Heat Network Mapping and Masterplanning for Newport and Ryde (Nicholson Road)

Report #3: Heat Network Masterplanning - Nicholson Road area, Ryde

Final report

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

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Glossary

AHU	Air handling unit	IoW	Isle of Wight
BEES	Building Energy Efficiency Survey (commissioned by BEIS)	IWC	Isle of Wight Council
BEIS	Department of Business Energy and Industrial Strategy	IWNHST	Isle of Wight NHS Trust
CCL	Climate Change Levy	IRR	Internal Rate of Return
CHP	Combined Heat and Power	JV	Joint Venture
CO_2	Carbon dioxide (emissions arising from energy use)	LCOE	Levelised Cost of Energy
CoP	Coefficient of Performance (of heat pumps)	LPHW	Low Pressure Hot Water
CRC	Carbon Reduction Commitment	MDPE	Medium Density Polyethylene (a form of plastic pipe)
CRT	Canals and Rivers Trust	MTHW	Medium Temperature Hot Water
C&I	Commercial & Industrial	MSW	Municipal Solid Waste
DC	District Cooling	NEED	National Energy Efficiency Data-Framework (BEIS)
DH	District Heating	NCV (LHV)	Net Calorific Value (Lower Hear Value)
DHW	Domestic Hot Water	NEED	National Energy Efficiency Database
DN	Nominal diameter in mm (Diametre Nominal)	NHS	National Health Service
DNO	Distribution Network Operator	NPV	Net Present Value
EED	EU Energy Efficiency Directive	O&M	Operation and Maintenance
GCV (HHV)	Gross Calorific Value (also referred to as Higher Heat Value)	PWLB	Public Works Loan Board
GIS	Geographic Information System	QEP	Quarterly Energy Prices (BEIS dataset)
GSHP	Ground-source heat pumps	RHI	Renewable Heat Incentive
HIU	Heat Interface Unit	ROC	Renewable Obligation Certificates
HOB	Heat-only Boiler	SPV	Special Purpose Vehicle – a company created for a specific purpose
HN	Heat Network	VAT	Value Added Tax
HNDU	Heat Network Delivery Unit (BEIS)	WACC	Weighted Average Cost of Capital
HNCP	CIBSE Heat Network Code of Practice	WDF	Waste Derived Fuel
HNIP	Heat Network Investment Project	WSHP	Water Sourced Heat Pump

1 Executive summary

This report presents an investigation into the potential for the development of energy network solutions (heat networks) for an area around the Nicholson Road development in Ryde, which is being led by the Isle of Wight council.

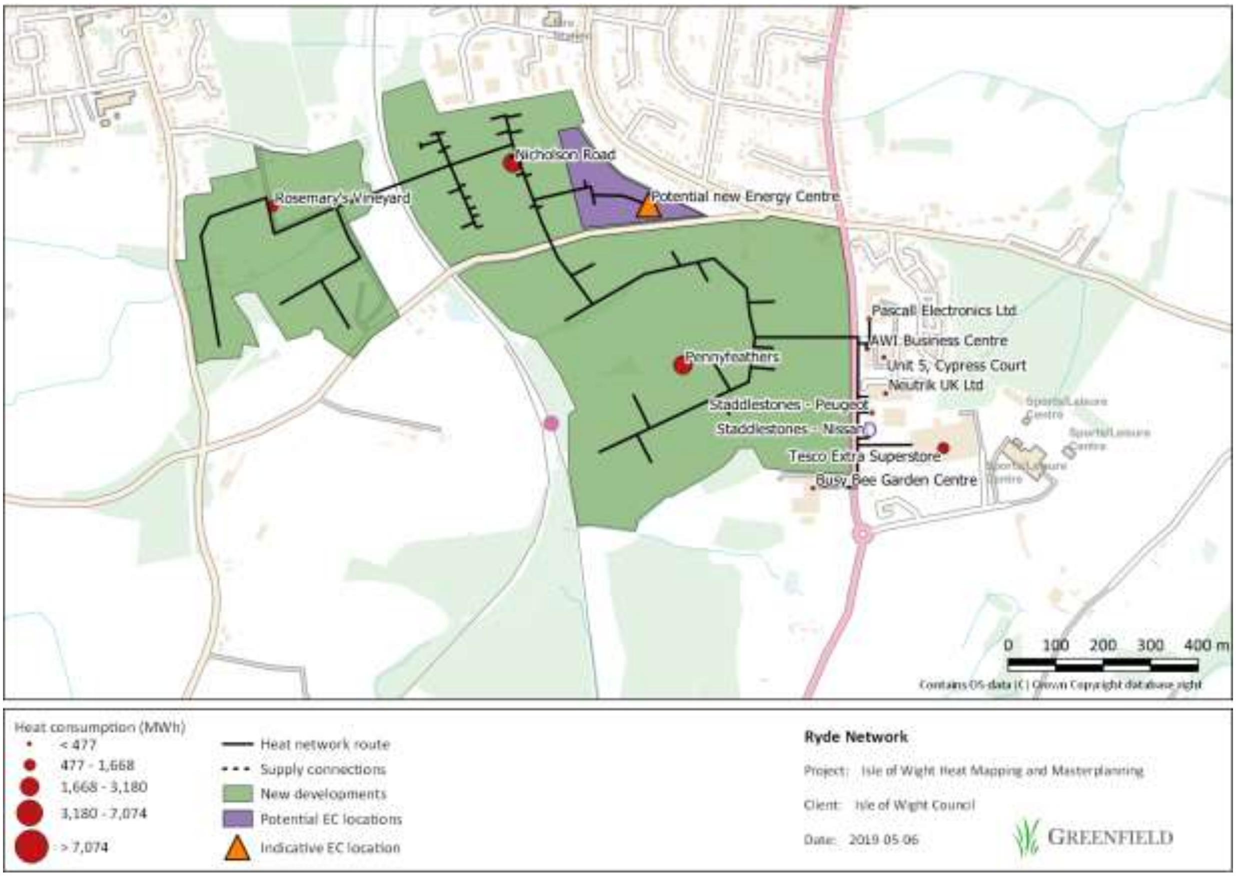
The work is defined as a mapping and masterplanning exercise. As such it involves a high-level review of potential consumers and low carbon supply opportunities, from which specific heat network opportunities have been notionally developed and tested. The testing explores economic and carbon reduction performance and the deliverability of the opportunities identified, drawing conclusions for the next steps of development, which would focus on detailed feasibility work.

Identifying consumers, low carbon supply and network options

Energy mapping based on primary consumption data, where available, or otherwise energy benchmarking has been completed. The heat demand identified is shown below. Points or "bubbles" identify a heat load and its size represents the approximate quantum of demand and green zones represent planned new development.

The following technology options where considered to supply a heat network: biomass boiler, gas CHP and Ground Source heat pumps (GSHP). The last was excluded after evidence from the British Geological Survey suggested the underlying soil/rock condition and hydrology were unlikely to support an open- or closed-loop GSHP system. Since gas CHP has an inherent carbon performance issue it was decided to examine biomass boilers on their own and a hybrid biomass/CHP solution.

Initial heat network designs, including indicative network routes (see below) and sizing, supply technology sizing, energy centre design and costings where completed, after which point they were tested through technical and financial modelling.



Economic / carbon performance

The analysis of economic performance of the two network options, as they are presently conceived, illustrates a poor rate of return but significant carbon savings as shown in the table below.

Techno-economic analysis results			
	Unit	Gas CHP & Biomass boiler	Biomass boiler
Financial			
Total CAPEX (to full build out)	£m	14.3	13.2
NPV (25 yr @ 3.5 %)	£m	-3.8	-3.4
IRR (25 yr)	%	0.9 %	1.0 %
Minimum grant to achieve 6 % IRR	£m	5.8	5.2
Carbon			
CO_2 savings over 25 yr	ktCO_2/yr.	13.9	17.4
CO_2 savings over 25 yr	%	31.0 %	41.8 %

In summary the conclusions from this analysis are as follows:

It is apparent that relatively low energy demand of the, primarily, new-build consumers restricts the rate of return to approximately 1% (IRR 25-year). This inclusion of CHP to the biomass boiler solution slightly reduces performance primary because the identified potential power consumption is low.

There are likely to be opportunities to improve economic performance through value engineering, identifying/attributing 'avoided costs' of the developments, and, more radical design solution such as a low temperature,direct property connections (removing heat interface units) or increasing power sales through inclusion of battery storage or electric vehicle charging. These are discussed in this report but would require further investigation to understand if they would bring sufficient benefit.

Gap funding, e.g. from the Heat Network Investment Project (HNIP), could support the project. However, unless improvements are made in base economic performance then circa 35% of capital costs are required to achieve a 5% IRR (25-year) and close to 50% (assumed to be the maximum possible as restricted by state-aid rules) would be required to achieve a 10% IRR. Whilst this level of funding may be possible, it is not considered likely because the scale of the heat network and the lack of expansion potential will mean it will not compete well against other funding bids.

If delivered, the project is estimated to provide a range of benefits including reduced consumer energy costs, reduction in carbon emissions (between 31% and 40% for connected properties - depending on supply technology) and inward investment (circa £13m to £14m).

If IWC further support this project, it will also be necessary to address the number of key risks (further the economic performance) which include:

1. Securing consumers: this risk is significant. Whilst it is a reasonable expectation that the council-led Nicholson Road scheme would be included (assuming it meets commercial and performance requirements), the other developments and existing prospective consumers are much less certain. It will be important for the council to balance general development and climate change/heat network objectives through engagement with development stakeholders. The timing of the availability of the heat network and the degree or confidence that developers could attribute to it will be important, or they will simple pursue more standard solutions.
2. Development Governance: it is anticipated that the council would need to lead development and so the primary risk resides around their ability to bring forward the resources and capability to implement.
3. Renewable Heat Incentive revenues: RHI is due to close in quarter 1, 2021 (with no extension/replacement currently planned). In any case, where a project relies on the RHI income this will expire after year 20, which is the standard contract term applicable. As shown in the sensitivity analyses, having no-RHI would severely worsen the case for investment into the scheme.

Recommendations

Key development recommendations for this heat network opportunity are as follows:

1. Examine and reflect on the evidence in this report and conclude whether the council perceives value in exploring the various improvement opportunities, in the context of the project and development risks highlighted

……assuming IWC agrees to pursue this scheme further, then:

2. Conduct a rapid and focused design review to explore key improvement opportunities and test the outcome of this with key stakeholders, i.e. the property developers (especially for the Pennyfeathers scheme which has a planning obligation to implement a CHP/heat network solution). Avoided or shared costs should also be reviewed with developers at this point.

…….assuming there is positive support from stakeholders and IWC, then:

3. Establish development management process. The nature of the project would require the council to take the lead on development. It is anticipated that the council would need be the

commissioning/procurement agency with a role in securing the finance, either through raising debt (such as PWLB) or negotiating private investment.

4. The council would need to establish internal governance and project management arrangements and implement the implementation plan that will come from this.
5. The council should initiate the approval process to move the opportunity on to a formal project development status.
6. The council would need to commission/implement a number of critical tasks (using internal and external resources), including:
    - further engagement with stakeholders;
    - further develop heat network design to address techno-economic improvement opportunities and mitigate key risks (a feasibility study); and;
    - establish ownership, procurement and funding strategies

2 Introduction

The scope of this study was to examine the feasibility of implementing a heat network in and around the Nicholson Road development, Ryde, which is being led by Isle of Wight Council (IWC). The work is defined as a mapping and masterplanning exercise and work is designed to be compliant with UK Heat Network Code of Practice (CP1).

In the study the area of focus has been expanded beyond the “Nicholson Road” development site in the knowledge that heat network solutions of larger scale will tend to perform better in economic terms.

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

Focus on new development

IWC have proposed a heat network solution in this area primarily in response to its own aims to deliver lower carbon development and responding to the planning requirement that all significant development on the Island is expected to install low carbon district heating systems as per planning policy DM1 - Sustainable Build Criteria, which states:

> *Proposals for developments containing in excess of 250 housing units, or having an aggregate domestic living area of greater than 18,000m2, shall be expected to install community district heating systems that use low carbon heat sources. The council will consider the viability and feasibility of each case on its merits and will consider evidence demonstrating why a development should not be required to deliver the above.*

In area around the Nicholson Road this policy requirement would apply to the “Pennyfeathers” development, which is proposed on land immediately to the south of the Nicholson Road scheme.

Other developments in the area including the proposed “Rosemary’s Vineyard” to which the following element of the DM1 policy would apply, as it sits under the 250 unit threshold:

> *Development on the Island should include measures to reduce carbon dioxide emissions from energy use, in accordance with the following energy hierarchy:*
>
> *i) Minimising energy requirements.*
> *ii) Incorporating renewable energy sources.*
> *iii) Incorporating low carbon energy sources.*
> *iv) Incorporating CHP/District Heating where feasible.*
>
> *The Council will support proposals which contribute to both mitigating and adapting to climate change and to meeting the national targets to reduce carbon dioxide emissions. All major development will incorporate renewable energy systems to provide at least 10% of the predicted energy requirements.*

As discussed within the report, the heat network solution developed and examined has focused on the major development schemes surrounding the “Nicholson Road” development together with suitable existing properties that could potentially be consumers on a heat network.

3 Scoping of heat network option

3.1 Key prospective energy consumers

Initial mapping of prospective consumer properties (and associated energy demand or loads) within the study areas has been conducted as described in Appendix 1.

The assessment of consumers has used various data sources, including:

- Filed EPC and DEC records
- Isle of Wight Strategic Housing Land Availability Assessment
- Development site planning documents
- Metered or billing consumption data for existing consumers, where it was made available by property owners/operators (used when exploring council properties)
- Open source information (e.g. Google Maps)

To maximise the certainty of the quantification of prospective demand, metered or billing data has been sought from all significant consumers. Where this was not available (and for smaller consumers), benchmarking was conducted using BEES[1] (non-residential) and NEED[2] (residential) consumption benchmarks to enable a reasonable representation of demands. As reviewed in the report, the new developments included in the analysis present uncertainty over quantum, type, and timing of development. The latest masterplanning information available and discussions with the developers (IWC, in the case of Nicholson Road) has been used to 'fix' key assumption.

The following sections summarise prospective consumers, with additional information in Appendix 2 (including information on those developments not subsequently included in the analysis).

3.1.1 Nicholson Road development

Nicholson Road is an employment development aiming to expand the capacity of Ryde Business Park in stages to provide additional employment space, including industrial and office and supporting uses. The development consists of a community hub, an office park, business incubators and flexible business park. In total the planned floor area is 29,251 m^2.

The latest iteration of the development strategy[3] recommends construction phasing is split into three character areas:

1 - COMMUNITY HUB

A cluster of six buildings ranging from 1 to 4 storeys at the entrance to the proposed business park, providing A and D uses, with ten ancillary residential (C3) units. The mix of uses is intended to create a civic hub for the site.

2 - OFFICE CAMPUS

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[1] Building Energy Efficiency Survey (BEES), BEIS
[2] National Energy Efficiency Data-Framework (NEED), BEIS
[3] Nicholson Road, Stage 2 Report, November 2018, RCKa

A series of five 2 storey B1(a) office buildings located to the west of the north/south hedgerow. Vehicles are restricted to the east of the hedgerow only, in order that the office users may benefit from a green landscape setting.

3 - BUSINESS PARK

Smaller B1(b) and B1(c) units each facing inwards to a central yard accessed off the main north-south road providing car/van spaces for each unit. Each unit is divided into a number of 90 sqm spaces, modelled on the existing Enterprise Court in the Nicholson Rd Business Park, intended for small and start-up businesses.

Larger B2 and B8 units arranged around the loop road, staggered in size from approximately 500 to 2,500 sqm. Each unit allows for sufficient space within its own yard or plot to accommodate the unit's parking requirements including HGV's and storage.

The development masterplan is shown in *Figure 3-1* and a development schedule (development type and quantum are shown in Appendix 2.

Figure 3-1 Nicholson Road Masterplan (2018)

3.1.2 Pennyfeathers development

Pennyfeathers is a planned mixed-use development with 904 residential units. A school, community centre, commercial buildings and a sports building are planned. Outline planning was granted in 2015 and discussions with the developer's planning agent has indicated that a detailed planning application for the 1st phase will be forthcoming in the near future.

The development was planned to be phased between 2015-2027, but the construction has not yet started. For the purpose of this analysis, the district heating construction is assumed to start in 2020.

Whilst the development has an obligation to install district heating as per planning policy DM1, discussions with the developer's agent did not suggest that district heating solution is being developed. As such, the development of the district heating strategy integrating Nicholson Road and Pennyfeather is likely to enable the Pennyfeather scheme to meet this planning obligation. For reference, the original outline planning submission refers to an energy strategy as follows:

"…..adopts the 'energy hierarchy' in full, combining energy efficiency measures to ensure energy demand and associated carbon emissions are minimised from the outset. Clean and zero/ low carbon energy technologies are also proposed, including district heating/ CHP and high efficiency gas boilers. On-site renewable energy is also anticipated for phase 2 onwards in the form of roof-mounted photovoltaic (PV) panels in order to further reduce carbon emissions."

For this analysis the scheme masterplan from the 2015 outline planning submission[4] has been used as a reasonable representation of the overall development. Figure 3-2 illustrates the proposed land-use phasing arrangement. Clearly this shows that the proposed non-residential development is clustered around the eastern edge of the site, in close proximity to existing large consumers (on eastern side of Brading Road).

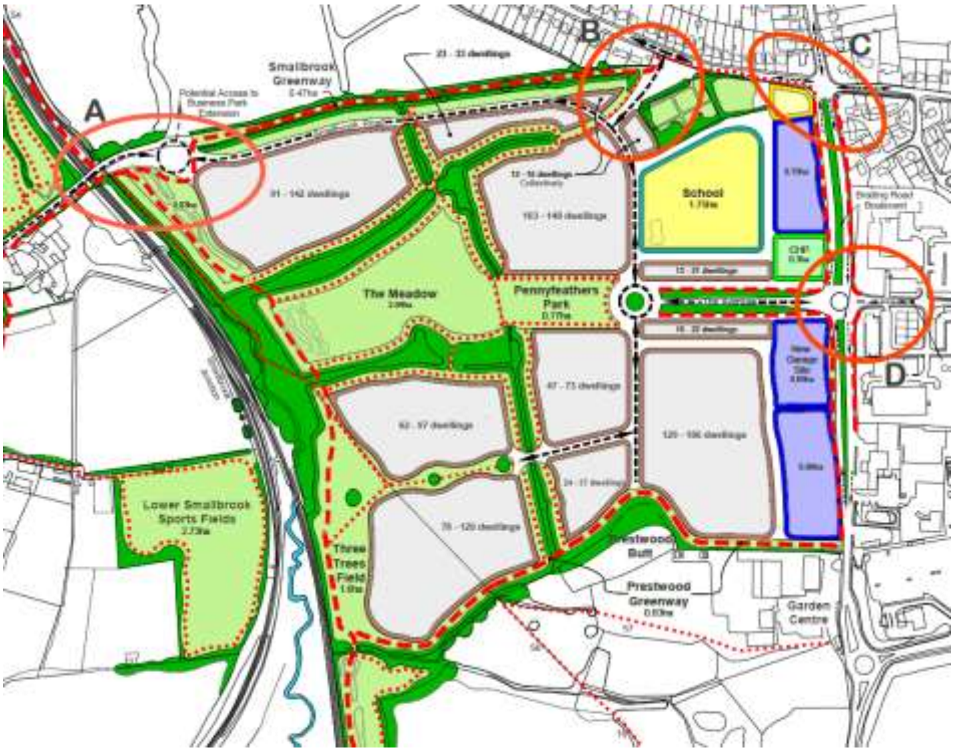

Figure 3-2 Pennyfeather Masterplan (2014)

3.1.3 Rosemary's Vineyard development

This is a largely a residential development off Smallbrook Lane. An original planning application was submitted in 2014[5] for 197 dwellings and a number of community buildings. The development is proposed to be built in three phases but completion dates have not been provided by the developer. For the purposes of analysis constructed is assumed to occur between 2021 and 2024.

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[4] *Design and access statement – Pennyfeather development, Farrell Design Studio, 2014*

[5] *Planning application: TCP/30335/B*

Figure 3-3 Rosemary's Vineyard development masterplan (2014)

3.1.4 Other new development sites

Two other new development sites to the north-east of the Nicholson Road development site were also considered. These developments, Westridge Farm (rear of Circular Road) and Land at Upton Road, were subsequently excluded from the analysis since:

(1) they would only add a small number (compared with Pennyfeather) of low density housing units
(2) require additional connecting heat network which would increase overall cost (with limited energy sales in return)
(3) it would add two further consumer stakeholders who would not be required to implement a heat network / CHP solution because they are not delivering "major development" (over 250 homes)

Further details of these development are shown in Appendix 2.

3.1.5 Existing prospective consumers

A number of existing properties were also identified to the east of Brading Road, which if they could be connected would provide a number of advantages that would support the case for a heat network. Firstly, they could provide an initial focus for consumer demand, without the uncertainty in terms of quantum and timing of the new development schemes. It would also provide a demand profile balance to the new development which, with the Pennyfeather and Rosemary's Vineyard developments included, would largely be residential. Residential consumption will, by its nature, present 'peaky' heat/hot water loads due to occupancy patterns and non-residential development with greater daytime demand will have a balancing effect, enabling more efficient operation of a heat network.

The following existing consumers were identified and have been included within the analysis:

- Pascal Electronics
- AWI Business Centre
- Cypress Court
- Neutric UK
- Staddlestones

- Tesco Extra Superstore
- Busy Bees Garden Centre

3.1.6 Schedule of prospective consumers

Table 3-1 summarises the prospective consumer included within the analysis.

Site	Peak heat (MW)	Heat Load (MWh)	Power Load[6] (MWh)	Data Source[7]	Engagement notes
Developments					
Pennyfeathers	2.40	2,704	792	New development benchmarking	Review of planning documentation and discussion with scheme land agent, Hepburns Planning Consultancy
Nicholson Road	1.55	2,172	724	New development benchmarking	Review of masterplanning documentation, including Stage 2 feasibility report (2018) and discussion masterplanning consulting team and IWC project manager
Rosemary's Vineyard	0.74	621		New development benchmarking	Review of planning documentation
Existing properties					
Neutrik UK Ltd	0.14	196		BEES	Benchmarked based on building footprint and no. of storeys
Tesco Extra Superstore	0.91	1,511		BEES	
Busy Bee Garden Centre	0.12	183		BEES	
Pascall Electronics Ltd	0.13	172		BEES	
AWI Business Centre	0.06	77		EPC	
Staddlestones - Nissan	0.03	40		BEES	
Staddlestones - Peugeot	0.02	22		BEES	
Unit 5, Cypress Court	0.01	12		BEES	
TOTAL (ALL)	**6.09**	**7,710**	**1,516**		

Table 3-1. Ryde prospective consumer schedule

Phasing

Based on review of the development plans, an indicative phasing plan was developed as follows for the new development sites:

- Nicholson Road development is connected in two phases between 2022-2026
- Pennyfeathers development is connected in five phases between 2022-2027
- Rosemary's Vineyard is connected in three phases between 2022-2026

Connection of existing consumers tends to be flexible because the need to replace existing plant is subjective and consumers may be prepared to connect earlier, if a heat network can offer sufficient commercial and/or operation benefit. In the modelling it has been assumed that all existing consumers are connected from the first year of operation.

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[6] *Showing only the loads assumed to be connected to private wire network (restricted to non-residential consumers within Nicholson Road and Pennyfeather developments*

[7] *BEES and NEED refers to benchmarking used*

Spatial distribution of demand

The heat demand identified is shown in Figure 3-4 in point-load format, where a point or "bubble" identifies a heat load and its size represents the approximate quantum of demand.

Figure 3-4 Nicholson Road area heat demands for selected consumers.

During consumer data collection no significant specific cooling demands were identified. Some cooling load is likely to exist, for example in the Tesco store and within office developments, but it is anticipated this would be too small and too distributed to justify a network supply solution.

3.2 Energy supply opportunities

Three supply options were explored in this study: Biomass boilers, gas CHP and ground source heat pumps. Appendix 3 provides general technology descriptions and the following summarises key issues in relation to inclusion in the heat network opportunity identified:

1. Gas CHP plant

   Location: Presumed to be located within the curtilage of the Nicholson Road development site (see indicative location in Figure 3-5)

   Summary: This option could provide heat to a heat network and power via a private wire network to nearby non-residential power consumers. Gas CHP is a low risk technology which can be scaled to meet the needs of wide range of applications. Whilst it provides a more efficient solution to provide heat, than gas boilers, it does present the challenge of diminishing carbon savings since the on-site power generation displaced power that would otherwise be 'grid' supplied, the carbon factor for which is consistently reducing due to the increased proportion of low carbon / renewable energy supply, e.g. wind energy. For this reason, it is only proposed to use gas CHP in combination with biomass boilers (as opposed to gas boiler that would typically be proposed), and that suitable thermal storage is included. Thermal storage will reduce the degree to which biomass boilers are required to modulate (turn down) their output.

2. Biomass Boiler plant

Location:	Presumed to be located within the curtilage of the Nicholson Road development site (see indicative location in Figure 3-5)
Summary:	Biomass boiler are a mature technology and can be scaled for a wide range of uses. By the nature of the fuel source, the associated carbon emissions will be significantly lower than the use of gas boilers, for example. Wood chip or more refined wood pellets can be used. A biomass boiler arrangement would require fuel storage, with appropriate transport access for fuel deliveries, in addition to the main boiler plant. Biomass boilers typically require active management and regular servicing to maximise system availability. A recently developed heat network scheme which supplies heat to the Bluebell Meadows housing development, south east Newport (Barton), is an existing example of the biomass heat network scheme on the Island. It is understood that this scheme which is currently operated with gas boilers will switch to a biomass fuel source, which as consequence should establish a biomass fuel supply chain that could benefit this scheme.

3. Ground Source Heat pump

Location:	Flexible - boreholes can be drilled as appropriate although a centrally located energy centre will be required
Engagement:	Initial investigation, including commissioning/interpretation of a British Geological Survey hydrology/geology report[8]
Summary:	Open-loop or closed-loop Ground Source Heat Pump installation providing heat for the network was considered as a possible option. The potential for GSHPs was assessed based on specific evidence provided by the BGS study which explored the possibility of heat transfer from sub-surface water and direct heat transfer from soil, with closed loop and open-loop heat pump systems, respectively. The BGS report identified that the Nicholson Road location was not suitable for either open-loop or closed-loop GSHP systems. This is due to low flow rates of the accessible sub-surface water and poor thermal transfer potential of the soil/rock in this location. More detail regarding the reasons for exclusion can be found in Appendix 3.

Figure 3-5 identifies an indicative location for the energy centre that would be required for either of the remaining supply options: biomass boiler or hybrid biomass / gas CHP system. The map shows a broader zone for the location of the energy centre since the location would need to adjust to the emerging development masterplan for the Nicholson Road development. It is proposed to be located around the eastern edge of the development to be in close proximity to the larger properties on the Nicholson Road site and also to the non-residential developments within the Pennyfeathers scheme. In addition, it would also be technically possible to locate the energy centre within the Pennyfeather scheme, if for example this had more scope to adjust the development masterplan.

[8] *Borehole Prognosis reports: GR_219923/1 (for grid ref: 459958,090995), March 2019*

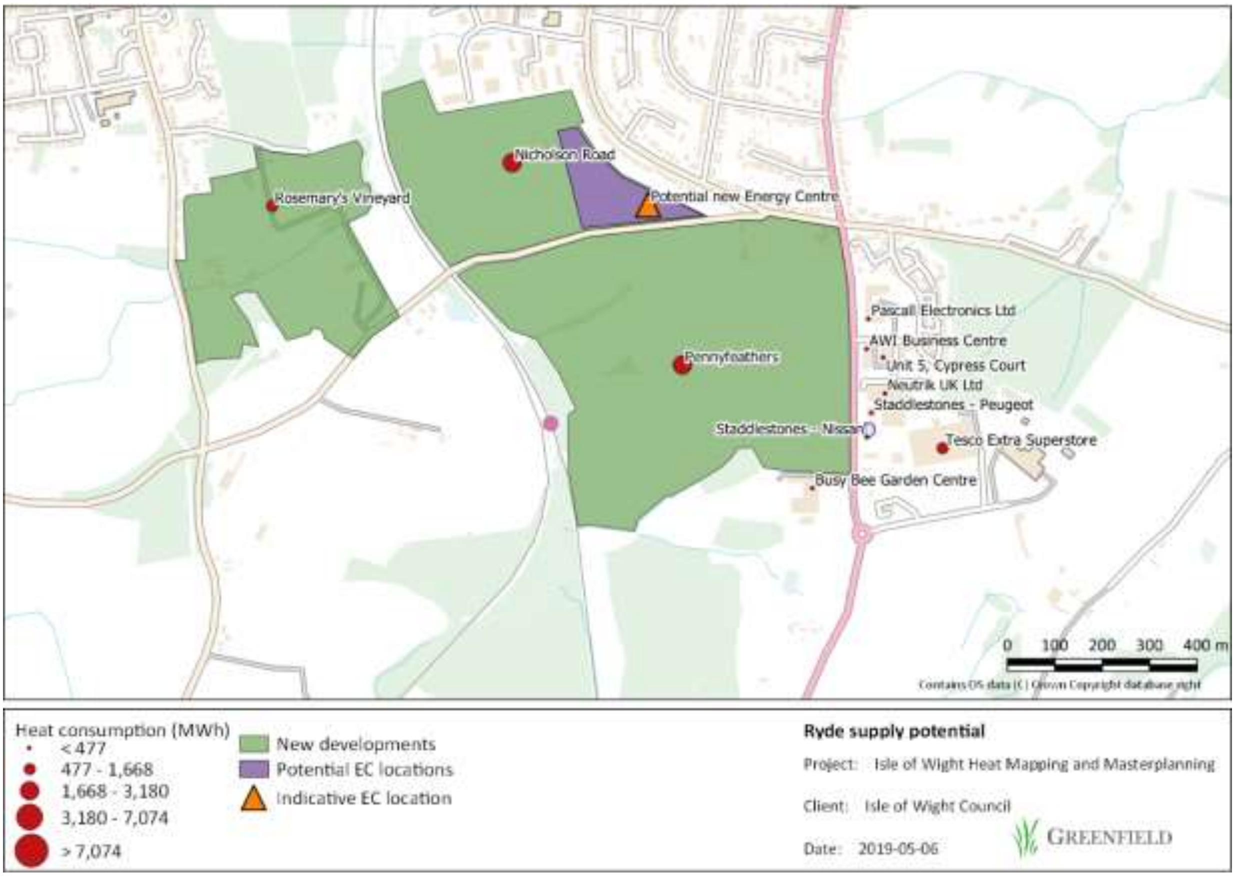


Figure 3-5 Ryde supply potential and energy centre locations.

3.3 General notes (regarding heat network design and assessment)

3.3.1 Network infrastructure routing and design

The routes for each heat network option have been developed to:

- minimise pipe lengths to limit cost and heat losses
- where possible, take advantage of land suitable for 'soft dig' to limit construction costs
- where possible, avoid routes along major highways to limit construction costs and traffic disruption (during installation and servicing)
- avoid significant constraints such as crossing major highways, rivers, other transport corridors and waterways

Any significant constraints that cannot reasonably be avoided have been identified and initial options to circumvent them are discussed, with specific costs attributed within the cost appraisals.

In all cases pre-insulated steel pipework has been selected and costed and pipe sizing has been conducted using the principles and the assumptions described in Appendix 4.

3.3.2 Air quality issues

All heat generation technologies that utilise combustion present a localised air pollution risk particularly in terms of NOx and particulates (particularly for biomass boilers). This can be mitigated using modern boiler technology (which is likely to be required under Medium Combustion Directive licensing) and appropriate siting of the boiler plant/energy centre. Where energy centres are to be developed, evidence would need to be prepared, including flue gas dispersal modelling, to enable licencing by the Environment Agency. There are currently no AQMAs declared by Isle of Wight Council according to DEFRA UK Air Information Resource and as such there are no known specific air pollution concerns in any of the locations proposed for energy centres.

In the network options considered the following supply options are included: gas CHP and biomass boilers. Heat networks would displace existing or planned (in the case of new development) property-level boilers. The impact of a heat network will therefore be to reduce the total volume of combustion gases entering the atmosphere and to reduce air pollution overall, except when gas CHP is used (since this is using gas locally to also generate power, which would otherwise be delivered via the 'grid'). This benefit is compounded by that fact that the individual boilers that would be displaced will be less efficient and more polluting than the highly managed energy plant within a heat network energy centre. Biomass present a risk of increased particulate emissions but this will be mitigated through use of modern boiler plant.

3.3.3 Revenue and operating cost assumptions

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

Revenue is assumed to be available from the Renewable Heat Incentive (RHI) for heat from the proposed biomass boilers. It should be noted that the current RHI programme is due to close in Q1 2021 and a replacement or extension has yet to be proposed (a financial sensitivity has been modelled with the exclusion of RHI). However, it is considered likely that some form of government subsidy will be made available to support the government's heat decarbonisation strategy.

Revenue is also assumed to be available from CHP power sales to non-domestic consumers.

Operating costs have been estimated largely on prior project experience accounting for the nature of the specific options to finalise key assumptions, e.g. fixed annual or variable on heat load and other parameters.

Key operating costs and revenue assumptions are scheduled in Appendices 7 and 8.

3.3.4 Consumer and other benefits

If developed as presently conceived, the heat network could deliver a number of benefits:

1. Reduced heating energy costs by a minimum of 5% compared to counterfactual estimates for connected consumers.
2. Mitigation of future energy cost increases especially in the case that renewable energy systems are used as a primary or secondary energy source
3. Operational benefits to connected consumers which would include reduced plant liability and releasing floor space which would otherwise be allocated to property-level energy supply plant
4. Short term reduction in carbon emissions for connected properties (each network section highlights specific carbon savings or each network option and will depending on supply technology and other design issues).
5. Long term, deeper reduction in carbon emissions through heat network expansion and/or the inclusion of additional low carbon supply technologies. This would be challenging to achieve by means other than a heat network.

6. Inward investment into the town of between £13.2m to £14.3m (estimated capital cost)
7. Development of a local energy generation / supply entity that would be an employer and would pay business rates to be a contributor to the local economy
8. Support new development in meeting planning obligations for the reduction in carbon emissions or including renewable energy supply
9. Development of local, lower cost, lower carbon energy supply may encourage retention of existing businesses or relocation of new businesses to the town

3.3.5 Project risks

All heat network projects present risks. By their nature, they involve managing multiple uncertainties and options to arrive at optimised solutions during the development stages. During construction and operation, they present numerous risks that can undermine the intended outcomes. It is important to understand these risks and to ensure the economic, carbon and other benefits outweigh taking these risks, which will be somewhat of a subjective judgement.

For all heat network options, an initial risk register has been developed as shown in Appendix 11. This collates the key risks, showing generic risks (applicable to all options) and a number of specific risks associated to each network. Each heat network section of the report highlights any key risks that apply.

The risks are attributed to the following classifications (described on the first page of Appendix 11):

- Risks Type
    - Design risk
    - Construction risk
    - Operational risk
    - Commercial risk: Demand risk & Price risk
    - Regulatory risk
- Development stage
    - Project Development (PD)
    - Construction (C)
    - Operational & Mngt (O)

At this stage the key risks to focus on are those affecting the Project Development stage, although the others are important to review and plan for.

Generic risks which will be important include::

1. Capability and capacity amongst the development lead, e.g. the council and key stakeholders to effectively manage the project development process
2. Securing consumers. It will be important to secure consumers and maximise revenues from energy sales to support the case for investment. At this early stage of investigation there is not a high degree of confidence that the consumers identified would connect and this would need to be an important focus of any follow-up investigation. Securing the largest consumers and forming clusters of connections that can occur at the same time will be important.
3. Secure a location for the primary energy centre.
4. Minimising heat network construction/servicing impacts, e.g. highways.
5. Improving economic performance, where possible and developing the case for grant support.

6. Renewable Heat Incentive (due to close in quarter 1, 2021): will affect revenues were it not available (see sensitivity analysis) and also long-term economics are impacted after 20 years, when RHI contract would expire.

3.3.6 Development governance

Key development recommendation include establishing development governance e.g. identifying a lead agency (where this is not the council) and managing the approval process to move any options to a formal project development status within the lead agency and conducting key tasks including further specific engagement with stakeholders; further development of the heat network design to address techno-economic improvement opportunities and mitigate key risks; review alternative design options that may add value; and; establish ownership, procurement and funding strategies.

4 Initial heat network design & techno-economic assessment

4.1 Heat Network summary

There are a range of potential options for consumer arrangements in a heat network within the study. However, it was agreed with IWC that a single primary option including all identified consumer as shown in Figure 3-4 would be focus within this study. This will test whether the maximum scale and mix (development and existing) of consumers possible could deliver an economically viable project. In general terms, the economic performance of a heat network is closely linked to the consumption scale and the geographical spread. The proposed network maximises both. Following review of consumer and supply options, the proposed heat network solution is summarised in Table 4-1, with Figure 4-1 showing indicative network routing.

Consumers	Supply technology options	Demand
Developments: • Nicholson Road development • Pennyfeathers development • Rosemary's Vineyard development Existing properties: • Pascal Electronics • AWI Business Centre • Cypress Court • Neutric UK • Staddlestones • Tesco Extra Superstore • Busy Bees Garden Centre	• Gas CHP • Biomass boilers	Heat: 8 GWh Power (PW): 2 GWh

Table 4-1 Ryde network options

The heat network route is designed to take advantage of land that would allow 'soft-dig' (reducing construction costs). There are plenty of opportunities for soft dig construction, throughout the new development sites; the heat network can be installed in sections following built-out phasing with individual property connections being made as properties are complete.

The main network constraints identified are as follows:

1. The Island Line railway: located between the Nicholson Road and Rosemary's Vineyard development sites. It is proposed that the crossing is achieved through directional drilling under the railway embankment. Where this adds excessive costs (depending on discussions with the rail operator) it may be necessary to exclude the Rosemary's Vineyard development from the heat network.
2. Principal roads around the development sites (highlighted in purple and orange on the network map): these are avoided where possible to minimise traffic disruption during installation and servicing. Branding Road and Smallbrook Lane would need to be crossed and the crossings is proposed to be made perpendicular to the road to minimise traffic impact.

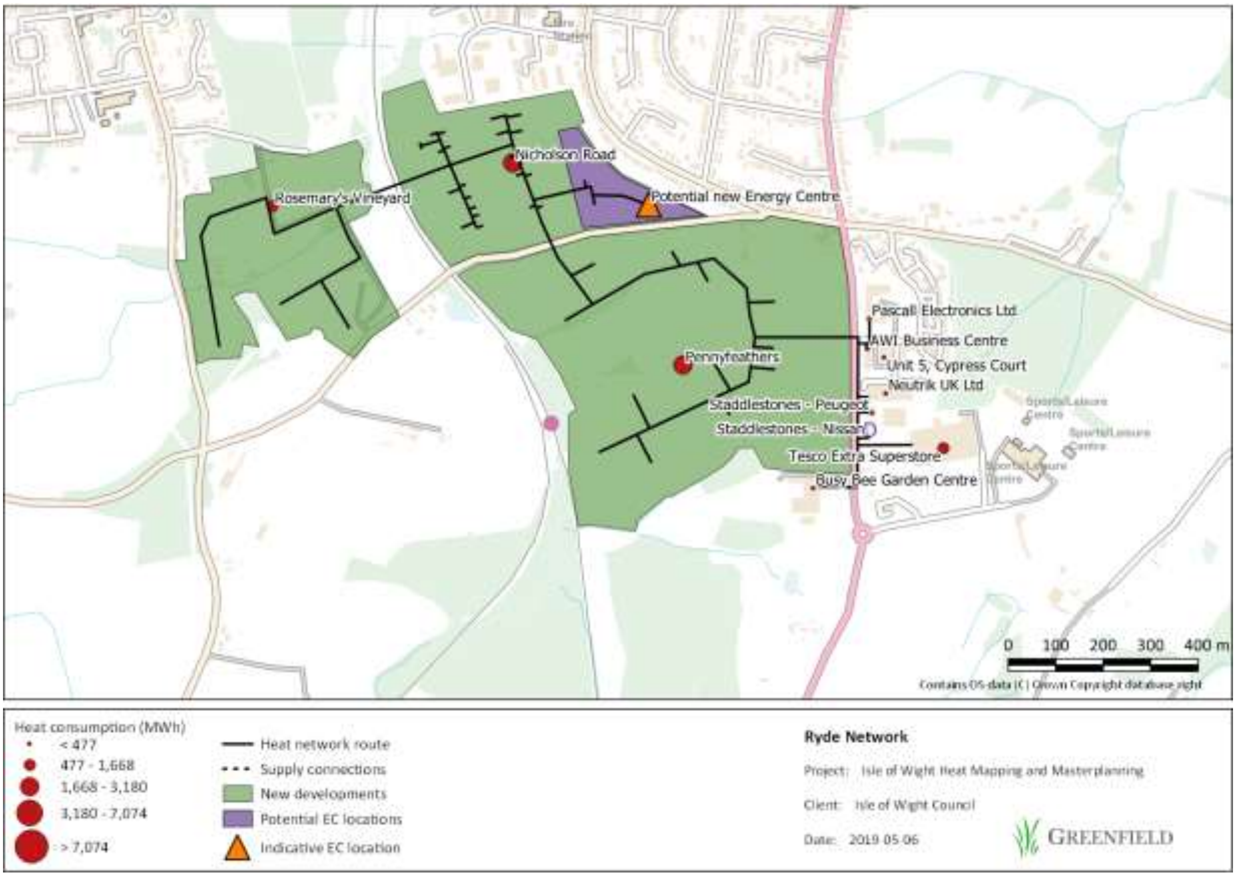


Figure 4-1 Indicative Nicholson Road area heat network route and connections.

Key network parameters, which help to describe the nature of the infrastructure proposed (at full build-out), are shown in Table 4-2.

Heat demand and network details			
	Unit	Gas CHP & Biomass boiler	Biomass boiler
Demand			
Heat demand	GWh/yr	7.7	7.7
Peak demand	MW	6.1	6.1
Number of connections			
Non-residential	No.	12	12
Residential (dwellings)	No.	965	965
Total	No.	977	977
Network			
Network trench length	km	10.0	10.0
Linear heat density	GWh/yr/km	0.8	0.8
Main pipe size	DN	200	200
Heat losses	%	10 %	10 %
Design temperatures[9]			
Flow	°C	90	90
Return	°C	45-55	45-55
Soft dig	%	86 %	86 %
Hard dig	%	14 %	14 %

Table 4-2 Nicholson Road area demand and heat network details

[9] *See Appendix 4 for further detail*

4.2 Energy supply concepts design & plant sizing

The baseload supply options reviewed in the analysis are: (1) Biomass boiler and (2) Hybrid Biomass boiler and Gas CHP.

Plant capacity modelling for the baseload production options was conducted to determine the economically optimal plant sizing against hourly demand profiles and accounting for variable costs and revenues (e.g. heat, power, RHI).

The following principles/assumptions together with key commercial assumptions shown in Appendix 6, 7 & 8 were used in the analysis:

Biomass boiler:

- The availability of biomass boiler units is assumed to be 8,592 hours per annual (accounting for annual shut-down and maintenance for one-week period during summer). Maintenance is assumed to be sequential (multiple units proposed).
- Operational efficiency is assumed to be 85%.
- The total proposed Biomass boiler capacity is divided into two identical units in the modelling. The range of operation for a single Biomass boiler unit is 100 % to 30 % of total thermal capacity of the unit.
- In base case modelling, revenue from RHI based on heat production, is included. A sensitivity is also calculated with no RHI income, to account for the uncertainty of the RHI being available after Q1 2021.
- Thermal storage was assessed in the optimisation analysis and gas boilers are dimensioned for back-up and reserve capacity.

Gas CHP:

- Gas CHP is modelled to produce heat and electricity with a power to heat ratio of 0.93 and efficiency of 83%, i.e. it produces 1 MWh of heat and 0.93 MWh of electricity while consuming 2.33 MWh of fuel.
- The total proposed Gas CHP capacity is divided into two identical units in the modelling. The range of operation for a single CHP unit is 100 % to 30 % of total thermal capacity of the unit.
- Power produced is distributed (by Private Wire) to Nicholson Road and Pennyfeathers development sites' non-residential power consumers. Excess electricity is assumed to be exported to the regional power network.
- The availability of CHP units is 8,592 hours per annual (accounting for annual shut-down and maintenance for one-week period during summer). Maintenance of the units is sequential (multiple units are proposed).
- Thermal storage was assessed in the optimisation analysis and biomass boilers are dimensioned for back-up and reserve capacity.

For the purposes of economic modelling, targeted sizing of the baseload systems has been set above the thresholds set by the EU Energy Efficiency Directive (EED) definition of efficient heat networks, which is required for Heat Network Investment Project (HNIP) funding. For both the biomass boiler biomass/CHP hybrid options the threshold is set at 50% of annual heat supply.

Biomass boiler option

For the Biomass boiler option, based on the recommended boiler capacity is 750 kW coupled with 100 m^3 of thermal storage. Figure 4-2 shows the modelled load-duration curve for the fully built-out network. Thermal storage is predicted to mostly be utilised during periods of lower demand.

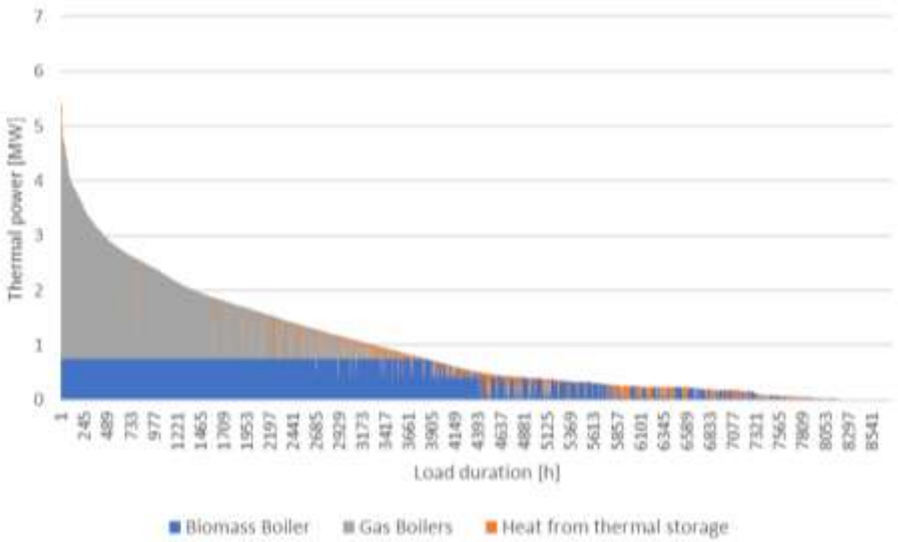


Figure 4-2 Modelled load-duration curve – Nicholson Road area network (Biomass Boiler)

Biomass / gas CHP hybrid option

Based on the energy modelling analysis, the cost-optimal Gas CHP capacity for the fully built-out network is only 280 kW due to low Private Wire power demand. Based on the modelling and considering the EED threshold requirements (required for HNIP funding), the recommended Biomass boiler capacity to support the CHP baseload supply is 470 kW. The system would also required 100 m^3 of thermal storage.

Figure 4-3 shows the modelled load-duration curve for a fully built-out network. As with the Biomass boiler-only option, thermal storage is mostly utilised during periods of lower demand as during periods of high heat demand the baseload production units already supply the network at full capacity. When power export to Private Wire is available, CHP operation is cheapest, so it has priority over Biomass boilers. When PW export is not available and power production has to be sold to the 'grid', Biomass boilers become a cheaper supply technology and operation priority switches to Biomass.

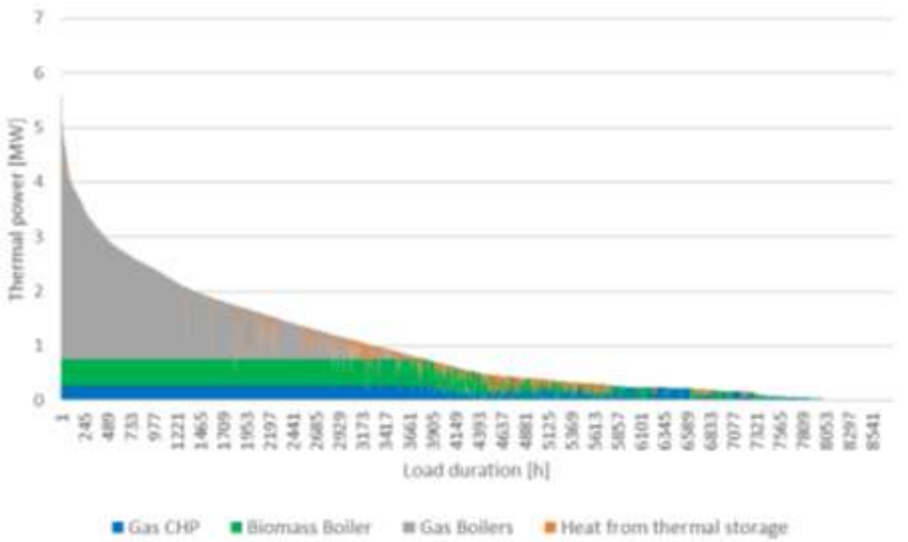


Figure 4-3 Modelled load-duration curve - Nicholson Road area network (Gas CHP/Biomass hybrid).

A summary of the energy modelling results for both energy supply options is shown in Table 4-3.

Heat and electricity production			
	Unit	Biomass Boiler	Gas CHP + Biomass Boiler
Supply capacity			
Gas CHP	kW	-	280
Biomass Boiler	kW	750	470
Gas Boiler	kW	6,690	6,690
Thermal storage	m^3	100	100
Heat production share			
Heat production	GWh/yr	8.6	8.6
Gas CHP	%	0.0 %	22.0 %
Biomass boiler	%	50.4 %	28.5 %
Heat purchase	%	0.0 %	0.0 %
WSHP	%	0.0 %	0.0 %
Gas boilers	%	49.6 %	49.5 %
CHP electricity			
CHP electricity production	GWh/yr	-	1.8
Consumed by EC site	%	-	4.9 %
To Private wire network	%	-	75.0 %
To grid	%	-	20.1 %

Table 4-3 Nicholson Road area network - heat and electricity production.

Indicative Energy Centre arrangement drawings are shown in Appendix 5 for the options considered.

4.3 Capital costs, operating costs and revenue

A summary breakdown of capital costs is shown in Figure 4-4 with a more detailed breakdown of shown in Appendix 6. In total the costs are estimated at £14.3m for the Biomass/CHP hybrid option and £13.2m for the biomass boiler option. At this stage where costings rely on a range of assumptions the tolerance on capital costs applied is ±20%.

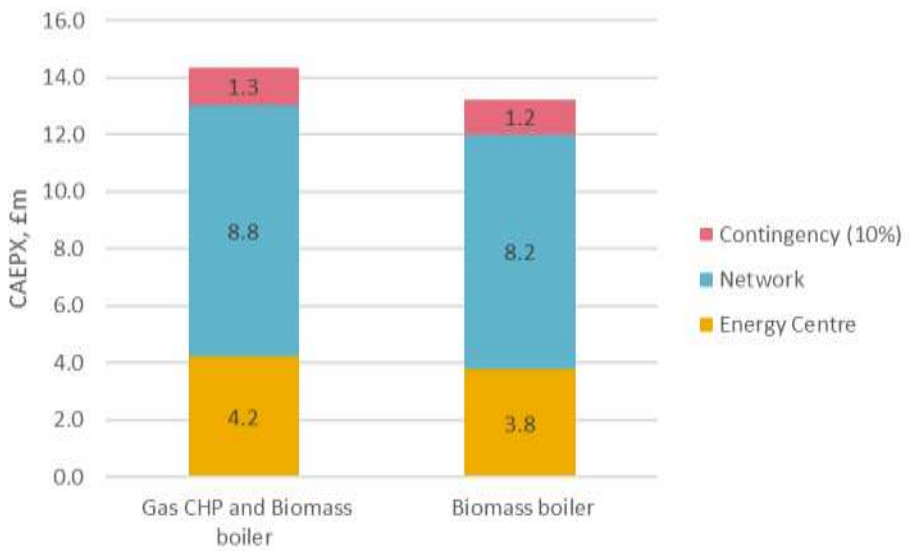


Figure 4-4 Capital cost for Nicholson Road area network.

In terms of revenues (or income) for the heat network, consumer tariffs are based on a 5% reduction of a calculated counterfactual cost, i.e. cost of the alternative energy supply solution (assumed to be building-level gas boilers in all properties). Tariffs will vary between consumer types, with domestic consumers paying more (per unit of energy delivered) than commercial properties, due to the counterfactual costs being lower for larger consumers. Connection fees would also be levied against each property when it connects to the network and this is estimated to be a 5% reduction of the calculated counterfactual cost of installing gas boilers. On this basis, connection would vary based on the heat capacity required by each consumer. In total connection fees are estimated at just under £1.7m.

Revenue is assumed to be available from the Renewable Heat Incentive (RHI) for the renewable energy options (biomass boilers), although it should be noted that the current RHI programme is due to close in Q1 2021 and a replacement or extension has yet to be proposed. Consequently, the impact of no RHI income is assessed in the financial modelling sensitivity analysis.

Revenue is also assumed to be available from CHP power sales to large non-residential consumers.

The estimated annual revenue and operating costs for the options are shown in Table 4-4, with Appendix 7 and 8 showing key operating cost and revenue assumption, including tariffs/connection fees for each consumer/consumer type.

4.4 Results of Techno-Economic analysis

The results of economic modelling are presented in the figures below, with summary tables in Appendix 9.

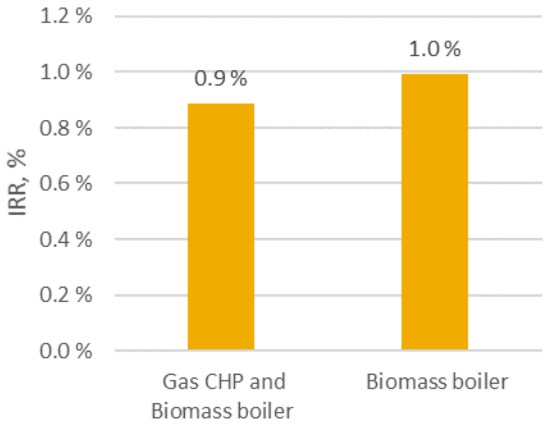


Figure 4-5 Internal Rate of return - IRR (25 years) for Nicholson Road area network.

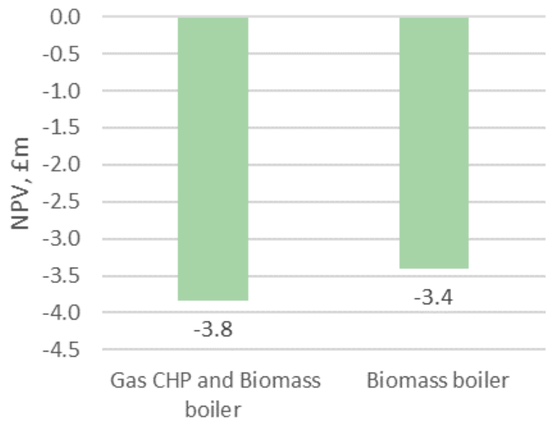


Figure 4-6 NPV (25 years @ 3.5%) for Nicholson Road area network.

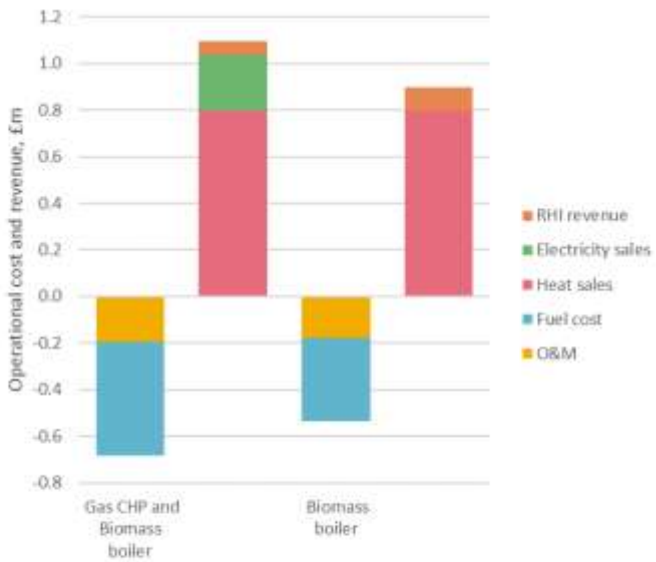


Figure 4-7 Annual operational cost and revenue for Nicholson Road area network.

A summary of the key economic assessment parameters is presented in Table 4-4 and discounted cash flow graphs are presented in Figure 4-8.

Techno-economic analysis results			
	Unit	Gas CHP & Biomass boiler	Biomass boiler
Financial			
Total CAPEX (to full build out)	£m	14.3	13.2
Total REPEX (full scheme)	£m	4.6	4.1
Total OPEX (full scheme)	£m/yr.	0.7	0.5
Annual revenue (full scheme)	£m	1.1	0.9
Heat tariff to consumers (full scheme) [10]	£/MWh	79.3	79.3
Total connection fees	£m	1.7	1.7
NPV (25 yr @ 3.5 %)	£m	-3.8	-3.4
IRR (25 yr)	%	0.9 %	1.0 %
Social IRR (25 yr) [11]	%	0.1 %	0.4 %
LCOE (25 yr)	£/MWh	146.4	142.4
Minimum grant to achieve 6 % IRR	£m	5.8	5.2
Carbon			
CO_2 savings over 25 yr	ktCO_2/yr.	13.9	17.4
CO_2 savings over 25 yr	%	31.0 %	41.8 %
CO_2 savings per £1,000 grant	tCO_2/£1,000	2.4	3.3
Cost of CO_2 savings	£/tCO_2	1,827	1,413

Table 4-4 Techno-economic analysis results for Nicholson Road area network.

[10] *Including variable and fixed heat tariff*

[11] *Social IRR accounts for impacts accrued to the heat network operator and those connected to the networks, as well as to the wider community and society as a whole. The calculation accounts for net impact on heating costs, carbon emissions and air quality.*

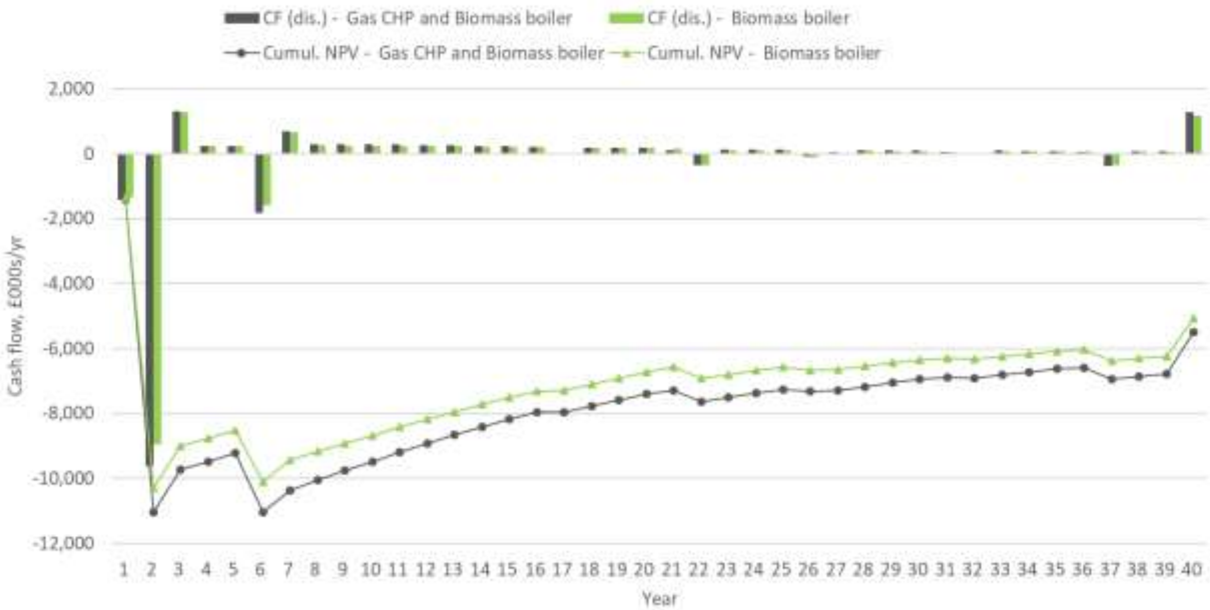


Figure 4-8 Discounted cash flow for Nicholson Road area network.

Within the financial modelling, sensitivities of key parameters have been assessed to examine the strength of the economic case for each option. Parameters have only been considered independently although, in reality, individual parameters could change together and have a compound impact (positive or negative); this should be considered in any subsequent investigations. The results of the sensitivity analyses are shown in Figure 4-9 and Figure 4-10.

The figures highlight the impact on IRR (25-year) with the variation of several key parameters. Changes in consumer tariffs and gas prices are most significant. Capital costs and energy demand are shown to be significant. The loss of the RHI changes in capital costs (with reductions being more impactful that increases), consumer tariffs and gas prices are most significant. Energy demand variation is important. The loss of RHI incomes is significant for the biomass-only option.

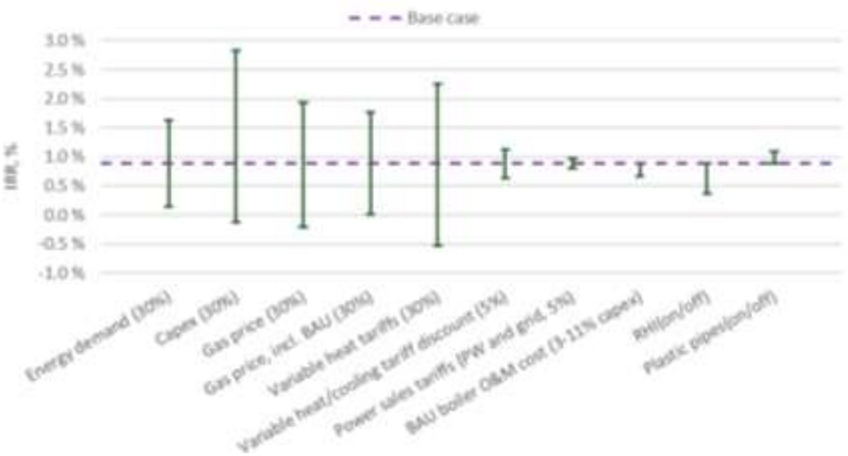


Figure 4-9 Sensitivities for Nicholson Road area network (Gas CHP & Biomass boilers).

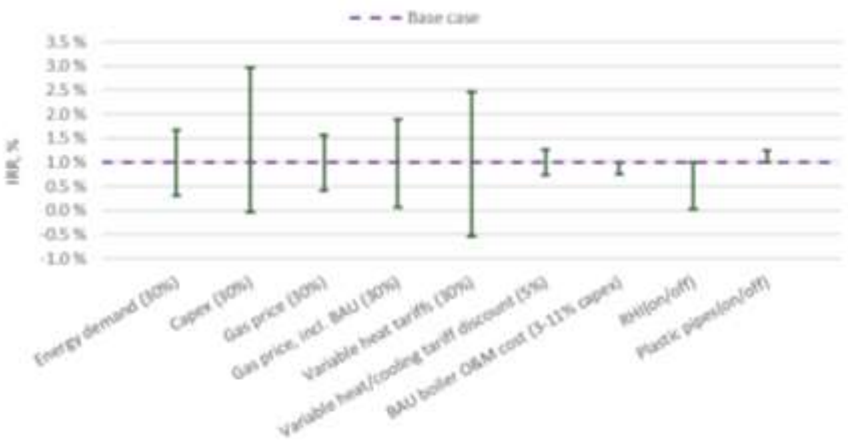


Figure 4-10 Sensitivities for Nicholson Road area network (Biomass boilers).

Table 4-5 also shows the level of the grant support (e.g. HNIP) that would be required to achieve specific rates of return. A 3-7% rate of return is assumed to be required for a wholly public funded project and above 10-12% is assumed to be required for a wholly privately funded project.

		Gas CHP & Biomass boiler	Biomass boiler
IRR 5.0 %	£m	5.1	4.6
	% capex	35.8 %	35.0 %
IRR 7.0 %	£m	6.2	5.7
	% capex	43.4 %	42.8 %
IRR 10.0 %	£m	7.1	6.5
	% capex	49.2 %	48.8 %

Table 4-5 Gap funding required to reach investment thresholds (IRR 25-year).

4.5 Techno-economic conclusions

The analysis shows poor economic performance for both technology options, with IRRs in the region of 1%. Further to this, the sensitivity analysis shows that variation of a number of individual modelling assumptions could move towards a more reasonable economic performance. For example, a 30% reduction in the capital cost would take either scheme towards a 3% IRR. Clearly combining positive improvements in several key parameters would take the schemes beyond this.

There are likely to be opportunities to improve economic performance which are discussed below but the relatively low energy demand density of the development sites is the principle cause. This ensures that costs (capital and operating) are high compared to the available energy related revenues.

It is possible, however, that parameters could worsen, particularly with respect to the consumer demand which is uncertain and related to the current development stage of the new-build consumers.

Gap funding, e.g. from the Heat Network Investment Project (HNIP), could support the project. However, unless improvements are made in base economic performance then circa 35% of capital costs are required to achieve a 5% IRR (25-year) and close to 50% (assumed to be the maximum possible as restricted by state-aid rules) would be required to achieve a 10% IRR. Whilst this level of funding may be possible, it is not considered likely because the scale of the heat network and the lack of expansion potential will mean it will not compete well against other funding bids.

4.5.1 Heat Network benefits

As discussed in section 3.3.4 there are a range of economic and environmental benefits that are estimated to be derived. In summary they are:

1. A general 5% reduction in consumer energy costs (the basis for revenue modelling) and mitigation of future energy cost increases
2. Operational benefits including reduced plant liability and releasing property floor space
3. Reduction in carbon emissions (between 31% and 40% for connected properties - depending on supply technology).
4. Inward investment into the town of between £13m to £14m, depending on option
5. Support new development in meeting planning obligations for the reduction in carbon emissions or including renewable energy supply
6. Development of a local energy generation / supply entity
7. Encourage commercial/residential tenant retention in the town

4.5.2 Project risks

As discussed in section 3.3.5 there are a range of project risks that will need to be addressed. An initial risk register, shown in Appendix 11, collates both generic and specific risks. Key risks with these network opportunities include:

1. Improving techno-economic performance: this is the biggest risk for this scheme because of the poor performance shown. Economic performance could be sufficiently improved through grant support, but it is likely to present a relatively poor case compared to other projects across the UK, making it unlikely to could receive a large gap funding contribution. This makes it critical, for this project to proceed to make significant changes to the heat network design. Potential adjustments are discussed in section 4.5.3.
2. Securing consumers: this risk is significant. Whilst it is a reasonable expectation that the council-led Nicholson Road scheme would be included (assuming it meets commercial and performance requirements), the other developments and existing prospective consumers are much less certain. It will be important for the council to balance general development and climate change/heat network objectives through engagement with development stakeholders. The timing of the availability of heat network and the degree or confidence that developers could attribute to it will also be important, if they are not to simply pursue more standard solutions which will not deliver the wider benefits of a heat network solution.
3. Development Governance: it is anticipated that the council would need to lead development and so the primary risk resides around their ability to bring forward the resources and capability to implement.
4. Renewable Heat Incentive revenues: RHI is due to close in quarter 1, 2021 (with no extension/replacement currently planned). In any case, where a project relies on the RHI income this will expire after year 20, which is the standard contract term applicable. As shown in the sensitive analyses having no-RHI would severely worsen the case for investment for the biomass option.

4.5.3 Techno-economic Improvement opportunities

Economic performance would be improved where capital costs and operating costs are reduced, or income is increased.

Increasing income is not considered possible as there are no nearby prospective consumers that have not already been included. There are other potential additional consumers, but they will involve additional infrastructure cost to enable connection, with limited energy sales revenue in return.

In addition, it is not likely to be possible to increase consumer tariffs since they have been set a level marginally (5%) below the estimated counterfactual cost. One exception is where the counterfactual is electrical heating, which is significantly more expensive that gas heating, although this would also increase capital costs since properties will need to conversion .

Reducing capital and operating costs could potentially be achieved through a value engineering process. This would include:

- rationalising the design/specification to limit capital costs (noting this may also increase replacement costs over time) but also making specific decision such as switching to plastic rather than steel pipework
- identify specific avoided costs, for example
    - if the Pennyfeather development is obliged to implement a heat network then the developer should be prepared to invest in an area-wide scheme at or below the counterfactual cost
    - all the development would need to invest in gas and power network infrastructure to connect all properties, again this cost, which has not been estimated, could passed over to support a heat network

Further to this, several more radical design changes could be considered, including:

- Switching to a low temperature designs strategy. This would require the new-build consumer properties to be designed to be compatible, i.e. with larger heat emitters (such as underfloor heating) which may add costs the developments. It may also increase infrastructure costs as pipe size may need to increase. The benefit, however, will be greater system efficiency and hence lower operating costs.
- Avoiding the use of heat interface units at property level, i.e. direct property connections. This reduces capital cost but presents operational risksIncreasing power sales, e.g. adding an electric vehicle charging hub to the Nicholson Road development.

5 Recommendations

The heat network focuses on connecting several new development sites together with a small number of existing consumers. At this early stage of investigation, the network as conceived, appears to be deliverable but not capable of achieving a reasonable commercial performance. If delivered, it would provide direct benefits to consumers, support economic development and provide a solution to long-term decarbonisation of heat consumption.

Several improvement opportunities are identified including exploring a low temperature system, non-standard design changes, increasing power sales (e.g. where an electric vehicle charging hub is included in the Nicholson Road development) and accounting for avoided developers' costs. None of these are straightforward and would require further design/analysis effort. Whilst grant support is likely to be available, e.g. from HNIP, it is also likely that the scheme would not attract that funding due to its limited scale and limited expansion potential. HNIP itself is also time-limited and it would be necessary for heat network schemes to proceed rapidly to enable access. Thus, a combination of improvements and grant is likely to be required.

There are also numerous uncertainties and project development risks that will need to be further considered in any subsequent investigation, the following being the most significant:

1. Improving techno-economic performance: see discussion above.
2. Securing consumers: this will require aligning the various developers with the proposal and ensuring a heat network solution could meet the timing constraints of this new development.
3. Development Governance: requires the council to develop is capacity and capabilities to lead the implementation process.
4. Renewable Heat Incentive revenues: address the possibility of zero RHI revenue, i.e. drop the WSHP option and end of revenue after 20 years, i.e. adjusting operating strategy, focusing of running the WSHP plant only at periods of low power costs.

Key development recommendations for this heat network are as follows:

1. Examine and reflect on the evidence in this report and conclude whether the council perceives value in exploring the various improvement opportunities, in the context of the project and development risks highlighted.

……assuming IWC agrees to pursue this scheme further, then:

2. Conduct a rapid and focused design review to explore key improvement opportunities and test the outcome of this with key stakeholders, i.e. the property developers (especially for the Pennyfeathers scheme which has a planning obligation to implement a CHP/heat network solution). Avoided or shared costs should also be reviewed with developers at this point.

…….assuming there is positive support from stakeholders and IWC, then:

3. Establish development management process. The nature of the project would require the council to take the lead on development. It is anticipated that the council would need be the commissioning/procurement agency with a role in securing the finance, either through raising debt (such as PWLB) or negotiating private investment.
4. The council would need to establish internal governance and project management arrangements and implement the implementation plan that will come from this.

5. The council should initiate the approval process to move the opportunity on to a formal project development status.
6. The council would need to commission/implement a number of critical tasks (using internal and external resources), including:
    - further engagement with stakeholders;
    - further develop heat network design to address techno-economic improvement opportunities and mitigate key risks (a feasibility study); and;
    - establish ownership, procurement and funding strategies

Appendix 1. Energy mapping

Heat mapping methodology

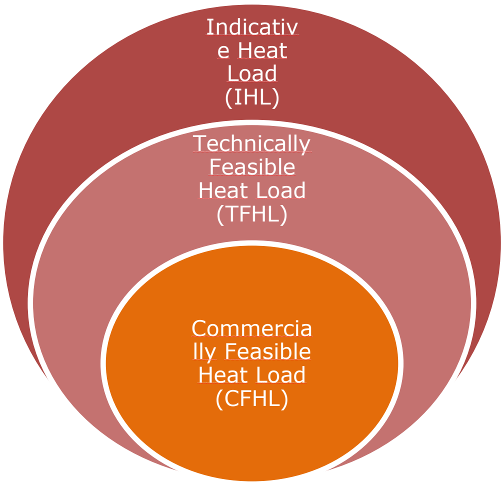
The heat mapping is conducted by utilising data from various sources including:

- Primary consumption data for existing consumers (replacing benchmarked data), where it was made available by stakeholders
- Filed EPC and DEC records
- Development site planning documents
- Open source information (e.g. Google Maps)

Where actual metered data or filed EPC and DEC records were not available, benchmarking analysis was used to estimate heat, electricity and cooling loads. The benchmarking methodology is described in the sections below.

Identifying appropriate loads

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



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

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

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

Existing buildings

Metered consumption

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

The consumption data, typically gas consumption data, was used to calculate the heat demand under the assumption of thermal efficiency of 80% for traditional boiler systems across the whole data set.

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

Benchmarking

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

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

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

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

New development

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

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

The following energy consumption benchmarks have been utilised:

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

Appendix 2. Additional consumer notes

1. Nicholson Road Masterplanning principles / development schedule:

Character Area	Plot no.	Plot Area (Ha)	Block no.	Use Class	no. storeys	Floor plate (GIA sqm)	Total (GIA sqm)	Footprint (GEA sqm)	no. parking spaces
Community Hub	CH.01	0.67	01	D1	2	176	221	209	11
			02	A3	2	190	113	220	8
				B1(a)			190		8
				D1			77		4
			03	A1	2	243	243	277	12
				B1(a)			243		8
			04	D1	4	300	1,200	340	60
			05	D2	2	432	575	477	29
			06	B1(a)	4	372	277	422	9
				C3			800		20
			Village Square		-	-	-	1,250	-
Total		0.67	06	-	-	-	4,069	3,191	165
Office Campus	OC.01	0.40	01	B1(a)	3	270	540	408	18
			02	B1(a)	2	270	540	408	18
			03	B1(a)	3	270	810	408	27
	OC.02	0.26	04	B1(a)	2	270	540	408	18
			05	B1(a)	2	270	540	408	18
	OC.03	0.20	06	B1(a)	3	270	810	408	27
			07	B1(a)	2	270	540	408	18
Total		0.86	07	-	-	-	4,320	2,842	144
Business Incubators	BI.01	0.21	01	B1(b&c)	2	540	1,080	570	24
			02	B1(b&c)	2	540	1,080	570	24
	BI.02	0.45	03	B1(b&c)	2	540	1,080	570	24
			04	B1(b&c)	2	540	1,080	570	24
			05	B1(b&c)	2	540	1,080	570	24
			06	B1(b&c)	2	540	1,080	570	24
Total		0.66	06	-	-	-	6,480	3,420	144
Flexible Business Park	BP.01	0.28	01	B2/B8	1	1,575	1,575	1,626	35
	BP.02	0.29	02	B2/B8	1	1,575	1,575	1,626	35
	BP.03	0.48	03	B2/B8	1	1,152	1,152	1,193	26
			04	B2/B8	1	1,152	1,152	1,193	26
	BP.04	0.46	05	B2/B8	1	1,152	1,152	1,193	26
			06	B2/B8	1	1,152	1,152	1,193	26
	BP.05	0.46	07	B2/B8	1	1,152	1,152	1,193	26
			08	B2/B8	1	1,152	1,152	1,193	26
	BP.06	1.16	09	B2	1	1,440	1,440	1,486	32
			10	B2	1	2,880	2,880	2,950	64
Total		3.10	10	-	-	-	14,382	14,844	320

Overall Production	
No. Residential Units	10
Total Residential C3 (GIA sqm)	800
Total Business B1/B2/B8 (GIA sqm)	25,882
Total Other A1/A3/D1/D2 (GIA sqm)	2,429
Total Floor Area (GIA sqm)	28,251

Non-Residential Mix Breakdown (GIA sqm)		
A1/A3 Retail/Cafe	356	1%
B1(a) Office	5,030	18%
B1(b&c) High-Tech/Light Industry	6480	23%
B2 General Industry	14,382	51%
B8 Warehouse		
D1 Health/Community	1,498	5%
D2 Leisure	575	2%

Car Parking	
Total no. Spaces	773
Total Area (25 sqm per car)	19,318

Car Parking Policy Requirements	
A1 Non-food retail	1 space per 20 sqm
A3 Food & Drink	1 space per 20 sqm
B1(a) Office	1 space per 30 sqm
B1(b&c) High-Tech/Light Industry	1 space per 45 sqm
B2 General Industry	1 space per 45 sqm
B8 Warehouse	1 space per 40 sqm
C3 Dwellings 1-2 bed	1 space per unit
C3 Dwellings 3-4 bed	2 spaces per unit
C3 Dwellings 5+ bed	3 spaces per unit
D1 GP Surgery	3 per consulting room
D2 Leisure	?

Quantum of Development (Ha)		
Site Area	15.07	
Buildings Footprint	2.43	16%
Parking Area	1.93	13%
Village Square	0.13	1%
Road Area (excl. within plots)	0.62	4%
Developed Area	5.11	34%
Undeveloped Area	9.96	66%

2. Notes and masterplan representations of new development schemes not included within the analysis

   a. Westridge Farm (rear of Circular Road)

   Summary:

   - Planning ref: TCP/11098/A
   - 80 dwellings proposed
   - Planning consent granted (2017)
   - Excluded from analysis on the grounds of:
     - scale (not major (>250 dwellings) and as such district heating is not required
     - distance to connect to the Nicholson Road (assumed location for energy centre)

b. Land at Upton Road

Summary:

- Planning ref: TCP/32435
- 70 dwellings proposed
- Planning consent granted
- Excluded from analysis on the grounds of:
    - scale (not major (>250 dwellings) and as such district heating is not required
    - distance to connect to the Nicholson Road (assumed location for energy centre)

Appendix 3. Supply technology descriptions

Gas CHP

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

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

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

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

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

Biomass Boilers

Using biomass boilers would achieve CO_2 emission savings and could also gain financial support in the form of the Renewable Heat Incentive (RHI); current rates for all capacities for Biomass Boilers are: tier 1, 31.1 £/MWh and tier 2, 21.8 £/MWh. Capital costs would be higher than a gas-fired boiler of comparable output due to ancillary fuel storage and handling facilities.

Generally, smaller biomass boilers under 200 kW only work well when fuelled on ENPlus A1 grade wood pellets. Above this size, wood chip can be considered.

The wood pellet fuel supply chain is reasonably robust across the UK. Numerous companies are able to guarantee regular supplies from UK and overseas manufacturers. These are generally supplied to the ENPlus 25 standard for both the fuel and delivery. Most pellets are A1 grade and suitable for the smallest size of boiler. These are generally made from sawmill residuals and are classified as virgin wood. Wood pellets are generally around 10% moisture content and have a calorific value (CV) of around 4.7 MWh/tonne and a bulk density of around 1.5 cubic metres/tonne.

The virgin wood chip fuel supply chain is not as mature as either pellet or waste wood in the UK, but it is possible to source virgin wood chip. The industry standard for virgin wood chip is Woodsure 26, which is critical for smaller sized biomass boilers 200kW to 1MW but becomes less important for larger size boilers, capable of handling a greater variation in fuel quality. Virgin wood chip will generally have a moisture content of 30% and a heat value of 3.5MWh/tonne and a bulk density of 4-5 cubic metres/tonne.

The waste wood fuel supply chain is relatively mature in the UK with numerous power plants in operation using this as a feedstock. There should be no difficulties in securing regular and large amounts of fuel in varying grades.

There are no firm grade specifications but there are some industry guidelines. Grades A and B are typically considered to be a clean waste capable of burning in a non WID 27 compliant boiler. Grades C & D will almost certainly require enhanced boiler equipment and additional licensing. Waste wood chip will have a moisture content of around 20%, a CV of 4.1 MWh/tonne and a bulk density of around six cubic metres/tonne.

Mixed grade waste wood will contain a high degree of contamination and will require a boiler which is compliant with the Waste Incineration Direction (WID) and the UK enactment of this. Clean wood wastes, as long as they can be proven to contain no heavy metals or halogenated organic compounds, are exempt from, but still have to be licensed above c400kW installed capacity by the Local Authority, under Environmental Permitting Regulations (formally Local Authority Pollution Control (LAPC)). Periodic monitoring may be required along with an annual license for installations up to circa 3MW. Above this size additional licensing and monitoring will be required and this may involve the Environment Agency as opposed to the Local Authority. Any system that claims RHI for biomass will have to source their fuel from a supplier on the Biomass Suppliers List (BSL) and submit sustainability updates along with their quarterly meter readings.

In general, the need to bring bulk fuel material on site, typically by road, requires energy centres to be located at sites with easy access by lorries. Biomass systems require a greater land-take than other energy supply alternatives as the plant is larger and additional space is required for fuel storage and to enable fuel lorry deliveries.

Consistent supply of fuel, appropriate to the specific energy plant installed, is essential to ensure reliability of the energy supply. Hence, it is necessary to secure fuel supply on long-term contract arrangements.

Ground-Source Heat Pumps

Ground-source heat pumps (GSHPs) are a well-established technology that can economically heat buildings in most locations by absorbing heat from the ground and/or ground water.

The system consists of a heat pump system (heat pump units and ancillary equipment including pumps, heat exchangers, pipes etc.) and a ground heat exchanger system or groundwater boreholes.

The type of ground source heat exchangers can be divided into two main groups which are shallow (1.0–2.5 m) horizontal heat exchangers and deep (15–200 m) vertical systems. Shallow horizontal heat exchangers are common for residential installations as their investment cost is lower compared to deep vertical systems. Due to the relatively low temperature of shallow ground layers during the heating season, efficiency is relatively low. Deep vertical systems are not dependent on the top layer of the ground as a source of heat, and the nature of its seasonally varying temperature, rather it relies on migration of heat from surrounding deeper geology, where the temperature is almost constant during the year. As a consequence, they are more efficient without necessarily being more expensive to install.

A vertical closed loop field is composed of pipes that run vertically in the ground. This would consist of and array of boreholes, commonly filled with bentonite grout surrounding the pipe to provide a good thermal connection to the surrounding soil or rock to improve the heat transfer. The conductivity will influence system performance.

In some cases, an open-loop system, which utilises groundwater abstracted from an aquifer may be possible. Groundwater is directly abstracted and pumped through the heat exchanger (evaporator) inside the heat pump, and water is returned (discharged) through a separate injection well back to the aquifer, meaning zero net abstraction. Abstraction and discharge or groundwater would require Environment Agency licensing, for a flow rates greater than 20 l/s. Groundwater systems are suitable where there is near-surface bedrock and is typically not suitable in locations where the geology is mostly clay, silt, or sand.

Further analysis on both open-loop GSHP and closed-loop GSHP was conducted based on a hydrology/geology report by British Geological Survey (BGS) for a specific location at the Nicholson Road development site. Based on the report's findings both open-loop and closed-loop GSHP were deemed unsuitable for the area and thus excluded as a supply option for the Ryde heat network.

Bedrock in the area is mostly various types of clay or sand, which means low ground thermal conductivity and poor performance for closed-loop systems. Poor thermal performance directly increases the GSHP systems £/kW cost as more boreholes or deeper boreholes are needed to generate the amount of heat demanded.

Furthermore, the sandy bedrock can potentially cause issues (based on logs from previous borehole drilling in the area) during drilling/installation of the ground-loop collectors, which further increases investment costs for the GSHP system.

An open-loop GSHP was also deemed unsuitable based on the BGS report. Potential water yield from the main aquifer in the area is very low; the best yield identified from any previously drilled borehole in the area is just 9 l/s (for a 10 hr period and to achieve a constant flow rate to support a heat network would mean extracting at the rate lower than the maximum identified. The BGS report also identified that boreholes in the area have experienced decline in yield over time due to clogging caused by the fine-grained sand. Sand screens and filter packs would be required to be installed to the borehole to minimise clogging effects, increasing the installation costs. Drilling costs are also increased due to the sandy ground type. Multiple boreholes are needed for any significantly sized open-loop system and careful siting of the boreholes is required to minimise any hydraulic and thermal interference effects.

In this study, were the GSHPs option possible then it would be assumed industrial-scale solutions based on centrifugal compressor units would be used. COP of the heat pump is typically at the level of 2.5 to 3.0, depending on the ground loop's and heat network's temperature levels.

Ground source heat pumps are characterised by high capital costs. Capital costs of boreholes with ground loop systems are typically between 20–30% of the total capital costs of GWHP's but this is dependent on local geological conditions. Land contamination can restrict the pipe location.

Renewable Heat Incentive (RHI) tariff payments are available for ground source heat pumps. In addition, waste heat can also be used to replenish ground heat, e.g. from cooling systems, with the full output of a heat pump receiving RHI payments where the waste heat contributes up to one third of the overall thermal input into heat pump, i.e. two thirds would need to come directly from the ground.

Gas Boilers

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

Heat Storage Systems

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

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

Appendix 4. Heat network pipe dimensions and capital costs

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

Parameter	Value	Source
Maximum design temperature Maximum operating temperature	140°C 120°C	HVAC TR/20, 2003
Upper dimensioning supply temperature – Flow (plant outlet)	90°C 85°C (AD) 80°C (heat pumps)	HNCP[12], BEIS report: Assessment of the costs and performance of HNs (Bulk schemes, max value), supplier data
Lower dimensioning temperature – Return (consumer HIU)	55°C 45°C (new developments)	HNCP
Maximum design gauge pressure	16.0 bar	HVAC TR/20, 2003
Static return pressure	3.0 bar	Greenfield experience from prior projects
Pressure loss guideline to be used in design Main lines Branches	 100 Pa/m 250 Pa/m	 London Heat Network Manual London Heat Network Manual
Minimum pressure difference at consumer HIU	60 kPa	HNCP
Pipe series	2	Greenfield analysis

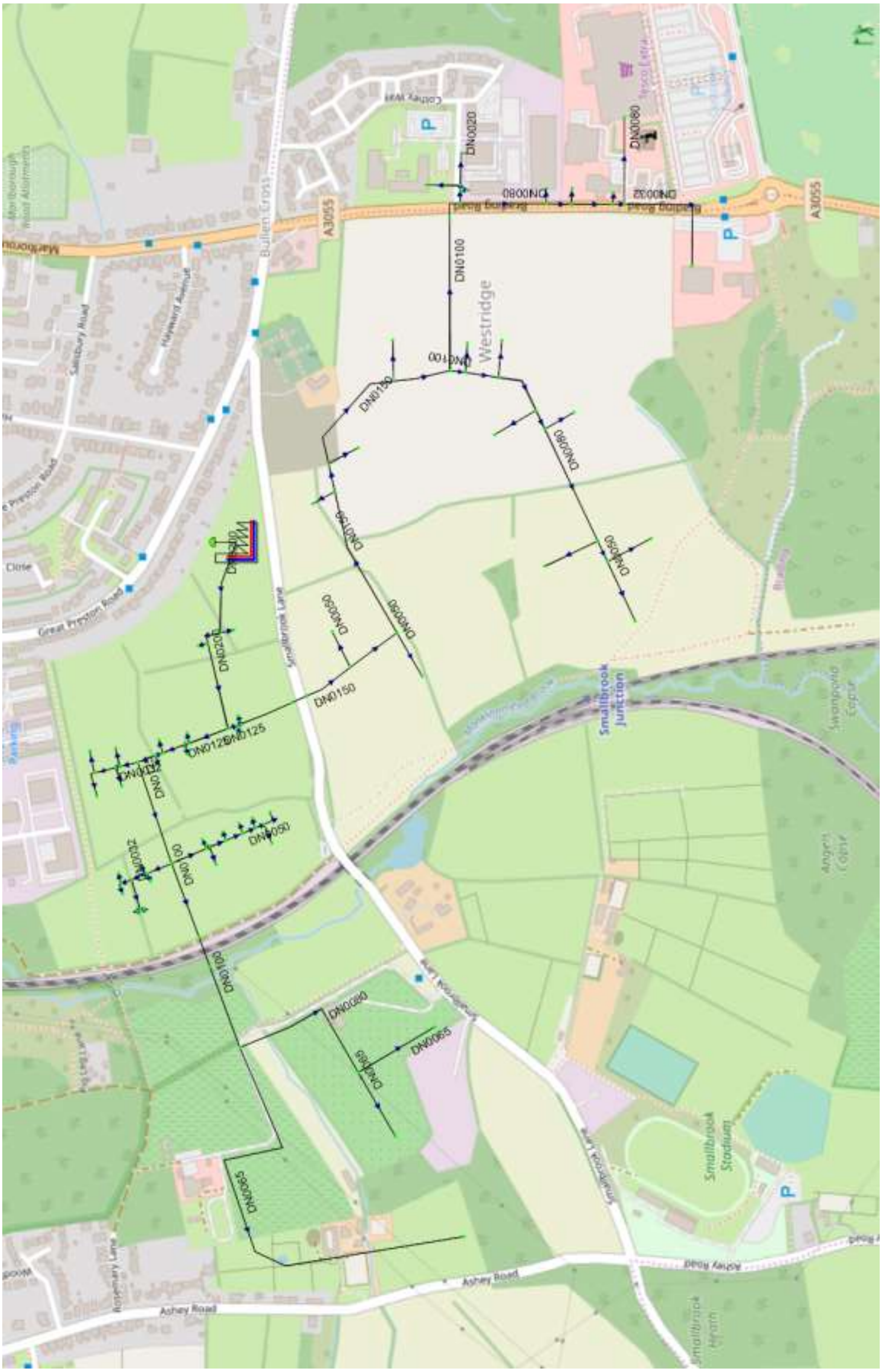
Design parameter assumptions used for hydraulic modelling of the heat network.

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

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

Pipe dimensions and capital cost breakdowns are presented in the tables below for all examined network options.

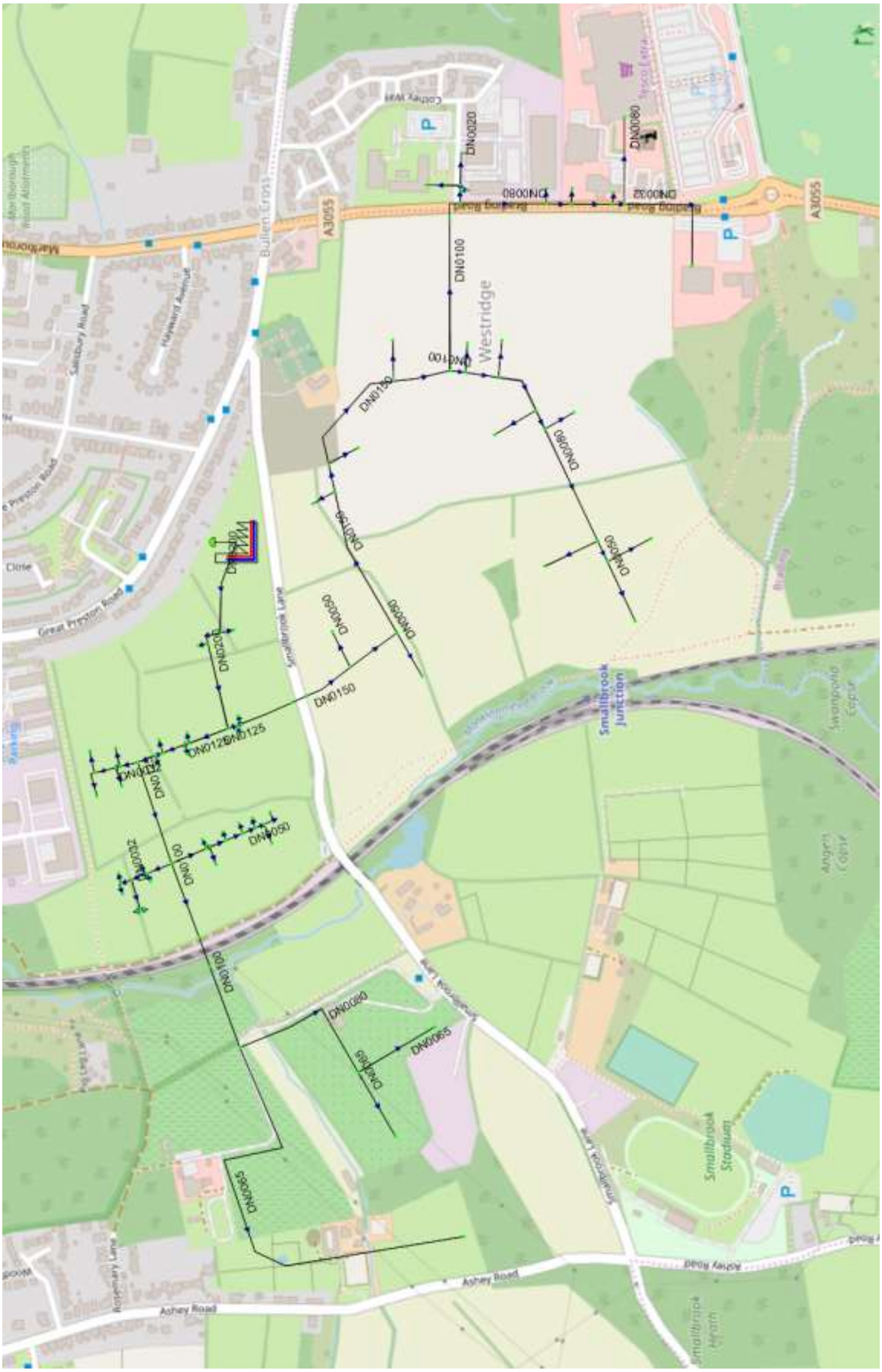
[12] *Heat Networks Code of Practice*



Nicholson Road area heat network pipe dimensions (Gas CHP & Biomass boilers)

	Trench length (m)	Pipe only supply and installation cost (£k)	Trenching and civils cost (£k)	Total cost (£k)
DN20	4,856	902.4	1,194.5	2,096.9
DN25	422	77.8	137.3	215.1
DN32	311	58.2	174.2	232.4
DN40	185	39.2	88.9	128.2
DN50	645	150.8	289.3	440.1
DN65	954	239.8	449.6	689.4
DN80	590	186.5	334.8	521.3
DN100	805	346.2	422.8	769.0
DN125	264	134.8	137.2	272.0
DN150	730	475.7	394.0	869.7
DN200	265	201.8	148.5	350.4
Subtotal	10,027	2,813.4	3,771.1	6,584.5
Constraint mitigation				200.0
Contingency (10%)		281.3	377.1	678.5
Total	10,027	3,094.7	4,148.2	7,463.0

Nicholson Road area heat network pipe dimensions and capital costs (Gas CHP & Biomass boilers)



Nicholson Road area heat network pipe dimensions (Biomass boilers)

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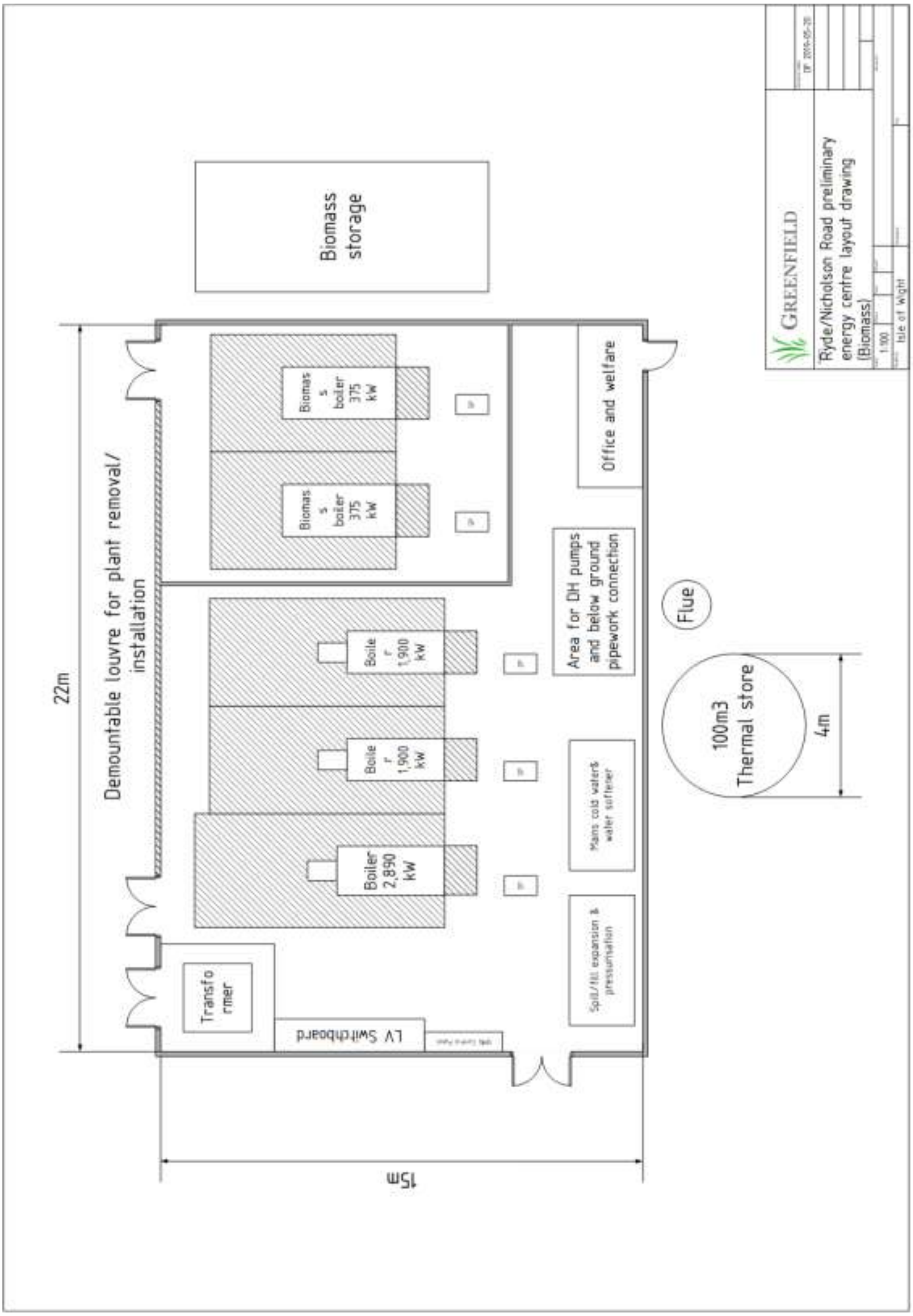
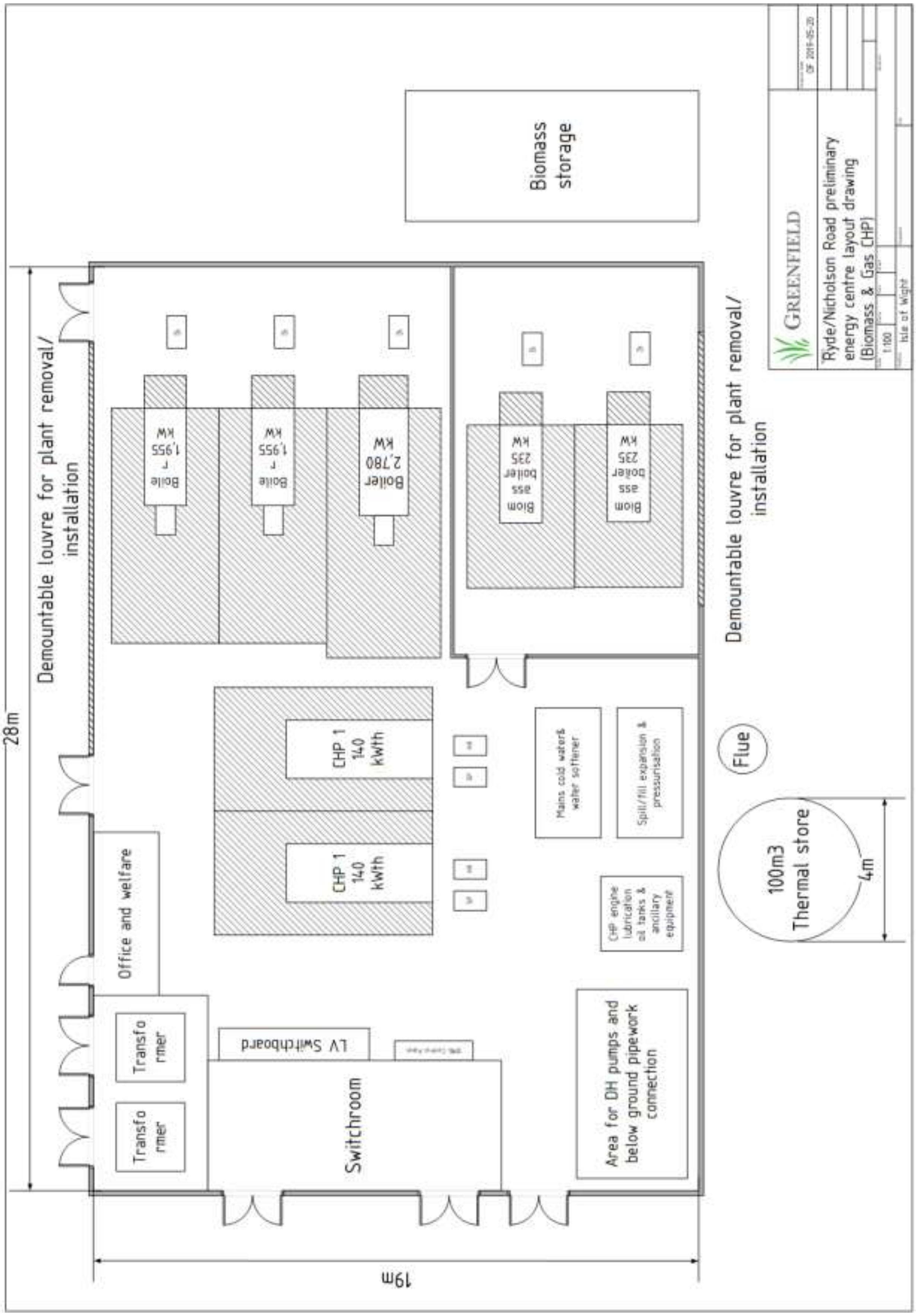
Nicholson Road area heat network pipe dimensions and capital costs (Biomass boilers)

Appendix 5. Preliminary Energy Centre layouts



Preliminary layout drawing - Biomass boiler energy centre.



Preliminary layout drawing - Biomass boiler + Gas CHP energy centre.

GREENFIELD

Appendix 6. Capital costs (Energy Centre and network)

Investment costs			
Network		4	4
Baseload supply technology		CHP & Biomass	Biomass
Total investment costs	£k	14,342	13,233
DH Network (steel)	£k	6,785	6,785
Heat substations, HIUs & metering		1,457	1,457
Private Wire network		584	0
Energy Centres		2,799	2,551
Utility connections (gas, power, water, drainage, telecoms)		203	107
Heat Store		260	260
Development costs[13]		950	871
Contingency (10%)		1,304	1,203

Capital costs breakdown

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

Energy Centre cost breakdown			
Baseload supply technology		**Biomass Boiler + Gas CHP**	**Biomass Boiler**
Land	£k	-	-
Energy Centre Building (shell and core) plus civils	£k	1,049	1,049
Energy generating technology costs	£k	708	557
CHP units	£k	272	-
Biomass Boilers	£k	202	234
Gas Boilers	£k	234	323
Energy Centre items, or refurbishment of existing plant areas, as applicable	£k	-	-
Thermal storage	£k	26	260
Electrical export switchgear and transformers	£k	98	-
Gas connection	£k	45	45
Electrical connections (export by Private Wire or export to grid)	£k	95	-
Water connection	£k	30	30
Drainage connection	£k	30	30
Telecoms connection	£k	2	2
Other Energy Centre capex (e.g. piping, valves, pumps, water treatment, cabling, electrical panels, etc.)	£k	945	945
Energy centre subtotal (exc. thermal store and connections)	**£k**	**2,799**	**2,551**
Energy centre subtotal (inc. thermal store and connections)	**£k**	**3,262**	**2,918**
Detailed engineering costs	£k	489	438
Professional fees	£k	163	146
Project Management	£k	98	88
Project Development	£k	200	200
Contingency (10%)	£k	421	379
Energy Centre total	**£k**	**4,633**	**4,168**

Energy Centre cost breakdown

Appendix 7. Operational costs assumptions

			Source:
Fuel costs – gas	£/MWh	24.9–42.1	BEIS QEP: Tables Annex, September 2018, non-domestic, very small to medium, excl. VAT, incl. CCL
Fuel costs – electricity (for heat pumps and energy centre)	£/MWh	113.8–144.4	BEIS QEP: Tables Annex, September 2018, non-domestic, small to large, excl. VAT, incl. CCL
Fuel costs - biomass	£/MWh	30.0	LHV basis, biomass supplier quote
Heat purchase price from EfW	£/MWh	5.0	Research report on district heating and local approaches to heat decarbonisation, Element Energy, 2015
Heat purchase price from AD plant	£/MWh	10.7	Greenfield analysis and experience from prior projects
Metering and billing cost	£/consumer/yr	90	Quote from heat network operator
Network management ("Account Manager")	£/yr	18,000	Quote from heat network operator
Utility costs and overheads (water, data, etc.)	£/yr	1,500	Greenfield experience from prior projects
Insurance		0.1% of CAPEX	Quote from heat network operator
Heat Trust	£/dwelling	4.5	Quote from heat network operator

Operational cost assumptions.

			Source:
Variable costs			
Gas CHP variable	£/MWh_{fuel}	2.43	Analysis based on plant maintenance costs based on operating hours
WSHP variable	£/MWh_{fuel}	3.00	
GSHP variable	£/MWh_{fuel}	3.00	
Biomass variable	£/MWh_{fuel}	2.00	
Gas boiler variable	£/MWh_{fuel}	1.25	
Annual fixed costs			
Gas CHP		3.5 % of CAPEX	Analysis based on plant maintenance costs based on operating hours
WSHP		3.5 % of CAPEX	
GSHP		3.5 % of CAPEX	
Biomass		3.5 % of CAPEX	
Gas boiler		2.0 % of CAPEX	
Other energy centre equipment		1.0 % of CAPEX	
Heat network fixed maintenance	£/m, trench	1.3	Greenfield experience from prior projects
Heat network replacement/repair	%-of HN capex/yr	0.5%	
Substation & HIU servicing	£/unit/yr	50	Quote from heat network operator

Maintenance cost assumptions.

			Source:
Gas boilers lifetime	*yrs*	25	Greenfield experience from prior projects
Gas CHP lifetime	*yrs*	15	
Biomass HOB lifetime	*yrs*	15	
WSHP lifetime	*yrs*	20	
GSHP lifetime	*yrs*	15	
Other energy centre equipment lifetime	*yrs*	35	
Heat network, steel lifetime	*yrs*	50	
Heat network, plastic lifetime	*yrs*	40	
Substations & HIUs lifetime	*yrs*	20	
REPEX		70% of Balance of Plant original CAPEX	

REPEX / lifetime assumptions.

Appendix 8. Revenue assumptions

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

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

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

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

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

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

Heat sales tariffs non-residential consumers.

	Unit rate for gas	Annual boiler O&M costs	Annual boiler replacement costs (based on 15 yrs)	Variable heat tariff (inc. 5% discount)	Fixed heat tariff inc. (5% discount)	Connection fee (inc. 5% discount)
	£/MWh	£/dwelling	£/dwelling	£/MWh	£/dwelling	£/dwelling
Residential, flats	44.1	205.3	77.8	54.7	272.2	1,451.6
Residential, houses	44.1	205.3	77.8	54.7	272.2	1,451.6

Heat sales tariffs residential consumers.

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

			Source
Electricity sales (grid)	£/MWh	45.1	BEIS (electricity wholesale, reference scenario) Price is inflated annually according to BEIS predictions
Electricity sales (private wire)	£/MWh	148.6 (peak) / 102.3 (off-peak)	QEP, inc. 5% discount. Price is inflated annually according to BEIS predictions

Power revenue assumptions.

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

		Rate	Term	Source
Biomass (> 1 MWth) Tier 1 (35 % of heat load) Tier 2 (65 % of heat load)	 £/MWh £/MWh	 31.1 21.8	20 years	Office of Gas and Electricity Markets: Tariffs and payments: Non-Domestic RHI

RHI revenue assumptions.

Appendix 9. Detailed financial modelling results

Project viability		CHP & Biomass	Biomass
NPV @ Discount rate:	3.5 %		
25 yr	£k	-3,550	-3,104
30 yr		-4,121	-3,663
40 yr		-5,081	-4,620
LCOE (heat consumption) @ Discount rate:	3.5 %		
25 yr	£/MWh	143.6	139.5
30 yr		136.0	133.0
40 yr		128.8	126.6
IRR			
25 yr	%	1.1 %	1.2 %
30 yr		0.9 %	1.0 %
40 yr		0.4 %	0.4 %
MIRR			
25 yr	%	2.1 %	2.2 %
30 yr		2.1 %	2.2 %
40 yr		2.2 %	2.2 %
Simple Payback (yr)	yr	NA	NA
Discounted Payback (yr) @ Discount rate:	3.5 %	NA	NA
Economic viability (including socio-economic benefits)			
NPV @ Discount rate:	3.5 %		
25 yr	£k		
30 yr		-4,683	-3,834
40 yr		-4,336	-3,444
IRR		-3,810	-2,721
25 yr	%		
30 yr		0.3 %	0.7 %
40 yr		0.6 %	1.1 %
		-22.3 %	1.8 %
Simple Payback (yr)	yr		

Detailed financial modelling results.

Gap funding required to reach		CHP & Biomass	Biomass
IRR 5.0 %	£m	4.9	4.4
	% capex	34.1 %	33.1 %
IRR 7.0 %	£m	6.0	5.5
	% capex	42.1 %	41.3 %
IRR 10.0 %	£m	6.9	6.3
	% capex	48.3 %	47.7 %

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

Appendix 10. Carbon reduction analysis

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

Emission Factors		
Gas[14]	tCO_2 / MWh	0.205
Biomass	tCO_2 / MWh	0.039
Grid Electricity (2018)[15]	tCO_2 / MWh	0.313

CO_2 emissions for each heat network option and for the ‘business as usual’ solution is calculated based on static 2018 factors. Subsequently the report goes on to show the impact of accounting for future projections for carbon emissions as estimated by HM Treasury[16], whilst also taking account of the specific carbon reductions that can be attributed to decentralised power generation from CHP as estimated by BEIS[17]. It is important to account for this since the carbon factor for electricity is forecast to significantly change over coming decades as the UK government seeks to decarbonise power supply, which would reduce the carbon benefits of locally generated electricity (when relative to grid power). The changes in electricity carbon factor predicted requires significant transformation of the UK power supply system which relies on major investment into new nuclear power, renewables and other low carbon technologies. Whilst it cannot be said with certainty that the rate of change predicted will be achieved it is a risk for a heat network scheme using CHP (whether gas, fuel cell or biomass) for baseload supply. Where carbon reduction is a key objective and stakeholders wish to apply the government’s future grid carbon factors projections then the lower figures should be utilised to interpret the analysis results.

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

[14] *BEIS: “Government emission conversion factors for greenhouse gas company reporting” (August 2017)*

[15] *BEIS: “Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal” (January 2018)*

[16] *"Grid Average, consumption-based" emission factor for electricity has been used from Valuation of energy use and greenhouse gas (GHG) emissions - supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government, HM Treasury, January 2018.*

[17] *“CHP exporting” and “CHP onsite” emission factors have been used from Emission factors for electricity displaced by gas CHP, Bespoke natural gas CHP analysis, Department of Energy & Climate Change, December 2015.*

Appendix 11. Initial risk register

Version	Date	Notes
0.1	28/5/19	First issue

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

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Demand	PD, C	**Demand for heat and power is lower than expected due to not being able to sign up consumers**	At this stage there is limited certainty over consumers connections (no MOUs/HOTs/contracts in place). The impact of losing consumers can be significant but some are more important than others (scales and proximity to others). Loss of consumers could be for a range of reasons, including (1) the scheme not being able to provide an attractive offer to stakeholders (site operators, end-consumers, developers) or (2) because the scheme is not available when required (although few require early connection)	4	4	16	1. Liaise with key stakeholders as scheme move through feasibility to investable proposition 2. Ideally establish MoU/HoTs with key consumers in near future 3. Refine understanding of programme / milestone issues and adjust scheme phasing and consider temporary solutions, where necessary 4. Revise scheme design based on secured consumers (allowing for expansion capacity)
Project Development	PD, C	**Development skills / resources (to deal with feasibility investment planning, project/contract management, technical appraisal)**	There is no present capacity and capability to act as an informed client to contract to market (feasibility, install & operate). Not resolving this will lead to the non-delivery and/or unintended consequences of poor delivery where it is attempted without sufficient resource.	4	3	12	Once there is a "live" project with good stakeholder support and appointed lead entity: 1. Formalise / Initiate project and establish project management structure and agreements between project champion and key stakeholders 2. Conduct skills audit 3. Work with / secure funding from HNDU for the follow-on investigation work 3. Recruit key resources (some will be external) 4. Up-skill decision makers and internal managers
Regulatory	PD, C	**Planning + consenting**	Energy Centres will need to planning permission and regulatory approvals	4	3	12	Once indicative scheme is established liaise with planners to review key information required and adaptations that may support a positive outcome
Supply	O	**Poor reliability and performance of consumer heat supply**	Poor design, construction or operational standards leading to poor service and/or non-service at times and a loss of trust in the system which could result in disconnections. The masterplanning stage has developed early-stage indicative design solutions but care will need to be taken to conduct design, installation and operation in compliance with the National Heat Code of Practice (and subsidiary guidance).	4	3	12	1. Apply best practice design, construction and operational standards, e.g. UK Code of Practice 2. Ensure specification meets longevity standards required 3. Ensure scheme revenues are sufficient to support O&M and meeting re-investment requirements 4. Transfer risks and incentives to operator to maintain optimal performance

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
							5. Give careful consideration for interfaces between design, build and operation
Supply	**PD**	**No access to RHI**	RHI is due to close by end of Q1 2021 and as such these heat network options will not be able to access it. It may be replaced or extended but this has not been confirmed by government	4	3	12	1 Develop solutions (technical/financial) in subsequent work that limit reliance on RHI
Demand	**PD, O**	**Demand for heat is lower than expected, due to poor data or change in consumption profiles**	Heat demand data for most properties is based on metered consumption data so provide high confidence. Other data, particularly in the new developments, is based on benchmarking and realised energy demand could be lower or higher than expected. Energy demands may also change over time as buildings are updated / operated differently. For example, refurbishment.	4	2	8	1. Highlight data weaknesses and seek to improve over time 2. Update consumption estimates (and update scheme design) as new data becomes available (at least at key decision points during the scheme development process) 3. Use new data to revise scheme design prior to project investment 4. Address consumption changes through operational management
Supply	**PD**	**Energy Centre utility constraints**	Technical or commercial constraint to connect energy centre servicing infrastructure, e.g. gas and power connections	4	2	8	1. examine connection issues with DNOs once EC sizing is completed
Financial/Commercial	**C**	**Overspend on capital budget**	Failure to deliver project within the estimated capital costs and contingency. Likelihood is low since costs have been benchmarked against major UK suppliers and a 10% contingency is added. However, there are risks such as greater construction and construction management costs for the network infrastructure and energy centre options.	4	2	8	1. Use effective project management framework/process 2. Produce clear specification of requirements and systematically de-risk 3. Use PM and advisers with experience of heat networks 4. Pass on risks, e.g. Design, Build & Operate council 5. Manage budget, making adjustments to capital allocation and finding balancing cost reduction, as necessary

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**C, O**	**Energy Centre & network: Poor end-consumer service delivery**	Poor service provision leads to user dissatisfaction and in worst case to disconnection	4	2	8	1. Ensure design, construction and commissioning are of a high standard and at least compliance against Code of Practice 2. Provide effective operational management, including annual consumer satisfaction surveys 3. Structure incomes/profits to management performance 4. Establish arbitration solution, e.g. Heat Trust or council operated scheme
Supply	**O**	**Energy Centre and network: Inadequate maintenance**	Poor maintenance could lead to system failures which will cause dissatisfaction and increased costs	4	2	8	1. Ensure design, construction and commissioning are of a high standard and at least compliance against the Heat Network Code of Practice 2. Design in effective monitoring and management capabilities 3. Provide effective asset management and ensure sufficient budget (O&M and repex) for planned and un-planned maintenance / replacement 4. Structure O&M contracts to performance
Demand	**C**	**Construction delays**	This refers to delays once a detailed construction plan is resolved which is likely to be linked to consumer and/or supply plant milestones. Delays may cause commercial impact but in the worst-case result in loss of supply option and/or consumers	3	2	6	1. Develop realistic programme 2. Implement effective project management and risk appraisal to predict constraints 3. Explore risks with stakeholders and development joint mitigation plans

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Financial/Commercial	**PD**	**Availability of appropriate investment**	A heat network scheme involves significant capital expenditure, which will be compensated by long term returns. Funding is required to be secured from amongst key stakeholders or external investors. At this early stage investment strategies are not in place; this is a task that will require further investigation as it proceeds through subsequent development stages. Options include 3rd party network ownership, public debt (PWLB, soft loan or grant support (e.g. HNIP, LEP/EU funds)) and private debt/equity and will depend on the nature of the project structure.	2	3	6	1.Explore options as the specific network schemes develop
Financial/Commercial	**O**	**Operating costs and revenues outside business case tolerances**	O&M costs exceed and/or revenues fall short, of the modelling tolerances. Modelling has been conducted on a conservative basis and so as are considered reasonable at this point.	3	2	6	1. Conduct independent due diligence 2. Monitoring costs and revenues during operation and develop operational responses 3. Pass risks on to operators, where possible
Financial/Commercial	**PD, O**	**Energy prices (general) vary on the medium/long-terms basis**	The financial modelling uses long terms price forecasts from BEIS and so retain inherent uncertainty, although there is a clear trend towards increasing energy costs over time. Changing energy prices will both affect costs of energy supply and the operation of the heat network, e.g. pumping and operation of heat pumps, but will also affect consumer tariffs since these will either be linked to UK energy or consumer price indices. These will typically act against one another to mitigate overall impact.	3	2	6	1. Carefully negotiate energy centre fuel/electricity contracts 2. Establish heat supply contracts that link tariffs to energy/consumer indices 3. Adjust business case accordingly
Supply	**PD, C**	**General network route constraints**	Various highway and junction constraints and existing buried services will present route constraint issues. These are likely to be surmountable but solutions will need to be developed.	2	3	6	1. Liaise with owner/operators of existing utility infrastructure 2. Survey other network constraints 3. Develop engineering solutions and examine capital costs impact

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**C**	**Runs beyond programme**	Construction delays leading to possible cost increases and potentially missing deadlines for the new consumer connections and/or supply	3	2	6	1. Use project management framework/process 2. Use experienced PM
Supply	**O**	**Future proofing network capacity**	A decision will need to be made regarding the sizing of the network infrastructure and the energy centre(s) based on a assumed demand, which clearly could increase overtime. Whilst there is significant capacity within the proposed network to allow for expansion, it is finite and major demand growth could exceed capacity. However, it important to avoid oversizing as this results in greater construction costs and if underutilised it will limit system efficiency (greater losses) and higher supply costs.	2	2	4	1. Make decision for initial network sizing based on reasoned opinion of future expansion strategies. 2. Continue to review as network design evolves
Regulatory	**PD, O**	**National legislation introduces new costs, e.g. taxation**	New carbon taxation of the heat network may add additional costs.	2	2	4	1. Due diligence against the possible changes 2. Make operational adjustments as required
Regulatory	**PD, O**	**Heat supply becomes regulated**	Currently unregulated, the supply of heat can be treated as any unregulated services. This is unlikely to be a major issue since heat sales are internal or to as part of the tenant arrangements.	2	2	4	1. Review implications in further detail as scheme progresses
Supply	**PD**	**Air quality impacts of energy centre(s) (perceived and real)**	Air quality impact may lead to regulatory constraints or may create public concern against development. Careful site selection and selection of appropriate plant with NOx and other emission mitigation systems are likely to address concerns, particularly as a heat network will displace emission relative to less efficient building-level boiler plant.	3	1	3	1 On next iteration of energy centre design, review this issue further

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**PD**	**Energy Centre location**	Location options are dependent on supply technology (CHP, EfW, AD, WSHP or combination) and the access to land/building facilities. Without securing this, the project will not proceed. Space would need to be found on the Hospital or MoJ sites to house the CHP plant (indicative location has been discussed with stakeholders). In case of the EfW, AD and Fairlee Water Treatment Works (WTW), space would need to be found on the sites to house an energy centre.	4	4	16	1. Explore site options with stakeholders (including NHS, MoJ, IoW Waste Recovery Park, Black Dog AD, and Southern Water) 2. Develop solutions for all options to provide fallback solutions until such as point as its necessary to make a decision of the supply option
Demand	**PD**	**Heat connections to new developments**	The developments included in the heat network are currently in a planning stage where final scales and timescales may still change before and during the sites are built out. Demands and timescales have been estimated based on currently available plans.	4	3	12	1. Engage with developers to ascertain final scale and timescale of development 2. Redesign network solution as needed
Supply	**PD**	**Energy Centre location - Nicholson Road**	The location of the energy centre in Ryde network is uncertain; an indicative location has been identified within the Nicholson Road development but would need to be further investigated and decisions made around the preferred location.	4	3	12	1. Explore EC location options with stakeholders
Demand	**PD**	**Power connections to new developments**	Private wire connections have been planned for the non-residential parts of the new developments. There is uncertainty over the likelihood of establishing the power connections and the scale that would be available for connection. The uncertainty is caused by the current stage of development where final extent of the developments is unknown.	2	3	6	1. Engage with developers to ascertain whether power connections are likely 2. Explore additional power consumers around the development sites

Risk theme	Phase: PD, C, O	Risk name	Risk description (and mitigation)	I	L	RV	Proposed action
Supply	**PD, C**	**Network route constraints - crossing train line**	This is required for a connection to the Rose-mary's Vineyard development. Directional drill-ing (under rail line) or building a gantry would be possible alternatives. Each will add additional cost, although this will be relatively small in the context of the full network cost.	2	3	6	1. Liaise with owner/operators of land and exist-ing utility infrastructure, including Network Rail 2. Identify options and complete review to iden-tify preferred solution (with fall-back) 3. Use this to inform the design of the proposed network such that it is future-proofed for future expansion

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