Flintshire County Council

Phase 2 Rural District Heating Study - Nannerch

Sustainable ENERGY

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Sustainable ENERGY

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List of Abbreviations

ASHP	Air source heat pump
AQMA	Air quality management area
CHP	Combined heat and power
CAPEX	Capital expenditure
DHN	District heat network
EfW	Energy from Waste
FCC	Flintshire County Council
GIS	Geographic Information System
GSHP	Ground source heat pump
HIUs	Heat interface units
HNCoP	Heat Networks Code of Practice
IRR	Internal rate of return
kWh	Kilowatt hour
LTHW	Low temperature hot water
NPV	Net present value
RHI	Renewable heat incentive
SE	Sustainable Energy
SPF	Seasonal performance factor (for heat pumps)
WSHP	Water source heat pump

Glossary

Heat clusters	A group of buildings/sites based on heat demand, location, barriers, ownership and risk
Heat demand	The heat requirements of a building or site, usually shown as an annual figure in megawatt hours (MWh) or kilowatt hours (kWh)
Linear heat density	Total cluster heat demand divided by indicative pipe trench length between buildings/sites within the cluster, although linear heat density does not consider pipe diameter it provides a high level indicator for the potential viability of network options and phases
Renewable technologies	Technologies that produce energy from resources which are naturally replenished such as sunlight, wind, geothermal heat, or water source heat
Heat clusters	A group of buildings/sites based on heat demand, location, barriers, ownership and risk
Heat demand	The heat requirements of a building or site, usually shown as an annual figure in megawatt hours (MWh) or kilowatt hours (kWh)

EXECUTIVE SUMMARY

This report presents the findings of a review of heat network options for the village of Nannerch, Flintshire.

Overall Project Priorities

Flintshire County Council (FCC) priorities include:

- Reducing energy costs of vulnerable households
- Reducing CO_2e emissions
- Opportunities to generate income and increase energy security

Issues that can restrict access to affordable warmth and increase fuel poverty include:

- Off grid location – many rural buildings are not connected to the main gas grid, often leading to increased fuel cost and carbon emissions (if oil heated)
- Older building stock – many buildings in rural areas are older solid wall buildings with high heat losses
- Rural temperatures – these are generally lower than urban temperatures and can lead to increased building heat demand
- Lower heat density – in many rural areas, heat density is low reducing the economics of communal and district heating schemes

It should also be noted that decentralised / district energy projects can benefit rural economies both in construction (e.g. civil works delivered by local contractors) and operation (e.g. development of a local woodfuel supply chain).

Data Collection and Review

The first stage of the work involved a data collection exercise that a required site visit, discussions with FCC and email correspondence with key stakeholders. We received feedback, building energy data and other relevant information from FCC and other stakeholders.

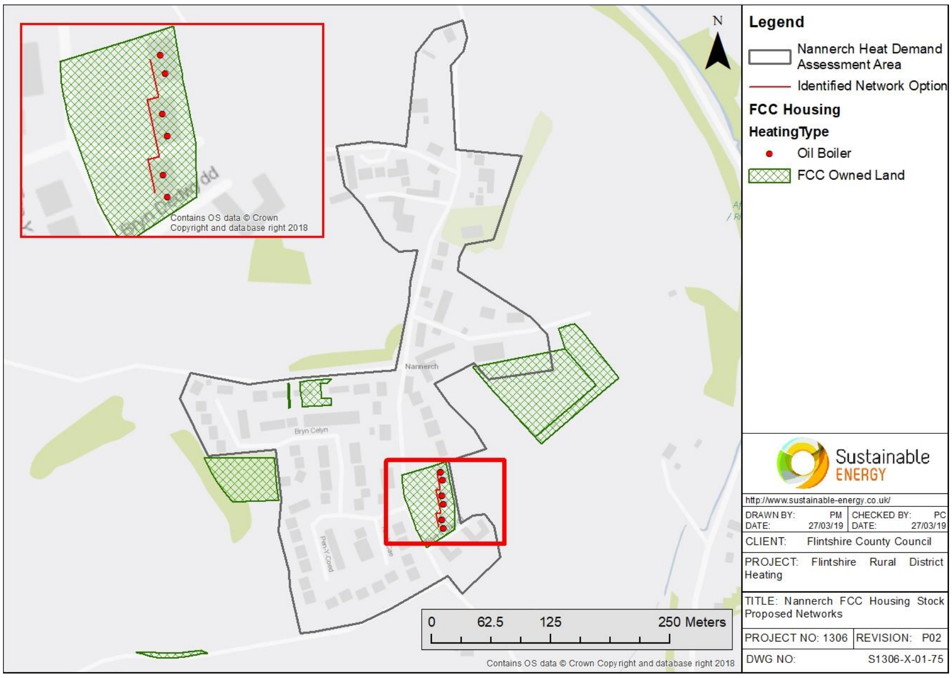
The FCC planning website and Local Development Plan were reviewed to establish the nature of developments and the likelihood of them being brought forward.

Heat Demand Assessment

Energy demand models were produced for existing buildings and planned developments and the heat demand profiles were combined to assess the overall demand for various network options.

The key heat demands include Ysgol Nannerch VC and Saint Michael and All Angels Nannerch.

FCC own several domestic properties within the heat demand assessment area (see adjacent).



Network Assessment

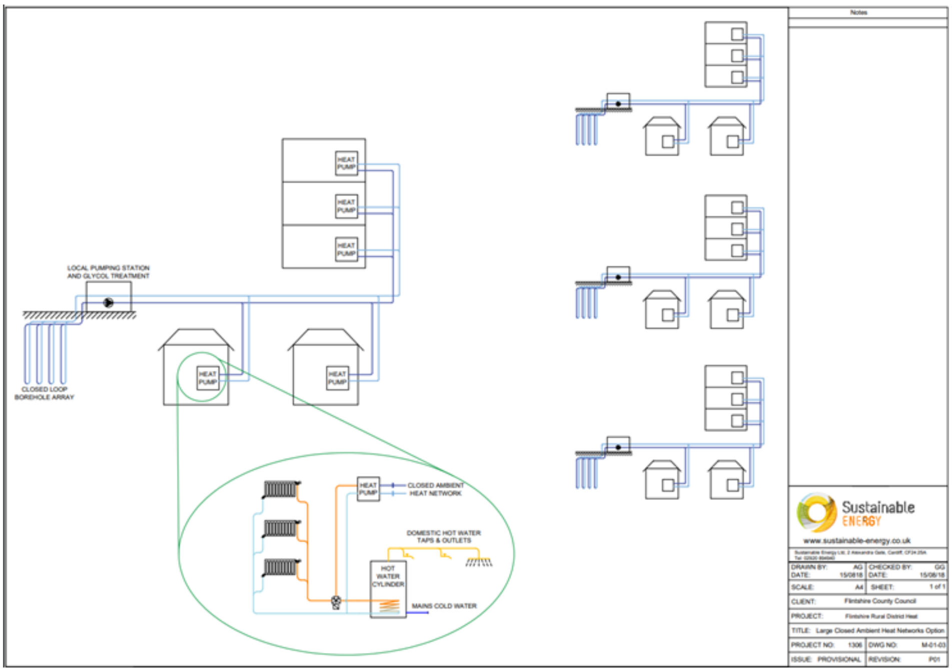
Discussion held with the client group indicated that a village wide network was very unlikely to be taken forward by FCC due to varied ownership, issues around fuel supply, low linear heat density and challenging economics.

One potential network option has been identified; a small closed loop system supplying individual heat pumps in FCC-owned properties at Bryn Dedwydd. This opportunity will have marginal economics and will be significantly impacted by the availability of non-domestic RHI and grant funding.

GSHP Option Assessment

Ground source heat pumps were found to be the preferred, and most beneficial, solution for Nannerch. Several ground source heat pump options we assessed including various closed loop and open loop options. A closed loop GSHP option was taken forward for further assessment. Traditional district heating scheme options were ruled out. A closed loop GSHP was chosen over an open loop GSHP due to the unlikely availability of sufficient groundwater (flowrate) and the potentially favourable ground conditions for a ground heat exchanger loop.

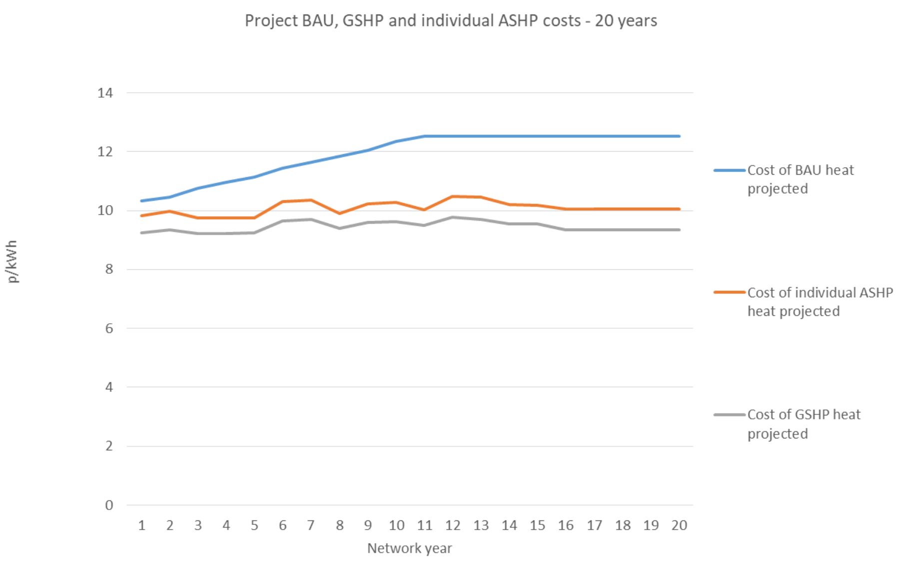
Heat is abstracted from the ground via brine circulating through plastic piping installed vertically in boreholes (ideally located on FCC land). The water is circulated (at source temperature) around the network and heat is supplied to the houses and buildings by individual heat pumps. Network size is usually determined by borehole capacity and amount of heat required; typical networks consisting of small clusters of domestic properties (~5 dwellings) connected to one borehole (100-200m depth) (see adjacent image).



Even with grant funding and RHI, there are no economic returns for FCC on the investment in the GSHP project. The reasons for this include:

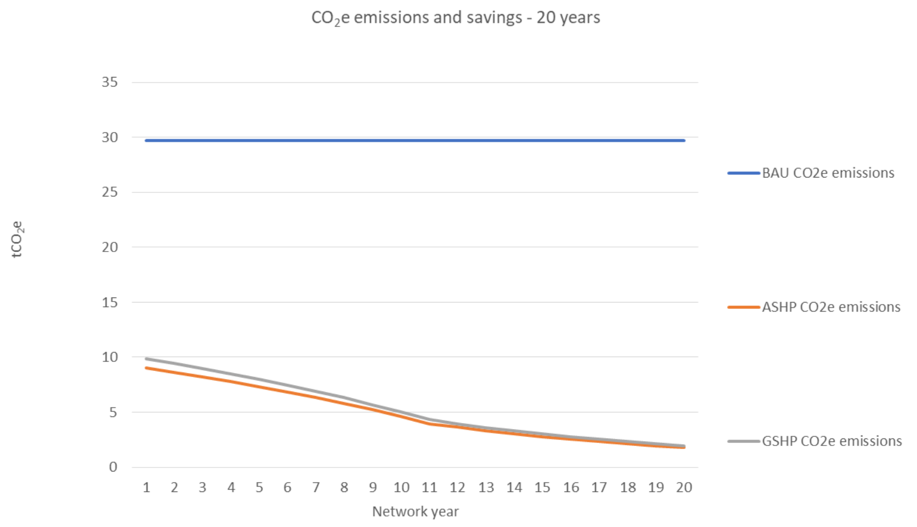
- The high project CAPEX that includes drilling boreholes and replacing internal heating systems such as radiators
- Some of the economic benefits associated with the scheme are passed to FCC tenants (i.e. the lower total cost of heat)

When the savings against BAU heating costs (i.e. oil boilers) for the FCC tenants are included (as well as grant funding and RHI), the overall project economics improve significantly to give a positive NPV. The GSHP option provides significant economic and carbon savings for the FCC tenants (see adjacent). As the GSHP option is more efficient than the ASHP options, the cost to the end user is lower. The carbon intensity of the heat and energy tariff risk could be further reduced if the heat pumps are partly supplied with electricity from solar PV (potentially with battery storage).



The advantage of the GSHP option over individual ASHPs are as follows:

- There is less noise impact with the GSHP option
- As the ASHPs will need to be located externally, the GSHP option has a lower visual impact and lower space requirements
- The GSHP option has a higher seasonal CoP and a higher CoP during the colder winter months (when the ASHP will be far less efficient)
- Non-domestic RHI is potentially available to support the GSHP option over 20 years (domestic RHI revenue only received for 7 years)



However, ASHPs are easier to retrofit and will provide a lower CAPEX option.

The main risks associated with the GSHP option are:

- Residential heat demands have been modelled but have been verified using data for FCC housing stock
- Electricity tariff significantly impacts project economics
- The project economics are significantly reduced without non-domestic RHI; RHI tariffs are subject to degression and the scheme is planned to close in March 2021
- Securing a location for boreholes and drilling needs to be carefully managed during the construction process
- Grant funding may not be secured; to avoid 'double funding' it has been assumed that the grant is used to fund the building upgrades and other works but not the close loop system itself
- Project IRR is significantly impacted by increase in CAPEX

The closed loop GSHP option has challenging economics, however it support FCC's carbon reduction strategy, renewable energy action plan and improvement plan and could be supported by public sector funding.

Next steps

The following next steps and recommendations should be considered by FCC:

- Decide whether to progress the GSHP project
- Endeavour to bring the project forward prior to the closure of the RHI scheme (potentially March 2021)
- If grant funding and RHI are being sought, carefully assess state aid rules and liaise with OFGEM to maximise grant funding and RHI revenue whilst avoiding 'double funding'
- If the project is not brought forward prior to the closure of the scheme, then fully assess the impact of any future subsidy and/or changes to fossil fuel tax on the schemes
- If a pilot project is progressed, undertake detailed monitoring to compare the GSHP performance with the existing ASHPs in FCC's buildings
- Engage with and support planning consents and highways activities

1 INTRODUCTION

1.1 General

Sustainable Energy have been commissioned by Flintshire County Council (FCC) to produce the Flintshire Rural District Heating Feasibility Study, a two-phase study into the potential for district heating in rural areas of the County of Flintshire. The study will assess 9 rural areas in Flintshire and undertake heat mapping and masterplanning studies on a prioritised selection.

This report presents potential opportunities for district heat networks in the village of Nannerch. Assessments were conducted in line with the CIBSE Heat Networks Code of Practice (HNCoP).

1.2 Project Scope

We were commissioned to undertake the following:

- Explore existing or planned rural district heating schemes within the UK with key learnings and potential applicability to Flintshire
- Determine the feasibility of rural district heating in Flintshire highlighting opportunities and barriers
- Identify opportunities for renewable energy generation assessing innovative technologies that could be demonstrated
- Identify measures to reduce the energy costs of vulnerable households as well as reducing greenhouse gas emissions
- Identify measures to reduce Council energy costs as well as meeting the Council's carbon reduction targets

The Flintshire Rural District Heating Feasibility Study will include two distinct phases. The phase 1 studies will provide a high-level screening and feasibility and phase 2 will be a heat mapping and masterplanning stage. To complete phase 1 we:

- Provided an overall review of existing and planned rural district heating schemes in the UK (see Introduction to Rural District Heating Report 2018 report)
- Summarised key learning (see Introduction to Rural District Heating Report 2018 report)
- Delivered a high level feasibility study for each area
- High-level energy mapping and modelling
- High-level assessment of potential heat sources for identified options, including high-level technology assessment, CAPEX assessment and identification of potential benefits and barriers.
- Prioritised opportunities and recommended schemes to be assessed further during heat mapping and masterplanning in phase 2

This report presents the heat mapping and masterplanning for the area of Nannerch. Phase 2 tasks include:

- Assessing energy supply and energy centre/central plant options
- Identify and confirm lowest cost and impact network route
- Produce initial economic assessment of scheme options and provide options appraisal to inform recommended scheme to progress to detailed feasibility stage

1.3 Project Drivers and Objectives

Funding for the project has been received by FCC through the Welsh Government Rural Communities – Rural Development Programme 2014-2020 which is funded by the European Agricultural Fund for Rural Development and the Welsh Government, administered by Cadwyn Clwyd (Rural Development Agency) in North East Wales.

There have been no previous heat demand studies in the areas identified and FCC's priorities and project drivers include:

- Reducing energy costs for vulnerable households
- Reducing GHG emissions
- To reduce council energy costs
- To meet FCC's carbon reduction targets (60% reduction in own emissions by 2021)

- To provide opportunities to generate income and increase energy security

1.3.1 National Policy

The key national policy objectives for district energy networks are:

- Carbon reduction, as set out in the Climate Change Act (2008)
- Energy security, heat networks are recognised as a resilient energy infrastructure
- Sustainable development, as detailed in the National Planning Policy Framework
- Economic development, where heat can be produced and delivered more cost effectively than the counterfactual

National policy includes:

- Energy Act (2013) - makes provision for the setting of Contracts for Difference (CfD) which will support renewable energy electricity generation, including CHP plant such as Energy Works
- Climate Change Act (2008) – includes targets for UK CO_2e emission to be at least 80 % lower than the 1990 baseline by 2050
- National Policy Statement for Renewable Energy Infrastructure EN-3 – promotes development of new energy infrastructure to deliver a secure, diverse and affordable energy supply
- National Planning Policy Framework (2012) - promotes sustainable development and encourages local authorities to establish low carbon energy generation schemes
- The future of heating: meeting the challenge (2013) - heat networks are included as one of five options for building heat infrastructure

1.3.2 Local Policy

There are several local policies currently deployed by FCC, including two key documents, namely the Carbon Reduction Strategy and the Renewable Energy 10-year Action Plan:

There are several local policies currently deployed by FCC, these include:

- Carbon Reduction Strategy – set out in 2007 to reduce its emissions by 60 % by 2021 through the targets set in the Carbon Reduction Strategy, such as implementation of energy efficiency measures and deployment of renewable energy technologies across the county. Aims of the Carbon Reduction Strategy include:
    - To help to achieve national carbon targets
    - Reduce the risks of fossil fuel price volatility and hence revenue cost and Carbon Tax implications to the authority
- Renewable Energy 10-year Action Plan – as part of the Carbon Reduction Strategy, FCC set out the Renewable Energy 10-year Action Plan to continue towards its target of 60 % reduction in emissions by 2021. Aims of the Renewable Energy Action Plan include:
    - To help develop the renewable energy industry locally to support the growth of sustainable jobs
    - Reduce reliance on imported energy sources
    - Reduce risks associated with rising energy prices
    - Consider in the medium to long term the opportunities to sell generated energy to third parties and the Fuel Poor at competitive rates
    - Investigate opportunities to create energy from waste (EfW)
- Improvement Plan 2017-2023 – sets out FCC's aims to work with local partners as a Public Services Board to combine resources for the benefit of Flintshire. The aims of the plan include:
    - Reducing energy consumption and using and developing alternative / renewable energy production
    - Maximising the recovery and recycling of waste
    - Reduce the impact of rises in fuel cost

2 HEAT MAPPING

2.1 Review of the Heat Map Area

We reviewed and provided advice regarding FCC's proposed heat map area. Considerations included existing buildings, domestic loads and planned developments. After investigations the red line boundary shown in Figure 1 was confirmed. This area reflects the development boundary for Nannerch.

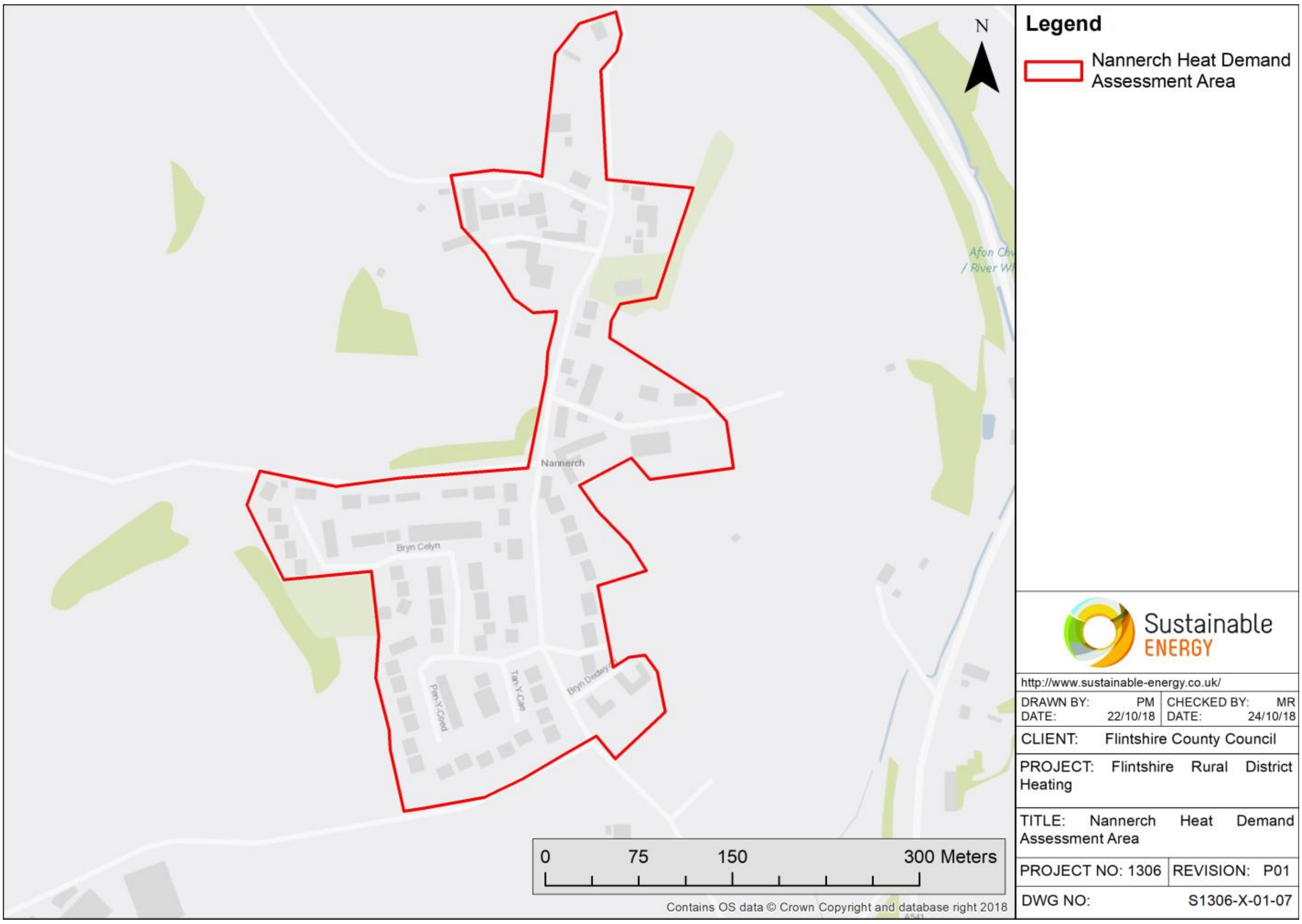


Figure 1: Heat map area

2.2 Data Collection

The purpose of the data collection exercise was to enable detailed energy mapping of existing and future energy demands and potential heat sources. An extensive list of potential heat loads and key energy sources within the heat map area was compiled.

2.2.1 Planned Developments

Planned developments may provide significant energy demands that should be considered when assessing district energy scheme options. There are opportunities to safeguard and futureproof layout and design to allow compatibility with and connection to existing or planned district energy networks.

We reviewed strategic documents and development plans to ensure that all future heat demands inform network development. This involved liaison with relevant individuals within FCC's planning department and included assessment of density, timeframe and phasing. It also included a review of FCC's planning policy.

The key documents reviewed were the:

- Local Development Plan 2015-2030: Preferred Strategy Consultation Document Background Paper, Consideration of Candidate Sites against the Preferred Strategy / Invitation for Alternative Sites (November 2017)
- Planning applications
- Recent planning permissions

There are a number of risks associated with energy mapping and basing network assumptions around planned developments, these include:

- The planned development not coming forward - there is no certainty as to whether all of the planned developments will come forward or that planning permission will be granted
- Committed developments not being built out
- Changes to the density, scale and timing of planned developments
- Connection risk - the developers not engaging with the heat network process and/or the potential network provider so that new buildings are not 'network-ready' or do not connect to an existing network

Conversely, there may be potential for the density of developments to increase and this higher linear heat density could improve the viability of networks.

2.2.2 Existing Non-domestic Buildings

Figure 2 shows the existing non-domestic buildings and sites within the heat map area. Further details of these are shown in Table 1.

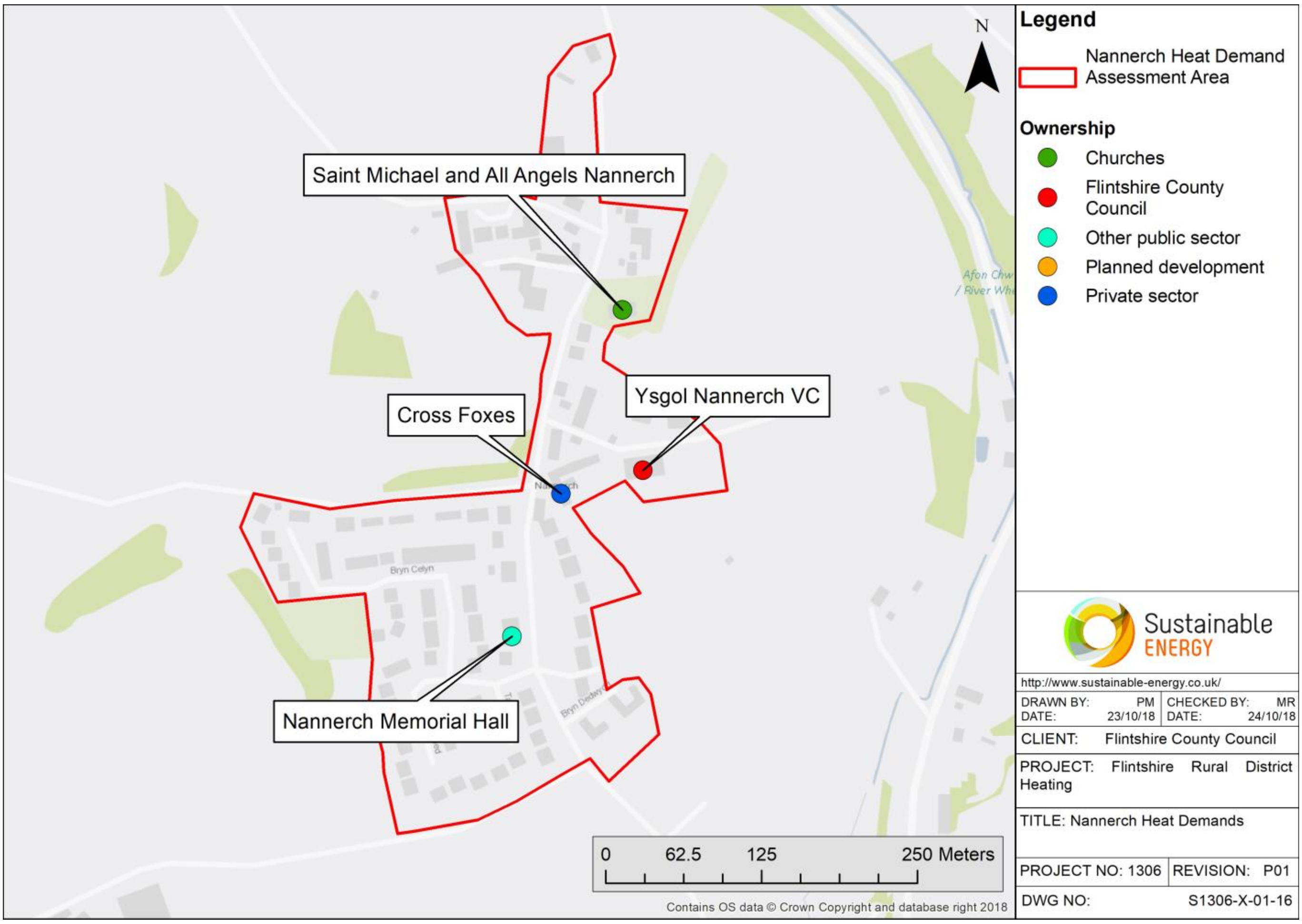


Figure 2: Existing non-domestic buildings

Table 1: Current information on existing buildings

Building/site name	Ownership	Available information
Nannerch Memorial Hall	Community Council	• Village hall
Cross Foxes	Private	• Public house
Saint Michael and All Angels Nannerch	Church in Wales	• Church
Ysgol Nannerch VC	FCC	• Primary school

2.2.3 FCC Housing Stock

Flintshire County Council own several domestic properties within the heat demand assessment area, shown in Figure 3 below.

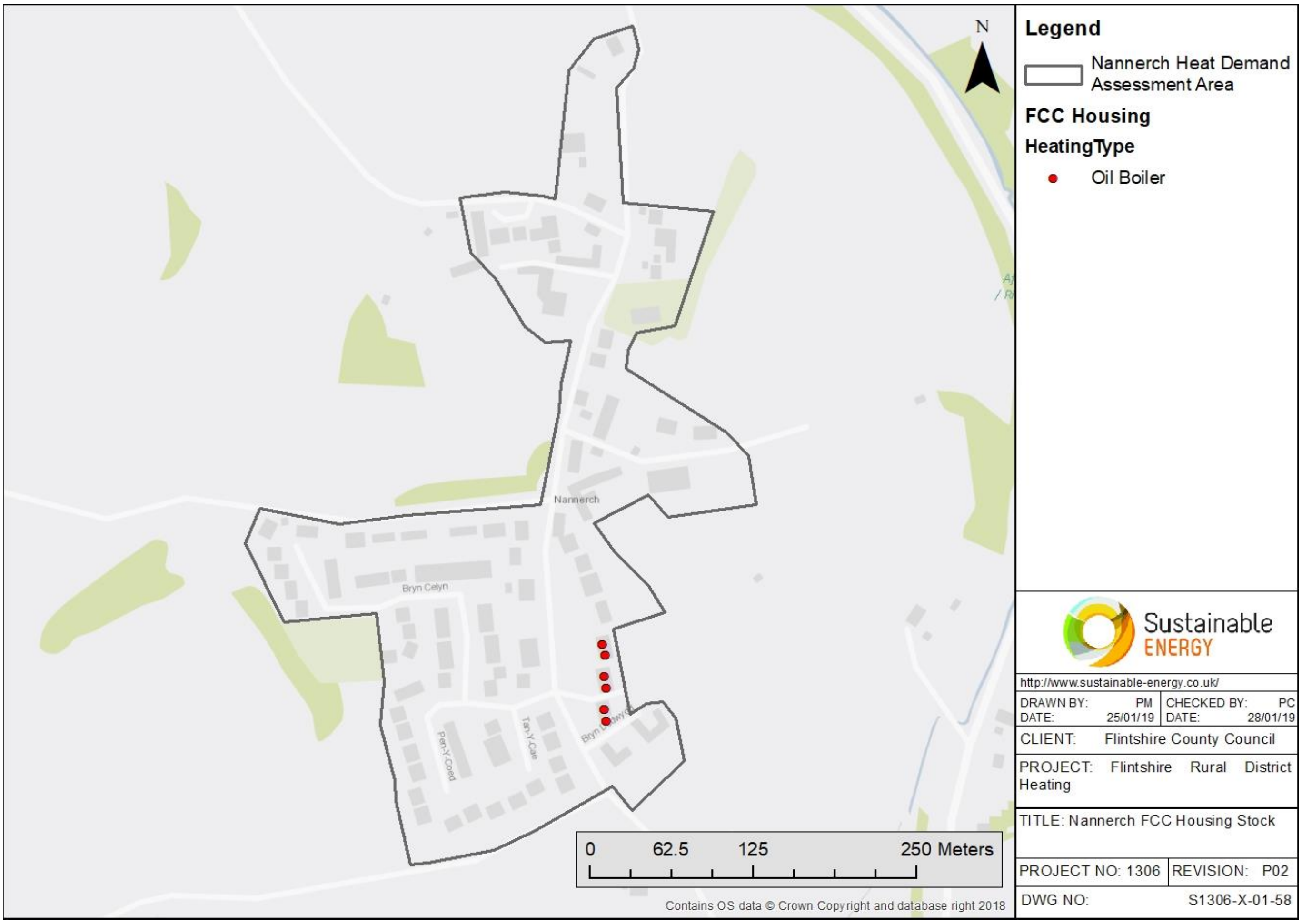


Figure 3: FCC housing stock

2.2.4 Fossil Fuel Consumption Benchmarking

Where actual energy data was not available domestic, non-domestic and industrial data for similar buildings was used to verify the expected fossil fuel consumption to be used in energy profiling (the source of all data has been identified in Appendix 2 – Energy Data). The fossil fuel consumption value was estimated; using gross floor area determined from the building plans or masterplans (where available) and assumed areas where no data exists. A tried and tested approach was then used to generate demand profiles verified by the benchmarked fossil fuel consumption, building type and use. We hold a database of hundreds of hourly annual demand profiles for a wide range of building types and these were adapted to provide an indicative heat demand profile for each site.

2.3 Energy Demands

Annual fossil fuel consumption values from historical data and data for similar buildings were used to determine an annual heat demand value for each potential key heat load within the heat map areas. The calculated annual heat demand values are listed in Appendix 2 – Energy Data.

2.3.1 Heat Demand Profiling

To further analyse heat demands, hourly heat demand profiles were constructed. The profiles were generated using in-house modelling software which apportions the annual heat demand figure into hourly loads over the year, considering degree day data[1], building use, occupancy, diversity and operating strategy. The in-house modelling software utilises a comprehensive database of hourly data from a wide range of buildings.

For each building/phase, the annual demand model was then used to identify the average, maximum and minimum hourly demand throughout the year. An example average, maximum and minimum heat demand profile is shown in Figure 4 (domestic load).

The profiles of typical winter and summer days were also produced to identify the demand variation on both a day-by-day and seasonal basis. The typical winter and summer profiles for a domestic load are also shown in Figure 4, by the green and blue lines respectively.

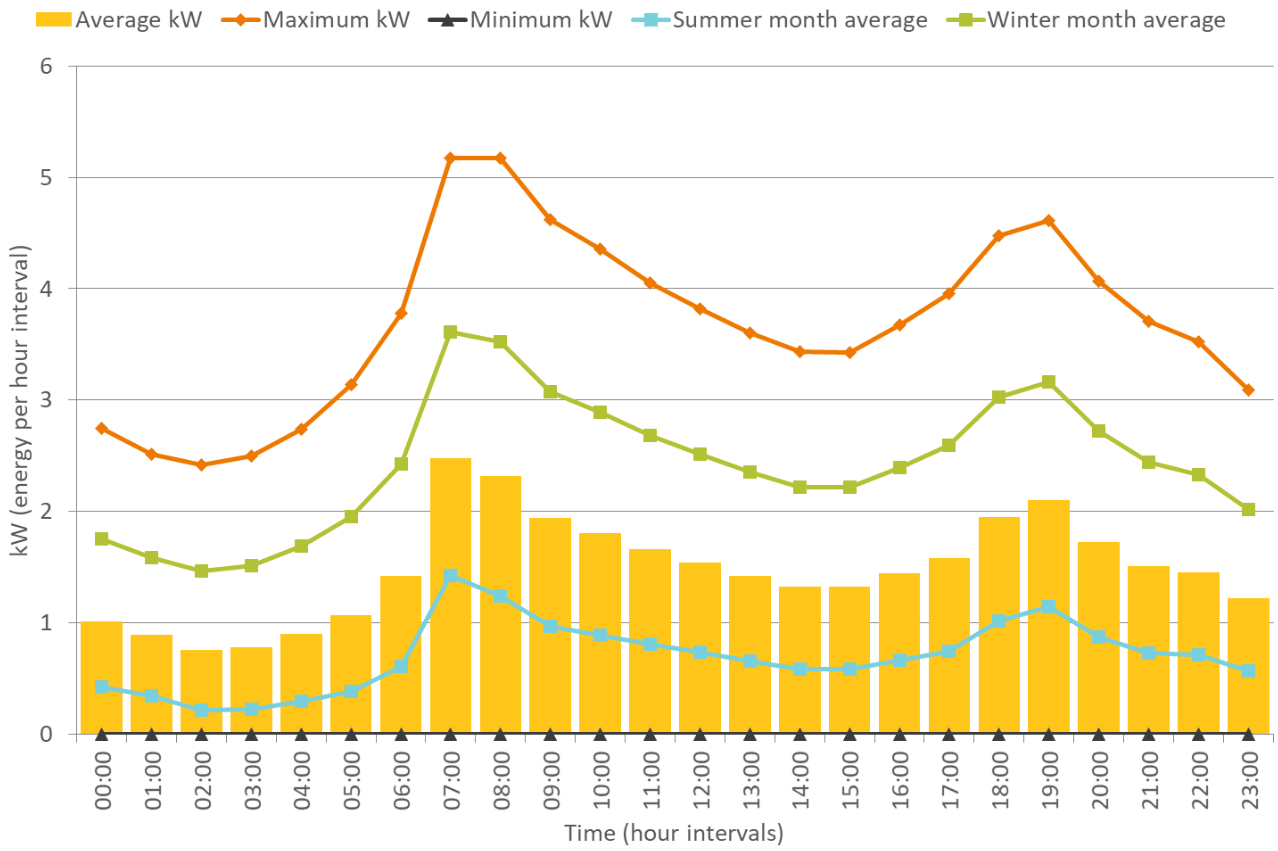


Figure 4: Average, maximum and minimum heat demand profile for an example domestic property

[1] Degree days are a type of weather data calculated from outside air temperature readings. Heating degree days and cooling degree days are used extensively in calculations relating to building energy consumption. They are used to determine the heating requirements of buildings, representing a fall of one degree below a specified average outdoor temperature (15.5°C) for one day.

2.4 Energy Mapping Results

Geographic Information System (GIS) software was used to map the identified heat demands. The symbols show the site location and graduate in size according to energy demand to depict the nature of the energy loads within the heat map area. The larger the symbol, the greater the energy demand. The demands for all buildings/sites are shown in Appendix 2 – Energy Data.

2.4.1 Heat Demands

The key heat demands are shown in Figure 5 and Table 2. The largest heat demand arises from Nannerch Memorial Hall (58 MWh) located to the east of the heat map area. As no energy data was received, the heat demand for this site has been estimated based on consultant experience of similar sites.

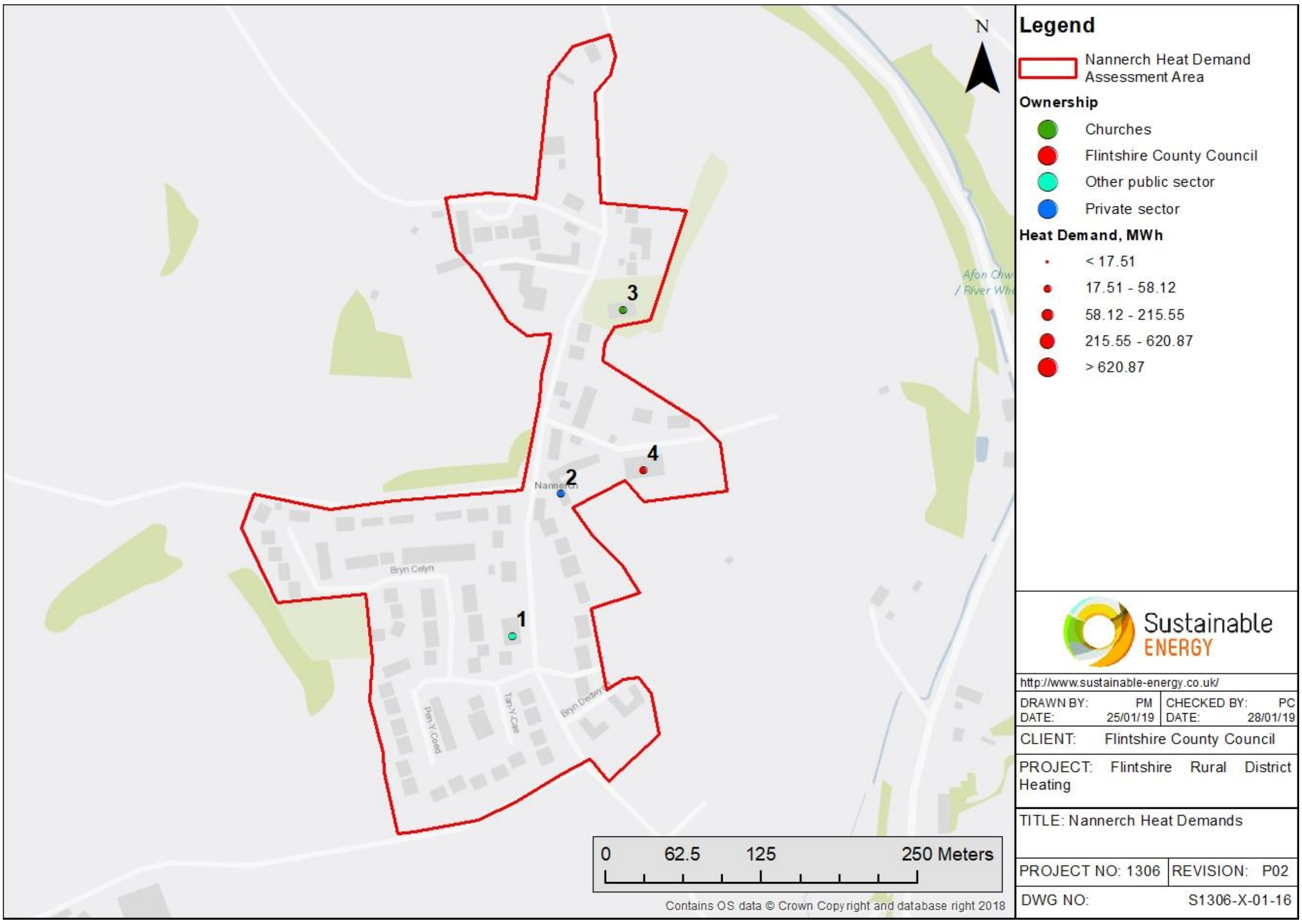


Figure 5: Non-domestic heat demands

Table 2: Heat demands

Ref	Name	Building use	Status	Heat demand, kWh
1	Nannerch Memorial Hall	Village Hall	Existing	58,115
2	Cross Foxes	Public House		31,708
3	Saint Michael and All Angels Nannerch	Church		37,173
4	Ysgol Nannerch VC	Primary School		46,411

2.5 Potential Energy Sources

Energy sources with potential to supply a network at Nannerch were investigated. Figure 6 shows the potential energy sources identified. A summary of these is shown in Table 3.

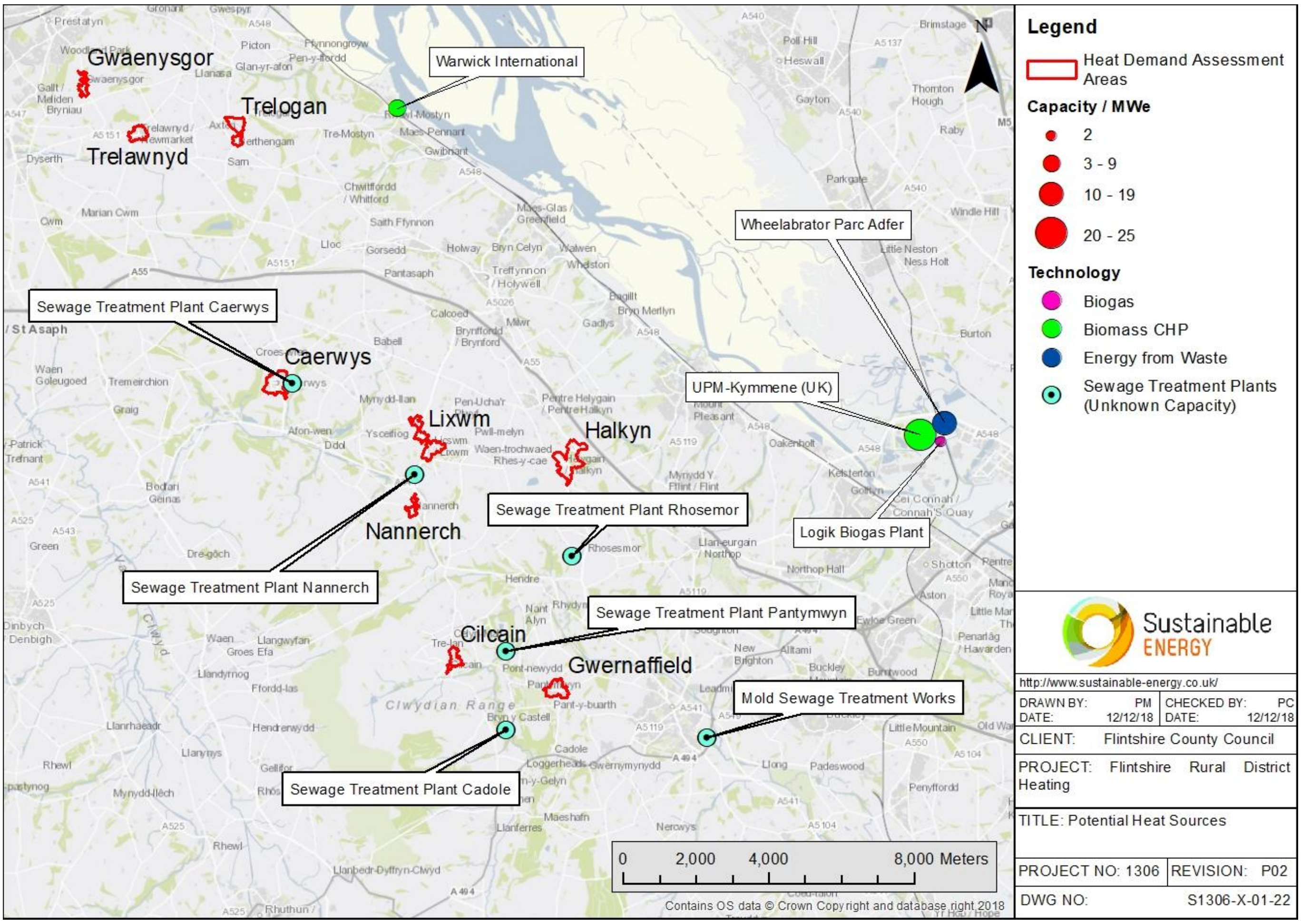


Figure 6: Potential energy sources

Table 3: Summary of potential energy sources

Potential energy source	Developer / owner	Status	Assessment of potential to supply energy to network	Taken forward?
Nannerch sewage works	Unknown	Existing	• Significant distance from key heat loads (~1 km) • Small sewage works, unlikely to provide opportunity for biogas CHP	No
Biogas plant	Logik	Planned	• Significant distance from key heat loads (~14.5 km) • Small (2 MW) amount of electricity generation, so no opportunity for significant heat offtake	
Energy from Waste	Wheelabrator Parc Adfer		• Significant distance from key heat loads (~15 km) • Large electricity generation capacity (19 MW)	
Biomass CHP	UPM-Kymmene (UK)	Existing	• Significant distance from key heat loads (~14 km) • Large electricity generation capacity (24.8 MW)	
Biomass CHP	Warwick International		• Significant distance from key heat loads (~11 km)	

Following an initial assessment, it was concluded that the existing and planned energy sources to the east and north of the assessment area not be taken forward for further consideration for heat offtake, primarily due to the significant distance from the sites to the key heat loads. It was also concluded that the sewage works would not be taken forward for further consideration due also to the distance from heat loads and the small scale of the sites indicating that they would be unlikely to provide the opportunity for a biogas CHP installation and heat supply.

2.6 Mine and Water Sources

Water sources with potential to supply a heat pump in Nannerch were investigated. Figure 7 shows an assessment of the ground water aquifer in the Flintshire area. Nannerch is in an area identified as potentially less favourable for open-loop ground source assessment, additionally historic boreholes show a generally low flow rate for the Flintshire area.

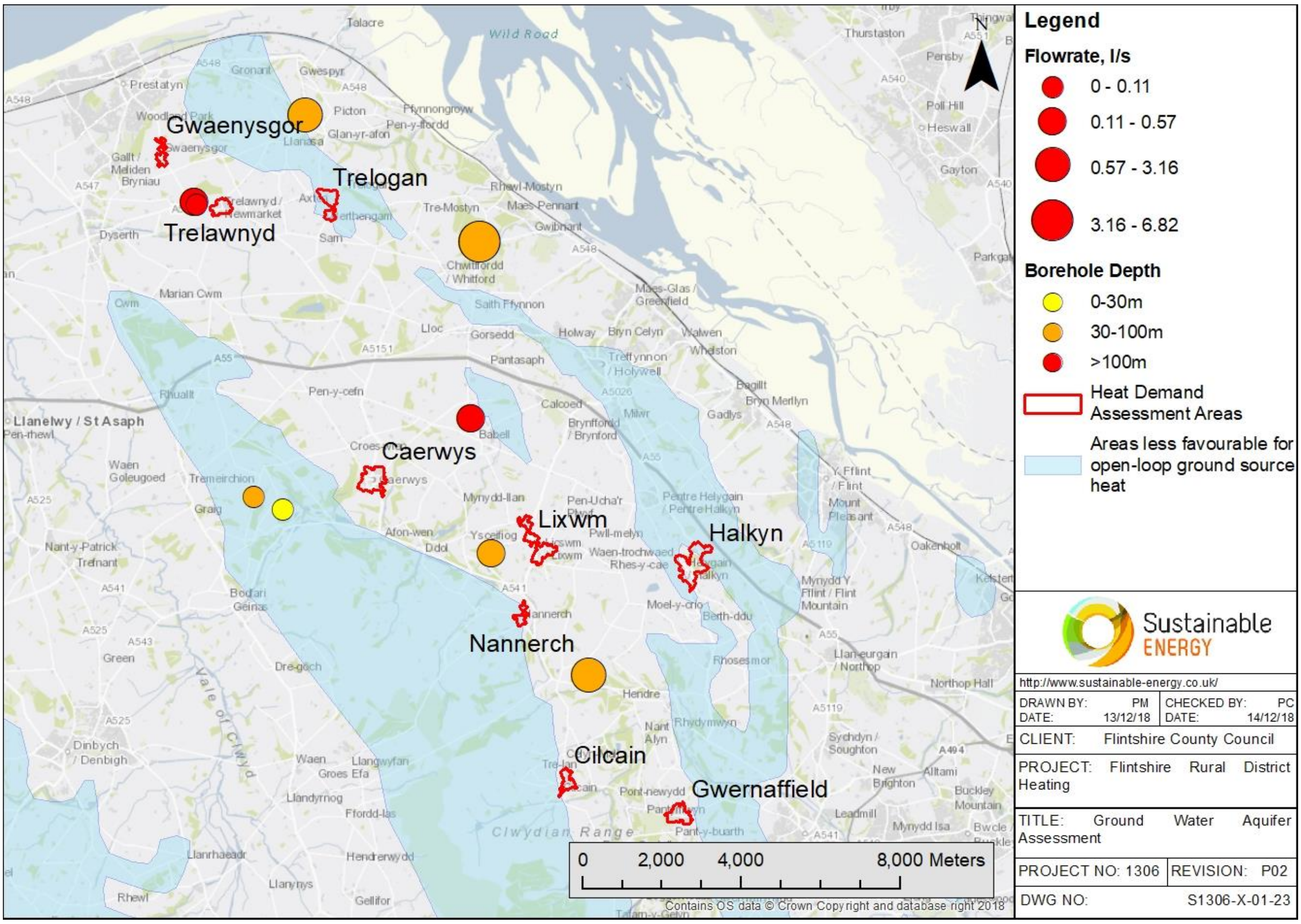


Figure 7: Ground water aquifer assessment

Figure 8 shows the location of all identified mine shafts, bodies of water and quarries. One body of water was identified close to the south-west of the village, but wasn't deemed suitable as the small body of stationary water would be unable to supply sufficient flow rate. There are no mine shafts within the heat demand assessment area and no significant number of mine shafts identified around Nannerch. One shaft is found to the north-east of the boundary (Figure 9), though the extent of the workings are unknown and more investigation would be required to rule it as a potential heat source or not. The village of Nannerch lies a considerable distance from the Milwr Tunnel, which was identified and located accurately through discussion with a local mining historian. This 10 mile drainage adit connects to and drains hundreds of old mines and lodes. Flow rate at the portal end can vary between 1210 and 1900 litres per second and according to historic monitoring data, the flowrate beneath may be around 35 litres per second. It was estimated water may be at a temperature of around 14°C. The tunnel is owned and managed by United Utilities and flow at the portal end is used for industrial purposes as part of papermill activities. Increased pipe costs, logistics of installing a pipe and huge efficiency losses from pumping would negate any temperature benefit gained from abstracting water from such a resource.

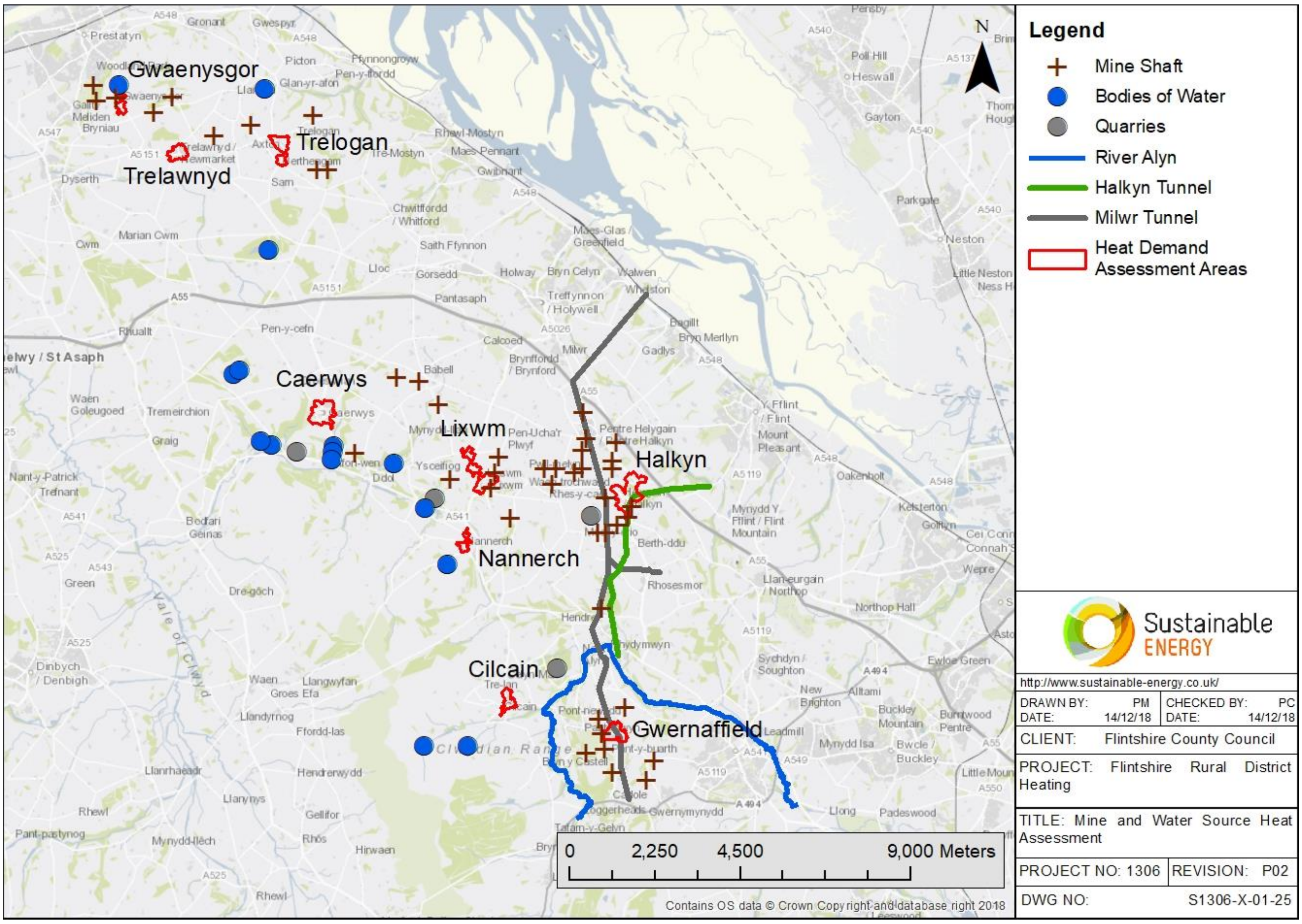


Figure 8: Mine and water source heat assessment

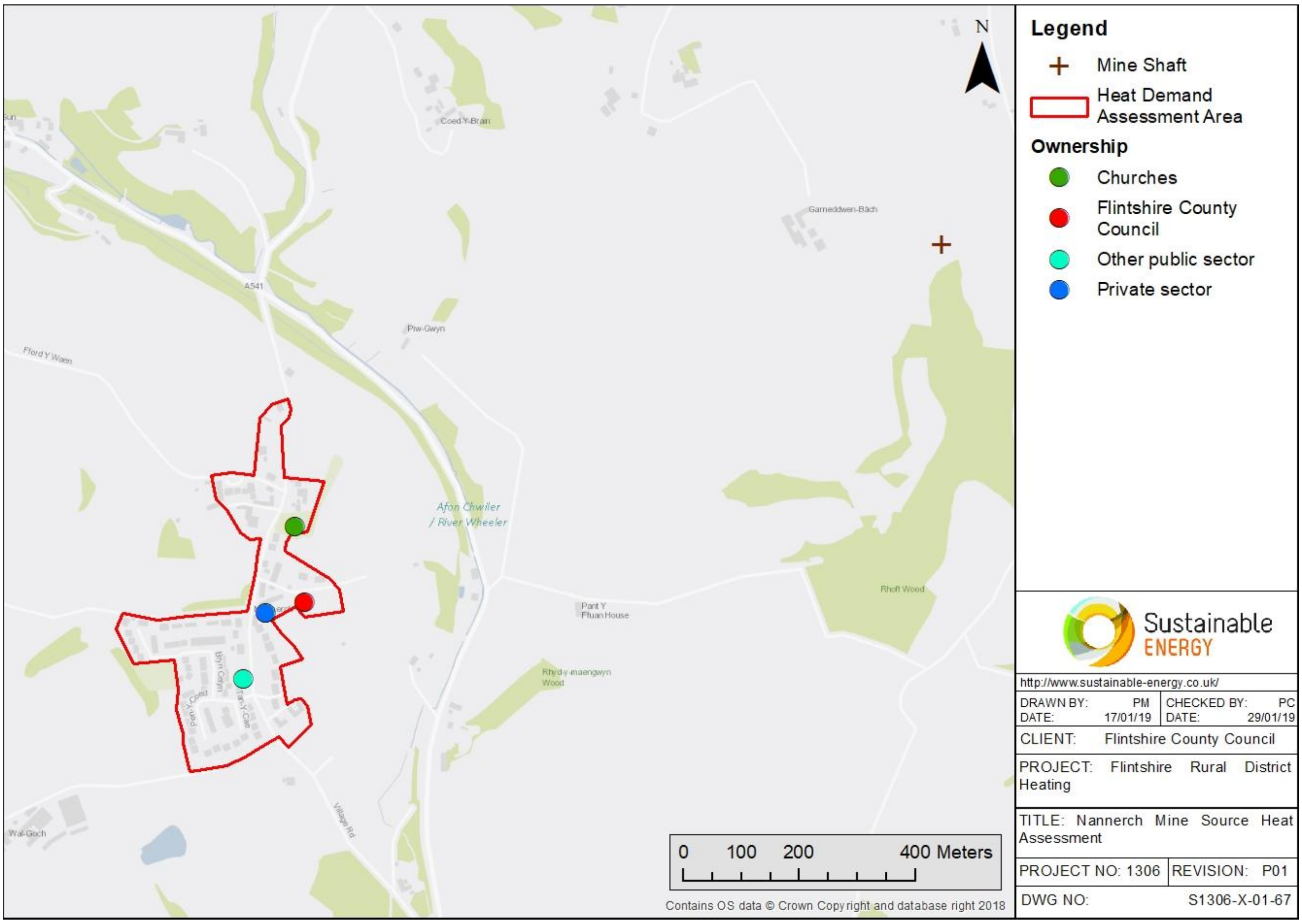


Figure 9: Nannerch mine source heat assessment

2.7 Potential Site Barriers

Existing key utilities and other infrastructure (including planned upgrades), local designations (such as Conservation Areas and local wildlife sites), site topography, areas of FCC owned land and development barriers were investigated to determine whether they pose any potentially significant risks to the development of district energy networks.

Figure 10 highlights potential site barriers, risks and issues for network development, pipe routes and energy centre locations.

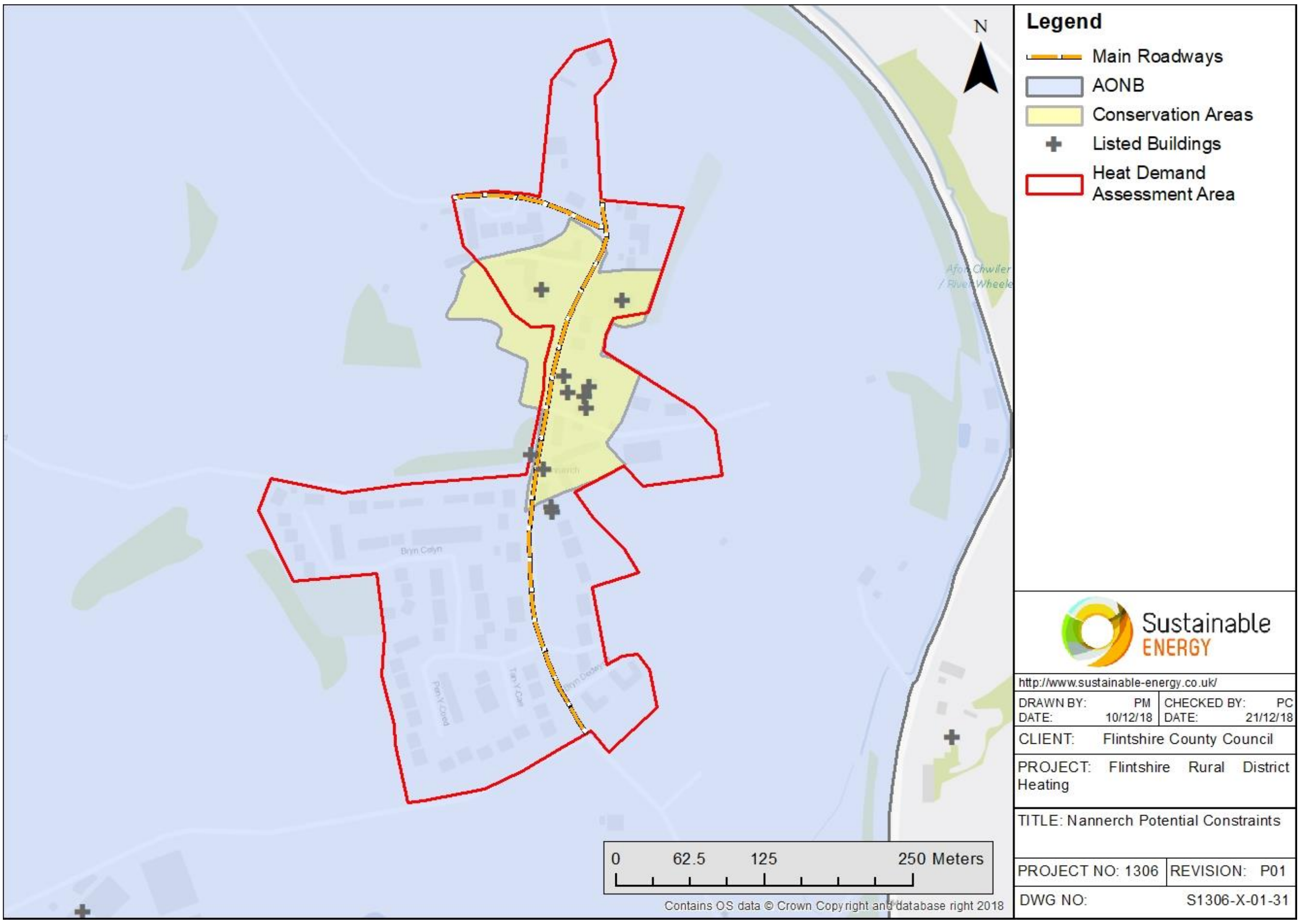


Figure 10: Potential site barriers, risks and issues for district energy network development

Several potential barriers, risks and issues have been identified within the heat map area. The heat demand assessment area falls within an AONB and a large proportion of the village is designated as a conservation area. No significant archaeological constraints were identified within the heat map area, besides a handful of listed buildings, one of which being the Church of St Michael and All Angels. There is a main road which intersect the heat demand assessment area, dividing the heat demand assessment area into two.

Figure 11 shows the high-level terrain for the heat map area. Gradient is unlikely to pose a risk to the development of a heat network or the location of the energy centre and the changes in elevation present no significant technical challenge to the pumping requirements of a district heat network.

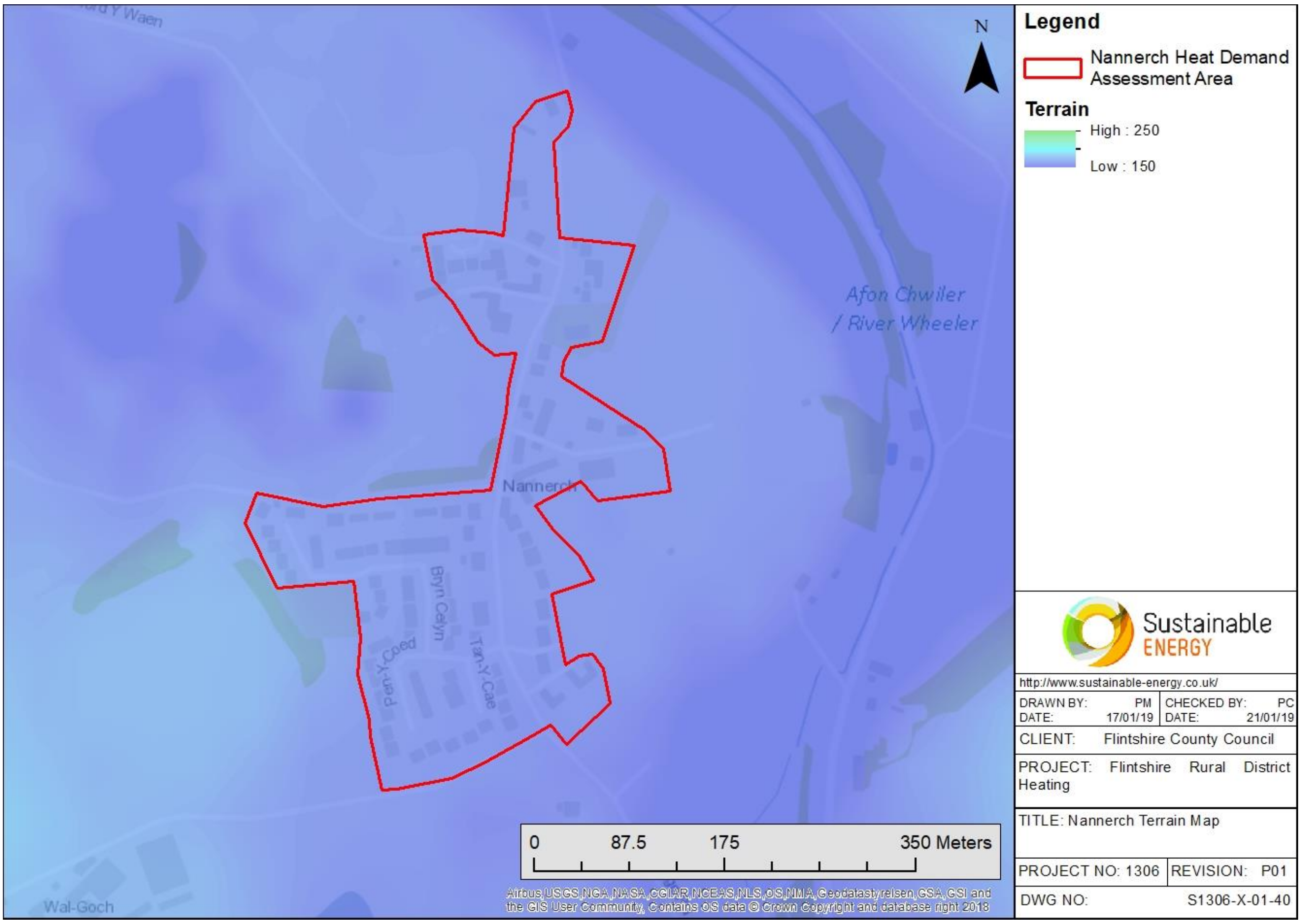


Figure 11: Terrain map for the heat map area

3 OPTIONS ASSESSMENT

The outputs from the energy mapping exercise were assessed to inform the development of low carbon district heat network options. This energy report identifies, evaluates and prioritises potential district energy scheme opportunities and constraints. All work meets the objectives and sub-objectives within section 2 of the CIBSE/ADE Heat Networks Code of Practice (relevant to this stage of work).

Indicative pipe routes were outlined to consider maximum cost-efficiency, by minimising pipe length and following routes with easier digging conditions where possible.

Existing key utilities and other infrastructure were considered to determine whether they pose any potentially significant risks to the development of district energy networks. The main road running through the heat demand assessment area, Village Road, was deemed to be the most significant barrier to heat network development; however, the road is not considered of a size to significantly affect network route planning.

3.1 Linear Heat Density

A linear heat density map was created for an indicative network route connecting all identified heat demands. The linear heat density is the ratio of heat demand to the length of pipe. It was assessed as areas of higher linear heat density provide a greater annual load whilst minimising capital costs and heat losses through the network. Although linear heat density does not consider pipe diameter it provides a high level indicator for the potential viability of network options and phases. The linear heat density is shown in Figure 12.

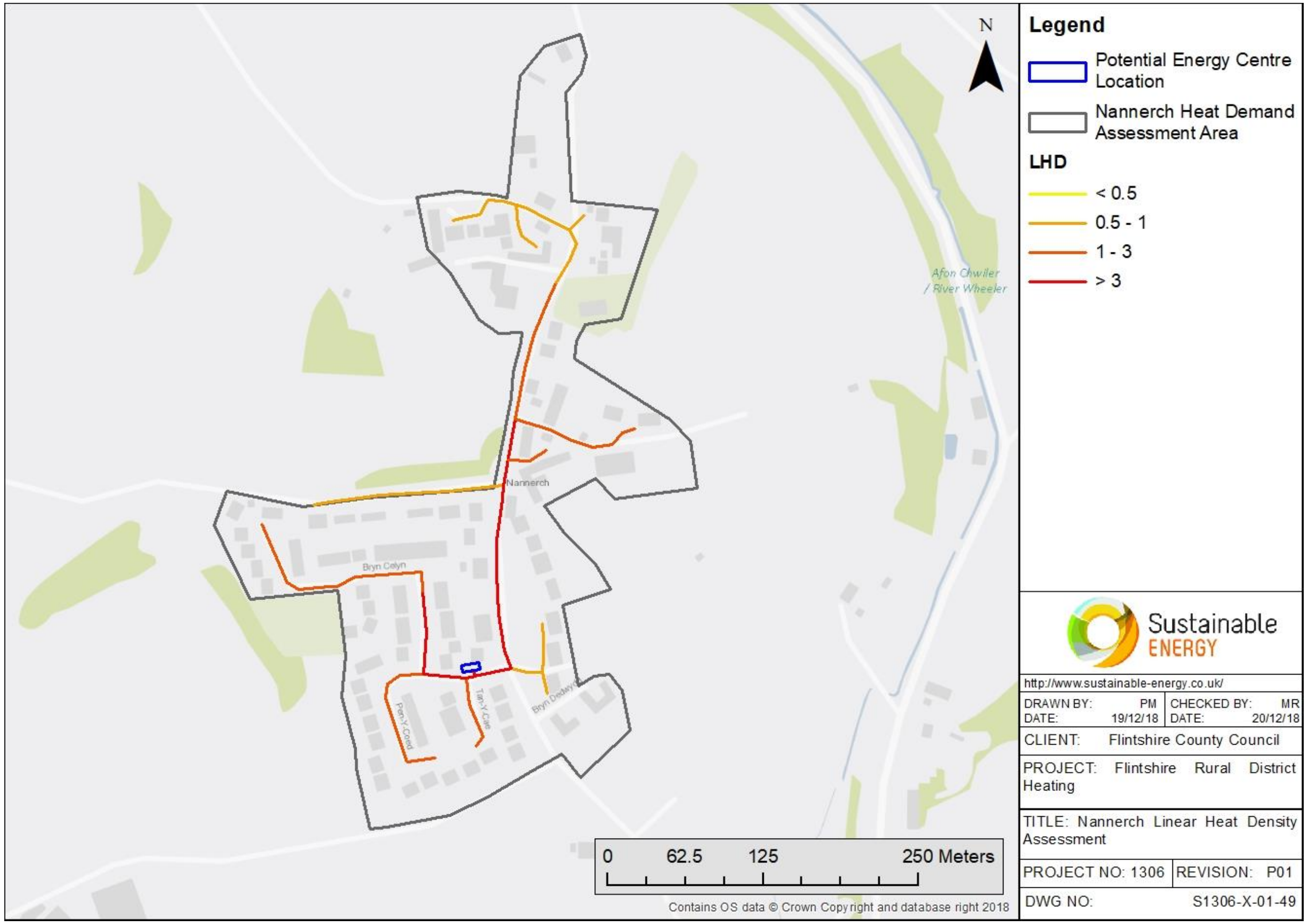


Figure 12: Linear heat density

Discussion held with the client group during completion of the more detailed Gwernaffield study indicated that a village wide network was very unlikely to be taken forward by FCC due to varied ownership, issues around fuel supply, low linear heat density and challenging economics.

Figure 13 shows a network of FCC-owned residential properties identified at Bryn Dedwydd; made up of 6 dwellings currently heated by oil boiler, the average linear heat density was found to be 1.24 MWh/m. . Also shown is land owned by FCC to illustrate available space for boreholes and pipework.

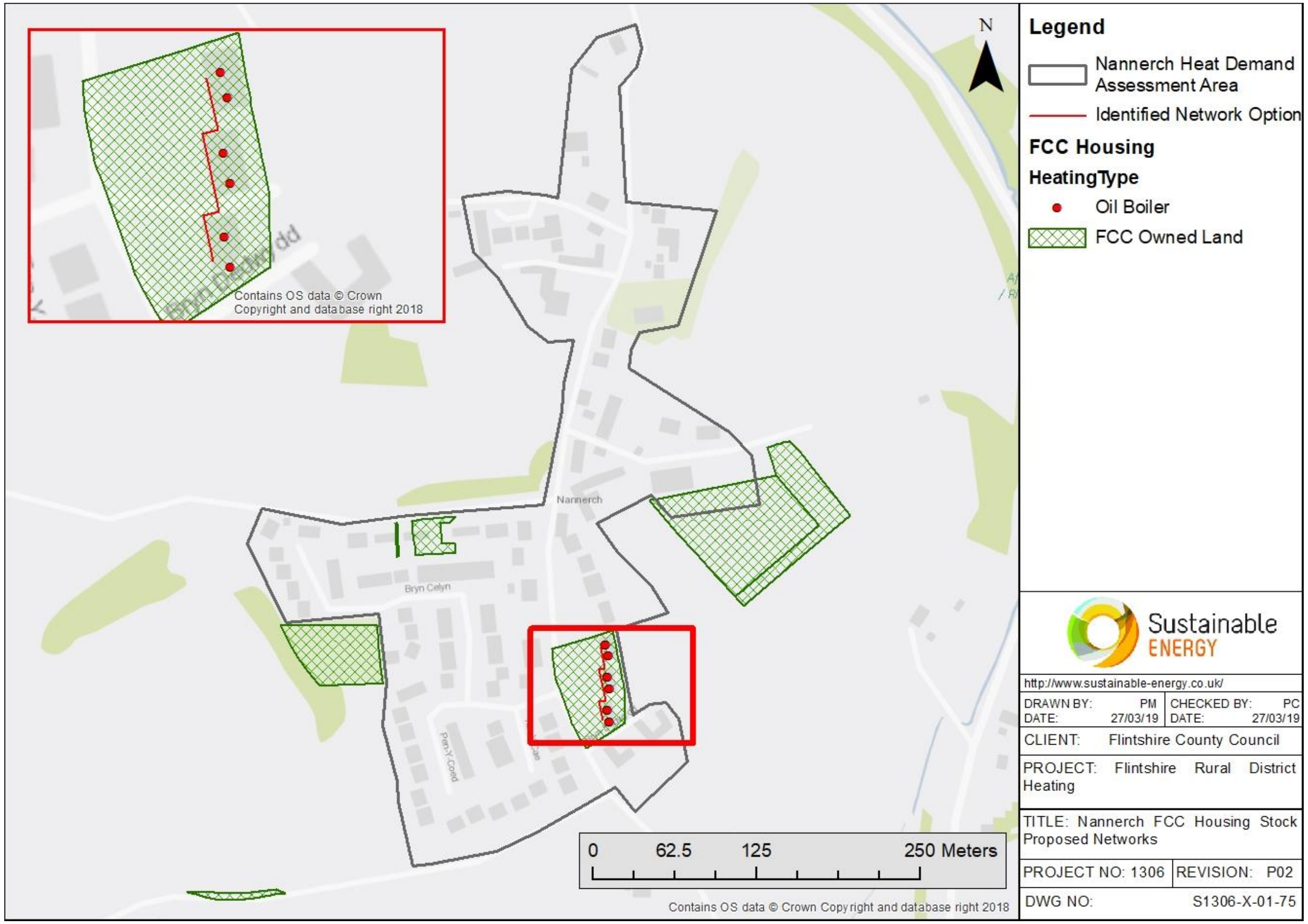


Figure 13: Proposed FCC residential heat network

3.2 Technology Options Assessment

Potential existing and planned energy sources within the heat map area have been assessed and are shown in Figure 6. We assessed the identified energy supply opportunities in relation to the technical suitability, key requirements and the cost implications on potential heat networks viability. None of the existing energy sources were identified as a potential heat offtake opportunity for a network. High level technical viability considerations for alternative potential energy sources are summarised in Table 4.

Table 4 shows that only small closed loop GSHP may be viable.

Table 4: Summary of potential heat sources

Technology	High level technical viability considerations		Taken forward for further consideration?
	Positive	Negative	
Anaerobic digestion	• Network temperatures compatible with existing buildings • Eligible for RHI (RHI scheme confirmed until 2021)	• No plans for anaerobic digesters within feasible distance • RHI scheme will potentially close to new applications in 2021	No
Biomass heat	• Network temperatures compatible with existing buildings • Eligible for RHI (scheme confirmed until 2021)	• High cost of fuel • No AQMA areas within rural Flintshire	No
Biomass CHP	• Network temperatures compatible with existing buildings • More reliable and economic at large scale	• High cost of fuel compared to mains gas • Large scale unlikely to be suitable for rural Flintshire villages • May be more suited to industrial setting • Heat demands unlikely to be within proximity	
Deep geothermal	• Network temperatures compatible with existing buildings	• Success of scheme dependant on geothermal[2] potential of rock • Heat availability in Flintshire estimated at 50-60 W/m^2	
Energy from Waste	• Network temperatures compatible with existing buildings	• Potential planning and air quality issues related to air quality • Heat demands required to be within feasible distance of EfW plant • Large scale unlikely to be suitable for rural Flintshire villages • May be more suited to industrial setting	
Natural gas CHP	• Network temperatures compatible with existing buildings	• Air quality issues, however, abatement measures likely to be viable • Less carbon savings compared to some other technologies so should be regarded as interim option	

[2] http://www.bgs.ac.uk/research/energy/geothermal/

Technology	High level technical viability considerations		Taken forward for further consideration?
	Positive	Negative	
		• CO_2e reductions will decrease over time and future operating hours will be constrained • Site is off gas grid	
Ground source heat pump	• Eligible for RHI (scheme confirmed until 2021) • Drilling boreholes may incur lower project management costs in rural areas (compared to urban) • Borefield footprint may be secured in rural area	• Lower operating temperatures suitable for new builds and retrofit existing buildings • Often large space required for borefield closed loop systems • Underlying rock strata and aquifer determine if a site is favourable area for open loop[3] GSHP • Borehole yields uncertain – test wells often required	Yes
Industrial waste heat	• Network temperatures compatible with existing buildings	• No industrial waste heat sources identified within a feasible distance	No
Water source heat pump	• Eligible for RHI (scheme confirmed until 2021)	• Lower operating temperatures suitable for new builds and retrofit existing buildings	
Mine source heat pump	• Eligible for RHI (scheme confirmed until 2021)Water bodies below 500m qualify for higher geothermal tariffs • Water temperature increases with depth	• Greater depths incur greater pumping cost and decrease total system efficiency • Mine water is likely to contain many contaminants and require treatment before use	
Air source heat pump (for DHN)	• Not dependant on accessing ground water or large borefield • Eligible for RHI, albeit at a lower rate than GSHPs and WSHPs (scheme confirmed until 2021)	• Limited product range for higher temperature ASHPs for DHN • Noise impacts may be significant in rural villages • Significant space requirements • Rural temperatures are generally lower than urban temperatures and can lead to increased building heat demand	
Hydrogen fuel cells	• Network temperatures compatible with existing buildings	• Hydrogen fuels may be best used in transport sector • If hydrogen derived from natural gas, then CO_2e reductions will reduce over time • Economics of hydrogen-based CHP very uncertain	

[3] Open loop GSHP refers to systems that exchange heat with subsurface water, and therefore require the existence of aquifers, rivers, docks or gravel water

Technology	High level technical viability considerations		Taken forward for further consideration?
	Positive	Negative	
		• Security of fuel supply issues • No local hydrogen generation • Fuel will need to be transported by road • Requires significant space for fuel cell • Sites assessed are off gas grid	
Bioliquid	• Network temperatures compatible with existing buildings	• Sustainability of fuel sources such as bio-oil in question • Local air quality issues associated with biofuel options as there are likely to be higher NOx and PM emissions • Biofuel deliveries by lorry into site • Operational risk on engine availability and maintenance cost • Potential closure of RHI scheme in 2021 • Sites assessed are off gas grid • No obvious local fuel supply • Heat demand areas assessed in rural Flintshire are not within proximity of operating bio-liquid plants	

4 GROUND SOURCE HEAT PUMP ASSESSMENT

Ground source heat pumps were found to be the preferred, and most beneficial, solution for Nannerch, (see summary of technology assessment in Table 4). Several ground source heat pumps options are available to provide heat to a district heating scheme. The different options vary in scale, circulatory medium and how the technology is applied, though all make use of the higher ambient temperatures found below ground level. The suitability of a scheme depends on the location and environmental factors, but generally they were assessed in the following order:

- Closed Loop GSHP District Heating Scheme – Heat is abstracted from the ground via brine circulating through plastic piping installed either vertically in boreholes (>100m) or horizontally in large shallow arrays (<1m). A large-scale heat pump then transfers the heat to the secondary side circulating fluid at somewhere between 40-80°C. The output temperature is dependent on secondary side heating conditions, but a lower temperature will increase seasonal performance factor of the scheme (see Figure 14).
- Open Loop GSHP District Heating Scheme – Ground water is abstracted directly from the ground (ground water aquifer/abandoned mine/saturated gravel) via a borehole intersecting the source, borehole depth is dependent on the depth of source. A large-scale heat pump then transfers the heat to the secondary side circulating fluid at somewhere between 40-80°C. The output temperature is dependent on secondary side heating conditions, but a lower temperature will increase seasonal performance factor of the scheme (see Figure 15).
- Open Ambient Loop GSHP – Ground water is abstracted directly from the ground (ground water aquifer/abandoned mine/saturated gravel) via a borehole intersecting the source, borehole depth is dependent on the depth of source. The water is circulated (at source temperature) round the district heating network and heat is supplied to the secondary side heating systems by heat pumps located in each building. Secondary side heating temperatures will vary according to the heat emitters present in the building (see

Figure 16: Open Ambient Loop GSHP

Figure 17: Closed Loop GSHP

-).
- Closed Loop GSHP – Heat is abstracted from the ground via brine circulating through plastic piping installed either vertically in boreholes or horizontally in large shallow arrays. The water is circulated (at source temperature) around the network and heat is supplied to the houses and buildings by individual heat pumps. Network size is usually determined by borehole capacity and amount of heat required; typical networks consisting of small clusters of domestic properties (~5 dwellings) connected to one borehole (100-200m depth) (see Figure 17).

Of the four options, a closed loop GSHP option was taken forward for further assessment. Both district heating schemes were ruled out as discussed in Section 3.2. A closed loop GSHP was chosen over an open loop GSHP due to the unlikely availability of sufficient groundwater (flowrate) and the potentially favourable ground conditions for a ground heat exchanger loop.

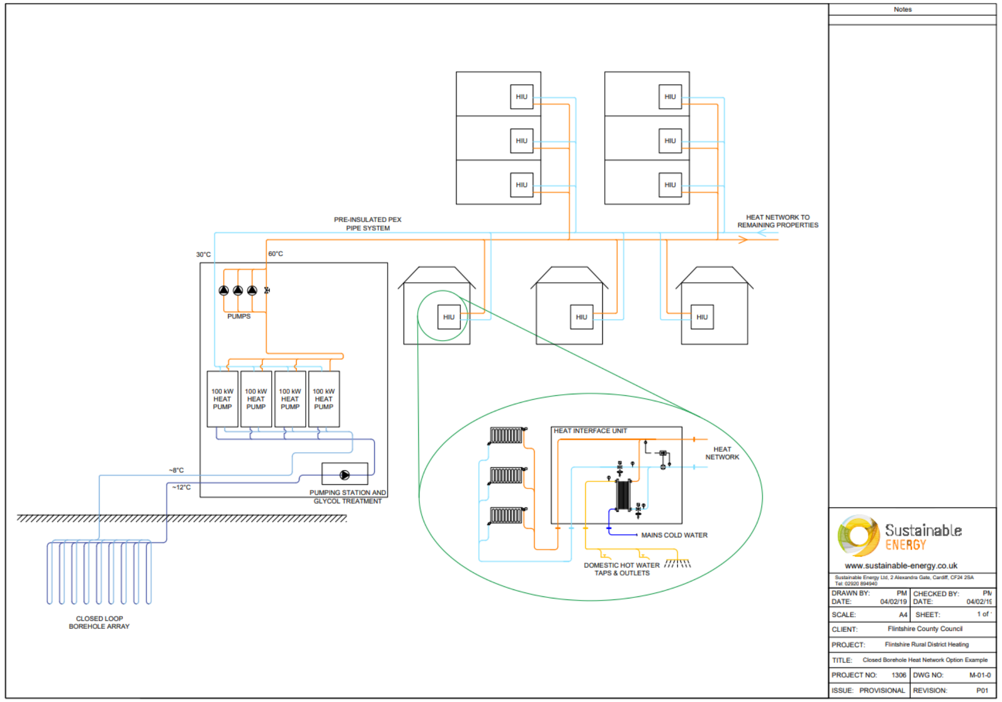


Figure 14: Closed Loop GSHP District Heating Scheme

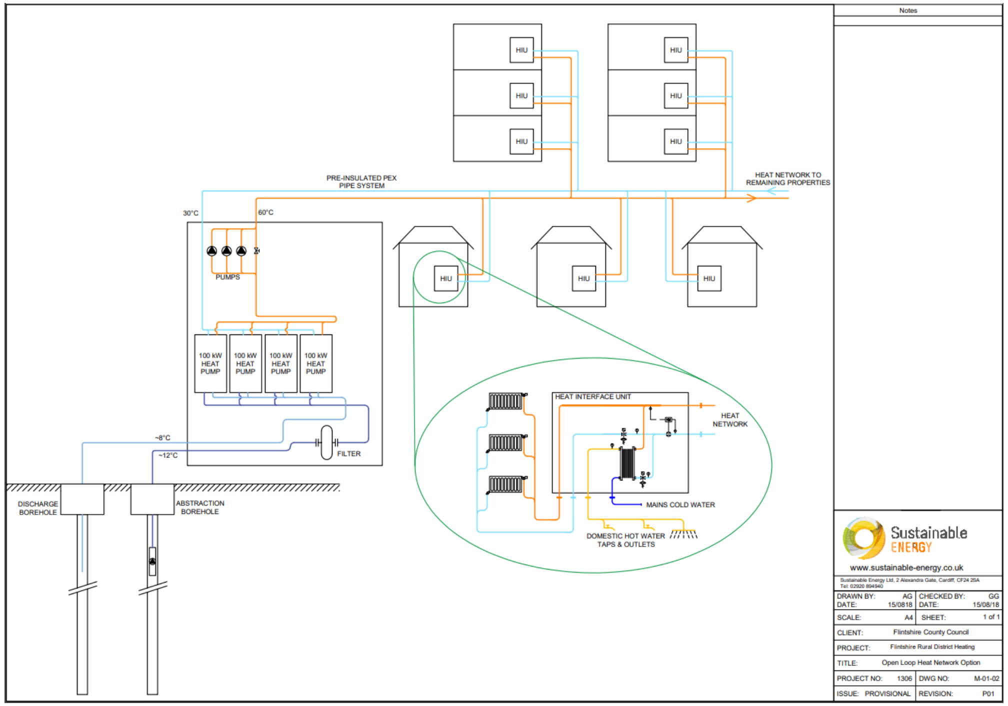


Figure 15: Open Loop GSHP District Heating Scheme

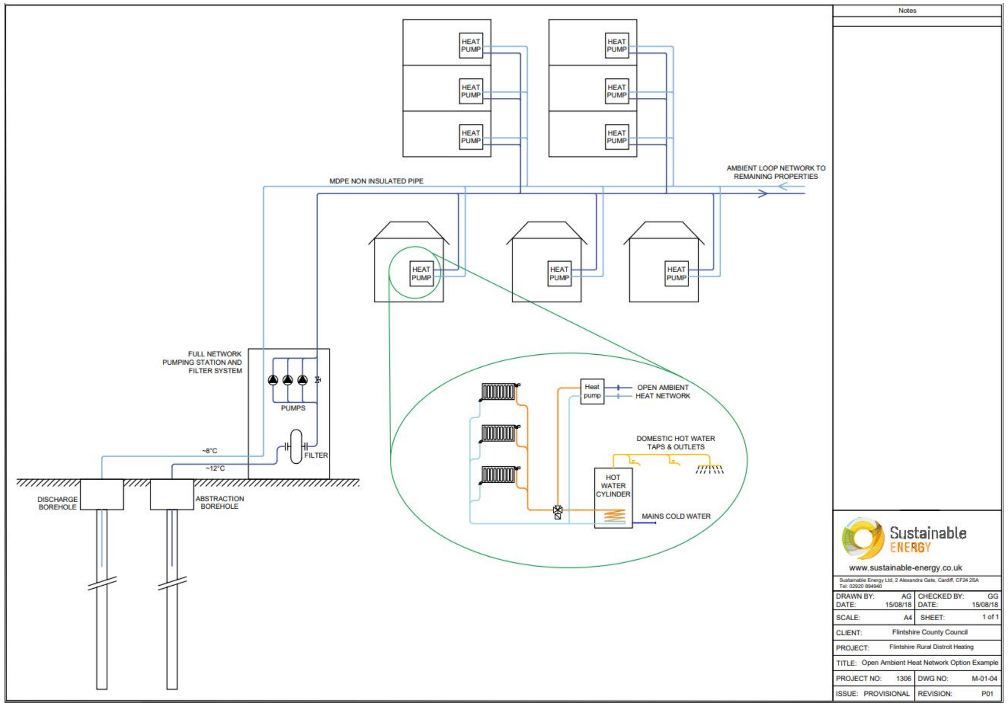


Figure 16: Open Ambient Loop GSHP

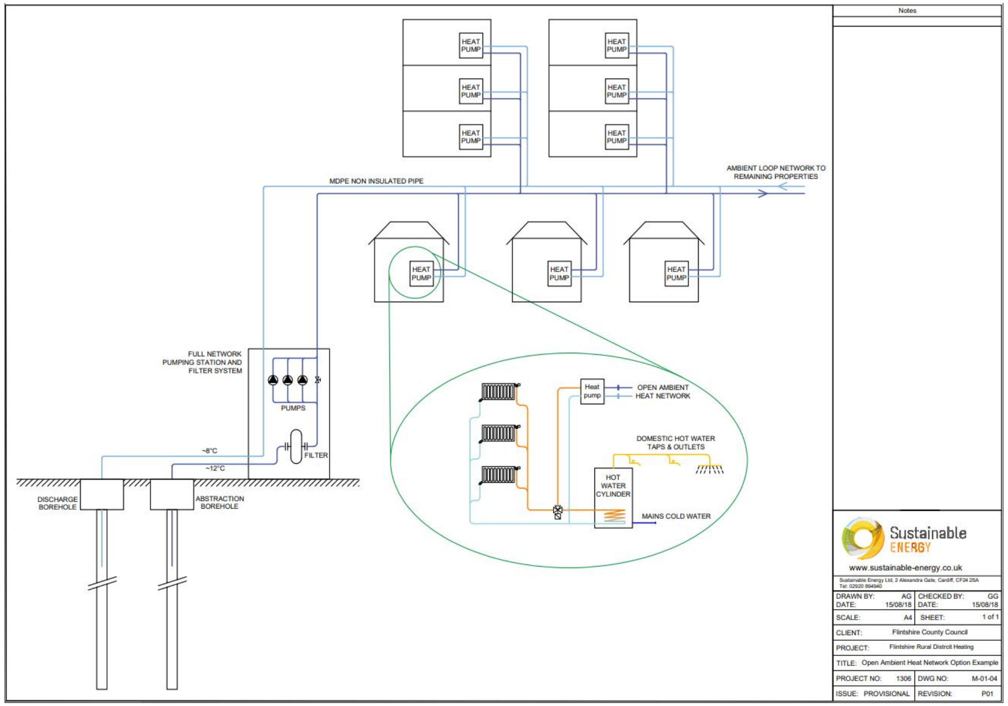


Figure 17: Closed Loop GSHP

4.1 Key Parameters for High Level Viability Assessment

4.1.1 Technology / Heat Source Assessment

A high level technology assessment was conducted to assess technical, financial, sustainability and environmental criteria of potential heat sources. These criteria include:

- Technology suitability/risk
- Financial performance including key sensitivities
- Availability of financial support
- Availability and sustainability of fuel and security of supply
- CO_2 reduction potential
- Cost per tonne of CO_2 saved (initial and potential) and other environmental impacts
- Development risk
- Timeframe for deliverability
- Cost savings to FCC, customers and developers
- Potential investment leverage including grant funding opportunities

Following a review of technical viability of selected technologies to serve potential network areas, the specific energy supply options that would be viable for both short term and long term for each specific option were identified.

4.1.2 High Level Economic Assessment

The high level economic assessment for the proposed option is presented to assess the economic case. The capital costs for the identified opportunity includes costs for plant and equipment supply and installation, distribution pipe work supply and installation, trench excavation and re-instatement. Indicative costs are also identified for the necessary integration works within existing buildings (radiator replacements etc) to connect to a ground source heat pump network.

Existing residential energy tariffs have been based on an average of quotes from local providers. Electricity tariff for the borehole pumps are based on the existing tariff for other FCC owned properties.

RHI has been included for the option; the tariffs used, eligible as of 1 January 2019, are shown in Table 5.

Table 5: Key assumption and parameters

Parameter	Value
Oil price (average domestic)	5.35 p/kWh
Electricity tariff (average domestic)	16.61 p/kWh
RHI tariff (GSHP)	9.36 p/kWh (tier 1)
	2.79 p/kWh (tier 2)
Electricity tariff (borehole pump)	14.298 p/kWh
Grant funding (Warm Homes Funding)	£5,000 per dwelling
Average domestic heat demand	13,000 kWh / dwelling
Heat pump SPF	2.8
Borehole pumping requirements	4.08 kW
Assumed existing oil and LPG boiler efficiency	75 %
Borehole heat abstraction rate	45 W/m

4.1.3 Assessment of the heat costs

The breakdown of components used in the calculation of cost of heat for BAU and ASHP are shown in

The business as usual cases are based on the respective existing fuel type, if each property were to continue with the current method of heating. ASHP has been included as a comparison in the cost of heat as it is considered to be a likely replacement option at the end of life of existing fossil fuel heating installations.

Table 6.

The business as usual cases are based on the respective existing fuel type, if each property were to continue with the current method of heating. ASHP has been included as a comparison in the cost of heat as it is considered to be a likely replacement option at the end of life of existing fossil fuel heating installations.

Table 6: Breakdown of cost of heat

	BAU - oil	BAU – gas	BAU – electric	ASHP
Cost of fuel / electricity tariff	5.35 p/kWh	6.62 p/kWh	16.61 p/kWh	16.61 p/kWh
Assumed efficiency / SPF	75 %	75 %	100 %	2.5
Cost of new replacement	£3,000	£2,000	£1,500	£5,000
Annual maintenance cost	£200	£150	£50	£140
Expected lifetime	15 years	15 years	15 years	20 years
Maintenance costs	1.54 p/kWh	1.15 p/kWh	0.38 p/kWh	1.08 p/kWh
Replacement costs	1.54 p/kWh	1.03 p/kWh	0.58 p/kWh	1.92 p/kWh
Annual output	13,000 kWh			
Average cost of heat	10.21 p/kWh	11.01 p/kWh	17.57 p/kWh	9.64 p/kWh

4.2 Closed loop GSHP assessment

A summary of the small closed loop ground source heat pump system identified for Nannerch is shown in Table 7.

A representation of a typical network is shown in Figure 18. Heat is transferred from the ground via brine circulating through plastic piping installed either vertically in boreholes (>100m) or horizontally in large shallow arrays (<1m). The water is circulated (at source temperature) around the network and heat is supplied to the houses and buildings by individual heat pumps. Network size is usually determined by borehole capacity and amount of heat required; typical networks consisting of small clusters of domestic properties (~5 dwellings) connected to a number of boreholes (100-200 m depth). The network is eligible for non-domestic RHI revenue as it serves more than one property, which improves the 20-year economics of the scheme.

This system will have a higher CAPEX than individual ASHPs but the ground (and the ambient loop) will provide a more consistent temperature than the ambient air, resulting in improved efficiency of the heat pump in cold periods. The GSHP scheme will also have a lower noise impact than individual ASHPs.

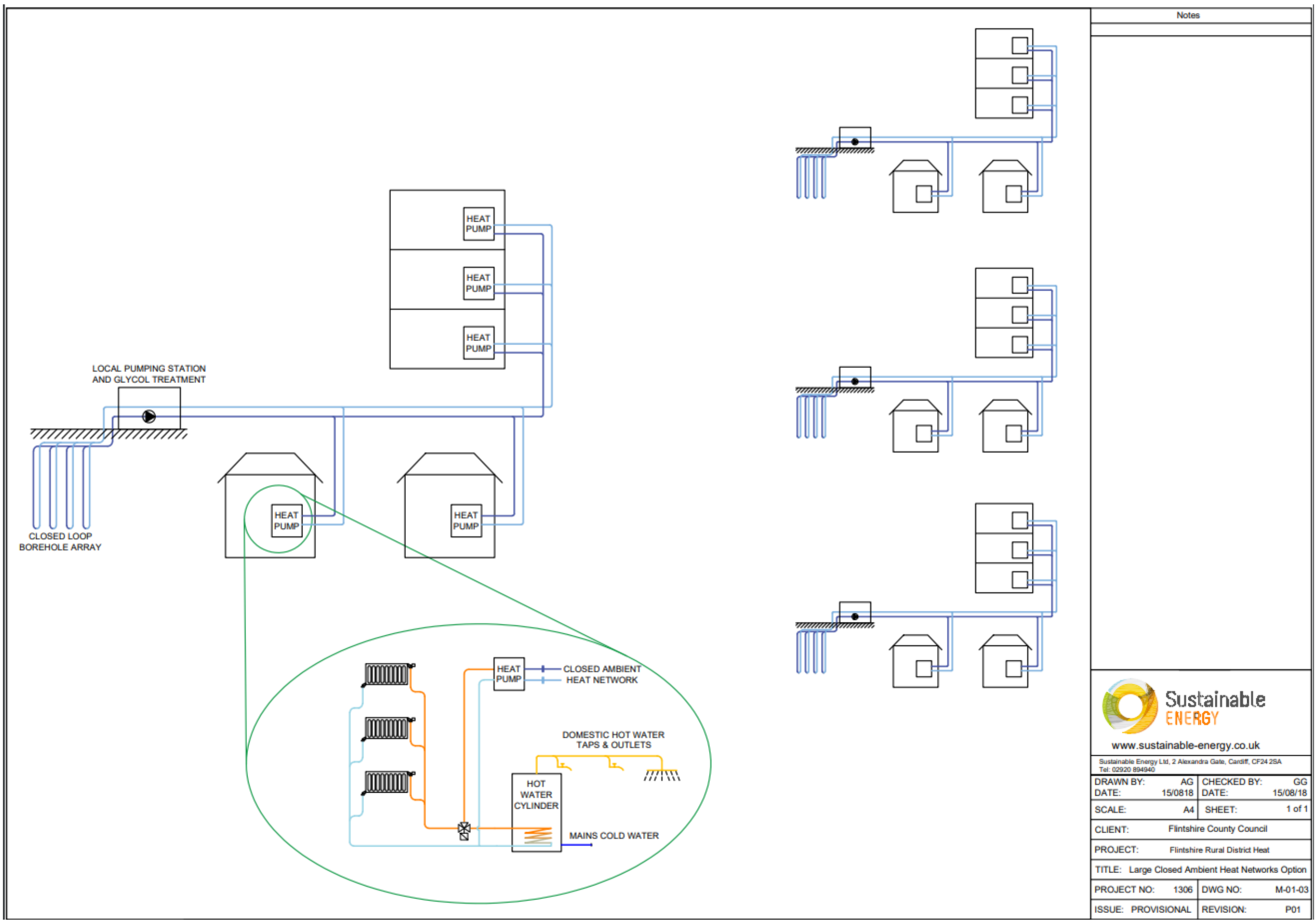


Figure 18: Small closed ambient loop network option layout

At Nannerch, a short network of approximately 63m length will connect 6 properties to a closed loop borehole located nearby. Boreholes will be located on council owned land as close as possible to the heat load to minimise connecting pipework. Individual heat pumps within each property will use the brine circulating through the network to generate heat. Low temperature radiators and hot water storage cylinders have been included in project CAPEX. The tenant would pay for heat pump operating costs through their domestic electricity bill and RHI payments would be received by FCC. In a district heating scheme with a central heat source, the tenant would purchase heat used, requiring FCC to introduce metering and billing infrastructure. Utilising the existing electricity infrastructure will save on CAPEX and ongoing costs for FCC.

Table 7: Small closed loop GSHP network summary

Total No. connections	No. dwellings with oil boiler	No. dwellings with gas boiler	No. dwellings with electric heating	Number of boreholes	Total trench length	Total heat demand	Peak heat demand
6	6	0	0	3	63 m	78,000 kWh	31 kW

4.2.1 High level economics and CO_2e savings

The high level economic case for a small closed ambient loop installation for Nannerch is shown in Table 8. This shows the cases for both just FCC (CAPEX and income) but also considers the savings to the tenant. The cost of heat is also compared to that of BAU and individual ASHPs (the only likely renewable heating alternative and a solution that has been installed at other FCC properties).

Table 8: High level economic case for small closed loop GSHP option

CAPEX	£112,846
Grant funding	£30,000
20 year IRR for FCC (not including resident savings)	-1.2 %

20 year NPV for FCC (not including resident savings)	-£30,991
20 year simple payback for FCC (not including resident savings)	> 20 years
20 year net income from RHI	£73,034
Heat sales price to achieve 3.5% IRR for FCC	2.80 p/kWh
IRR considering consumer savings	3.8 %
NPV (3.5% discount factor) considering consumer savings	£2,123
Total cost of heat for BAU	10.21 p/kWh
Total cost of heat for individual ASHPs	9.64 p/kWh
Total cost of heat for small closed loop GSHP option	9.08 p/kWh

The breakdown of the calculation of the cost of heat from GSHP is shown in Table 9 below. This includes electricity input costs and lifetime operational costs.

Table 9: Breakdown of total cost of heat for GSHP

Residential electricity tariff	16.61 p/kWh
Assumed SPF	2.8
Annual maintenance cost	£150
Expected lifetime	20
Annual borehole pump electricity cost	£881
Annual pipework system monitoring and maintenance	£315
Annual staff costs	£270
Annual insurance cost	£90
Annual total heat demand	78,000 kWh
Average cost of heat	9.02 p/kWh

Table 10: CO_2e Savings

	GSHP option	Individual ASHPs
CO_2e savings - 20 years	488 tCO2e	496 tCO2e
First year CO2e savings	20 tCO2e	21 tCO2e
First year CO2e intensity of delivered heat	126 g/kWh	116 g/kWh

4.3 Sensitivity and risk

The following section assesses key sensitivity parameters for the scheme. The base case is assumed to be BAU i.e. the properties continue to be served by their existing fossil fuel or electric resistance heating e.g. for Nannerch this is oil.

Table 11: RHI and grant funding dependency

Base case (for FCC)	-1.2 %
Without RHI (for FCC)	< -10 %
Without grant funding	-3.8 %

The figures below show how an increase or reduction in an individual financial parameter can affect the economic case. Figure 19 shows how the 20 year IRR will increase with increase in heat demand and similarly how it will decrease when the heat demand reduces. Figure 20 and Figure 21 show the effect on 20 year IRR of a change in capital costs and borehole pump electricity tariff respectively.

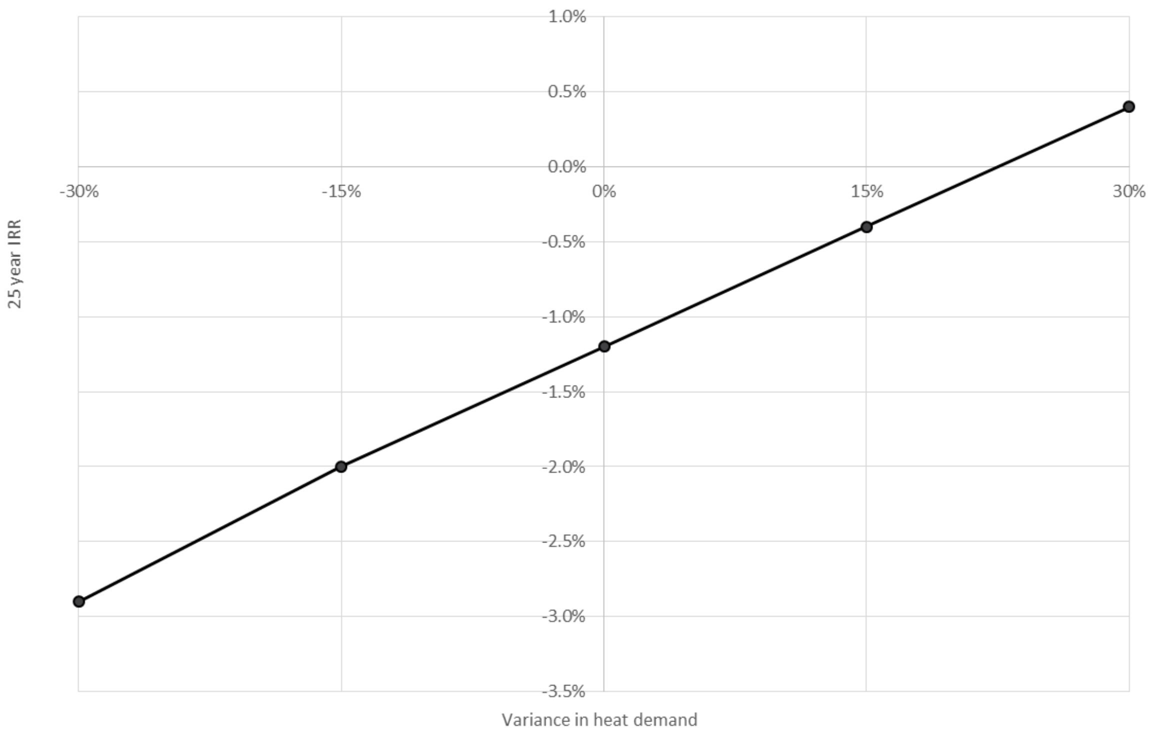


Figure 19: Variation of IRR with variation in heat demand

We can see that an increase in heat demand of 30% provides approximately 1.5% increase in 20 year IRR.

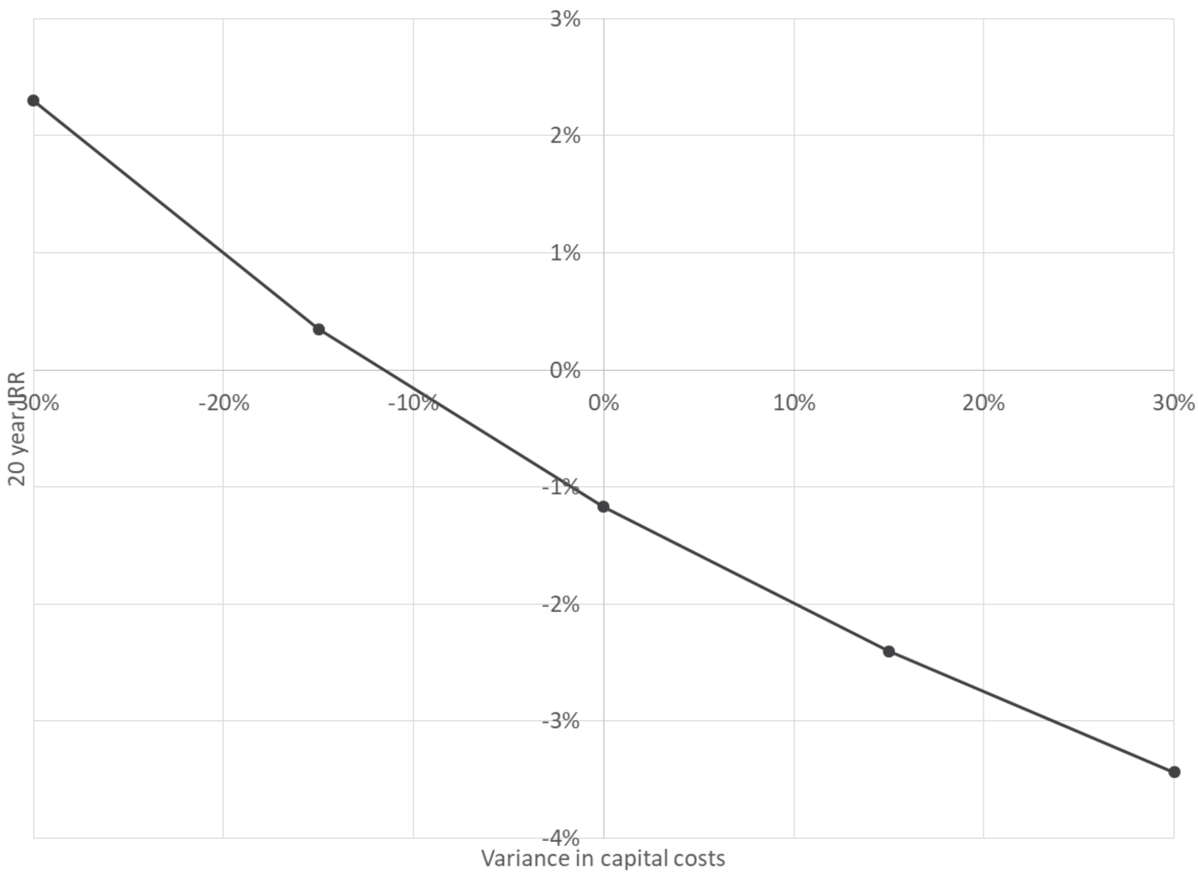


Figure 20: Variation of IRR with variation in capital costs

An increase in 30% of capital costs decreases the 20 year IRR by approximately 2.5% showing the case is particularly sensitive to CAPEX.

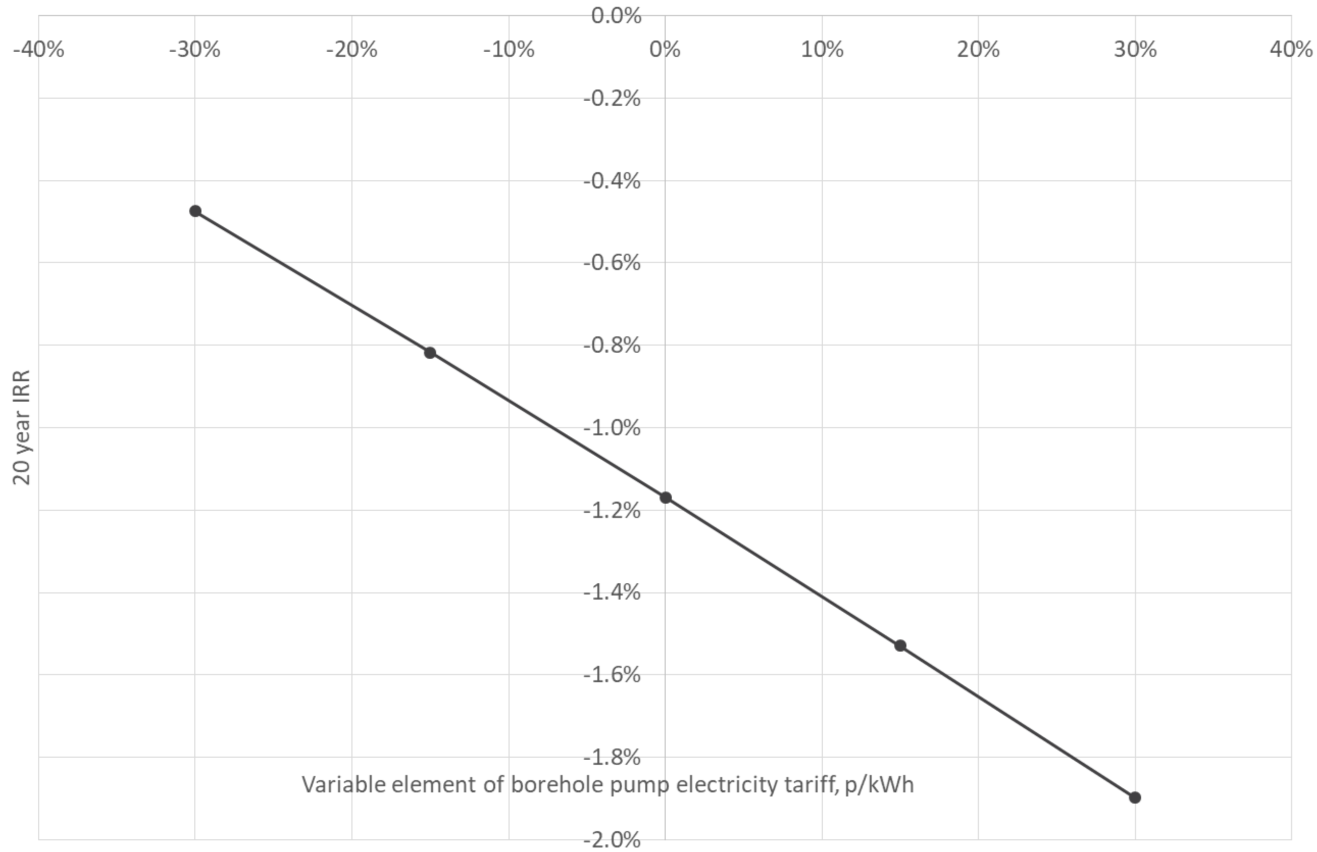


Figure 21: Variation of IRR with variation in borehole pump electricity tariff

An increase in 30% of borehole pump electricity tariff will decrease the 20 year IRR by approximately 0.7%.

The main risks associated with implementation of the proposed GSHP option are:

- Residential heat demands have been modelled but have been verified using data for FCC housing stock (see Figure 19)
- Electricity tariff significantly impacts project economics (see Figure 21)
- The project economics are significantly reduced without non-domestic RHI (see TEM); RHI tariffs are subject to degression and the scheme is planned to close in March 2021
- Securing a borehole location and drilling needs to be carefully managed during the construction process to minimise associated capital costs
- Grant funding may not be secured; to avoid 'double funding' it has been assumed that the grant is used to fund the building upgrades and other works but not the close loop system itself. Building upgrades include new low temperature radiators, conversion to wet system (where appropriate) and installation of hot water storage cylinder; there may be the possibility of securing grant funding for the ground source heat pump unit replacing the existing heating system, but this will need further investigation.
- Project IRR is significantly impacted by increase in CAPEX

5 CONCLUSIONS AND NEXT STEPS

This report presents the findings of the Nannerch assessment. Options were assessed against their potential to reduce energy costs, improve energy security, reduce carbon emissions and generate revenue.

Energy Demand Assessment

Energy demand models were produced for existing buildings and planned developments and the heat demand profiles were combined to assess the overall demand for various network options.

The adjacent map shows the key heat demands in Nannerch and these include Ysgol Nannerch VC and Saint Michael and All Angels Nannerch. FCC own several domestic properties within the heat demand assessment area.

Options Assessment

One potential network option has been identified to take forward to phase 2 for further investigation – a small closed loop system supplying individual heat pumps in FCC-owned properties at Bryn Dedwydd. This opportunity will have marginal economics and will be significantly impacted by the availability of non-domestic RHI and grant funding.

Even with grant funding and RHI, there are no economic returns for FCC's on the investment in the GSHP project as:

- The high project CAPEX that includes drilling boreholes and replacing internal heating systems such as radiators
- Some of the economic benefits associated with the scheme are passed to FCC tenants (i.e. the lower total cost of heat)

When the savings against BAU heating costs (i.e. oil boilers) for FCC tenants are included (as well as grant funding and RHI), the overall project economics improve significantly to give a positive NPV. The GSHP option provides significant economic and carbon savings for the FCC tenants (against the BAU option) (see Figure 22 and Figure 23). As the GSHP option is more efficient than the ASHP options, the cost to the end user is lower (see Figure 22). In the base case, the electricity cost for pumping is being met by FCC at a slightly lower rate than the assumed customer tariff, however, this cost could be transferred to the customer, increasing their overall cost of heat. The carbon intensity of the heat and energy tariff risk could be further reduced if the heat pumps are partly supplied with electricity from solar PV (potentially with battery storage).

The individual ASHP option offers similar carbon savings to the GSHP option as the lower efficiency of the ASHP option, is counteracted by the pumping energy required for the GSHP option.

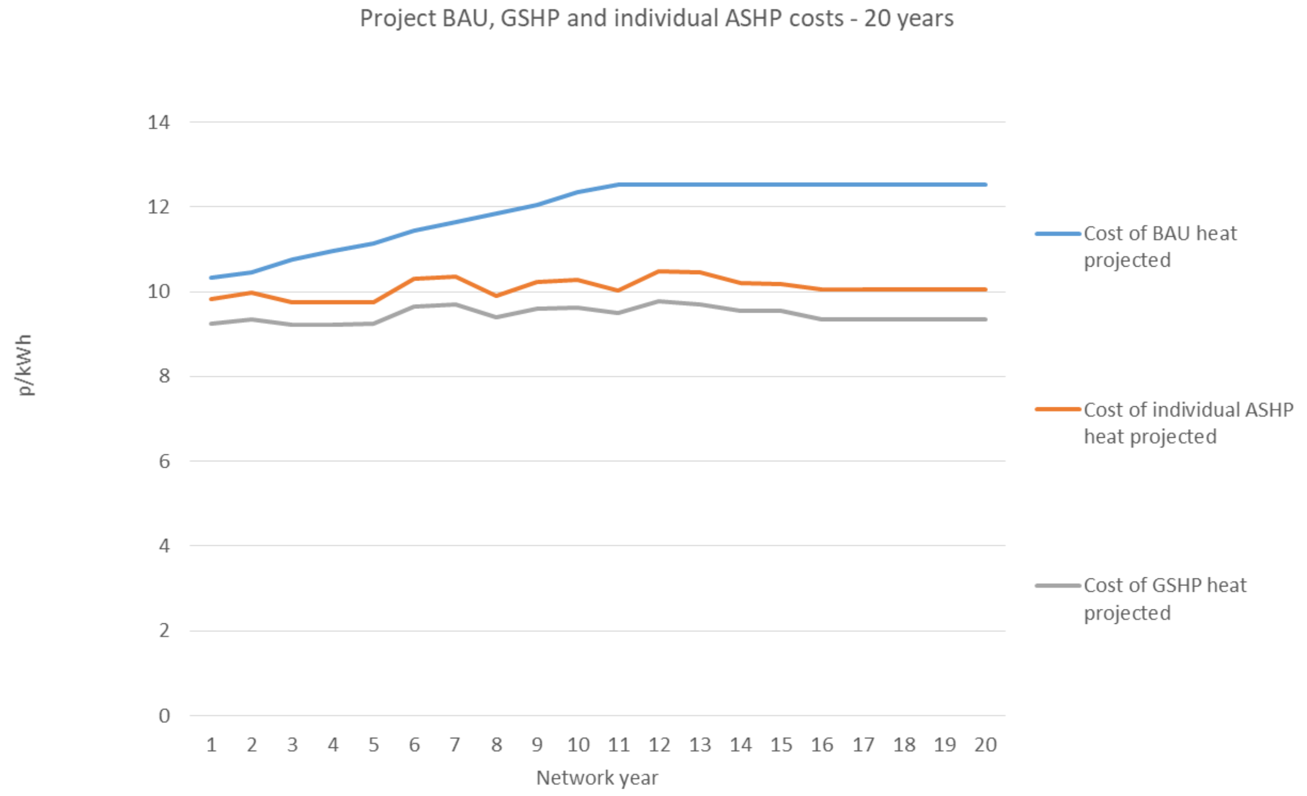


Figure 22: Projected costs for BAU, GSHP and individual ASHP

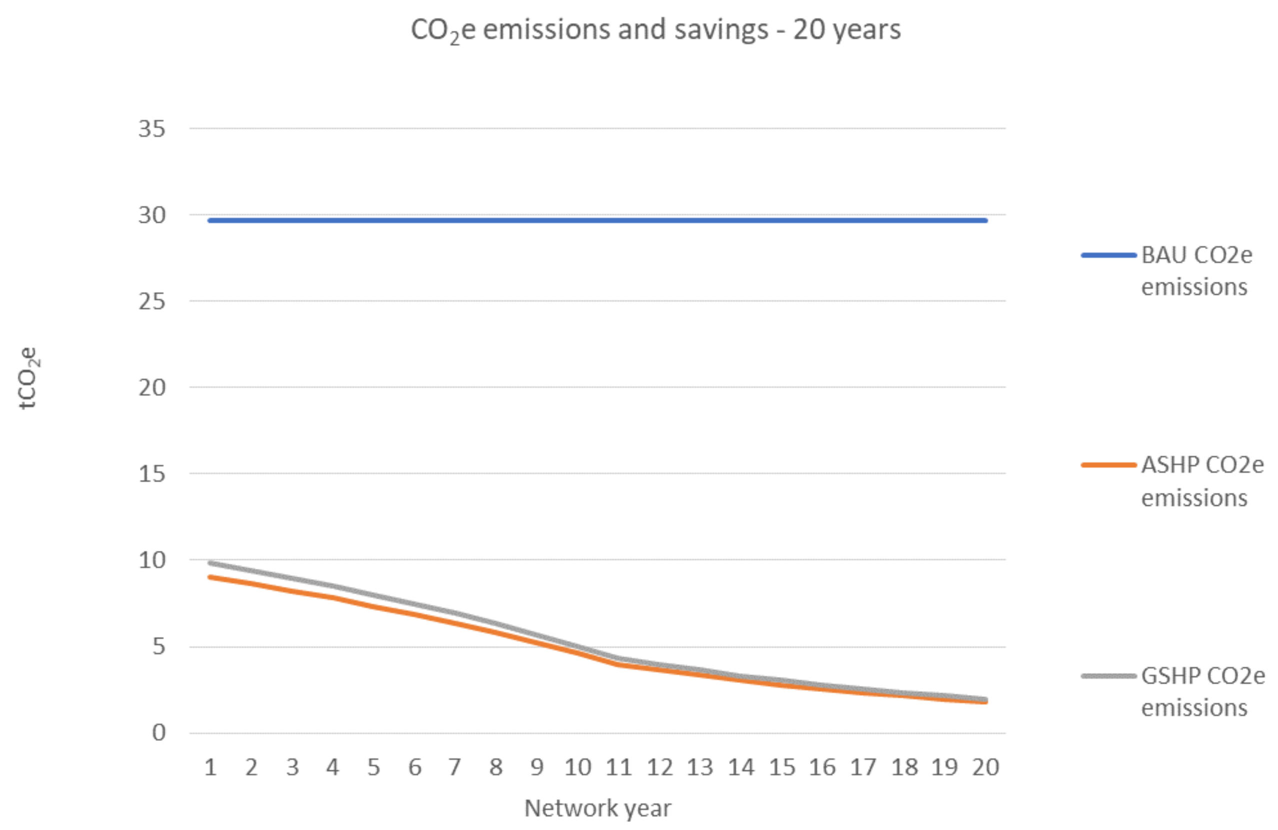


Figure 23: Projected CO_2e savings for BAU, GSHP and individual ASHP

The advantage of the GSHP option over individual ASHPs are as follows:

- There is less noise impact with the GSHP option
- As the ASHPs will need to be located externally, the GSHP option has a lower visual impact and lower space requirements
- The GSHP option has a higher seasonal CoP and a higher CoP during the colder winter months (when the ASHP will be far less efficient)
- Non-domestic RHI is potentially available to support the GSHP option over 20 years (domestic RHI revenue only received for 7 years)

However, ASHPs are easier to retrofit and will provide a lower CAPEX option and do not require space for boreholes.

The closed loop GSHP option has challenging economics, however it support FCC's carbon reduction strategy, renewable energy action plan and improvement plan and could be supported by public sector funding.

Next steps

The following next steps and recommendations should be considered by FCC:

- Decide whether to progress the GSHP project
- Endeavour to bring the project forward prior to the closure of the RHI scheme (potentially March 2021)
- If grant funding and RHI are being sought, carefully assess state aid rules and liaise with OFGEM to maximise grant funding and RHI revenue whilst avoiding 'double funding'
- If the project is not brought forward prior to the closure of the scheme, then fully assess the impact of any future subsidy and/or changes to fossil fuel tax on the schemes
- If a pilot project is progressed, undertake detailed monitoring to compare the GSHP performance with the existing ASHPs in FCC's buildings

- Engage with and support planning consents and highways activities

APPENDIX 1 – KEY ORGANISATIONS CONTACTED

List of contacts of key organisations where owners were contacted by Sustainable Energy to request information.

Table 12: Key organisations contacted

Organisation	Site contact	Job description	Contact established
FCC	Sadie Waterhouse, Leanna Jones	Project Manager	Yes
	Andy Brown	Geographic Information Services Manager	Yes
n/a	Cris Ebbs	Local Mining Historian	Yes

APPENDIX 2 – ENERGY DATA

Table 13: Key energy loads within the Nannerch heat map area

Building name	Existing site / planned development	Building use	Ownership	Heat demand, kWh	Energy data source for heat modelling and profiling
Nannerch Memorial Hall	Existing	Public Building	Nannerch Community Council	58,115	Estimated using data for similar sites
Cross Foxes	Existing	Hospitality and entertainment	Private	31,708	Estimated using data for similar sites
Saint Michael and All Angels Nannerch	Existing	Church	Church in Wales	37,173	Estimated using data for similar sites
Ysgol Nannerch VC	Existing	Education	FCC	46,411	Historic data

APPENDIX 3 – INTRODUCTION TO TECHNOLOGIES ASSESSED

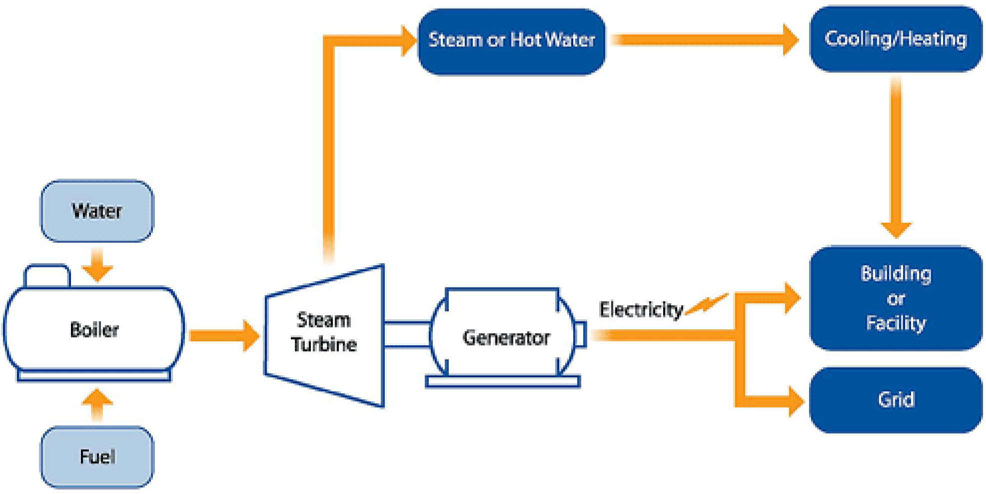
Biomass Boiler – a biomass boiler burns wood fuel in the form of wood pellets, chips or logs to provide heat in the form of low temperature, medium temperature hot water or steam. A biomass boiler comprises two main parts, the combustion chamber where wood fuel is combusted with unrestricted oxygen and the boiler tubes which transfer heat from the combustion chamber to the water or steam medium. The heated water or steam is then distributed around the heating system as required.

6MW Wood Chip Boiler at Sawmill Site in Mid-Wales, Photo Courtesy of Sustainable Energy Ltd

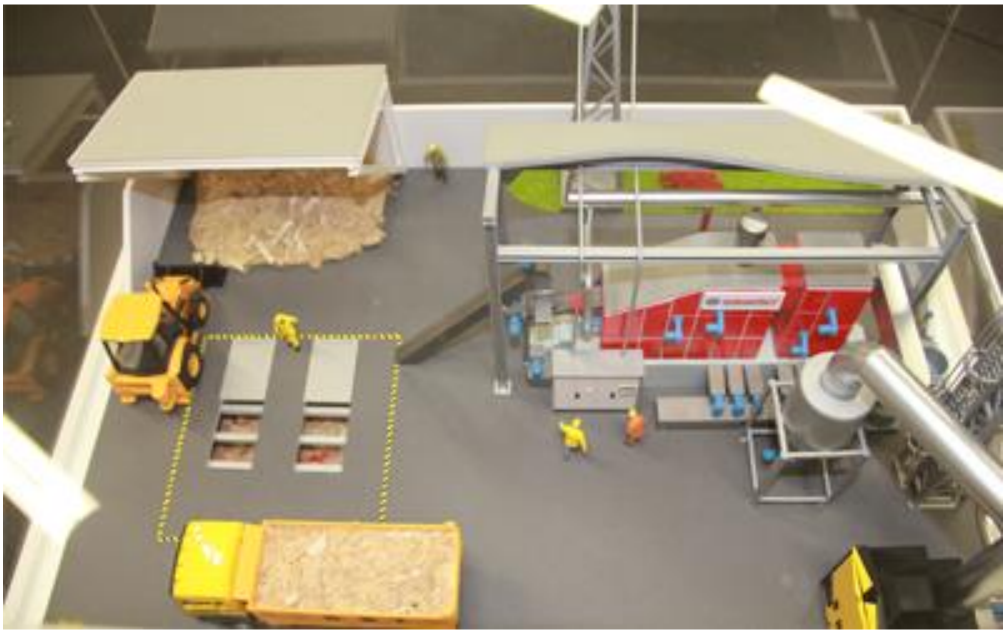
Wood Chip Delivery to Wood Chip Store for 6MW Biomass Boiler, Photo Courtesy of Sustainable Energy Ltd

Biofuels CHP - Cogeneration from biomass fuels can be achieved by three means, medium to large scale steam turbine systems; smaller scale ORC systems and advanced thermal conversion with gas engines systems.

Biomass Steam Turbine CHP – This utilises biomass in the form of wood chip, wood pellet or bio oils as a fuel source for a boiler which is then used to raise steam which drives a steam turbine to generate electricity, with heat recovered from the steam turbine's exhaust and cooling systems to provide useable heat.



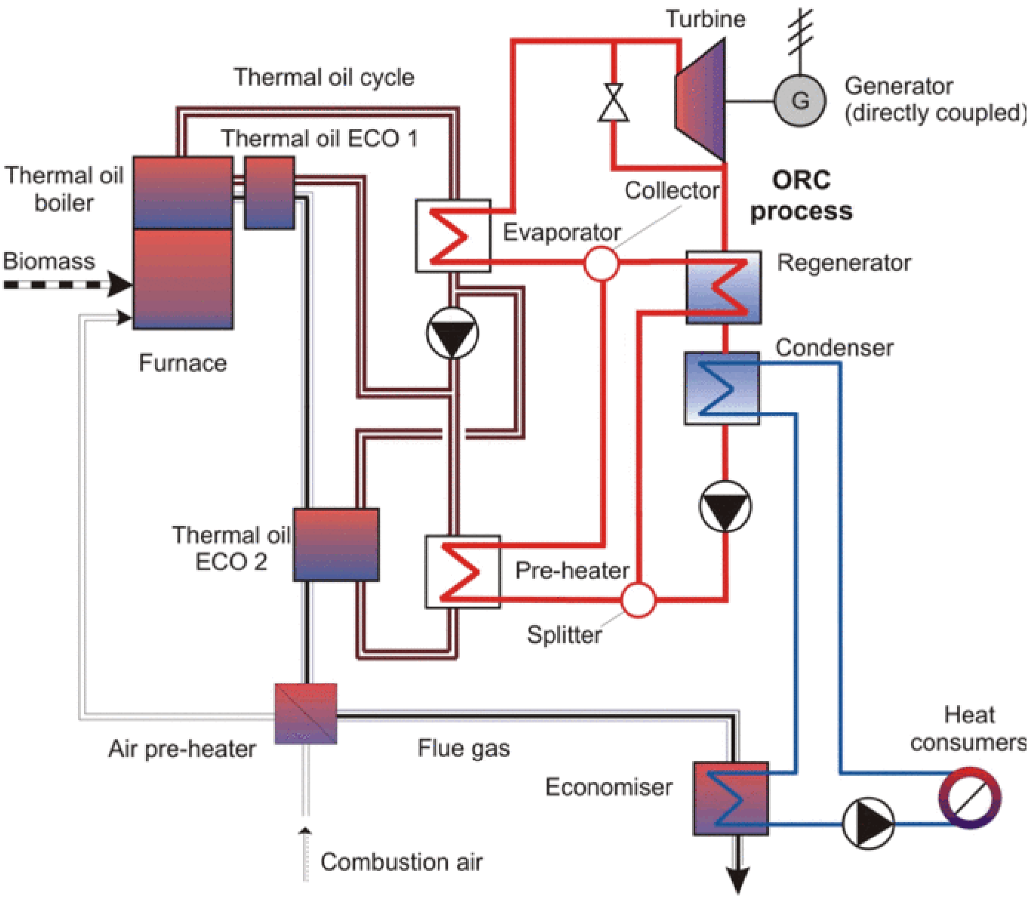
Picture courtesy of www.epa.gov



130kWe Biomass CHP Plant, Photo Courtesy of www.environltd.co.uk

Biomass Organic Rankine Cycle CHP (ORC) – Reciprocating steam engines and steam turbines use a thermodynamic process called the Rankine Cycle. At small scale, this is inefficient due to the high temperatures and pressures involved. However, it is possible to replace water as the working medium with an organic compound with a lower boiler point, such as a silicone oil or organic solvent. This allows the system to work at much lower temperatures, pressures and at smaller scale. The working medium is usually less corrosive than water to components such as turbine blades and the turbine can operate at a lower speed which can improve reliability. CHP systems where biomass fuel is used to produce heat to evaporate an organic compound to drive a turbine are known as Organic Rankine Cycle systems.

Picture courtesy of www.endswasteandbioenergy.com



Picture Courtesy of www.bios-bioenergy.at

Biomass Gasification CHP – For Biomass Gasification CHP, instead of wood fuel being combusted to raise steam to generate electricity via a steam turbine, the wood fuel is burned with restricted oxygen levels to produce a wood gas which is then combusted within an internal combustion engine. The engine is then used to generate electricity, with heat recovered from the engine's exhaust and cooling systems to provide useable heat.

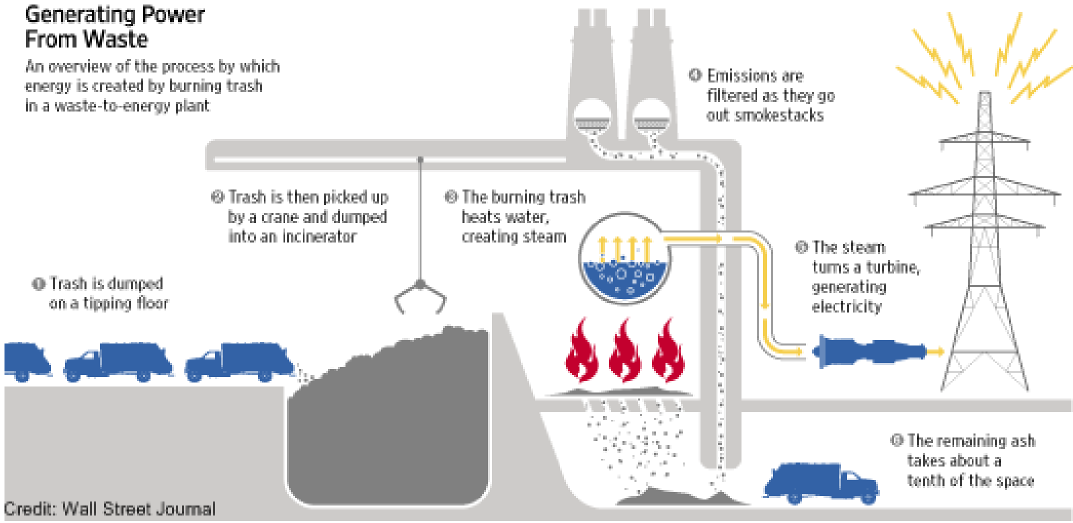
250kWe Wood Gasification System, Photo Courtesy of Sustainable Energy Ltd

The temperatures of the usable heat available from different CHP systems depends on the type of prime mover[4] used. Higher flow temperatures can be achieved from engines for gas CHP and biomass gasification CHP or ORC systems whereas fully condensing steam turbines will not generate temperatures suitable for district heat systems unless electrical efficiency is sacrificed to achieve higher flow temperatures. Indicative flow temperatures for different CHP technologies are shown below:

	Internal combustion engine	ORC	Steam turbine – full condensing
Flow temperature	80°C to 90°C	80°C to 90°C	40°C to 50°C
Potential thermal efficiency	55%	50% to 60%	60% to 70%
Use as LTHW	Yes	Yes	No

Energy from Waste – Energy from Waste plants burn waste to generate electricity via a prime mover such as steam turbine or engine. The waste normally combusted in such plants is the residual waste from Municipal Solid Waste which is left over after all recycling possible has been done. This waste is normally a mix of items made from oil such as plastics and items that are biodegradable such as paper, wood and food. The most common thermal treatment for waste is incineration; waste is incinerated and the heat produced is used to heat water to raise steam which then drives a turbine and generates electricity. Significant amounts of heat are generated in this process which are often dumped, but this could be used to provide a heat source for a district heating scheme by recovering the heat from the exhaust and cooling systems of the steam turbine. Advanced thermal conversion processes such as gasification and pyrolysis can also be used to generate electricity from waste; by converting the waste into a product such as oil or gas that can then be burnt directly in gas engines or turbines. Advanced thermal conversion systems are potentially more efficient but are technically difficult and relatively unproven at commercial scale.

[4] The CHP prime mover is the heart of the CHP system. It is a mechanical machine which drives the electricity generator or develops mechanical power for direct use



Picture courtesy of www.edouardstenger.com

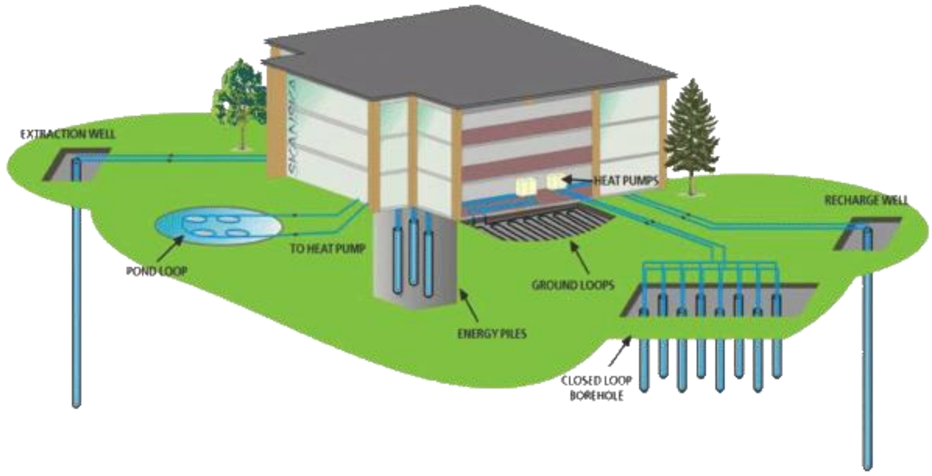
Heat Pump Technologies[5] **-** Ground and Water Source Heat Pumps take heat from the ground or water and transfer it into buildings or a district heating system. The technology used is the same as that used in refrigerators. Just as a fridge extracts heat from the food and transfers it into the kitchen, so a ground source heat pump extracts heat from the earth and transfers it into a building. For every unit of electricity used to power the heat pump, approximately 3-4 units of heat are captured and distributed. At this efficiency level there will usually be less carbon dioxide emissions than for a gas boiler heating system.

A Ground or Water Source Heat Pump system comprises three basic elements - a ground loop / collector array, the heat pump itself and the heat distribution system. The ground loop is a pipe buried underground in a horizontal trench, in a vertical borehole or immersed in water.

Horizontal trenches can be dug >2 m below ground level and, although covering more land surface than a borehole, they are usually cheaper for smaller systems. Boreholes are drilled to a depth of between 15-150 m and benefit from higher ground temperatures than trenches. However, there are a variety of types of pipe (e.g. the coiled pipe known as a 'slinky') which can be used in a trench instead of a straight one, which increase the amount of heat absorbed from the ground and so enhance performance. The ground area required for trenches will vary with the location, the property and the heat output required. A water/anti-freeze mixture is circulated through the pipe where it absorbs heat from the surrounding medium. A heat exchanger then extracts the absorbed heat and transfers it to the heat pump.

The third basic element of a ground or water source heat pump, the heat distribution system, can be either low temperature radiators or, preferably, underfloor heating. If the heat pump is asked to produce higher temperatures, for a conventional radiator circuit, then its efficiency will significantly reduce.

[5] Summarised from GSHP Association



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