Swaffham Prior Renewable Heat Network Feasibility Study

2017

Bioregional

carbon alternatives

Contents

Executive Summary

This study indicates that there is a marginal economic opportunity to develop a heat network in Swaffham Prior. The heat network would predominantly serve older housing, with there being few non-domestic properties within Swaffham Prior. The majority of the newer housing is to the north east and slightly separated from the village and has not be considered for connection due to low heat loads, nearly new boilers / ASHP and the extra distance from the energy centre.

Based on potential customers paying the same at their current heating cost the economic returns are around 7%, but it is acknowledged that a significant discount will need to be offered to encourage customers to connect. The study assumption is that 70% of the houses in the area proposed to be served with District Heating. If only 50% of the houses connect then the rate of return drops to between 4.5 and 5%.

Two renewable heat supply options were considered, straw boilers benefiting from the local straw resource and ground source heat pumps. Both technologies had similar economics the key difference between the options being that the heat pump option requires far less day to day management due to the lack of requirement for fuel deliveries. The straw option would need a larger energy centre and require regular fuel deliveries but it’s efficiency would be less sensitive to achieving low return temperatures from the heating and hot water systems in each house.

The carbon savings for the straw based scheme are expected to be around 80% and 70% for the heat pump based scheme.

The capital cost for the system to supply 180 homes is of the order of £2.5 million for the straw boiler scheme and £3 million for the ground source heat pump based scheme.

A community survey, based on a questionnaire sent to every house in the village achieved a 33% response rate and indicated that 66% of those that responded are in favour of a village wide heat network, 28% weren’t sure and less than 4% against it. This is a great response but the challenge will be to convert this enthusiasm into contracted heat customers.

This work, we believe, is sufficient to justify a more detailed feasibility study to develop a business case and commitment from potential customers such that an application could be made for funding from the Heat Network Investment Project (HNIP) capital funding of the project.

1. Introduction

1.1 Background to Swaffham Prior and Swaffham Prior Community Land Trust

Swaffham Prior is a village of just over 300 houses in South East Cambridgeshire, about 5 miles west of Newmarket (Suffolk) and 10 miles North East of Cambridge. Burwell, Reach and Swaffham Bulbeck are its immediately neighbouring villages. Swaffham Prior used to be known as Great Swaffham; Swaffham Prior and Swaffham Bulbeck together are often known as 'The Swaffhams'.

The Swaffham Prior Community Land Trust (SPCLT) was set up by members of the village to deliver housing for people linked to Swaffham Prior and the surrounding villages who struggle to rent at normal market rents or who need to rent a different type of home. It delivered eight affordable homes comprising 2x two bed bungalows, 3x two bed semi-detached houses, one three bed semi-detached house and 2x three bed detached houses. The homes are located in what is locally known as Dencora Field along Rogers Road. The homes are managed on a daily basis by Hundred Houses Society.

1.2 Project Background

Swaffham Prior Community Land Trust (CLT) want to appoint a consultant to undertake an investigation into the feasibility of successfully developing a community scale renewable heat energy installation. The results of this investigation will be presented to WRAP as a feasibility report to deliver Stage 1 of the Rural Community Energy Fund (RCEF) grant scheme.

The ideas behind the Swaffham Prior Community Renewable Heat Scheme (SPHN) are in the early stages of development. This feasibility study aims to identify feasible and practical ways of getting Swaffham Prior off oil as the main heating fuel and replacing oil with a renewable heat source.

Historically, Swaffham Prior has remained unconnected to the gas main network, (although it is understood that a high pressure gas main runs parallel to the bypass). Therefore, oil is the main heating fuel source for most buildings.

An indicative study area for the project was not formally set but the feasibility study will consider the whole of Swaffham Prior Village. The CLT, in early consultation with Swaffham Prior Parish Council has outlined an approximate project area. This includes up to 300 houses, a small primary school, a village hall, pub and a number of indoor and one outdoor swimming pool. Early investigations have also highlighted available employment land on Heath Lane to the South East of the village adjacent to Goodwin Farm and behind this allocated land agricultural land own by the County Council.

Figure 1: SPHN and energy centre location

Heat networks overview

A heat network or district heating (DH) system conveys heat to multiple buildings though a piped supply of hot water to each building. This water is heated at a central location with heat provided from one or more sources. They range from communal heating systems in apartment blocks to city-wide systems with multiple heat sources, such as in Copenhagen. The heat can be waste heat from a power plant, dedicated heat from a boiler, or a secondary heat source for example from computer data centre chillers.

One of the potential advantages of heat networks is that they can help reduce carbon emissions because they can use heat sources that would not be practical at an individual building level (e.g. wood chip boiler) or heat sources that are cheaper at scale – e.g. one large heat pump and bore hole is cheaper than many small heat pump systems. A further benefit of a heat network is that the more complex heat technology is the responsibility of the professional DH operator rather than individual renewable heating systems per house where, to get the best out the system, the householder often needs to be quite technically knowledgeable about the installed system. Heat networks are agnostic to the heat generation technology, and it is simpler and cheaper to change one centralised DH heat source to a lower carbon heat source, as they become available, than it is to change the heat sources in the many buildings a heat network may supply.

Although heat networks have enormous potential, historically in the UK they have not performed as well as they should. This can lead to overheating as well as higher installation and maintenance costs. There are numerous factors, but oversizing and poor system design are commonplace. The Heat Networks Code of Practice (HNCoP) was launched in 2015 to start to address these issues and learn from best practice across the world, in particular Scandinavia.

The key themes of the Code are:

1. Correct sizing of plant and network
2. Achieving low heat network heat losses
3. Achieving consistently low return temperatures and keeping flow temperatures low
4. Use of variable flow control principles
5. Optimising the use of low carbon heat sources to supply the network
6. Delivery of a safe, high quality scheme where risks are managed and environmental impacts controlled

Theme 3 is especially important if heat pumps or solar thermal heat sources are to be used as these are significantly more efficient at lower operating temperatures.

1.3 Project scope and Report Structure

This study will investigate the feasibility of developing a successful community-scale renewable heat network. The report covers the following areas:

- Description of the site area
- Development of heat load and heat demand of the village
- Technical review of low carbon technologies suitable for heat network connection
- Planning review of potential technologies
- District heating network design and energy centre considerations
- Economic/ financial assessment of proposed heat network
- Community engagement and support for the proposed scheme from local residents
- Management options/and governance
- Key conclusion and recommendations

2. Description of the Study Area

2.1 Overview

Swaffham Prior is a village of just over 300 houses in South East Cambridgeshire and a population of over 800 residents. The village is 5 miles west of Newmarket (Suffolk) and 10 miles North East of Cambridge. Burwell, Reach and Swaffham Bulbeck are its immediately neighbouring villages.

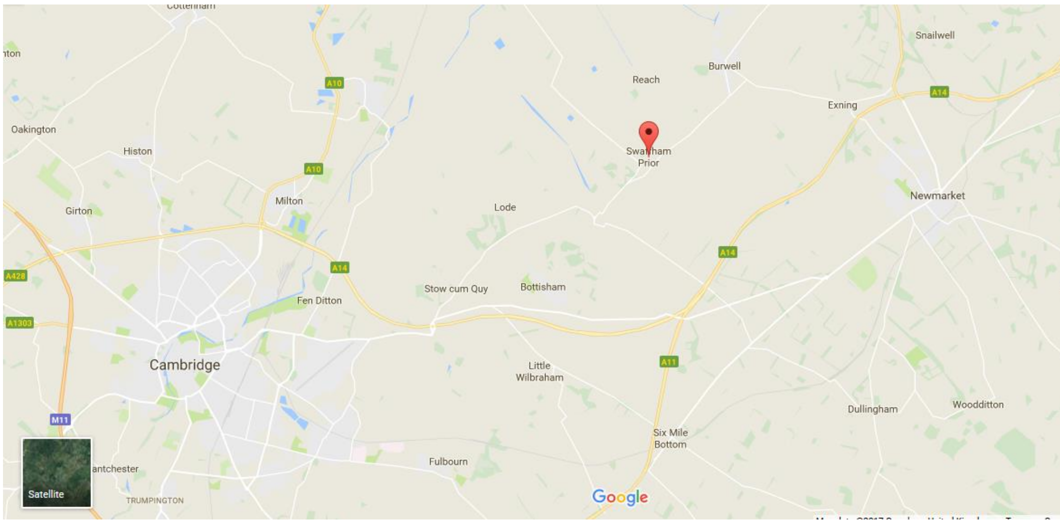


Figure 2: Location of Swaffham Prior in relation to Cambridge and Newmarket

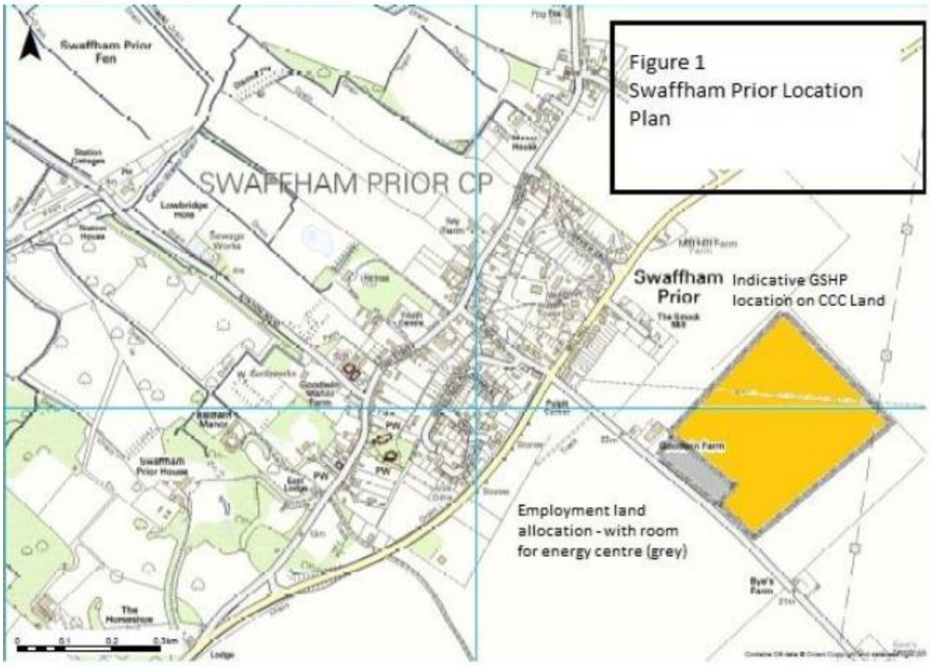


Figure 3: Map of Swaffham Prior

3. Heat Load Development

3.1 Understanding the heat demands

To evaluate the feasibility of a heat network it is key to understand the potential customers heating needs. The network needs to supply the maximum demands of all the customers. This peak demand establishes how big the pipes and heating plant need to be. The typical annual heat demands must be understood as these will set the revenues from the heat sales. Finally, the profile of the heat demand, how the heat demands vary over each day and over each year, is needed. Knowing the profiles allow the heating plant size to be minimised and the size of thermal calculated such that the peak loads can be supplied by the combination of the heating plant and the thermal store.

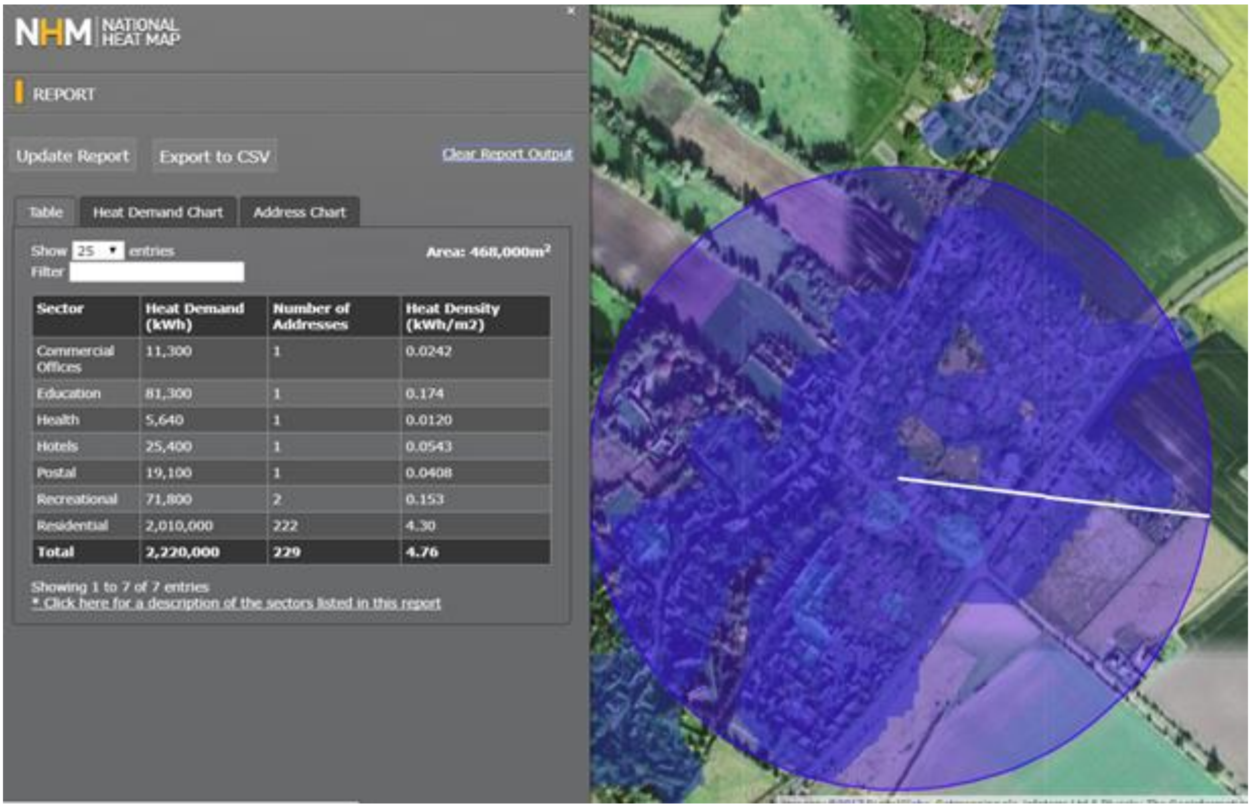
3.2 Property Profile

Swaffham Prior is a village old enough to be mentioned in the Domesday Book. The centre of the village has the oldest solid wall housing and further out from the historic centre are newer houses, the majority of which are cavity wall construction which results in lower heating demands. The newest houses, built in the last few years, are situated along Rogers Road. There is a distinct gap between these houses and the majority of the village. Due to this this gap and the lower heat loads of the newer houses, Rogers Road has been left out of the heat network feasibility.

3.3 Heat Demands

The source data for the assessment of the annual heat demands used was the National Heat Map (http://nationalheatmap.cse.org.uk/) and the EPC (Energy Performance Certificate) database (www.epcregister.com). EPCs are required to be produced when a house is sold or is rented out, hence over time more of the housing stock will have an EPC. EPCs are still only an estimate of the heat demands as although they consider the levels of insulation for each house, the ultimate demands are significantly influenced by the resident’s choice of how warm they heat the property and for how much of the day the property is kept warm.

An extract of the National Heat Map is shown in figure 4. The blue circle shows the area covered in the tabulated data. About 90% of the heat demand is from residential properties.



Sector	Heat Demand (kWh)	Number of Addresses	Heat Density (kWh/m2)
Commercial Offices	11,300	1	0.0242
Education	81,300	1	0.174
Health	5,640	1	0.0120
Hotels	25,400	1	0.0543
Postal	19,100	1	0.0408
Recreational	71,800	2	0.153
Residential	2,010,000	222	4.30
Total	**2,220,000**	**229**	**4.76**

Figure 4: National heat map – excluding Rogers Rd.

The EPC data includes information on the estimated heat use for space heating, DHW (Domestic Hot Water), construction type, heating type and other energy efficiency measures. There were 167 entries in the EPC database for Swaffham Prior, the heat map indicated there are 229 addresses, excluding the Rogers Road area.

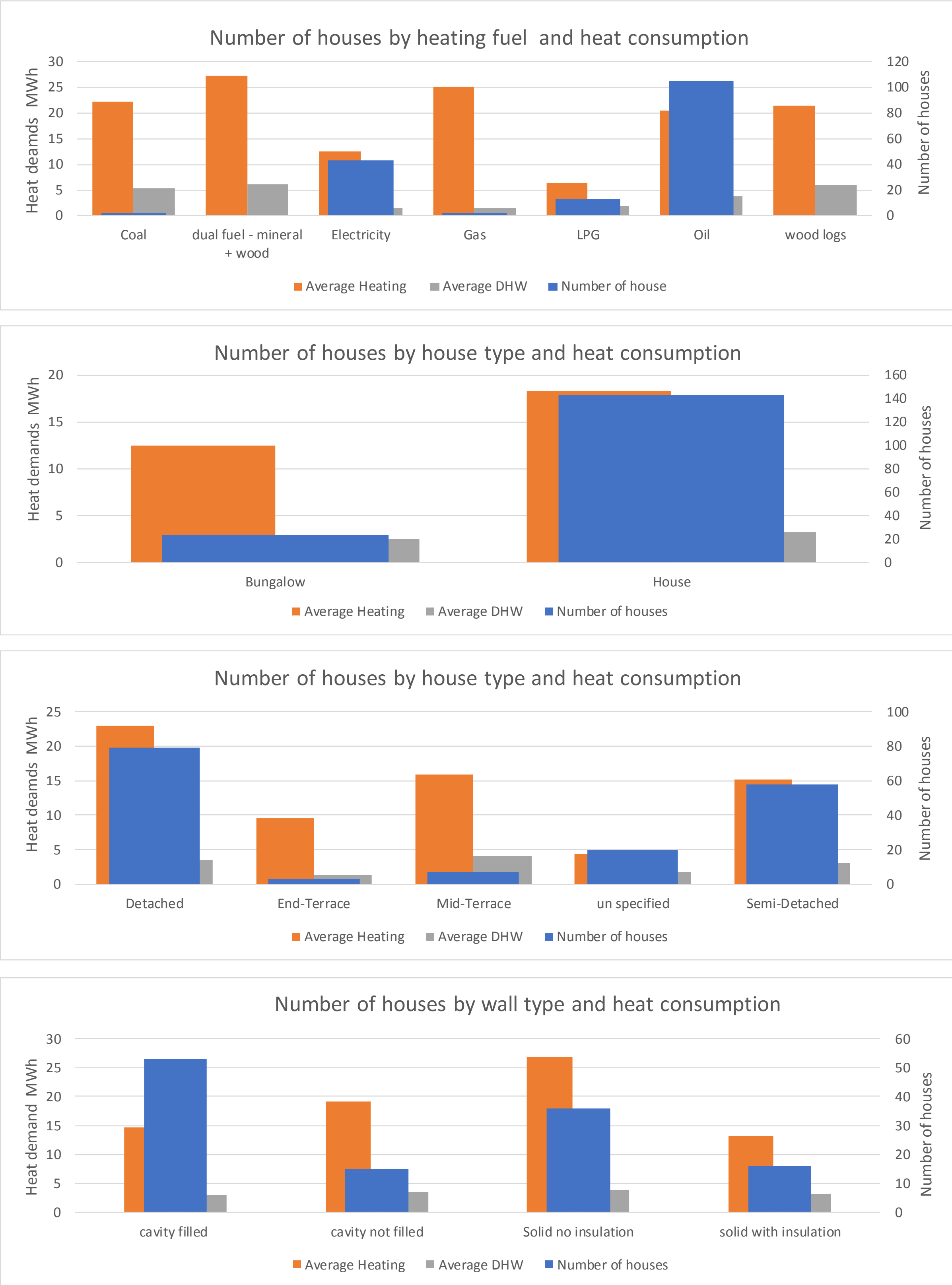


Figure 5: Housing stock characterisation from EPC data

To model the heat demands we are seeking to categorise the housing stock in a way that best represents the diversity of heat demands across the stock whilst keeping the number of types down.

Figure 5 shows the range of variables reviewed from the EPC data. In summary the data shows:

- 75% of houses heated with oil or LPG and 25% with electricity + a very few other heat source
- The stock is about 15% bungalows
- The stock is predominantly detached and semi-detached houses
- There is a wide variation in house heat demand depending upon the wall construction – which is a good indicator of the overall level of thermal insulation in of the house.
- On the basis that the wall construction gives the widest range of heat load this has been chosen to sub categorise the EPC data. The insulated cavity and insulated solid wall categories have been combined as they are have very similar heat loads.

The proportion of these wall types and space heat demands were then increased pro-rata up to the number of houses included in the heat network feasibility. The three house types were modelled separately as the modelling software allows the ambient temperature at which heating is needs to be set for each house type.

The houses with poor insulation / higher annual heat demands have typically a longer heating season (i.e. space heating required at higher ambient temperatures) than the better insulated houses. The domestic hot water (DHW) demand for the houses was modelled separately. All houses are assumed to use the average annual DHW consumption of 3,190 kWh per year.

Wall type	number of houses	space heat kWh/yr/ house	DHW heat kWh/yr/ house
Cavity not filled	15	19,100	3,400
Solid wall no insulation	36	26,900	3,800
Combined insulated cavity and insulated solid wall	89	12,100	2,900
Average			**3,190**

Table 1: Summary EPC wall construction categories

To develop an hour by hour assessment of the heat loads for the year the heat demand profile is needed, this reflects the time of day DHW is used and space heating is turned on. Data from the Ofgem Energy Demand Reduction Programme (EDRP) was used to estimate the daily demand profile.

EDRP monitored the hourly gas use in a large number of homes where gas was used for heating and so should give a representative view. The DHW demand profile is based on the summer EDRP data and the space heating profile based on the EDRP winter data.

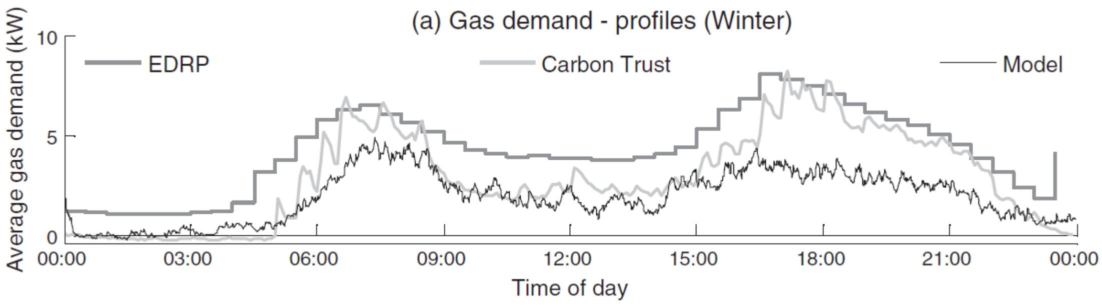


Figure 6: Gas demand profiles in winter

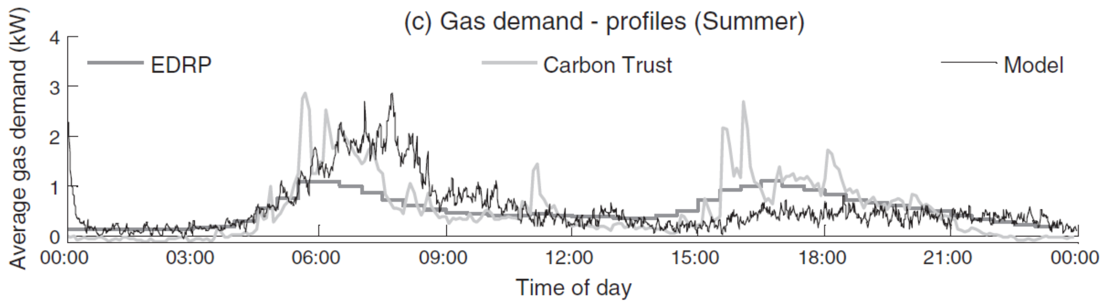


Figure 7: Gas demand profiles in summer

The peak heat demands have been based on the EDRP data too. The peak demands determine the sizing of pipework, pumps and the heat production plant. The data shows that the typical peak heat demand for houses in England is around 7 kW for space heating and heating of hot water cylinders. Since the houses in Swaffham Prior are older and more detached, we have used an estimated the average peak load to be 8 kW.

For the domestic hot water (DHW), we used 33 kW (the output of a typical gas combi boiler) which is typically sufficient for 1 tap and 1 shower simultaneously for instantaneous production. These sizes have been used to develop a reasonably accurate model for the SPHN pipe and plant sizing. In practice some connections will be larger and some smaller, but this will average out.

Non-domestic heat loads
The heat load of Swaffham Prior Primary School is based on the DEC (Display Energy Certificate) information and the demand profile based on monitored data for a primary school of similar construction.

For the other non-domestic loads, the heat demands as identified in the Heat Map data (figure 4) was used. The 'Recreational' demands identified in the Heat Map data are most likely to be the two churches. The churches have not been included in the study as previous work on similar studies typically find that churches only need to be warm for very few hours of the week, so little heat is actually required, but a big DH connection is needed to heat the building up in a reasonable time.

The consequence of these factors make a church expensive to connect to the SPHN and then the income is low due to the low heat use. Also, low temperature

DH is slow to heat a building, especially buildings like churches with very high thermal mass. Churches are better heated either with radiant heating or from heat sources that can provide rapid high outputs such that air in the church can be brought up to temperature just for the period the church needs to be warm. If appropriate, the churches can be included in the SPHN network at a more detailed design stage.

	Number of buildings	Annual heat demand (kWh)
Houses	222 [heat map]	4,873,000 [EPC data]
School	1	84,400 [DEC data]
Other non-domestic	6 [heat map]	61,440 [heat map]
Total	**229**	**5,018,864**

Table 2: Village heat demands with data source in brackets

4. Low carbon heat source selection

The ambition is to utilise a renewable or at least low carbon heat source to provide heat for the heat network. The appropriate renewable heat options shortlisted for this study are:

- biomass boiler;
- heat pumps;
- solar thermal.

Each of these are commented on below. Other renewable technologies such as biomass CHP, anaerobic digestion were not studied due to lack of proven technical solutions at this scale (biomass CHP) and lack of awareness of local resource for feedstock (Anaerobic digestion).

4.1 Heat pumps

Heat pumps take low temperature heat and use some electricity to produce higher temperature heat. The categorisation of heat pump is through the heat source used. The warmer the heat source the more efficient the heat pump. Higher efficiency results in lower operating costs and greater carbon savings. The heat source options are:

Surface water source – e.g. drawing heat from river, lake or the sea. The National Heat Map indicates potential water heat sources. An extract of the map for the Swaffham Prior area is shown in figure 8. The nearest useful heat source is the Gutter Bridge Ditch which has up to 300 kW of heat but is over 1500 m from Swaffham Prior and therefore has been discounted due to the high cost of such a length of pipework and the amount of heat available would only be sufficient to meet part of the heat demand.

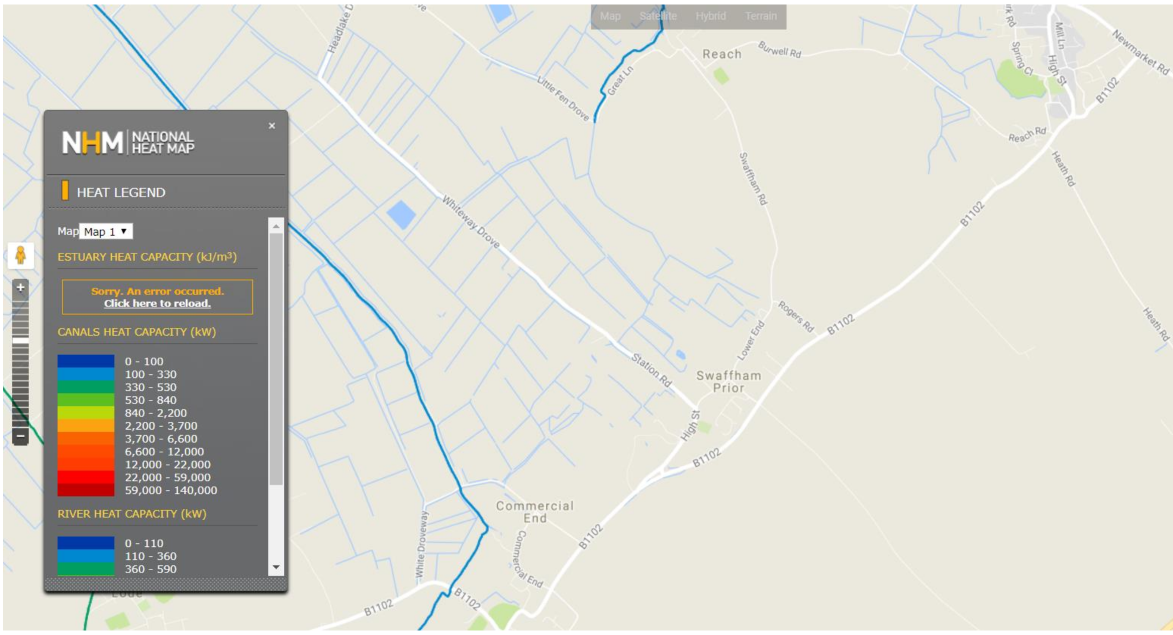


Figure 8: National Heat Map water source potential

Air source (ASHP) – taking heat from the air. This is inherently a less efficient application of heat pumps as the heat demands are higher in the winter when the air is colder than ground or water heat sources. The benefit of air source heat pumps is the lower capital cost. For the SPHN, where the utilisation of the heat pump is high, the higher operating efficiency of ground or water heat source heat pumps tends to lead to better economics despite the higher capital costs. For this reason, ASHP is not considered.

Ground source (GSHP) – is when the heat for the heat pump is drawn from the ground this can be achieved in several ways:

1) Burying pipes in trenches in the ground a meter or so below the surface, commonly called a ‘slinky’ as shown in Figure 9. Slinkys tend to be used on smaller schemes; as a rule of thumb, 10 m of trench is needed per kW of heat pump capacity. For a heat pump of the size required for this project, the required trench would be over 5 km. At much shorter lengths than this bore holes, described below, are a cheaper option.

Figure 9: 'Slinky' GSHP loop, photo courtesy of Centre for Sustainable Energy

2) Open loop bore holes – groundwater is abstracted at ambient temperature from the ground typically 12°C, passed through a heat pump before being re-injected back into the ground or discharged at the surface. The British Geological Survey provide a web based tool[1] that gives an indication of the likely technical and economic feasibility of an open loop bore hole heat source for GSHP over 100kW. The tool indicates that the conditions for open loop bore holes are likely to be favourable in Swaffham Prior given the underlying chalk geology. There is an uncertainty in how much water can be drawn from the boreholes until they have been drilled and tested. If yields are low additional, expensive, boreholes may need to be drilled. This uncertainty is a major risk for open loop solutions generally, but the chalk aquifer suggests that conditions should be favourable.
3) Closed loop bore holes – is where the pipes are placed into vertically drilled boreholes and the water is circulated through these pipes to draw heat from the ground. This is more expensive to install but there is less performance risk and less scope for problems associated with direct use of ground water.

Based on keeping capital costs down the study is based on the use of open loop boreholes.

Heat pumps offer a solution that requires a minimal intervention during normal operation. Heat pumps, although complex, are reliable machines and the installation would typically consist of 2 or 3 heat pumps such that the range of high and low loads can be supplied and there is redundancy in heat supply.

4.2 Biomass option

Biomass is any fuel that is developed from organic materials, commonly wood chip or wood pellet. The options of most relevance to Swaffham Prior are described below.

Wood chip is chopped up seasoned timber, it is bulkier than pellet but cheaper and easier to locally produce, it lends itself to areas where there are local woodlands, or where short rotation coppiced wood could be grown.

Wood pellet is a manufactured product that uses wood waste, has a higher energy density and uniform size. These characteristics make pellet easier to transport and for each m^3 of space contains more energy. The uniform standards that pellets are manufactured to make the fuel handling systems and boilers simpler than for wood chip which has more varied size and moisture content. Pellet is more expensive and would not be locally produced.

Straw burning is less commonly considered in the UK for DH schemes, but for Swaffham Prior it may well be the best biomass source. Straw is essentially an agricultural waste, it has a low energy density and so is expensive to transport over long distances, but Cambridgeshire grows many crops that leave straw as a by-product, hence there is local availability. Ely Power Station 8 miles North West of Swaffham Prior burns around 60,000 tonnes of straw each year. The benefit of this is that there is an existing fuel supply chain and locally accepted quality standards for straw. There is good operating experience of smaller scale straw boilers on farms in the UK and there are rural DH systems in Denmark that have straw boilers. We have contacted Melton Renewable Energy the owner of Ely Power Station to ask if they may be able to offer advice on the fuel supply arrangements but we received no response.

Other biomass such as energy crops (Miscanthus or similar), food waste, slurry from cattle (which is a biomass although commonly considered under the categories of anaerobic digestion, a process by which these more liquid wastes are broken down to produce biogas and more pleasant solid waste). These other biomass sources have not been further considered due to their more complex fuel supply chains.

The key issues and challenges with biomass are:

- Need for operator intervention to: accept fuel deliveries, check fuel quality, load boiler, address any issues arising from boiler / straw feed system
- Ordering of fuel in good time
- Ensure year-round supply of fuel which is seasonally harvested
- Management of air pollution

Heat source recommendations

Based on the above factors our recommendation is that two options are evaluated, the straw boiler and open loop ground source heat pump.

These two options have the following characteristics:

	Heat pump	Straw boiler
Capital costs	Higher – heat pump costs higher and need more thorough work in houses to achieve low operating temperatures.	Straw boiler cheaper. Possibly less work required in houses.
Fuel cost	Higher	Lower
Fuel supply process	Simple	Complex
Requirement for day to day management of energy centre	Low	Higher
Energy centre size	Smaller	Larger + depends where seasonal store of straw is.
Carbon saving	Lower, but increases due to the decarbonisation of the electricity grid.	Higher
Local pollution	Lower	Higher
Additional transport movements	Few	Regular fuel deliveries
Keeping money in local economy	Fuel costs not spent locally	Fuel and O+M costs spent locally
Increasing local employment	Low	Higher – for straw production, delivery and boiler O+M.
Technology maturity	Mature	Mature
Operating costs – sensitivity to heat network operating temperatures	High – if low DH temperatures are not achieved the plant efficiency will be lower	Low – there in no plant efficiency impact if DH operating temperatures. (DH heat losses will be higher with higher temperatures though)
Key risks	Bore hole yields, required operating temperatures of DH network (the setup achieved in each house)	Long term straw price and straw availability. Boiler may be able to accept other biomass fuels
Predominant operating costs	Electricity	Straw, maintenance and managing straw deliveries

In comparison to heat pumps, a straw boiler requires much more day to day intervention and will need more maintenance and more response to faults, but the capital cost and cost of heat is lower than for heat pumps.

The issues for a straw boiler would be best addressed through the use of a local contractor or willing local resident for whom visiting the energy centre would not be too time consuming. This may be possible to achieve in the short term but such local support might not be ensured in the long run.

Discussions with straw boiler suppliers indicate that there are many straw boilers in operation in the UK but these tend to be on farms and other sites where there are practically skilled people onsite who can manage the basic requirements of the fuel supply and boiler systems. In the absence of such staff, there are automated systems that can feed straw bales into the boiler as required.

One of the benefits of the biomass boiler option is that the plant efficiency is not significantly affected by the operating temperatures of the heat network. This removes the risk that low flow and return temperatures cannot be achieved, due to the costs of the required interventions in each house. Not achieving low operating temperatures would have significant impact on the operating efficiency of a heat pump.

4.3 Thermal storage

A thermal store is a large hot water tank. The use of thermal stores is key to the economics of expensive renewable heat technologies. The store allows a small plant to supply large peak heat demands. When demand is low the renewable heat source heats the store and when the demands are higher than the renewable plant output heat is drawn from the store to meet the peak. The smaller plant reduces the capital costs and the store allows the plant to run at a steady output over long time periods which enables the plant to operate efficiently.

The plots below show how the thermal store allows the systems to operate. Figure 10 shows the operation of a straw boiler during a week in summer when the heat demands are low. In the upper chart the red line is the heat demand and the yellow shows the boiler operation 4 times over the week. In around 6 hours of operation the boiler heats the thermal store, the lower chart shows the stored heat increasing when the boiler operates, and then slowly discharging over a couple of days to meet the heat demand.

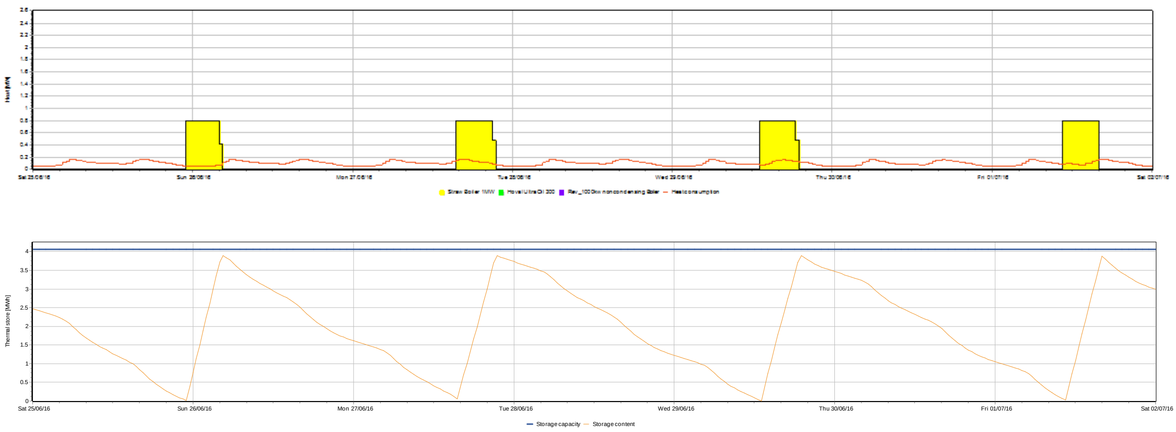


Figure 10: Thermal store in summer for straw boiler

In winter the store helps meet the peak heat loads as shown over the period of a week in figure 11. The yellow is the heat pump operation and the purple the oil boiler operating when the store and heat pump have insufficient heat. The heat pump will always operate after midnight and fill the thermal store (the vertical black lines are midnight), at these times the electricity price is lower so charging the thermal store at these times lowers the cost of generating the heat.

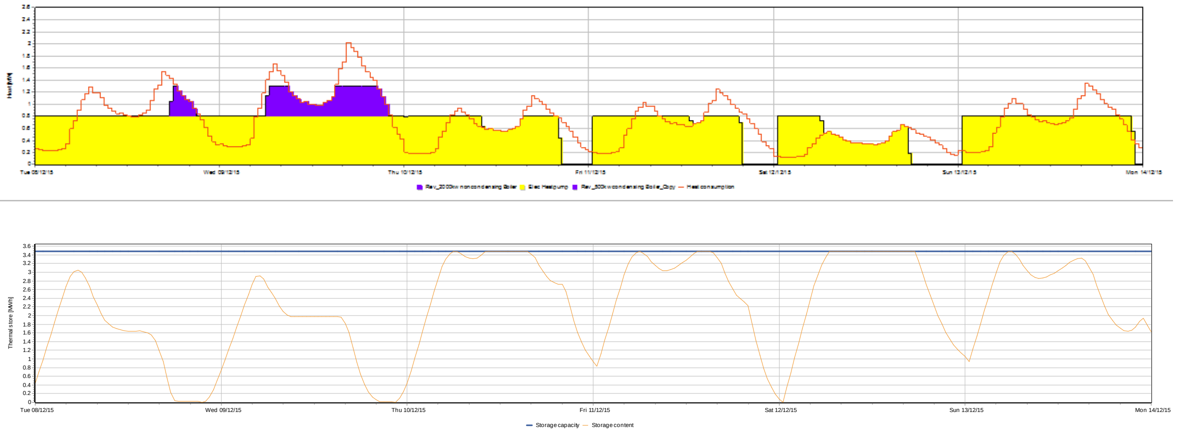


Figure 11: Thermal store in winter on system with heat pumps

4.4 Addition of solar thermal

Solar thermal is using the sun's heat to directly heat water. Solar thermal can be used to provide an additional renewable heat source for the SPHN and reduce the electricity used for heat pumps or the straw burnt. The seasonal nature of the solar resource means that it is simpler to use solar as an additional heat source rather than design it as the primary heat source. Solar thermal can be the predominant heat source through the use of very large thermal stores, the size of a lake which stores summer heat for use in the winter. With limited thermal storage sizes, such as the store sizes economic for use with heat pumps or straw boilers, solar thermal, could supply up to 25% of the annual heat demand of the SPHN.

Figure 12: A Danish solar thermal installation with inter-seasonal thermal storage in the background

Solar thermal is much less common in the UK, but is potentially a better land use than PV. Solar thermal is around 60% efficient which is about 3 times the efficiency of photovoltaics. Solar thermal has high capital cost but is then very low cost in operation and hence removes uncertainty from fuel price risks.

4.5 Back-up and peak load heating plant

The proposed designs include the provision of back up oil-fired boilers. These boilers serve a number of purposes:

1) Allow a significant reduction in size of renewable plant, whilst still allowing a very high proportion of annual heat supplied from the renewable heat source. Without a backup boiler the renewable heat plant and or thermal store would have to be sized significantly large to meet the rare peak heat demands to ensure the system never runs short of heat.
2) The back-up plant ensures reliability of heat supply. In case the heat pump or biomass boiler trips off the back up will take over and there is less requirement for 24/7 instant response to faults. Fixing faults during the working week is much cheaper than undertaking such work outside of normal working hours.
3) In the event of failure to biomass supply or electricity supply the oil boilers could take over. In the case of a power outage, a small generator of only a few kW would be required to run the SPHN pumps and oil boilers and therefore guarantee security of supply.

Oil boilers are cheap in the context of the whole scheme and their actual use should be small so the carbon emissions are low. The paramount scheme requirement is to always ensure a reliable supply of heat to customers.

4.6 Heat source sizing and economic evaluation

Using energyPRO techno economic modelling software, we have evaluated the two recommended heat sources and economically optimised the plant and thermal store sizes. The economic evaluations assume 75% of the houses connect to the SPHN as 100% connection is highly unlikely.

The presented economic returns are based on the heat customers having no discount on their current heating cost, this will be considered later in the report. The analysis indicates the size of plant for each technology that is most economic and indicates the carbon savings.

Both options have 1,500 kW of back up oil boilers, 25% of which are more efficient condensing boilers and a 10 kW PV array mounted on the energy centre roof. The PV panels generate electricity contributing to the power requirements of the plant in the energy centre, the 10 kW size based on what could fit on the energy centre roof.

Results

	Plant output	Thermal store	Capital cost	IRR 20 years	% Heat Renewable	CO2 reduction
	kW	m3	£k			
Straw	1000	150	£2,510	7.4%	98%	82%
Straw	**1000**	**100**	**£2,460**	**7.6%**	**97%**	**82%**
Straw	1000	75	£2,435	7.6%	96%	81%
Straw	500	100	£2,335	4.5%	70%	47%
Straw	500	75	£2,310	4.2%	69%	47%
Heat pump	800	150	£3,065	6.9%	91%	69%
Heat pump	**800**	**100**	**£3,015**	**7.0%**	**89%**	**67%**
Heat pump	800	75	£2,990	6.9%	88%	65%
Heat pump	600	100	£2,816	6.1%	78%	54%
Heat pump	600	50	£2,766	6.8%	76%	51%
Heat pump	600	30	£2,746	5.8%	74%	49%

Table 3: Economic evaluation of range of plant sizes

The economic evaluation leads us to recommend either of the 2 options in bold.

- Heat pump option: 800 kW Ground source heat pump and 100 m^3 of thermal storage
- Straw option: 1 MW straw boiler and 100 m^3 thermal storage

Modelling assumptions for plant selections:

Electricity price – day	12p/kWh for heat pumps 15p/kWh Biomass option
Electricity price – night	8p/kWh for heat pumps 15p/kWh Biomass option
Straw price	£50/tonne
Heat pump O+M	£/yr £12,000
Straw boiler O+M	£/yr 25,000
Oil condensing boiler efficiency	93%
Oil non-condensing boiler efficiency	85%

4.7 Energy centre design

Figure 1313 shows a simplified schematic of a ground source heat pump of 800 kW, taking its heat from open loop boreholes, a thermal store to manage the peak demands, shift heat production from day to night and decrease the need for the oil boiler.

Back-up / top-up boilers of total capacity of 1,500 kW are added in series. Both the heat pump and boiler module can exist of multiple units to provide low load conditions and redundancy. The heat pump will be selected to provide 55-60°C which is high enough to provide instantaneous DHW supply and space heating when outside temperatures are above 5°C. When temperatures are below 5°C, the oil boiler is required to step in to increase the temperature of the heat pump output. These higher supply temperatures (up to 75°C) ensure the radiators in the houses are hot enough to keep all the houses warm.

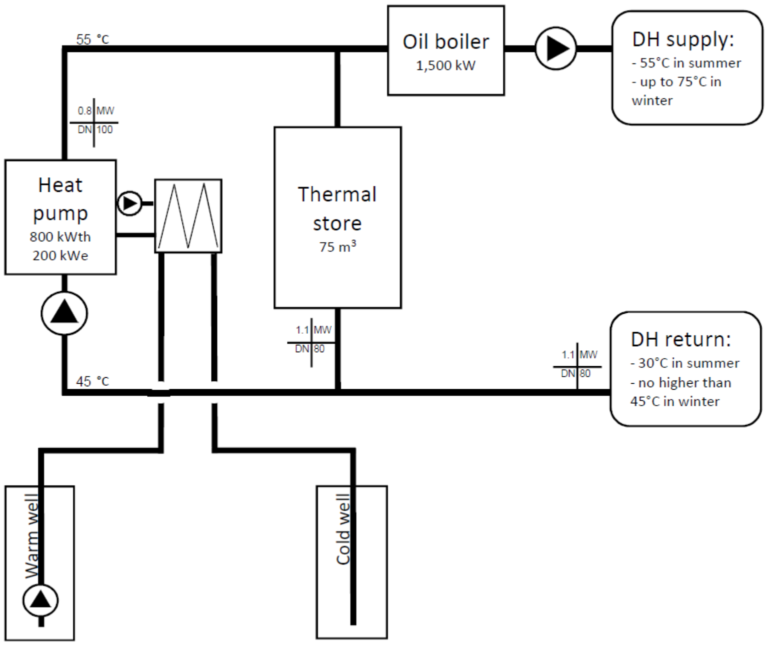


Figure 13: Example schematic for ground source heat pump option

The schematic in figure 14 has a single straw boiler of 1 MW and a thermal store of 100 m^3. As with the heat pump scheme there are back-up and top-up oil boilers to provide security of supply. Since the straw boiler can achieve high operating temperatures without significant drop in efficiency achieving the higher operating temperatures to provide sufficient comfort to the users does not need the use of the top up boilers. Due to these higher operating temperatures, the distribution losses will be higher for the straw boiler option.

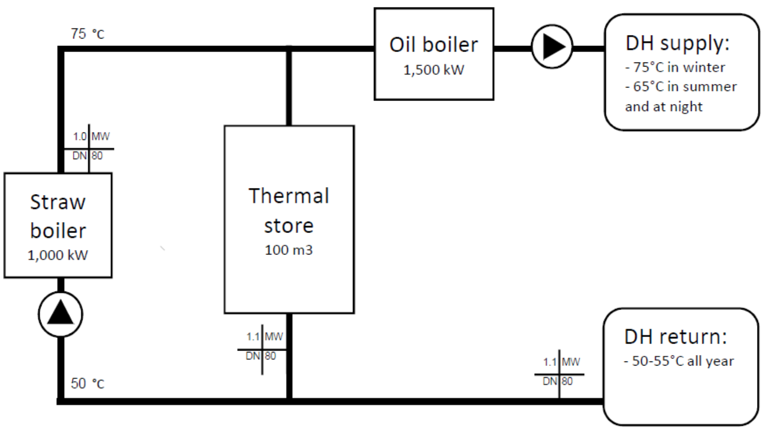


Figure 2: Example schematic for straw boiler option

As discussed before, both options can be extended with solar thermal, which for both the straw and heat pump options would reduce the operating cost.

5. Energy Centre Location

The proposed location in Heath Road is suitable for an energy centre. The nearest house is some distance away which reduces the chance of disturbance from noise (e.g. deliveries of straw) and reduces the required flue height for oil and biomass boilers. The proximity to the B1102 would minimize any disturbance arising from the deliveries of straw. The downside is the 300 m of the SPHN pipe to get to the edge of the village which adds around £100k to the costs.

For the heat pump option there could be other suitable locations as the plant is smaller, there are no fuel deliveries and no biomass boiler flue with associated emissions and may therefore be more acceptable to the local community.

Promising locations could be the school, or the water tower which seems to have some free space. Both facilities already have maintenance staff who could be trained to perform a daily/weekly visual check on the condition of the energy centre. The water tower may have an additional benefit in for ground source heat pumps as the heat from the water which is pumped out of the ground for Swaffham Prior's fresh water supply could be utilised by the heat pumps. Or there may be other council owned areas of land within the village.

Figure 35: Heat network and energy centre location

6. District Heating Design

6.1 Main network

The DH pipe work is one of the largest costs in the development of a DH scheme so minimising the cost of a heat network is key to the economic viability. Not oversizing the pipework will reduce the capital costs and the heat losses in operation. With every increase in nominal pipe size the heat losses increase by 10% and the capital costs by 15%. The high-level design undertaken for this study is based more on experience from operating schemes than the common UK design standards and has far less design margin than is common in most new UK DH systems which if monitored once in operation are significantly oversized.

The SPHN pipe is assumed to be mostly plastic twin pipe. Twin pipe is where the 2 pipes are wrapped in the same insulated outer pipe. This configuration reduces the heat losses by approximately 40% over two separate pipes. The operating temperatures are assumed to be a flow temperature of between 55 and 70°C depending upon the heat load and weather. The return temperatures are assumed to be 40°C for the heat pump option and 55°C for the biomass option. This leads to estimated heat losses of 250 MWh (6%) for the heat pumps and 370 MWh (8%) for the straw boiler option. These are significantly lower than the distribution losses experienced across most UK DH networks. The 4 main differences are low operating temperatures (55/40°C for 80% of the year compared to typically 80/60°C), significantly smaller pipe sizes (2 sizes smaller than typically sized), using a pre-insulated twin pipe system and a larger heat consumption per connection compared to new-builds which most new UK heat networks serve.

Within the trenches for the SPHN duct can be installed to allow fibre to be installed to each house and to allow a data cable to be installed to collect the heat meter data and potentially control the SPHN equipment in each house.

The technical assumptions for the SPHN design are stated in the Technical Appendix.

6.2 Pipe branches to each house

To connect each house a DH 'service pipe' needs to connected to the SPHN mains in the pavement / road in front of the house. The service pipe is buried in the front garden and then has to get through or round the house to the point where the current boiler is and the new DH connection made. Pipework through the house is likely to be standard copper pipe unless there are other options such as laying pipe under suspended floors.

This is an area where it will be important to explore in more detail at the next stage. There is not much UK experience of retrofit DH to existing houses such as in Swaffham Prior.

6.3 Modifications in houses

To enable use of the SPHN heat delivered modifications will need to be made in each house. District heating requires radiators or underfloor heating to deliver space heating and for hot water the SPHN can either heat a hot water cylinder or it can deliver DHW on demand like a combi boiler does.

For houses currently using oil or LPG it is assumed these have radiators and either hot water cylinders or combi boilers delivering instantaneous water heating. The design intention would be to reuse the currently installed radiators and hot water cylinders and connect them to the SPHN. The boiler would be removed and an HIU (hydraulic interface unit) will then be installed in its place. The HIU contains the equipment to connect the house heating and domestic hot water (DHW) from the SPHN. The HIU would either supply DHW instantaneously or it could connect to an existing hot water cylinder.

For properties without radiators, such as those currently heated electrically, then radiators would need to be installed and the electric heaters removed. In these properties, the existing hot water cylinder probably could not be re-used and it's technically better for the SPHN if an HIU delivering instantaneous DHW is installed. A comparison of the DHW options is given in Table 4 below.

As detailed in figure 5 the vast majority of houses are either oil/LPG or electrically heated. The few houses that fall out of these categories will probably need the same installation as for the currently electrically heated properties.

	Instantaneous DHW	**DHW cylinder**
Installation cost	Lower	Higher (unless already fitted)
Installation	Incorporated into HIU that would replace boiler.	Tailor made for every house to work with existing cylinder.
Impact on network	Allows more efficient DH operation. DH supply can be decreased to 55°C when space heating loads are low and return temperatures are lower	Tends to result in less efficient DH operation. Requires DH supply to be >65°C and gives higher return temperatures. Both resulting in higher distribution losses
Space	Makes the HIU a little larger so that it's a similar size to a wall-mounted boiler,	DHW cylinder takes up valuable cupboard space.
Customer benefits	Mains pressure DHW – which allows good showers	Older installations operate at pressures insufficient for showers which can result in the installation of electric showers which are expensive to run and reduce heat sales from DH
Security of supply	More vulnerable to operational issues on the DH network	Due to local storage, a short outage won't be noticed. Can include and electric immersion heater for back up.

Table 4: Comparison of domestic hot water supply options

The HIU includes a heat meter for the billing of heat used. It is recommended that the DH operator has ownership of the HIU and repairs and maintains the HIU. The correct setup and operation of the HIU is fundamental to achieve efficient DH operation. There is little skill base in the UK to maintain HIUs. For both these reasons it is beneficial to both the heat customer and the DH operator for the DH operator to take on responsibility for the reliable operation of the HIU.

If the heat pump option is installed then it is important to minimise the required DH flow temperature and to lower the DH return temperatures from the houses, and the operating efficiency of a heat pump is sensitive to increases in DH temperatures.

7. Operation of District Heating

In operation, the scheme's key priority is the reliable supply of heat. Customers who connect to the SPHN will lose the opportunity to switch to an alternative heat supplier as they could with an electricity supplier. So it is paramount that the heat supply is reliable, the costs competitive or lower that the alternatives and that the customers are satisfied with the service they receive.

In operation there are a number of ongoing requirements:

1. Energy centre operation and maintenance
2. Maintenance and repair of HIUs in houses
3. Customer heat meter reading, billing and management of payments
4. Administration function, managing requirements set out above, setting heat tariffs, managing investors etc.

Items 1 and 2 need 24 hour cover to ensure reliable heat supply to customers. For this to be achieved it is best for these roles to be undertaken by a local contractor. This contractor does not need knowledge of the more complex renewable heat plant as this can be subcontracted to a contractor with the correct experience. In the case of failure of the renewable plant the local contractor needs to ensure the oil boilers operate reliably to maintain the heat supply to the customers.

Item 1 has a much larger role if the straw boiler is installed as there may be requirements to open the energy centre to accept straw deliveries, to feed straw on to the supply conveyors and generally, due to the more mechanical process involved in burning straw, there are more likely to be day to day issues arising that need managing. The current controls technologies allow the energy centre plant to send out fault messages to the maintenance operator's computer and phones. The operator can then often make the required adjustments remotely such that the fault is remedied and the heat supply is maintained.

To fulfil item 2 the local contractor will need to develop some understanding of the operation of the HIU in each house. This is a fairly simple extension of conventional plumbing knowledge.

Item 3 can be simplified by installing a heat metering system which automatically reads the meters and where the provider has a website that offers a wide range of payment options. These systems can operate on a prepayment basis, similar to prepayment available electricity customers. Prepayment systems help manage potential bad debt issues. Occasionally there are faults on the heat meters and data collection systems, which ideally the billing provider manages.

Item 4 can be undertaken locally or contracted out.

8. Financial Assessment

The results of the financial assessment is shown in Table 3 above, as the assessment has been used to evaluate the optimum plant size. The section below describes the inputs to the economic assessment.

8.1 Assumptions

The base assumption is that 75% of the houses (180 houses), the school and the other non-domestic loads in Swaffham Prior connected to the heat network.

The assumed income from heat sales is equal to the current costs of provision of oil based heating in each house.

The current RHI payments are:

GSHP	first 1314 hours	9.09p/kWh
	remaining hours	2.71p/kWh
Biomass < 1MW	first 3066 hours	2.96p/kWh
	remaining hours	2.08p/kWh

8.2 Current heating costs

The EPC data estimates the current fuel costs for supplying heating and hot water as:

Heating fuel	Cost per year	Heat supplied kWh/yr
Oil	£ 1404	24,400
LPG	£901	8,400
Electricity	£1223	14,100

Table 5: EPC data on current heating costs

The LPG fuelled houses are cheaper to heat as LPG is predominantly installed on the newer houses which are better insulated. Most of the new houses are on Rogers Road which has been excluded from the SPHN assessment area due to lower heat demands and length of DH pipe required. Therefore, LPG is not considered any further.

<u>Fixed costs</u>

Fixed costs for oil heating:

Boiler cover (including service, call-outs and repairs)	£180 per year
Cost of boiler replacement every 15 years	£135 per year
Cost of new oil tank every 20 years @£2000	£52 per year

Total fixed costs £367 per year

Fixed costs for electric heating:

None, as the SPHN connection would require radiators which probably have a similar replacement requirements and costs as the storage heaters currently installed.

Current variable costs for heating

Oil - Based on oil @ 42p/litre from an 80% efficient boiler = 4.9p/kWh

Electricity –15p/kWh day rate and 10p/kWh night rate

There are no fixed charges for those who currently heat with electricity but the variable cost for the electricity is much higher, hence the EPC data on Table 5 indicating that an electrically heated property is costs nearly as much to heat as the oil heated property despite the using only 60% of the heat. There are additional capital costs for electrically heated houses to connect to the SPHN as radiators need to be fitted in place of the current electric heaters.

DH heat selling price

This analysis, to establish a baseline economic position, assumes the DH heat selling prices are equal to the current heating cost for oil heated properties. This is a fixed charge of £382 per year and heat at 4.9p/kWh. Typically, the costs of boiler provision, boiler maintenance, replacing oil tanks every 20 years are not considered in the users' perceptions of heating costs, but these are costs that a DH supply would save. As the DH economics are challenging it is important to value all the benefits the DH can offer although it is acknowledged that potential DH heat customers may not typically consider these non-fuel costs as part of their heating costs.

The SPHN network needs to be cheaper than oil to attract customers and make it worthwhile to connect. The heat network operating costs should be significantly lower than these heat prices but a surplus is required to fund the loan for the capital costs.

For the average customer who has electric heating these costs based on cost of an oil heating system will be significantly cheaper than their current costs, but as noted above the installation of radiators needs to be funded in currently electrically heated homes. Based on the current high cost of running electric heating it is, at this point, assumed the capital cost of installing radiators can be financed from the future savings and a zero upfront capital cost to connect to the SPHN will be possible.

The level of discount over current heating costs needs to be considered against the economics of the scheme. From a risk perspective it is good if the fixed income from the standing charge approximately matches the fixed costs of the scheme (e.g. loan repayments, billing and O+M costs) and for the consumption based costs to match the SPHN fuel costs. In this way the economics are less sensitive to the annual variations in heat demands due to weather and the accuracy of the initial design estimates of heat sales.

8.3 Capital Cost

The budget price for the district heating pipework is based on two similar projects that Carbon Alternatives has been involved in, which are lower than typically quoted DH pipe costs.

For the connections to the houses we have estimated £4,000 per house for branching off from the pipework in the street, installing a pipe up to the HIU installation and connection of the secondary side. For the straw option we have reduced the connection cost by £300 as less works need to be done in the houses to ensure lower temperature operation.

The energy centre costs are estimated for a GSHP (ground source heat pump) installation of 800 kW, a thermal store of 100m^3 and oil boilers to a capacity of 1,500 kW for back-up and peak loads. Including the drilling and the building itself with all its utilities, we have estimated a cost of £1.3 million for the energy centre. For the 1,000 kW straw boiler option we estimate the energy centre cost to be £0.9 million. The costs of the GSHP and straw boiler are estimated from budget quotes from suppliers.

The local electrical distribution network operator (DNO) UK Power Networks was contacted for a budget cost of the electrical connection to the energy centre location. The budget costs provided have been used in the assessment of energy centre capital costs.

The estimated capital costs are detailed below. These costs equate to £16,700 and £13,200 per house connection for the heat pump and straw option respectively.

(Costs in £1000)	**Heat pump**	**Straw**
SPHN pipework	850	850
SPHN connections	731	667
Energy Centre	1,342	863
Design and PM	83	70
Total	**3,005**	**2,460**

Table 6: Scheme capital costs

8.4 Operating costs and revenues

The operating costs consist of energy cost mainly and costs to operate and maintain the energy centre and the network. We estimate the yearly costs to be as set out in Table 7.

Annual Costs in £,000	**Heat pump**	**Straw**
Heat sales	199	199
standing charges	66	66
RHI	187	109
Total Income	**451**	**374**
Oil	18	5
Straw	0	73
Day electricity	81	3
Night electricity	35	3
Plant maintenance	12	25
SPHN and HIU maintenance	14	14
Billing and admin	17	17
Total Operation expenditures	**178**	**141**
Net revenue	**274**	**233**

Table 7: Income and costs

The heat sales revenues and standing charges are the same for each technology. The RHI, fuel costs and maintenance costs vary between the heat pump and straw options. The heat pump option results in a higher net revenue but the capital costs are higher.

8.5 Investment returns

The investment returns are stated in Table 3 and are:

Straw boiler 7.6% IRR over 20 years

Heat pump 7.0% IRR over 20 years

This is a very simplistic cash flow assessment without any cost of capital.

Dropping the heat price such that there is a 25% discount on the current cost that oil heated house use drops the IRR to 3.5% for the best straw option and 3.8% for the best heat pump option.

8.6 Scheme funding

The key opportunity for funding the construction of the heat network is the Government's Heat Network Improvement Project (HNIP) fund. HNIP has £320 million to spend supporting the development of heat networks in the next 4 years. The next round for applications to this fund is expected to be in autumn 2018 and the requirements, eligibility etc. are still under development. The expected key features of the HNIP funding are:

- The public sector, the private sector and community organisations can apply
- Funds can be given as a grant or a loan – though probably grants will only be available to the public sector. The loans will potentially have very low interest rates and start of repayment of capital can be delayed.
- The fund will cover all the proposed works apart from the installation of new heating systems in private houses where the removal of electric heating requires radiators to be installed
- The maximum proportion of HNIP loan to the total investment required is limited by State Aids requirements
- State Aids requirements prevent RHI being claimed on equipment purchased with HNIP funds
- The basis of HNIP funding is to bridge the gap between a scheme that is economic but the returns are insufficient to attract the remaining required investment. The HNIP will provide sufficient funds such that the other investor's investment hurdles can be met.
- One of the key scoring criteria for receiving HNIP funds is carbon savings per £ of HNIP investment. The high carbon savings of this scheme should ensure a high probability of receiving funds if the other requirements are met.
- To apply for HNIP funds there needs to be a robust business case, detailed understanding of costs and a demonstration of the agreement of customers to connect to the SPHN.

Any HNIP funding is unlikely to exceed 50% of the required investment and hence other funding sources will need to be found. Some ideas with a focus on the non-conventional:

- Community co-operative – such as Reach Solar farm could raise part of the required investment both locally and from further afield. There is a good track record of wind, PV, hydro and even a few heat projects being funded this way. Organisations can raise the funds themselves or seek the support of the like of Ethex or Energy4All to assist in raising the money (and mange other elements of the co-op too). The heat network, which serves some of its owners, will not fall foul of the FCA current challenge to the co-operatively owned renewable electricity project which struggle to meet all the Co-operative principals as the under the UK electricity supply structure prevents direct supply to co-op members. Also unlike co-op electricity project the heat network should be eligible for EIS.
- Abundance – crowd funding platform for renewable energy projects

8.7 Sensitivities

HNIP requires an economically viable project, but probably prevents RHI income and HNIP funding. The impacts of removing the RHI are shown in Table 8 below.

	Plant output	Thermal store	IRR over 20 yrs
	kW	m3	
Straw	1000	150	0.6%
Straw	1000	100	0.8%
Straw	1000	75	0.8%
Straw	500	100	-0.9%
Straw	500	75	-0.8%
Heat pump	800	150	-3.9%
Heat pump	800	100	-3.9%
Heat pump	800	75	-4.0%
Heat pump	600	100	-3.8%
Heat pump	600	50	-3.9%
Heat pump	600	30	-4.1%

Table 8: SPHN economics without RHI

As you can see the removal of the RHI has a very significant impact on the economics. In this analysis the plant sizes have not been optimised – the plant sizes are the same as with the RHI optimisation presented in Table 3. The capital costs and CO_2 savings are the same for each option as in Table 3. To apply for HNIP funds a project needs a positive IRR – which only the larger straw boiler achieves and this is before a discount is placed on the heat selling price. The discount, which is essential to attract customers, will reduce the IRR further.

How HNIP funds can be applied for will need to be part of further investigation and discussion with BEIS. Separation of assets could be an option, the energy centre, funded on the back on the RHI income, separate to the heat network, funded by HNIP, could work but would introduce additional complexity.

The feasibility of the project mainly depends on the connection rate. Less connections initially results in only a small decrease in investment (£4,000 per house) and a partial decrease in operating costs (only the energy costs). Table 9 shows the economic impacts of only 50% of the houses (120 houses), the school and business loads connecting.

SPHN economics at 50% connection rate (120 houses)	Plant output	Thermal store	Capital cost	IRR 20 yrs
	kW	m3	£k	
Straw	1000	150	£2,287	4.1%
Straw	1000	100	£2,237	4.3%
Straw	**1000**	**75**	**£2,212**	**4.4%**
Straw	500	100	£2,112	1.4%
Straw	500	75	£2,087	1.5%
Heat pump	800	150	£2,824	4.9%
Heat pump	**800**	**100**	**£2,774**	**4.9%**
Heat pump	800	75	£2,749	4.8%
Heat pump	600	100	£2,575	4.2%
Heat pump	600	50	£2,525	4.2%
Heat pump	600	30	£2,505	4.1%

Table 9: SPHN Economics at 50% connection rate

9. Carbon savings

Both the heat pump and straw boiler options will significantly reduce the village carbon emissions. The current emissions based on the EPC data are:

Heat source	Proportion of houses	Annual Fuel use kWh	Emission factor $kgCO_2/kWh$	CO_2 per house Kg/yr	No. of houses	Total annual CO_2 tonnes
Oil	71%	24,426	0.245	5,984.47	128	764
Electricity	29%	14,128	0.144	2,034	52	106
Totals					180	871

Table 10: Current carbon emissions for 180 houses

The above table is the estimated current emissions from the 180 houses that have been modelled to connect to the SPHN. The electricity emission factor is the projected average factor for 2019- 2039.

The heat network supplying 180 houses would annually save:

SPHN option	CO_2 reductions	% reduction
Straw 1000kW boiler	720 tonnes	82%
Heat pump 800kW	580 tonnes	67%

Table 11: CO2 emissions from the SPHN supplying 180 houses

In essence the savings of either option are very significant, the actual savings are very sensitive to the selection of electricity emission factor and the chosen period to average it over. The actual emissions from straw are most sensitive to how far the straw needs to be transported.

10. Planning considerations

East Cambridgeshire District Council's adopted local plan (2015) has a specific policy on the development of renewable energy. This policy outlines how renewable energy installations will be considered in East Cambridgeshire

Policy ENV 6: Renewable energy development Proposals for renewable energy and associated infrastructure will be supported, unless their wider environmental, social and economic benefits would be outweighed by significant adverse effects that cannot be remediated and made acceptable in relation to:

- *The local environment and visual landscape impact*
- *Impact on the character and appearance of the streetscape/buildings*
- *Key views, in particular those of Ely Cathedral.*
- *Protected species*
- *Residential amenity*
- *Safeguarding areas for nearby airfields; and*
- *Heritage assets*

Renewable energy proposals which affect sites of international, national and local nature importance or other irreplaceable habitats will be determined against the relevant sections of Policy ENV 7.The visual and amenity impacts of proposed structures will be assessed on their merits, both individually and cumulatively. Provision should be made for the removal of facilities and reinstatement of the site, should they cease to operate

Information is provided on the planning considerations of each of the recommended low carbon technologies below:

Ground Source Heat Pumps

Since the end of 2011, if you live in England, all heat pumps (air, ground and water) are considered a permitted development, so no planning permission is required in a domestic setting. This was legislated in parliament to make it easier for individuals to install renewable technologies for their homes. However, if the Ground Source Heat Pump is being installed in a listed building or within an area of conservation then it would be good practice to check the specific rules and regulations with the local council, East Cambridgeshire District Council.

In the Swaffham Prior case, the size of the heat pump is likely to be considered a commercial installation, so it would be advisable to contact East Cambridgeshire District Council planning department. Additionally the location and setting might also be considered outside of permitted development.

Solar Thermal

Ground–mounted solar thermal panels are also considered as part of the energy mix. The installation of small ground mounted solar systems comes under 'permitted development' when:

- The solar array must be no more than 4m high;
- The solar array must be installed more than 5m from the property boundary;
- The size of the solar PV array must not exceed 9sqm (4-5 large solar panels);
- The solar array must not face onto or be visible from the highway if located within a conservation area or a world heritage site.

Ground mounted systems of greater than 9 sqm will require planning permission. Therefore, in the Swaffham Prior case, planning permission would be required for any proposed installation of solar thermal panels.

Straw (biomass) Boiler

Planning permission is generally required for most non-domestic biomass installations above 45kW. Some biomass systems will require the construction of outhouses or areas to store the wood materials. They may also require the development of a new means of access for service vehicles – the provision of which may need planning permission.

Planning authorities are concerned about the height and visual impact of the flue as well as environmental health implications (predominantly the emissions of very small particulates). These will generally be unlikely to cause a problem with modern biomass systems unless it concerns a listed building or the development is in a conservation area or an air quality management zone.

The planning authority is also likely to ask about vehicle movements associated with fuel delivery. Again, problems are not likely to occur unless the boiler is very large and the fuel storage is small.

In the Swaffham Prior case, planning permission would be needed due to the size of boiler proposed as well as the associated thermal storage, energy centre building and infrastructure needed to support its construction and on-going operation.

Based on the information above, **planning permission is likely to be required for the installation of ground source heat pumps or a straw boiler and/or a ground mounted solar thermal array**. Things to consider when applying for planning permission are:

- Community Engagement – full engagement with the community should be evidenced and feedback should be clearly described and shown how this has been considered in the application. In the Swaffham Prior situation the community are part of the process already and the level of visual intrusion to the community is minimal.

- Visual landscape impact - East Cambridgeshire has an attractive and distinctive landscape which is characterised by three main landscape types: the fens, chalk and clay hills. The visual impacts on the landscape as a result of renewable energy development will come about as a result of changes in the available views through intrusion or obstruction and whether these views may be improved or reduced.
  In the Swaffham Prior case the visual impact relates to the creation of a ground-mounted solar thermal array and also the size of any proposed flue for the straw boiler option. The creation of a landscape and visual impact assessment will usually be required to understand the impacts on the surrounding landscape, key views and associated buildings and infrastructure.
- Heritage assets – Any renewable energy application will need to consider the impacts (both during and after construction) on the district's designated and non-designated heritage assets and potentially heritage assets in neighbouring districts. Heritage assets are defined in the NPPF as *"A building, monument, site, place, area or landscape identified as having a degree of significance meriting consideration in planning decisions, because of its heritage interest".* The creation of a heritage statement should outline the impact on listed buildings, conservation areas and ancient monuments.
- Biodiversity and geology - Applicants will need to consider the impacts of renewable energy development on designated nature conservation and geodiversity sites, and any functionally linked or supporting habitat, protected and priority species and habitats of local importance. In the Swaffham Prior cases this will the impact on any national and local conservation sites and protected species. However, this is unlikely due to the type of installations considered. In the case of using a Ground Source Heat Pump then careful consideration of the local geology will need to be evidenced and presented.
- Residential amenity - Applicants will need to consider the effects of renewable energy schemes on residential amenity including the potential for noise, solar glare, air quality, loss of light, and odour both during and after construction. In this case consideration will have to be given to the air quality arising from the biomass boiler option and light and solar glare from the installation of solar panels. Consideration of any construction impacts will also have to be presented.
- Access and transport impacts – The access and highways considerations associated with renewable energy development are similar to those considered for most other types of development. However certain types of renewable energy development such as solar farms can have a significant impact on the local network of roads (due to the level of traffic movements associated with construction). There is also a need to consider the impact of the development on the local highway network during the operational stage. In the Swaffham Prior case this will be particularly important when looking at the delivery of straw for the biomass option.

11. Community and Stakeholder Engagement

11.1 Site walkover and visit

On the 8th June 2017, Bioregional and Carbon Alternatives met with Emma Fletcher and Mike Barker of Swaffham Prior Community Land Trust for a project inception meeting and site walkover.

During this time we discussed the project scope, structure and potential outcomes. It was agreed at this time that the project would look to include as much of the village as possible with a view to engage with social landlords early on as the feasibility of any heat network depends on the buy in and commitment from households.

During the site walkover we explored potential energy centre locations, possible pipe routes and began to look at how the main heat network will enter individual homes, replacing oil boiler and their associated tanks. Images of our site visit can be seen below.

Figure 16: Swaffham Prior households and their oil tanks

Figure 4: Swaffham Prior village centre

11.2 Community Questionnaire

Overview

In order to gain an understanding of the current housing stock of Swaffham Prior and to identify the level of community support for a local district heating system a Community Energy Questionnaire was created and distributed to the residents of Swaffham Prior. The questionnaire was made available to residents via hard copies delivered to each house (with a return address for completed questionnaires included) and an online version advertised on the village Facebook page and Parish Council website.

The questionnaire was accompanied by an information sheet which outlined the purpose of study, what a district heating network is and the benefits of installing a community renewable heat network in the village.

In total 82 questionnaires were completed and returned. 17 responses were received from the online questionnaire and the remaining 66 responses from the hard copy versions.

Understanding the housing stock

Of the 82 respondents the majority, 49 (60%), live in detached homes. This is followed by semi-detached houses where 18 respondents live, then bungalows (7 respondents), terraced houses (6 respondents) and end-terrace houses (2 respondents). Most of the homes have 3-4 bedrooms, with 23 (30%) being 3 bedroom and 30 (39%) being 4 bedroom properties. 80% of respondents own and occupy their property with 10% private renting and 9% renting through a housing association.

The questionnaire enquired about the main source of space heating in the home. As indicated in Figure 18 oil boilers and radiators represent the main source in the majority of homes, at 69%. Electric storage heaters are the second most common main heat source with 11% of respondents selecting this option; followed by LPG boilers and radiators which are used in 7% of respondent's homes.

To gain an understanding of any secondary heat sources used a separate question was inserted in the questionnaire. There are a variety of other sources used however the most popular ones, in decreasing order, are: wood burners (35%), electric under floor heating (17%), open fires (16%) and electric fans (15%) and bottled gas heaters (6%).

Regarding heating for hot water, heating boilers and hot water tanks are the most common source according to the questionnaire responses. As indicated in Figure 18 this source is used in 49% of homes. Immersion heaters are also relatively common, with 23% of homes using it.

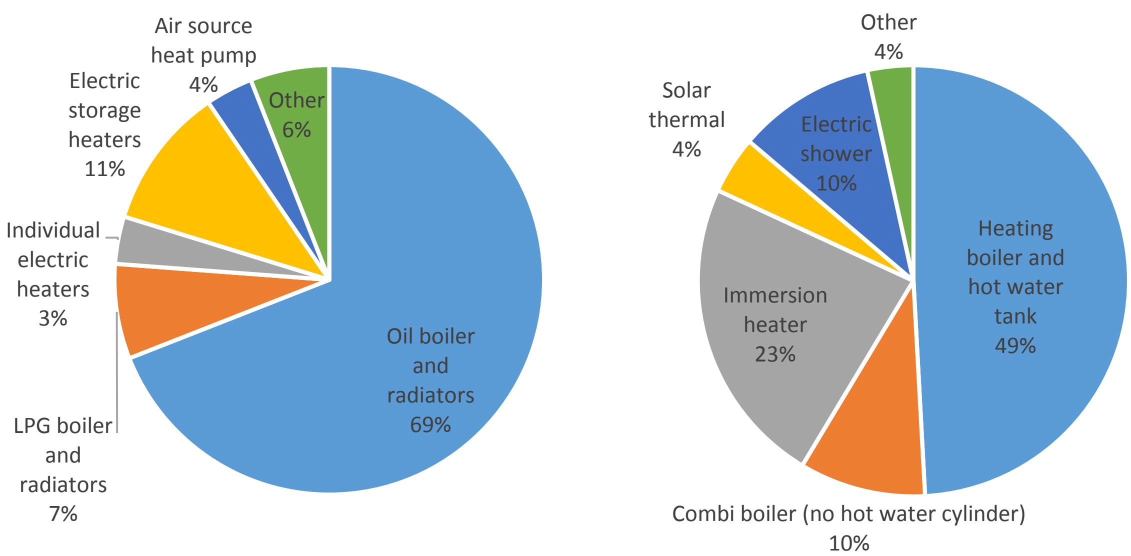


Figure 5: Main source of space heating (left) and heating used for hot water (right) in the respondents' homes

Identifying the level of community support

The questionnaire has provided a useful indication of the level of interest the respondents have in connecting to a village wide heat network. As indicated in Figure 19 the majority of people, 54 respondents out of the 80 that answered the question, are in favour of a village wide heat network. However it is apparent from the 23 respondents who selected 'not sure' that there is a level of uncertainty around connecting. This could perhaps be addressed through further engagement with the community and providing more information about district heating, including the variety of benefits. A very small number of respondents (3) would prefer not to connect to a village wide heat network.

There are higher levels of uncertainty amongst respondents about whether they would be willing to potentially invest in a village wide heat network. Of the 77 responses to this question, 42 were not sure, 21 were yes and 14 were no.

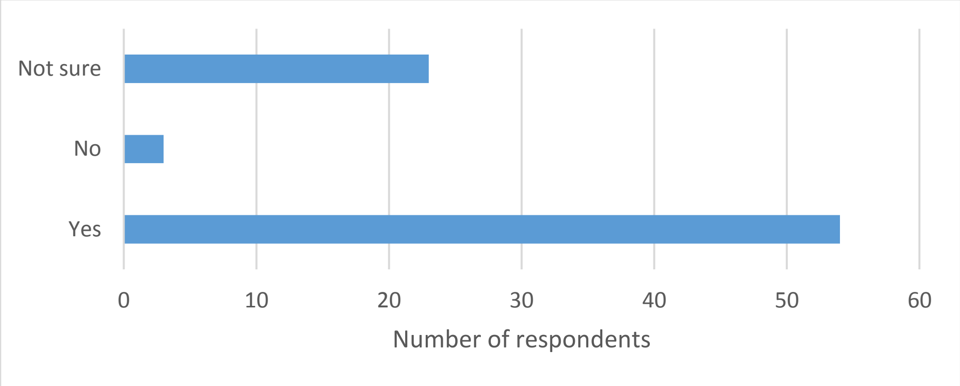


Figure 19: The residents were asked 'Would you be interested in connecting to a village wide heat network?' The results are presented here

To understand the main motivational factors behind those who are in favour of a village wide heat network the residents were asked to select, from a list of options, the factor/s which apply to them. Environmental reasons was determined to be the strongest factor with 48 respondents selecting this option, followed by the potential cost benefits that a heat network could bring which received 40 votes. Convenience had the fewest votes at 18.

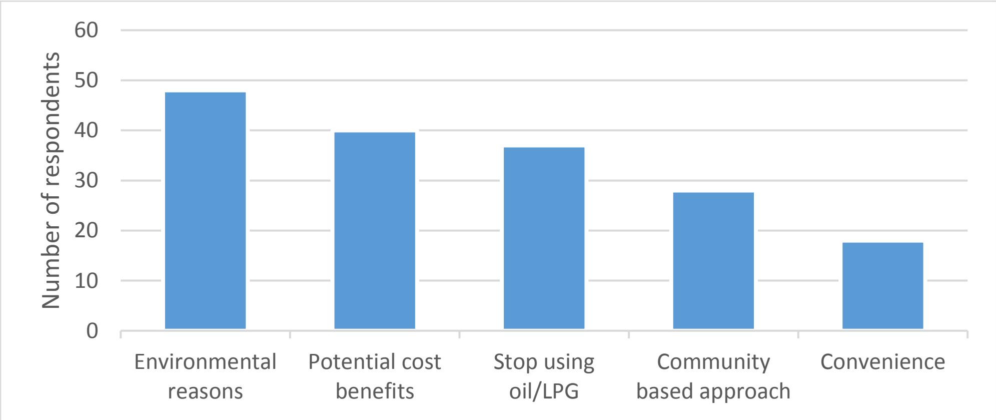


Figure 20: The main motivational factors behind those in favour of a village heat network.

With regard to ownership structure of the village heat network just under half of respondents (49%) support it being owned and run by a co-operative of local people. There was also a relatively strong backing for the network to be owned and operated by a local company, gathering support from 32% of the respondents. Only 4% would want the heat network to be run by a larger national company, such as an electricity supplier.

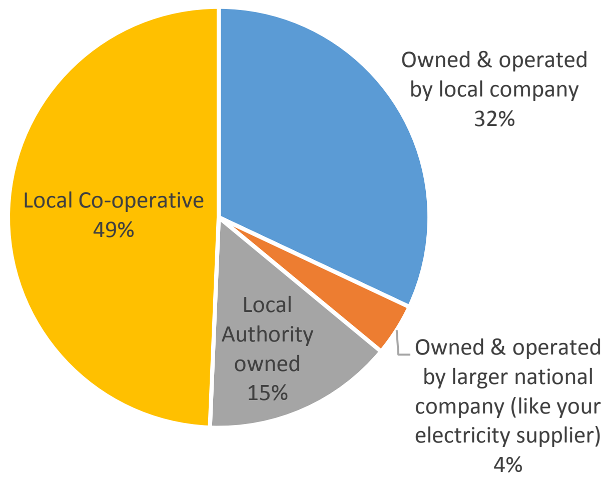


Figure 21: Favoured ownership structure of the potential heat network

11.3 Review of community benefits

From the community engagement carried out and our understanding of heat networks the benefits to residents of Swaffham Prior are:

- Cost savings due to lower energy costs. This is dependent on the commercial model and running of the network but it is assumed if it is locally or co-operatively run then a significant reduction on oil costs will be made.
- Significant carbon savings are associated with moving towards a more renewable heat source. This could be somewhere in the region of 5 tonnes CO_2 per house per year
- No individual reliance upon oil or LPG deliveries that can be inconvenient as well as costly.
- Potentially investment opportunities for residents into the network. This could be financially beneficial but also helps to generate a community-led approach.

12. Business Model and Governance Structures

The business model and governance options for heat networks has been very well written up for BEIS's HNDU Team. The full HNDU document can be accessed at the link below: http://www.luxnovapartners.com/2016/11/01/dbeis-guidance-heat-networks-published-collaboration-lux-nova-arup-consortium/ . The pages relevant to business models are attached as a pdf. The main document is a recommended reference, but is 500 pages long.

From discussions we understand there is most enthusiasm for a community owned heat network. In the UK there are few examples of this model to follow. As noted in the funding section there are a number of co-operatively owned solar, wind and hydro schemes which have raised the required money, manage the operation of the plant and sell the electricity. What they don’t do is serve customers and 24/7 reliability is not paramount as it is for DH. In Denmark local co-operatives own and operate most of the DH network outside the larger towns and cities.

13. Conclusions and Recommendations

13.1 Conclusions

Technically the construction of a heat network to supply Swaffham Prior is possible and large carbon savings can be achieved. The economics of the heat network are challenging which is why there are few, possibly zero, UK precedents of retrofit DH into a village situation. A recent development is the potential availability of HNIP loans at very low cost which offers a significantly improved possibility of economic viability.

The key challenge is getting customers to voluntarily connect. This is an untested proposition in the UK. Most new UK DH network are either new build, so the network is installed as a planning requirement and hence is the only heat option.

The UK DH retrofit experience serving residential properties has been mainly at sites that are in Local Authority or Housing Association ownership and hence the DH can be imposed on residents. Typically the DH replaces electricity heating, which is expensive to operate and not user friendly, also the DH tends to be part of a number of measures to improve the building energy efficiency. So for these residents the DH is part of a free to resident package that will make their home more comfortable and cheaper to heat, and ultimately the resident can’t say no as they are tenants or leaseholders.

A Swaffham Prior heat network has less benefits to offer and no compulsion to connect, but low connection rate would make the scheme totally uneconomic.

The resident survey has shown there are positive views of the potential for a heat network, any further work needs to build on this. There are no UK precedents on how to engage and motivate a whole community (connection rate of over 60% is likely to be needed to make the scheme viable) to connect to the SPHN.

A key part of this, we would expect, would be the demonstration of the success of other DH schemes in delivering low cost reliable heat. We would suggest that a not for profit / co-operative ownership model would be the easiest route to demonstrating this. Case studies of the success of this model in Denmark can be presented and developing a UK version of this model with the most experienced UK energy co-op operators and with ample contribution of Danish experience could increase the chance of success.

This model of DH development has also had success in Germany. In Germany, like the UK, there is little compulsion to develop DH, (as there is in Denmark) and DH is less familiar, again like the UK (and not like Denmark!) so there is valuable experience to learn from Germany also.

13.2 Recommendations and next steps

The study shows there is a technical and economic opportunity for a heat network in Swaffham Prior and that it would lead to significant carbon savings. We recommend that this opportunity is further developed with the ambition to use the soon to be available HNIP money to part fund the construction.

Further work needs to:

- Engage the community and develop commitment from prospective customers to connect
- Develop a community business model that is sufficiently well developed to give confidence to: the potential customers that they can commit to the heat network; potential investors, including HNIP, such that they will invest in the heat network
- Develop the detail of the technical option, especially improving the understanding of how best to retrofit the SPHN into existing housing
- Improve the estimates of heat demands, for example by working with any residents who have records of their current oil/LPG/electricity consumption. For the study we have used the EPC data but this shows significantly higher heat demands than the National Heat Map data and it would be good to understand the basis of the Heat Map data.
- Improve the assessment of capital costs – especially the costs with higher uncertainties such as the boreholes for the heat pump and the SPHN pipework.
- Progress the required permissions such as Environment Agency and Planning permission for the energy centre
- Explore scope for local straw supplies and a local contractor willing to do the day to day work required if straw boiler option selected. E.g. Explore any local connections that could help engage Melton Renewable Energy the owner of Ely Power Station, any scope to utilise their well-established supply chain, cost and quality control of straw could be very beneficial to developing the business model for the straw option. Carbon Alternatives did send an email to Ely Power Station but have not received any response.
- Make contact with Sun Edison the owner of the Exning PV farm asking if they may be interested in a direct electrical connection to the Swaffham Prior Energy Centre. This could significantly reduce the electricity cost to a heat pump based solution. The size of the solar farm would mean that during all daylight hours there would be sufficient generation to power the heat pumps even on cloudy days. Carbon Alternatives sent an email but no response was received.
- If the heat pump based SPHN were based in the village it may be viable to connect to the community owned Reach Solar farm. This is one hundred times smaller than Exning and so would supply a much small proportion of the heat pump power demands.

Technical appendix

13.3 Heat network sizing

The peak heat demands and therefore the initial sizing of pipework, pumps and the heat production plant have been based on the EDRP data. This data shows that the actual peak demands are significantly smaller than the typical design values for the sizing of gas or oil boilers. The data shows that the typical peak heat demand for a house in England is only 6 kW. Since the houses in Swaffham are older and more detached, we estimated the average peak load to be 8 kW. For the domestic hot water (DHW), we used 33 kW which is typically sufficient for 1 tap and 1 shower simultaneously for instantaneous production.

The network is designed at higher velocities (up to 30%) than the CIBSE guidelines as these are primarily fit for purpose for constant flow systems. In a variable flow system, the peak flow rates only occur for some limited hours per year in which one can allow higher velocities and increased pump heads. Only for the critical paths in the network, certain pipes were increased to achieve an acceptable pump head of 3 bar.

The Swedish diversity factor was used for DHW and in analogy with the Danish design standards, a diversity factor for heating was used as well. These factors are used to consider the simultaneity of the use of heating and hot water of the different users in the network. Applying these factors results in an average peak load of 6.8 kW per house for the 33 kW and 8 kW peak loads for DHW and heating. Figure shows the resulting sizing of the pipework.

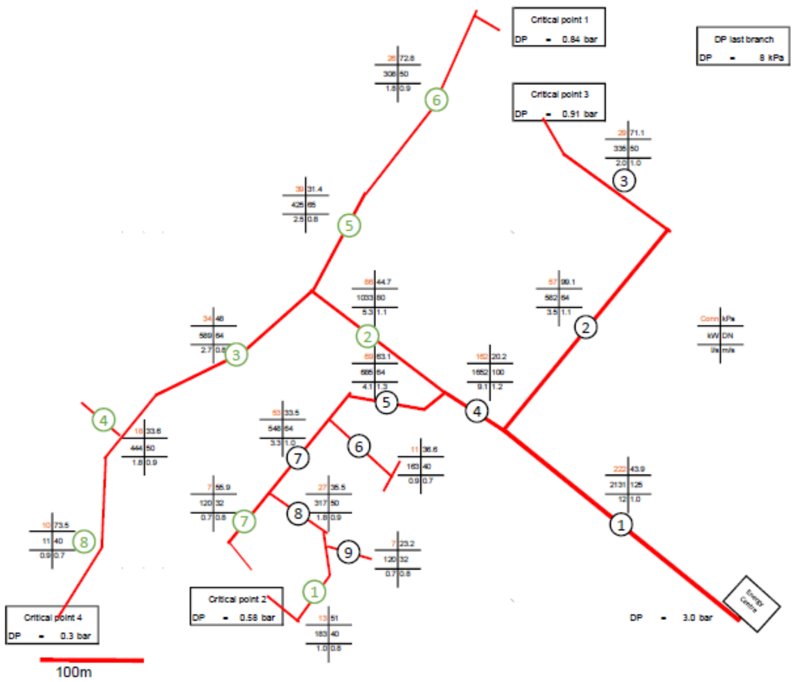


Figure 22: Initial pipe sizing for Swaffham Prior, used for budgeting the heat network

Table 12 gives an overview of the modelling assumptions which are performed in the EnergyPRO software.

Electricity import day	12 p/kWh
Electricity import night	8 p/kWh
Oil (5,000l deliveries)	38 £/l
Straw	50 £/tonne
Heat domestic	4.9 p/kWh
Heat non-domestic	4.4 p/kWh
Network loss heat pump option	6%
Network loss straw option	9%
Oil boiler efficiency	85%
sCOP heat pump (45/55°C)	3.6
Straw boiler efficiency	80%

Table 12: Modelling assumptions

For the calculation of the carbon savings, the emission factors in Table 13 were used.

Natural gas	198 g/kWh
Current grid electricity	349 g/kWh
Next 20 year average grid electricity	144 g/kWh
Burning oil	248 g/kWh
Straw	19 g/kWh

Table 13: Emission factors used for carbon savings

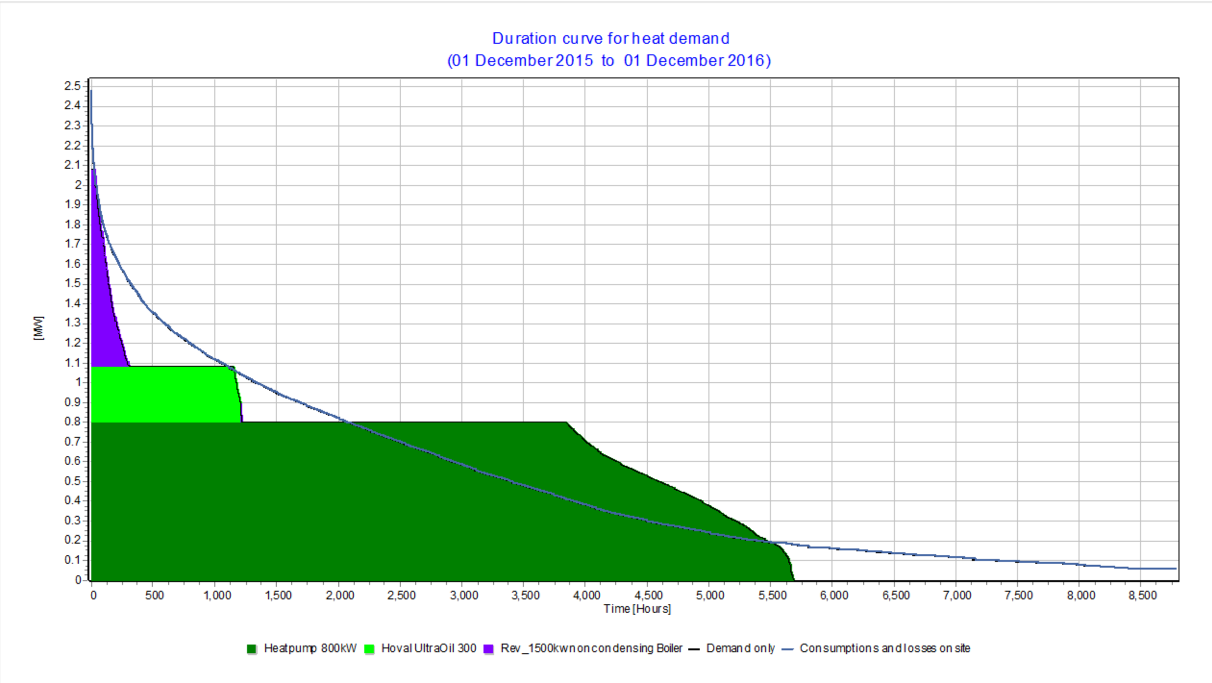


Figure 23: Load duration curve for heat pump option

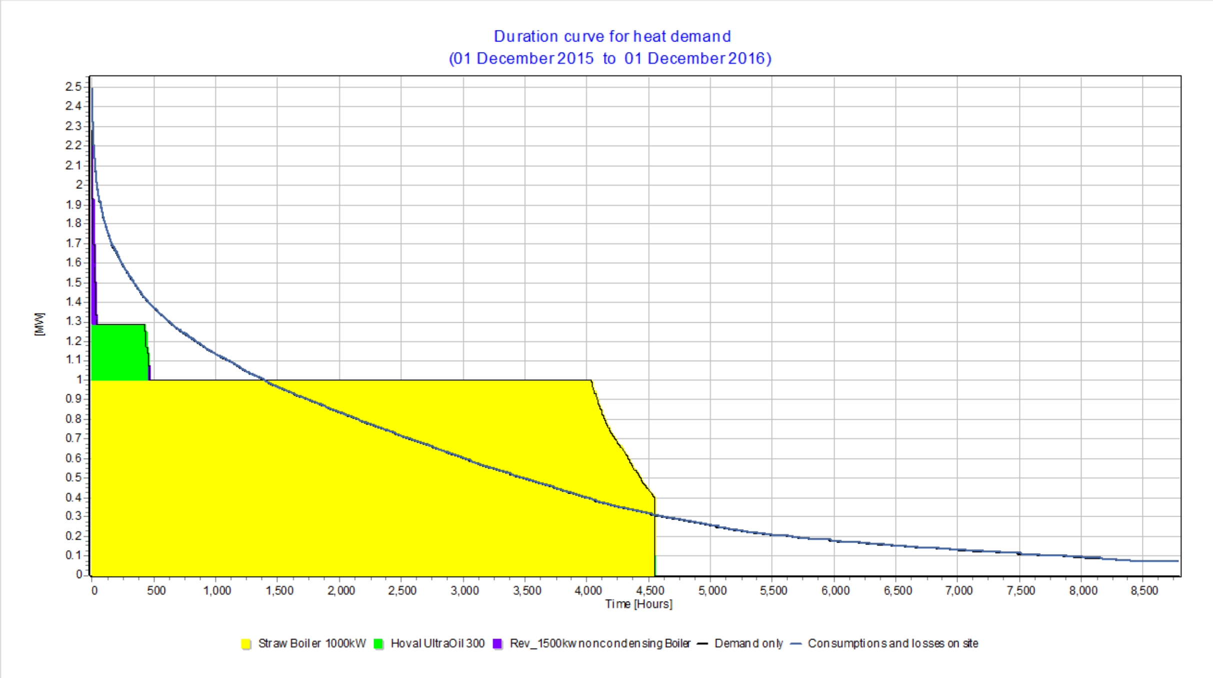


Figure 24: Load duration curve for straw boiler option

Community Questionnaire Appendix

Dear Swaffham Prior Resident,

The Swaffham Prior Community Land Trust (CLT) was awarded a government grant of £20,000 to investigate the possibility of taking the village off oil. The use of oil is a pain, costs vary to buy it, the tanks are huge and increasingly people are put off buying and renting homes with oil heating systems. It is also not sustainable in the long term.

We are looking to use a community heating technology well used in Europe (85% of Danish villages run on this type of system) to see if we can create a network of insulated pipes to deliver hot water to each house. This hot water then provides heat for the radiators and your hot water. There is then no need for oil tanks and boilers in your home. As part of this process we need more information to assess whether the project is feasible and can be delivered.

Please can you help us by completing and returning this survey on household energy use and a possible village wide heat network? The survey should only take 5 minutes and as a small thank you, **all completed forms returned by Tuesday 31st October, will be entered into a free prize draw to win £40 M&S vouchers (5 small prizes of energy monitors are also available).**

Please return your completed survey to the letter box at Well House, 50 High Street, Swaffham Prior (yellow house opposite the church).

There will be an online version available on the Swaffham Prior Facebook Noticeboard and on the village website http://www.swaffham-prior.org.uk/ if this is more convenient.

Please note: Your information will only be kept for the duration of the project and will be anonymised for all economic and housing data without names or contact details.

This survey is being carried out by Bioregional, www.bioregional.com an award winning company chosen by the CLT, which helps communities plan, create and manage more sustainable places to live.

Why are we doing this survey?

Bioregional and another company Carbon Alternatives are working with Swaffham Prior CLT to undertake an investigation into how to replace the long-term unsustainable and expensive use of oil for heating homes in the village, with a community renewable heat network for the village. This project is supported by Swaffham Prior Parish Council and has been funded entirely by a central Government grant.

The study will assess the technical feasibility of providing heat to the village, the primary school, village hall, churches and pub using renewable energy sources. We also aim to understand the technical and cost challenges faced by offering district heating to local homes.

Why now and why here?

- 100% grant funding (£20,000) was secured through the Rural Energy Community Fund (RECF) for an initial scoping survey of a community wide heat-network.
- The cost of oil is on the rise again – this system we believe would be cheaper to run.
- A sustainable heat source is achievable in the village with public land.
- It will remove the need for an oil tank in your garden and no more oil deliveries.
- It will provide a renewable and sustainable form of heating for the village.
- Difficult to retrofit other technologies especially in villages with old properties and conservation areas.
- Paris Agreement in 2015 – the world must achieve greenhouse neutrality in the second half of the century.
- It could possibly be set up via the existing Community Land Trust.
- The technology is well used in Europe – 85% of Danish villages run this type of system.
- The costs could be cross-subsidised by laying fibre broadband at the same time in the village.

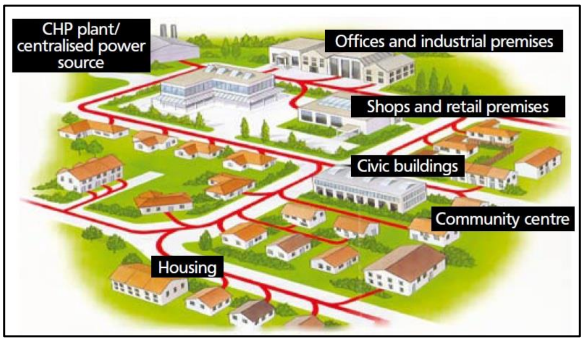
Organisation and Ownership

The feasibility study will look at various options of organisation and ownership before making recommendations. The Reach Community Solar Farm[1] is one possible model, it is owned and run by a co-operative of local people. Other models include not-for-profit and private sector-for-profit ownership

What is district heating?

A district heating (DH) – *sometimes known as community heating or Heat Network* – scheme comprises a network of insulated pipes used to deliver hot water to each house. This hot water then provides heat for the radiators and for domestic hot water use. A central energy centre would use renewable heat sources such as ground source heat pumps (pipes buried about 1m below the ground), solar or biomass (straw) to provide the heat. Due to the use of renewable fuel sources the DH can greatly reduce carbon emissions and reduce oil and LPG imports.

[1] https://reachsolarfarm.co.uk/



A typical district heating network. Source: Energy Saving Trust. (2004). Community Heating – a guide.

How would it work?
The DH would remove the need for oil/LPG boilers or electric heating in each house. For properties with electric heating, radiators would need to be installed. For houses with hot water cylinders these could be heated by the DH or the DH could be used to heat hot water as and when it is needed (*similar to a combi boiler*). The DH would be the same price or cheaper than your current heating costs. The more houses that connected the lower the costs could be. The heat use would be metered in each home and there would be a standing charge that covers the cost and maintenance of the DH equipment which would be equivalent to the costs currently spent on maintaining your boiler.

THE SURVEY

A. Your house

1. House Number/Name …………………………………………………………..
   Street Name ……………………………………………………………………

2. What type of accommodation do you live in? *Please tick the relevant box.*

a. Flat/annexe		c. Terraced house		e. Semi-detached house	
b. Bungalow		d. End-terrace house		f. Detached house	

3. How many bedrooms are there in the property? ……………………….

4. What type of tenure do you have? *Please tick the relevant box.*

a. Owner-occupier		b. Private rented		c. Council rented	
d. Housing association, *please name*				e. Other *Please specify:*	

Additional questions for tenants only:

Who is responsible for paying fuel bills? Tenants Landlord
Other ………….

Who is responsible for boiler maintenance? Tenants Landlord
Other ………….

B. Energy use in the home

5. What is the main type of heating for the home? *Please tick the relevant box.*

a. Oil boiler and radiators		b. LPG boiler and radiators		c. Individual electric heaters	
d. Electric storage heaters		e. Air source heat pump		e. Other *Please specify:*	

6. What other types of space heating do you use in the home? *Tick all that apply.*

a. Electric fan		b. Bottled gas heater		c. Wood burner	
d. Electric under floor heating		e. Oil heater		e. Other *Please specify:*	

7. What heating do you use for hot water? *Tick all that apply.*

a. Heating boiler and hot water tank		b. Combi boiler (no hot water cylinder)		c. Immersion heater	
d. Solar thermal		e. Electric shower		f. Other	

8. Do you have double glazing? All windows Some None

9. Do you have any cavity wall insulation? Yes No Don't know

10. Do you have loft insulation? Yes No Don't know

11. What is the thickness of the loft insulation and how recently it was installed?
………………………………………………………………………………………
………………………………………………………………………………………

12. Where is your boiler positioned?

a. Front of house		b. Back of house		c. Downstairs		d. Upstairs	

13. What is the approximate age of the boiler?

a. Less than 5 years		b. Less than 10 years		c. More than 10 years		Not known	

14. Do you get it serviced every year?

a. Yes		b. Yes – as part of a boiler maintenance package		c. No	

15. If a heat network was installed there may be an opportunity to install fibre for faster broadband at the same time. Would this be of interest to you?

a. Yes		b. No		c. Maybe	

16. Do you think a village wide heat network would be a good idea?

a. Yes		b. No		c. Not sure	

17. If yes, what motivates you? Tick as many as apply (indicate your top priority with a "1".

a. Environmental reasons		b. Stop using oil / LPG		c. Community based approach	
d. Convenience		e. Potential cost benefits			

18. Would you be interested in connecting to a village wide heat network? This would cost no-more than your current heating costs.

a. Yes		b. No		c. Not sure	

19. Would you be interested in potentially investing in a village-wide heat network? *More details will be provided as the project develops.*

a. Yes		b. No		c. Not sure	

20. If this project was to go ahead, what would your favored ownership structure be?

a. Owned & operated by local company		b. Owned & operated by larger national company (like your electricity supplier)		c. Local Authority owned	
d. Local Co-operative					

Finally, if you would like to be kept informed of the progress of this project and be contacted regarding further please provide your contact details.

Name ……………………………...…….. Email …….……………………………

Telephone…………...………………..

If you need any help with the questions or if you want to know more about the feasibility study please contact:

Lewis Knight: lewis.knight@bioregional.com (project manager for feasibility study)

Emma Fletcher: EmmaFletcher@smithsonhill.co.uk (Swaffham Prior resident)

Or

Mike Barker: barkerm@rpsgroup.com (Swaffham Prior resident)

Thank you so much for your time