North Star and Wichelstowe District Heating Feasibility Studies – Technical Annexes

Swindon Borough Council

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Contents

1. Introduction

This document is to accompany the North Star energy centre project concept note produced by Verco and Pöyry on behalf of Swindon Borough Council in August 2012. The document compiles background information and analysis results from the district heating feasibility studies for North Star and Wichelstowe.

It contains three sections:

- **Section 1 – North Star energy centre** contains site plans and the estimated energy demand of energy consumers at North Star.
- **Section 2 – North Star – feasibility of district heating to non-Moirai consumers,** presents the high level financial analysis of district heating to ‘external’ non-Moirai energy consumers (BT, Swindon College and the Research Council) as an extension to the possible energy system serving the Moirai leisure hub.
- **Section 3 – Middle Wichelstowe district heating feasibility,** presents a high level financial analysis of two district heating network scenarios utilising waste heat from a CHP unit situated within the proposed supermarket within the urban centre of Middle Wichelstowe, and supplying heat to the surrounding mixed use development.

2. North Star energy centre – additional information

2.1 Site location and plans

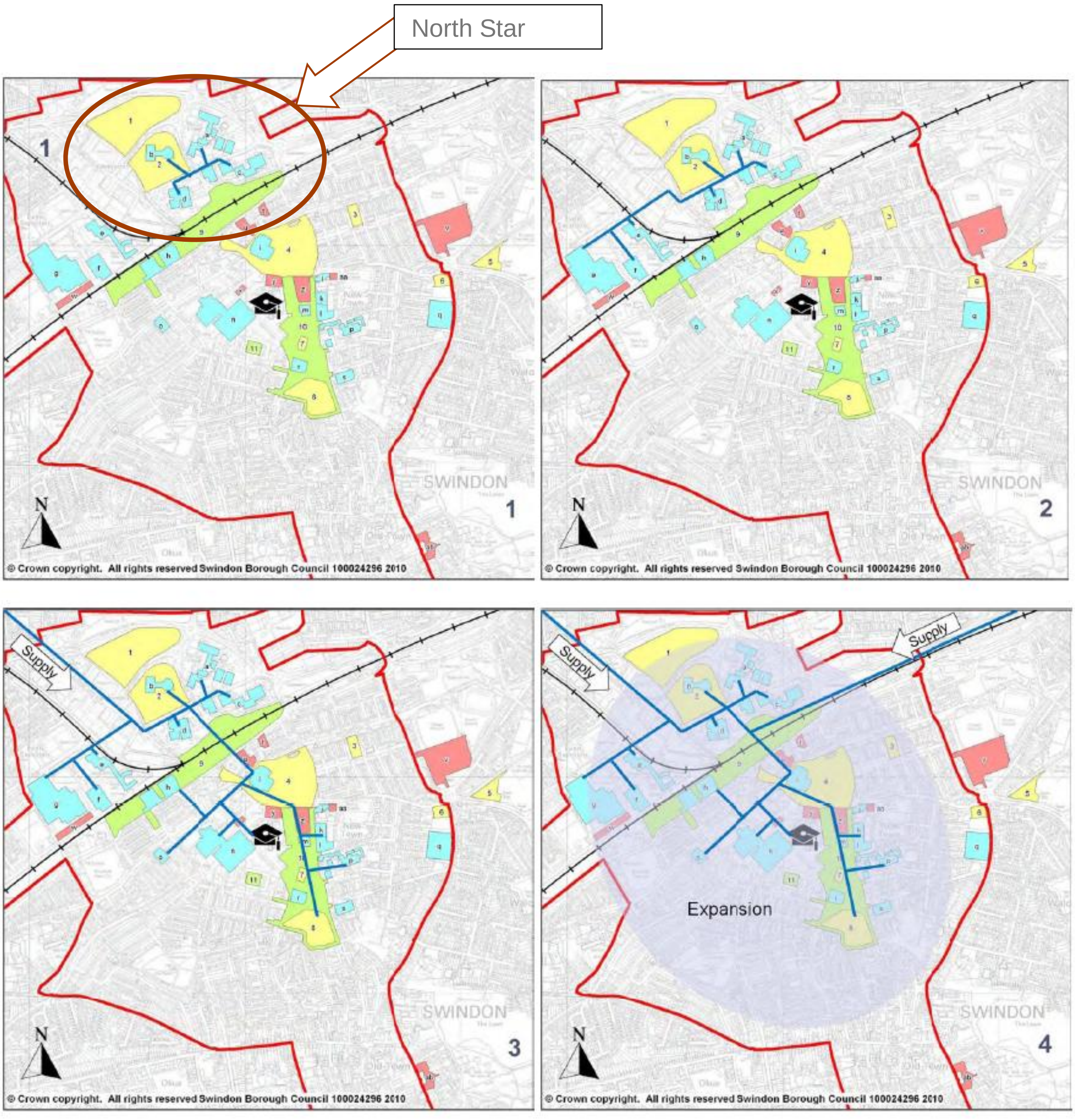


Figure 1: Suggested network expansion in the Town Centre

(Source1 Bizcat, 2011 ((http://www.swindon.gov.uk/ep/ep-planning/ep-planning-localdev/Documents/district_energy_final_report__march_2011_-2[1].pdf)))

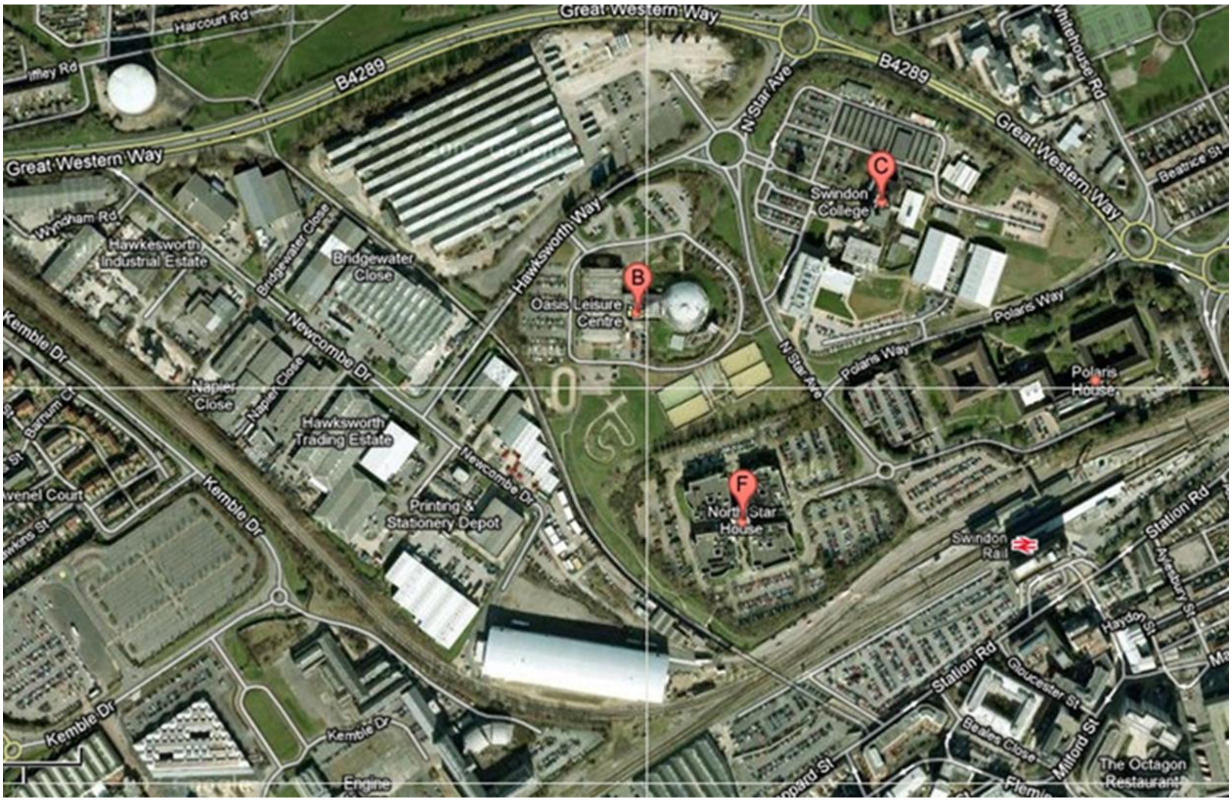


Figure 2: Aerial image of North Star

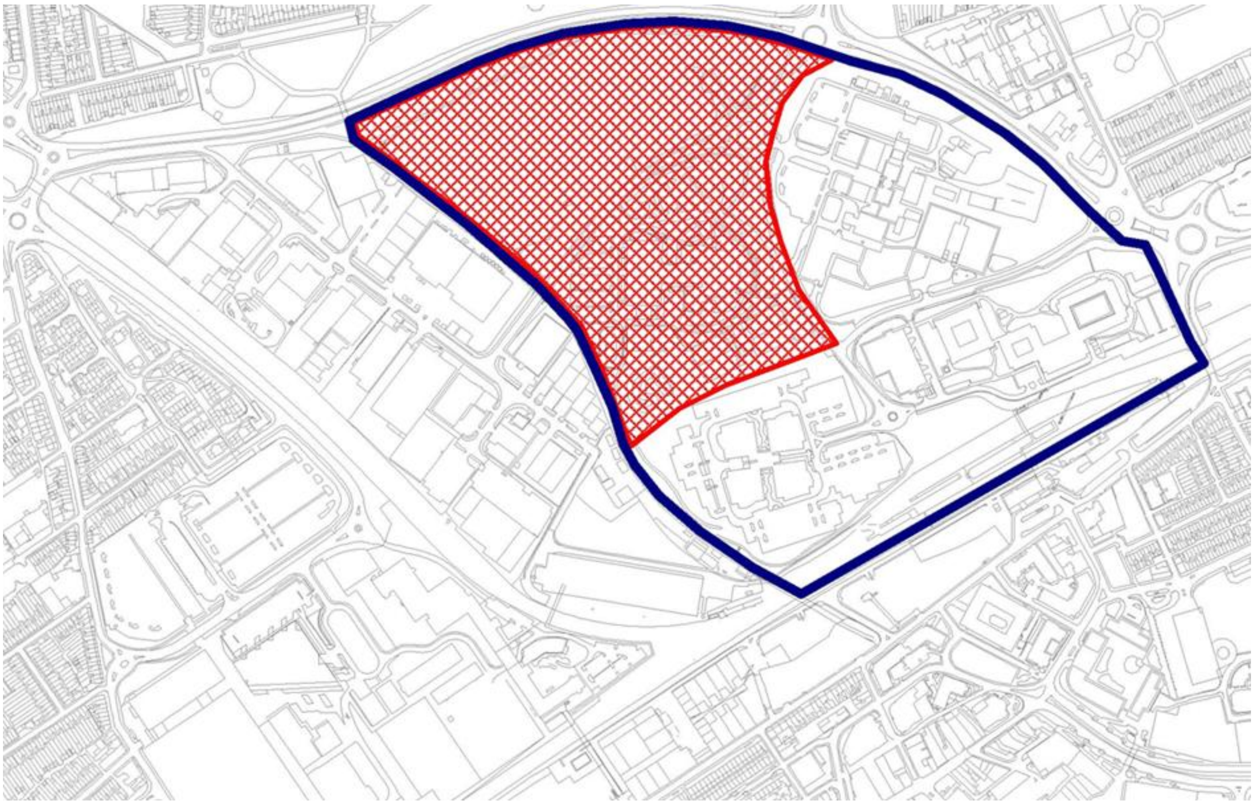


Figure 3: Oasis redevelopment area

2.2 Energy demand summary table

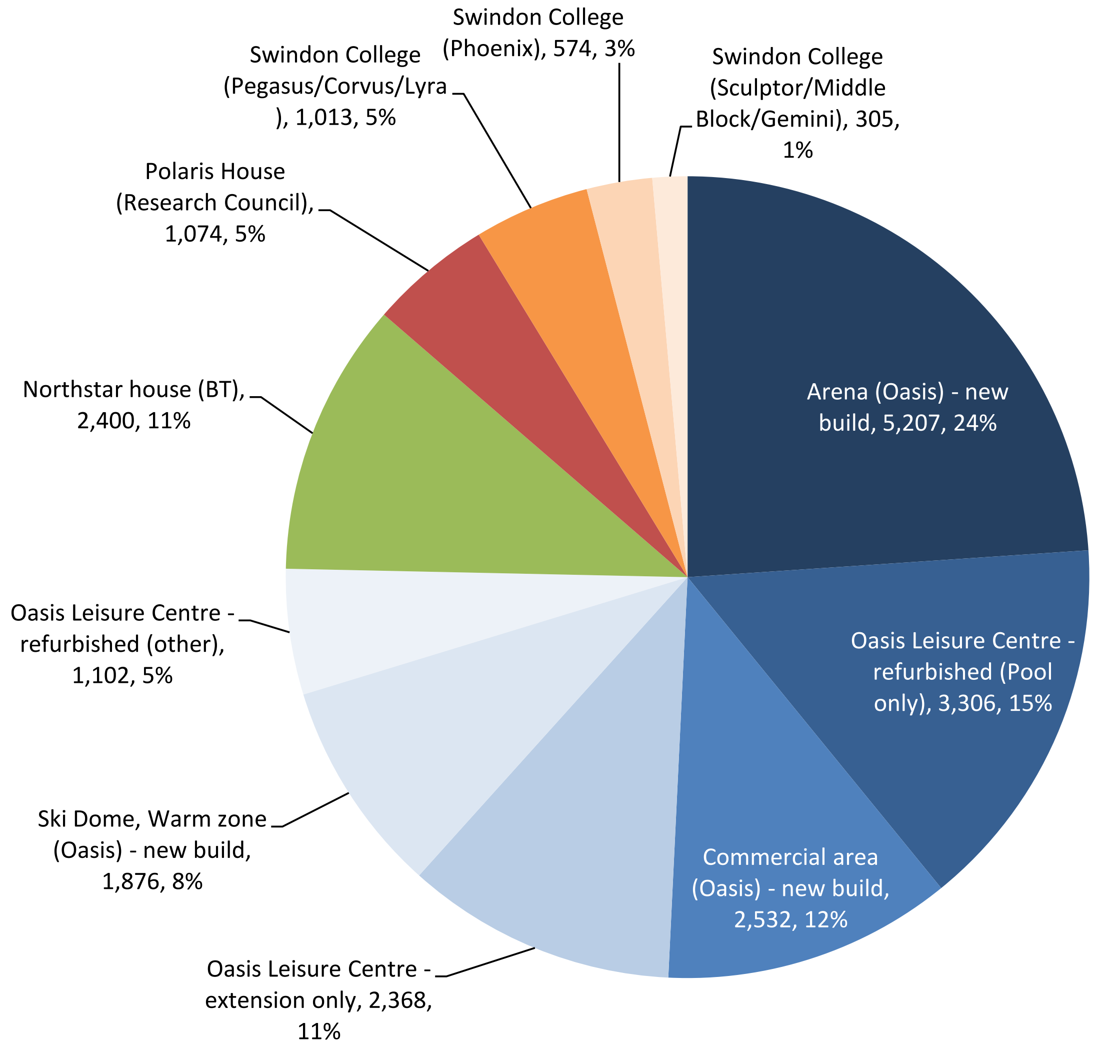
Land use type	Building details: Type	Area (m2)	Commiss-ioning date	Energy data source	Energy demand totals: Total Heat Demand (MWh)	Total Electricity Delivered (MWh)	Thermal Cooling demand (MWh)	Thermal Energy by heat / cooling grade: District heating hot water (~90°C)	Swimming pool heating (could use ~40-50°C)	Office cooling (~6°C)	Industrial Cooling (~-10°C)
Oasis Leisure Centre - refurbished (Pool only)	Moirai - existing	4,200	2013	Estimate based on 15% improvement on historical consumption	3,306	517	0	0	3,306	0	0
Oasis Leisure Centre - refurbished (other)	Moirai - existing	1,400	2013		1,102	172	0	1,102	0	0	0
Oasis Leisure Centre - extension only	Moirai - new build	5,700	2017	CIBSE benchmarks and Buro Happold estimates from previous ski slope project.	2,368	704	211	2,368	0	211	0
Ski Dome, Cool zone (Oasis) - new build	Moirai - new build	34,575	2017		0	13,620	38,816	0	0	0	38,816
Ski Dome, Warm zone (Oasis) - new build	Moirai - new build	16,525	2017		1,876	3,089	0	1,876	0	0	0
Commercial area (Oasis) - new build	Moirai - new build	29,750	2017		2,532	4,894	1,468	2,532	0	1,468	0
Arena (Oasis) - new build	Moirai - new build	13,475	2017		5,207	2,021	606	5,207	0	606	0
Total (Morai buildings only)					**16,390**	**25,017**	**41,101**	**13,084**	**3,306**	**2,286**	**38,816**
Swindon College (Pegasus/Corvus/Lyra)	Non-Moirai existing	12,312	existing	2011/12 utility consumption and assumed plant efficiencies	1,013	866	0	1,013	0	0	0
Swindon College (Phoenix)	Non-Moirai existing	3,774	existing		574	811	0	574	0	0	0
Swindon College (Sculptor/Middle Block/Gemini)	Non-Moirai existing	25,200	existing		305	404	0	305	0	0	0
Polaris House (Research Council)	Non-Moirai existing	25,200	existing		1,074	3,550	0	1,074	0	0	0
Northstar house (BT)	Non-Moirai existing	17,477	existing		2,400	4,908	0	2,400	0	0	0
Total (including non-Moirai consummers)					**21,757**	**35,555**	**41,101**	**18,451**	**3,306**	**2,286**	**38,816**

Table 1: Data table of energy demand estimates of buildings at North Star

2.3 North Star – heat demand by building type (MWh/yr)

Figure 4 shows the annual estimated heat demand of all buildings considered for connection in this feasibility study post development of the Moirai project. The total annual estimated heat demand is 22GWh. More than three quarters of this estimated demand comes from the Moirai buildings.

Note that the pie chart below shows MWh/yr for a variety of heat qualities, as illustrated in Figure 5 on the next page.



Key:

Segments in blue are for the Moirai development

Segments in other colours are for the existing non-Moirai North Star buildings

Figure 4: Heat demand by building (MWh/yr)

Figure 5 breaks out the estimated 22GWh of heat demand by heat quality and similarly shows the break out of the estimated 41GWh of cooling demand. Heat is shown in red and cooling in blue.

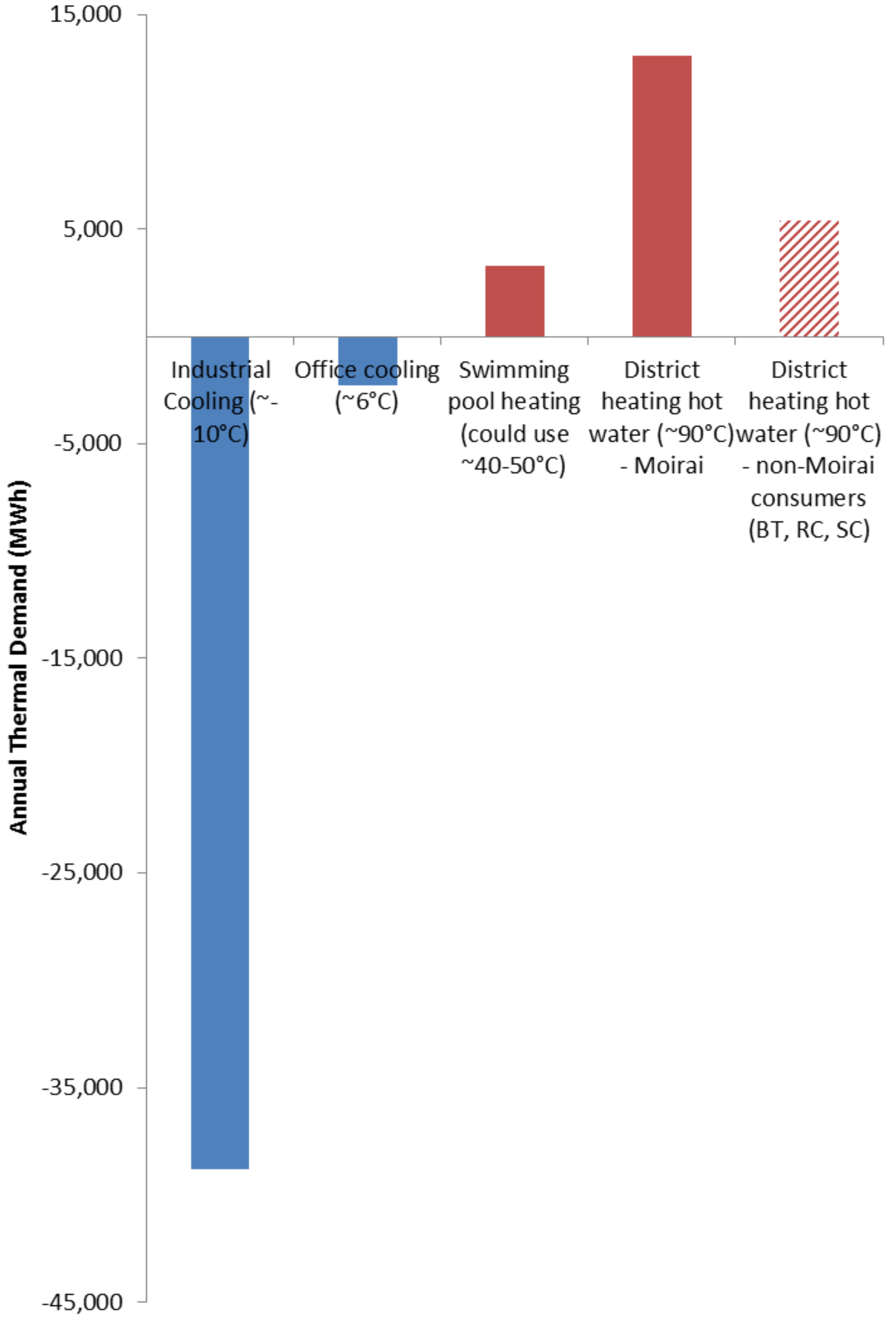


Figure 5: North Star energy demand by heat quality

*Note: the flow and return temperatures of the swimming pool heating system currently installed is c. 90ºC/75ºC (Buro Happold – correspondence 15/8/12). In principle this load could be supplied from a lower grade heat source.

2.4 Estimated heat demand profile

Figure 6 below the estimated aggregate load duration curves for the heating loads shown on the previous page. Three scenarios are shown for comparison, representing three scopes of heating provision:

The assumed profile for the refurbished wet leisure centre is based on historical records of the half-hourly gas consumption of the (un-refurbished) Oasis leisure centre.

The profiles of the other elements of the Moirai master plan are generic 7 day heat profiles and thus are a rough approximation only.

The profiles of the existing non-Moirai consumers is based on a mixture of half hourly gas consumption information and generic profiles - see section 0 for further details.

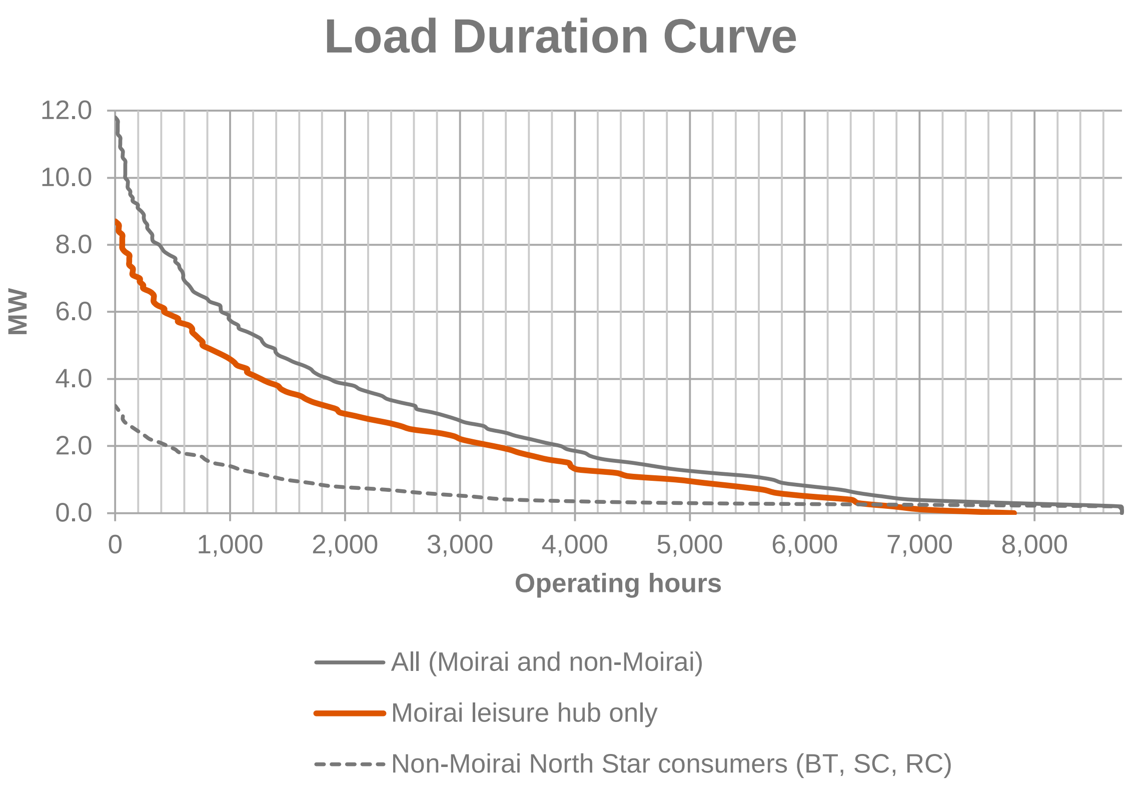
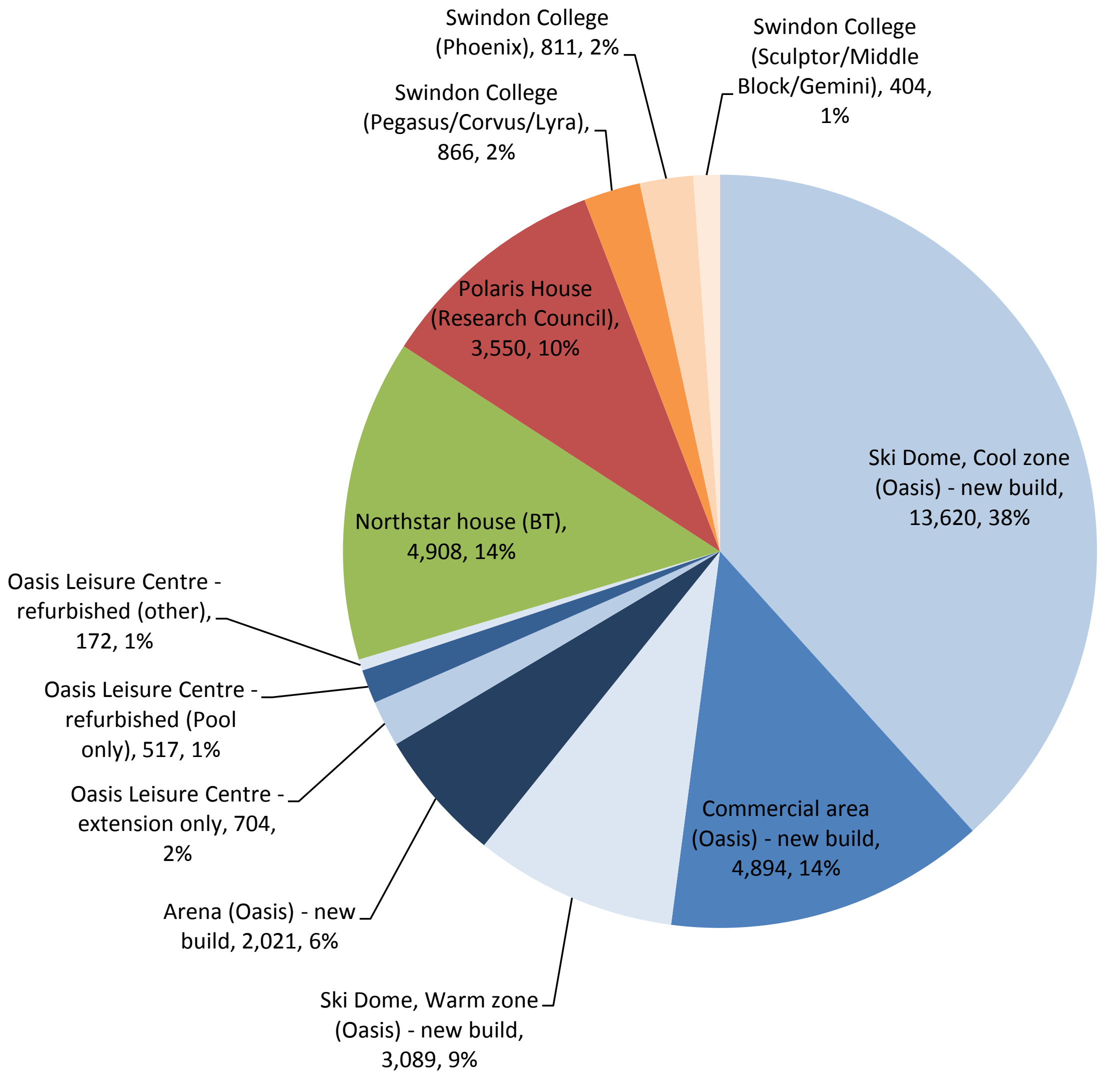


Figure 6: Estimated aggregate load duration curve for North Star

2.5 North Star – electricity demands

Figure 7 shows estimated annual electricity demand by building post development. The total estimated demand is 36GWh. More than two thirds of the demand comes from the Moirai buildings.



Key:

Segments in blue are for the Moirai development

Segments in other colours are for the existing non-Moirai North Star buildings

Figure 7: North Star electricity consumption (MWh/yr)

3. North Star – district heating to non-Moirai consumers

3.1 Introduction

This section presents the results of the scenario analysis of extending a district heating network to the non-Moirai consumers at North Star. The network would be supplied from the Oasis leisure hub energy centre.

Key assumptions made are given below.

- The Moirai energy centre supplies heat to the network for free (on the basis that if the network is unviable with free heat, then it is not worth investigating further).
- Customers are charged at 2p/kWh (assumed to be competitive with market rates for gas).
- The energy centre provides 24/7 service and 100% of the load.
- Individual connection points are possible to the plant rooms in all buildings (see Figure 8). Some Swindon College buildings are excluded in the analysis, due to the technical incompatibility of connection district heating of their internal distribution systems – e.g. direct gas-fired heating.

3.2 Indicative heat network routing

Figure 8 shows the layout considered for the scenario of connecting all relevant North Star buildings (BT at North Star House, Research Council, Swindon College). Note that Swindon College would have three separate connections. Pipe routes are shown in red and connections are indicated with orange circles.

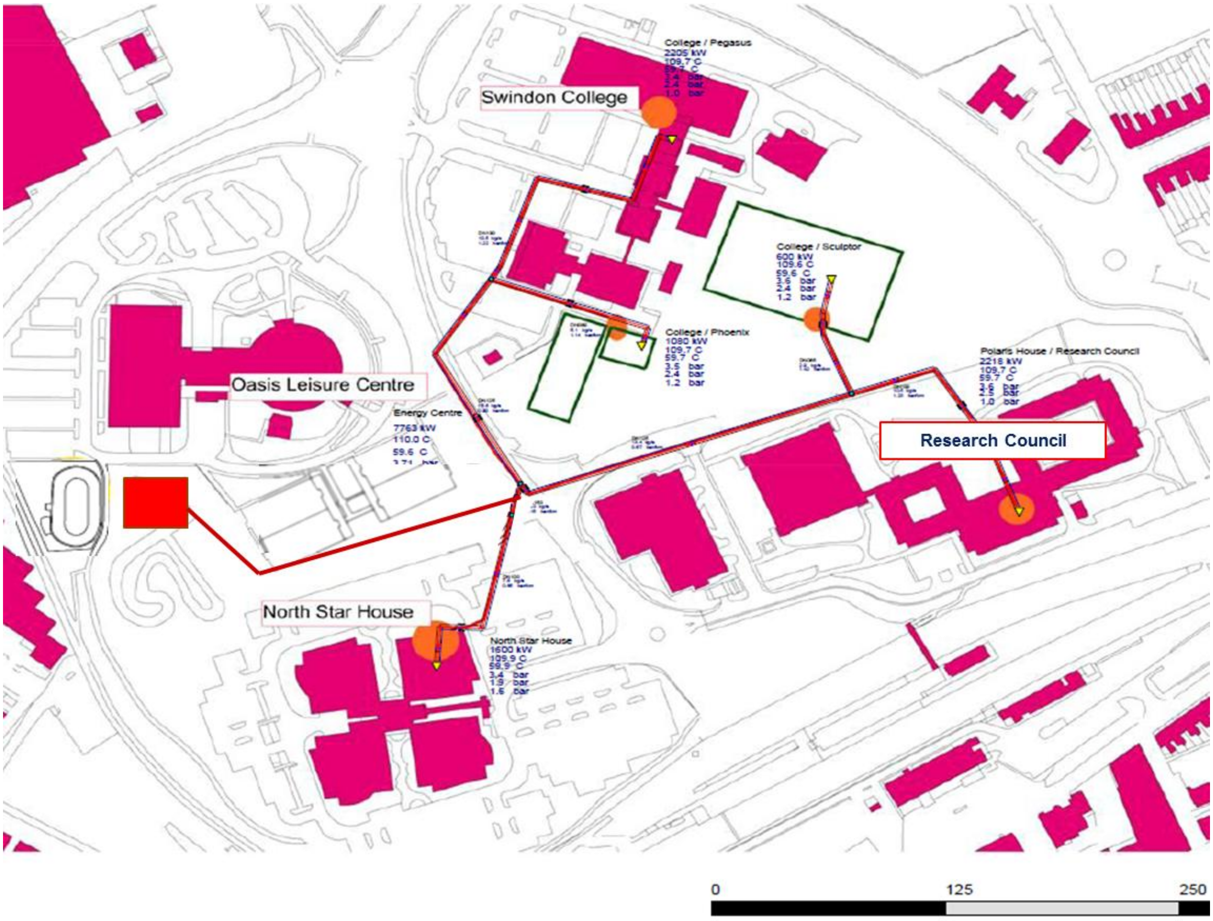


Figure 8: Possible district heating network routing

3.3 Details of existing plant rooms

Table 2 provides a summary of the installed plant and fuel usage at the 5 connection points.

Building	Total boiler capacity (MW)	Boiler efficiency (reported / estimated)	Total Heat Demand (MWh/yr)	Average load factor	Comment
Swindon College (Pegasus/Corvus/Lyra)	2.2	74%	1,013	5%	2x880kW, 1x440kW, 1x50kW, oil fired.
Swindon College (Phoenix)	1.1	80%	574	6%	New building, 2x540kW gas
Swindon College (Sculptor/Middle Block/Gemini)	0.6	80%	305	6%	2x300kW gas
Polaris House (Research Council)	2.2	89%	1,074	6%	4x530kW, 2x98kW Spare capacity? Plant on roof
Northstar house (BT)	1.6	80%	2,400	17%	24/7 building, very flat daily gas demand profile
Oasis (refurbished estimate)	4.7	/	4,408	11%	CHP 228 kW(e) 358kW(t), 3x1000MW, plus some direct fired gas heating
Total	12.4		12,174	11%	

Table 2: North Star non-Moirai consumer plant room details

3.4 Estimated heat demand profile

The load duration curve in Figure 9 shows the relationship between energy load demand and yearly hours required for the external non-Moirai buildings only. The maximum demand is 3.2MW.

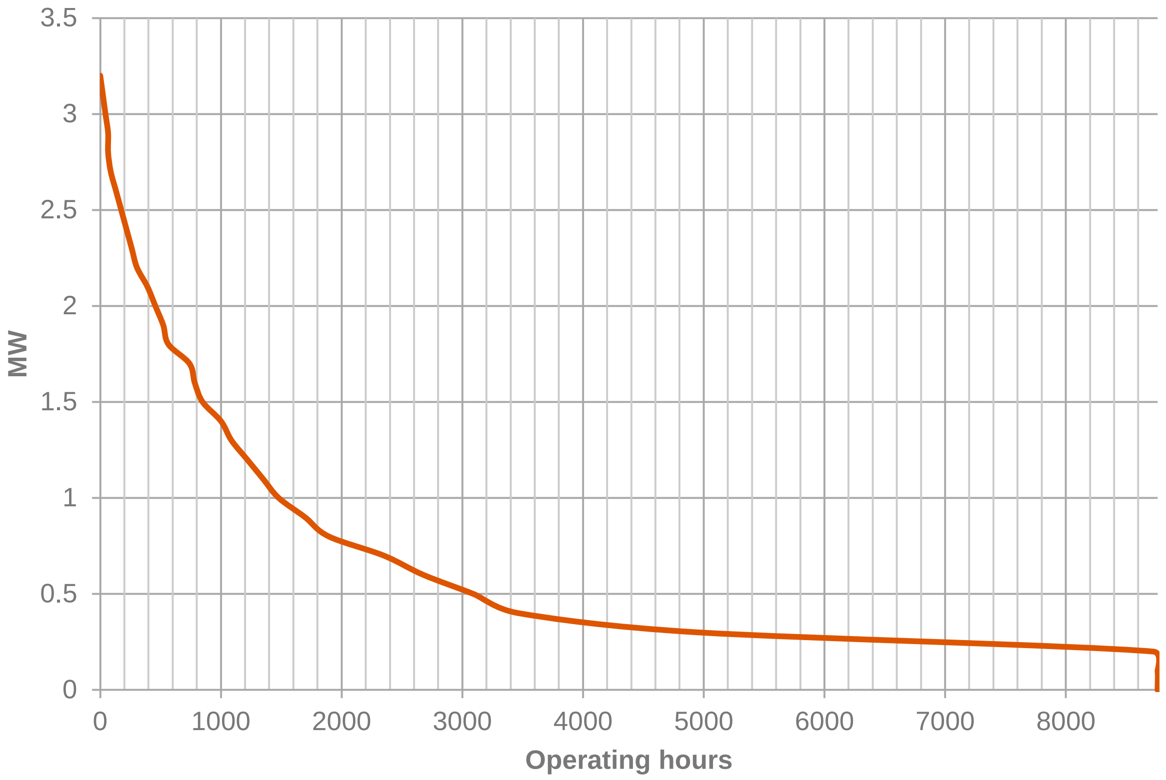


Figure 9: Estimated load duration curve for North Star non-Moirai buildings

The load curve above includes all the non-Morai space heating and hot water loads, excluding district network losses.

3.4.1 BT at North Star house

Figure 10 shows the assumed profile for space heating and hot water combined at North Star House. This is based on the gas meter reading for the property obtained for the period May 2011 to April 2012 and an assumption of 80% boiler efficiency.

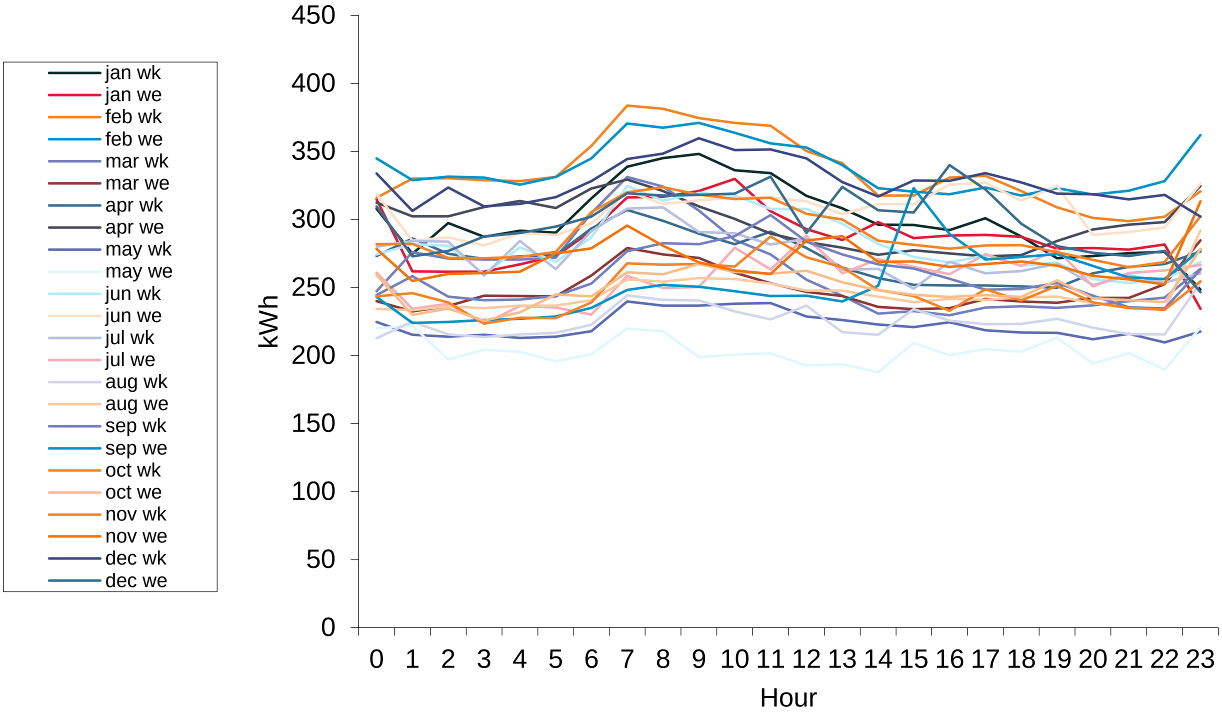


Figure 10: Total Heating Profile for North Star House

3.4.2 Swindon College

Figure 11 shows the assumed space heating profile for Swindon College buildings. This is a theoretical profile for an education establishment. It is not based on meter readings and is for space heating only. Hot water demand is assumed to be 10% of the total heat demand, and a further generic demand profile is assumed.

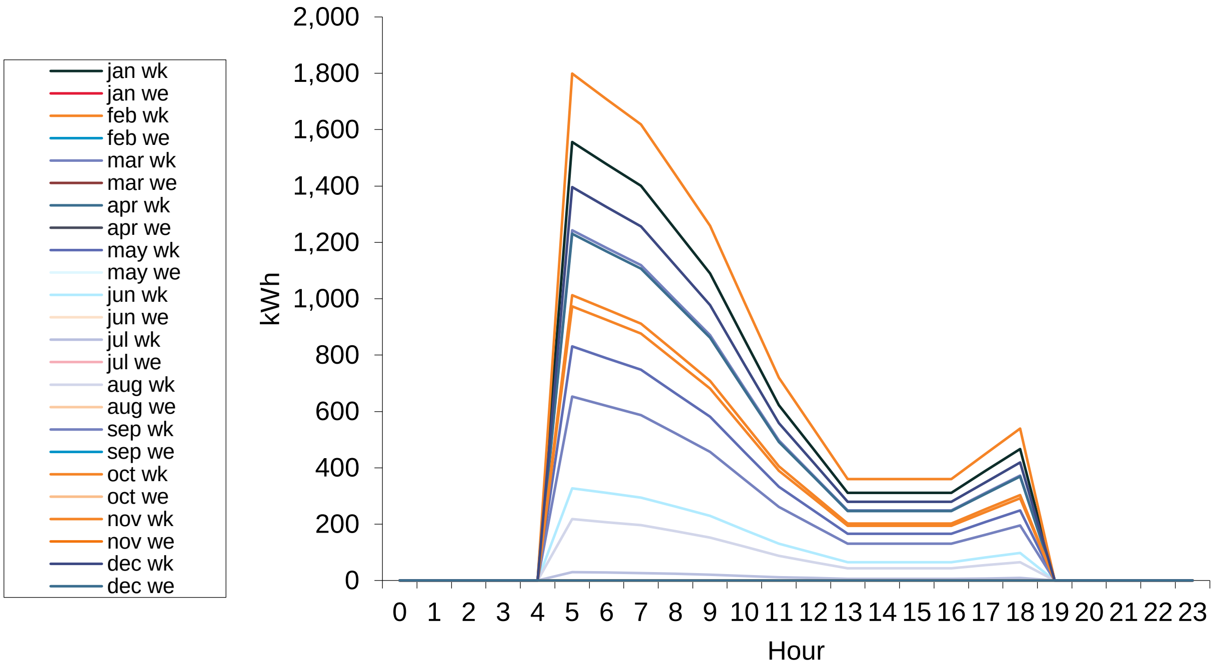


Figure 11: Assumed Space Heating Profile for Swindon College Buildings

3.4.3 Research Council at Polaris House

Figure 12 shows the assumed heating profile for the Research Council at Polaris House is shown below. This is a theoretical profile based on an office operational for 5 days a week. Again hot water demand is assumed to be 10% of the total heat demand, and a further generic demand profile is assumed.

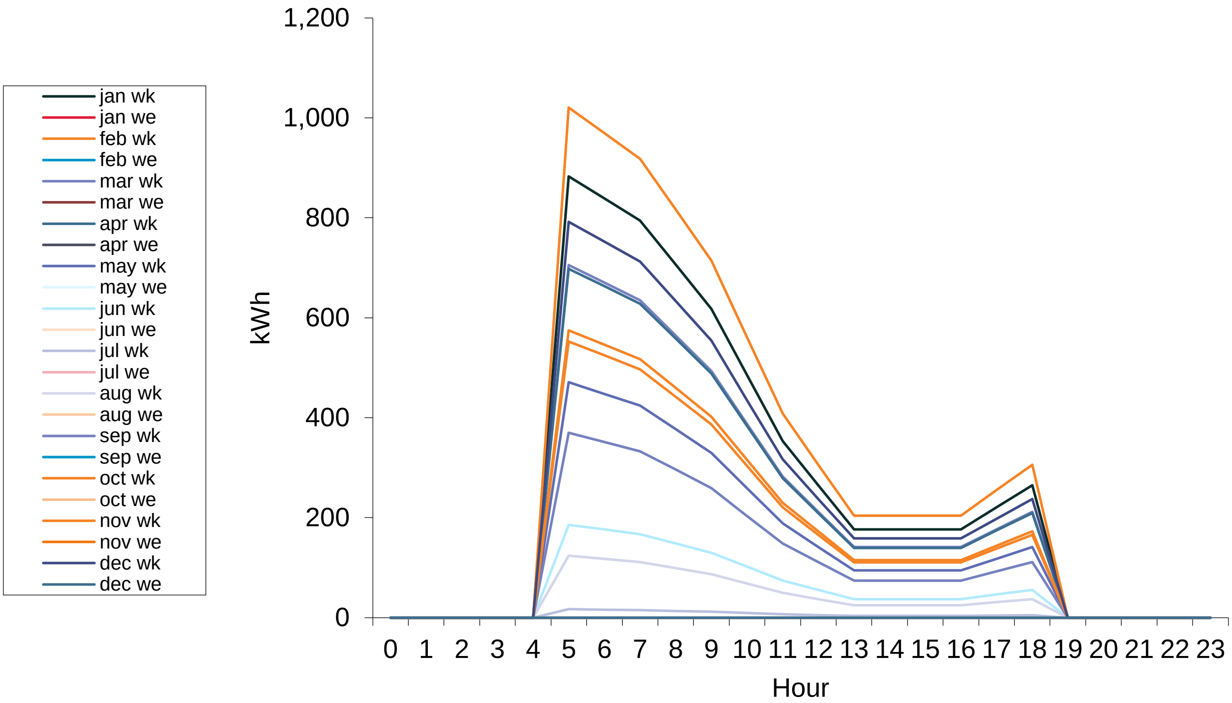


Figure 12: Assumed Space heating profile for Polaris House (Research Council)

3.5 Financial analysis – scenarios and assumptions

Two network scenarios are considered in

Table **3**.

- Scenario 1: five connections covering all non-Moirai buildings.
- Scenario 2: reduced scope – three connections, excluding the network leg to the Research Council and the Sculptor/Middle Block/Gemini buildings at Swindon College.

Scenario definition	(1) All connections	(2) Reduced scope
Scope of heat network	BT, SC, RC	BT, SC (excl. Sculptor)
Assumed cost of heat purchased (p/kWh)	0	0
Assumed cost of heat sold to end consumers (p/kWh)	2	2
Consumer connections	5	3
Pipe length (m)	958	655
Average pipe unit cost (£/m)	720	646
Heat supplied (MWh)	5,366	3,988
Capital cost	**£'m**	**£'m**
DH pipeline	0.69	0.42
Consumers substations	0.39	0.24
Standalone energy centre		
Moirai energy centre additional costs	0.36	0.36
DH pipeline between backup and energy centre	0.2	0.2
Total	**1.6**	**1.2**

Table 3: North Star Network Scenarios – definitions and financial performance

Assumption	Unit	Value		Comments
ESCo model duration	years	25		
Revenue				
Combined heat tariff	p/kWh	2.00		
% inflation assumption	--	4.0%		
Opex				
Imported Heat				
Heat Import Tariff	p/kWh	0.00		Assumed will supply heat for free
% network losses	--	20.0%		
Other operating expense				
Pumping costs	£'000	2.0		
Metering	£'000	0.3		
Cost per heat meter	£	100		
No of heat interface units	--	3.0		
Maintenance	£'000	12.3		
% of capex		1%		
Admin	£'000	0.4		
% of Revenue (year 1)		0.5%		
Insurance	£'000	6.1		
% of capex		0.5%		
Other operating expense total	£'000/yr	21.1		
% inflation assumption	--	3.0%		Median inflation 1989-2011 (per RPI indices - All items)
% of Revenue (year 1)	--	-26.5%		
% of capex		1.72%		
Replacement cost				
Replacement fund contribution	£'000	0		Assuming zero as replacement network would be financed on future revenues

Table 4: North Star Network Scenarios - further financial analysis assumptions

3.6 Results

Table 5 shows a comparison between the scenarios in terms of financial performance. Scenario 1 has a higher IRR, NPV and payback. This is because the reduction in revenue associated with Scenario 2 is greater than the reduction in capex.

Financial performance	(1) All connections, reduced capex	(2) Reduced connections, reduced capex
Duration (years)	25	25
Capex (£m)	1.6	1.2
IRR	5.6%	5.4%
NPV@5% (£m)	+0.1	+0.1
Payback	15	16

Table 5: North Star Financial Performance of Scenarios

Figure 13 shows the sensitivity of IRR in scenario (1) to changes in capex and the assumption that the energy centre supplies free heat, which is then distributed as sold to consumers at 2p/kWh.

Heat input price (Gross margin, p/kWh)		Capex (Variance, £m) -50% 0.8	-38% 1.0	-25% 1.2	-13% 1.4	0% 1.6	+13% 1.8	+25% 2.0	+38% 2.2	+50% 2.4
100%	0.0	14.7%	11.5%	9.2%	7.4%	5.6%	4.6%	3.5%	2.5%	1.6%
90%	0.2	12.7%	9.7%	7.5%	5.8%	4.2%	3.2%	2.1%	1.1%	0.3%
80%	0.4	10.5%	7.8%	5.8%	4.1%	2.5%	1.6%	0.5%	-0.5%	-1.4%
70%	0.6	8.2%	5.7%	3.8%	2.2%	0.6%	-0.3%	-1.4%	-2.4%	-3.3%
60%	0.8	5.6%	3.2%	1.4%	-0.2%	-1.7%	-2.8%	-3.9%	-5.0%	-6.1%
50%	1.0	2.4%	0.2%	-1.7%	-3.3%	-5.1%	-6.3%	-7.7%	-9.2%	-10.8%
40%	1.2									
30%	1.4									
20%	1.6									
10%	1.8									
0%	2.0									

Commercial return (>10%)
Greater than public sector return (>6%) *[3.5% Green Book discount rate + 2.5% RPI assumed]*
Less than public sector return (<6%)

Figure 13: Scenario 1 IRR sensitivity analysis

3.7 Conclusions

- Weak financial case as a ‘stand-alone’ district heating project, taking free waste heat from the Oasis leisure hub to distribute and sell to adjacent non-Moirai consumers (IRR of 5.6%).
- Network cost would have to be reduced significantly (-40%) to achieve a commercial rate of return assuming free heat and 2p/kWh for heat sales to heat consumers. To pay for heat from the Oasis leisure hub would require an even greater reduction in capital cost (~50%) or an increase in revenues.
- The financial model does not include service charges and connection charges in lieu of maintaining decentralised plant. If these charges where included it would improve the business case.
- There is a potential opportunity to use existing boiler assets within the buildings for back up and peak heat service with the system. The utilisation (load factor) of some of the boilers of the “non-Moirai” consumers appears to be relatively low.
- The connection of non-Moirai consumers could potentially improve, or absorbed into a viable ESCo business case for leisure hub energy centre, by virtue of economies of scale and by allowing more intensive use of generation assets to increase revenues from heat and power sales and renewable benefits (FiT/RHI). It is worth stressing that the energy centre design solution would require good integration of heat loads between the Moirai development and the remaining "non Moirai" heat loads, to meet the range of temperature heat, cooling and power loads in the most efficient manner.

4. Middle Wichelstowe district heating feasibility

4.1 Introduction

This section presents the feasibility study conducted by Verco and Pöyry for the proposed residential development at Middle Wichelstowe as a second discrete area for a district heating network. Similar to North Star the proposition, it is a first stage network that could provide a foundation node for possible interconnection with a wider system in due course. Being a green field development, the heat network could be potentially be integrated into the site infrastructure.

4.2 Middle Wichelstowe Development

The Wichelstowe development comprises three development areas, East, Middle and West. This analysis focuses on the district centre of Middle Wichelstowe, as it is the next area to be developed and contains the highest density of mixed used development within the master plan and thus offers the best initial opportunity for a district energy system. A central section of the Wichelstowe Development plan, as drawn up by LDA, is shown below:

Figure 14: Middle Wichelstowe development schedule scenario

Plot MW_07 will house the district centre which will include a hotel, restaurant, pub and other retail and community buildings. Plot MW_06 will house a supermarket and MW_16 the primary school. The remaining plots MW_08, MW_10, MW_09, MW_18 and MW_19 will be residential plots.

4.3 Area schedule and plot use assumptions

Table 6 below shows the areas of the Wichelstowe plots considered for district heating by building type. This information has been obtained from the LDA Design master plan and district centre study as of April 2012.

Plot Reference	Description	Land use	Indicative Build-Out	Floor Area per unit (m2)	Units	Total Floor Area (m2)
mw_06	District centre	Retail	2013		1	4,000
mw_07	District centre	Restaurant/Bar			1	781
mw_07	District centre	Public House			1	660
mw_07	District centre	*Other Retail*			1	159
mw_07	District centre	Retail	2016		3	1,600
mw_07	District centre	Community centre			1	329
mw_07	District centre	Childrens centre			1	377
mw_07	District centre	Library			1	350
mw_07	District centre	Police Drop-in			1	125
mw_07	District centre	GP Surgery			1	1,090
mw_07	District centre	*Other Community*			1	29
mw_07	District centre	Community	2016		6	2,300
mw_07	District centre	Hotel	2016		1	4,500
mw_08	District centre	Retail	2016		1	930
mw_08	District centre	Terrace		85	22	1,896
mw_08	District centre	Apartments		63	11	724
mw_08	District centre	Residential	2016	78	34	2,619
mw_09	Development block	Terrace		85	8	646
mw_09	Development block	Apartments		63	15	929
mw_09	Development block	Residential	2016	70	22	1,575
mw_10	Development block	Commercial	2015		1	5,825
mw_10	Development block	Terrace		85	49	4,165
mw_10	Development block	Courtyard housing		80	27	2,160
mw_10	Development block	Apartments		63	39	2,478
mw_10	Development block	Residential	2015	76	115	8,803
mw_16	Middle Wichel primary school	School	2016		1	1,640
mw_18	Development block	Terrace		85	25	2,083
mw_18	Development block	Apartments		63	25	1,544
mw_18	Development block	Residential	2013	74	49	3,627
mw_19	Development block	Terrace		85	18	1,563
mw_19	Development block	Apartments		63	18	1,158
mw_19	Development block	Residential	2014	74	37	2,721
TOTAL					**271**	**40,140**
Residential					257	19,345
Other					14	20,795

Table 6: Middle Wichelstowe District Centre – area schedule assumptions

4.3.1 Annual heat demand

Figure 15 below breaks out the annual energy demand by building type and plot number. The hotel and supermarket (MW06_Retail) are the largest single potential heat consumers.

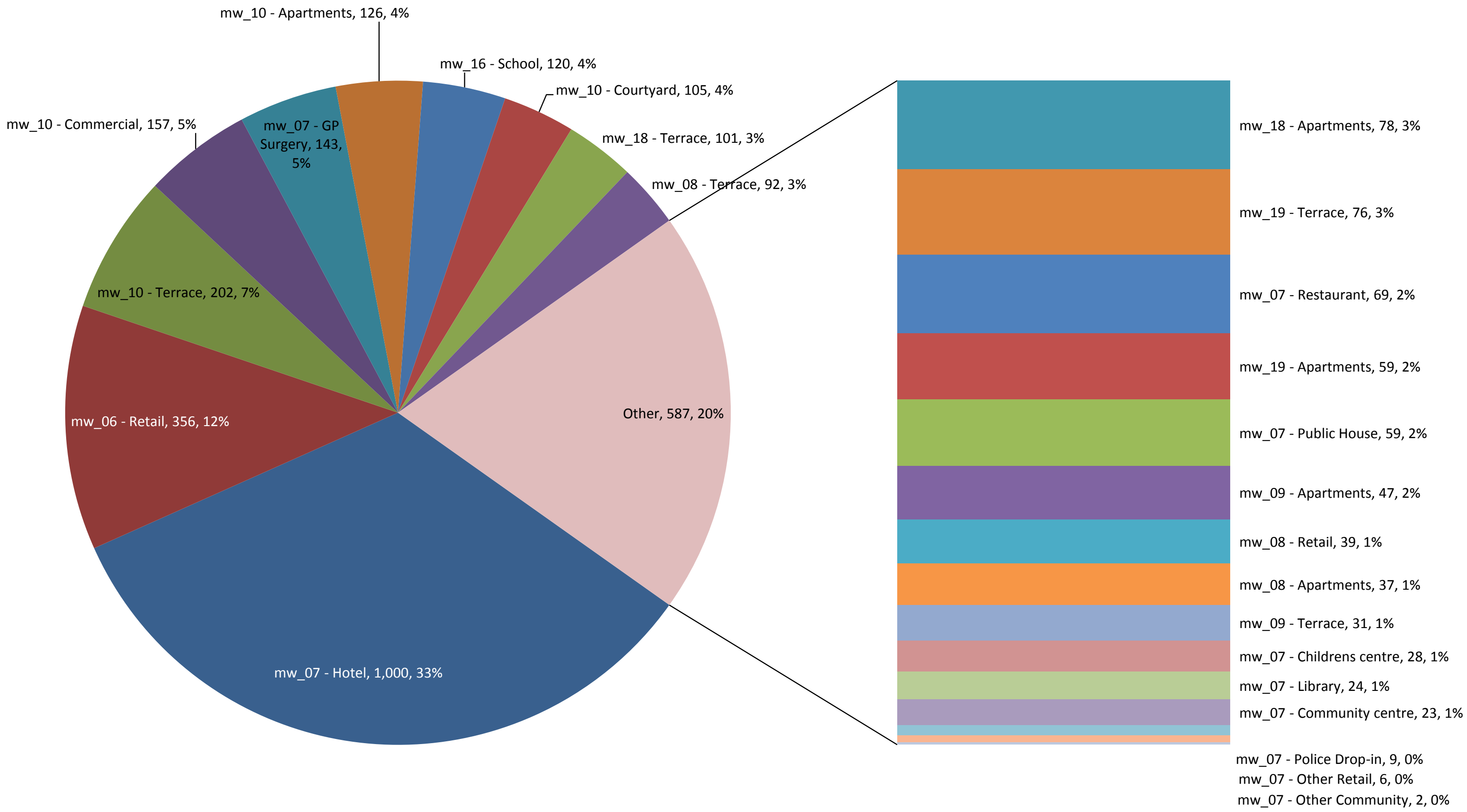


Figure 15: Annual Heating Demand by plot area (MWh, %)

The chart below shows the phasing of the heat demand in line with the proposed build out plan:

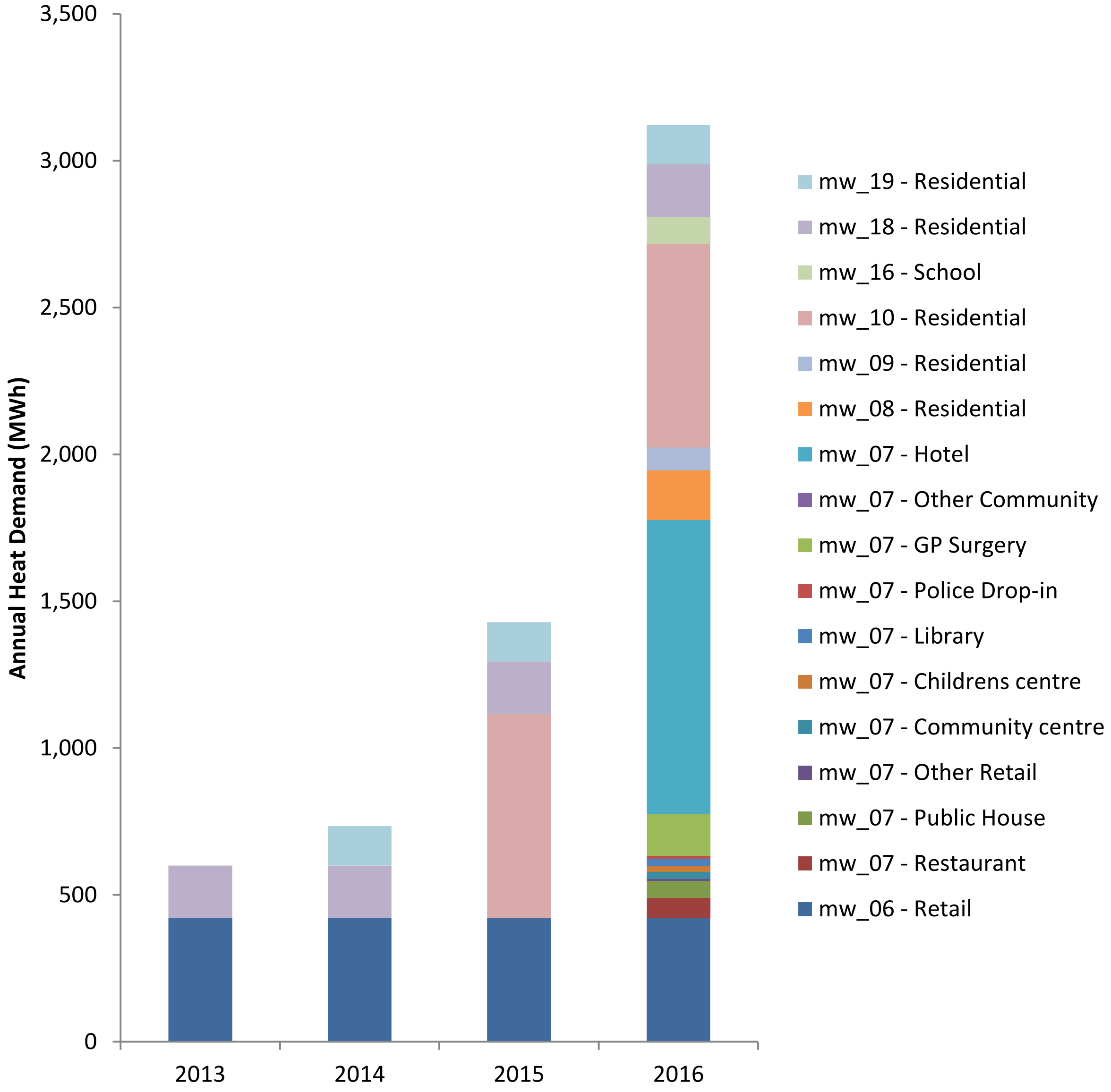


Figure 16: Phasing of Heat Demand

The supermarket provides the majority of demand in 2013 and 2014. Significant levels of additional demand come on-line in 2015 with the development of mw_10 and in 2016 with the completion of the hotel.

4.4 Supermarket energy centre

It is expected that the location for the energy centre will be at the proposed supermarket site in MW_06. Verco are aware that a prospective supermarket chain is considering two CHP prime mover options, as a means to meet their corporate carbon targets for new stores. Each would have implications for the heat network as shown in Figure 17.

Supermarket energy centre option	Excess heat temperatures (oC)	Excess heat capacity (MWth)	Consequences for DE scheme
(1) Stirling engine CHP (144kWe)	80 flow – 60 return	0.7 (can boost to 1)	• Smaller quantity of waste heat, but at higher grade than ORC CHP. • Near to 'conventional' DH temperatures. • Better potential to grow network with additional heat sources than ORC option
(2) Organic Rankin Cycle CHP (240kWe)	64 flow – 44 return	1.2	• Greater quantity of heat, but at lower grade than Stirling engine CHP. • Temperature is below that normally used DH • Implies novel approach (e.g.): • Plastic pipe to reduce network costs & DHW design to prevent legionnaires • 'Step up' temperatures at point of use or prior to transmission (e.g. heat pumps) • Suitable for small network only, limited technical options for expansion

Figure 17: Supermarket CHP options – implications for district heating

4.5 Indicative heat network routing

Two network scenarios were considered for Middle Wichelstowe. The first is a district heating pipe running from the supermarket across the canal to connections at the hotel, school and GP surgery. The proposed footbridge is another potential crossing point, which would warrant investigation as it would shorten the network considerably.

The second option is for the network to run south west from the supermarket, across the car park, to the predominantly residential development of plot MW_10.

Both potential network routings are shown on Figure 18 below.

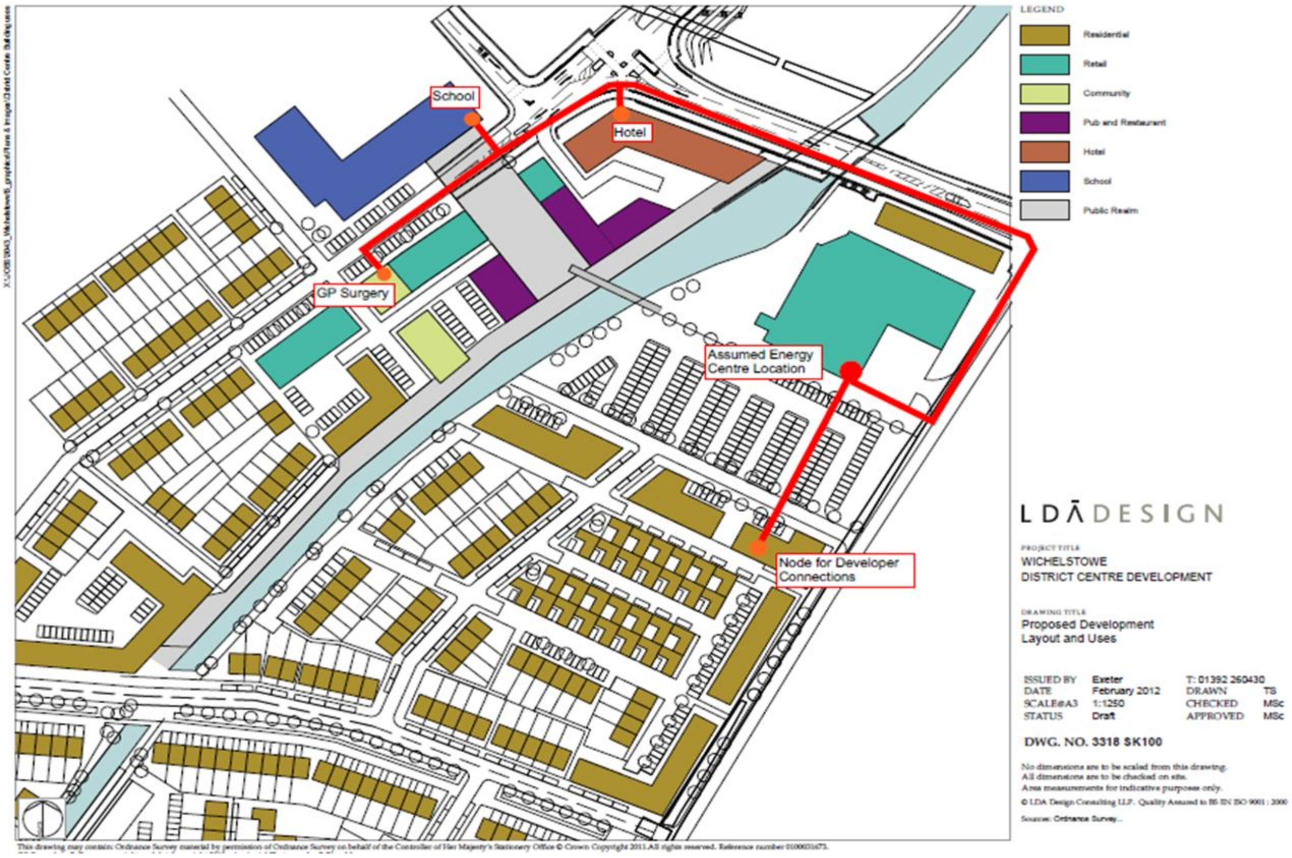


Figure 18: Wichelstowe network scenario

4.6 Financial analysis

Figure 19 shows the estimated revenue and capital cost associated with the two CHP options along the network route chosen. Option (1) generates twice the revenue of (2) but the capital cost is two and half times greater.

The purchase price of heat and other operational costs have been excluded in order to obtain a ‘first cut’ assessment of financial viability. Even on this basis the payback period is very long.

Capex and revenue summary	(1) Stirling Engine - over the bridge	(2) ORC - plot 10 resi/comm development
Consumer connections	5	1
Pipe length (m)	448	75
Average pipe unit cost (£/m)	730	900
Heat supplied (MWh)	1,263	589
£'k		
Revenue (if free heat and excluding opex)	25	12
Simple payback (if free heat and excluding opex)	17	15
Capex £'k		
DH pipeline	327	68
Bridge crossing	40	/
Consumers substations	37	69
Energy centre marginal costs (assume gas boiler capacity only)	18	35
Total	**422**	**171**

Figure 19: Wichelstowe capital cost and revenue summary

4.7 Conclusions

- The potential heat loads at Middle Wichelstowe are far smaller and of lower heat density than at North Star. This is a function of development types within the master plan and the layout. It will be further exacerbated by the high thermal performance required by Building Regulations.
- The prospect of CHP within the supermarket does however create an opportunity to share heat with neighbouring development and to integrate district heating early within the design process, thus establishing district heating on a modest scale at Wichelstowe. The supermarket’s final choice of CHP unit will be an important factor in network design, as it will dictate the quantities and qualities of heat available.
- The heat network is not viable as a standalone project, even if heat were gifted to the network for free (itself on a commercially unviable assumption). In both network scenarios explored,

the potential annual revenue is too small in absolute terms (£12-25k) to warrant setting up a heat distribution business and there would be little or no financial return.

- Viability of a DH network centred on the supermarket will depend on quantifying and/or recognising the value of:
    - Avoided capital cost in new buildings (no individual boilers, smaller plant rooms, potentially reduced gas network)
    - Reduced cost of Building Regulations compliance for developers relative to micro generation, which could be monetised as capital contribution towards system.
    - Sustainability and CO_2 reductions – CRC value, corporate targets and PR value.
- Scheme viability can also be assisted though master planning and dialogue, e.g. minimising network cost through routing and integration with other construction works.