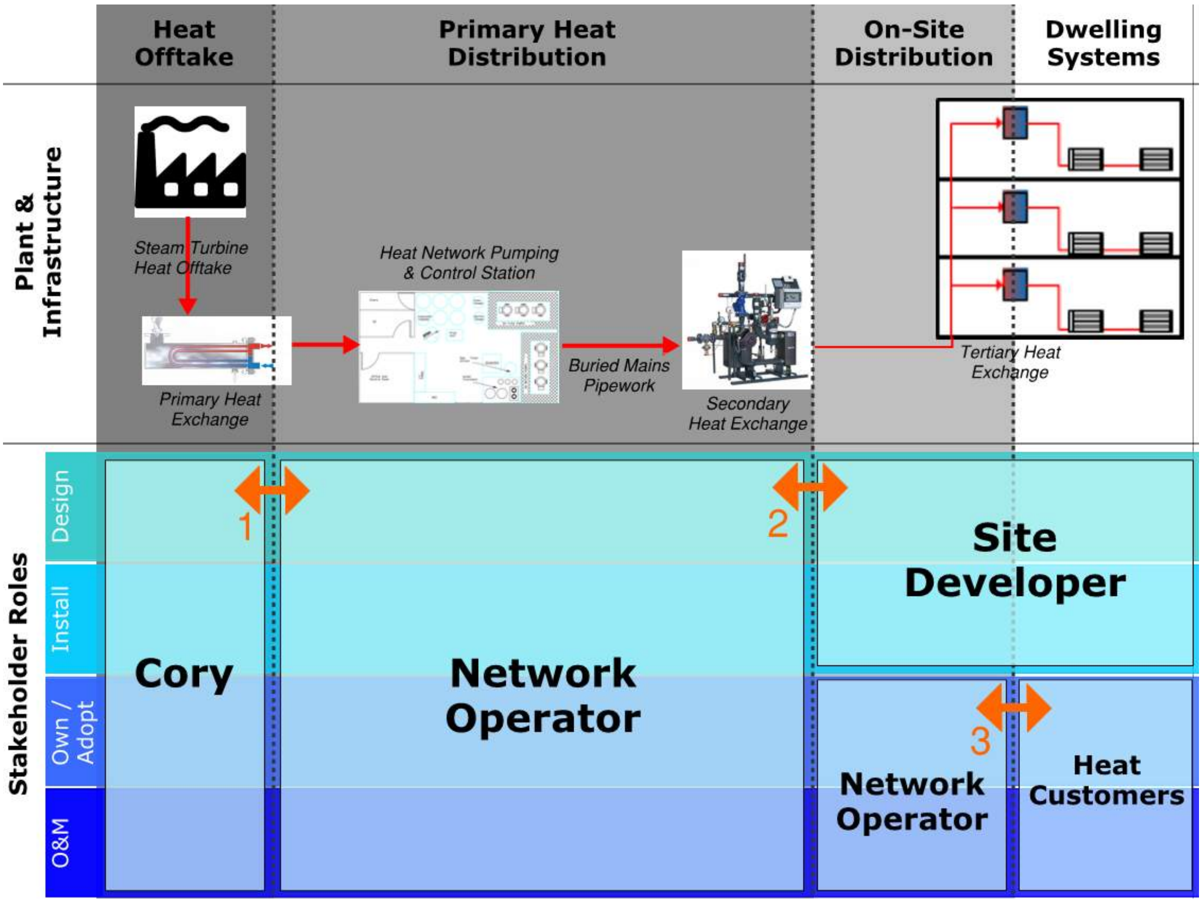


Figure 33: Heat network stakeholder role delineation

Key economic performance indicators were derived for the identified Core Scheme option, as displayed in Table 9 and Figure 34.

Table 9: Core Scheme economic performance indicators

Core Scheme (Belvedere plus Thamesmead & Abbey Wood)			
years:	*25*	*30*	*40*
IRR	4.5%	6%	8%
NPV	£1,440,000	5,070,000	£12,530,000

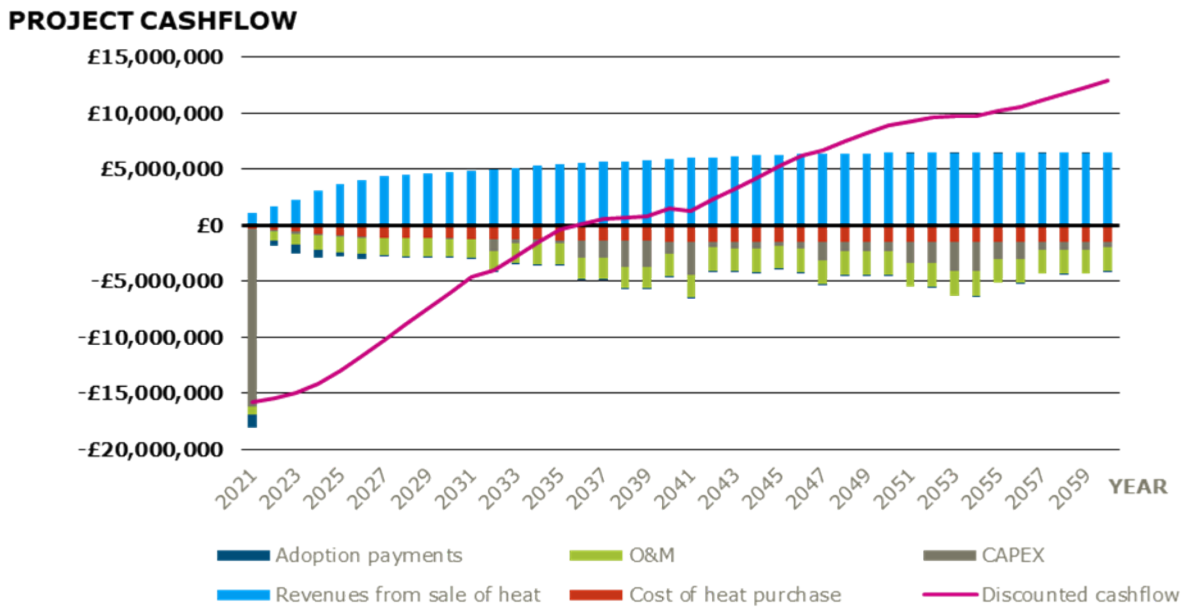


Figure 34: Core scheme cashflow

Finally, to further test the economic performance of the proposed Core scheme network, a series of sensitivity analyses were undertaken in respect of selected key variables, as shown in Table 10.

Table 10: Results of sensitivity analysis on Core Scheme

IRR	Project Period	-20%	-10%	0%	10%	20%
DH Network CAPEX	25	7.2%	5.8%	4.5%	3.4%	2.4%
	40	9.8%	8.7%	7.8%	7.0%	6.3%
Heat Offtake Price	25	6.4%	5.5%	4.5%	3.5%	2.4%
	40	9.2%	8.5%	7.8%	7.1%	6.3%
Heat Sale Price (Residential)	25	-20.7%	2.5%	4.5%	6.3%	10.7%
	40	0.3%	6.4%	7.8%	9.1%	12.6%
Heat Sale Price (non-Residential)	25	3.6%	4.1%	4.5%	5.0%	5.4%
	40	7.2%	7.5%	7.8%	8.1%	8.4%
Connected Heat Loads	25	1.6%	3.1%	4.5%	5.8%	7.0%
	40	5.7%	6.8%	7.8%	8.8%	9.6%
Cost of Financing/Borrowing	25	4.7%	4.6%	4.5%	4.5%	4.4%
	40	7.9%	7.9%	7.8%	7.8%	7.7%

The following next steps were identified to be undertaken during Work Package 2, to refine the business case modelling undertaken:

i. Reflection of refined heat network modelling and sizing work in revised CAPEX allowance.
ii. Inclusion of revised costs involved with achieving required heat offtake from Cory plant.
iii. Incorporation of refined methodology and metrics applied in derivation of assumed bulk heat purchase pricing.

iv. Reflection of cost impacts from identified existing buried services and related impacts upon network routing.
v. Application of further load sensitivity testing to reflect identified variances to potential future connecting heat loads.
vi. Identification of potential sources for project capital funding.
vii. Refinement of counterfactual case for heat provision to inform carbon savings calculations.

WORK PACKAGE 2 REFINEMENT

5.1 Network CAPEX Refinement for Pipe Sizes

Following the undertaking of hydraulic modelling, to refine network sizing, previously compiled CAPEX figures were revisited and updated.

5.2 Refined Heat Offtake Facilitation Costs

Following consultation with Cory and their commercial advisors, the costs applied for the necessary heat offtake arrangement has been revised.

Whilst an initial estimate of £1m was made and applied during WP1, Cory and their advisors have used the early concept design developed for all associated plant, including provision of new structure to support and house it, to arrive at a cost of £2.534m.

This investment CAPEX, plus Cory's associated expenses including cost of capital and margins, have been applied within the refined tariff structure as per Cory/ Inventa recommendations.

5.3 Refined Heat Offtake Tariff Structure

Whereas the heat offtake charge determined during WP1 considered a single tariff, on a per kWh exported basis, the refined WP2 modelling considered a tariff broken down into variable and fixed/standing charges. This is to disassociate heat tariffs from heat demand estimations, thereby de-risking the heat offtake agreement.

The annual standing charges were determined using a discrete cashflow model, generated in recognition of Cory's projected initial CAPEX investment in the heat offtake plant (including related cost of capital) plus the related annual O&M costs.

Both of these were provided direct by Cory, to ensure their validity and acceptability, and led to the determining of a standing charge of £276,647 per year to break even including a 12% margin.

Table 7 displays the key metrics applied and derived from this approach, including the resulting fixed and variable cost paid to Cory for the heat offtake.

Table 11: Heat Offtake price calculator

Variable charge		***Standing charge***	
Z factor (1 MWh of el to X of heat)	4.3	Discount factor	6%

Variable charge		***Standing charge***	
Exported electricity price (£/MWh)	63	Charge (£/year)	247,006
Margin	12%	Margin	12%
Cost of heat (£/MWh)	16.4	Cost of heat (£/MWh)	276,647

5.4 Network CAPEX Refinement for Pipe Routing

All minor changes made to intended pipe routing, as a result of the route walk and information gathered on existing buried services, have been reflected within updated costs for the Core Scheme network.

A breakdown of the total cost (by pipe size) is shown in Table 8 while the length can be found in the hydraulic analysis (Section 4.3.2).

Table 12: DHN pipe CAPEX

Pipe size Nominal bore (mm)	Total Cost (£) Core Scheme	Total Cost (£) Core & Erith Scheme
25	£380,622	£407,248
32	£31,520	£79,886
40	£113,278	£197,441
50	£66,002	£677,429
65	£625,028	£559,290
80	£270,682	£455,783
100	£350,677	£1,321,763
125	£1,333,856	£1,333,856
150	£92,672	£960,577
200	£1,526,618	£3,602,547
250	£1,154,044	£0
300	£4,648,695	£5,216,969
Total	**£10,593,693**	**£14,812,788**

5.5 Sources for Capital Funding

The most likely source for capital funding, in support of all or part of the proposed DH network, is the Government's Heat Networks Investment Programme (HNIP).

5.5.1 Heat Networks Investment Programme

HNIP is a Government scheme offering partial capital funding for the delivery of heat network projects capable of achieving significant annual cost and carbon savings but which, without support, could not achieve the delivery body's required commercial hurdle rates for investment.

Even if a large network, once fully built out, can demonstrate an acceptable return on investment it is likely that the costs involved with installation and operation of initial elements may not perform as well.

In order to avoid the downsizing of key elements to save on initial CAPEX, which could reduce or remove elements of future-proofing for latter network expansion, funding could be sought through HNIP to retain the strategic forward plan for the project.

5.6 Refinement of Heat Sale Tariffs

As part of developing a new techno-economic model for the Core Scheme network, considerably more granularity and detail was considered in developing heat sale tariffs. This section describes the logic behind this reworking and the results it produced.

Similar to the refinement made to derivation of the Cory heat offtake tariff, the heat purchase prices for connected customers has been developed to comprise variable and fixed components, comprising a per kWh tariff linked to consumption and an annual standing charge.

This model, as before in WP1, assumes an adoption of the secondary distribution infrastructure installed on development sites to deliver heat to individual consumer HIUs/plate heat exchangers.

5.6.1 Residential Heat Tariff

A heat price comparator calculation has been used to determine a residential heat sale price offering a 10% saving, when compared against the marginal cost of heat produced by an alternative gas boiler arrangement. This utilised data on typical domestic gas charges of major utility companies operating in the Bexley area.

The details of this price comparator are provided in Table 13.

Table 13: Heat Price comparator for Residential customers

Component	Unit	Value
Heat Sales	*kWh/year*	4,000
Cost of gas	*£/kWh*	0.0404
Gas boiler eff.	-	90%
Cost of fuel	*£/year*	179
Gas standing charge	*£/year*	92
Boiler maintenance	*£/year*	100
Boiler replacement	*£*	2,000
Boiler lifetime	*years*	15
Boiler sinking fund	*£/year*	133

Component	Unit	Value
Counter factual standing charge	*£/year*	325
Counterfactual variable charge	*£/year*	179
Counterfactual cost of heat	*£/year*	505
DH discount	*%*	10%
DH cost of heat	*£/year*	454
DH heat cost of heat	*£/MWh*	113.5
DH standing charge	***£/year***	**293**
DH variable charge	***p/kWh***	**4.04**

5.6.2 Non-Residential Heat Tariff

A similar methodology has been applied in using a separate price comparator calculation to determine a heat sale tariff for non-residential customers, as displayed in Table 14.

Table 14: Heat Price comparator for non-Residential customers

Component	Unit	Value
Heat Sales	*kWh/year*	300,000
Connection Capacity	*kW*	239
Cost of gas	*£/kWh*	0.0279
Gas boiler eff.	-	90%
Cost of fuel	*£/year*	9,300
Gas standing charge	*£/year*	92
Boiler maintenance	*£/year*	1,013
Boiler replacement	*£*	67,500
Boiler lifetime	*years*	15
Boiler sinking fund	*£/year*	4,500
Counter factual standing charge	*£/year*	5,604

Component	Unit	Value
Counterfactual variable charge	*£/year*	9,300
Counterfactual cost of heat	*£/year*	14,904
DH discount	*%*	10%
DH cost of heat	*£/year*	13,414
DH heat cost of heat	*£/MWh*	44.7
DH standing charge	***£/kW capacity***	**21.1**
DH variable charge	***p/kWh***	**2.79**

5.7 Techno-Economic Modelling Results

5.7.1 Refined CAPEX & OPEX

All cost components used within the refined WP2 techno-economic analysis are displayed in Table 15, comprising capital, operating and replacement costs, with a borrowing cost factor of 4.5% assigned against all CAPEX figures.

It should be noted that some parameters requiring details not available at the time of writing, such as secondary network lengths allowing the calculation of associated OPEX elements, were not included in the financial modelling undertaken.

Table 15: Cost Components considered

	CAPEX Component	OPEX Component	REPEX Component
Energy Centre	Boiler Costs	Energy Centre	Gas Boiler
	DHN Pump CAPEX	Boiler	Pumping
	Thermal Store CAPEX	Water Treatment	
	Pressurisation /expansion specific CAPEX	Thermal Store	
	Water treatment capex		
	Mechanical fit out capex		
	EC wiring costs capex		
	ICA & Scada capex		
	Utilities capex		
	Metering Cost		
	EC building costs		
	Ventilation costs		

	CAPEX Component	OPEX Component	REPEX Component
	Planning support (air quality, noise, transport) Builders work in connection Testing and commissioning Consultancy fees Design costs Contractors costs Contingency Prelims		
Network	DHN CAPEX DHN Testing and commissioning DHN Consultancy fees DHN Design costs DHN Contractors costs DHN Client's PM and legal costs DHN Contingency DHN Prelims DHN Consultancy fees DHN Design costs DHN Contractors costs	Fixed Network Cost Variable Network Cost Plant Room Connection	DH Network Plant Room DH Substation HIU

Table 16 and Table 17 summarise the overall capital, operating and replacement costs specific to the two modelled scenarios, comprising the Core Scheme and the addition of the Erith extension.

Table 16: Summary of CAPEX for scenarios modelled

CAPEX ITEM	Core Scheme	Core & Erith
Energy Centre & central plant (£m)	2.86	3.52
Energy Distribution Systems (£m)	15.31	21.35
TOTAL CAPEX (£m)	18.18	24.87

Table 17: OPEX and REPEX summary per scenario

ITEM	Core Scheme	Core & Erith
TOTAL DISCOUNTED OPEX over 40 years (£m)	26.21	32.75

TOTAL DICOUNTED REPEX over 40 years (£m)	13.67	16.07

5.7.2 IRR and NPVs

Key economic performance indicators derived for the two modelled network scenarios are shown in Table 18, comprising ranges of internal rate of return (IRR) and net present value (NPV) calculated over project periods of 25, 30 and 40 years.

Table 18: Financial modelling results

Scenario	Item	25 YEARS	30 YEARS	40 YEARS
Core	IRR	10.4%	10.9%	11.1%
	NPV 3.5% Discount Rate (k£)	13,125	17,270	20,636
Core + Erith	IRR	7.5%	8.2%	8.5%
	NPV 3.5% Discount Rate (k£)	10,744	15,376	19,558

5.7.3 Cashflow

Projected cashflows for the two modelled scenarios are shown in Figure 35 and Figure 36.

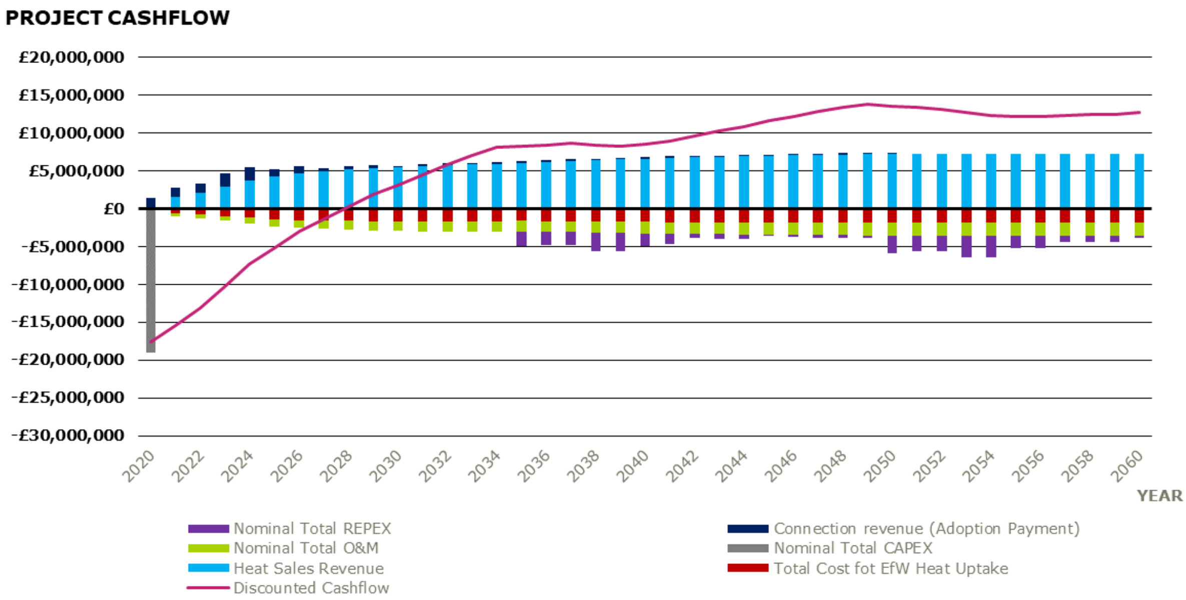


Figure 35: Cashflow for Core Scheme

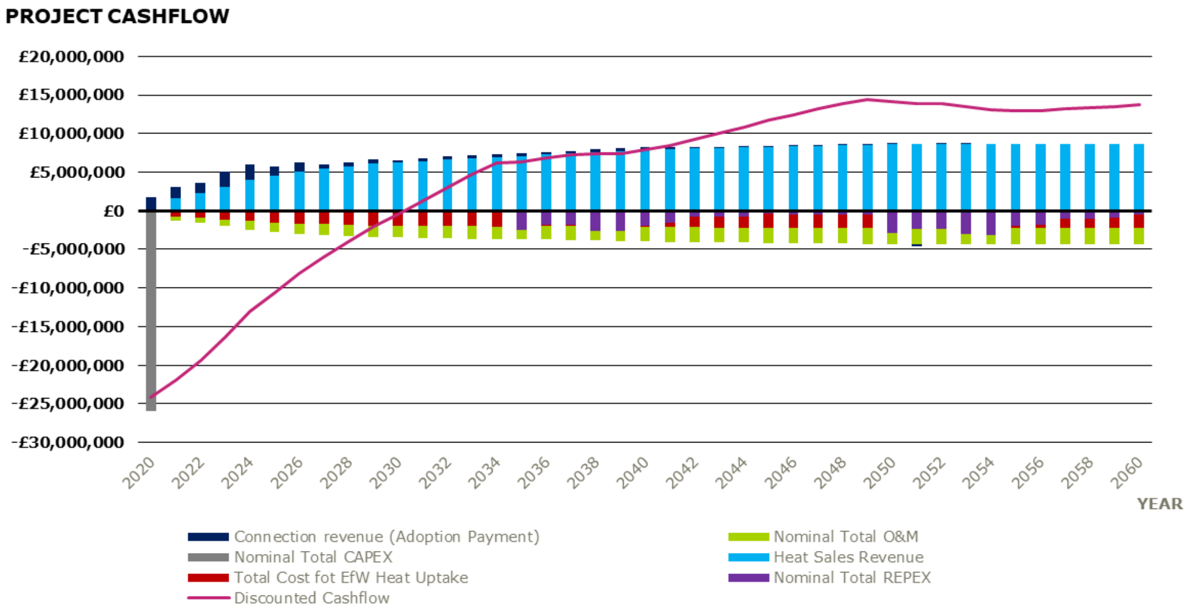


Figure 36: Cashflow for Core Scheme plus Erith extension

5.7.4 Sensitivity Analyses

Sensitivity analyses were performed on the WP2 techno-economic model to test its response to a varying of the following key variables:

1. CAPEX
2. Resi variable heat price
3. Resi Standing
4. Non Resi Variable
5. Non-Residential Standing
6. Sensitivity Variable
7. EfW Availability
8. Network Heat Losses
9. Connected Customers Reduction
10. Resi and Non Resi
11. Sensitivity Variable
12. Occupancy levels
13. Sensitivity Variable
14. Investment Hurdle Rate (m£)

5.7.4.1 Core

The findings presented in Table 19 and Table 20 use a colour code to illustrate the variables that lead to an increased (Green) and decreased (Red) IRR.

Table 19: Sensitivity Analysis Results - Core (1)

Sensitivity Variable	IRR	-30%	-20%	-10%	0%	10%	20%	30%
CAPEX	25 years	17.1%	14.3%	12.1%	10%	8.9%	7.7%	6.6%
	30 years	17.3%	14.6%	12.6%	11%	9.5%	8.4%	7.4%
	40 years	17.4%	14.7%	12.7%	11%	9.8%	8.7%	7.8%
Resi variable heat price	25 years	6.5%	8.0%	9.2%	10%	11.4%	12.4%	13.3%
	30 years	7.4%	8.7%	9.8%	11%	11.9%	12.8%	13.7%
	40 years	7.5%	8.9%	10.0%	11%	12.1%	13.0%	13.8%
Resi Standing	25 years	2.9%	6.0%	8.4%	10%	12.1%	13.6%	15.1%
	30 years	4.2%	6.9%	9.1%	11%	12.5%	14.0%	15.4%
	40 years	4.0%	7.1%	9.3%	11%	12.7%	14.2%	15.5%

Sensitivity Variable	IRR	-30%	-20%	-10%	0%	10%	20%	30%
Non Resi Variable	25 years	9.4%	9.8%	10.1%	10%	10.6%	10.9%	11.2%
	30 years	10.0%	10.3%	10.6%	11%	11.2%	11.4%	11.7%
	40 years	10.3%	10.5%	10.8%	11%	11.4%	11.6%	11.9%
Non-Residential Standing	25 years	10.2%	10.3%	10.3%	10%	10.4%	10.4%	10.5%
	30 years	10.8%	10.8%	10.9%	11%	10.9%	11.0%	11.0%
	40 years	11.0%	11.0%	11.1%	11%	11.1%	11.2%	11.2%

Table 20: Sensitivity Analysis Results - Core (2)

Sensitivity Variable	IRR	25%	50%	75%
EfW Availability	25 years	No IRR available	-2.0%	7.4%
	30 years	No IRR available	0.3%	8.1%
	40 years	No IRR available	No IRR available	8.3%
		50%	**150%**	**200%**
Network Heat Losses	25 years	10.1%	9.5%	9.1%
	30 years	10.6%	10.1%	9.8%
	40 years	10.8%	10.3%	10.0%
		-10%	**-20%**	**-30%**
Connected Customers Reduction	25 years	7.4%	4.6%	-1.5%
Resi and Non Resi	30 years	8.2%	5.7%	0.6%
	40 years	8.4%	5.8%	-0.4%
	IRR	**90%**	**80%**	**70%**
Occupancy levels	25 years	10.2%	10.1%	9.9%
	30 years	10.8%	10.6%	10.5%
	40 years	11.0%	10.8%	10.7%
	IRR	**8%**	**10%**	**12%**
Investment Hurdle Rate (m£)	40 years	0	0	1

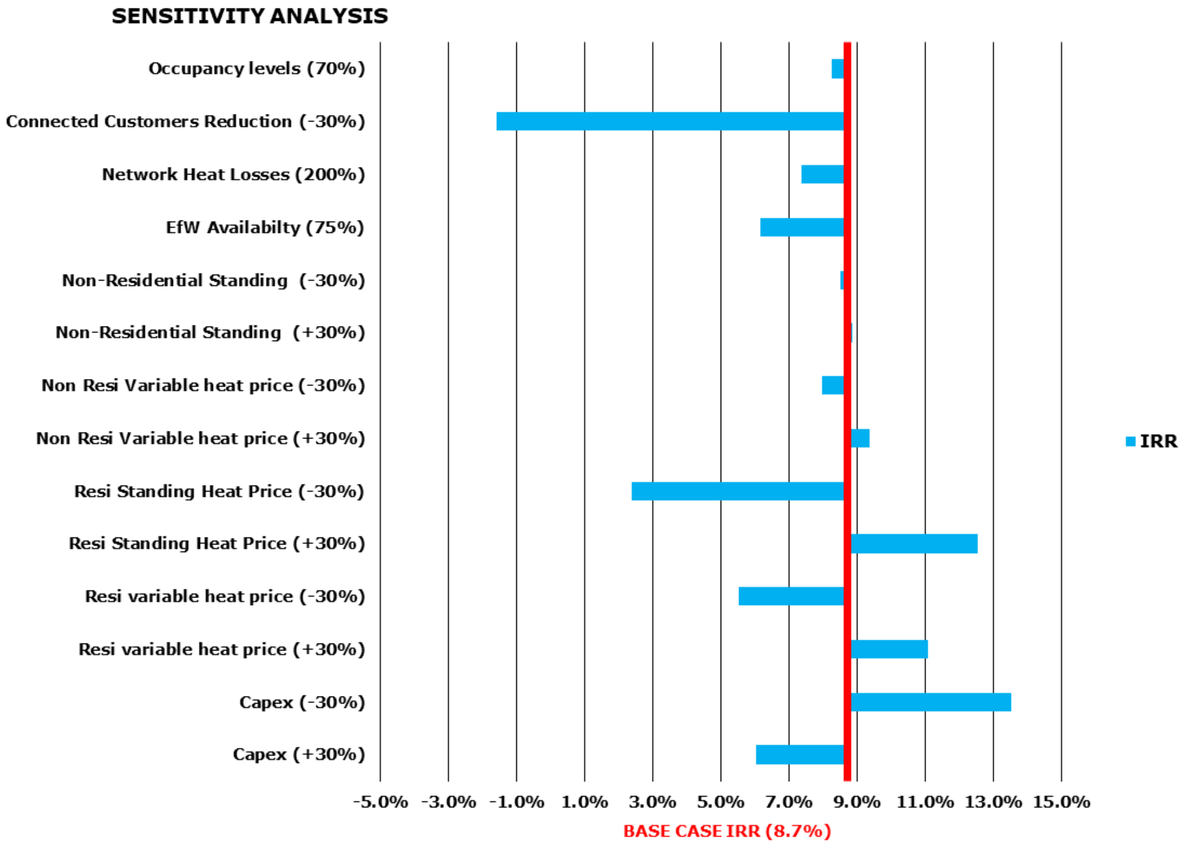


Figure 37: Sensitivity Analysis for the Core Scheme

5.7.4.2 Core & Erith

The findings presented in Table 21 and Table 22 use a colour code to illustrate the variables that lead to an increased (Green) and decreased (Red) IRR.

Table 21: Sensitivity Analysis Results – Core & Erith (1)

Sensitivity Variable	IRR	-30%	-20%	-10%	0%	10%	20%	30%
CAPEX	25 years	12.8%	10.6%	8.9%	7%	6.3%	5.3%	4.4%
	30 years	13.2%	11.1%	9.5%	8%	7.1%	6.2%	5.4%
	40 years	13.3%	11.3%	9.8%	9%	7.5%	6.6%	5.9%
Resi variable heat price	25 years	3.9%	5.3%	6.4%	7%	8.4%	9.3%	10.1%
	30 years	5.0%	6.2%	7.2%	8%	9.1%	9.9%	10.7%
	40 years	5.3%	6.5%	7.6%	9%	9.4%	10.2%	11.0%
Resi Standing	25 years	0.5%	3.5%	5.7%	7%	9.1%	10.5%	11.8%
	30 years	1.9%	4.5%	6.5%	8%	9.7%	11.0%	12.2%
	40 years	2.0%	4.9%	6.9%	9%	10.0%	11.3%	12.5%
Non Resi Variable	25 years	6.7%	6.9%	7.2%	7%	7.7%	8.0%	8.2%
	30 years	7.4%	7.7%	8.0%	8%	8.4%	8.7%	8.9%
	40 years	7.8%	8.1%	8.3%	9%	8.8%	9.0%	9.2%
Non-Residential Standing	25 years	7.4%	7.4%	7.5%	7%	7.5%	7.5%	7.6%
	30 years	8.1%	8.1%	8.2%	8%	8.2%	8.3%	8.3%
	40 years	8.5%	8.5%	8.5%	9%	8.6%	8.6%	8.6%

Table 22: Sensitivity Analysis Results – Core & Erith (2)

Sensitivity Variable	IRR	25%	50%	75%
EfW Availability	25 years	No IRR available	-4.6%	4.7%
	30 years	No IRR available	-2.3%	5.6%
	40 years	No IRR available	No IRR available	6.0%
		50%	**150%**	**200%**
Network Heat Losses	25 years	7.0%	6.3%	6.0%
	30 years	7.7%	7.1%	6.8%
	40 years	8.1%	7.5%	7.2%
		-10%	**-20%**	**-30%**
Connected Customers Reduction	25 years	4.9%	2.2%	-3.4%
Resi and Non Resi	30 years	5.8%	3.4%	-1.3%
	40 years	6.2%	3.7%	-2.1%
		90%	**80%**	**70%**
Occupancy levels	25 years	7.3%	7.2%	7.0%
	30 years	8.1%	7.9%	7.8%
	40 years	8.4%	8.3%	8.1%
		8%	**10%**	**12%**
Investment Hurdle Rate (m£)	40 years	0.0	3.0	6.0

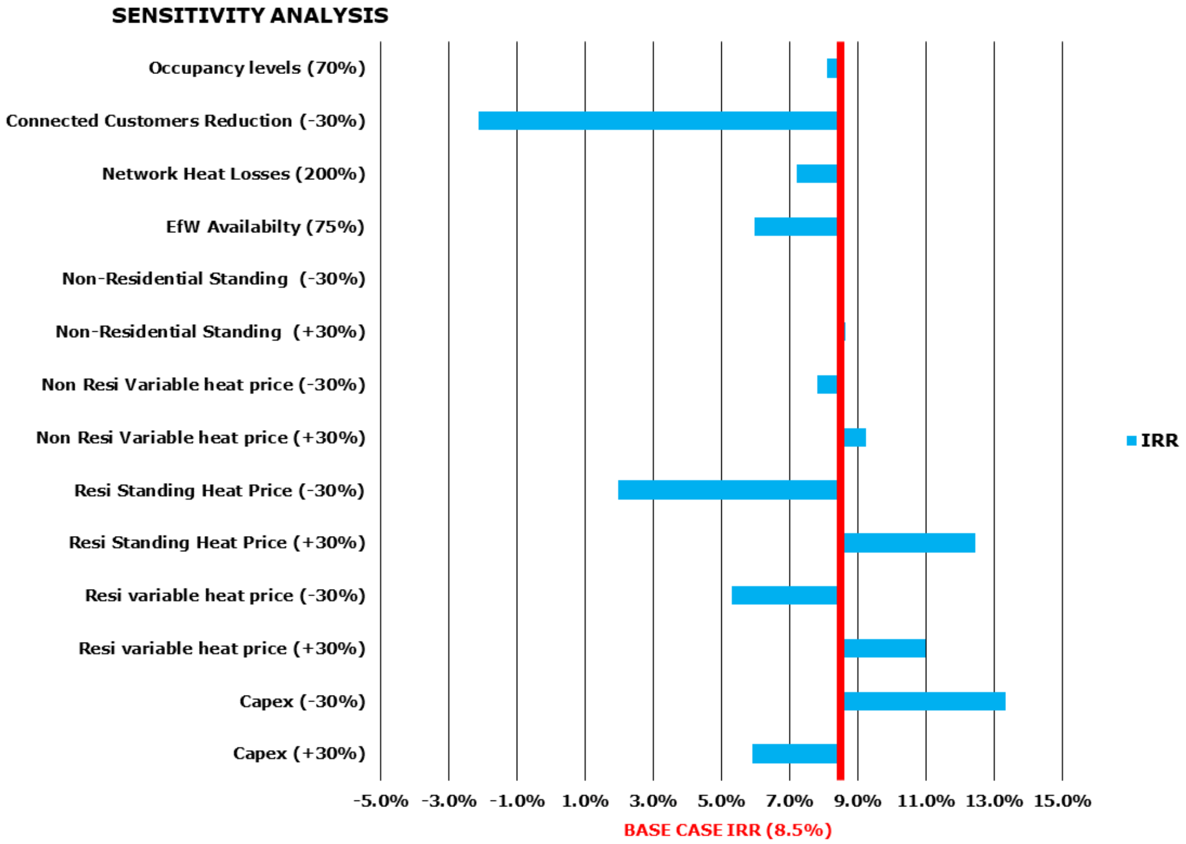


Figure 38: Sensitivity Analysis for the Core & Erith Scheme

5.7.4.3 Compound Sensitivity

In addition to the sensitivity analysis based on key parameter variation in isolation, a compound sensitivity analysis was also undertaken within which every identified parameter was set to a negative 10% increment in terms of financial performance.

For example; overall CAPEX was INCREASED by 10% whereas variable heat price for residential customers was *REDUCED* by 10%. This approach led to application of the following sensitivities for each parameter:

- CAPEX +10%
- Resi variable heat price -10%
- Resi Standing -10%
- Non Resi Variable -10%
- Non-Residential Standing -10%
- EfW Availabilty 81%
- Network Heat Losses 110%
- Connected Customers -10%
- Occupancy level 90%

When applied to the Core scheme, the 40 year IRR figure resulting from this compound sensitivity was **-1.2%**.

The investment hurdle rate to reach an IRR of 5% was also assessed which indicated a requirement for capital injection of **£7.2m**, representing 38% of the total capital cost of the scheme.

5.7.5 Dividend Return Analysis

A further discrete analysis was undertaken to test (at a high level) the impact upon the modelled Core scheme network commercial performance of a third-party investor, such as LBB, requiring receipt of an annual dividend from commencement of the project.

With the techno-economic model compiled at this stage not being a full commercial model, and not featuring full financial variables and functionality, an approximation of this arrangement was tested via an inflation of the applied borrowing cost factor. Set at 4.5% by default, this was increased to 9.5% in order to simulate the provision of a 5% dividend against CAPEX investment.

Revised ranges of approximate internal rate of return (IRR) and net present value (NPV) resulting from this approach, calculated over project periods of 25, 30 and 40 years are displayed, in Table 23.

Table 23: Financial modelling results for dividend return simulation

Scenario	Item	25 YEARS	30 YEARS	40 YEARS
Core	IRR	9.6%	10.2%	10.4%
	NPV 3.5% Discount Rate (k£)	12,175	16,320	19,686

6. CO_2 EMISSIONS ASSESSMENT

Following commencement of Work Package 2, a meeting was held with the GLA on 28th January 2019 to discuss an acceptable method for determining CO_2 emissions attributable to network operation and, in particular, the relative savings provided when compared against a counterfactual case.

In recognition of the changing requirements placed on new developments within London, it was decided to reflect and model multiple counterfactual cases, as described further in this section.

6.1 Counterfactual Definition

The carbon intensity of heat produced by the energy from waste plant was calculated and compared against three counterfactual cases, comprising the following:

1. A scheme served by Air-Source Heat Pumps (ASHP).
2. A scheme served by gas-fired CHP plant.
3. A scheme served fully by gas boilers.

In the case of the gas CHP and ASHP scenarios, the low carbon assets were assumed to cover 70% of the annual heat demand, supplemented by gas boilers.

Results determined from these counterfactual cases are summarised in Table 24.

Table 24: Summary of Counterfactual Cases

Counterfactual Heat Supply Technology	Specifications of Heat Supply Technology	Additional Heat Source	Percentage Contribution from Additional Source	Specifications of Additional Source
ASHP	COP 2.8	Gas Boilers	30%	Efficiency 88%
Gas CHP	Electrical Efficiency 38%; Thermal Efficiency 40%	Gas Boilers	30%	Efficiency 88%
Gas Boilers	Efficiency 88%	-	-	-

6.1.1 Counterfactual Emissions Calculation

The carbon intensity of the counterfactual scenarios was calculated for the years 2019 to 2045, using BEIS projections of the carbon intensity of gas[2] and electricity[3] over this period. This takes into account the future expected decarbonisation of the electrical grid.

The carbon emission for the heat output of a combined heat and power cycle (CHP) is driven by a combination of the carbon factor of gas and the carbon offset in the electricity grid. DECC has commissioned a report to examine the typology of electrical generation offset by additional CHP capacity.[4]

[2] Greenhouse gas reporting: conversion factors 2018, https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018

[3] Green Book supplementary guidance, https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[4] https://www.gov.uk/government/publications/bespoke-natural-gas-chp-analysis

Figure 39 provides a resulting time series for the average carbon intensity of electricity displaced by gas CHP, either via export on on-site consumption.

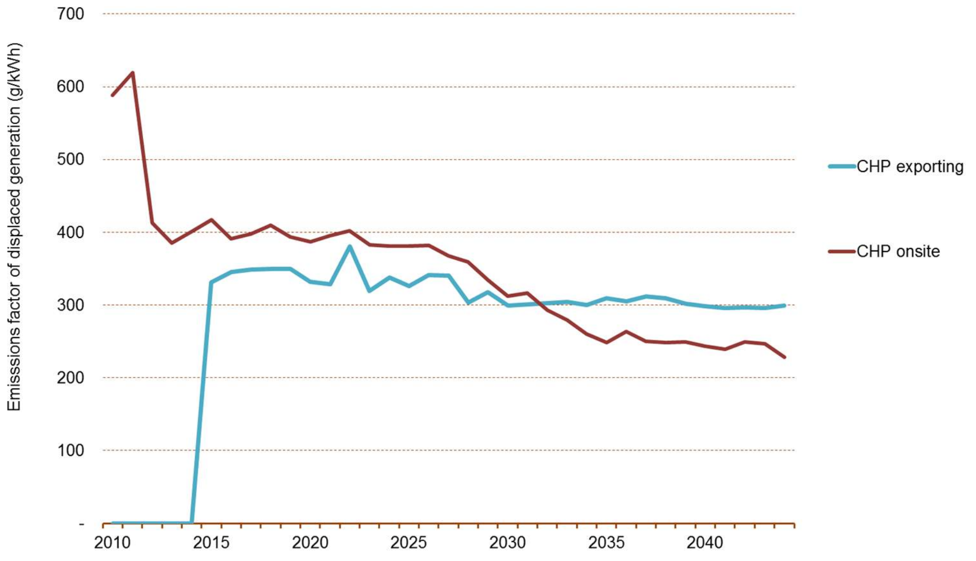


Figure 39: Figures underlying chart on p.67 of Modelling the impacts of additional Gas CHP capacity in the GB electricity market (LCP)

The fluctuations shown in the emissions attributed to electrical generation from gas CHP lead to a corresponding variability in the resulting carbon intensity of heat, as displayed in Figure 40 alongside those for other counterfactual cases modelled.

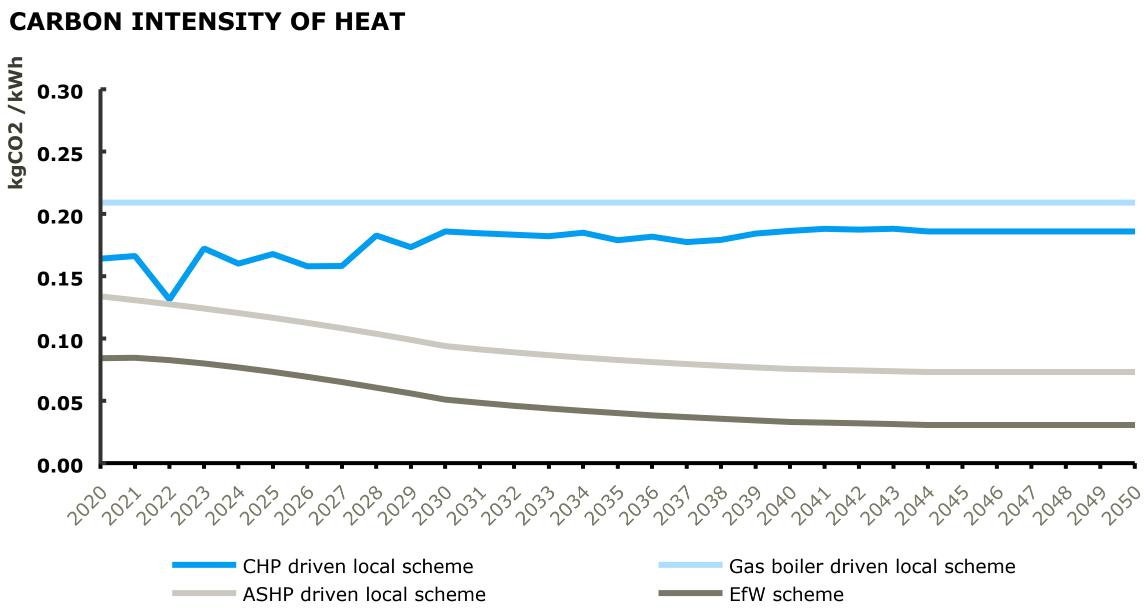


Figure 40: Carbon intensity of heat from network and all counterfactual scenarios

In all cases the annual heat demand was assumed to be consistent over time. When necessary this demand was split between gas boilers and another technology, as stated in Table 24.

Using the specifications listed in this table, the annual gas and electricity consumption was calculated for each scenario and the carbon intensities applied in order to determine the carbon emissions in each case. In this way, the amount of carbon dioxide equivalent emissions per kWh of heat energy were calculated, with the results shown in Table 25 .

Table 25: Annual carbon emissions predictions

	Year	2021	2026	2031	2036	2041	2046
ASHP driven local scheme	ton CO2e	2,862	7,657	7,195	7,033	7,099	7,262
CHP driven local scheme	ton CO2e	3,638	10,747	14,541	15,765	17,800	18,468
Gas boiler driven local scheme	ton CO2e	4,576	14,222	16,479	18,136	19,793	20,768
EfW scheme	ton CO2e	2,122	4,934	3,972	3,447	3,182	3,136
Net savings from a gas boiler scheme	ton CO2e	2,454	9,288	12,507	14,689	16,611	17,632
	%	54%	65%	76%	81%	84%	85%

Table 25 summarises carbon emission figures for selected years based on technology and development of heat demand. The EfW emissions include the emissions corresponding to distribution losses (3%-13% depending on build-out) as well as the boiler share of heat.

Overall, while the grid decarbonises and the EfW emissions associated with reduced electrical exports diminish, the scheme is expected to save up to 85% compared to a gas boiler driven heat network.

Compared to an ASHP driven network, the EfW scheme is expected to emit less than 50%. The main drivers is the z factor which is way higher than an ASHP seasonal COP (~2.8) and the significant gas boiler contribution to any ASHP scheme (~ 30%).

6.2 Network Heat Emissions

From Table 25, it can be seen that consumption of heat offtake from the energy from waste plant has a lower carbon intensity than all counterfactual cases over the entire period modelled.

These emissions were calculated using the following assumptions:

- The EfW plant was assumed to meet 90% of the yearly demand, with a 10% contribution from gas boilers with an efficiency of 88%.
- The ratio of sacrificed electrical generation in order to produce heat (the 'Z-Factor') was modelled at 4.3.
- Electrical consumption for pumping and other parasitic load was modelled as 2.5% of the annual heat supplied by the network.

In keeping with the counterfactual cases modelled, the gas and electricity consumed along with the carbon factors for gas and electricity were used to calculate the carbon intensity of the heat from the energy from waste plant.

7. CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

The key conclusions emerging from Work Package 2 are as follows:

1. The total level of heat demand and annual consumption determined for all loads modelled for connection to an initial "Core Scheme" network, comprising the Belvedere, Thamesmead and Abbey Wood redevelopment areas (plus limited adjacent existing buildings/sites) can be met via heat offtake from the Cory EfW plant.

2. In line with Cory's proposed annual availability of 90% for heat offtake, the provision of supplementary heat generation and storage is required to meet year-round demand and is proposed to comprise a mix of centralised and distributed plant.

3. The techno-economic modelling undertaken indicates that delivery and operation of a full Core Scheme network could achieve IRRs in the region of 7.5% – 11.1% (depending upon its extension into Erith) and positive NPVs, whilst providing competitively priced heat to all connected customers.

4. The utilising of heat generated from the Cory plant, at the point of full Core Scheme buildout, could deliver an overall CO_2 saving of 3,970 tonnes/annum against a counterfactual case of new Air-Source Heat Pump plant, adhering to projected new London Plan requirements, or 14,900 tonnes/annum against a case of gas-fired CHP led communal heating schemes.

5. If a more aggressive build-out scenarios are considered for both the Core Scheme and additional sites further afield, in both Bexley and Greenwich, it is likely that a further heat source(s) beyond the existing Cory plant would be required to meet total heat demands.

7.2 Recommendations

Based on the works undertaken throughout Work Packages 1 & 2 of this feasibility study, the following recommendations are made

i. A number of differing growth scenarios exists and have been seen for the various development areas identified by the London Boroughs of Bexley and Greenwich. Whilst the scenarios agreed to be most realistic have been applied within this feasibility study, the next stage of work should revisit and confirm the most appropriate growth figure to use going forward.

ii. Following early discussions around the principle of locating plant on Cory's site associated with operation of the DH network, further development of the space and access requirements in recommended in order to validate assumptions and ensure feasibility.

8. NEXT STEPS

The following are the perceived key next steps to be followed for the project as a whole, as it proceeds toward more detailed development. The timing and order of these will be subject to LBB's preference and plans, however all are intended to assist a re-risking the project and maximising its likelihood of delivery and commercial success.

A. Project to be taken forward to the stage of developing an Outline Business Case.

B. LBB to progress early discussions with Cory over the principles and arrangements for heat offtake pricing (with meetings in this regard already planned).

C. Engagement with other LBB development partners to be sought to the level already in place with Peabody, with Orbit Homes identified as one such key party.

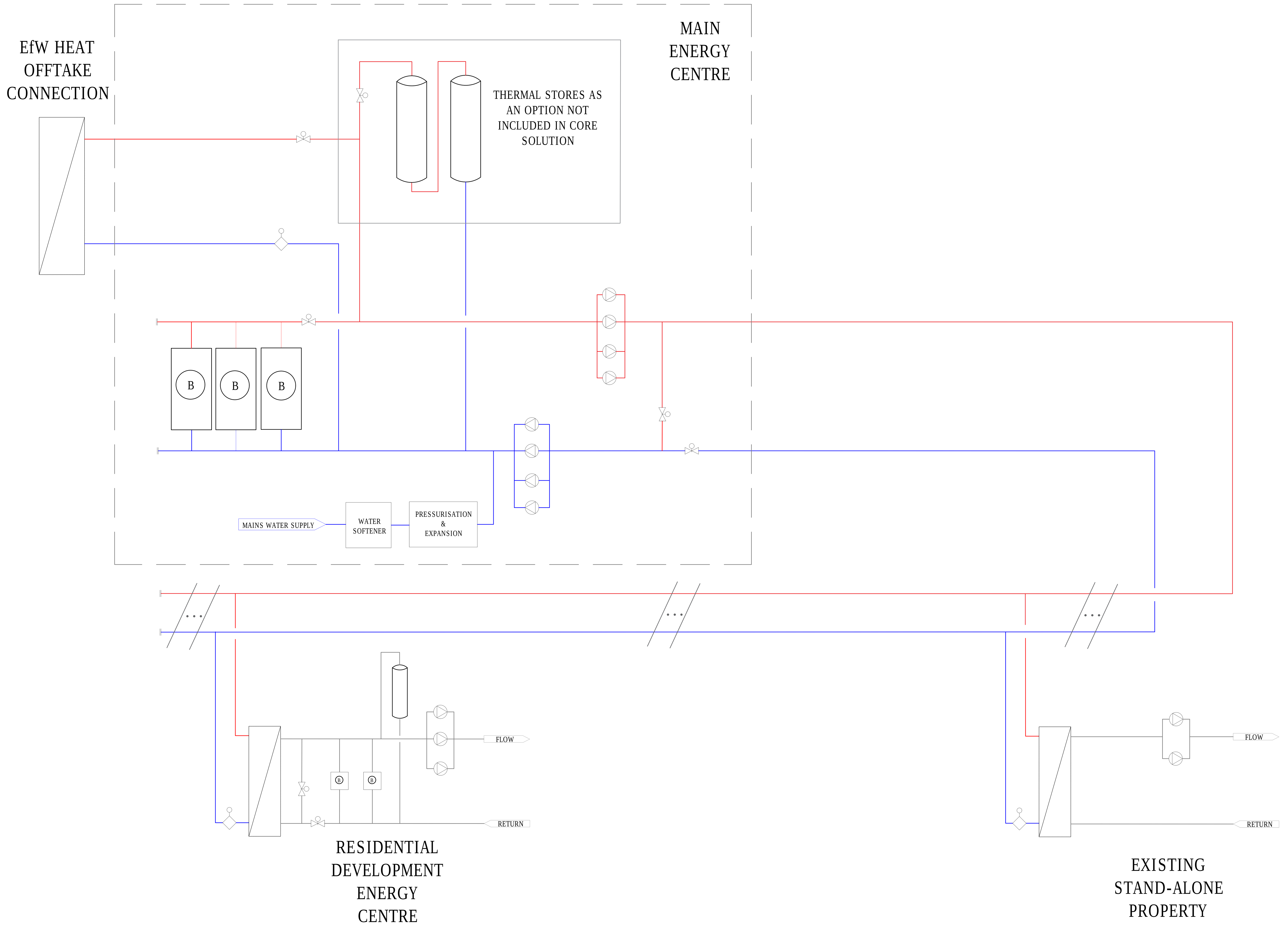
D. LBB to consider and determine its key objectives and goals for the network and with this its preferred role and level of engagement going forward in development and delivery of the scheme, as part of wider discussions with known and potential partners.

E. LBB to continue close working with the GLA, given the strategic importance of the project, to maintain and maximise their support and added value going forward.

F. Seeking of advice and support from appropriate Commercial and Legal partners to develop draft agreed Heat of Terms for heat sale agreements, expected to involve (at least) Cory and Peabody.

G. Consider in more detail the option of seeking project capital funding via the Government's HNIP scheme, including identifying the best time during project development to apply for this support.

APPENDIX 1
HEAT NETWORK SCHEMATIC



Notes

1. ALL DIMENSIONS ARE IN METERS U.N.O.

Rev	Description	Date	By / Chk	App
01	PRELIMINARY	Apr-19		

Thamesmead & Belvedere DHFS

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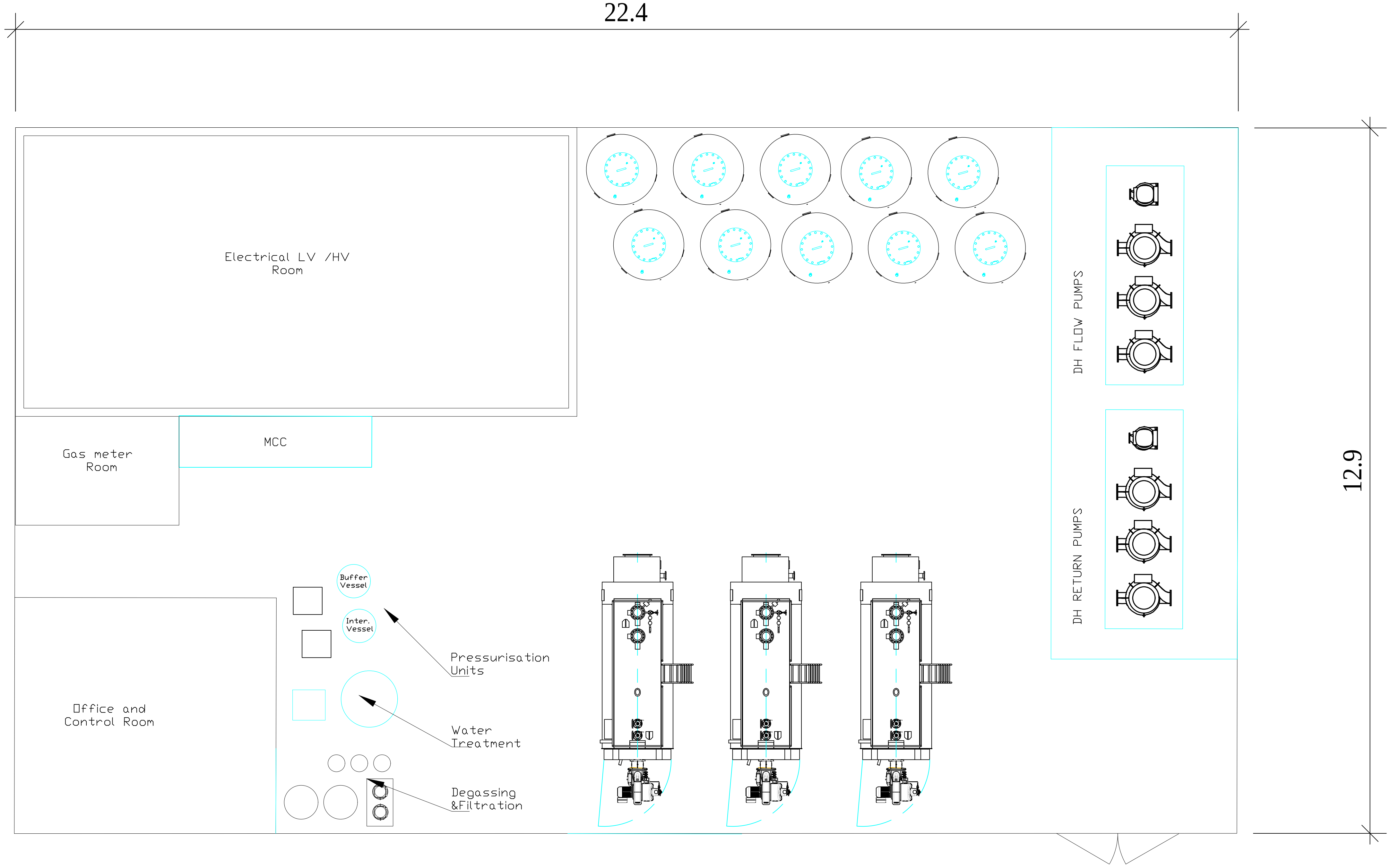
BEXLEY DHN SCHEMATIC

Project No:	Scale (@A1):	Drawn:	Date:
1620005147		ELOCK	Apr-19

Drawing No:	Rev:
	01

APPENDIX 2
DH NETWORK PUMPING & CONTROL CENTRE LAYOUT



Notes

1. ALL DIMENSIONS ARE IN METERS U.N.O.

Rev	Description	Date	By / Chk	App
01	PRELIMINARY	Apr-19	AC / OP	OP

Thamesmead & Belvedere DHFS

RAMBOLL
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DHN Distribution Plantrroom

Project No:	Scale (@A1):	Drawn:	Date:
1620005147		ACHAT	Apr-19

Drawing No:	Rev:
1620005147-PS-GA-001	1.1

18/04/2019

APPENDIX 3
DESIGN RISK REGISTER

DESIGN RISK ASSESSMENT

Project Name:	Thamesmead & Belvedere DH Feasibility Study	**Job No:**	1620005147	**Document Ref:**	0-05-054
Stage / Section of works:	Work Package 2	**Issue date/revision:**	30.04.2019 / V2	**Project Director Approval:**	LPADF

Activity /Element Cat¹	Nº	Risk / Opportunity Item	Implication	Risk Estimation (Residual Evaluation) Probability Rating (1-4) a	Severity Rating (1-4) b	Resulting risk level (1-16) a x b	Control / Influence	Ramboll action to eliminate risk and maximise opportunity	Residual risks / actions that remain	Action By	Status
	1	**ENERGY DEMAND ASSESSMENT**									
P	i	Applied energy consumption benchmarks are higher or lower than those occuring in reality.	Loads determined for connecting buildings/sites are either over or under-estimated, leading to over or undersizing of related distribution infrastructure.	1	2	2	C	Benchmarks used in WP1 have been further refiend to take account of latest Ramboll project experience in this field.		Ramboll	*Closed*
P	ii	Modelled development quanta does not reflect that ultimately brought forward.	Loads are incorrectly determined and related distribution infrastructure not sized appropriately.	2	2	4	C	Development information has been consulted on with all relevant parties.		Ramboll	*Closed*
P	iii	Identified existing buildings/loads operate heating systems incompatible with connection to heat network.	Loads are incorrectly included and related distribution infrastructure not sized appropriately.	2	1	2	C	A minimal number of existing buildings are being considered for connection to the network, with the largest of these visited during WP2 to assess feasibility.		Ramboll	*Closed*
	2	**ENERGY SUPPLY ASSESSMENT**									
P	i	Estimates of heat offtake availability from Cory plant are inaccurate.	Heat offtake and distribution equipment & infrastructure are incorrectly sized.	1	2	2	C	Cory have been consulted with during WP2 works and a heat availability factor confirmed and used within WP2 modelling work.		Ramboll	*Closed*
P	ii	Parameters used to determine heat offtake capacity and associated costs are inaccurate.	Impact upon accuracy of commercial case derived for new heat network.	1	3	3	C	Key parameters applied have been provided by Cory.		Ramboll	*Closed*
	3	**ENERGY DISTRIBUTION ASSESSMENT**									
P	i	Presence of obstacles or constraints preventing or limiting ability to route new heat network pipes as propsed.	Change in network routing leading to increased capital costs.	2	2	4	C	WP2 has included both a physical walking of the majority of proposed network route plus the gathering of concise information on existing buried services.		Ramboll	*Closed*
P	ii	Underestimation of pipework involved with connecting to new development loads within Erith area.	Alteration to hydraulic operation of network.	1	2	2	C	Further detail around Erith development quanta has been received and applied during WP2 work.		Ramboll	*Closed*
P	iii	Assumed pipe sizes for main distribution network are not approriate for final derived loads.	Potential limitation of network heat carrying capacity.	2	2	4	C	Full hydraulic modelling has been undertaken during WP2,a nd allowance has been made to future-proof the load-carrying capacity via an oversizing of main distribution pipework.		Ramboll	*Closed*
P	iv	Works not completed to size thermal stores.	Space required for thermal stores not determined.	2	3	6	C	Modelling undertaken during WP2 to size and locate thermal storage volumes, both centralised and distributed.		Ramboll	*Closed*
P	v	Selected approach to network hydraulic separation does not match Developer connection expectations.	Additional costs invovled with providing additional hydraulic breaks and heat exchange equipment.	1	2	2	C	Engaged developers have been provided with proposed approach to hydraulic separation and have raised no concerns.		Ramboll	*Closed*
	4	**ECONOMIC ASSESSMENT**									
P	i	Bulk heat offtake purchase price assumptions do not match those expected by Cory.	Impact upon modelled business case.	3	2	6	C	WP2 economic model has been built and includes heat offtake & purchase assumptions in line with Cory discussions.	Further development of a project Commercial Case to continue process of Cory engagement.	LBB	**Open**
P	ii	Definition and delineation of heat network roles do not reflect stakeholders preferences.	Alterations required to economic modelling.	2	1	2	C	WP2 modelling has been based around current thinking of all parties on roles within network delivery and operation.		Ramboll	*Closed*
P	iii	Price comparator calculations undertaken for Resi and non-Resi customers do not reflect true market values.	Impact upon modelled business case.	1	3	3	C	Price comparators have been revised as part of WP2 modelling work to ensure these are as representative as possible.	Subsequent Commercial Case development to include a revisitation of these calculations.	LBB	**Open**
P	iv	Underestimation of CAPEX associated with plant and infrastructure.	Impact upon modelled business case.	2	3	6	C	Ramboll experience and means-tested benchmarks used to derive CAPEX figures.		Ramboll	*Closed*
P	v	Underestimation of pipework involved with connecting to new development loads within Erith area.	Impact upon accuracy of commercial case derived for new heat network.	2	2	4	C	Further detail around Erith development quanta has been received and applied during WP2 work.		Ramboll	*Closed*
P	ix	Underestimation of pipework involved with connecting to new development loads within Erith area.	Impact upon accuracy of commercial case derived for new heat network.	2	2	4	C	Further detail around Erith development quanta has been received and applied during WP2 work.		Ramboll	*Closed*

1 (C) CDM / (P) Project / (E) Environmental