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LEVENSEAT RENEWABLE ENERGY LTD

LEVENSEAT EFW PLANT

HEAT PLAN REPORT

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MANAGEMENT SUMMARY

Levenseat Ltd (Levenseat) is proposing to build a gasification facility at the former quarry at Levenseat, Scotland. The facility will be known as the Levenseat Thermal Waste Treatment Plant (Levenseat TWTP) and will include a materials recycling facility (MRF) and gasification facility. The gasification facility will have a design annual throughput of 100,620 tonnes per annum of refuse derived fuel which will be produced on-site from commercial and industrial waste and generate approximately 12.3 MW of electricity from the gasification of the residual element when operating in fully condensing mode. The facility will be Combined Heat and Power (CHP) enabled with capability to export up to 12.0 MW_{th} of heat. The turbine design has been selected to maximise electrical efficiency while allowing for the option of heat export.

Fichtner Consulting Engineers Ltd (Fichtner) was engaged by Levenseat to develop a heat plan by assessing the feasibility of implementing a heat network with the purpose of exporting heat to local consumers. The Scottish Environment Protection Agency (SEPA) Thermal Treatment of Waste Guidelines (TTWG) 2014 state that all new thermal treatment plants must ensure that the recovery of energy from waste takes place with a high level of energy efficiency. For facilities processing over 70,000 tonnes per annum of fuel, heat export must result in a CHPQA QI of 93 or the indicative overall plant efficiency must be 35% or above. For the heat network identified, including the thermal dryer and Heartlands Development, an efficiency of 35.2% is achieved. We therefore consider that the TTWG conditions are met.

A thermal dryer will be located in the MRF building from the outset of the project and receive an average of 4.86 MW_{th} of heat from the gasification facility. Additional heat demand is necessary to achieve the heat export capacity to meet the requirements stipulated in the SEPA guidance. No existing large heat consumers were identified within 10km of the facility, but the Heartlands Development was identified as a technically feasible heat demand located approximately 6.5km from the Levenseat TWTP. Heartlands is a three stage housing and business development which, when complete in the year 2035, will consist of 5,000 homes and 139,000m^2 of commercial premises. The network will supply an average and peak demand of 8.4 MW_{th} and 16.4 MW_{th} respectively. Due to the uncertainty in the specific land use and therefore the potential heat demand, the commercial development is not included in the heat network at this stage, but may be connected if the network capacity can be expanded in the future.It is proposed to supply heat to all consumers via a secondary hot water circuit, to which heat is transferred from a series of condensing heat exchangers. Two potential routes have been identified between the Levenseat TWTP and the Heartlands Development based on a heat transmission appraisal commissioned by Ramboll Energy (Ramboll), and associated risks are highlighted. An implementation timescale for network development is presented and demonstrates the increase in heat demand in line with the Heartlands Development build phasing.

An action plan should be put in place to ensure that this heat load can be secured and the Levenseat TWTP achieves the requisite level of heat export capacity by maintaining momentum in the development process.

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1 Introduction

Levenseat Ltd (Levenseat) is proposing to build a materials recycling facility (MRF) and gasification facility at the existing Levenseat Waste Management facility in Levenseat, Scotland. The facility as a whole will be known as the Levenseat Thermal Waste Treatment Plant (TWTP) and will have design capacity for the receipt of up to 220,000 tonnes per annum of waste. The facility will be designed to recover recyclates from the incoming commercial and industrial waste (C&I) and to generate up to approximately 12.3 MW of electricity from the gasification of 100,620 tonnes per annum of the residual element which is not suitable for recycling.

This document forms a heat plan in support of a PPC permit application by identifying local heat users and assessing the technical feasibility of including these in a Combined Heat and Power (CHP) network.

1.1 Background

Levenseat have prepared a heat and power plan titled 'Thermal Waste Treatment Plan at Levenseat Waste Management Site', issued in July 2010 to consider distribution of heat from the gasification facility to a number of possible consumers in the vicinity of the site. The Scottish Environment Protection Agency (SEPA) Thermal Treatment of Waste Guidelines 2014 state that all new thermal treatment plants must ensure that the recovery of energy from waste takes place with a high level of energy efficiency. Ensuring plant design is conducted in line with the requirements of the guidelines allows Levenseat to include provisions for heat export at an early stage of their plant design.

This study intends to build on information provided in the heat plan submitted in the original planning application by demonstrating how the proposed facility will utilise energy from the thermal treatment process in an efficient manner, and is updated with current data.

1.2 The Site

Levenseat is located on the west side of the A706, 2km north of Forth and 2km south of the junction with the A71 at Breich. The site entrance is just within West Lothian on the border with South Lanarkshire. The site is located approximately 3km south of Fauldhouse.

The existing landfill site extends to some 10 hectares and is located in a former sandstone quarry and accessed from the A706 along a tarmac roadway to the south-east corner of the site.

The Levenseat site is a well-established fully integrated waste management facility that offers a broad spectrum of waste handling, sorting and recycling facilities.

1.3 Objective

Fichtner has been asked to assess the feasibility of supplying heat from the Levenseat TWTP to local consumers. The principle objectives of this study are as follows.

(1) Identify potential heat consumers from a desktop survey, as required by SEPA's TTWG.

(2) Produce provisional pipe routing drawings from the facility to the principal heat consumers. Routing will follow the most efficient and logical route based on physical constraints and include indicative pipe sizing calculations.

(3) Calculate the heat network capacity based on likely consumers and the resulting energy efficiency measures.

(4) Prepare a Heat Plan, reporting on the items identified above, which will support a PPC permit application.

2 CONCLUSIONS

The Levenseat TWTP will be Combined Heat and Power (CHP) enabled with capability to export up to 12.0 MW_{th} of heat. The site will include a thermal dryer located in the MRF building which will require an average of 4.86 MW_{th}, corresponding to 90% of the peak heat load of 5.4 MW_{th}.

Demand local to the Levenseat TWTP is predominantly made up of existing domestic sector buildings. These are unlikely to be suitable for inclusion in a heat network due to the prohibitive costs of modifying heating systems to facilitate heat supply from an external source. In addition, no single point large heat consumers were identified within 10km of the Levenseat TWTP. The most likely demand will be from new developments whose heating systems can be incorporated into the heat network from the outset.

One such consumer is the Heartlands Development, a three stage housing and business development which is located approximately 6.5km from the facility. The Heartlands Development will require increasing heat demands in line with its proposed growth profile. By 2018, it is proposed to build 2,000 houses (400 of which have already been built so will not be suitable for inclusion in the network), then a further 1,500 by 2025, and a further 1,500 by 2035. In addition to the housing, a 1.5 million square feet commercial development will be constructed comprising a variety of leisure and commercial premises. Currently the commercial development is not included in the heat network due to the uncertainty of its heat demand, but could be incorporated in the future when demands from the development are more certain and if there is potential to increase network export capacity.

The heat estimated heat demands for the identified consumers are presented in Table 2.1 below.

Table 2.1 – Estimated Heat Demand for Thermal Dryer

Heat Consumer	Annual Heat Demand (MWh/year)	Average Heat Demand (MW)	Peak Heat Demand (MW)
Thermal Dryer	32,750	4.9	5.4
Heartlands Development (2013-2018)	9,430	1.1	3.7
Heartlands Development (2018-2025)	18,260	2.1	7.1
Heartlands Development (2025-2035)	27,100	3.1	10.6

Heat network profiles were developed to determine the daily and seasonal variation in heat demand for the network. The thermal dryer is considered to demand a constant supply of 4.86 MW of heat during its scheduled operational hours but the demand for Heartlands Development will be irregular due to variation in individual heat consumption throughout the day and during each season when the ambient temperature varies. A combined heat demand profile for each development phase was then derived from the sum of the individual heat load profiles of the network users. The total average heat load for the network including the demand from the dryer and the Heartlands Housing Development in each of the development phases is given in Table 2.2. As a conservative approach, heat transmission losses in the heat network have been calculated using the network peak demand.

Table 2.2 – Average Network Heat Demands				
Development Timescale	**Total Average Heat Load (MW)**	**Heat Loss (MW)***	**Adjusted Average Heat Load (MW)**	**Pipe Size**
2013-2018	5.9	0.4	6.3	DN 250
2018-2025	7.0	0.4	7.4	DN 250
2025-2035	8.0	0.5	8.4	DN 300
*Heat loss calculation based on peak heat load				

Given the maximum heat supply capacity of 12 MW_{th} based on turbine design selected to maximise electrical efficiency while allowing for the possibility of heat export, it is possible for the Levenseat TWTP to supply this demand. The peak loads for each stage of the development are given in Table 2.3.

Table 2.3 – Peak Network Heat Demands				
Development Timescale	**Total Peak Heat Load (MW)**	**Heat Loss (MW)***	**Adjusted Peak Heat Load (MW)**	**Pipe Size**
2013-2018	9.1	0.4	9.5	DN 250
2018-2025	12.5	0.4	12.9	DN 250
2025-2035	16.0	0.5	16.4	DN 300
*Heat loss calculation based on peak heat load				

The facility is not able to supply peaks in network demand independently. To ensure heat consumers are provided with a stable heat supply throughout the year, back-up boilers can be designed to provide peak heat demand lopping and supplement heat supply where necessary. It is proposed to design the back-up system to ensure the maximum heat export capacity can be met but also provide sufficient turndown to supply smaller summer loads with reasonable efficiency.

The Z ratio, which is the ratio of reduction in power export for a given increase in heat export, was estimated based on thermodynamic modelling of the Levenseat TWTP and Fichtner's experience of similar projects. This enabled the effect of variations in heat export on the electrical output of the plant to be estimated and the results are presented below.

Table 2.4 – Heat and Power Export			
Load Case	**Annual Heat Export at Turbine (MW)**	**Net Power Exported (MW)***	**Z Ratio**
1. No heat export	0	10.6	0
2. Average network heat load	8.4	8.8	4.67
3. Heat load required for QI value of 93	8.6	8.7	4.67
4. Maximum heat load available	12.0	8.0	4.67
*For calculation of net power export, the energy used in the fuel preparation stage is not included as a parasitic load, as stipulated in SEPA's Thermal Treatment of Waste Guidelines 2014			

For the heat network identified (load case 2), an average heat export of 8.4 MW_{th} will result in a net power export of 8.8 MW_e. In order to comply with SEPA's Thermal Treatment of Waste Guidelines 2014, facilities processing over 70,000 tonnes per year of fuel must meet or exceed the following criteria in order to demonstrate best practice for thermal treatment of waste facilities:

- QI ≥ 93; or
- indicative efficiency ≥ 35%.

The CHPQI and efficiency values for the various load cases have been calculated and are presented in Table 2.5.

Table 2.5 – CHPQI Calculation

Load Case	Power Efficiency (%)	Heat Efficiency (%)	Overall Efficiency (%)	CHPQA QI
1. No heat export	22.9	0.0	22.9	84.9
2. Average network heat load	19.6	15.7	35.2	92.8
3. Heat load required for QI value of 93	19.5	16.1	35.5	93.0
4. Maximum heat load available	18.2	22.3	40.5	96.2

The results indicate that Levenseat TWTP will be marginally below achieving the QI threshold for the average heat load export case (load case 2). Final sizing of the network, which will be undertaken when heat demand is more certain, may indicate that the identified consumers are able to accept sufficient heat to achieve the QI threshold. Based on current estimates however, the overall plant efficiency is sufficient to meet the threshold stipulated in the guidance and therefore demonstrates best practice.

For reference, a heat export of 8.6 MW_{th} is required to obtain a QI of 93, as demonstrated in load case 3. While this quantity of heat demand has not been included in the network presented in this heat plan, there is potential for the Heartlands Commercial Development to increase the heat demand above that required to exceed the QI threshold if it is deemed suitable for inclusion in the network. In addition, if further heat loads are identified in the future, it is technically possible for the Levenseat TWTP to export at least this amount, as demonstrated by load case 4 which corresponds to a heat export of 12.0 MW_{th}.

Whilst the Heartlands development is considered a suitable and likely heat offtake for the project, as it is a third party development there remains some element of risk regarding the timing and size of implementation. As a result, an onsite wood chip drying facility with a heat demand of approximately 7.5 MW_{th} is considered as a viable alternative should the full heat demand from the Heartlands development not be realised. This is sufficient to exceed the TTWG threshold for both QI and overall efficiency.

An action plan should be put in place to ensure that heat load can be secured. A proposed action plan is outlined in Section 6.

3 Description of the Technology and Heat Network

3.1 The Facility

The Levenseat TWTP will consist of the following plant areas.

(1) Materials Recycling Facility (MRF)

The MRF has been designed to process 42 tonnes per hour of commercial and industrial (C&I) waste or municipal solid waste (MSW). The proposed plant will allow Levenseat to produce a high grade solid recovered fuel (SRF) fraction to be baled and wrapped, along with a refuse derived fuel (RDF) fraction to be processed in a close coupled gasification plant. The proposed system layout will also allow for the recovery and removal (through a combination of automatic and manual separation methods) of; wood, old corrugated card (OCC), ferrous metals, non-ferrous metals, mixed plastics and mixed paper.

(2) Gasification Facility

The gasification facility will consist of a single stream fluidised bed gasification facility which will have a design set-point RDF feedrate of 12.9 tonnes per hour, with a net calorific value (NCV) of 13.0 MJ/kg. The actual mass throughput of RDF will vary depending on its actual calorific value. The gasification facility is designed to combust fuels with a NCV of between 10.1 and 17.5 MJ/kg. A process flow diagram for the gasification facility is shown in Figure 3.1 below.

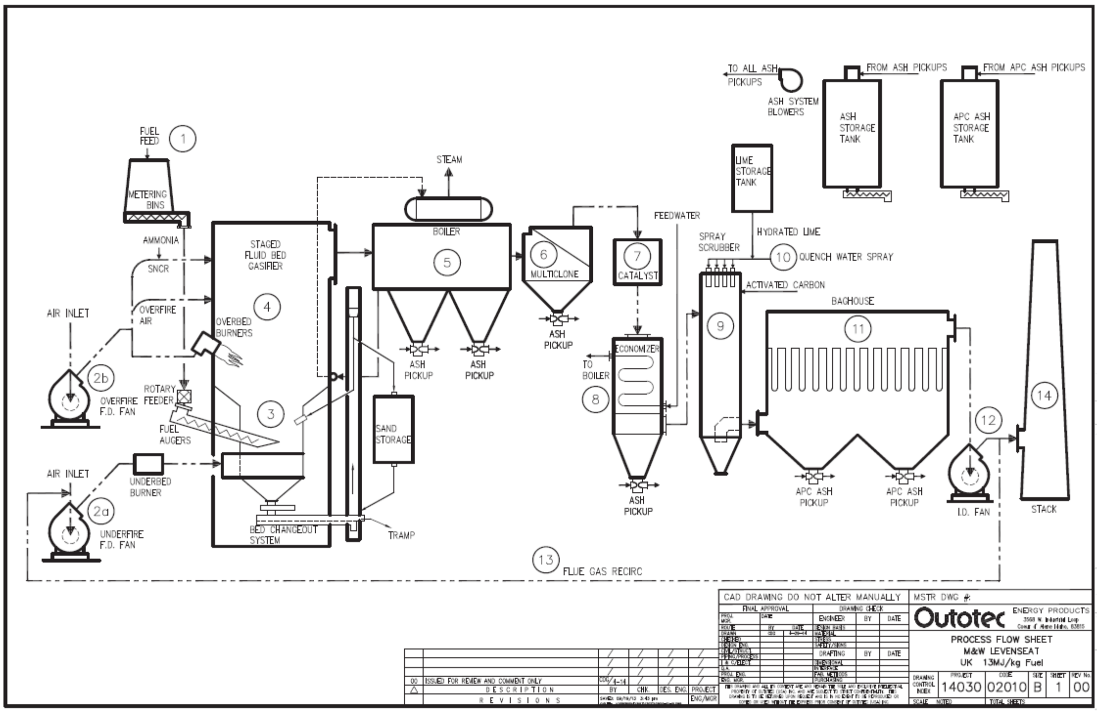

Figure 3.1 – Gasification Plant Process Flow Diagram

The steam generating system will combine heat transfer surfaces in the vapour-space area with evaporative surface areas in the waste-heat boiler. Flue gases from the gasifier will enter the steam generator through a vertical tube, natural circulation and evaporative screen section. The superheated steam from the boiler will be used to drive a steam turbine, which can generate up to approximately 12.3 MW of electricity when operating in fully condensing mode, with a parasitic load of approximately 1.8 MW_e. The gasification facility will also export up to 2.2 MW_e to the co-located MRF, depending on the quantity of waste processed, leaving approximately 8.3 MW of electrical power available for export to the local public electricity supply network.

The facility will be 'CHP enabled' with capability to export up to 12.0 MW_{th} of heat. A single steam extraction will facilitate heat export to external consumers either directly via low pressure steam, or via condensing heat exchangers in order to provide hot water in a secondary closed loop circuit. Assuming an annual availability of 7,500 hours per annum, the maximum heat export capacity that can be supplied by the Levenseat TWTP will be 90,000 MWh.

3.2 Electricity Supply

Levenseat have applied for and received a grid connection offer from Scottish Power Energy Networks (SPEN) for the export of up to 11 MW of electricity to the distribution network. This is attached at Appendix A and has been accepted by Levenseat. Discussions have also been ongoing with potential offtakers for a Power Purchase Agreement and this will be in place at the time of financial close for the project.

3.3 Details of Heat Supply System

Steam for consumption by heat users will be bled from the turbine via a single extraction at 6.99 bar(a) and 199°C. Heat users identified for inclusion in the Levenseat TWTP heat network require heat in the form of hot water, as explained in Section 4. This is provided by condensing bled steam through a series of condensing heat exchangers, transferring heat to a secondary hot water circuit. Hot water will be pumped to heat users for consumption before being returned to the primary heat exchangers where it is reheated.

Since multiple heat users are identified as having differing hot water supply temperatures, it is proposed to install two heat exchangers in a serial arrangement. This ensures that each consumer is supplied with heat at the required temperature while minimising the reduction in electrical export when energy is exported to the heat supply circuit.

3.4 Distribution Contracts and Network Management

One potential model for contracting the distributed heat, apart from that sent to the MRF dryer, is to set up a single Energy Supply Company (ESCO) which will contract Heat Off-take agreements with any existing or potential future heat consumers (such as Heartlands, discussed later in this report). However the decision as to whether to go down this route will depend if other customers are identified in the future. The current plan is for there only to be a single offsite supply to a heat exchanger at the customer end and for the customer to be responsible for managing the local heat network to the individual premises. As a result, management of the Levenseat network would be restricted to the supply and return from the site to the single high level remote customer and hence only one contract would need to be in place.

3.5 Legislative Requirements

The Thermal Treatment of Waste Guidelines[1] sets out the approach of SEPA to permitting thermal treatment of waste facilities.

SEPA guidance states that any permit authorising the incineration of waste contains "conditions necessary to ensure the recovery of energy takes place with a high level of energy efficiency". To comply with the guidelines, it is recommended that information is supplied in the form of a robust and credible heat and power plan.

SEPA expects that new waste thermal treatment plants achieve a minimum level of energy recovery. As a consequence, any PPC permit application for a new waste thermal treatment plant will need to demonstrate that it can achieve at least 20% (gross calorific value basis) energy recovery as electricity only, electricity and heat, heat only or as exported fuel (energy) equivalent on commissioning.

The design and construction of the plant must provide for the available floor space / infrastructure / facilities to allow for the installation of additional energy recovery equipment, such as heat exchange and / or heat pump systems. A point of connection to allow steam / hot water to be taken to a heat recovery system will be required; for example in the case of high efficiency electricity generating steam turbines, suitably designed steam off takes should be installed to provide high quality heat for use in an appropriate heat network / supply.

The heat plan must be maintained, implemented and reviewed on an annual basis. SEPA has a duty to ensure compliance in the event that these conditions are not met.

The QI value is to be estimated and calculated in accordance with the relevant CHPQA method for the relevant type of thermal treatment plant and fuel type and as a minimum meet or exceed a value of 93, based on a plant throughput of above 70,000 tonnes per year.

[1] SEPA Thermal Treatment of Waste Guidelines 2014, May 2014.

4 Identified Potential Heat Consumers

4.1 Thermal Dryer

A thermal dryer will be located in the MRF building to prepare 12 tonnes per hour of alternative fuel from commercial and industrial (C&I) waste and municipal solid waste (MSW) from the MRF. The dryer is a continuous thermal fluid bed dryer with a drying area of 35.5m^2, and is operated for 6,739 hours per year. It is designed to reduce the incoming waste from a moisture content of 48% to a moisture content of 15%, resulting in an outlet product flow of 7.5 tonnes per hour. This is combined with other non-recycled residues from the MRF and transferred to the gasification plant where it is processed as a fuel.

At peak loads, the dryer requires 5.4 MW of heat supplied by 123 m^3/h flow of hot water at an inlet temperature of 140°C. During normal operation the dryer is operated at 4.86 MW_{th}, corresponding to 90% of the peak load. Heat is transferred from the hot water supply to heat air from ambient conditions to a maximum of 130°C, which in turn is used to dry the wet material. Heat demand for the dryer is summarised in Table 4.1.

Table 4.1 – Estimated Heat Demand for Thermal Dryer

Annual Heat Demand (MWh/year)	Average Heat Demand (MW)	Peak Heat Demand (MW)
32,750	4.86	5.40

4.2 National Heat Mapping

Potential heat loads external to the site have been identified using a review of publicly available datasets on the Scottish Government's National Heat Map[2]. The tool geographically represents heat demand density and this allows for identification of heat network opportunities. **Error! Reference source not found.** Figure 4.1 is a screenshot taken from the National Heat Map and shows the existing distribution of heat demand in the area surrounding the Levenseat TWTP.

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[2] http://heatmap.scotland.gov.uk/

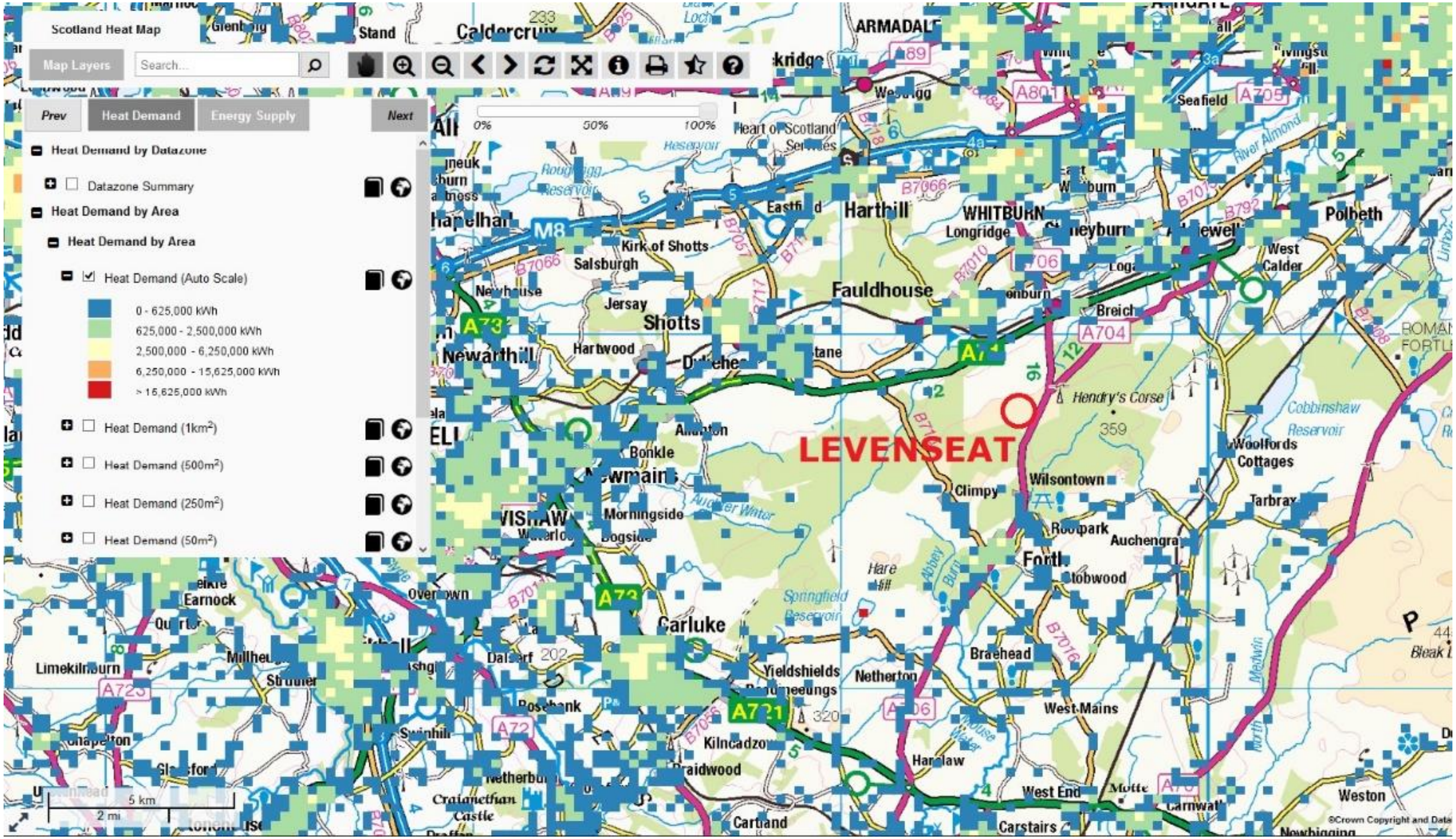

Figure 4.1 – Local Heat Demand Density

Table 4.2 shows the average heat demand in kW, for all sectors and building types within 10km of the Levenseat TWTP. These values were obtained using the Department of Energy and Climate Change (DECC) UK CHP Development Map[3] which is a tool that geographically represents the heat demand across various sectors within the UK.

Table 4.2 – Local Heat Demand by Sector

Sector	Heat Demand (%)	Heat Demand (kW)
Communications and Transport	0.09%	179
Commercial Offices	0.36%	725
Domestic	84.88%	170,641
Education	0.71%	1,431
Government Buildings	2.24%	4,496
Hotels	0.55%	1,099
Health	0.34%	674
Other	1.42%	2,845
Small Industrial	2.98%	5,984
Prisons	0.01%	10
Retail	1.00%	2,005
Sport and Leisure	0.26%	520
Warehouses	5.19%	10,429
Total	**100.0%**	**201,039**

From the data presented above it can be seen that the heat demand in the area surrounding the Levenseat TWTP is predominately from the domestic sector. In most cases, existing domestic buildings are unsuitable for inclusion in a heat network as a result of the prohibitive costs of replacing existing heating infrastructure and connecting multiple smaller heat consumers to a network.

No significant single point consumers have been identified from non-domestic sectors. Potential consumers will be reconsidered in the future if they present technically and economically feasible heat demand which can be used to expand heat network capacity. Further analysis must be carried out on non-domestic heat demand to ensure that the necessary heat quality can be supplied by the Levenseat TWTP.

4.3 Large Heat Loads

A review of large heat loads within 10km of the facility has been undertaken using the DECC UK CHP Development Map. No existing large heat loads were identified, as shown in Figure 4.2. The nearest large heat load site is NHS Lothian, part of the University Hospital Division, with a total demand of 5.2 MW_{th}. This consumer is located approximately 15km from the site but the cost of transmitting heat over such a distance is deemed excessive. Therefore, there are no single large scale existing heat consumers external to the proposed facility which represent a financially viable option for inclusion in the heat network.

[3] http://chptools.decc.gov.uk/developmentmap/

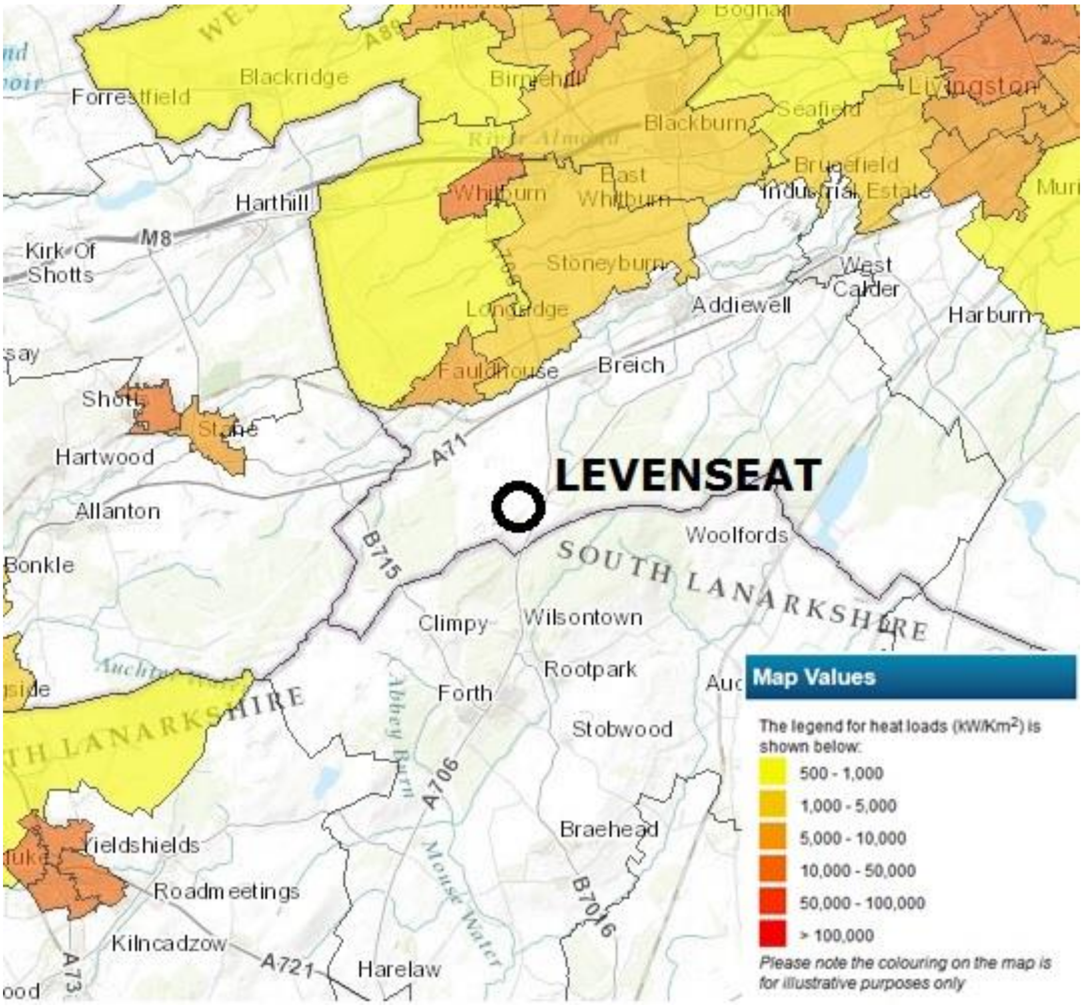

Figure 4.2 – Local Large Heat Loads

4.4 Heartlands Development

The most likely source of heat demand which can be supplied by the Levenseat TWTP is from new developments where the heating infrastructure can be built in from the outset. The largest such development within reasonable distance of Levenseat is the Heartlands Development which is located 6km to the north of the facility.

The Heartlands Development is a £650m regeneration project that will include residential, retail and business premises[4]. Discussions have been held with the principle developer, who has expressed an ongoing interest in securing attractively priced energy for heating of the housing development, leisure facilities and commercial developments.

4.4.1 Heartlands Housing Development

Approximately 2,000 homes are included in the plans for the development site between 2014 and 2018, although 400 are not available for connection to the heat network as they are already under development and have alternative heating arrangements. A further 1,500 are proposed by 2025, and an additional 1,500 by 2035.

[4] http://www.heartlands-scotland.com/

Broad assumptions were made regarding the estimated heat demand from individual properties. The heat demand for the development has been calculated based on a benchmark figure of 65 kWh/m^2/year per property from the Chartered Institution of Building Services Engineers (CIBSE) Guide F (Energy Efficiency in Buildings)[5]. This is a good practice benchmark figure based on energy performance of existing buildings. In the CIBSE Guide, loads are expressed in terms of kWh_{th} per square metre of floor space per year of fossil fuel use (natural gas is typically assumed). Based on estimates of floor areas and an assessment of the development type, it is possible to estimate annual energy usage. Converting natural gas use to actual heat loads (which might be provided by hot water distribution systems) requires an assumption of gas-fired boiler efficiency. In this heat plan, an efficiency of 85% is assumed, based on industry norms.

The indicative growth in demand for residential buildings at the Heartlands Development is quantified in Table 4.3. The estimated heat demands and peak loads were compared with the values provided by Ramboll Energy (Ramboll) in their report 'Levenseat Heat Transmission Initial Route Appraisal and Risk Assessment' issued May 2013. Values were found to be in line with those estimated in Ramboll's report, with minor discrepancies as a result of a revised benchmark heat consumption figure and heat load profile.

Table 4.3 – Estimated Heat Demand for the Heartlands Development

Predicted Development Timescale	Cumulative Number of Homes Connected	Cumulative Annual Heat Demand (MWh/year)	Average Heat Demand (MW)	Peak Heat Demand (MW)
2013-2018	1,600	9,430	1.1	3.7
2018-2025	3,100	18,260	2.1	7.1
2025-2035	4,600	27,100	3.1	10.6

4.4.2 Heartlands Commercial Development

Approximately 1.5 million square feet of commercial development is planned in addition to the housing outlined above. This includes potentially a supermarket, hotel, restaurant, fitness centre and crèche in addition to community facilities. Detailed heating demand data for the commercial development is unknown, but the CIBSE Guide F provides a benchmark figure for commercial developments of 55 kWh/m^2/year. This was assumed as a conservative approach to estimating heat demand, given the likely multiple use and varying demand of the premises.

The Ramboll report stated a peak heat demand of between 5 MW and 15 MW for the development including both the housing and additional commerce. Fichtner estimates the annual heat load of the commercial development to be approximately 7,700 MWh, with a peak load of 2.30 MW_{th}. Due to the uncertainty in the specific land use and therefore the potential heat demand, the Heartlands Commercial Development is not included in the heat network and will be not be analysed further in this study. The development could be considered for inclusion in the future once the heat demand has been clarified and confirmed.

[5] CIBSE Guide F: Energy Efficiency in Buildings

4.5 Heat Network Design

An outline proposal for delivery of heat to the Heartlands Development and thermal drier has been considered and heat will be supplied through a preinsulated hot water pipeline. A number of considerations influence the design of the district heating system. The following assumptions have been made in relation to sizing the heat transmission pipe diameter and estimating heat losses in the network.

Table 4.4: District Heating Network Design Criteria

Description	Measure
Water supply temperature to consumer	105°C
Water return temperature from consumer	70°C
Distance between flow and return pipes	150mm
Soil temperature	10°C
Depth of soil covering	600mm

The length of piping between Levenseat TWTP and Heartlands is estimated at 6,500m. Pipe route selection is discussed further in Section 4.7. As a conservative approach, heat transmission losses in the heat network have been calculated using the network peak demand. The total average heat load, including the demand from the thermal dryer and the Heartlands Housing Development in each of the development phases is given in Table 4.5.

Table 4.5 – Average Network Heat Demands

Development Timescale	Total Average Heat Load (MW)	Heat Loss (MW)*	Adjusted Average Heat Load (MW)	Pipe Size
2013-2018	5.9	0.4	6.3	DN 250
2018-2025	7.0	0.4	7.4	DN 250
2025-2035	8.0	0.5	8.4	DN 300

*Heat loss calculation based on peak heat load

Given the maximum heat supply capacity of 12 MW_{th}, it is possible for the Levenseat TWTP to supply the average network heat demand throughout all stages of development. However, heat demand is subject to variations; peak network demands determined from profiles developed in the following section are given in Table 4.6.

Table 4.6 – Peak Network Heat Demands

Development Timescale	Total Peak Heat Load (MW)	Heat Loss (MW)*	Adjusted Peak Heat Load (MW)	Pipe Size
2013-2018	9.1	0.4	9.5	DN 250
2018-2025	12.5	0.4	12.9	DN 250
2025-2035	16.0	0.5	16.4	DN 300

*Heat loss calculation based on peak heat load

It is possible for the Levenseat TWTP to supply the estimated peak demand until part way through the second phase of the Heartlands Development when the growth of the network will cause the demand to be exceeded. If network demand exceeds that which can be supplied from the facility, peak lopping plant will be necessary as explained in Section 4.8.

4.6 Heat Network Profile

It is likely that there will be a significant daily and seasonal variation in heat demand as a result of the quantity and type of consumers that are likely to be included in any proposed heat network. Where a district heating system supplies a large number of buildings with seasonal demand, the peak winter load can be as much as ten times higher than the summer load and up to four times the annual average load.

The thermal dryer is considered to demand a constant supply of 4.86 MW of heat during its scheduled operational hours. While the dryer peak demand is used in calculating the total peak demand for the network, for the purposes of modelling daily and seasonal variation, any fluctuations in the dryer demand are disregarded.

Heat demands for Heartlands Development will be irregular due to variation in individual heat consumption throughout the day and during each season when the ambient temperature varies. Heat demand profiles were developed to model the seasonal and daily change in heat demand for each of the major consumers. A combined heat demand profile for each development phase was then derived from the sum of the individual heat load profiles of the network users. Daily and monthly profiles are provided in the following figures and include the heat load to the Heartlands Housing Development and the thermal dryer.

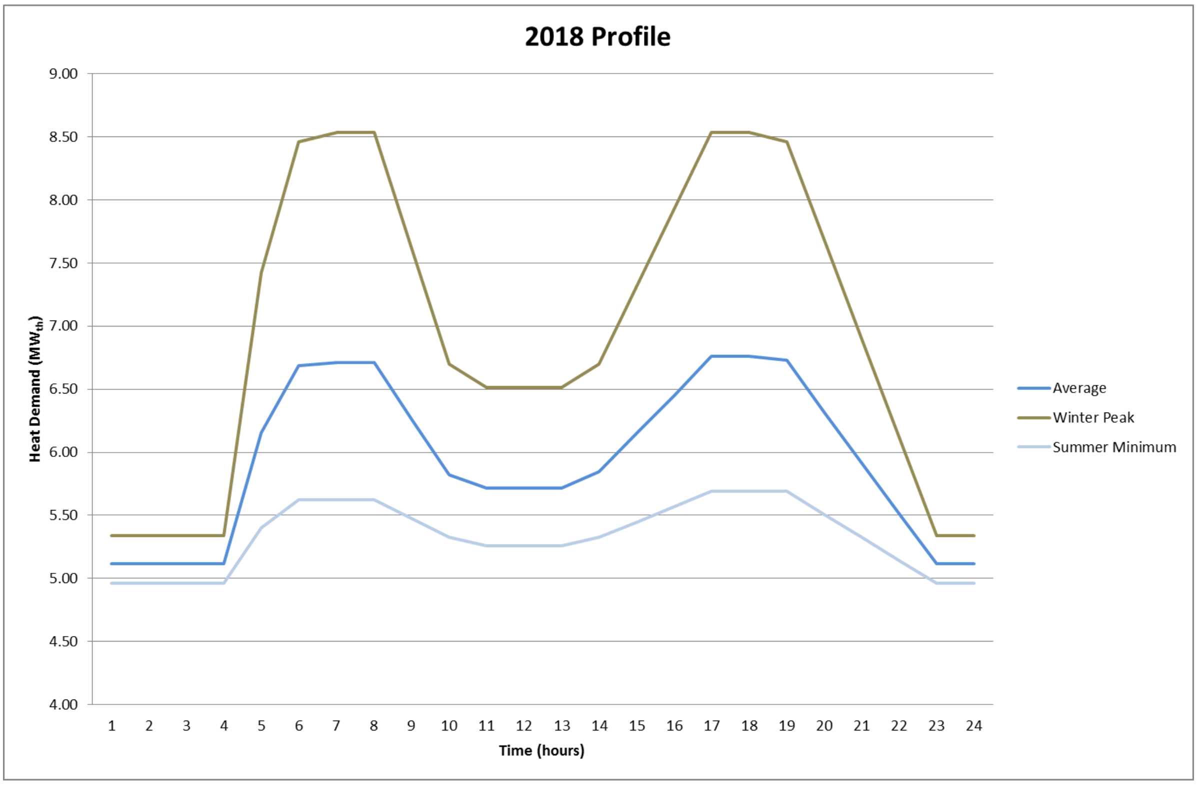

Figure 4.3 – Predicted total daily heat load variations for 2013 - 2018

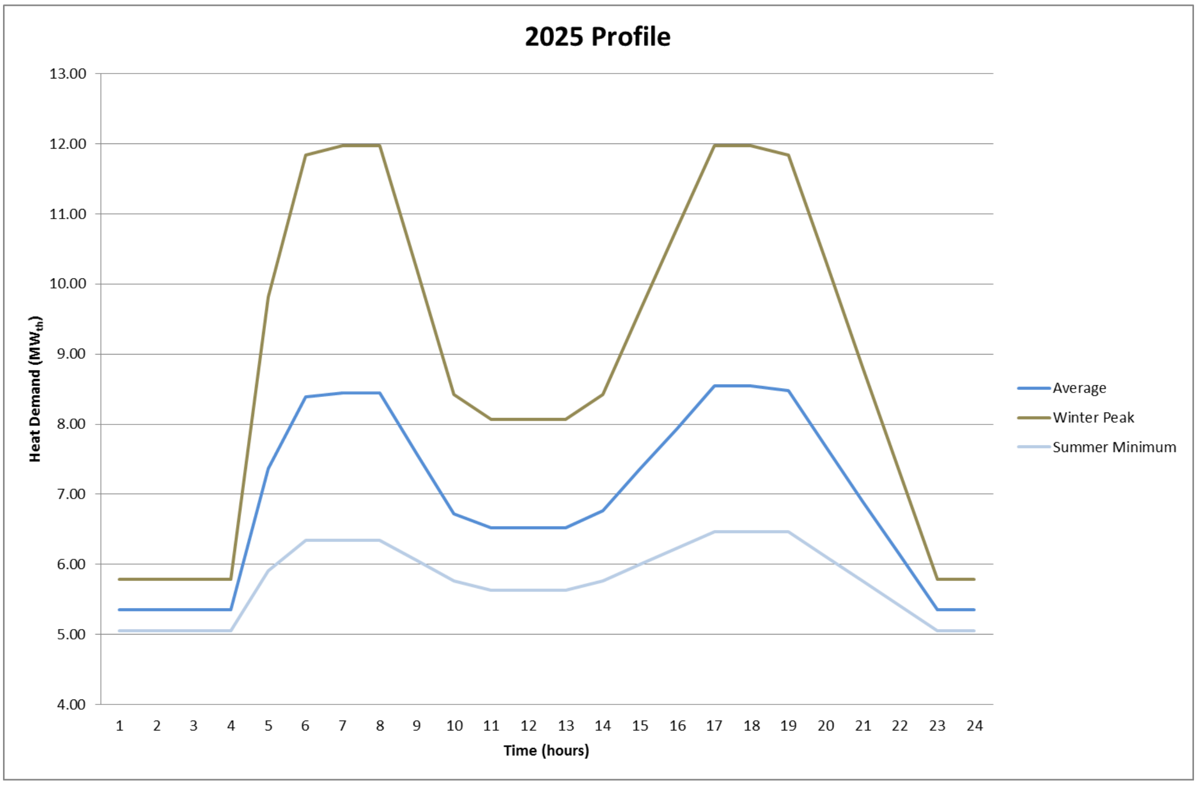

Figure 4.4 – Predicted total daily heat load variations for 2019 - 2025

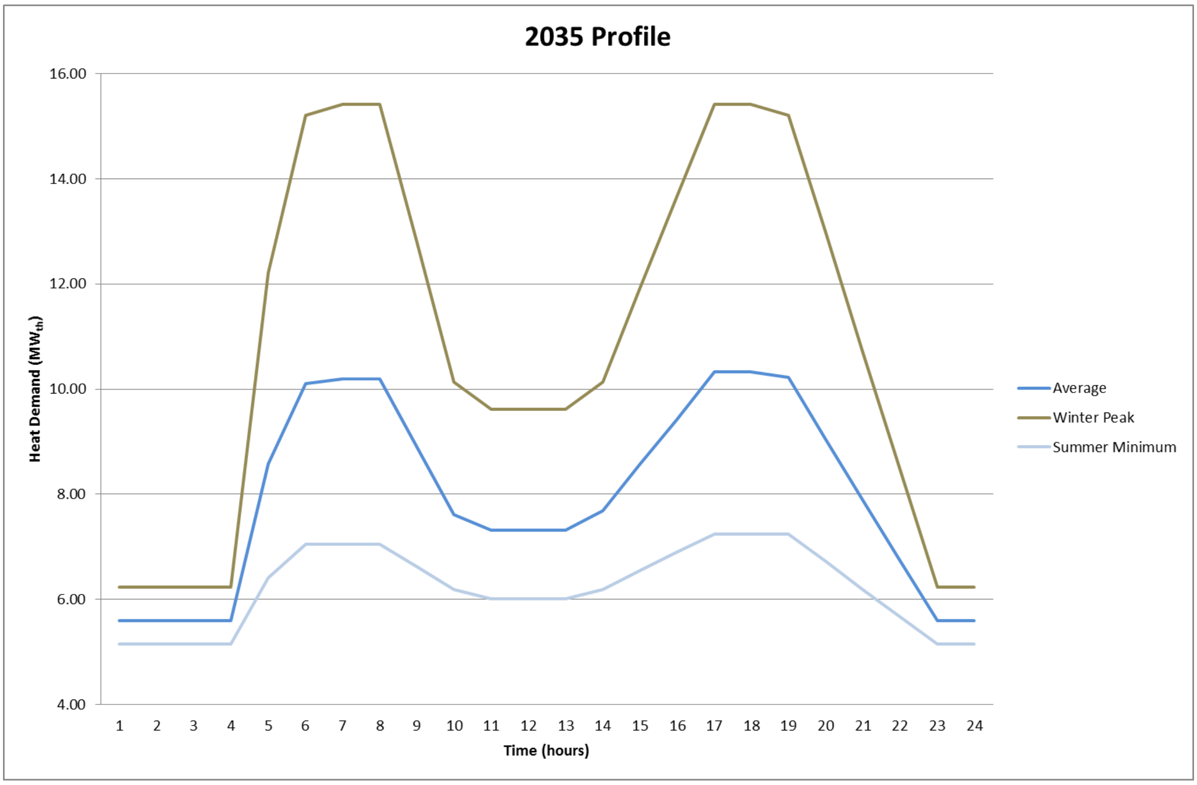

Figure 4.5 – Predicted total daily heat load variations for 2026 – 2035

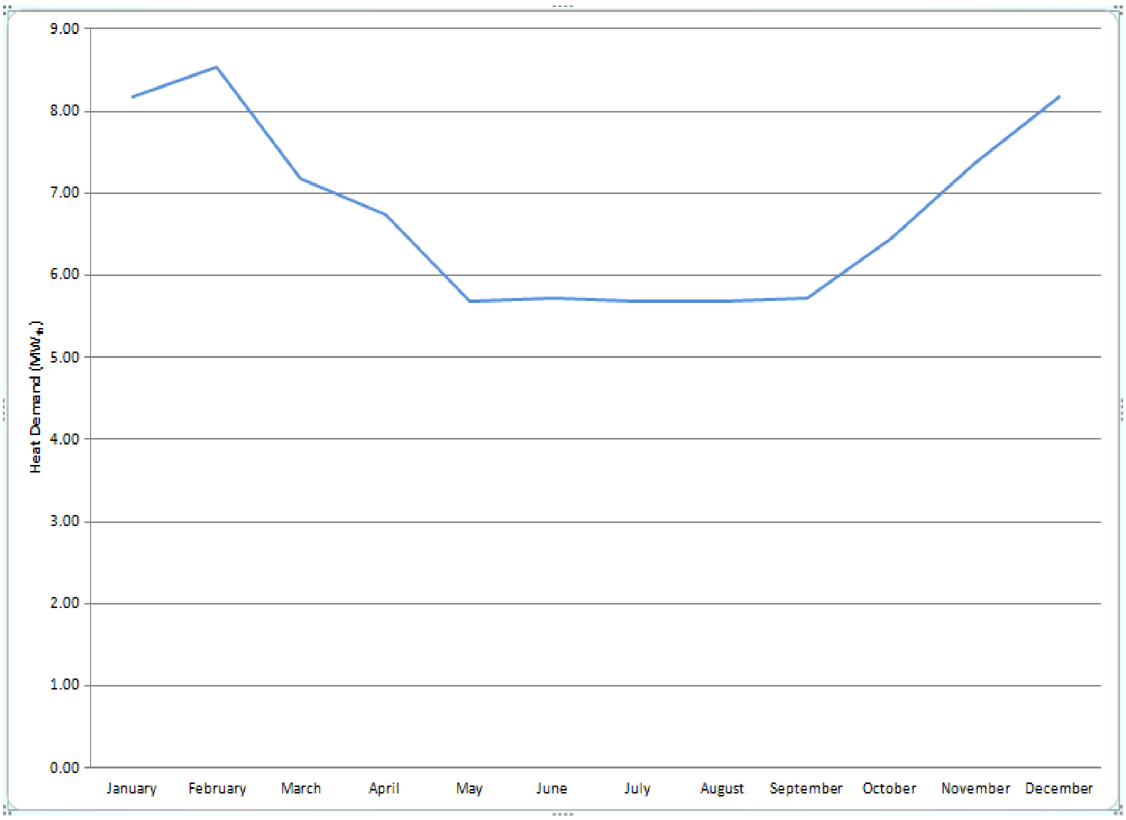

Figure 4.6 – Predicted total monthly heat load variations for 2013 – 2018

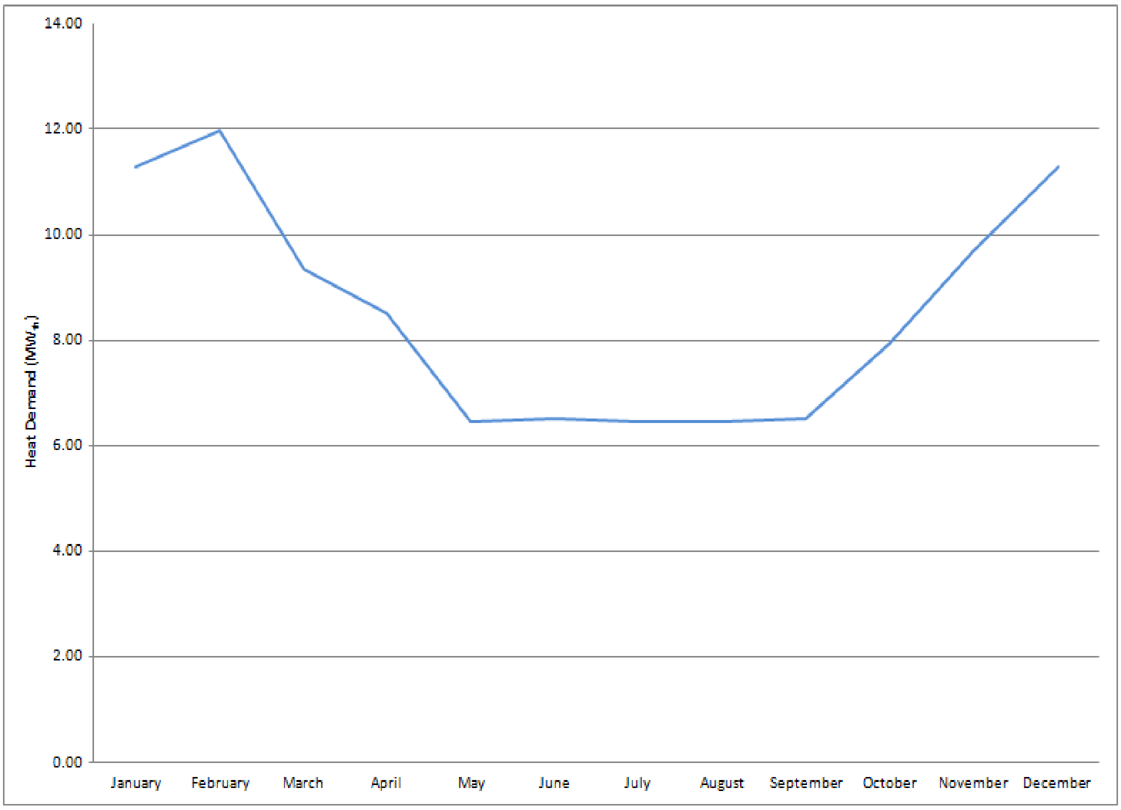

Figure 4.7 – Predicted total monthly heat load variations for 2018 – 2025

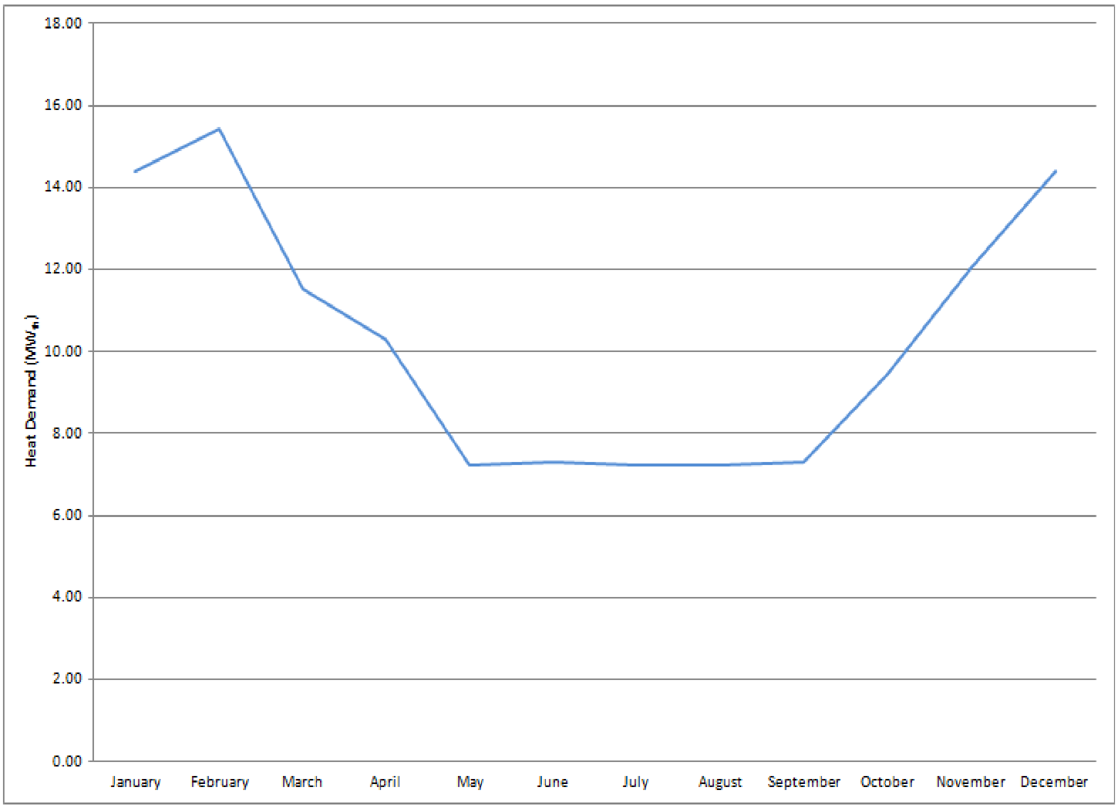

Figure 4.8 – Predicted total monthly heat load variations for 2025 – 2035

4.7 Heat Network Pipe Route

Pipe routing for supply of heat to the thermal dryer is considered relatively straightforward since the consumer is located on the same site. However, the piping to supply the Heartlands Development with heat has a number of associated risks.

Two routes were considered by Ramboll as possible options for the pipe connecting the Levenseat TWTP to the Heartlands Development in their report 'Levenseat Heat Transmission Initial Route Appraisal and Risk Assessment'. Both are presented in Figure 4.9.

Discussions between Ramboll and Levenseat concluded that the more eastern route would be taken (outlined in black). This was selected as the preferred route as it extends for the greatest length over land controlled by Levenseat and is predominantly soft dig, reducing the cost of installation. The length of the chosen route is approximately 6.5km.

The predominant engineering issue associated with the supply of heat by hot water relates to the installation of the heat supply pipeline. The pipe line required to supply hot water is likely to be of a large diameter, in this case 250 to 300mm internal diameter for the main supply pipe. The hot water circuit comprising supply and return preinsulated pipework will be laid in an underground trench traversing a mix of private land and public highways. The route identified is indicative; a detailed engineering assessment would be required to determine the optimum route which is not appropriate at this time.

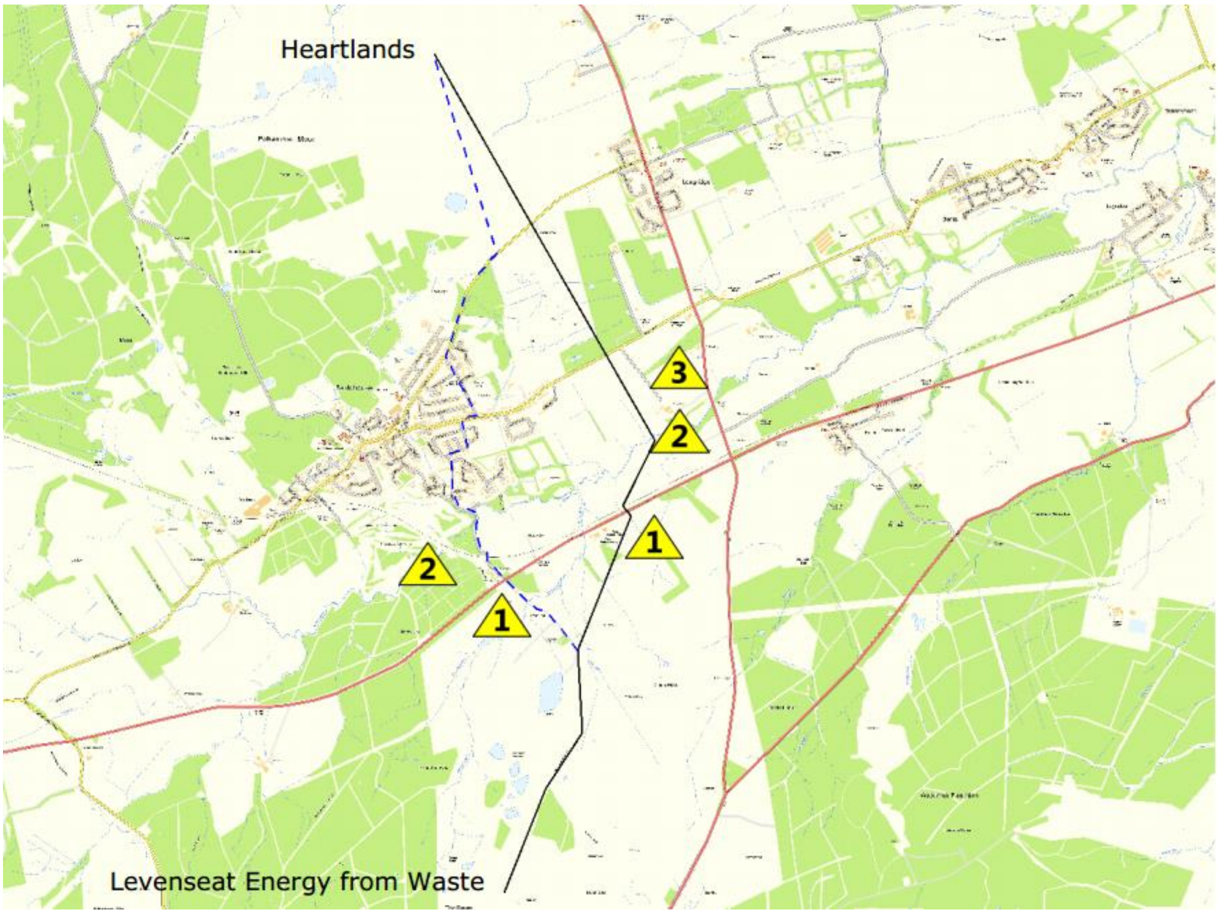

Figure 4.9 - Potential Pipe Routes from the Levenseat TWTP to the Heartlands Development[6]

The risks identified for the two potential routes shown are listed in Table 4.7. The hazard numbers from the table correspond with the numbers shown in the figure, while the risks that exist along the length of the pipe have not been allocated numbers.

Table 4.7 – Identified Risks Associated with Pipe Routes

Risk	Hazard Number	Implications
Road crossing	1	Trenching in road crossing will require traffic management and permission from highway authority.
Railway crossing	2	Approval required from Network Rail to bury pipe in a trench through existing livestock railway crossing.
River crossing	3	Construction of pipe bridge will require complex methodology and SEPA approval.
Ground conditions		Possibility of encountering rock or other difficult ground conditions. Extending time and equipment required for pipe installation.

6 Levenseat Heat Transmission Initial Route Appraisal and Risk Assessment, Ramboll, 13th May 2013

Table 4.7 – Identified Risks Associated with Pipe Routes

Risk	Hazard Number	Implications
Land ownership		Landowners will have to be consulted, wayleave agreements and access permission granted. Annual payments will be required which will be subject to escalation.
Utilities		Full survey of services to be carried out to assess impact on pipe installation.
Commercial interface with heat distribution network operator		The transmission pipe will supply district heating to a single point at the developer's site. A heat distribution network will need to be developed and a heat sale price agreed between Levenseat and the operator of the distribution network.
Heat supply guarantees		Levenseat, as the transmission heat supplier will need to agree the terms of heat supply. They will need to consider the effect of planned and unplanned outages at the generation plant and the need to provide peak heat supply at the distribution network.

4.8 Back-up Heat Source

During periods of routine maintenance or unplanned outages the Levenseat TWTP will not be operating, however heat consumers connected to the network will still require heat. Specifically the Heartlands Development will require a constant source of heat to provide a means of heating homes and businesses located on the site. There is therefore a need, somewhere within the heat transmission system, to provide a back-up source of heat to meet the demand during plant outages. The standby plant would likely comprise oil- or gas-fired boilers located in close proximity to the point of use, in order to minimise heat losses in the transmission pipework.

The peak heat export estimated at the Levenseat TWTP boundary is 16.4 MW when the development has reached its maximum size. Since the intention is to design the plant with the capability to export up to 12 MW of heat, this configuration will not allow the facility to supply peaks in network demand independently. To ensure heat consumers are provided with a stable heat supply throughout the year, back-up boilers can be designed to provide peak heat demand lopping and supplement heat supply where necessary. It is proposed the back-up system should be designed to ensure the maximum heat export capacity can be met but also provide sufficient turndown to supply smaller summer loads with reasonable efficiency.

Since both the drier and the gasification facility will undergo periods of routine maintenance, planned outages should be aligned to minimise the requirement for operating back-up plant.

4.9 Implementation Timescale

Since the thermal dryer will be built as part of the MRF on the Levenseat site, the full dryer heat demand will be realised from the outset of the heat network, subject to sufficient waste throughput being achieved. The demand of the Heartlands Development will increase in line with the house build phasing explained in Section 4.4.1. **Error! Reference source not found.** Table 4.8 provides an indicative programme for the development of the heat network based on the estimated heat demand figures for the thermal dryer and the Heartlands Development.

Table 4.8 – Heat Consumer Implementation Timescale (MWh/year)			
	2018	**2025**	**2035**
Thermal Dryer	32,750	32,750	32,750
Heartlands Development	9,430	18,260	27,100
Total	**42,180**	**51,010**	**59,850**
CHPQA QI	90.8	91.8	92.8
Overall Efficiency	32.2%	33.7%	35.2%

4.10 Alternatives to Heartlands

Whilst the Heartlands development is considered a suitable and likely heat offtake for the project, as it is a third party development there remains some element of risk regarding the timing and size of implementation. As a result, consideration has been given to alternative heat offtake options, centred around an on-site materials drying facility. The results of a feasibility study are attached in Appendix B which concludes that it would be economically feasible in the current market to build a wood chip drying facility on site. The largest size of dryer considered (with 90,000 tonnes per annum of feedstock) would utilise approximately 7.5 MW of thermal energy as baseload, which will be sufficient to meet the TTWG threshold for both Quality Index (QI) and overall efficiency, as detailed in Section 5.2.

5 Achievement of Energy Efficiency Threshold

5.1 Heat and Power Export

The Z ratio, which is the ratio of reduction in power export for a given increase in heat export, can be used to calculate the effect of variations in heat export on the electrical output of the plant. A value of 5.5 was obtained following CHPQA Guidance Note 28[7], assuming steam extraction at a pressure of 6.99 bar(a). Based on thermodynamic modelling of the Levenseat TWTP and Fichtner's experience of similar projects, a more conservative value of 4.67 was selected and the results are presented in the following table.

Table 5.1 – Heat and Power Export

Load Case	Annual Heat Export at Turbine (MW)	Net Power Exported (MW)*	Z Ratio
1. No heat export	0	10.6	0
2. Average network heat load	8.4	8.8	4.67
3. Heat load required for QI value of 93	8.6	8.7	4.67
4. Maximum heat load available	12.0	8.0	4.67

*For calculation of net power export, the energy used in the fuel preparation stage is not included as a parasitic load, as stipulated in SEPA's Thermal Treatment of Waste Guidelines 2014

The results indicate that for the heat consumers identified, load case 2 corresponding to an average heat export of 8.4 MW_{th} will result in a net power export of 8.8 MW_e. An annual average of 8.6 MW_{th} of heat must be exported in order to achieve a QI of 93, and under this condition, the plant would export an average of 8.7 MW_e, as demonstrated by load case 3.

5.2 CHP Quality Index

CHPQA (Combined Heat and Power Quality Assurance) is an Energy Efficiency Best Practice Programme initiative by the UK Government. CHPQA aims to monitor, assess and improve the quality of UK CHP. In order to prove that a plant is a 'Good Quality' CHP plant, the Quality Index (QI) is calculated. The QI for CHP schemes is a function of their heat efficiency and power efficiency according to the following formula:

$$QI = X\eta_{power} + Y\eta_{heat}$$

where:

η_{power} = power efficiency; and

η_{heat} = heat efficiency.

The power efficiency within the formula is calculated using the gross electrical output, and is based on the gross calorific value of the input fuel. The heat efficiency is also based on the gross calorific value of the input fuel. The coefficients X and Y are defined by CHPQA based on the total gross electrical capacity of the scheme and the fuel / technology type used.

[7] http://www.chpqa.com/guidance_notes/GUIDANCE_NOTE_28.pdf

In December 2013, the Government released a revised Guidance Note 44[8] entitled 'Use of CHPQA to obtain support for electrical output from renewable CHP under the Renewables Obligation'. The key amendment to the document was to change the X and Y values used within the QI formulae. This is intended to ensure schemes which receive Government support are supplying significant quantities of heat and delivering intended energy savings. The QI calculation for the Levenseat TWTP employs the following factors specified in Guidance Note 44:

- X value = 370; and
- Y value = 130.

SEPA's Thermal Treatment of Waste Guidelines 2014 stipulate that for facilities processing over 70,000 tonnes per year of fuel, the plant must meet or exceed the following criteria in order to demonstrate best practice for thermal treatment of waste facilities:

- QI ≥ 93; or
- indicative efficiency ≥ 35%.

The CHPQI and efficiency values for the various load cases have been calculated and are presented in Table 5.2.

Table 5.2 – CHPQI Calculation

Load Case	Power Efficiency (%)	Heat Efficiency (%)	Overall Efficiency (%)	CHPQA QI
1. No heat export	22.9	0.0	22.9	84.9
2. Average network heat load	19.6	15.7	35.2	92.8
3. Heat load required for QI value of 93	19.5	16.1	35.5	93.0
4. Maximum heat load available	18.2	22.3	40.5	96.2

The results indicate that Levenseat TWTP will not achieve the QI threshold for the average heat load export case (load case 2). This heat load results in a QI value only marginally below the threshold and confirmation of the heat demand in the future may indicate that the identified demand is sufficient. Regardless, at this load case the overall plant efficiency is sufficient to meet the efficiency threshold stipulated in the guidance.

For reference, a heat export of 8.6 MW_{th} is required to obtain a QI of 93, as demonstrated in load case 3. While this capacity of heat demand has not been confirmed in the area surrounding the plant, it is possible for the Levenseat TWTP to export at least this amount, as demonstrated by load case 4 which corresponds to a heat export of 12.0 MW_{th}.

[8] http://www.chpqa.com/guidance_notes/GUIDANCE_NOTE_44.pdf

6 Action Plan

It is theoretically feasible to deliver heat to the onsite heat consumer (thermal dryer) and the area surrounding the Levenseat TWTP (Heartlands Development). In order to build the plant with CHP from the outset and realise the full energy export potential of the plant it is recommended that an action plan is implemented. The outcome of this action plan will be to ensure that the plant can expand as a CHP facility by maintaining momentum with key stakeholders in the development process.

The action plan should be structured and have well defined objectives, involving all the local stakeholders and be supported at the highest levels within Levenseat. The action plan should identify the strategic phases required for the heat network development. Potential heat consumers are more likely to engage in the process if they know that there is a realistic prospect of a connection; it is therefore proposed that the action plan would be implemented alongside the construction program. The following project development phases are suggested.

Initial phase

(1) Follow up initial heat load plan and research with a detailed heat load survey when more information is available from potential consumers;
(2) engage with the local authority;
(3) build a detailed database of potential heat consumers;
(4) target buildings identified as potential heat consumers;
(5) carry out heat use surveys at targeted heat consumers;
(6) verify seasonal heat demand over time;
(7) develop pipe routing options and / or phases;
(8) size and configure the required infrastructure;
(9) confirm technical viability;
(10) develop capital cost estimates;
(11) develop cost estimates for operation and maintenance;
(12) assess economic viability;
(13) establish a carbon saving benchmark;
(14) draw up a project master plan;
(15) set up a joint working group with stakeholders; and
(16) develop a marketing strategy.

Intermediate phase

(1) Undertake detailed negotiations with heat consumers;
(1) finalise initial heat demand;
(2) finalise sizing of infrastructure;
(3) discuss pipe routing options with the local highway authority;
(4) finalise pipe routing;
(5) tender for initial infrastructure;
(6) sign heads of terms for heat supply agreements with ESCO;
(7) install initial infrastructure;
(8) sign heat supply agreement with an ESCO; and
(9) commission the network.

Final phase

(1) Market the scheme;

(2) expand the scheme by adding major phases (if possible); and

(3) expand the scheme by developing on existing infrastructure (if possible).

Constructing a detailed and reliable database of potential heat consumers is a key activity. This should be revisited and updated at least every two years so that new developments can be added and existing developments can be updated. Change in building ownership and use can affect the potential to be a heat customer. Boiler age can be tracked so that the consumer can be targeted when they are already considering investing in a new heating system.

The Levenseat TWTP will be CHP enabled to be able to deliver up to 12 MW_{th}. In order to achieve CHP status, the scope of the any proposed heat network needs to be well defined and technically assessed to prove that it is deliverable. Potential consumers need to be approached so that there is a high degree of certainty over heat sales. The economic viability of the network then needs to be confirmed.

Should the full heat demand from the Heartlands Development not be realised, the wood chip drying facility described in Section 4.10 is considered a suitable alternative, with the potential to demand sufficient heat in order to exceed the TTWG threshold for both QI and overall efficiency. In this case, the heat offtake technicalities will be developed to maximise energy efficiency while exporting heat to the drying facility. The development phases will differ from the primary action plan outlined above.

Appendix A Grid Connection Offer

Appendix B Materials Drying Feasibility Study

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