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ENGINEERING DISTRICT HEATING FEASIBILITY STUDY
LYNDON VERMONT

LYNDON VERMONT

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1. INTRODUCTION

At the end of December 2009 Greenergy Development entered into an agreement with Horizons Engineering L.L.C. in partnership with Ramboll Denmark A/S (Ramboll) to carry out a engineering feasibility study of a district heating network to supply heat to a number of residential, private and public buildings in the town of Lyndonville, Vermont.

The purpose of the study was to outline the technical considerations and approach for a heat network and recommend the design concept. In this process we have prepared a preliminary network design for the system assuming a heat source at the Biomass Energy Park, to deliver heat to the previously identified anchor loads (phase 1), and some future connections (phase 2).

This study is as stated in the scope of works only for the district energy system, NOT the Green Mountain Biomass CHP plant as that project will be developed separately.

Horizons Engineering and Ramboll has teamed up to combine Horizon's local with Ramboll's international expertise and experience with district heating systems.

This initial draft report presents the result of the engineering study. Upon accept of the outline design presented here the commercial aspects of such a project will be evaluated and a final report presented.

2. HEAT DEMANDS

Heat demands for the Lyndon Institute and Lyndon State College are based on the oil and gas consumptions from 08'- 09' and 08' respectively. Oil and gas consumptions have been turned into annual heat demands using a heating value for oil of 140,000 btu/gal (39,000 kJ/l) and 92,000 btu/gal (25,600 kJ/l) for propane. A boiler efficiency of 90% has been used where no efficiency is stated.

The annual heat demand for a normal year is calculated using heating degree day data from Burlington, Vermont since it appears that no climate data is recorded in Lyndonville. It is assumed that 20% of the total recorded heat demand of the Lyndon Institute and Lyndon State College is independent of degree days i.e. used for domestic hot water or similar base load.

For a normal year 7,665 heating degree days are used, 08' – 09' had 7,429 heating degree days while 08' had 7,212 heating degree days.

For all other consumers a global heat demand of 0.072 mmbtu/sf/yr (220 kWh/m^2/yr) has been used. The number has been assessed by calculating the area specific heat demand of the various buildings in the Lyndon Institute. Obviously, there is a great deal of uncertainty associated with applying a global area specific heat demand to a whole group of consumers but at this early planning stage of a district heating scheme it is normal practice.

Consumers connected in phase 1 i.e. primarily the Lyndon Institute and Lyndon State College are estimated to have an annual heat demand of 40,700 mmbtu/yr (11,925 MWh/yr).

Consumers connected in phase 2 i.e. primarily residential buildings are estimated to have an annual heat demand of 56,100 mmbtu/yr (16,440 MWh/yr).

The fully developed network should thus be designed to meet an annual heat demand of 96,800 mmbtu/yr (28,365 MWh/yr).

3. COMPLETE DISTRICT HEATING SYSTEM

The complete district heating system is everything between and including the heat production facility to the consumer's heat exchangers.

A complete district heating system includes as main components:

- Heat Production
- Pumps
- Pressurisation system
- Controls
- Pipes
- Heat exchangers and/or End-user installations

In addition a thermal store would often be part of a system as well, when considering Combined Heat and Power as heat production.

Not until a preliminary or detailed design would we look in detail at identifying all the equipment necessary for a specific district heating system.

The heat production facility can be heat only boilers (HOB) or production of both electricity and heat i.e. as Combined Heat and Power (CHP).

CHP is as a rule of thumb only operated as a base load, as depending on the technology it may be difficult and/or inefficient to operate according to daily variations in demand. In a well-designed district heating network heat from CHP, this will provide between 60% and 80% of the annual heat requirement with heat-only boiler plants providing the peak load and back-up.

There are technical and hydraulic components of a district heating scheme that are important to the design and operation of a system and there are considerations to be made in respect to temperatures, pressure, base and peak heat load and reserve or back-up requirements.

The main components in a district heating scheme such as the one for Lyndon and some of the main considerations to be made are briefly described in this section.

3.1 Energy Centre

The energy centre facility will contain the main heat production facility whether it being HOB and/or CHP.

Distribution pumps are placed in the energy centre. Several pumps can be installed in parallel so the system can function at all loads and individual pumps can be serviced while still running the system.

If a thermal store is implemented it would generally be sited near the energy source. Peak load and back up production capacity is often also placed at the energy centre. For larger networks there may also be some heat production facilities placed out in the heat network.

Within the energy centre consideration should be given to piping work for pumps, valves, heat meters, pressurisation system, ventilation system and boiler plant and thermal storage, temperature and pressure measurements, filters and air release valves. This will all be part of a detailed design.

Section 9 looks in a little more detail at the Energy Centre for the district heating scheme.

3.1.1 Peak Load and Back-up Plant Capacity

The estimated heat demands and peak loads can be used to estimate the size of the required plant.

Some heat producing technologies are most efficient if the run continuously and biomass HOB and CHP is generally sized to meet base load consumption. Plant is therefore required to meet variations in load and peak load. Back-up plant is required in case of breakdowns and maintenance.

This plant can be gas or oil fired as it is expected to only be operating a minimum amount of hours.

Where district heating is being installed to replace conventional heating systems there are opportunities to re-use existing boilers as peak load and back-up boiler plant. For new developments, any interim boilers established at an early stage can also later be utilised for peak load and back-up.

For a district heating network a heat load duration curve can be constructed based on the heat load demands during the year. The heat load demands can then be listed starting with the highest (peak load) and then descending. The heat load duration curve will also help establish the operation strategy for the energy centre as a whole and the peak and back up plant in relation to the main plant.
This sort of detail is not required to design a network and as this study is not to deal with the Green Mountain Biomass CHP plant a detailed duration curve or daily demand profiles have not been produced.

3.1.2 Circulation Pumps and Booster Pumps

Pumps for circulating the district heating water can be located either on the flow or return or as a combination. This will depend on the detailed design and operation of the system. The circulation pumps are generally placed within the energy centre or near by.

If a system has special requirements in respect to transport of the energy in the district heating water, booster pumps may also be installed. Generally this will not be part of a smaller distribution network.

However, this is something that could be considered for the scheme proposed for Lyndon due to changes in level up to Lyndon State College. Section 6 looks at outlining the conceptual design of the network and this is considered in a little more detail.

When taller buildings are considered for connection, local booster pumps may be required to be able to supply heat and hot water to the upper floors.

3.1.3 Pressurisation System

The distribution pumps supply the necessary pressure to distribute the water to the consumers. To keep the pressure level in the system a pressurisation system is installed. It consists of a number of large volume expansion vessels and some auxiliary equipment such as heat buffer tanks (heat traps).

3.1.4 Heat Storage Tanks (Thermal Stores)

It is likely that a heat storage tank would be part of a scheme such as the one proposed for Lyndon, to optimise the heat production from CHP. Heat storage tanks make it possible to create a time delay between heat consumption and heat production.

The purpose of such time delay is mainly of economical nature in combination with CHP and is related to the cost of heat production varying with time. By introducing a storage tank in the district heating system it is possible to produce heat at a time where the heat production price is low and then utilise this low cost heat at a time, where the production cost for the heat would be high. If the heat is produced at a CHP plant, then the heat production price is not only related to the fuel costs but also to the selling price of the electricity.

The size of the tank is determined through an optimisation between the overall capital and operational costs which in turn will also be decided by the size of the network and the heat demand which is to be met.

We will in Section 9 outline some initial size options but the determination of the more precise benefits of a heat storage tank would require a more detailed design study.

3.2 District Heating Network and the Pipes

In general a district heating network can be divided into three main parts:

- The transmission network
- The distribution network
- The internal heating system at the consumer.

The transmission network operates at high temperatures and pressures and carries large amounts of heat from larger heat producing units such as central power plants, waste incineration plants etc. to strategically placed heat exchanger stations where the heat is transferred to the distribution network.

The distribution network, operating at lower temperatures and pressures than the transmission network, supplies heat to each individual consumer. Normally, the transmission and distribution network interact only through heat exchangers meaning that they are hydraulically separated. In many cases this also applies for the interface between the distribution network and the internal heating system at the consumers.

3.2.1 District Heating Pipes

District heating systems these days are generally using preinsulated pipes directly buried in the ground. Although for large transmission systems with large dimensions, steel pipes with insulation installed in concrete ducts are also used.

A typical outline of a preinsulated DH pipe is illustrated in Figure 3.2.1.

A preinsulated pipe consists of the medium pipe that can be of steel, copper, PEX (cross linked polyethylene) or Aluminium PEX.

In the insulation there are in most cases alarm wires made of copper for leakage monitoring. The outer casing is normally made of polyethylene.

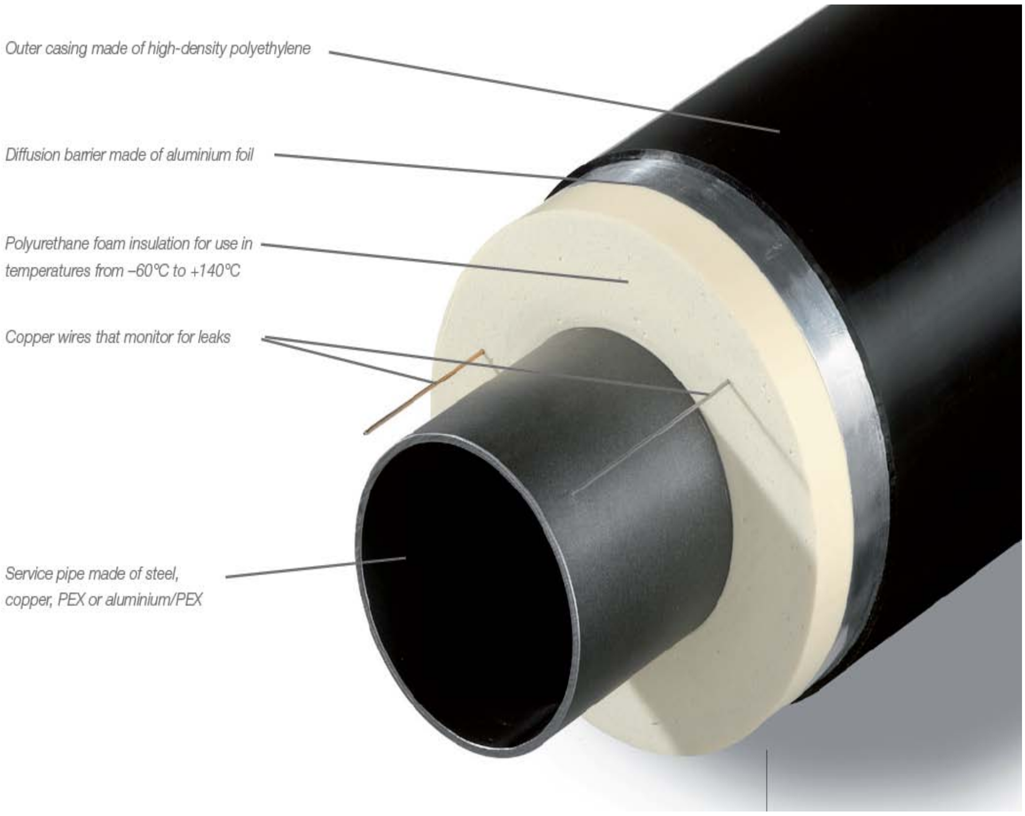


Figure 3.2.1: Illustration of a preinsulated DH pipe (from www.LOGSTOR.com)

Preinsulated district heating pipes options including PEX are of the types called bonded pipe systems, where the medium pipe, insulation and outer casing is a bounded system.

Preinsulated pipes also come in a twin pipe option which has two medium pipes within the same outer casing.

3.2.2 Service Pipes

The pipe connecting the distribution network with the building is called the service pipe. The service pipes to single dwellings are sometimes carried out with other types of preinsulated district heating pipes than traditional preinsulated pipes with medium pipes of steel. Often the service pipes are flexible pipes.

The types of pipes available for service pipes are:

- Flexible preinsulated DH pipe with medium pipe of copper (cu-flex)
- Flexible preinsulated DH pipe with medium pipe of PEX or AluPEX material
- Flexible preinsulated DH pipe with medium pipe of steel (steelflex)
- Traditional non-flexible preinsulated DH pipes with medium pipe of steel

Except from steel flex all the above types of service pipes are available both as a pair of pipes and as twin pipes. Steel flex is only available as a pair of pipes. The PEX pipes have limits on maximum allowable pressure of 6-10 bar and maximum temperature of 85-95ºC depending on which type is chosen.

The steel flex pipes are available in limited dimensions.

There are small variations on prices of the different types with the cu-flex slightly more expensive.

3.2.3 Twin pipes

Twin pipes will normally reduce the construction costs and the system heat loss. Twin pipes are often used on longer pipe sections where the network does not branch off and where no service pipes are connected. The use of twin pipes will typically reduce the costs by some 10% and heat losses can be reduced by as much as 50%.

3.3 Consumer Interface

The consumers could be connected to the distribution network either directly or indirectly. The direct connection without a hydraulic interface unit (HIU) (which is basically a heat exchanger) between the distribution network and the internal heating system in the buildings has the advantage of being a cheaper installation. It is also possible to achieve a lower return temperature (i.e. larger temperature difference or cooling of the district heating water) from the consumer, and this gives a more efficient system. The disadvantage of the direct connection of consumers is that the design pressure would probably be restricted. Furthermore, if there is a leak in the internal heating system in a building there is a risk of getting a large amount of water from the distribution network into the building which can cause serious damage. If consumers are directly connected leakage protection systems are essential.

The direct connection can and is often considered in new smaller systems but the specific conditions needs to be looked at during preliminary or detailed design.

It is at this stage of the study recommended that consumers connecting to the heat network proposed are indirectly connected because it gives a safer system with heat exchanger separation between distribution network and the internal heating system in the buildings. The hydraulic separation also makes it possible to use pressures of 10-25 bar in the distribution network if necessary.

Domestic hot water (DHW) can be either instantaneous or through a cylinder. The installation of hot water storage tanks for DHW instead of instantaneous water heaters will reduce the heat demand for DHW. Subsequently this will have an effect on the pipe dimensions of the district heating network, especially the service pipes to each dwelling or building. They can be reduced if there is a cylinder because it acts as a buffer, i.e. as a storage tank.

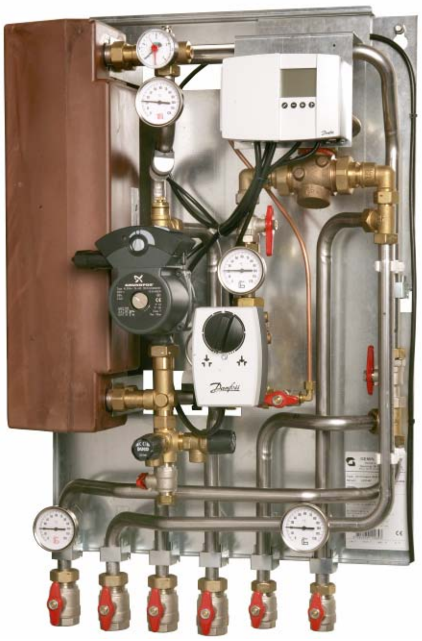


Figure 2: HIU. Capacity: 270 MBH

The main consideration for consumer interface is whether the connection is to be direct or indirect but the interface also consists of some auxiliary equipment such as valves, filters and meters.

The boundary of the district heating network is most likely to be at this consumer interface unit.

Depending on the scheme the consumer interface unit may be paid for by the district heating scheme or by the consumer themselves.

The design of the unit is important as it will have an effect on the design and operation of the system. Often the maintenance of the unit is left to the consumer but again it will depend on the boundaries for the specific scheme.

The customer interface is these days generally done through pre-fabricated off the shelve unit solutions especially for smaller thermal load connections and single family homes. The units include all equipment such as circulating pump and a heat meter.

3.4 Metering

Energy or utility metering, metering of electricity and heat or gas (and water) has developed rapidly over the last 10 years. Individual heat metering specifically is especially used in the district heating business.

These days the heat meter is not only used for the settlement of the customer's energy consumption. The meter is also a natural tool for a constructive dialogue between the heat supplier and the consumer. The possibilities of the meter are such that it can help the consumer ensure that their heating needs are covered at the lowest possible costs.

In most district heating networks where CHP is incorporated in the heat supply, the lower the return temperature, the better the economics are for the system as a whole. District heating is energy efficient because of the way the heat is produced in a single point and because of the technology and/or fuel (CHP and/or renewables). The required temperature level is here an important factor. Low temperature district heating with return temperatures of 30-40°C can utilise CHP plants that are very efficient and extract more energy from renewable fuels. However, such low return temperatures can be difficult to achieve especially when connection existing properties and buildigns where the design of the heating system may have had other priorities such as small radiators.

3.5 Operation and Maintenance

The operation and maintenance (O&M) will depend on the size of the system, the design and the set-up of ownership and operation. The district heating scheme can be a separate entity or it can be part of the production facility.

With the development of the area being planned to take several years, the demand for O&M resources will gradually increase, but the management structure will have to be in place from the beginning.

The management structure is important to the efficiency of the O&M. The O&M activities may be regarded as belonging to one of three different categories:

- Daily operation of the plants and pipe systems
- Scheduled maintenance
- Response maintenance

The daily operation can be taken care of by an on-site O&M team maybe shared with the production facility, but scheduled maintenance and response maintenance services may be contracted to subcontractors according to an O&M programme. The reason for utilising a subcontractor could be that the activity requires certain skills, equipment or tools. It could also be a question of resources.

An important issue to consider and plan as part of the operation and maintenance of a system is water treatment. Water treatment of a heating network is extremely important as poor water quality will reduce the lifetime of pipes and equipment and it may cause malfunction of even newly installed equipment.

3.6 Temperatures

In order to find the optimum temperatures it is necessary to find a compromise between temperature differences i.e. difference between supply and return temperatures and low supply temperature.

A large temperature difference is an advantage as smaller pipe dimensions can be used and subsequently installation costs can be reduced. Furthermore, operation and maintenance costs are also likely to be reduced. Increasing the temperature difference between supply and return is achieved by optimising the end-user installations, but can also be achieved by increasing the flow temperature.

Low supply temperature has the advantage of reducing the heat loss from the network significantly and subsequently reducing the operation costs. However, reducing the supply temperature normally also leads to a reduction in temperature difference.

Furthermore, it is worth noting that every time there is a heat exchanger in the system there is a temperature loss which generally means that the supply temperature in the distribution network needs to be higher than the supply temperature required internally in buildings.

3.7 Pressure

The design pressure of distribution networks are typically 6-16 bar depending on the type of installation at the consumer, the levels in the network and the size of the distribution network.

If the consumers are directly connected to the distribution network, meaning that there is no heat exchanger between the distribution network and the internal heating system in the buildings, then it is the internal heating system in the buildings that determines the maximum allowed pressure in the distribution network. The design pressure in district heating networks where the consumers are directly connected is typically 6 bars. This type of district heating network is common in the western part of Denmark where the landscape has a relative flat level and where the connected properties are predominantly single storey family houses but it is generally not used to connect consumers directly.

If the consumers are indirectly connected to the distribution network then the design pressure is typically 10 bar. If it is a large distribution network and/or there are large variations in altitudes then the design pressure is sometimes 16 bar. The pipes, other components and the installation work in a 16 bar system are more expensive than in a 10 bar system, and therefore, if possible, 10 bar is recommended in the distribution networks.

It is possible to install booster pumps in the distribution network, in order to avoid the high design pressures or to overcome large differences in altitude.

In comparison the design pressure of transmission networks are often 25 bar. This is because transmission networks in general are characterised by distributing a large amount of heat over a relatively long distance.

4. CONNECTION OF PROPERTIES TO DISTRICT HEATING

The proposed district heating (DH) scheme is outlined such that connection to the network is to be indirect i.e. through a hydraulic interface unit (HIU) or heat exchanger configuration separating the internal heating systems in the buildings from the DH network.

The houses, flats and buildings whishing to connect to a DH system can be heated by radiators, floor heating or by a combination of radiators and floor heating. In some cases hot air can also be used. However, radiators and floor heating generally gives a better thermal comfort than air heating.

It should be noted that none of the properties proposed for connection have been surveyed by Ramboll.

4.1 Refurbishment of heating systems

As a general note it is expected that the domestic hot water for most of the existing systems is via a tank. The outline design of the DH scheme assumes that the domestic hot water is instantaneous. This means that the space for the hot water tank is free or it can be used for the smaller HIU.

4.1.1 Converting from a gas or solid fuel LPHW boiler (except for back boilers)

A gas or solid fuel fired boiler heats up the water which is circulated through the property's radiators to provide space heating. Alternatively to radiators the space heating system can be based on under-floor heating. In addition the boiler can also heat up the domestic hot water. This is either done by heating up a coil in the hot water tank, which then supplies domestic hot water or by directly and instantaneously providing domestic hot water via a plate heat exchanger each time a hot water tap is opened (Combi boiler).

Generally, if the current heating system is based on a boiler system, it should be possible to replace the existing gas or solid fuel boiler with a HIU without considerable work or expense by reusing the existing radiator installation (both the radiators and the piping). It might even be possible to place the HIU, where the gas boiler was located before. In some cases however, it can be necessary to carry out some changes to the existing radiator installations in order to obtain an acceptable cooling of the DH water.

Many radiator installations where in the past designed for a temperature set of 180/160 °F (82/71 °C). Such systems can operate with 176/122 °F (80/50 °C) if heat losses from the building are reduced by 25%.

The radiators should ideally be connected to a two pipe system and each radiator should be equipped with a thermostatic valve (TRV) with pre-set flow reduction on the supply pipe and bleeding valve for the extraction of air. In some cases it might also be necessary to replace the existing radiators with new ones with a larger surface area.

The major difference between a gas boiler and solid fuel boiler is the fuel. Therefore the conversion from a solid fuel boiler based heating system to a DH based system should be similar to a conversion from a gas boiler. A solid fuel boiler is typically larger.

4.1.2 Converting from a back boiler

A back boiler is fitted at the back of a fireplace. Similarly to a wall mounted boiler or a floor standing boiler it heats up the water which is circulated through the property's radiators to provide space heating. The back boiler can also heat up the domestic hot water.

In addition to the considerations regarding the conversion from a wall mounted or floor standing boiler based heating system to a DH based system, the conversion from a back boiler based system implies moving the HIU to somewhere else in the property than behind the fireplace, where the back boiler is placed. This might mean that the piping between the new HIU and the existing radiators needs to be refurbished.

4.1.3 Converting from warm air

Warm air units are central heating systems that do not contain any water (i.e. a dry system). Air is warmed and then circulated through ducts within the property.

An option for the conversion to a DH based system is to replace the fuelled heating unit with a fan coil. The fan coil heats up the air for space heating by transferring heat from the hot water provided by the HIU. In this manner the duct system is maintained and the major conversion work from a dry system (warm air) to a radiator system is avoided. When weighing this solution it is necessary to take into account the necessary air flow as well as both the DH temperature set and the air temperature set.

If it is concluded that it is not possible to maintain a warm air based system, then the conversion implies the installation of a HIU, radiators and piping to connect these properties.

4.1.4 Converting from electrical heating

An electrical heating system is usually based on electrical radiators for space heating and a water tank with an electrical immersion heater for heating up the domestic hot water.

The conversion from electrical heating to DH based heating implies replacing the electrical radiators with hot water radiators and the installation of piping to connect them to the HIU. The design of the radiator system should follow the guidelines that are presented for the systems to be installed at new properties.

The HIU replaces also the electrical immersion heated tank and it might be an option to place the HIU where this was located before.

4.2 Existing steam heating systems

Steam distribution is more widespread than hot water district heating in the US, but for heating purposes the hot water distribution can replace steam.

One important difference between steam and hot water district heating is the temperature that the heat is supplied at. Hot water systems are generally designed with a maximum temperature around 200 °F. If an existing system is converted to hot water, air handling units will have to be replaced in the connected buildings. Buildings with a water central heating system may also require a replacement of radiators, depending on the design criteria.

5. ALTERNATIVE HEAT PRODUCTION TECHNOLOGIES AND USE OF HEAT

Conventionally in a district heating (DH) system, especially large ones, the heat demand is met by waste heat from power stations and EfW utilising a heat generation which would otherwise be wasted and subsequently it can come at a very low cost.

In smaller schemes it is common to look at installing the heat production, which often unfortunately adds extra cost to the scheme. The production plant is therefore often specifically sized for know and secured customers.

The advantage of a district heating system is the flexibility and the ability to utilise a variety of heat sources, including what can be called low-grade heat.

One obvious example is the use of solar thermal energy. There are a number of examples in Europe where large-scale solar thermal arrays have been integrated with district heating networks as district heating schemes offer maximum energy utilisation from solar thermal as a heat sink for the low temperature water.

The largest system in Denmark is connected to the district heating network in a small town. In combination with a heat storage it covers 30% of the annual heat demand of 1,200 single-family houses, a few public buildings, a school and a hotel.

Ramboll is presently looking at the first phase of a development of solar heating plants to supply heat to a district heating network in Minnesota.

5.1 Alternative Heat Utilisation – Heating Greenhouses

Another possibility is to use the heat for warming greenhouses. In Denmark greenhouses are usually heated, so replacing gas or oil heating with district heating will reduce CO_2 emission.

As mentioned earlier the cooling of the district heating water is an important issue. For new greenhouses a cooling of 122 °F (50 °C) with the temperature set 176/86 °F (80/30 °C) is possible and this is an advantage to the heat network.

Connecting greenhouses to district heating is always made with indirect connection through a heat exchanger. The internal heating system in greenhouses is typically designed for lower pressure than the district heating system and therefore direct connection should not be used.

Greenhouses have a high heat demand between 200-300 kWh/m^2/year (0.065 – 0.1 mmbtu/ft/annum) for the Danish climate. New greenhouses should be prepared for heat supply from district heating in order to get high cooling of the water.

The heat consumption can change rapidly for greenhouses. If the sun starts to shine and clouds disappear the heat consumption can go from maximum to zero in 15 to 20 minutes. During the summer the greenhouses will be heated during the night so there is a demand throughout the year. The large and fast variations in heat consumption in the greenhouses need attention in terms of controlling and regulating the district heating network. Many greenhouses are operated with small gas or oil fired CHP schemes, with thermal storage to smooth out these variations.

5.2 Using Distribution Network for District Cooling

It might be an option to use the heat distribution network for district cooling purposes in the summer. For example, the network can be used to transmit hot water to decentralised absorption chillers producing chilled water for a group of consumers. In this way it is possible to utilise the surplus heat from the heat production plant e.g. the CHP plant in the summer.

From a design and operation point of view higher temperatures are desirable when considering the use of absorption chillers. A high temperature heat source will reduce the overall size of the chilled system. Therefore, from a district cooling point of view, the higher the operation flow temperature in the distribution network the better.

6. DISTRICT HEATING NETWORK

This design of the district heating (DH) network considered in this study is based on the preconditions outlined in this section. The section also highlights any design consideration that needs to be taken.
The cost of installing the heating network depends in summary on four factors:

- The design operating temperature and pressure
- The complexity of existing services
- The length of the network
- The peak heat demand

and the DH network is designed by considering these in its optimisation.

6.1 Design Preconditions

The flow temperature is 198 ºF (92 °C) and the cooling of the DH water, which could also be expressed as the average ΔT through consumer installations is assumed to be 62 ºF (35 °C).

The distribution network is recommended to be at least a 16 bar system due to the considerable difference in elevation from the energy centre to the Lyndon State College (approx. 322 ft (100 m)). If the system was to be carried out as a 10 bar system, one or more booster pumps would be needed to supply Lyndon State College which would add to the complexity and cost of the system.

The minimum pressure in the (return) system should at no point drop below 1 bar to avoid the risk of cavitations as it may cause structural damage to the various components of the system. A pressure difference of a minimum 0.5 bar at the end-user installations is used.

The energy centre is for this assessment located on Main Street, lot number 22-175.

The necessary pipe dimensions are estimated by using Ramboll's software package "SYSTEM RORNET", which is a simulation programme for hydraulic and thermal analysis of DH networks. SYSTEM RORNET (SR) calculates the optimum diameters of the pipes based on knowledge on temperature difference between flow and return, pressure levels, costs for piping and the maximum velocity in the pipes.

The estimated construction costs per meter trench and the maximum acceptable velocity for each dimension is shown in Figure 6-1.

The costs are for both flow and return pipe work. The construction costs are based on Ramboll 's price estimate database collecting prices from supplier and installers in the US on a variation of projects.

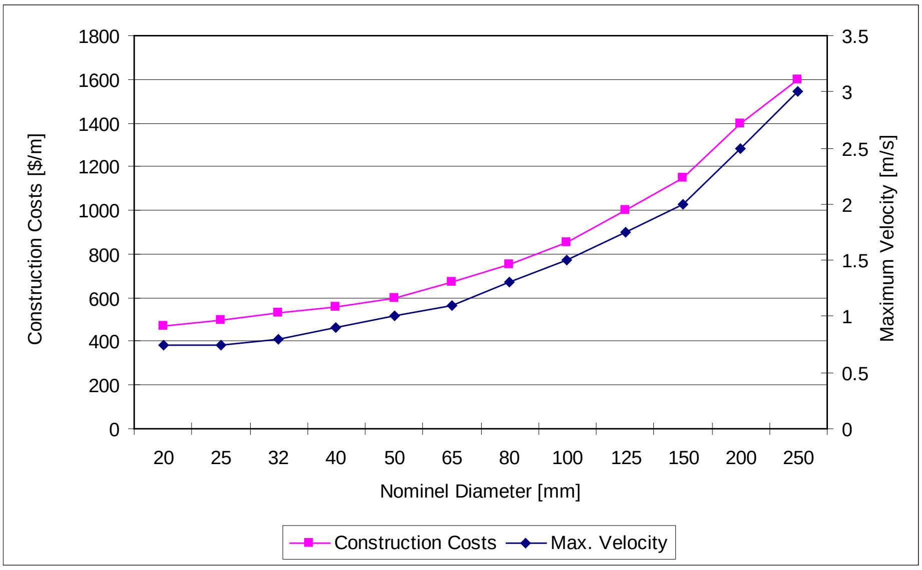


Figure 6-1: Construction costs per meter trench and maximum velocity.

It should be observed that there are substantial uncertainties related to these costs because the experience of low temperature systems from the US market is quite limited beyond study stage. From our experience with Danish and international schemes we know that not only variations in the size of the scheme but also the prospect of more schemes can push prices both up and down quite considerably in an unpredictable pattern. When it is decided that this scheme should move forward it is therefore very important that the price estimates are verified at an early stage.

Furthermore, the prices are based on pair of pipes, but if twin pipes are used which may be an option on the section from the Lyndon Institute to Lyndon State College since there are no consumers along this part of the route, the construction costs can typically be reduced by up to 10%, as stated previously.

6.2 Utilisation time and diversity

The district heating (DH) supply will cover both the heating of the buildings and the domestic hot water (DHW) demand. The heat demand of the buildings will depend on the heat loss of the building and to some extent on the type of occupancy.

The provision of DHW, instantaneous or via individual storage cylinders is important in determining the load. The advantage of DHW via a storage cylinder is that the peak load capacity demand from the buildings is reduced considerably which results in smaller pipe dimensions of the DH system compared to a system based on instantaneous DHW via a heat exchanger. The disadvantage is that the hot water cylinder will take up a little more space. Instantaneous DHW will have a higher demand and subsequently it can generally be assumed that the size (diameters) of the network but in particular the service pipes will increase.

The peak load consumption will not occur simultaneously for all buildings in an area. The heat demand and the diversity will depend on individual usage, which means that non residential usage will have a different profile than that of residential. The individual use of DHW will also vary between residential buildings and it is unlikely that everyone within a larger area will need their maximum demand at the same time. The utilization and diversity is assessed for individual schemes based on experience and may vary depending on the combination of residential and non-residential buildings together with their usage, i.e. domestic, retail, offices, industry, etc.

Heat loads are calculated from the demand by introducing an annual utilisation time and the concept of heat consumption diversity.

The annual utilisation time is used to calculate the maximum capacity requirement for space heating for each individual consumer. The annual utilisation time used is 1500 hrs/annum, a number based on Ramboll's experience with similar district heating projects.

Diversity factors are introduced in the network dimensioning to take into account that not all consumer installations are fully active at the same time. Service pipes should be dimensioned to be able to meet the consumer's maximum capacity requirement while all distribution pipes will experience some degree of diversity. The closer to the energy centre the distribution network is located, the higher degree of diversity it will experience.

For this particular scheme automatic calculation of diversity factors has been found suitable. An algorithm within the SYSTEM RORNET program package assigns diversity factors to each pipe section in the DH system with the purpose of minimising pipe diameters and thus the cost of the system. The lowest diversity factor is assigned to the part of the network connected to the energy centre and has a value of 46% (for the fully developed network). This means that the pipe is dimensioned to transport a heat flow of 46% of the consumer's accumulated capacity requirement.

6.3 Domestic hot water

Domestic hot water is accounted for in the dimensioning by adding a capacity requirement of 0.12 mmbtu/hr (35 kW) to each consumer connection, corresponding to the capacity of a standard instantaneous water heater for domestic purposes. Heat consumption associated with DHW is subject to a very high degree of diversity meaning that the dimensioning of the distribution network will be close to unaffected by the capacity requirement from DHW. The impact of the DHW contribution on the dimensioning of service pipes may be substantial for relatively small consumers but negligible for large consumers.

6.4 Heat loads

The heat load for phase 1 is found as the sum of the contribution for space heating and the contribution for DHW multiplied by the diversity factor seen from the energy centre.

$$\dot{Q}_{phase1} = \left(\frac{40{,}700\ mmbtu/yr}{1500\ hrs/yr} + 44\,consumers \cdot 0.12\ mmbtu/hr/consumer \right) \cdot 0.55 = 17.8\ mmbtu/hr$$

The heat load for the fully developed network is calculated in the same manner:

$$\dot{Q}_{total} = \left(\frac{96{,}800\ mmbtu/yr}{1500\ hrs/yr} + 238\ consumers \cdot 0.12\ mmbtu/hr/consumer \right) \cdot 0.46 = 42.8\ mmbtu/hr$$

This is equivalent to 5,2 MW for phase 1 and 12.5 MW for the fully developed network.

A full list of all consumers, their annual heat demands and maximum capacity requirements is found in Appendix 1.

6.5 Dimensioning

Only the fully developed network is of interest in the dimensioning procedure. Service pipes for phase 1 consumers are included in the network dimensioning while phase 2 consumers are accounted for by simulating evenly distributed heat consumption [btu/hr/foot] along the distribution pipes in the areas of phase 2 consumers i.e. primarily on the eastern side of the Passumpsic River.

This is normal procedure at this stage of the planning where uncertainty is connected to the type and precise location of future connections. With the methodology used the distribution pipes will be sized correctly while dimensions and cost of service pipes for phase 2 consumers will be estimated.

The change in level of approximately xxx ft (100m) from the area around the Interstate 91 (I91) and up to Lyndon State College requires some consideration in the design. If the network was to be outlined as a 10 bar system which would be normal for this type of system it would require a booster pumping station. Due to the lift in pressure the network around Lyndon State College was then likely to be 16 bar. This was discussed with the client group during an early project status meeting and it was felt that the pumping station option should be avoided.

6.5.1 16 bar system

As a first estimate a hydraulic design calculation is performed assuming a pressure difference of 14 bar (16 bar system, static pressure 2 bar) at the energy centre. Furthermore, it is assumed that the total required heat load of 42.8 mmbtu/hr (12.5 MW) is supplied from the energy centre. Appendix 2 contains a plot that graphically displays the energy levels in the main DH pipe from the energy centre to the Arnold Hall at the Lyndon State College for both flow and return system. The gauge pressures in the flow and return system are illustrated by the difference between elevation and energy level in the flow and return system respectively. It is seen that the energy levels in both flow and return system drops below the elevation line before reaching the Lyndon State College meaning that gauge pressures will be negative, resulting in high risk of cavitations. The solution is not viable.

A new design calculation is performed with the aim of keeping pressures at acceptable levels through out the system and in particular at the Lyndon State College. The pressure difference applied at the energy centre is reduced to 8.5 bar while keeping the maximum pressure at 16 bar. Appendix 3 contains the profile plot for this calculation. Gauge pressures are at no point lower than 1 bar and the network design is therefore a possible solution. It is stressed that for this network design to be viable it is required that the system pressure is fixed at 16 bar in the flow system at the energy centre. The network dimensioning has been done simulating a full load situation but in a low load situation i.e. at the summertime where the capacity demand may be only 20% of that of full load, the pressure levels in the return system are bound to drop to negative gauge pressures at the Lyndon State College if the pressure is fixed in the return system at the energy centre.

6.5.2 25 bar system

A 25 bar system makes it possible to perform the network dimensioning at a higher pressure difference resulting in overall smaller pipe dimensions and reduced pipe work costs. The downside is that the costs of various components in the system, HIUs in particular, increases as they should be designed to handle higher pressures.

A profile plot is found in appendix 4. The pressure difference at the energy centre is 18 bar while the maximum pressure is 25 bar. With this configuration all consumers will experience a pressure difference higher than 4.5 bar since network dimensions are unable to be reduced any further due to built in water velocity limitations in SYSTEM RORNET. In other words, the system dimensions and cost cannot be reduced any further by applying a higher pressure differential at the energy centre. As in the case with the 16 bar system, the system pressure should be fixed in the flow system at the energy centre to avoid cavitations risk in low load situations.

Note that the system only requires a pressure difference of 14 bar at the energy centre for all consumers to experience a differential pressure of at least 0.5 bar.

6.6 Network Layout

Figure 6.6 shows an outline of the proposed Lyndonville DH scheme.

The network has been digitalized based on the concept plan “Greenergy Development, Energy Feasibility Study, Lyndon District heating System, Proposed Piping Network Phase 1 and 2” received from Horizons Engineering.

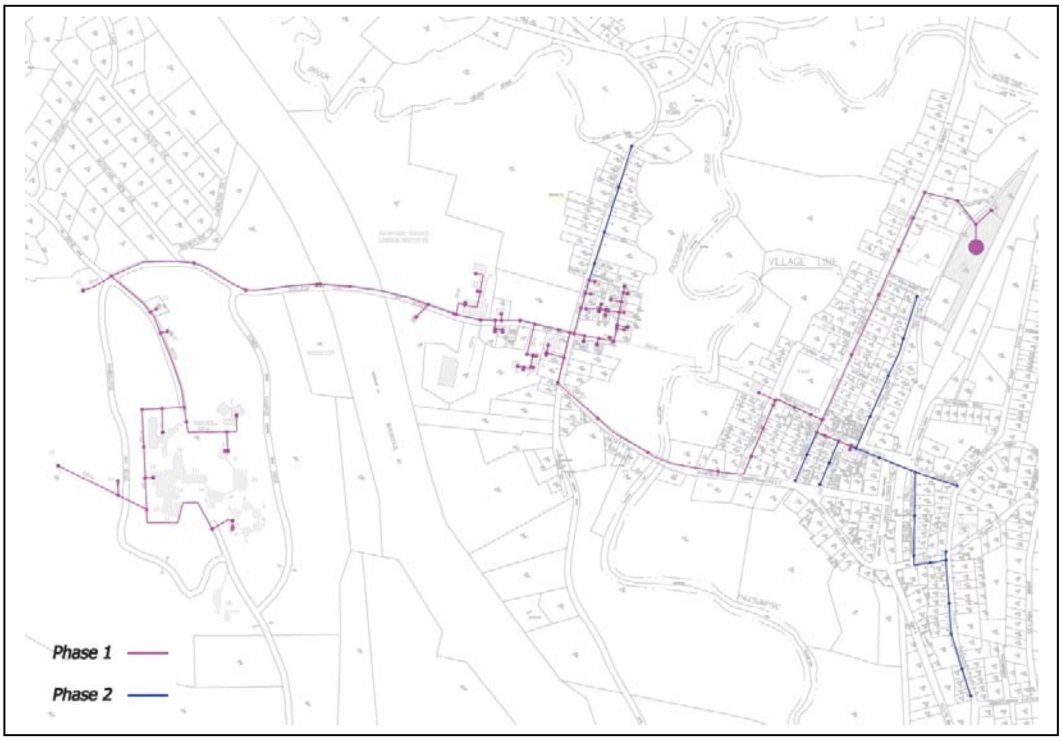


Figure 6-6: Outline of proposed Lyndonville DH Scheme.

Phase 1 requires by far the most network construction work while phase 2 consumers are estimated to have a higher total heat demand than that of phase 1 consumers. As described earlier, only service pipes for phase 1 consumers are included in the outline.

The original network outline indicated a loop system in the middle of the network where a pipe line was entered without any potential for customers now or in the future. This is an unusual approach for a network of this size as it adds an extra cost which will be difficult to finance based on the connected customers. Ramboll has therefore not included it in the sizing of the network.

6.6.1 Network Dimensions

The calculated dimensions for the 16 bar system and the 25 bar system appear from Appendices 5 and 6.

Table 6.6.1 shows the trench length for each dimension for both the 16 bar system and the 25 bar system.

Service pipes supplying phase 2 consumers are assumed to have the dimension DN32 and an average length of 10 m. Since some 194 consumers are expected to be connected in phase 2, the total service line trench length adds up to 1940 meters. Due to the requirements in pressure all phase 2 (and 1) service pipes are assumed to be carried out in traditional preinsulated pipes.

		16 bar system		25 bar system	
		Phase 1			
Nominel diameter	Trench costs	Trench length	Costs	Trench length	Costs
mm	$/m	m	$	m	$
20	470	259	121,730	259	121,730
25	500	205	102,400	205	102,400
32	530	208	110,346	410	217,459
40	560	252	141,344	294	164,808
50	600	663	397,860	419	251,460
65	670	287	192,357	302	202,340
80	750	219	164,400	632	474,075
100	850	879	747,065	506	429,760
125	1,000	340	340,200	1,655	1,654,600
150	1,150	1,467	1,686,590	628	721,740
200	1,400	1,702	2,382,240	1,172	1,640,380
250	1,600	57	91,520	57	91,520
Phase 1 total:		**6,540**	**6,479,000**	**6,540**	**6,073,000**
		Phase 2			
20	470	0	0	0	0
25	500	21	10,500	21	10,500
32	530	1,940	1,028,200	1,940	1,028,200
40	560	200	112,056	200	112,056
50	600	328	196,740	328	196,740
65	670	614	411,112	614	411,112
80	750	356	266,850	356	266,850
100	850	370	314,160	370	314,160
125	1,000	75	74,800	75	74,800
150	1,150	0	0	0	0
200	1,400	0	0	0	0
250	1,600	0	0	0	0
Phase 2 total:		**3,910**	**2,415,000**	**3,910**	**2,415,000**
Total:		**10,450**	**8,894,000**	**10,450**	**8,488,000**

Table 6.6.1: Pipe dimensions and cost estimate

6.7 Heat Loss from Network

The heat loss from the fully developed network has been estimated based on proposed pipe dimensions for the 16 bar system and the proposed flow and supply temperatures combined with a temperature of 8ºC of the surrounding soil. The heat loss in a full load situation is found to be around 1.3 mmbtu/hr (380 kW), which gives a heat loss of around 10,000 mmbtu per annum (2930 MWh). The heat loss from the 25 bar system will be only slightly lower.

The network heat loss is around 10% of the total estimated heat demand, which is a relatively efficient DH network.

The heat loss calculation is based on LOGSTOR series 2 preinsulated pipes for district heating. If twin pipes are used for parts of the network the heat loss may be reduced with approximately 10%.

The heat loss has not been calculated for the phase 2 service pipes.

6.8 Network outline design conclusion

Ramboll recommend the DH network to be carried out as a 16 bar system. Even though the capital cost of the 16 bar system is $400.000 higher than that of the 25 bar system, that money is easily spent upgrading the various components in the system such as heat exchangers, valves, fittings etc. from PN 16 to PN 25.

7. OTHER DISTRICT HEATING NETWORK ISSUES

The network route has not been surveyed in detail by Ramboll at this stage.

The network pipe route should be chosen in accordance with the following principles:

- The route should be as short as possible
- The route should avoid busy roads in order to minimise the cost of traffic management
- The route should make it as easy as possible to avoid interference with other services, both during construction and later
- The route should avoid areas which are difficult to access because this may cause construction to become more complicated and more expensive
- The route should avoid too soft ground, which can affect the construction.

7.1 Network Space Requirements

During installation the space requirement for the heating network can be quite substantial depending on the method adopted and the difficulties of the installation. However, the available working area for the installation of pipes is often restricted and the contractor will in that case have to choose a construction method which is more complicated and therefore more expensive than the preferred basic method.

It is Ramboll's recommendation that the installation of a district heating network generally is given serious consideration. It is a long term investment that if carried out correctly could last for more than 50 years. Ramboll suggests that detailed installation specifications and guidelines are incorporated in the future work with the project.

Once the pipes have been installed it is important to secure the right of the district heating company to come back to pipes and installations to carry out scheduled maintenance or to replace them. This includes the space along the route to establish the required construction site. In many cases this is typically done through a declaration zone on each side of the pipes, normally resulting in a 15-25 feet wide corridor but this will depend on local conditions.

7.2 Pipes Above Ground

Although buried pre-insulated pipes are the preferred technical option for a distribution pipeline. In some instances placing pipes above ground could be an option and here there can be a limitation in respect to utilising the traditional pre-insulated pipes with plastic casing. Other options may be considered such as horizontal directional drilling and various tunnelling techniques when crossing rivers and heavy trafficked roads.

The pre-insulated pipes can to some extent be run in tunnels, under bridges or they can be used for other special purposes but they are normally buried in the ground and this is what the pre-insulated systems have been designed for. The stress and strain conditions of the pre-insulated piping systems are based on the friction between the pipes and the surrounding soil and the plastic casing pipes have not been developed to resist solar radiation or mechanical impact above ground. In addition to this the relatively flexible casing pipe has to be supported with shorter intervals than other types of pipe.

Long pipe sections above ground will often have a steel casing pipe but for some purposes a different type of casing may be used.

7.3 Crossing River and Interstate 91

The proposed route includes a crossing of the Passumpsic River and the crossing of Interstate 91 (I91). Both crossings call for a technical approach which is different from the traditional trenching.

There are a couple of options at each location but this study proposes a horizontal directional drilling (HDD) for the road crossing and a river crossing where the Center Street road bridge will be used to support the pipes.

The directional drilling results in the pipes being installed in a shallow arc by using a surface launched drilling rig. The method will normally require a pit to receive the drill and the pipe. Each pipe is installed separately. HDD is very suitable for the crossing of major roads because there is limited impact on the environment and traffic is left undisturbed. Also the costs are limited when compared with the alternative of trenching at a difficult location.

The river crossing could also be carried out as a HDD, depending on the local conditions e.g. how soft the surrounding ground is, but it is the crossing on the road bridge that is described here. Using an existing bridge construction to support cables and pipes is a common approach to crossings of waterways or infrastructure, often using a cavity in the bridge construction or by mounting supports at the side of the bridge. A number of issues has to be dealt with in the technical design such as the weight and the thermal expansion of the pipes, the pipe run to and from the bridge itself, the anchoring of supports and the requirement for future access to inspect both the bridge construction and the pipes.

Both crossings will have to be considered in more detail during detailed design.

7.4 Utilities

Other utilities and their location in roads, pavements and footpaths will need to be investigated in relation to assessing the suitability of the proposed district heating route.

For very large areas it may be worth going though a third party which specialises in producing utility survey reports.

Utilities to consider could be:

- Electricity
- Gas
- Water
- Sewerage
- Drainage
- Major telecoms (may or may not include CATV)

It may be decided to exclude the minor utilities from an investigation as this can unnecessarily increase the complexity of the utility search and it is likely that the district heating main would not be diverted because of minor utilities in any event.

7.5 Land Ownership

The chosen district heating route is to Ramboll's knowledge predominantly public roads or public owned land. It is therefore assumed that there will be no issues associated with obtaining licences, permits and wayleaves for the installation of the network.

Should the preferred route cross privately owned land requiring a wayleave, the implications and costs of agreeing this can only be determined through negotiation with the landowner.

7.6 Water Quality

Water in DH systems needs treatment to ensure that the water quality is at an acceptable standard to prevent corrosion and the build up of calcareous deposits in the system.

In Denmark there is no general standard for the quality of DH water but a set of guidelines is issued by Danish District Heating. One set of guidelines applies for DH water and another and stricter set applies for make up water.

According to these guidelines DH water should have the following properties:

- pH value: 9.5 – 10
- Electrical conductivity: < 50 μS/cm
- Oxygen content: < 50 μg/l
- Water hardness: < 1 dH

While the following properties should apply for make up water:

- pH value: 9.6 - 10
- Electrical conductivity: < 20 μS/cm
- Oxygen content: < 20 μg/l
- Water hardness: < 0.1 dH

Plants for treatment of DH water include filters for removal of calcium, a unit for removal of oxygen and other gases and a pH conditioning unit.

8. DISTRICT HEATING NETWORK COST ESTIMATES

The network costs of the 16 bar system were estimated in Section 6 to some $8.9 million for the main pipe work only. In addition, costs associated with river crossing, interstate crossing, internal pipe network and hydraulic interface units need to be estimated.

The cost of implementing the network for phase 1 is $6.479 million excluding the crossing of the river and I91. The cost of phase 2 is approximately $2.145 million.

8.1 Costs of Hydraulic Interface Units

(QA of prices in progress)

8.2 Phasing of Total Network Estimated costs

Costs of the piping network are listed above in table 6.6.1.

9. ENERGY CENTRE, INCL. PEAK AND BACK-UP

The Lyndonville DH scheme has a total heat load of approximately 42.8 mmbtu/hr (12.5 MW) consisting of build out in a phase 1 of around 17.8 mmbtu/hr (5.2 MW) and a phase 2 of 25 mmbtu/hr (7.3 MW).

Ramboll is aware that due the fiscal measures available in the country and different requirements for carbon heat CHP options but with or without renewable fuel are often pushed even for quite small developments. The results unfortunately, are often that they run into technical and/or financial difficulties.

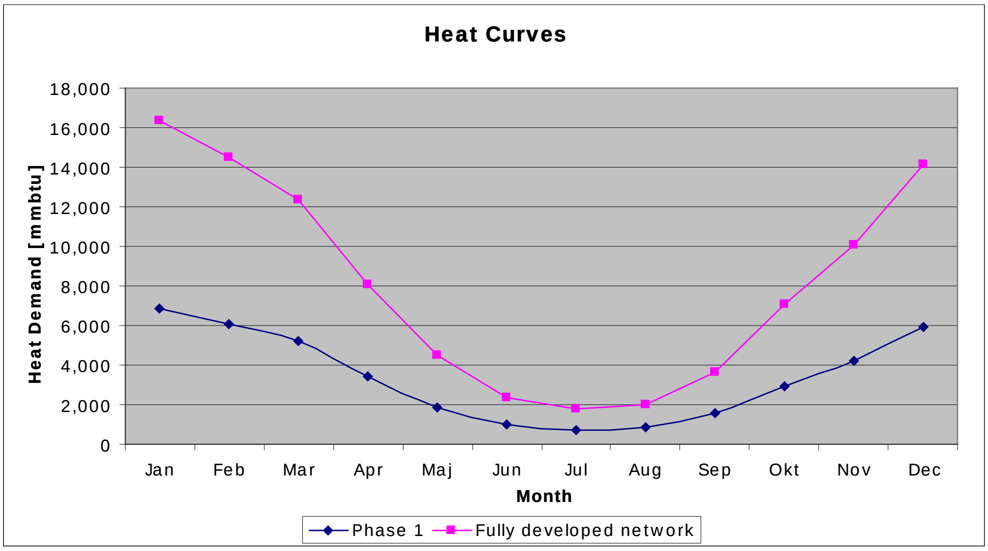
A biomass CHP option is proposed for the Lyndonville DH system which is being developed by others. Ramboll is informed that this will be able to deliver around 32 mmbtu/hr (9.5 MW) of heat to the network.

In this section Ramboll looks at outlining the equipment specifically required for the operation of the district heating system.

9.1 Heat Demand Profile and Plant Capacity

A heat demand profile has been estimated to give an overview of the heat demand on a monthly basis. The profile can be seen in the chart below.

The annual heat demand is divided into monthly heat demands using degree day data and the assumption that 20% (domestic hot water) of the heat demand is independent of the actual degree day data.



Typical boilers based on solid bio fuels can be regulated down to 25% of full capacity, without violating emission standards, though reducing the efficiency of the boiler.

A more detailed outline of duration curve, daily demand and operational pattern is only required for the CHP plant and could look at a suitable operation pattern and different plant sizing.

There will have to be some peak load and back up capacity; this could be oil- or gas-fired boilers. With the proposed district heating network layout there is no reason for this scheme to introduce back up boilers at any other location than at the central point of heat production but large boiler located out in the system could be incorporated.

Back-up and peak load boiler capacity is assumed to be met by fuel oil boilers. It should be noted that the fuel consumption of a peak and back up boiler depending on the design of the system is expected to be very small as the boiler will only be operating during limited periods of peak heat demand.

In an optimised phase 1 system the use of backup boilers could typically be limited to 100-200 hours or less, depending on weather conditions and the requirements for maintenance. Depending on the build out of phase 2 this is likely to be more.

9.2 Heat Exchangers

It is assumed that all heat is supplied at the energy centre and therefore the main heat exchangers should be dimensioned for the total maximum heat load of 42.8 mmbtu/hr. A two equally sized heat exchanger solution would be the traditional approach since it offers a high degree of operation security. If one heat exchanger fails one is still operational. Furthermore, only one heat exchanger is required for phase 1 (max. heat load 17.8 mmbtu/hr) meaning that installation and cost of the second heat exchanger can be postponed until it is certain that phase 2 will be carried through.

9.3 Distribution pumps

Distribution pumps should be dimensioned for a flow of 1390 gal/min (316 m^3/hr).

As mentioned in section 6.5.1 the required pump head to overcome resistance in the PN 16 DH network is 8.5 bar. By experience, pressure loss in the main heat exchangers at the energy centre is less than 1 bar. Therefore, distribution pumps should be dimensioned as follows:

16 bar system: Flow = 1390 gal/min, pump head = 9.5 bar

Ramboll recommend three parallel connected 50% distribution pumps, two operational and one for backup. However, it can just as well be chosen to have two 100% pumps.

The pumps are to be located on the flow leg of the distribution network.

9.4 Thermal store

A thermal storage makes it possible to introduce a time delay between heat production and heat consumption. A thermal storage is usually dimensioned to contain the equivalent of 8 to 48 hours of full load heat consumption.

In this particular project a thermal storage with the capacity of 48 hours of full load would mean a storage volume of 1390 gal/min · 48 hours · 60 min/hr = $4 \cdot 10^6$ gallons = 15,160 m^3 which is very large for this type of system, (in a full load situation the flow is 316 m^3/hr as stated above).

A thermal storage with the capacity of 8 hours of full load corresponds to a storage volume of 2,528 m^3 which is a more realistic size storage tank.

However, the actual optimum size will need to be determined in a detailed operational evaluation looking at capital and operational costs including assessing electricity income and heat sales which is not part of the requirements of this study.

9.5 Pressurisation system tanks

Pressurisation system tank(s) should be dimensioned to meet the volumetric expansion/contraction of the DH water as a result of seasonal temperature variations.

The total volume of the DH network is estimated to be 300 m^3, including consumer installations.

It's assumed that the flow temperature may decrease from 198 °F (92 °C) in cold winter to 158 °F (70 °C) in warm summer and that the return temperature in the same period will decrease from 136 °F (57 °C) to 104 °F (40 °C). The expansion of the DH water from summer to winter, ΔV_{water} is estimated as:

½

It's therefore recommended that the pressurisation system is equipped with a 5 m^3 water storage tank.

9.6 Control Strategy

The return temperature in the DH system is solely determined by the combined effects of the hydraulic interface units (HIU) in every building. This temperature can, therefore, be an indication of the heat demand at a given time.

The flow temperature in the DH network is chosen by the system operator, and it should be the control parameter for the pump set in the primary loop. This temperature will vary between a maximum, normally used during winter, and a minimum, normally used during summer.

It is suggested to implement a DH network system with a fixed maximum pressure of 16 bar in the flow system at the energy centre. The pressure is fixed by constantly supplying or extracting water to or from the network due to contraction or expansion of the water in the system. The pressurisation system consists of two parts; pressurised vessels, which take care of minor water supply or extraction, and a non-pressurised make up water storage tank which may exchange water with the network through pumps and valves.

The heat storage tank may be non-pressurised or pressurised to some extent depending on the design supply temperature for the system, here is can be non-pressurised. The heat storage is charged or discharged by exchanging water with the DH system through a number of pumps and valves.

An advantage of fixating the pressure in the flow system is that pressures in both flow and return system will stay within acceptable limits during a pump trip situation. After a period with fluctuations pressure levels in both systems will come to rest at 16 bar throughout the network with no danger of cavitations.

9.6.1 DH system pumps

The distribution pumps should be automatically controlled to maintain a differential pressure of at least 0.5 bar across all consumer installations. In practice it's sufficient to monitor the differential pressure at Lyndon State College since the DH installations here will experience by far the lowest differential pressures. Furthermore, absolute pressures in the return system should be monitored at Lyndon State College to prevent return gauge pressures to drop below 1 bar (full load situation) to stay clear of cavitations risk.

9.6.2 Boilers

As a consequence of a decrease in the flow temperature in the DH system, the flow in the primary loop increases and the heat delivered by boilers will increase to satisfy the demand.

The interaction between boilers, determining when a boiler should be operating or be on stand-by, as well as the heat output of each boiler, should be automatically controlled by the boiler's control system. However the possibility of manual control should also be available.

The boiler's control system should be able to communicate with the BMS, in order for this to send a mobile phone text message to the operator, if one of the boilers comes to a halt.

9.6.3 Pumps on the primary loop

The pump set on the primary loop could be automatically controlled to maintain a constant temperature on the flow line of the DH system.

The pump set should be equipped with a safety pressure-switch on the discharge end of each pump. In case the discharge pressure reaches the system's limit, then the pressure switch shuts off the pump. The pump should then only be able to be restarted after the pressure switch has been reset. It would be convenient, if the BMS gathered these alarms and sent them to the operator via a mobile phone text message.

9.6.4 Pressure holding system

Water feeding to and tapping from the expansion vessel is expected to be automatically controlled by the pressure holding system.

If this pressure holding system provides an alarm in case of low pressure, it would be convenient, that the operator receives this alarm via a mobile phone text message.

9.7 Space Requirement of the district heating Energy Centre

A plan drawing of the energy centre in principle is enclosed.

We expect the energy centre to be requiring an area of minimum 2,500 ft^2 (250 m^2).

9.8 Boiler Plant Costs Estimates

The capital costs for an all inclusive boiler installation we would expect to be in the region of $3 million.

The estimate includes components and piping work for pumps, valves, heat meters, pressurisation system, ventilation system and buffer tanks and flues. An allowance has also been made for the building and electrical and gas connections to the grid.

Unit cost	
Pumps	
Heat exchangers	
Water treatment	
Control systems	
Electrical and gas connections	
Pressurisation System	
Chimney and flues	
Fuel storage	
Building Services	
Misc.	
Building	
Total	$3,000,000

The cost of the boiler assumes two boilers and allows for the fuel feeding system.

The energy centre building and equipment has been outlined as a standard installation and therefore the costs are subject to changes, once a contractor and suppliers take the design further.

10. PHASING OF TOTAL ESTIMATED COSTS

(To be completed in the 2nd draft version of the report)

11. FINANCIAL APPRAISAL

11.1 Scenarios

11.2 Summary of estimated costs

11.3 Further assumptions

11.4 Results

12. PLANNING ISSUES

13. DEVELOPMENT STRATEGIES

13.1 New business development

13.2 Funding

14. STUDY SENSITIVITY

15. CONCLUSIONS

16. RECOMMENDATIONS

Appendix 1: Consumer list

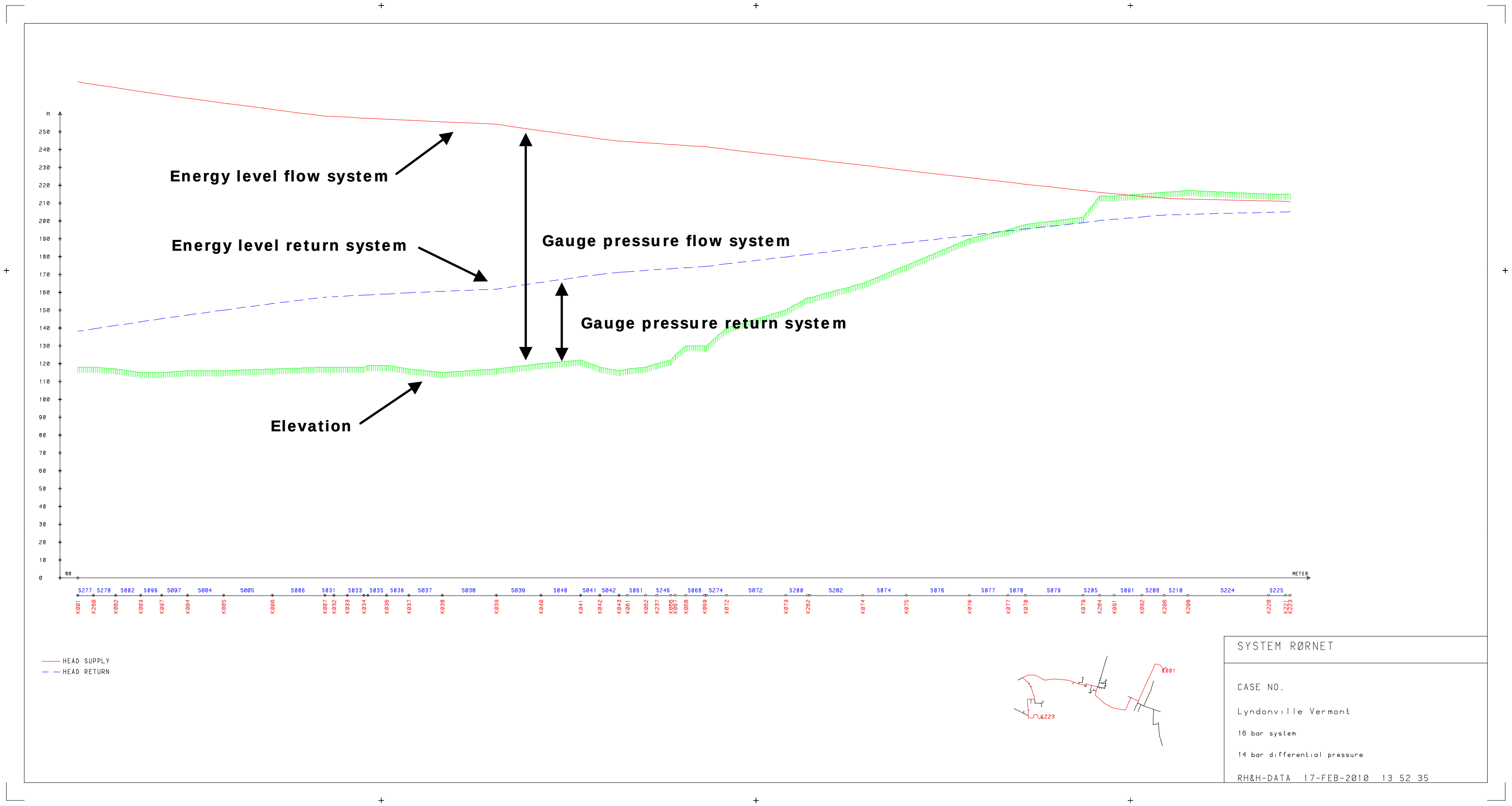
Phase	StreetName / Consumer	Street Number	p_taxmap	Annual heat demand	Max. heat load
#	-	#	#	mmbtu/yr	MBH
1	PARK AVE	119	21-078	1,593	1,182
1	DEPOT ST	76	21-123	1,810	1,327
1	COLLEGE RD	27	21-183	1,245	950
1	CENTER ST	379	21-215	427	404
1	COLLEGE RD	39	21-227	581	867
1	CENTER ST	400	21-230	282	308
1	MATTY HOUSE CIR	40	21-237	539	480
1	MATTY HOUSE CIR	49	21-258	266	297
1	KING DR	12	21-259	114	196
1	CENTER ST	325	21-260	83	176
1	MATTY HOUSE CIR	105	21-261	98	185
1	MATTY HOUSE CIR	117	21-262	239	279
1	MATTY HOUSE CIR	78	21-263	678	572
1	KING DR	85	21-264	87	178
1	KING DR	83	21-265	400	387
1	KING DR	134	21-266	183	242
1	KING DR	114	21-267	47	151
1	KING DR	100	21-268	492	448
1	KING DR	63	21-270	592	515
1	KING DR		21-271	118	199
1	MAIN ST		22-219	95	183
1	COLLEGE RD	115	30-004	159	226
1	COLLEGE RD		30-006	4,808	3,565
1	COLLEGE RD		30-007	173	235
1	COLLEGE RD	221	30-0071-500	264	296
1	VAIL DR	180	30-008	294	316
1	VAIL DR	378 & 392	30-050	184	243
1	COLLEGE RD	72	30-053	215	264
1	COLLEGE RD		30-054	159	226
1	Wheelock, LSC	-	-	8,061	5,494
1	Activities, LSC	-	-	5,797	3,985
1	Arnold, LSC	-	-	4,710	3,260
1	Arnold (DHW), LSC	-	-	599	520
1	Rita Bole, LSC	-	-	950	753
1	Vail, LSC	-	-	3,048	2,152
1	Emergency Services, LSC	-	-	212	261
1	President House, LSC	-	-	300	320
1	Gray House, Daycare, Alumni, LSC	-	-	750	620
2	MAIN ST	26	21-002	332	341
2	MAIN ST	42	21-003	222	268
2	MAIN ST	52	21-004	132	208
2	MAIN ST	66	21-005	116	197
2	MAIN ST	128	21-007	1,321	1,001
2	MAIN ST	154	21-011	324	336
2	MAIN ST	170	21-012	302	321
2	MIDDLE ST	24	21-013	299	319
2	MIDDLE ST	31	21-014	291	314
2	MAIN ST	230	21-015	207	258
2	MAIN ST	248	21-017	374	369
2	MAIN ST	278	21-019	175	237
2	MAIN ST	278	21-0190-700	186	244
2	MAIN ST	298	21-020	224	269
2	MAIN ST	316	21-022	929	739
2	MAIN ST	420	21-024	5,745	3,950
2	MAIN ST	420	21-0240-700	5,971	4,101
2	MAIN ST	450 & 454	21-025	150	220
2	HILL ST	731	21-025	153	222
2	HILL ST	719	21-026	161	227

2	HILL ST	709	21-027	90	180
2	MAIN ST	417	21-033	157	224
2	MAIN ST	395	21-034	494	449
2	MAIN ST	377	21-035	468	432
2	MAIN ST		21-036	177	238
2	MAIN ST	349	21-038	154	222
2	MAIN ST	337	21-039	260	293
2	MAIN ST	319	21-040	325	337
2	MAIN ST		21-041	419	399
2	MAIN ST	307	21-042	163	229
2	MAIN ST	227	21-043	199	253
2	MAIN ST		21-045	325	336
2	MAIN ST	241	21-047	114	196
2	MAIN ST	223	21-048	253	289
2	MAIN ST	101	21-050	652	555
2	MAIN ST	93	21-051	343	349
2	MAIN STREET	85	21-052	240	280
2	MAIN ST	77	21-053	239	279
2	MAIN ST	63	21-054	436	411
2	MAIN ST	35	21-056	178	239
2	MAIN ST	15	21-057	229	273
2	CENTER ST	805	21-058	322	335
2	CENTER ST	801	21-059	345	350
2	PARK AVE	52	21-060	125	203
2	PARK AVENUE	74	21-061	198	252
2	PARK AVE	78	21-062	129	206
2	PARK AVE	92	21-063	214	263
2	PARK AVE	114	21-064	219	266
2	MAPLE ST	51	21-065	216	264
2	MAPLE ST	45	21-066	225	270
2	MAPLE ST	35	21-067	84	176
2	CENTER ST	673	21-068	131	208
2	CENTER ST	697	21-069	122	201
2	CENTER ST	731	21-070	151	221
2	CENTER ST	739	21-071	397	385
2	PARK AVE	47	21-072	195	250
2	PARK AVENUE	63	21-073	135	210
2	PARK AVE	75	21-074	176	237
2	PARK AVE	85	21-075	189	246
2	PARK AVE	105	21-076	150	220
2	PARK AVE	117	21-077	139	213
2	PARK AVE	157	21-080	241	281
2	CHURCH ST	201	21-094	102	188
2	CHURCH ST	185	21-095	79	173
2	CHURCH ST	177	21-096	158	225
2	CHURCH ST	165	21-097	177	238
2	CHURCH ST	30	21-098	212	261
2	CHURCH ST	141	21-0980-500	217	265
2	CHURCH ST	117	21-100	155	224
2	CHURCH ST		21-101	504	456
2	CHURCH ST	69	21-102	218	265
2	CHURCH ST	47	21-103	259	293
2	CHURCH ST	39	21-104	100	187
2	CHURCH ST	23	21-107	207	258
2	DEPOT ST	71	21-108	512	462
2	DEPOT ST	61	21-109	687	578
2	DEPOT ST	45	21-110	696	584
2	DEPOT ST	37	21-111	417	398
2	DEPOT ST	29	21-113	138	212
2	DEPOT ST	32	21-114	857	691

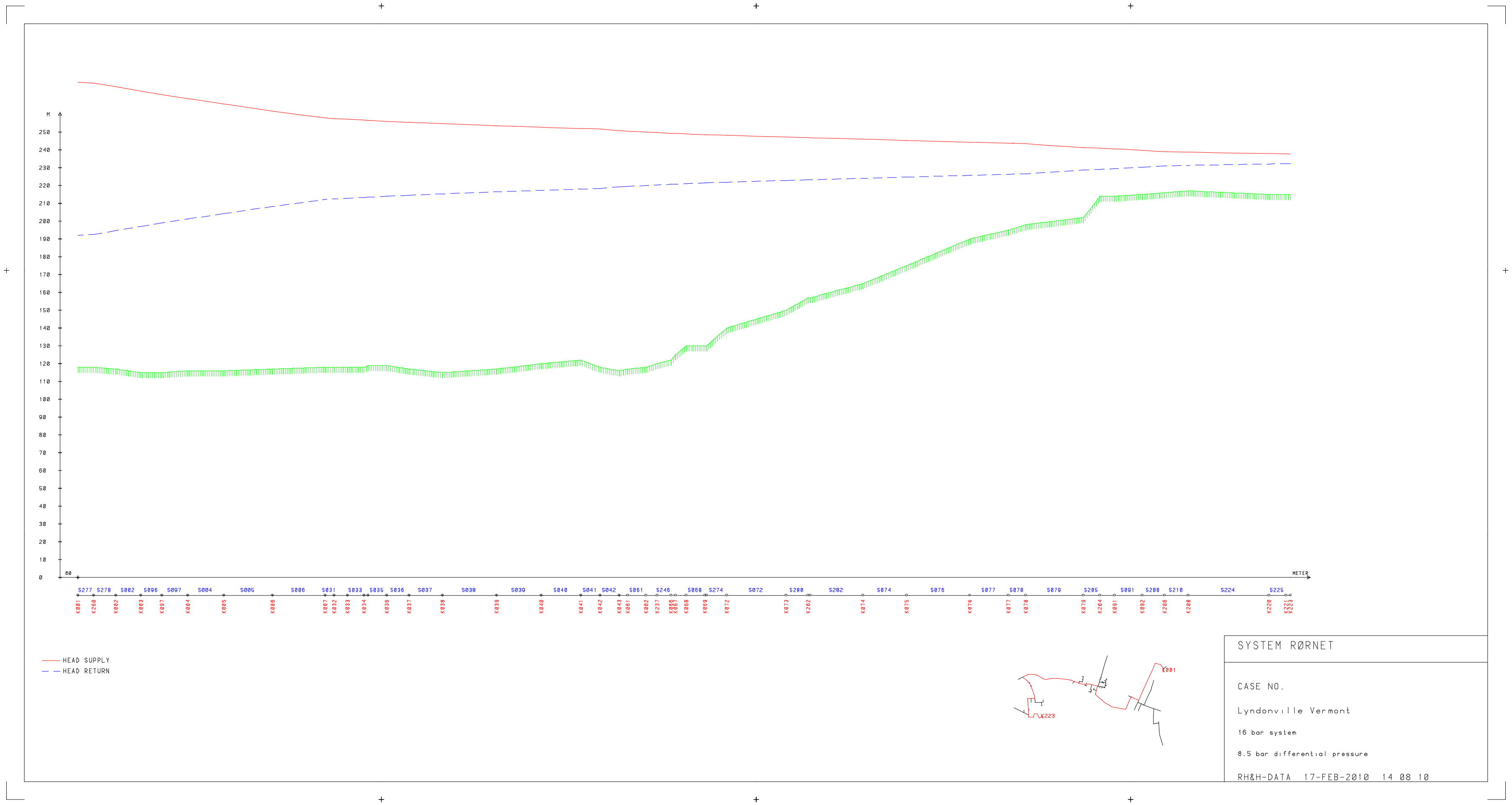
2	ELM STREET	43	21-115	100	187
2	ELM STREET	43	21-115	212	261
2	ELM ST	35	21-116	185	243
2	ELM ST	27	21-117	118	199
2	ELM ST	11	21-118	104	190
2	CENTER ST	921	21-119	263	295
2	ELM ST	20	21-120	105	190
2	ELM ST	48	21-122	352	355
2	DEPOT ST	101	21-132	1,450	1,087
2	DEPOT ST	133	21-133	258	292
2	PARK AVE	115	21-145	142	215
2	MAIN ST	486	21-149	97	185
2	DEPOT ST	183	21-152	245	284
2	WILLIAMS ST	130	21-154	173	235
2	WILLIAMS ST	116	21-155	302	321
2	WILLIAMS ST	98	21-156	182	241
2	WILLIAMS ST	80	21-157	290	313
2	WILLIAMS ST	72	21-158	193	249
2	WILLIAMS ST		21-161	216	264
2	CHURCH ST	136	21-162	567	498
2	CHURCH ST	70	21-163	205	257
2	CHURCH ST	88	21-164	146	217
2	CHURCH ST	116	21-165	335	343
2	CENTER ST	546	21-166	170	234
2	CENTER ST	504	21-167	121	201
2	BACK CENTER RD	1376	21-169	254	289
2	BACK CENTER RD	1393	21-180	132	208
2	BACK CENTER RD	1403	21-181	76	171
2	CENTER ST	416	21-182	357	358
2	CENTER ST	431	21-186	155	223
2	CUTTING LN	44	21-187	78	172
2	CUTTING LANE	25	21-188	448	418
2	CENTER ST	399	21-189	142	215
2	KING DR	25	21-191	237	278
2	CENTER ST	215	21-193	328	339
2	CENTER ST	183	21-194	171	234
2	CENTER ST	161	21-195	129	206
2	CENTER ST	153	21-196	111	194
2	CENTER ST	121	21-197	137	211
2	CENTER ST	109	21-198	269	299
2	CENTER ST	73	21-199	130	207
2	CENTER ST	67	21-200	243	282
2	CENTER ST	33	21-201	143	215
2	CENTER ST	76	21-202	98	186
2	CENTER ST	88	21-203	287	312
2	CENTER ST	106	21-204	103	189
2	CENTER ST	118	21-205	175	237
2	CENTER ST	124	21-206	48	152
2	CENTER ST	138	21-207	89	179
2	CENTER ST	166	21-208	186	244
2	CENTER ST		21-209	216	264
2	CENTER ST	188	21-210	153	222
2	CENTER ST	202	21-211	238	278
2	CENTER ST	226	21-212	124	203
2	CENTER ST	238	21-213	155	224
2	CEMETERY CIR	87	21-214	165	230
2	CHURCH St	49	21-217	262	295
2	CHURCH ST		21-219	130	207
2	CHURCH ST	44	21-220	659	559
2	MAIN ST	49	21-221	185	243

2	CENTER ST	590	21-222	185	244
2	CENTER ST	580	21-223	262	294
2	CENTER ST	574	21-224	124	203
2	CENTER ST	548	21-225	64	163
2	BROAD ST	1000	21-240	263	295
2	CHURCH ST	116	21-249	117	198
2	CENTER ST	379	21-272	220	267
2	MAIN ST	247	21-275	294	316
2	MAIN ST	247	21-275	294	316
2	DEPOT ST	220	22-006	121	201
2	DEPOT ST	211	22-007	106	191
2	EAST ST		22-132	429	406
2	MAIN ST		22-1450-500	289	312
2	MAIN ST	548	22-147	145	217
2	DEPOT ST		22-201	281	308
2	CHARLES ST	438	22-216	85	177
2	HILL ST	29	23-001	292	315
2	WILLIAMS ST	32	23-002	139	213
2	WILLIAMS ST	46	23-003	237	278
2	WILLIAMS ST	56	23-004	137	211
2	HILL ST	728	23-014	147	218
2	HILL ST	710	23-015	124	202
2	WILLIAMS ST		23-053	577	505
2	DEPOT ST		23-054	231	274
2	EAST ST	7	24-020	276	304
2	CHARLES ST	154	24-037	160	227
2	CHARLES ST	164	24-038	116	197
2	CHARLES ST	182	24-039	126	204
2	CHARLES ST	194	24-040	133	208
2	CHARLES ST	206	24-041	119	199
2	CHARLES ST	214	24-042	152	221
2	CHARLES ST	234	24-043	127	205
2	CHARLES ST	256	24-044	107	191
2	CHARLES ST	286	24-045	112	195
2	CHARLES ST	306	24-046	173	235
2	CHARLES ST	320	24-047	178	238
2	CHARLES ST	330	24-048	151	221
2	CHARLES ST	354	24-049	68	165
2	HILL ST	690	24-054	116	197
2	CHARLES ST	363	24-055	268	299
2	CHARLES ST	343	24-056	229	273
2	CHARLES ST	331	24-057	116	197
2	CHARLES ST	295	24-058	227	271
2	CHARLES ST	283	24-059	144	216
2	CHARLES ST	275	24-060	184	243
2	CHARLES ST	263	24-061	167	231
2	CHARLES ST	225	24-062	131	207
2	CHARLES ST	193	24-063	54	156
2	CHARLES STREET	177	24-064	85	177
2	CHARLES ST	169	24-065	72	168
2	CHARLES STREET	155	24-066	120	200
2	COLLEGE RD		30-001	154	223
2	COLLEGE RD	91	30-002	118	199
2	COLLEGE RD	81	30-003	122	201
Total				**96,800**	**93,000**

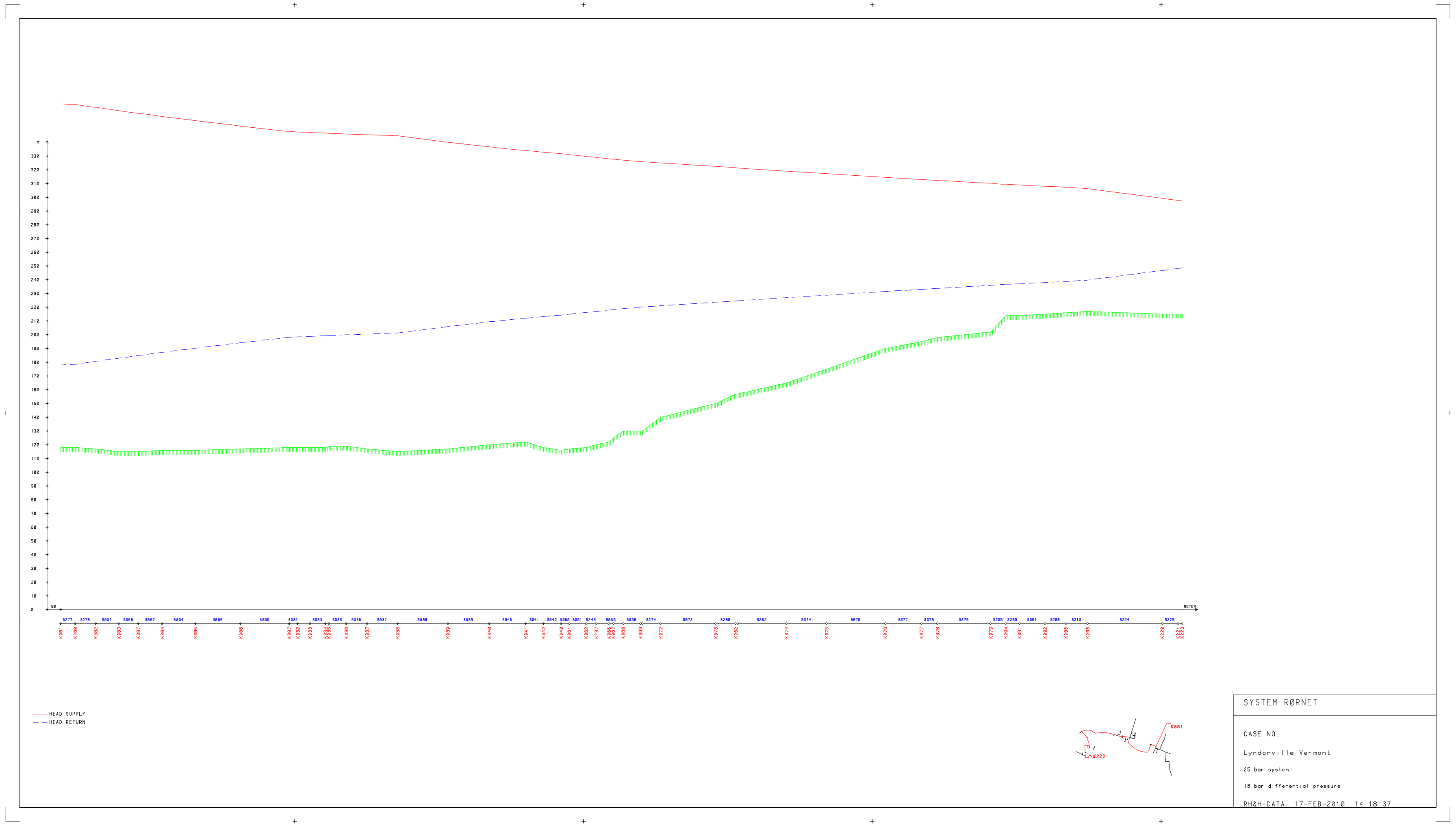
Appendix 2: Profile plot, 16 bar system, 14 bar differential pressure applied at energy centre.



Appendix 3: Profile plot, 16 bar system, 8.5 bar differential pressure applied at energy centre.

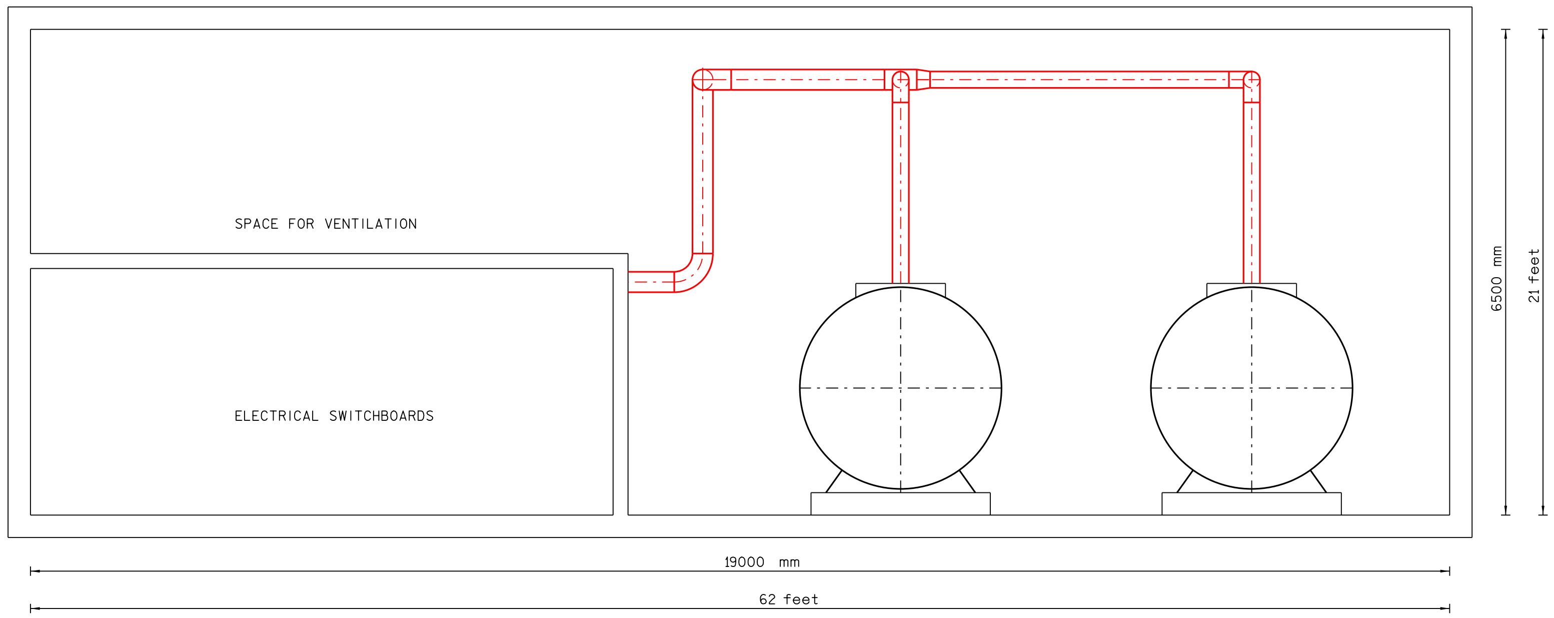


Appendix 4: Profile plot, 25 bar system, 18 bar differential pressure applied at energy centre.

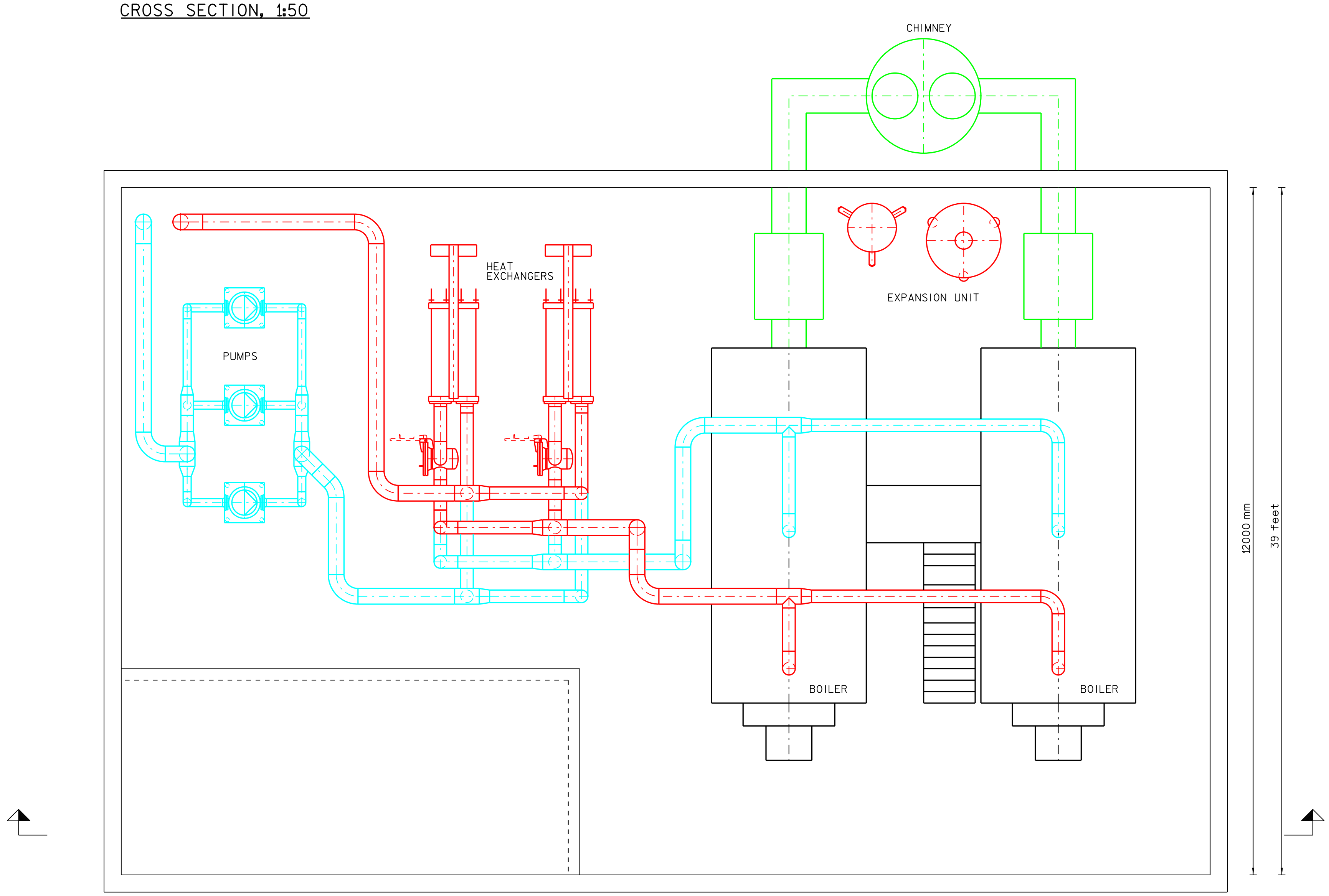


Appendix 5: Network dimensions, 16 bar system

Appendix 6: Network dimensions, 25 bar system



CROSS SECTION, 1:50



PLAN, 1:50

NOTE.
IF PRINTED IN A3 FORMAT, THE SCALE WILL BE 1:100

Edition.	Date	Drawn	Control	App.
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