OUTWOOD PARISH COUNCIL RENEWABLE ENERGY FEASIBILITY STUDY

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Date:	21 June 2021
Version:	v1.0

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EXECUTIVE SUMMARY

Avieco was commissioned by Outwood Parish Council to conduct a renewable energy feasibility study for the community, with the ambition to reduce the village's carbon footprint and make the community more sustainable. This project is supported by the BEIS-funded Rural Community Energy Fund (RCEF), which is managed by the Greater South East Energy Hub.

This report outlines the feasibility of renewable energy technologies for heat within Outwood parish, covering technical, financial and governance factors, and identifies key barriers to the scheme's success, and actions for the community to consider.

Results of the analysis

Our analysis shows that there is no village-wide heat system that can offer lower cost heat to residents than individual oil boilers. Key factors affecting this are:

- Closure of the Renewable Heat Incentive for non-domestic projects
- High cost of capital for heat networks, spread over a relatively small number of properties
- High cost of electricity compared to oil – even with the increased efficiency of a heat pump

A biomass-fired system is the most cost effective of the renewable solutions assessed, however the community has raised legitimate concerns about the carbon accounting approach used for woodfuels, the need to secure long-term fuel supply contracts, and the increased risk of a planning challenge due to this system.

The team held an online public meeting on 15th June 2021 to present the project and next steps. There is clear support for a village-wide ground source heat pump solution, and the Committee consider this the preferred option. This solution could be deliverable, subject to two key barriers being removed:

1) Securing a revenue stream in addition to heat sales – effectively to replicate the Renewable Heat Incentive
2) Agreeing access to 25 acres of land for the borehole array. At the time of writing, no suitable site has been agreed, however there would be land available, albeit owned by two different landowners

The details of this analysis and the outputs demonstrating this systemic challenge follow in the body of the report.

This means that currently the most cost-effective way for residents to decarbonise their homes is at the building level – with domestic air-source heat pump systems or biomass boilers; complemented by solar PV if desired. Example business cases for these systems are included in Appendix D, should residents which to explore these options.

Next steps for Outwood and other community decarbonisation projects

This study provides evidence of the challenge that communities face when seeking to decarbonise their homes and communities, under the current policy regime. We believe there is a good opportunity to work with other communities across the UK who are experiencing similar barriers, to raise awareness and present evidence for the need for change in incentive regimes and electricity pricing. These measures would make the case for Outwood pursuing a village-wide scheme, and facilitate many more communities to take similar action to decarbonise and contribute to our net zero targets.

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OVERVIEW

Outwood Parish Council has identified an opportunity to explore renewable energy systems in the Outwood parish to benefit residents, reduce carbon and improve the sustainability of the village.

The Parish Council formed a Climate sub-committee in October 2019, to tackle decarbonisation and other environmental initiatives in the community. In November 2019, the sub-committee held their first public meeting and received strong initial support for the idea of implementing a renewable and low-carbon energy heating network.

The Parish Council was awarded a Rural Community Energy Fund (RCEF) grant for the purposes of a feasibility study. Avieco, along with Niras and RPS, have assisted the Parish Council with specialist support to assess the potential for renewable energy schemes within the parish and identify which schemes to progress.

CONTEXT

In 2015, the Paris Agreement, the world's first legally binding global climate change agreement, was adopted, with the objective to limit global warming to 1.5°C – 175 entities signed the agreement on the first date it was open for signature. With an increasing number of countries around the world pledging Net Zero targets, the UK joined them in 2019 as the first major economy to make the pledge with the target of 2050. To reach this legally binding target, all parties need to take action, from individuals, to businesses and communities.

The UK Government published an energy white paper Powering our Net Zero Future in December 2020. Particularly of interest for residents is the plans to phase out fossil fuel heating systems in new and existing homes off the gas grid through the 2020s. Supporting this Net Zero roadmap, the government published The Ten Point Plan for a Green Industrial Revolution in November 2020. Point 7: Greener Buildings, in The Ten Point Plan focuses on electrification of the UK's heat network. specifically through heat pump installation. Additionally, the government have pledged to ban all fossil fuel boiler installations in new-build homes by 2025 – this will include coal, oil, and LPG systems.

As of 2017, nearly 400,000 post codes within Great Britain are off the mains gas grid[1]. While this figure represents more than just communities that are off the gas grid, it does illustrate the scale and need the UK faces in transitioning to a low-carbon heating system. Furthermore, within the two-year span that Avieco worked with a similar project in Swaffham Prior, Cambridgeshire, to develop a local heat network, 20 communities and organisations contacted the team wanting to progress projects like this in their own communities. There is a clear need to support communities like Outwood and others to decarbonise their homes – and currently UK policy regime does not support this.

The Parish Council recognised these trends and have acted ahead of time to commission a feasibility study to help understand what can be done within the parish and to provide the residents with a guide to the available renewable energy solutions.

[1] Centre for Sustainable Energy, March 2020 https://www.cse.org.uk/news/view/2441

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SITE DETAILS

Outwood is a village of around 750 residents and 250 homes in Surrey Weald. Within the parish, there is local National Trust owned land and National Trust agricultural tenancies, along with a Sutton and East Surrey Water reservoir. Outside of the developed areas, the parish predominantly consists of agricultural land, see Figures 1 & 2. It is important to note that the parish is an off-gas grid community, and households rely on heating oil or electric heating to heat their homes.

Figure 1: Arial View of Outwood Parish

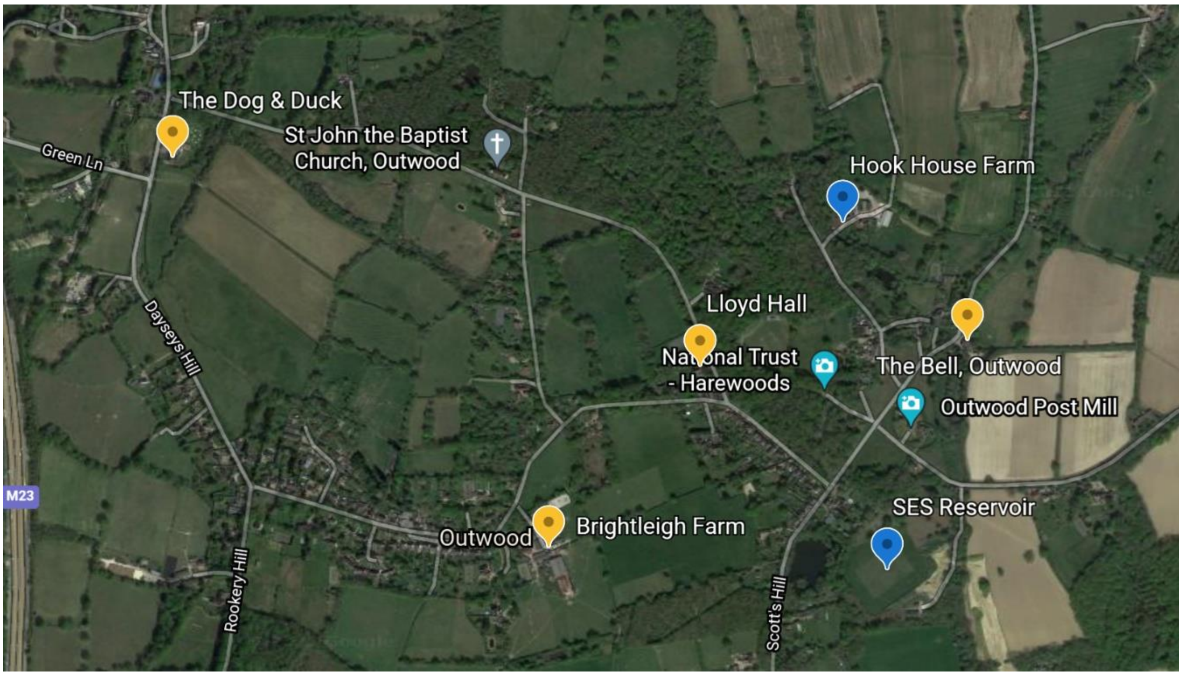

Figure 2: Outwood village – showing the location of Lloyd Hall and some of the National Trust land. The top of the reservoir can be seen in the bottom right of the image.

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COMMUNITY ENGAGEMENT

Outwood has a close community of residents, and therefore their engagement with this project was very important. We designed and delivered a range of community engagement activities, which identified the main stakeholders and events to be held over the course of the project. The community engagement plan is included in this report as Appendix A.

To properly understand the community's interest in implementing renewable energy within the parish, we undertook several community engagement activities throughout the project, including:

- **Regular meetings with the Sustainable Outwood Parish Council Working Group:** the Parish Council and Avieco met fortnightly to discuss all aspects of the project including communication and engagement strategy
- **Advertising for the project:** We designed leaflets that were shared around the village, created a press release for Outwood News and Outwood Matters email and posts for the Sustainable Outwood website. See Appendix B for copies of these materials.
- **Energy demand survey:** With the support of the Parish Council, we surveyed the community to understand the local energy consumption of homes and businesses, results of the survey can be found in Appendix C. We received 60 survey responses in total – c. 30% of the households in the village. The data from these surveys was used to inform the heat demand mapping.
- **Online meetings with the Parish:**
    - **Focus group:** over the course of the project, Avieco facilitated two focus groups via Zoom with selected stakeholders to understand preferences, questions and objections to the project
    - **Public meeting:** Avieco facilitated a meeting with the general public towards the end of the project to share findings
- **In person events**
    - **Drop in event:** Avieco facilitated a drop in event at The Bell Pub on 24th May 2021 to give the public the opportunity to see a proposed heat network map, meet some members of the team, and ask questions. This was well attended with over 30 residents including many who had not otherwise attended Parish Council or Focus Group meetings.
    - **Home surveys:** in addition to the energy demand surveys, Avieco surveyed 10 households in the parish, covering a sample of the different building types in Outwood, and the Lloyds Hall. These surveys supported the building-level recommendations in Appendix F.
- **Online collateral**
    - **Sustainable Outwood website and Facebook page:** Avieco provided messages and posts for online platforms to inform and engage the community in the project and project events

COMMUNITY RESPONSE

Overall the response from the community to the project has been positive, with a wide range of individuals from different demographics engaging through the focus group, drop in event and public meeting. No major objections or complaints were raised during the course of the project.

Below is a summary of the key questions collected from the different community engagement events, such as the in-person drop in event and online focus groups.

- Total cost of project and funding sources
- Cost of heating on renewable network as compared to current network
- Information of proposed renewable technologies (cost, lifespan, expected maintenance)
- Environmental impact of biomass as an energy source

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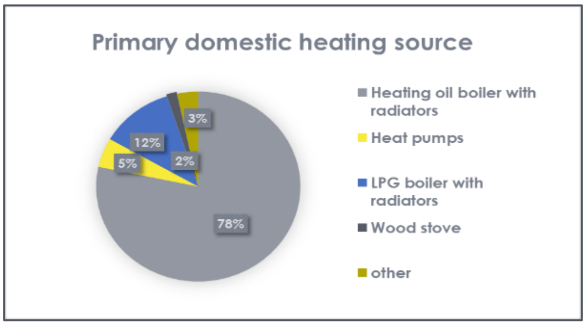
- Options for households outside of the proposed network boundary
- Extent of works to retrofit houses
- Expected timeline of project
- Disruption to utilities during installation

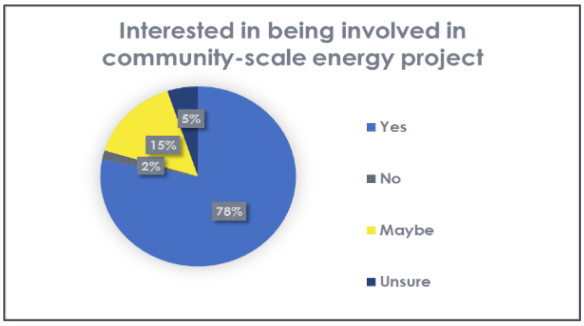
Copies of the publicity material and press releases are included as Appendix B, and a copy of the survey results are in Appendix C. Below is a brief analysis of the survey responses.

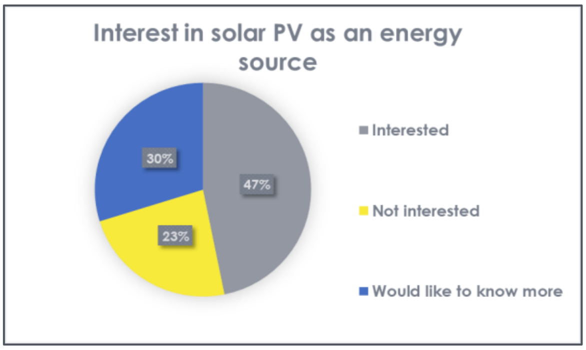
RESIDENT SURVEY ANALYSIS

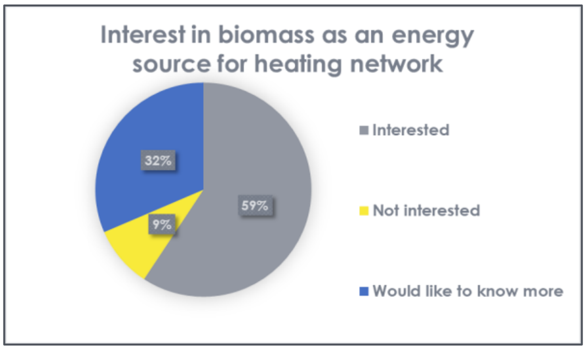
The full results of our survey are included in Appendix C. The graphs below indicate the response of the community to the different options, with the majority in favour of biomass, ASHP and GSHP solutions, and a significant minority supporting solar PV, however solar PV also had the greatest number of respondents opposed to the technology.

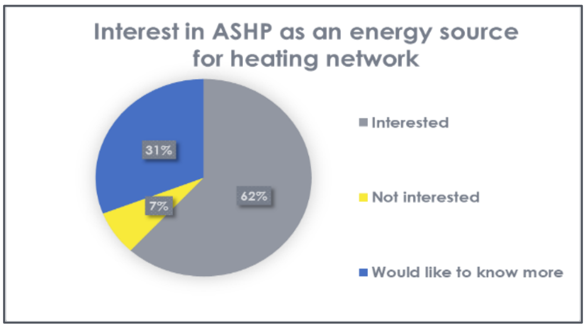
The graphs also show the predominance of heating oil with boilers and radiators in the village – this suggests that a high temperature heat network would have the least impact on "tertiary systems" inside the properties, and require fewer changes to homeowners existing systems (e.g. replacing radiators, controls, adding insulation, etc).

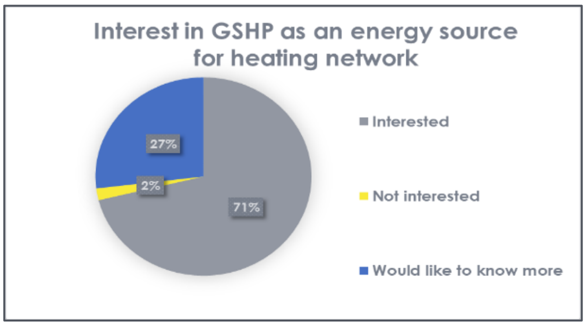












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OTHER STAKEHOLDER ENGAGEMENT

In addition to the resident engagement in Outwood, we also sought input from a range of other stakeholders locally.

TABLE 1: STAKEHOLDER ENGAGEMENT

Stakeholder	Contact	Outcome	Next steps
Surrey County Council	Meeting with Carolyn McKenzie and team Discussions with Your Fund Surrey	Broad support for the scheme, although no land parcels or other assets known in the village. Willingness to engage with other project leads (e.g. Swaffham Prior / Cambridgeshire County Council). In principle support for a funding application from Outwood for a renewable energy project.	SCC officers attending public meeting 15th June. Brief SCC on likely cross-country campaign with Cambridgeshire and other communities. Leverage local authority networks.
Tandridge District Council	Meetings and email exchanges with Will Mace	Broad support for the scheme. No land parcels or other assets known in the village. Introduced local authority sustainability officers group to the project. Advised that pre-planning service from TDC is closed.	TDC invited to public meeting 15th June.
East Surrey Conservatives	Claire Coutinho MP	Ms Coutinho has been very supportive of the community and the project, and spoke at the public event on 15th June 2021.	
Sutton & East Surrey Water	Meetings and email exchanges with Henrietta Stock (Energy & Carbon Manager) and James Ratcliffe (Production Engineer)	Local resident brokered introduction. SES supportive of community energy schemes, however cannot permit access to the reservoir for heat extraction. Would consider hosting energy asset at the pumping station site.	Share findings from final report. Consider joint solar PV project at the reservoir – potential to supply power to an electrified energy centre.
National Trust	Emails and phone calls with Celia Meacham (local land agent); Henry Barnard (local ranger) took part in focus group.	NT is the landowner for Hook House Farm, one of the potential energy centre locations. NT advised that they would support the tenant with their decision regarding the use of land. NT also landowner of local woodland – a potential source of biomass. Advised that other NT sites are used for woodfuel production, however this is managed by the contractors under a licence agreement. NT do not produce woodfuels themselves.	Share final report and maintain open dialogue, largely via Hook House Farm tenants.
Sussex Wildlife Trust	Email exchange with Henri Brocklebank regarding local	Introductions to South Downs National Park, Small Woods, and Forestry England, regarding local woodfuel supplies.	Share final report.

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	biomass producers	Advised the WT is not taking a position nationally on biomass. N.B. woodfuel project with Surrey WT recently ceased (Logs for All).	
Small Woods	Meeting with Amanda Calvert	Advised on local woodfuel availability, and how these suppliers are audited and certified. Advised on criteria and considerations for biomass energy centre design and operation. LC Energy and South East Woodfuels are both reputable local suppliers.	Contact local suppliers directly if desired.
Forestry England	Email exchange with Matthew Woodcock	Advised that FE aware of a number of managed woodlands and that Surrey/the Weald should have sufficient yield for a project. Recognised the challenge of securing a robust enough woodfuel supply chain for projects.	Share final report.
South Downs National Park	Meeting with Bob Epsom	With the National Park doesn't manage woodland itself, Bob is aware of a number private estates within the region who do supply their wood for community biomass projects. Recommended myForest directory to identify local woodfuel producers: https://myforest.sylva.org.uk/	Contact local National Trust forester, if desired. Share final report.

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COMMUNITY BENEFITS

We have assessed a range of factors that contribute benefit to Outwood of low carbon heat schemes. These include financial benefit (for building level solutions only), environmental benefit and social benefits.

TABLE 2: COMMUNITY BENEFITS

Scheme option	Benefit to Outwood	Description	Impact
Biomass heat network	Environmental	Carbon reduction compared to oil boilers	1,124 tCO_2e / year from heat network compared to oil boilers
Biomass heat network	Environmental	Air quality improvements compared to oil boilers	Reduced NOx and particulates compared to oil boilers
Biomass heat network; heat pump heat networks	Technical	Higher temperature heat to properties compared to building-level electrified systems	Reduced cost and disruption of in-home upgrades (insulation, replacement radiators, etc)
Heat pump heat networks	Environmental	Carbon reduction compared to oil boilers Carbon reduction through reduced vehicle movement	ASHP: 735 tCO_2e / year GSHP: 839 tCO_2e / year from heat network compared to oil boilers
Heat pump heat networks	Environmental	Air quality improvements compared to oil boilers Air quality improvements through reduced vehicle movement	Reduced NOx and particulates compared to oil boilers
Heat pump heat networks	Technical	Reduced grid impacts compared to building-level electrified systems	Peak power demand from the energy centre will be less than the combined peak demand from 160+ homes using electrified heat systems. Energy centre can also use thermal store to manage peak load.
Building-level heat pump solution	Financial	Cost savings in years 1-7 compared to oil	Net annual benefit c. £2,000 - £5,000 depending on property/system size; inclusive of incentive payments
Building-level biomass solution	Financial	Cost savings in years 1-7 compared to oil	Net annual benefit c. £1,500 depending on property/system size; inclusive of incentive payments
Building-level solar PV	Financial	Cost savings on household electricity bills	Net annual benefit c. £400 depending on system size
All options	Financial	Greater price certainty compared to oil	Reduced price fluctuation through the year

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TECHNOLOGY & ENGINEERING SOLUTIONS

Based on the Parish Council's requirements for a low-carbon alternative to heating oil, we developed a technology shortlist in discussion with the community, selected because of the potential to deliver high-temperature heat to properties, and reduce carbon compared to oil. These were:

- Biomass (woodchip) boilers with heat network;
- Air-source heat pump with heat network;
- Ground-source heat pump with heat network;
- Water-source heat pump with heat network; and
- Electric boilers as back-up heating systems

The following sections describe the technical and engineering approach taken to assess the potential for each of these options.

HEAT DEMAND MAPPING

We used a range of data sources to capture the heat demand database for Outwood village. We used GIS address level data to capture all the buildings in the village, and verified this using Google maps and a village walk over in May 2021. This identified 248 properties in the community.

Using this address list, we used the following steps to estimate the energy demand at a property level:

i. We used the Domestic EPC register as a source of energy demand estimations per property. Around 55% of the properties had EPCs.
ii. We issued an energy survey to the whole village through "Outwood News" – the parish magazine, the SustainableOutwood.org website and Facebook pages, reinforced by committee members contacting residents directly. We had 60 responses to the survey – 28% of the households in the village. Where residents gave us data on their energy usage, we included this in the demand database.
iii. For properties with neither EPC nor energy data, we estimated their energy demand based on the average of know energy data (EPC and energy survey results), excluding significant outliers.

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HEAT NETWORK MODELLING

We used the TERMIS software to analyse and model the heat loads in Outwood, and design a heat network to supply properties in the village.

The technical and financial viability of a heat network depends on having a high enough heat density – i.e. enough properties with high enough heat demands. Our modelling also accounted for geospatial differences, using the following data sources:

- Consumer list in tabula form including: Address and yearly energy consumption in kWh
- X and Y coordinates with specification of coordinate system
- Cadastral map/layer of the area as shp-, tab- or dwg-/dxf-file,
- Elevation map/layer of the area as points or/and contours registered either in a table with X/Y-coordinates or as shp/tab-file

For the modelling of the heat network the following technical input have been used:

iv. Maximum supply pressure: 6 bar
v. Minimum differential pressure at connection: 0.3 bar
vi. Design supply temperature at energy centre: 85 °C (at peak supply)
vii. Return temperature at connection: 55 °C
viii. Minimum supply temperature at connection: 72 °C (usually during summer)

The network model based on the above input includes the Supply Zone 1 (green), 2.1 (yellow) and 2.2 (yellow) as primary supply areas for district heating, and Supply Zone 3 (orange) as a potential to be considered during the first phase of the installation of the district heating system.

From the modelling the following number of connections and heat demands can be calculated:

Table 3: Network Heat Demand

Supply zone ID	**Number of connections**	**Total heat demand [MWh]**
1	133	3,106
2.1	7	129
2.2	27	690
“Core network” connections	**167**	**~3,925**
3 – potential next phase connection area	17	384
Excluded connections		
4	10	232
5	8	210
6	9	287
7	4	76
8	4	88
9	4	88
Grand total	**223**	**5,290**
Other properties beyond the supply zones	9	227

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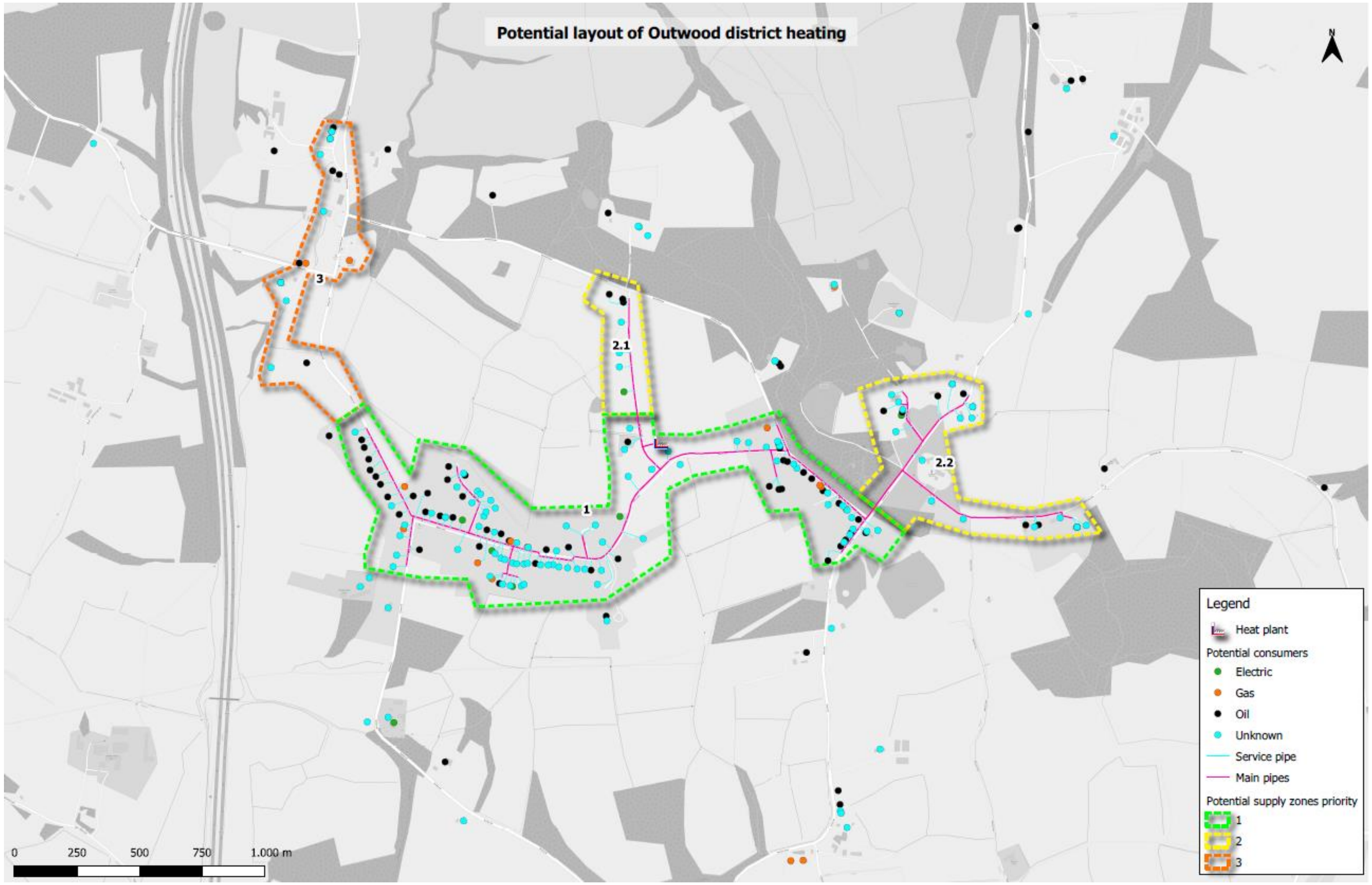

FIGURE 3: MODELLED VILLAGE HEAT NETWORK – SUPPLY ZONES 1, 2.1 AND 2.2 (CORE) AND ZONE 2 (FUTURE PHASE) – SEE ALSO APPENDIX E

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The remaining sections (red) shall be considered included at a later phases as the heat density is not considered sufficient.

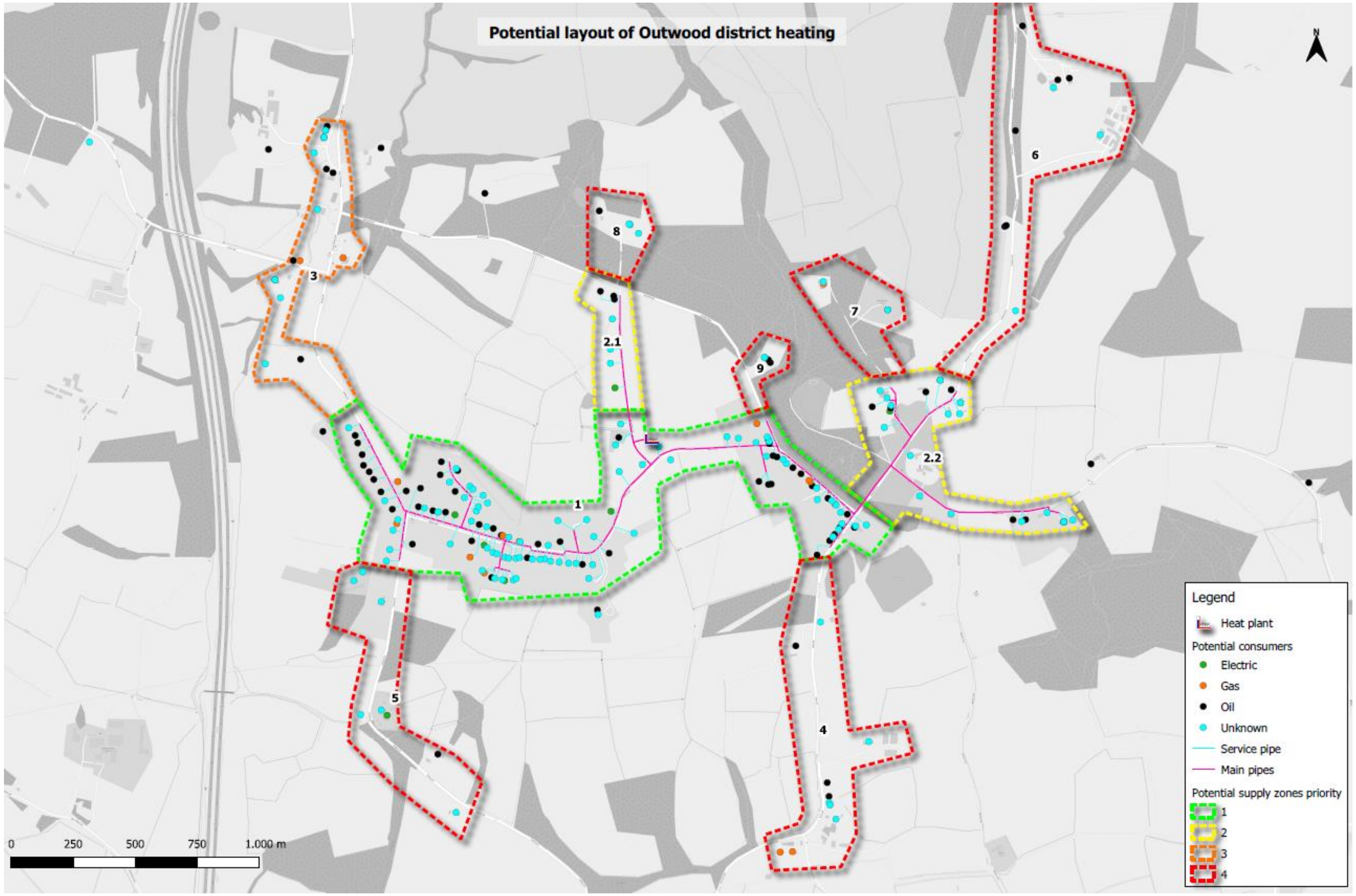

FIGURE 4: SUPPLY ZONES – ZONES 4-9 ARE CONSIDERED TOO FAR TO CONNECT TO THE NETWORK IN THE FIRST PHASE – SEE ALSO APPENDIX E

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Using total meter length of district heating pipes, the temperature levels, pressure levels and required pumping power, we modelled a number of typical scenarios for the network operation, using EnergyPRO.

The table below shows the various scenarios consisting of different temperature ranges and duration during the year, resulting in a proposed size for the energy centre and an estimated energy production for a typical year.

Table 4: Temperature and Energy Production Scenario Analysis

Period	Unit	1	2	3	4	5
Duration	hours	1	1,000	2,500	2,500	2,759
Load factor	-	1	0.7	0.5	0.3	0.15
Temperature supply plant	°C	85	80	75	75	75
Temperature return plant	°C	55	55	55	55	55
Power production	kW	1,445	1,028	748	469	256
Annual energy production	MWh	1	1,028	1,871	1,171	705

In total this results in:

Energy production	4,777	MWh
Total heat demand (zone 1, 2.1, 2.2)	3,925	MWh
Heat loss	852	MWh
Relative heat loss	18%	

As can be seen from the above table the heat loss from transportation and distribution of the heat in the network is calculated to approx. 18%, which is acceptable for a district heating network system as the one modelled for the Outwood village.

The results from the modelling in the TERMIS software also include the total length of various pipe sizes to be installed, being:

Table 5: Heating Network Pipe Length

Diameter (mm)	Pipe Length [m]
20	178
25	441
32	764
40	281
50	604
65	298
80	422
100	800
125	119
Grand Total	**3,906**

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HEAT TECHNOLOGIES

In the village there is a keen interest in how the sustainability and the use of renewable energy can be designed and secured when deciding the heating technology into the future. This supports the community's commitment to transition away from fossil fuels to green energy with a sustainable solution.

Taking this into account a number of technologies for production of heat have been looked into when modelling the energy centre, being the main:

ix. Heat pump
   - air-source heat pump
   - ground-source heat pump
   - water-source heat pump

x. Wood chip fired boiler

In the following these technologies are briefly described.

AIR-SOURCE HEAT PUMP

Description of Technology

Heat pumps are a highly efficient way to deliver heat into district heating system for heating of domestic and public buildings. They draw in heat from the ambient air, and use electricity to raise the temperature to a suitable level for space heating and hot water. Typically for each kWh of electricity consumed, 2.5-4 kWh heat is supplied, depending on the quality and size of the heat pump and the local climate – the average ratio of heat delivered to the total electrical energy supplied over the year is known as the Seasonal Performance Factor (SPF). Air-source heat pumps deliver lower temperatures than boilers, so they work well with underfloor heating or radiators with a larger surface area for a building level solution, but industrial scale systems can deliver higher temperature heat.

From a recent installed air-source heat pump plant in Denmark size 1.2 MW the size of the building and the fans are indicated[2].

Air-source heat pump systems have a life expectancy of approximately 20 years.

TABLE 6: ASHP ADVANTAGES AND DISADVANTAGES

Advantages	Disadvantages
Low carbon energy source	External equipment (fans) produces noise and cold air plumes
Minimal maintenance requirements	Depends on electricity to produce heat – which is more expensive per unit than biomass or oil
No additional fuels required	Is more efficient when delivering lower-temperature heat – this is manageable at a large scale, however for building-level solutions, lower temperatures may require radiator replacement

[2] From: https://www.energy-supply.dk/article/view/783975/ny_varmepumpe_til_saltum_fjernvarme, 1.2 MW air-source heat pump

Figure 5: 1.2 MW ASHP Structure

Suitability for Outwood

A heat network supplied by ASHP is suitable for Outwood because the industrial scale can deliver high temperature heat, compatible with existing buildings' heating systems. There is less impact on land from ASHP, as no boreholes are needed, and the footprint of the energy centre would be smaller.

At a building level, it is more likely that in-home upgrades would be needed to accommodate a lower temperature heat, for example larger radiators or underfloor heating. It is possible to run building-level ASHPs to a higher temperature, although the efficiency will decrease. Domestic installations are also still eligible for the Domestic Renewable Heat Incentive, meaning that homeowners would earn incentive payments for installing such a system, offsetting the increased cost of heat due to electricity use.

GROUND-SOURCE HEAT PUMP

Description of Technology

As with air source heat pumps, ground-source heat pumps extract heat from the environment and use electricity to raise the temperature. For ground-source heat pumps, each kWh of electricity can deliver 3-4 kWh heat, depending on the quality and size of the heat pump and the local sub-surface conditions. A ground source heat pump system needs land available to lay heat collectors in the ground – either laterally in trenches, or vertically in boreholes (see Figure 6).

The internal components of the heat pump have a life expectancy of approximately 20 years, and the ground loop (either horizontal or vertical) has a life expectancy of up to 60 years.

The horizontal version of this technology is well established and widely used in the UK, whereas the vertical version is less common.

From the ongoing project in the Swaffham Prior village boreholes will be drilled and a ground-source heat pump will be installed to extract heat and lift the temperature to district heating level – see figure below.

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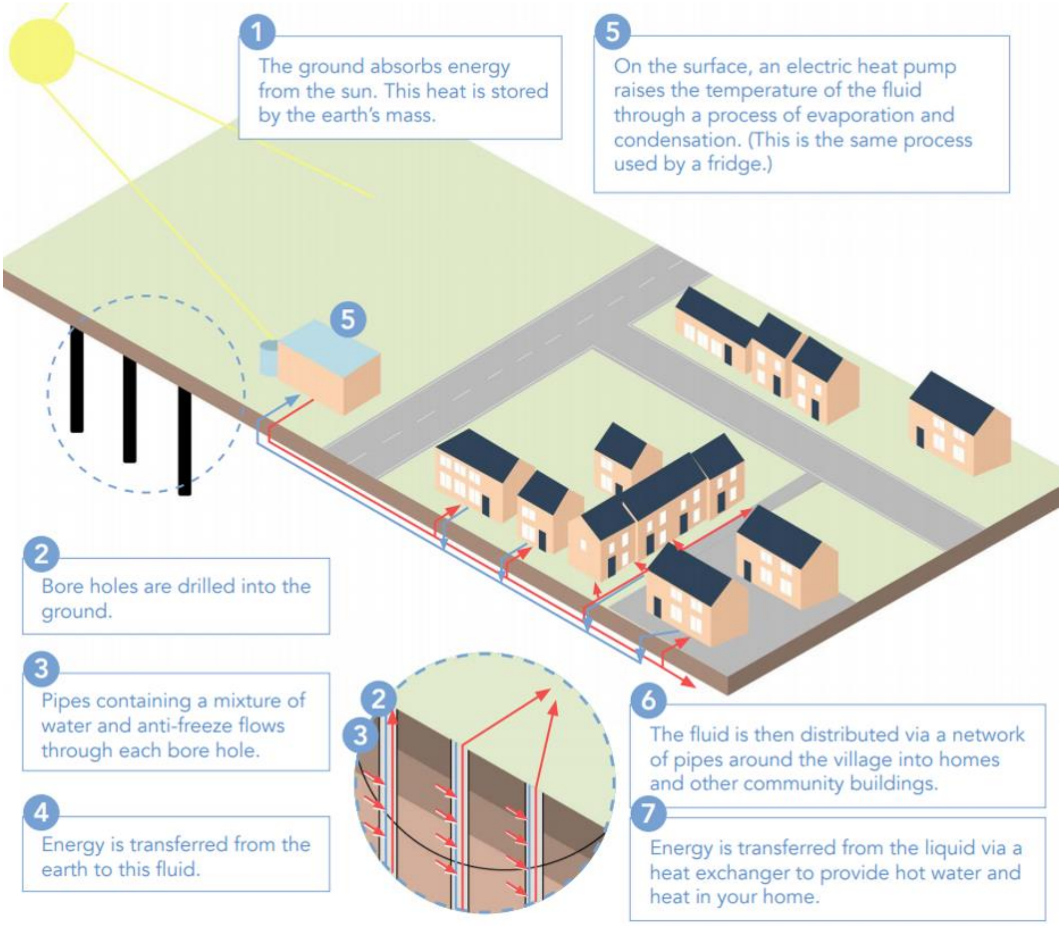

Figure 6: GSHP System [3]

Table 7: GSHP Advantages and Disadvantages

Advantages	**Disadvantages**
Low carbon energy source	Groundworks can be expensive
Minimal maintenance requirements	Requires substantial ground space
Long operational lifespan	Depends on electricity to produce heat – which is more expensive per unit than biomass or oil
No additional fuels required	Is more efficient when delivering lower-temperature heat – this is manageable at a large scale, however for building-level solutions, lower temperatures may require radiator replacement

[3] From: https://www.cambridgeshire.gov.uk/residents/climate-change-energy-and-environment/climate-change-action/low-carbon-energy/community-heating/heating-swaffham-prior

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Suitability for Outwood

Ground-source heat pumps are suited to both individual domestic properties and larger scale heat networks, however this does depend on available area to host the horizontal or vertical heat collectors. Our analysis of space requirements for each system is outlined in the Site section below.

The ground conditions and geology below Outwood are anticipated to be suitable to support ground-source heat pumps, although the aquifer formations are at some depth. Two target unit formations are identified and described in more detail in the Site Description section (p. 25ff). The first formation is the Tunbridge Wells Sands (TWS) which is around c. 200m to 250m below ground level, with the second target unit the Purbeck and Portland Beds being at a depth of between c. 550m and 600m below ground level. Both formations are classified as aquifers (Secondary A). These factors make ground-source heat pumps a possible technical solution for the parish.

The main challenge to GSHP deployment in Outwood will be availability of land for boreholes. Our analysis shows that to supply the core network, ~120 boreholes will be needed, covering ~25 acres of land. No land parcel of this scale was identified during our study, and so we have deprioritised this technical solution.

WATER-SOURCE HEAT PUMP

An initial review of surface water resources indicated that there are no substantial rivers or other watercourses in the study area that would be available as a heat source.

There are two waterbodies in the study area: the Marl Pond to the east of the village and also a covered service water reservoir owned and operated by Sutton and East Surrey Water. The Marl Pond although surface water fed, does not have a significant throughflow of water. Our initial view is that the Marl Pond is too small to be an adequate heat source for a community scheme.

The covered service reservoir does have a reasonable throughflow of water but it is potable water already treated and 'in supply' held in the reservoir for just a short period before being distributed to customer taps. Sutton and East Surrey Water indicated that because the operational site stores potable water in close proximity within the network to the customer tap, it is not suitable as a heat source due to the need to prevent contamination risk of drinking water.

Water source options have therefore been excluded from further evaluation.

WOOD CHIP FIRED BOILER

Description of Technology

Biomass for burning as a fuel includes wood, energy crops, agricultural crop residues, wood manufacturing by-products and farm animal litter. Burning biomass releases carbon dioxide to the atmosphere, however this is considered offset by the carbon absorbed in the original growth of the biomass, resulting in low net carbon emissions over the lifecycle of the system. Biomass boilers can typically be divided into wood pellet boilers and stoves for individual/domestic use and wood chip boilers for commercial use as district heating provider. These range in size from small domestic units of a few kilowatts to commercial units of megawatt size.

The technology for burning wood chip is well-established and there are several suitable suppliers of not only the boiler and auxiliaries but also the building. The photos below show a 800 kW installation, comparable to the required size for Outwood.

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Figure 7: 800 kW biomass structure interior [4]

Figure 8: 800 kW biomass structure exterior [5]

Biomass boilers have a life expectancy of 20 to 30 years.

As the Outwood village is situated close to forests, the use of wood chip as fuel has been focused at when modelling the energy centre for production of district heating.

[4] From: https://omegaenergy.dk/produkter/heizomat-rhk-ak-800-fliskedel.

[5] From: https://omegaenergy.dk/produkter/heizomat-rhk-ak-800-fliskedel.

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FIGURE 9: 500KW BIOMASS ENERGY CENTRE WITH CLADDING

TABLE 8: BIOMASS BOILER ADVANTAGES AND DISADVANTAGES

Advantages	Disadvantages
Renewable source of energy	High maintenance system
Low volatility of fuel price	Regular fuel deliveries required
Reduced carbon emissions compared to oil	Additional space required for fuel storage
Delivers high temperature heat which will be more readily compatible with existing systems	Securing fuel supply contracts can be a constraint
	Likely to be harder to secure planning permission due to larger footprint and building height

Fuel Supply

Based on our sizing calculations (see below), a biomass boiler supplying the core network (~4,000 MWh) annually would require ~1,600 tonnes of wood chip per year. To generate this from managed woodland, Outwood would be harvesting wood chip from an area of ~190 hectares of woodland. We estimate that the Harewoods Estate has c. 50 hectares of woodland in Outwood, so the project would need to secure fuel supplies from other producers in the south.

We have initiated discussions with local wood fuel producers and woodland managers, including Surrey Wildlife Trust, South Downs National Park, Small Woods, and Forestry England. There is a wide range of local managed and ancient woodlands that could be part of the supply chain to a biomass energy centre in Outwood.

In particular LC Energy and South East Woodfuels are suppliers in the south of England, with operations based 20 miles and 40 miles from Outwood respectively. These suppliers are accredited on the Biomass Quality Assurance scheme, with rigorous testing and approvals of the quality and sustainability of their products. Both suppliers will be sourcing their roundwood from within 60 miles of their operations, and can provide the volume of woodchip required for a heat network biomass boiler. Our contact advised that Outwood could work with either supplier to harvest roundwood from woodlands close to the community, and have it processed by the supplier, further reducing the

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transportation distance to site. This might be a good solution for bringing the National Trust woodland locally into active management and woodfuel production.

Suitability for Outwood

A centralised biomass boiler would deliver high temperature heat to connected properties, at an operational cost comparable or cheaper than oil. However the community has raised concerns about the long-term sustainability of biomass as a heating solution. There is also an impact on planning, with the biomass energy centre having a larger footprint and height than the electrified systems, so more liable to face challenges during the planning process.

The requirement of Outwood Parish is that sustainability is of major importance – this also includes ensuring a sustainable usage of wood chips. Much analysis of the sustainability of biofuels and woodfuels has been conducted. One good source is the BioGrace category model is a European life cycle model that evaluates European fuel pathways under the Renewable Energy Directive (RED).

Across the industry, the following requirements have been implemented in order for a fuel source to be called sustainable:

1. Legally felled and traded.
2. Protection of forest ecosystems.
3. The productivity and ability of forests to contribute to the global carbon cycle must be maintained.
4. Forests must be healthy and well-functioning.
5. Protection of biodiversity as well as sensitive and conservation-worthy areas.
6. Social and work-related rights must be respected.
7. Limit values for CO_2 emissions from the biomass value chain must be met.

Criteria 1 - 6, which concern sustainable forestry, can be met through one of the following certification schemes:

- Forest Stewardship Council (FSC) - www.dk.fsc.org / www.ic.fsc.org
- Program for the Endorsement of Forrest Certification schemes (PEFC) – www.pefc.org
- Sustainable Biomass Program (SBP) – www.sbp-cert.org

Other certification programmes include:

- Biomass Suppliers List https://biomass-suppliers-list.service.gov.uk/find-a-fuel
- Sustainable Fuels Register https://www.sfregister.org/ for non-woodfuels

Taking the above into account, the installation of a biomass boiler to deliver district heating for Outwood could be a suitable and economical viable solution, if acceptable to the community.

ROOFTOP SOLAR PV

Description of technology

Solar photovoltaic (PV) panels capture energy from sunlight and convert it to electricity. Panels can be mounted on building rooftops or installed as stand-alone ground-mounted systems. This technology is well established and widely used in the UK.

The potential for generating electricity through solar panels is determined by the amount of sunlight falling upon that location. The orientation of the installation relative to the due south (for the northern hemisphere) and the distance from the equator, both determine the energy production per kWp installed (called the "Kk value").

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We have assumed a Kk values for Outwood of 1128 kWh/kWp – which means that for every kWp of solar panels installed, 1128 kWh are generated per year.

Advantages	Disadvantages
Low carbon energy source	Electricity supply determined by weather
Minimal maintenance requirements	Potentially visually disruptive
Long operational lifespan	Relatively high capital cost
No additional fuels required	Larger installations require planning permission
Familiar technology	

FIGURE 10: ROOFTOP SOLAR PV – C. 9KWP CAPACITY

Suitability for Outwood

Solar PV installations are quick and easy to install on the ground and on rooftops, making it a good solution for residents in Outwood. A typical domestic installation would cost between £4,000 - £6,000 depending on the size, and would payback in ~7 years.

We surveyed ten properties in the village, of which seven would be suitable for rooftop solar PV, if desired. Extrapolating this to the whole village, the following could be achieved in Outwood:

	Number	Number suitable for solar PV	Total installed capacity (size)	Indicative investment need	Carbon benefit (tCO_2e/ year)
All households surveyed	10	7	29 kW	£3,000 - £8,000 per property, depending on size Total cost: £34,500 (est.)	8
All households in Outwood	248	173	716 kW	£850,000 (est. collective purchasing could reduce this significantly)	198

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Considerations for households

- Listed properties

Roof mounted solar installations are considered "permitted development" (i.e. do not require any planning permission), so long as the following criteria are met:

- Panels should not be installed above the highest part of the roof (excluding the chimney) and should project no more than 200mm from the roof slope or wall surface.
- The panels must not be installed on a building that is within the grounds of a listed building or on a site designated as a scheduled monument.
- If your property is in a conservation area, or in a World Heritage Site, panels must not be fitted to a wall which fronts a highway[6].

This means that the listed properties in Outwood would need to apply for planning permission to install solar PV. Given the likely objection to such works, we would not advise this currently.

- Visual impact

To minimise the visual impact of solar PV panels, we recommend installing on roofs that do not face the road. To generate the most electricity from the panels, south, east or west facing roofs should be chosen. This means that properties on the north side of Millers Road are less likely to be suitable for solar PV, as their south facing roofs will face the road.

- Collective purchase

Communities can take advantage of "collective purchasing" whereby several local buyers join together to order equipment. This is well-established for solar PV – Tandridge District Council are signed up to a scheme with Solar Together: https://solartogether.co.uk/tandridge/home

The purpose of these schemes is to reduce cost to individuals, and provide a level of quality assurance and customer protection when buying solar PV.

For more details of the suitability of solar PV for households in Outwood, please see Appendix D – household surveys summary.

[6] https://www.planningportal.co.uk/info/200130/common_projects/51/solar_panels/2

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HEAT PRODUCTION CAPACITY SIZING

The design of the energy centre has been divided into a baseline scenario and four alternatives:

- Baseline scenario: Existing individual oil-fired boilers
- Alternative 1: Wood chip fired boiler
- Alternative 2: Air-source heat pump and electric boiler
- Alternative 3: Ground-source heat pump with boreholes and electric boiler
- Alternative 4: Wood chip fired boiler, air-source heat pump and electric boiler

These alternatives have been used for calculation of CAPEX and OPEX.

Alternative 1: Wood chip fired boiler and electric boiler

The proposed energy centre to consist of:

- 800 kW biomass boiler
- 1,500 kW electric boiler for peak-load and backup
- 1,000 m³ heat storage tank
- Approx. 500 m² building for boiler, fuel storage and administration
- Flue stack approx. 20 m height

The footprint below indicate how the setup of the energy centre could be.

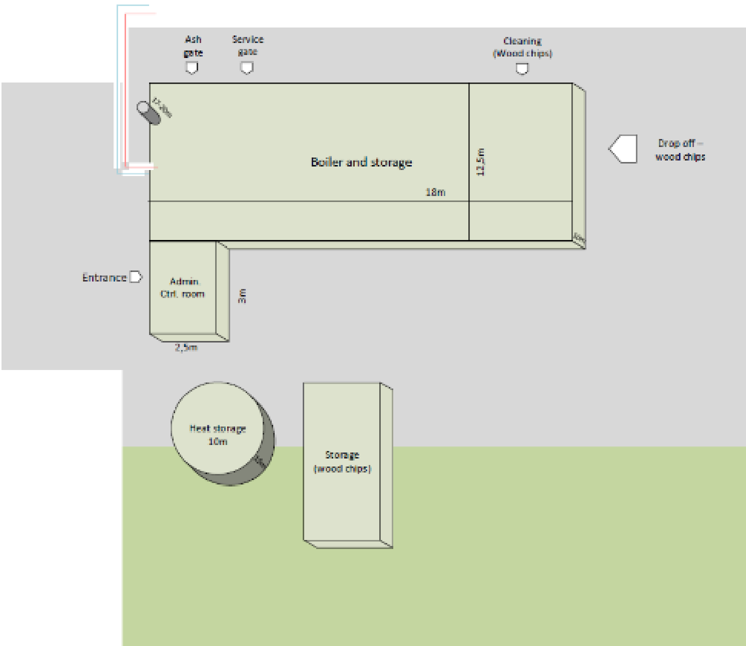

FIGURE 11: ALTERNATIVE 1: WOOD CHIP FIRED BOILER AND ELECTRIC BOILER

Alternative 2: Air-source heat pump and electric boiler

The proposed energy centre to consist of:

- 750 kW air-source heat pump
- 1,500 kW electric boiler for peak-load and backup
- 1,000 m³ heat storage tank
- Approx. 60 m² building for air-source heat pump and administration
- Approx. 115 m² fenced area for fans

The footprint below indicate how the setup of the energy centre could be.

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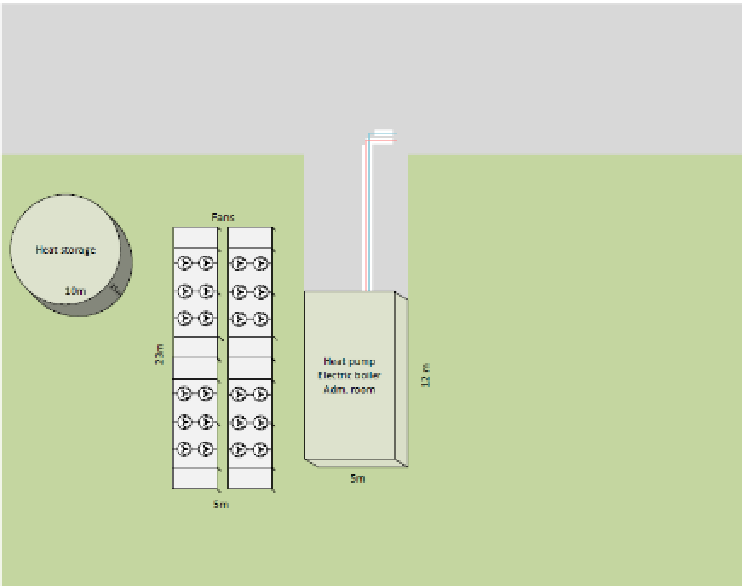

FIGURE 12: ALTERNATIVE 2: AIR-SOURCE HEAT PUMP AND ELECTRIC BOILER

Alternative 3: Wood chip fired boiler and air-source heat pump

The proposed energy centre to consist of:

- 400 kW air-source heat pump
- 600 kW wood chips fired boiler
- 1,000 m^3 heat storage tank
- Approx. 500 m^2 building for boiler, fuel storage, air-source heat pump and administration
- Flue stack approx. 20 m height

The footprint below indicate how the setup of the energy centre could be.

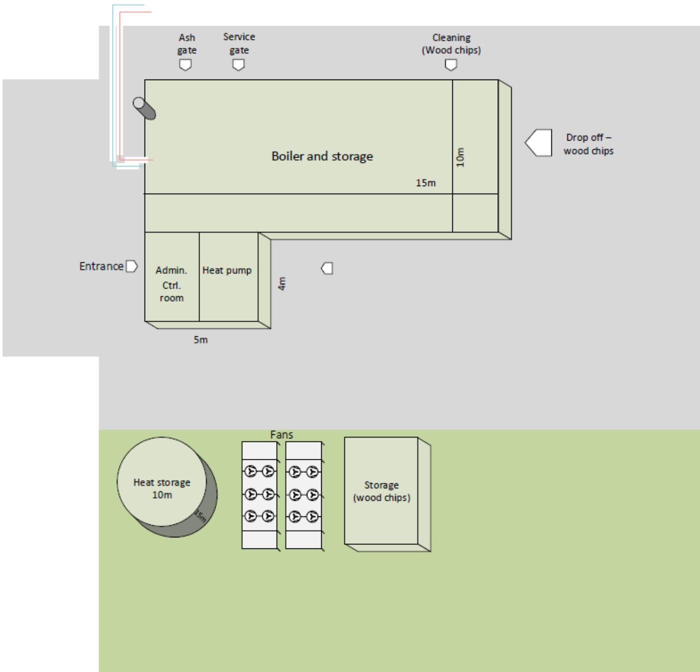

FIGURE 13: ALTERNATIVE 3: WOOD CHIP FIRED BOILER AND AIR-SOURCE HEAT PUMP

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Alternative 4: Ground-source heat pump with boreholes and electric boiler

The proposed energy centre to consist of:

- 500 kW water-source heat pump
- 1,500 kW electric boiler
- 1,000 m^3 heat storage tank
- Approx. 60 m^2 building for water-source heat pump and administration
- Approx. 115 m^2 fenced area for fans
- 117 boreholes placed at approx. 25 acres of land

The footprint below indicates how the setup of the energy centre could be.

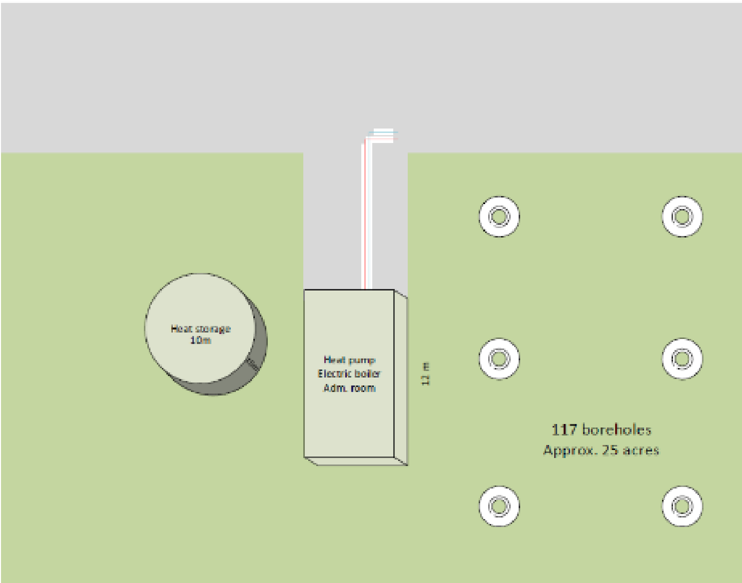

FIGURE 14: ALTERNATIVE 4: GROUND-SOURCE HEAT PUMP WITH BOREHOLES AND ELECTRIC BOILER

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FINANCIAL PROJECTIONS

We used the EnergyPRO model described above to simulate the energy flows of the base line scenario (oil boilers) and the four alternative district heating systems proposed. We also estimated the capital requirements of the four alternatives, and calculated a "whole life cost of heat" for the base line and the four alternatives.

This analysis is presented below, and the assumptions behind this analysis are included in Appendix H.

BASE CASE

Figure 15: Investment costs

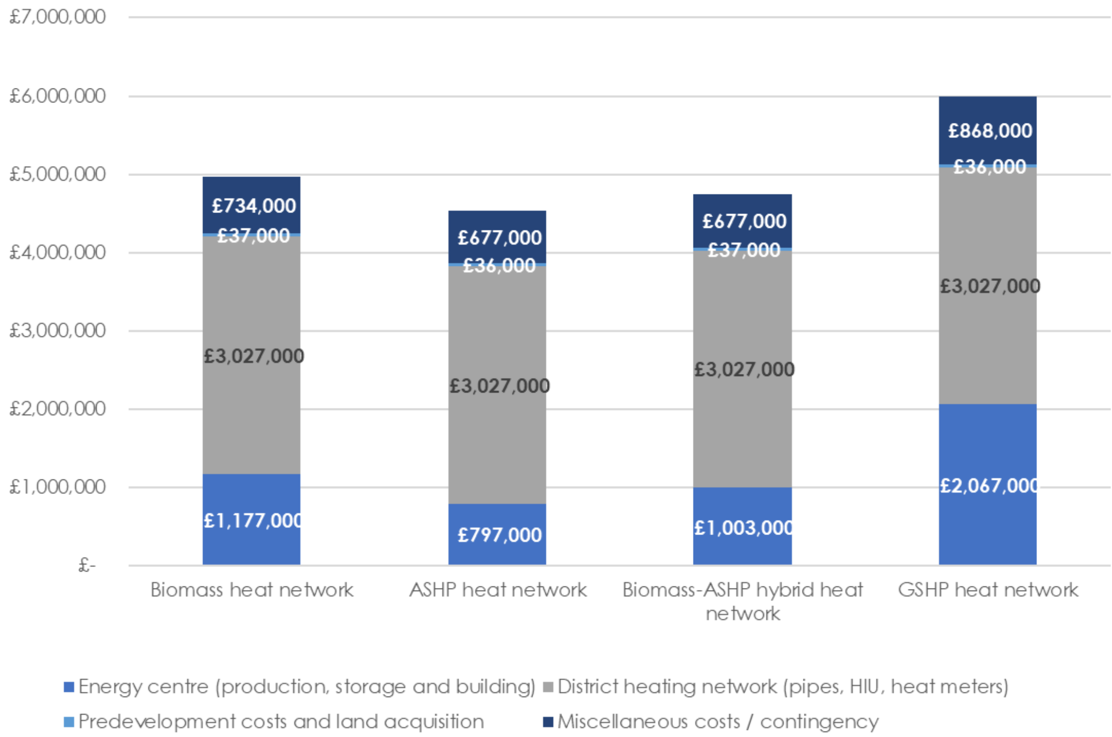

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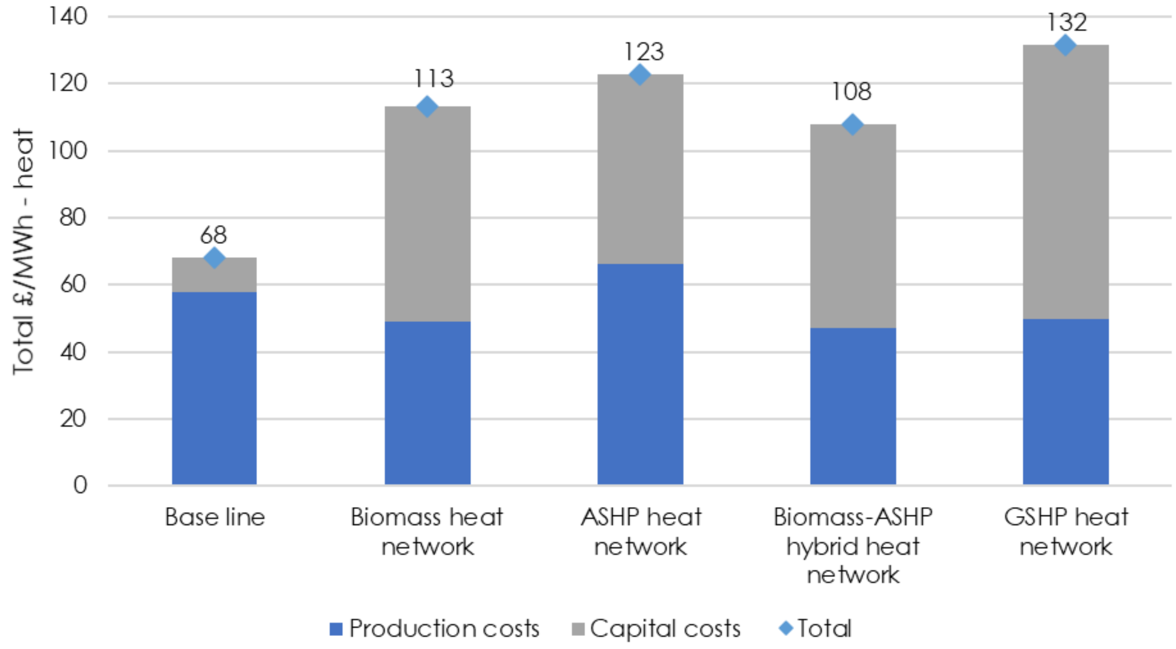
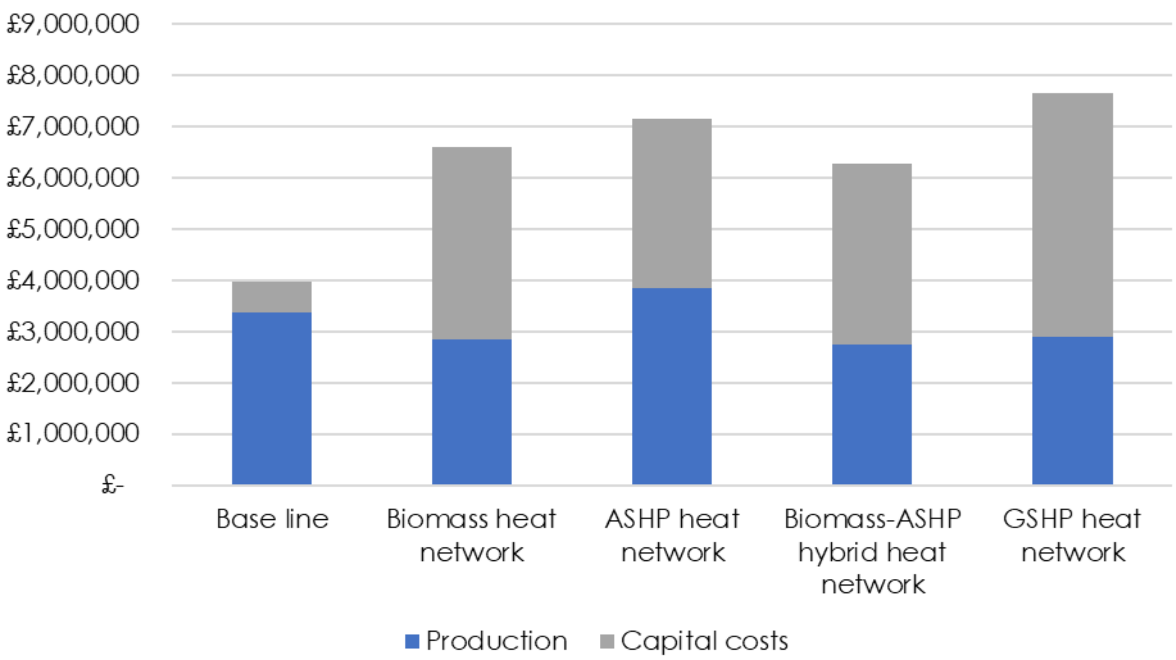
FIGURE 16: WHOLE-LIFE COST OF HEAT (OPEX + CAPEX)



This graph demonstrates the challenges to heat network schemes under current policy regime, in that the production cost of heat (i.e. operation only) is more expensive or only marginally cheaper than fossil fuel alternatives. Defraying the capital costs over the project lifespan and number of connections raises the whole-life cost of heat far above fossil fuel systems.

FIGURE 17: NET PRESENT VALUE (OVER 20 YEARS)



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SCENARIO ANALYSIS

To test the viability of these schemes under difference scenarios, we also ran the analysis to test sensitivity to electricity price – which is the main factor in the high production cost of heat for the electrified systems. The CAPEX requirements are unchanged.

We ran two scenarios:

1) 24% price reduction on electricity (day and night tariffs) – in line with the proposed review of electricity pricing to move "policy costs" elsewhere in taxation
2) Flat-rate 12p/kWh electricity price – a potential target power price

The results are shown below:

Scenario 1 – 24% price reduction on electricity (day and night tariffs)

FIGURE 18: SCENARIO 1 - WHOLE-LIFE COST OF HEAT (OPEX + CAPEX)

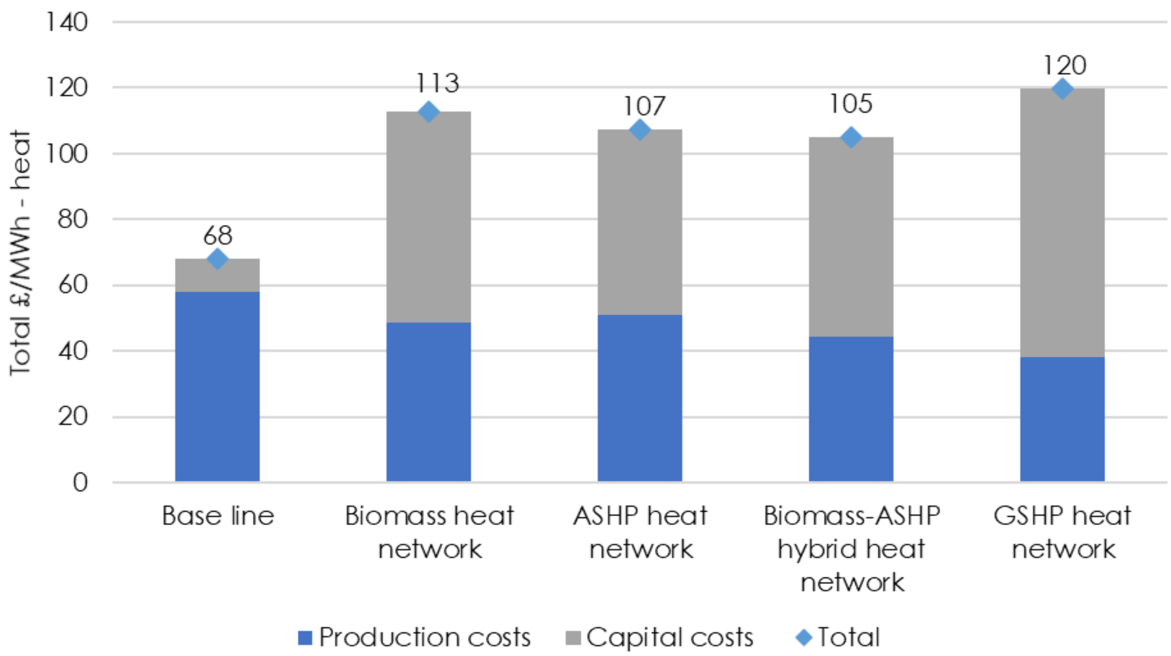

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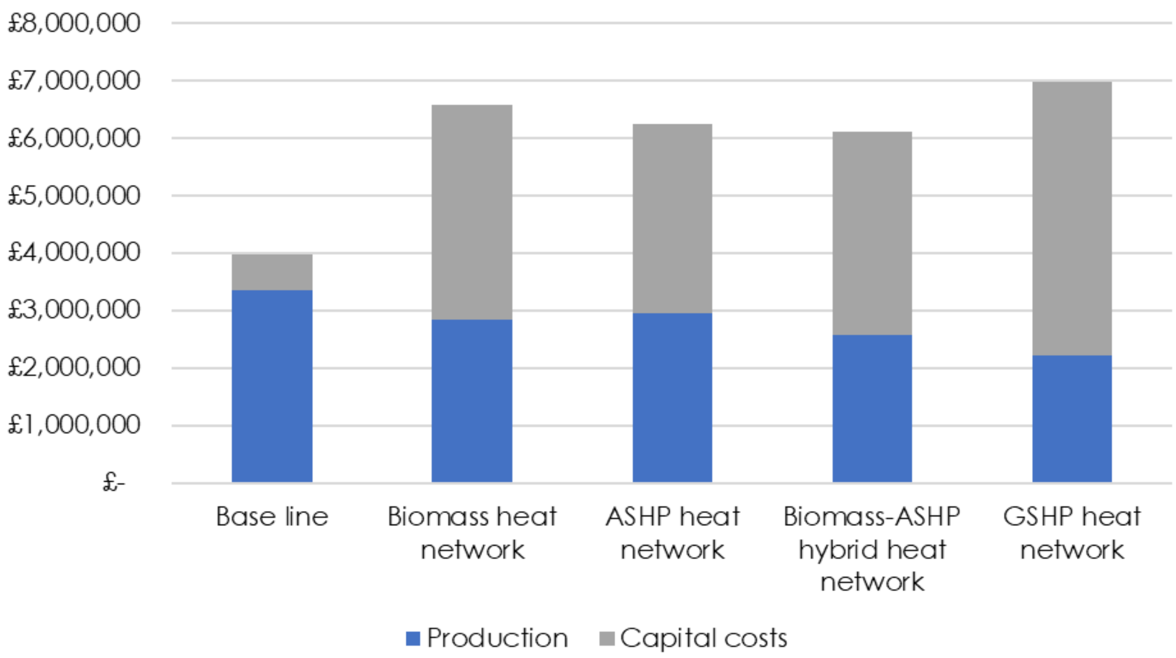
FIGURE 19: SCENARIO 1 – NET PRESENT VALUE OVER 20 YEARS)



Scenario 2 – flat-rate 12p/kWh electricity price

FIGURE 20: SCENARIO 2 – WHOLE-LIVE COST OF HEAT (OPEX + CAPEX)

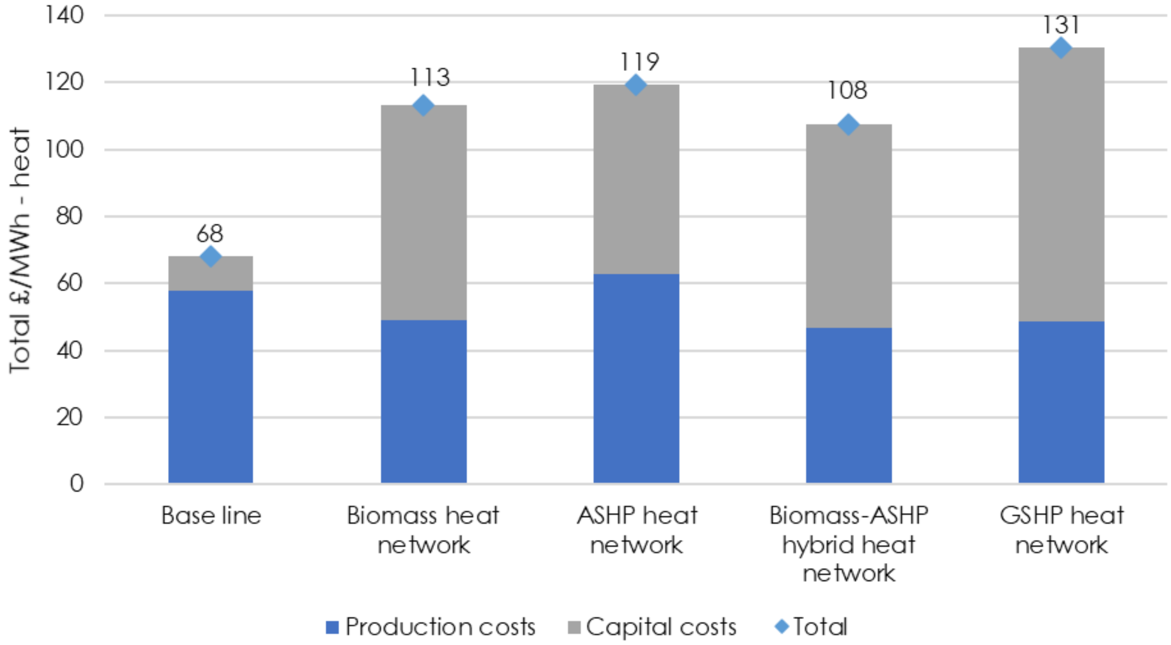


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FIGURE 22: SCENARIO 2 – NET PRESENT VALUE (OVER 20 YEARS)

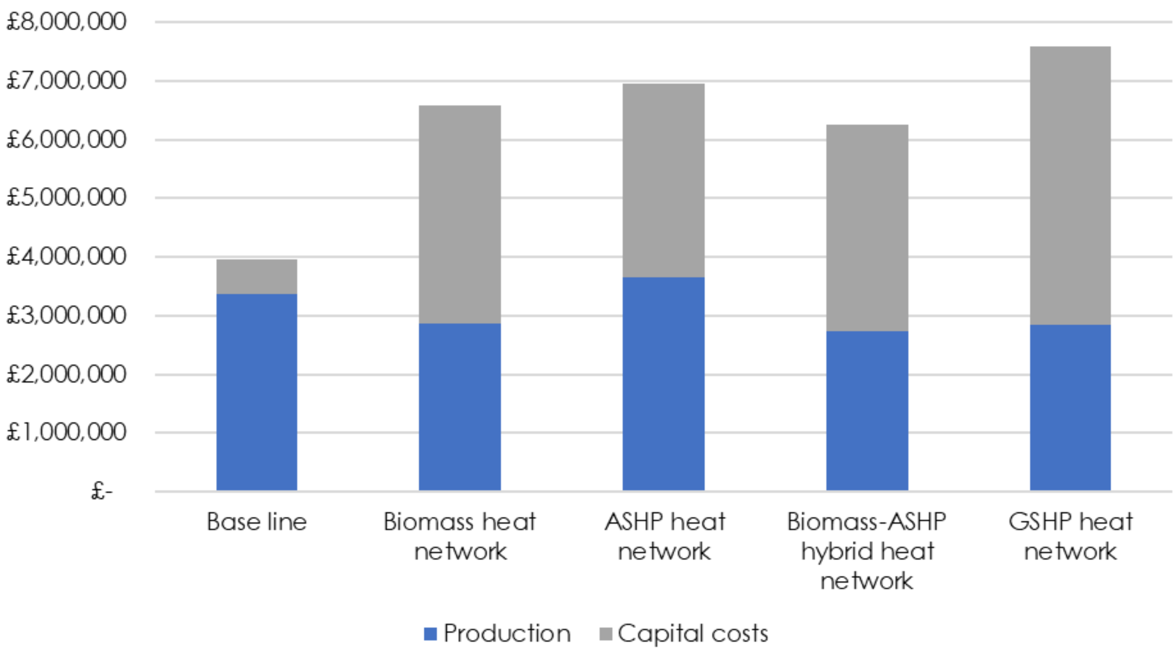
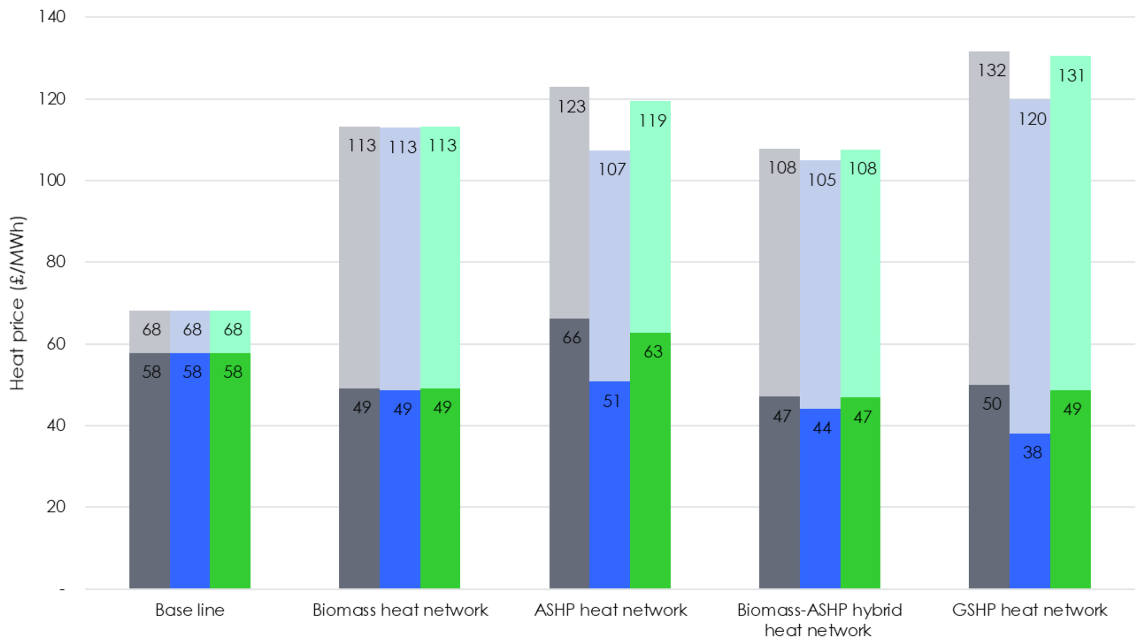


FIGURE 21: VARIATION OF WHOLE-LIFE COST OF HEAT WITH ELECTRICITY PRICE



Key:

Grey – base case electricity price

Blue – scenario 1 – policy review – 24% reduction on power price

Green – scenario 2 – securing cheap power

The total bar represents the whole-life cost of heat, with the lower section the production costs alone.

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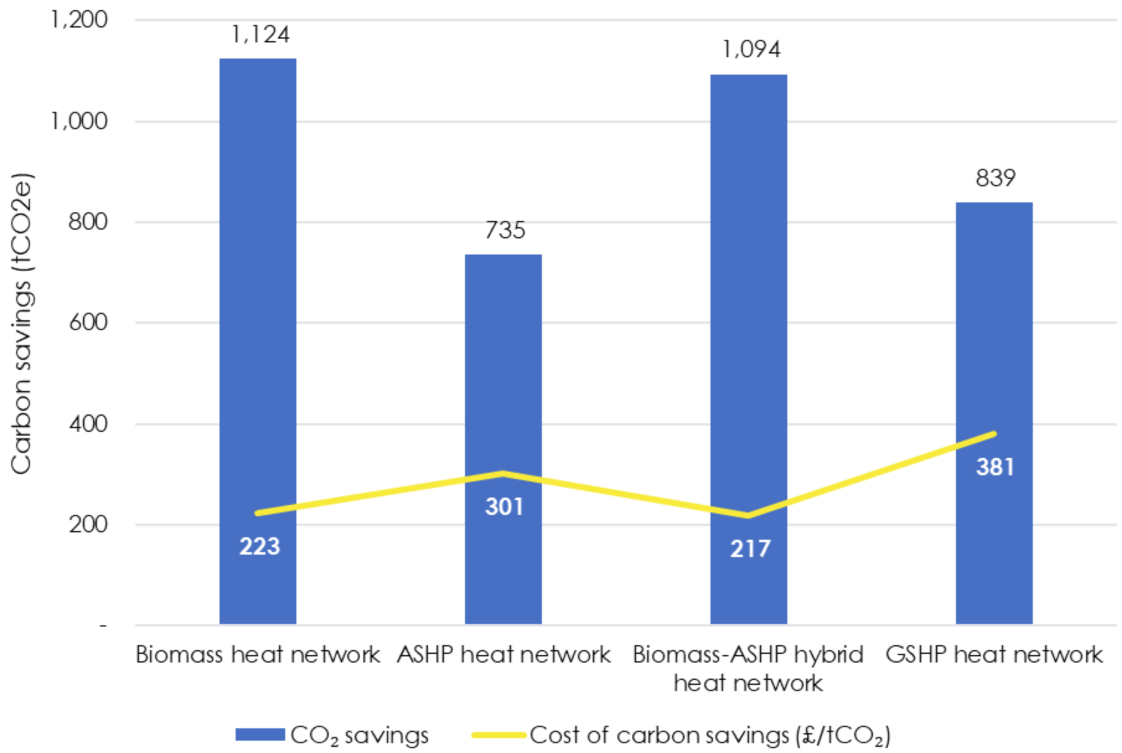
FIGURE 23: CARBON SAVING FOR EACH OPTION COMPARED TO OIL BOILER COUNTERFACTUAL



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FUNDING SOURCES

We have researched suitable funding sources for Outwood and summarized the priority funding sources in the table below. These funding options could be used for the capital costs of a project. We note that some funding routes are only available to certain legal entities so not all funds would be available to building level solutions or village wide heat networks.

Table 9: Funding Sources

Funding Type	Funder	Fund Name	Link	Specific Criteria	Funds Available	Suitable for:
Grant	Surrey County Council	Your Fund Surrey	https://www.surreycc.gov.uk/people-and-community/voluntary-community-and-faith-sector/funding/community-projects-fund	Your Fund Surrey can be accessed for capital, one-off costs. Projects must fit with the aims of Surrey's Community Vision, and have the support of your local community.	£10,000 minimum	Heat network projects
Grant	National Lottery	National Lottery Community Fund - Partnerships	https://www.tnlcommunityfund.org.uk/funding/over10k	Grants are available to voluntary and community organisations in England which work together with a shared set of goals and values. Partnerships funding is specifically designed to support generous leadership and increased collaborative working, which starts with shared goals and values between different organisations and an understanding of the bigger picture.	£10,000 minimum	Heat network projects
Grant	UK Government	Clean Heat Grant	https://www.gov.uk/government/consultations/clean-heat-grant-further-policy-design-proposals	The Clean Heat Grant is due to come online in 2022. This Grant will be directed towards households and small non-domestic buildings with upfront installation costs of heat pumps to provide space heating and hot water.	Unknown (final scheme design will be confirmed late 2021)	Building-level solutions
Project Finance	CO2 Sense	Environmental and Renewable Energy Finance	https://www.co2sense.co.uk/	Keen to support projects within the environmental spectrum including (but not limited to) renewable energy, energy efficiency, energy storage, smart grids and demand management, and waste management	Typically invests between £100k - £2 million per investment	Heat network projects

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FINANCIAL CONCLUSIONS

Our analysis shows that with current electricity pricing, only biomass can deliver whole-life cost of heat to Outwood more cheaply than oil. Should the proposed electricity price reform be approved, then Outwood could generate heat using heat pumps more cheaply than oil – an electrified system would be the community's preference, as it avoids the risk of fuel supply security, ongoing vehicle movements in the village, and increased risk of planning application being rejected.

The capital costs for the network under current policy regimes could be part-funded by investment vehicles like the Green Heat Network Fund, or other grant funding sources (e.g. Your Fund Surrey). The revenue risk is the fundamental constraint on this project's viability.

THE RENEWABLE HEAT INCENTIVE AND ITS IMPACT

The Renewable Heat Incentive (RHI) is an incentive mechanism from Central Government to support renewable heat projects in the UK. There are two elements to the scheme – incentives for non-domestic projects, and incentives for domestic projects.

	Non-domestic RHI	**Domestic RHI**
Eligibility	Schemes with 2+ domestic connections, or any number of non-domestic connections. Heat networks would be eligible for NDRHI. Heat source must be renewable – most heat pumps and biofuel systems are eligible.	Individual households. Heat source must be renewable – most heat pumps and biofuel systems are eligible.
Payment duration	20 years from registration date	7 years from registration date
Current status	NDRHI closed to new applicants on 31 March 2021.	DRHI will close to new applicants on 31 March 2022.

Because the NDRHI scheme is no longer available, there is no income stream from incentive payments available to the committee. This means the cost of producing heat, especially from electrified sources (like heat pumps), is higher than fossil fuel sources. Therefore, there would be no cost benefit to households connecting to a heat pump heat network – even if funds could be raised for the capital costs – as the cost of heat to households would be higher than oil.

The DRHI is still available for households wishing to install building level solutions (N.B. the scheme closes to new applicants in March 2022). Our analysis shows that these systems (building level air source, ground source or biomass systems) are more expensive to run than oil, and so after year 7 (when the RHI payments stop) there would be a net cost to households in running these systems. In most cases the payback period is less than 7 years, and so this could be seen as a bridging solution for the short term, while government policy is introduced to support solutions like community heat networks.

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PLANNING & PERMITTING

PLANNING EVALUATION OF THE ENERGY CENTRE

A long list of potential energy centre locations was sifted based on feasibility, environmental, engineering and landownership factors which then defined a short list of three options. The three different locations for the proposed Outwood Energy Centre considered within this short list are set out in Figure 28 (see site details plan).

For the purposes of the planning review the Outwood Energy Centre is defined as being able to supply energy in the form of heat extracted via a Ground Source Heat Pump (GSHP) and other methods to the dwellings in Outwood. The heat demand is likely to be in the order of 1-2MW of heat but the solution is likely to be a blend of technologies (including air source and ground source; or biomass and ground source for example). The three options are:

- Option 1: National Trust land North of Millers Lane – which is close to the centre of the village;
- Option 2: Brightleigh Farm south of Millers Lane – is an efficient location for the pipe network and has good vehicle access;
- Option 3: Fields north-west of Outwood – is a good central location, however the fields are owned by two separate private individuals.

A review of the Tandridge District Council planning register has been completed for all applications since 1st January 2000. Other than a few minor applications on the neighbouring land for replacement dwellings, side extensions and roof extensions, new or replacement garages, or applications for other ancillary residential uses (including their subsequent discharge of conditions, non-material amendments and variations) the sites have no other Planning History of note.

The sites are all located within Flood Zone 1 therefore at the lowest risk from flooding. From an ecology perspective, the three sites are located near Outwood Common, a large local National Trust woodland.

There are several Public Rights of Way in close proximity to the three sites; the Option 3 site in particular is located near three footpaths.

From a desktop perspective, the Options 1 and 2 sites appear to be well contained from a visual and environmental standpoint and should be explored in preference to the Option 3 site – this appears to be less connected to the site, and there are existing ecological features (hedgerows) within the land that should be retained.

RELEVANT PLANNING POLICY

Tandridge is a predominantly rural district and about 94% of the area is designated as Green Belt.

There are three main built up areas in the 'north' of the District are Caterham, Warlingham and Whyteleafe, with Oxted, Hurst Green, Limpsfield to the south of the M25. There are two larger rural settlements (excluded from the Green Belt) of Lingfield in the south-east and Smallfield in the south-west. There are also a number of villages and some other smaller settlements and areas of sporadic development in the Green Belt. The central part of Woldingham is also excluded from the Green Belt and forms a "detached" built up area.

There are two Areas of Outstanding Natural Beauty (AONB). These are the Surrey Hills AONB in the north and the High Weald AONB in the south-east. AONBs are landscapes of National importance.

The Tandridge District Core Strategy (TDCS) was adopted by the Council in October 2008. It sets out key planning policies for the District. Those policies of particular relevance to this proposal are:

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- CSP1 – Location of Development
- CSP 11 – Infrastructure and Services
- CSP 14 – Sustainable Construction
- CSP 15 – Environmental Quality
- CSP 17 – Biodiversity
- CSP 18 – Character and Design
- CSP 21 – Landscape and Countryside

The Core Strategy is silent on proposals for 'Energy Centres' or applications relating to Ground or Air Source heat pumps, however Policy CSP 14 'Sustainable Construction' states that 'small scale renewable energy projects will be permitted except where there are overriding environmental, heritage, landscape, amenity or other constraints'. The overwhelming planning constraint in this case is the Green Belt.

The TDCS sets out the acknowledges the importance of the Green Belt as a way of keeping land open and preventing the outward spread of London and existing built-up areas from coalescing. In Green Belt policy terms, both the local Development Plan and National Planning Policy Framework (NPPF) makes it clear that very special circumstances would need to be demonstrated and that any other harm resulting from the proposal is clearly outweighed by other considerations.

The NPPF states the following:

133. The Government attaches great importance to Green Belts. The fundamental aim of Green Belt policy is to prevent urban sprawl by keeping land permanently open; the essential characteristics of Green Belts are their openness and their permanence.

134. Green Belt serves five purposes: a) to check the unrestricted sprawl of large built-up areas; b) to prevent neighbouring towns merging into one another; c) to assist in safeguarding the countryside from encroachment; d) to preserve the setting and special character of historic towns; and e) to assist in urban regeneration, by encouraging the recycling of derelict and other urban land.

…

147. When located in the Green Belt, elements of many renewable energy projects will comprise inappropriate development. In such cases developers will need to demonstrate very special circumstances if projects are to proceed. Such very special circumstances may include the wider environmental benefits associated with increased production of energy from renewable sources.

Policy CSP 1 'Location of Development' confirms that development should be focused towards previously developed land in sustainable locations and there will be no changes to Green Belt boundaries. This largely restrictive approach to development in the Green Belt is highlighted in 'Issue 1' of the TDCS which states the following:

'The Green Belt is seen as <u>vitally important to protect the existing character of the District,</u> particularly as the District is so close to London. Without the Green Belt the outward spread of London would be uncontrolled and would result in an expanding urban area that would swamp the existing communities. Also without the Green Belt existing communities would eventually merge. It is also important to protect the Green Belt as it provides opportunities for access to the countryside and outdoor recreation for the population of London. Parts of the Green Belt in the urban fringe suffer from neglect and the challenge is to improve the quality and usefulness of these areas. To enable the Green Belt to be protected <u>it is essential to make the best use of previously developed land (brown field) particularly surplus commercial sites.' (RPS emphasis).</u>

The Council does set out within 'Issue 5' of the TDCS the '*need to make best use of existing resources and to protect the Green Belt… by <u>reusing previously developed land</u>. In particular surplus commercial sites… the redevelopment of previously developed land may afford opportunities to*

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remediate contaminated land'. *(RPS emphasis)*. There are, however, very few available redundant commercial sites within the search area.

In addition to the Green Belt issue, along with the attractive environment provided by the countryside, the built-up areas and villages in Tandridge generally have an attractive character and local distinctiveness that is highly valued by the community. It is therefore important that the environment and character of Outwood is protected and where necessary enhanced; it will be essential that any development does not adversely affect the environment and character and that a high standard of design is achieved (Policies CSP 14, CSP 18 and CSP 21).

Development proposals should protect biodiversity and provide for the maintenance, enhancement, restoration and, if possible, expansion of biodiversity, by aiming to restore or create suitable semi-natural habitats and ecological networks to sustain wildlife in accordance with the aims of the Surrey Biodiversity Action Plan. Opportunities to explore ecological enhancements to achieve an overall biodiversity net gain should be incorporated into the design of the heating scheme.

CONSTRAINTS AND OPPORTUNITIES

If at all possible, the following planning/environmental constraints should be avoided:

- Green Belt locations – if development in the Green Belt us unavoidable, then any previously developed land, or available land within the settlement boundary, should be explored in preference to undeveloped land adjoining, neighbouring, or being in close proximity to settlements.
- Ancient Woodland
- Heritage assets (including Listed Buildings, Registered Parks and Gardens and their settings).
- Buried Archaeology – which will require an assessment in the stages to follow;
- Existing underground assets (buried gas mains, buried electricity mains, sewage pipes, water supply pipes)
- Ecological features – water features, protected species, valuable habitats.

Equally, the following opportunities should be explored through your proposal:

- Council support for small-scale renewable energy projects.
- Encouraging the reuse of previously developed land for commercial and community uses.
- Achieving at least a 10% 'net gain' in biodiversity post development.
- Opportunities for mitigation planting in the form of additional hedgerows and trees to help the proposal 'blend in' with its surroundings
- New development to be constructed in accordance with sustainability principles.

PLANNING SUMMARY & CONCLUSIONS

There is a well-recognised presumption against development in the Green Belt. However, there are local polices which seek to support renewable energy development, particularly small-scale / decentralised energy schemes (Policy CSP 14).

Based on this desktop assessment opportunities to explore the Options 1 and 2 set out above should be considered. However, it is important to stress the Green Belt designation is a significant barrier to development, and very special circumstances should be demonstrated in an attempt to override the Green Belt harm. This could include the benefits of renewable energy, the net zero emissions legislation, local support for small-scale renewable energy projects, a community led proposal, significant sustainability benefits in an 'off-grid' location.

It is therefore recommended that pre-application discussions are held with Tandridge District Council in order to establish whether the principle of the proposed development is acceptable in this area,

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given its Green Belt location. However, Tandridge District Council have advised their pre-application enquiry service is currently suspended so that planning officers can clear the backlog of planning applications.

Provided the project can overcome the Green Belt harm argument, Local Development Plan compliance will be critical to the success of the project. In particular, with reference to Policy CSP 14, the benefits of the proposal must outweigh the harms in terms of environmental, heritage, landscape and amenity impacts.

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SITE DETAILS

GEOLOGY ASSESSMENT

The Energy Centre site options comprise three nearby parcels of land at Outwood, Surrey. Figure 22 shows the topographic setting of the area. The village is situated at an elevation of between approximately 105 and 110 mAOD, 600 m to the west of the local highpoint of 120 mAOD.

The EC options are located at the head of two mapped surface water courses flowing in a north west direction that join Salford Stream approximately 2.5 km to the north. Salford Stream, at an elevation of 60 mAOD, joins the River Mole approximately 6 km to the west.

A spring line is tentatively identifiable from the topographical mapping, at an elevation of between 100 and 110 mAOD, feeding a number of local surface watercourses.

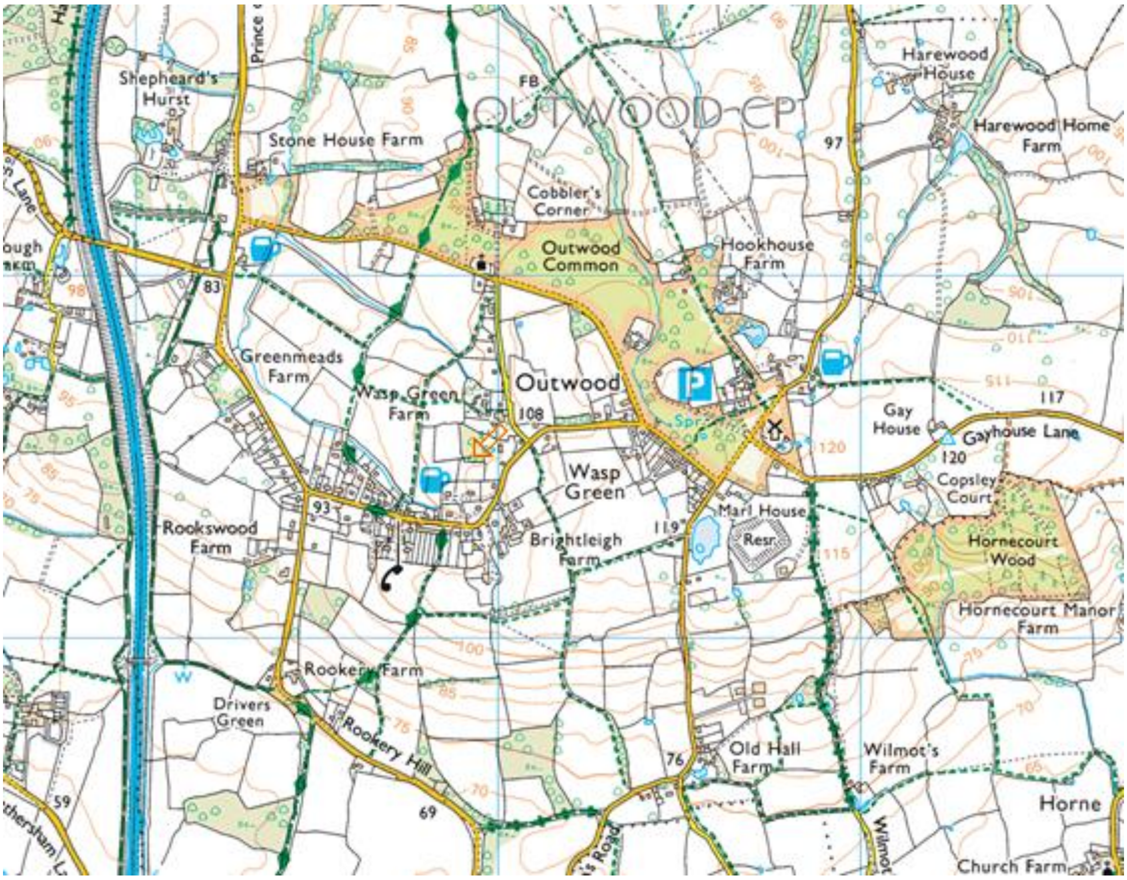

FIGURE 24: TOPOGRAPHIC MAP OF AREA SURROUNDING OUTWOOD

<u>Regional Geology and General Aquifer Status</u>

The key geological units expected at the proposed borehole location and their general aquifer status is summarised in Table 1. The geological sequence and associated aquifer status have been determined from a review of the following:

- British Geological Society (BGS) (http://mapapps.bgs.ac.uk/geologyofbritain, presented in Figure 2);
- The physical properties of major aquifers in England and Wales (BGS, 1997);

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- The physical properties of minor aquifers in England and Wales (BGS, 2000); and
- UK Hydrogeology Viewer (http://mapapps.bgs.ac.uk/hydrogeologymap/hydromap.html).

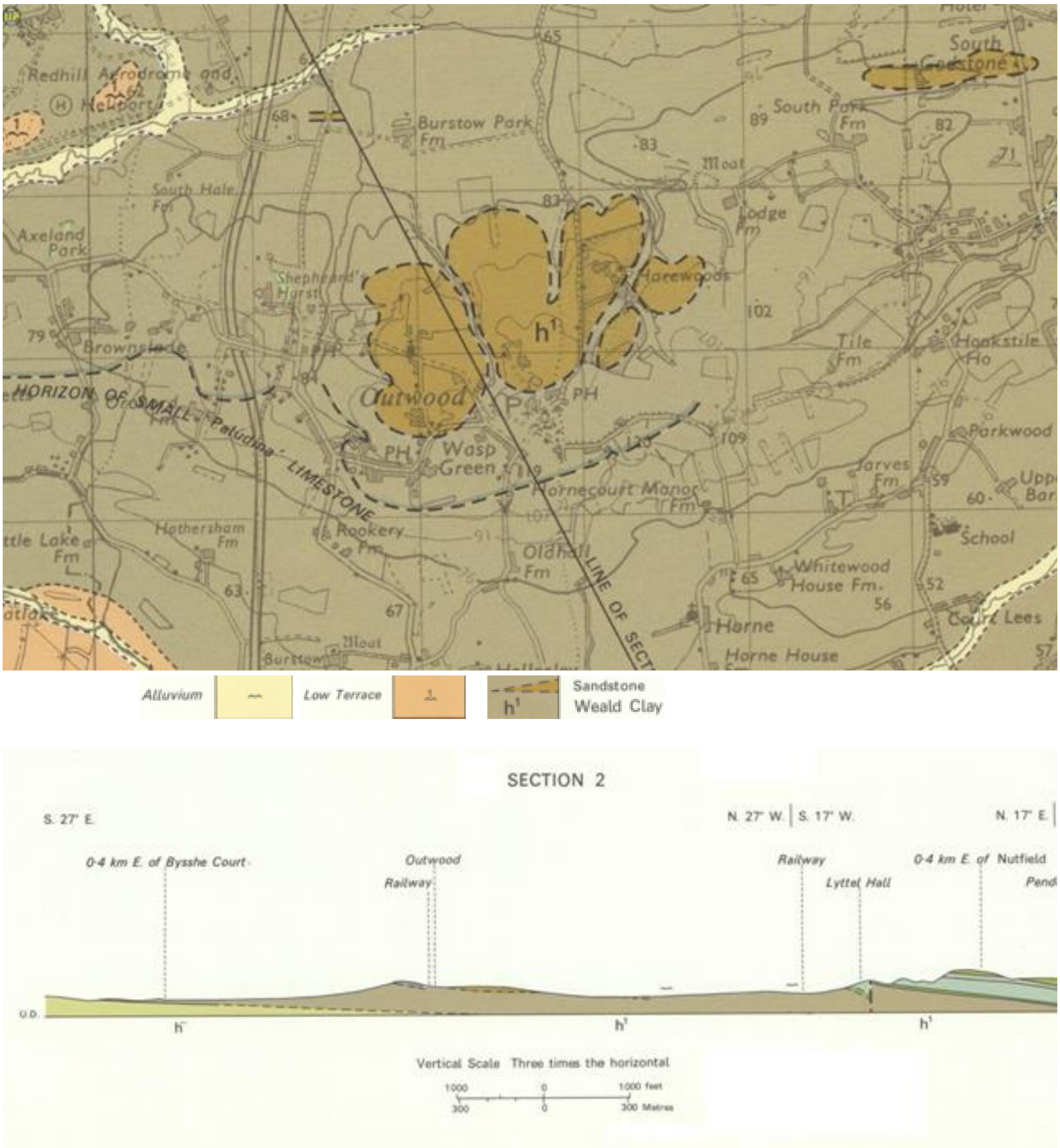

FIGURE 25: GEOLOGICAL MAP AND CROSS SECTION OF THE AREA (BGS GEOLOGICAL SHEET 286 REIGATE)

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TABLE 10: GEOLOGICAL SUMMARY AND GENERAL AQUIFER STATUS

Geological period	Group	Geological unit & description*	Hydrogeological status (EA)	Hydrogeological status (BGS)	Thickness (m)*
Quaternary	-	no superficial deposits	-	-	0
Cretaceous	Weald Group	Weald Clay Formation – Sandstone (h[1])	Secondary A	Minor Aquifer	10-20
Cretaceous	Weald Group	Weald Clay Formation - Mudstone	Unproductive Strata	Non-Aquifer	110
Cretaceous	Wealden Group	Tunbridge Wells Sand Formation -composed of: Upper TWS Grinstead Clay Lower TWS	Secondary A Unproductive Secondary A	Aquifer	46 18 40
Cretaceous	Wealden Group	Wadhurst Clay - Comprises soft, dark grey thinly-bedded mudstones ("shales") and mudstones with subordinate beds of pale grey siltstone, fine-grained sandstone	Unproductive Strata	Non-Aquifer	61
Cretaceous	Wealden Group	Ashdown Beds -Siltstones and silty fine-grained sandstones with subordinate amounts of finely-bedded mudstone	Secondary A (?)	Aquifer	120
Jurassic		Purbeck Beds - Interbedded mudstones, limestones and evaporites	Secondary A	Aquifer	134
Jurassic		Portland Beds – Principally limestone in upper part and argillaceous, dolomitic sandstones/sands; some mudstones/shales, and thin beds or nodular layers of micrite in lower part	Secondary A	Aquifer	37
Jurassic	Ancholme	Kimmeridge Clay - Onshore: Mudstones (calcareous or kerogen-rich or silty or sandy); thin siltstone and cementstone beds; locally sands and silts	Unproductive Strata		424

* Approximate thickness taken from BGS and borehole records (BGS Lexicon).

Geological unit & Description references notation in Figure 23.

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The geological sequence underlying the proposed borehole location comprises the Weald Group, the Wealden Group, the Purbeck Beds, Portland Beds and Ancholme Group.

The site lies on the Weald Sandstone and Weald Mudstone formations which is underlain by the Turnbridge Wells Sand Formation (TWSF), which should be saturated. The uppermost sandstones at the assessment site comprise sandstones of the Weald Group. These outcrop locally to the north of Outwood between a surface elevation of approximately 90 and 115 mAOD.

Local Geology

Geological logs and information for one borehole identified in close proximity to site and deemed representative of the geology below the site is provided in Appendix 1. The borehole log produced forms part of a set of four similar boreholes which investigate the geology to significant depth, up to 2,000 m below ground level) and provide valuable information for GSHP.

The borehole selected is referenced TQ34NE9 called Bletchingley is located south of South Godstone, approximately 5 km to the north east of the site. This borehole is located upon the Weald Group geological strata, although the sandstones mapped outcropping at Outwood are absent.

Aquifer Units

The formal aquifer designation for the geological sequence expected at the proposed site is also summarised in Table 1.

The outcropping sandstones of the Weald Group are expected to be partially saturated owing to their likely moderate permeability and the presence of a groundwater fed spring line toward the southern fringe of the exposures. The elevation of this spring line mapped on Figure 1b between 100 and 110 mAOD suggests only partial saturation of these strata which are potentially important for maintaining baseflow to these surface waters. Aquifer saturated conditions are expected to be strongly seasonally affected as recharge reduces during drier seasons.

These sandstone strata only possess limited lateral persistence comprising an area of approximately 2 km x 1 km. A thickness of between 10 and 20 m is expected for these strata. The sandstones are underlain by the unproductive Weald Clay Formation comprising mudstones.

Underneath the Weald Clay, the Tunbridge Wells Sand Formation (TWS), a Secondary A aquifer, could provide a more reliable and resilient source of water and constitute the Target Unit 1. The Purbeck Beds and Portland Beds, at further depth could provide increased potential heat generation with a similar reliable and resilient source of water, albeit with potentially lower yield, and could represent the Target Unit 2.

Groundwater Levels & Aquifer Conditions

The presence of faulting in the area causes large variations in water level, which have not been well studied or documented. Consequently, it is often difficult to predict the potentiometric levels in boreholes. In the Tunbridge Wells area, Tunbridge Wells Formation rest water levels range from 17 to 105 m AOD, with the highest level occurring beneath the highest ground (Bristow and Bazley, 1972).

Yield Data and Aquifer parameters

Yields from the Tunbridge Wells Formation are generally less than 400 m3/d, and often less than 100 m3/d, although significantly higher yields have been obtained on occasion. BGS/EA (2000) description of the TWS indicates seasonal fluctuation is small with approximately 2 metres. Values of transmissivity for the Tunbridge Wells Formation range from 6.1 to 39.5 m2/d, with a geometric mean of 19.0 m2/d and an interquartile range of 13.8 to 35.4 m2/d.

The Purbeck Beds and Portland Beds porosities range from 3.3 to 16.2% and hydraulic conductivities from less than the measurable minimum to 1.8x10-4 m/d. The Purbeck Beds of the Weald consists of shales with horizons of limestone, sandstone and gypsum. The limestones contain water of limited

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importance for supply, as their outcrop is very limited. However, water from the fractured limestones enters the gypsum and pumping rates of 850 m3/d have been recorded (Lake and Shephard-Thorn, 1987). The water is very hard due to its contact with the limestone and gypsum.

Ground Source Heating

GSHP has been screened using BGS online tool. The screening tool is designed for buildings and other projects with heating/cooling demands greater than 100 kW (thermal).

The tool screens bedrock aquifer potential (i.e. hydraulic conductivity), depth to bedrock, protected areas and existing licensed abstraction. The tool also screens for water quality that would inform the capacity of the system to corrode or accrete minerals within pipes.

Open Loop Screening Assessment

The result of the screen of the site is shown in *Figure 26: Open-loop screening tool*. The site lies within an unfavourable location based on the absence of a suitable bedrock aquifer found within 50m depth from ground level.

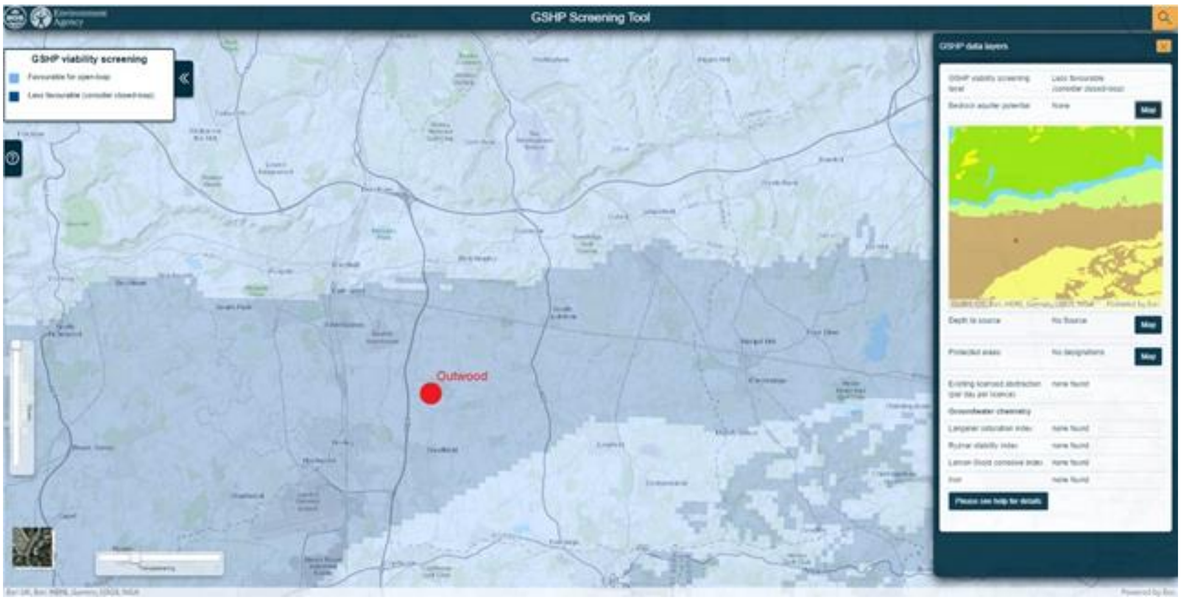

FIGURE 26: OPEN-LOOP SCREENING TOOL

Closed Loop Assessment

A close loop could similarly be installed within Target Unit 1 or Target Unit 2 depending on the amount of energy that is required and the ground conditions encountered.

Temperatures at depths of 100, 200 and 500 metres have been predicted by Busby et al. (2011) and reproduced in Appendix B. These show favourably positive temperature anomalies for groundwater within the Weald Basin below the assessment site, with a groundwater temperatures of c. 18-20^{o}C being suggested.

There is a clear requirement for an early text borehole needed to inform the project if GSHP options are to be taken forward.

Groundwater Quality

Groundwater quality with the TWS is currently used for potable supply within SE England.

A closed loop system which contained a mixture of chemical compounds could provide a pollution risk that would require management.

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An open loop system would be less susceptible with chemical pollution and only the potential generation of a heat plume would need assessment which, is typically smaller when considering heat and cooling over the course of an annual heating cycle.

Borehole Construction

Depending on the target unit, the depth of the boreholes, one for abstraction and one for injection, would be:

- TWS (Target Unit 1) depth of between c. 200 and 250 m below ground level.
- The Purbeck Beds and Portland Beds (Target Unit 2) depth of between c. 550 and 600 metres below ground level.

Licensing Framework

A closed loop ground source system does not impact the groundwater resource itself, as it does not change natural sub-surface water flow and as such is not directly regulated by the environment agencies. However, pollution caused directly or indirectly by a closed loop scheme would still come within the remit of the environment regulators e.g. pollution caused by a leaking system or the cross-connection of two aquifer units. An open loop ground source system uses groundwater and can impact on the groundwater resource and groundwater temperature and has the potential to impact surface water where there is connection with groundwater.

Open loop schemes are regulated, as direct abstraction of groundwater and discharge of wastewater (either hotter or colder) is involved; both of these activities are governed by national legislation.

Abstraction from the TWS or Purbeck Beds and Portland Beds are not seen unfavourably by the Environment Agency (EA, 2013). A licence for the abstraction and discharge would need to be sought from the Environment Agency for volume in excess of 20m3/d based on their current Catchment Licensing Management Strategy (CAMS), where they state:

'The Hastings Beds refer to the grouping of the Ashdown Sands, the Wadhurst Clay, and the Tunbridge Wells Sands formations. Although there are a number of small abstractions from the Tunbridge Wells Sands, the majority of groundwater abstraction within the Hastings group is from the Ashdown Sands. It is thought that as a generalisation, the Tunbridge Wells Sands provide the largest contribution to the baseflow component of river flow, whilst the underlying Ashdown Formation constitutes the major resource. On a catchment scale, a comparison of estimated aquifer recharge and licensed abstraction shows a theoretical surplus of water within this groundwater management unit.'

An abstraction licence will be required from the Environment Agency if the volume abstracted is more than 20 cubic metres per day from either surface water or groundwater.

GSHP can be exempt from needing an environmental permit for the discharge, but must register an exemption, if the ground source heating and cooling system comply with any of the following:

- a cooled aquifer system with a volume of less than 1,500 cubic metres per day
- a balanced system with a volume of less than 430 cubic metres per day
- a heated aquifer system with a volume of less than 215 cubic metres per day

Existing Groundwater Utilisation

The Local Authority would need to be contacted to obtain Private Water Supply within the area. Locations of unlicenced private water supplies are not publicly available, however given the low yields associated with the Weald strata at the site, these are not anticipated to be present.

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The review of public water supply indicates the absence of Source Protection Zone in the vicinity (Magic website, Defra). The nearest abstraction total catchment boundary is located 4.5 km to the north.

Environmental Sensitivity

There is no statutory Land based designation in the vicinity that could be affected by the development of a GSHP.

Land Quality

The surrounding land use is predominantly low-density settlements and farmland with no indication of heavy industry, historical or current, that would lead to significant contamination of groundwater. This would need to be verified during drilling and following appropriate analytical testing of soils and groundwater sampled from the borehole.

GEOLOGY SUMMARY

The site is underlain by productive aquifers at depth which are suitable for GSHP. Research undertaken on groundwater temperatures at depth within the UK suggest positive temperature anomalies are present with temperatures of approximately 18-20°C may be present within the study area to depths up to 500 metres below ground. The Environment Agency do not consider there to be a constraint on groundwater abstraction at the site from the identified deeper aquifers subject to the granting of an abstraction licence. The Environment Agency should be contacted for further advice once details of the proposed heating scheme are available.

Heating demand has not been used to inform these conclusions. An appropriate heat flux assessment would be needed to verify suitability of the aquifers described to support rates of heating and cooling required for the proposed GSHP system.

ECOLOGY FINDINGS

A desktop study was undertaken to identify ecological constraints and designated sites in the vicinity of the village and a 2km buffer zone. In addition, web-based sources of information would be accessed where appropriate including www.magic.gov.uk.

No designated sites within the 2km search area, but whole Outwood area is within SSSI Impact Risk Zone for Blindley Heath SSSI. This Impact Rick Zone flags risks likely for the project types below:

- Infrastructure - Airports, helipads and other aviation proposals.
- Air Pollution - Livestock & poultry units with floorspace > 500m², slurry lagoons > 750m² & manure stores > 3500t.
- Combustion - General combustion processes >50MW energy input. Including energy from waste
- incineration, other incineration, landfill gas generation plant, pyrolysis/gasification, anaerobic digestion, sewage treatment works, other incineration/ combustion.
- Discharges - Any discharge of water or liquid waste

These risk categories are generally not applicable to the Outwood heating project or the thresholds are set well beyond the likely required scale of the project (e.g., combustion >50MW is much more than the thermal loads necessary to heat this rural community).

Several priority habitats present in search area – traditional orchard, deciduous woodland, ancient woodland, wood pasture and parkland.

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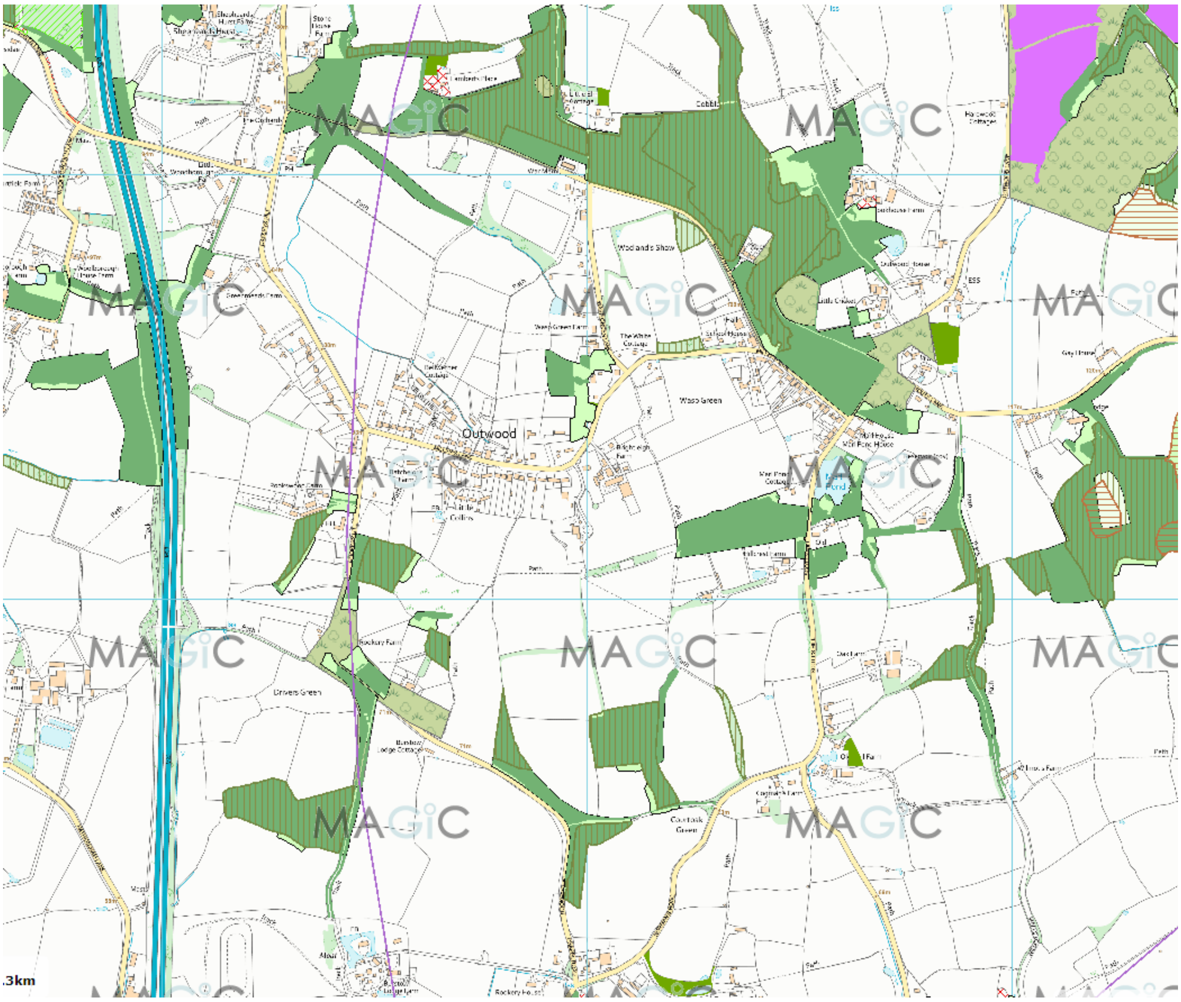

FIGURE 27: WIDER AREA PRIORITY HABITATS

These priority habitats are at their closest adjacent to the energy centre locations, but none of the options are within priority habitat areas.

Site photos of the three Energy Centres were taken during the site visits in May 2021 and these have also been evaluated to inform the land use and ecological context for the three options. All three are permanent grassland sites. Options 1 and 2 (the National Trust and Brightleigh Farm fields are both 'improved' permanent grassland fields used for cattle grazing and so are of limited ecological value. The Option 3 fields are smaller and could be more ecologically diverse. A full Phase 1 habitat survey and protected species scoping will be required prior to planning but broadly the ecological context of the three options sites is similar. Care will be required to minimise hedgerow removal and other construction impacts.

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FIGURE 28: BRIGHTLEIGH FARM FIELD (EAST OF FARMHOUSE)

FIGURE 29: BRIGHTLEIGH FARM FIELD (WEST OF FARMHOUSE) – SHOWING PASTURE AND HEDGEROW

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LAND PARCELS FOR CENTRAL PLANT

During the project, we engaged with landowners and tenants of a range of prospective sites for the central plant (energy centre and/or heat collectors). These are outlined below.

FIGURE 30: LAND PARCELS IN OUTWOOD VILLAGE

Our initial view of potential land parcels in the village for an energy centre or heat collectors are as follows:

TABLE 11: SUMMARY OF POTENTIAL ENERGY CENTRE LOCATIONS

Site ref	Location name	Landowner	Area available (m²)	Advantages	Disadvantages	Current status
1	Hook House Farm fields	National Trust (tenanted farm)	11,354	Central location Pasture only Landlord considered supportive	Tenant requires more land, not less	Following discussions, the tenant is unlikely to agree to lease of land for energy centre
2	Brightleigh Farm fields	Privately owned	33,230	Central location Pasture only	Field is actively used and installation of energy centre would result in disruption	Following discussions and site visit, landlord is open to further consideration

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				Field is close to street access		
3	Privately owned paddocks	Privately owned	13,805	Central location Pasture only	Two landowners, would have to coordinate Not as central as other options	Landowners have indicated they would not want to lease land for an energy centre
4	Hook House Farm north	National Trust (tenanted farm)	30,700	Underused field, preferable to turn over to other uses	Too far from main heat demand	Following discussions, the tenant is unlikely to agree to lease of land for energy centre
5	Surrey & East Sussex Water reservoir	SES Water	16,110	Publicly owned Would not disturb land	Actively used for drinking water	Following discussion with SES Water, this is not a viable option as it supplies drinking water

LAND TAKE FOR CENTRAL PLANT

We analysed the land take requirements for each of the potential technical solutions, summarised below:

Table 12: Technical Solution Land Take

Technical solution	Land requirement	Total area required	Suitability to available land parcels
Biomass heat network	Energy centre, fuel store, thermal store	c. 20 x 25m, depending on size of fuel store, vehicle access	Brightleigh Farm or Hook House Farm fields suitable
Air-source heat pump heat network	Energy centre, thermal store, fan beds	c. 25 x 25m	Brightleigh Farm or Hook House Farm fields suitable
Ground-source heat pump heat network	Energy centre, thermal store, boreholes	c. 15 x 15m for energy centre **c. 25 acres for boreholes**	No land parcels large enough for borehole array
Combined biomass and air-source heat pump heat network	Energy centre, thermal store, fan beds, fuel store	c. 25 x 25m, depending on size of fuel store, vehicle access	Brightleigh Farm or Hook House Farm fields suitable

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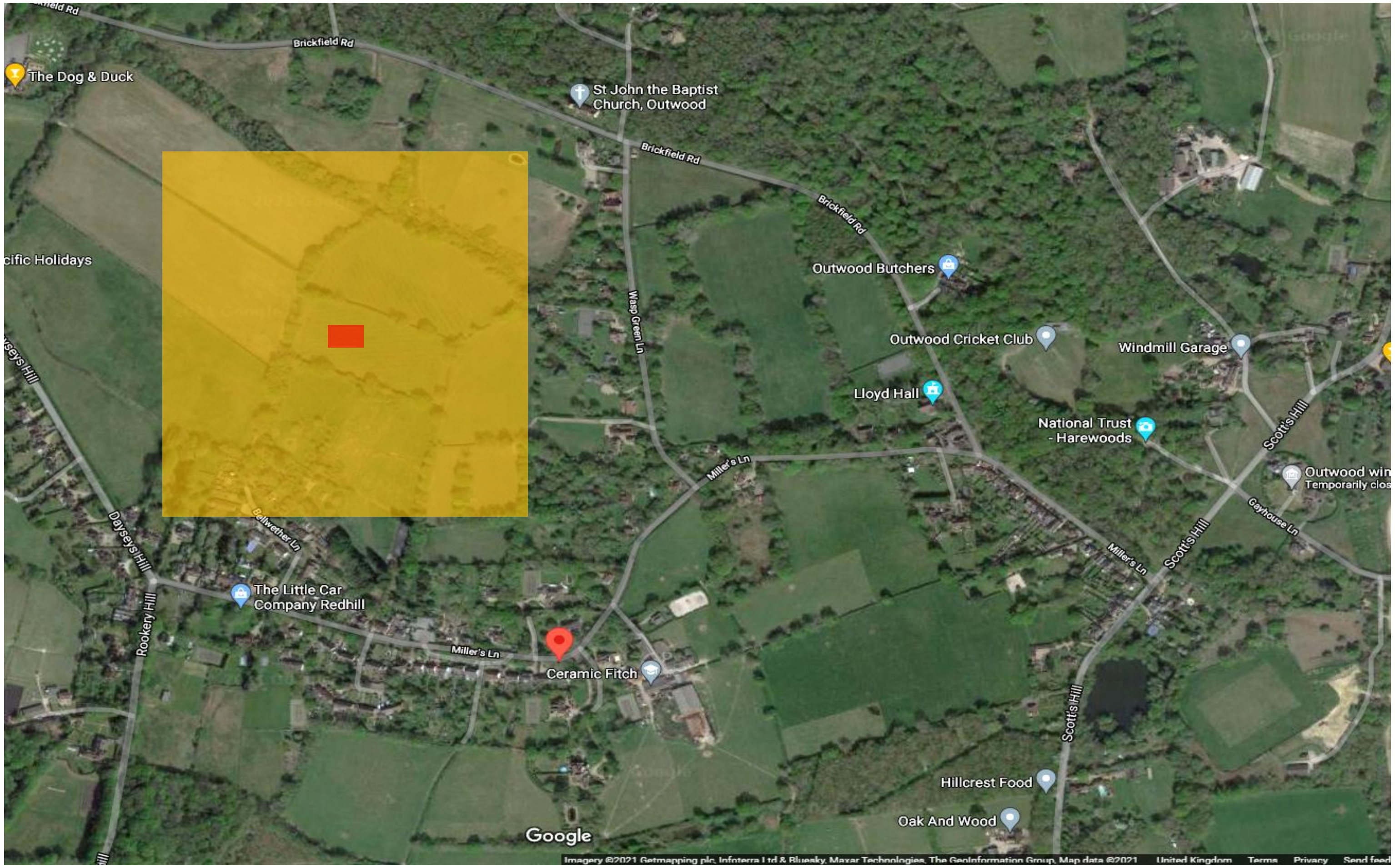

FIGURE 31: INDICATIVE LAND REQUIREMENTS FOR THE BOREHOLE ARRAY (ORANGE) AND AN ENERGY CENTRE (RED)

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OPERATION & GOVERNANCE

Typically, community energy projects can take a number of governance routes, outlined below with an assessment of the advantages and disadvantages for Outwood Parish Council:

TABLE 13: ADVANTAGES AND DISADVANTAGES OF GOVERNANCE MODELS

Governance model	Description	Advantages for Outwood	Disadvantages for Outwood
"In house" delivery	Parish Council owns and operates the scheme	Maximum control over project development, heat tariff, co-benefits	Maximum risk for Parish Council Significant development timescales and cost
Establish new dedicated entity	Separate legal entity for the scheme – e.g. co-operative, CIC, etc	Clear demarcation of roles and responsibilities Focus on delivering this project	Time (and cost) investment to set up new entity Different legal structures have different pros/cons
Concession	Parish Council contracts with a third party to operate the scheme, but still retains ownership	Parish Council retains high degree of control (e.g. tariff, design and build) Specialists operate the scheme – reducing risk to Parish Council	Residents' main interaction with be with the operator Reduced control over operation Design and build risk with Parish Council
Wholly outsourced to an Energy Services Company (ESCo)	A third-party specialist energy project operator builds, owns and operated the scheme	Minimum project risk to Parish Council Expert partner delivers the scheme	Minimal control over design, build and operation Minimal control over tariff, co-benefits
Strategic partnership with other local authority	District / County Councils have access to other support for energy projects	Leverage local authority support (e.g. BEIS / HNDU) Gives Outwood profile with District and County Council	Depends on strong relationship and capacity at District / County Council Development and delivery likely taken on by another party

However in this case for Outwood Parish Council, any shared heat network scheme with central plant will need considerable third-party capital investment and revenue investments (or subsidies) to achieve a financially viable project.

On that basis, it is not recommended to progress these schemes currently, until a solution to the revenue financing for heat network schemes can be achieved. The priority for Outwood should be establishing potential partnerships with Surrey County Council, BEIS and the Heat Network Delivery Unit, the Energy Hub, and other local actors to lobby and monitor the response from policy makers to the challenge of decarbonising off-gas grid communities.

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NEXT STEPS & IMPLEMETATION

At the time of writing, we cannot recommend a village-wide to progress to Stage 2 RCEF Development, due to the challenge of the high cost of production of heat compared to oil boilers. Based on this, we recommend that the Parish Council prioritise engagement with policy makers and government stakeholders to raise awareness of this issue and lobby for change.

There are key trigger moments that would affect the viability of this scheme:

1) Change in electricity pricing and tax to reduce cost of power by c. 24% - this would make the ASHP electrified systems cheaper to run than oil.
2) Introduction of new revenue incentives for renewable heat (a successor to the Renewable Heat Incentive) which would subsidise the operational costs. Government has recently consulted on this, and we would expect an announcement later this year.
3) Tax on fossil fuels that would increase oil costs above the production costs of electrified heat.

Next steps for Outwood Parish Council

Short term:

- Review this report and its recommendations
- Initiate awareness raising and lobbying, in collaboration with other community groups
- Consider the biomass heat network option
- Continue with other sustainability initiatives in Outwood through the Sustainable Outwood committee

Medium term:

- Monitor government policy regarding electricity pricing, and specifically the "policy costs" review
- Monitor government policy regarding revenue incentives for heat projects, and/or move to identify alternative revenue funding streams (for example through Surrey County Council)
- Re-engage Tandridge District Council's pre-planning team for advice on a planning application for the energy centre
- Consider collective purchase of heat pump systems for households wishing to install individual air- or ground-source heat pumps (see for example Solar Together for collective solar PV purchasing – www.solartogether.co.uk)

Long term:

- Monitor government legislation regarding oil pricing and tariffs, for example the introduction of a carbon tax on fossil fuels
- Monitor government legislation regarding availability of oil boilers – these are likely to be phased out in the next decade, and this may affect capital and operational costs of household oil boilers

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CONCLUSIONS

Technical outcomes

Our analysis shows that there are three technically viable solutions for a village-wide heat network in Outwood: a 800kW biomass boiler, a 750kW air-source heat pump, and a hybrid system with 400kW air-source heat pump and 600kW biomass boiler. Each would deliver carbon savings compared to the current situation (domestic oil boilers).

A ground-source heat pump system could be technically viable, if agreement could be reached to lease 25 acres of land around the energy centre for the boreholes. Several potential land parcels have been identified, and one landowner has indicated interest in hosting the energy centre, however it is not known if their landholding is large enough for the energy centre and the borehole array.

Financial outcomes

Under the base case scenario, both the biomass option and the ground-source heat pump option could generate heat at a lower cost than oil – excluding the capital costs of the project.

When the capital costs are defrayed through the lifespan of the system, none of the heat network systems can deliver heat more cheaply than oil. This is due to the high cost of electricity, the lack of a revenue stream other than heat sales (i.e. the closure of the RHI scheme), and the high cost of construction of the heat network.

There are potential sources of grants and funding for the capital requirements of the schemes, however the main barrier to the financial viability of the schemes is the lack of revenue funding, such as the RHI.

Our recommendations

We recognise that this is not the outcome the Parish Council or its partners were hoping for from this feasibility study. While we have not been able to demonstrate proof-of-concept for a village-wide heat network currently, due to the barriers described above, there are carbon-saving alternatives to oil boilers in Outwood that the Parish Council can recommend to the community:

1) Consider building level solutions – air-source or ground-source heat, depending on land availability, or biomass; or solar PV for a renewable power supply
2) Consider the biomass boiler option – perhaps as a bridging solution for the next

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APPENDICES

A: COMMUNITY ENGAGEMENT PLAN

B: COMMUNITY OUTREACH MATERIALS

C: ENERGY SURVEY RESULTS

D: HOUSEHOLD SURVEYS SUMMARY

E: HEAT DEMAND DATABASE

F: HEAT DEMAND BOUNDARY MAP

G: GEOLOGY REPORT

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APPENDIX H: TECHNICAL PARAMETERS AND FINANCIAL ASSUMPTIONS FOR THE APPRAISED OPTIONS

	Expected lifetime (years)	Value	Unit
Financial assumptions			
Heat pumps	20	546,512	£/MW
Biomass boiler	20	988,372	£/MW
Electric boiler	20	129,942	£/MW
Predevelopment cost	20	34,884	£
Heat storage	20	192	£/m³
Land acquisition	40	2	£/m²
Heat network – pipework and civils	20	775	£/m
Heat interface units and heat meters	20	2,301	£/pcs
Controls/energy management system	20	46,512	£
Borehole energy generation		27.5	MWh/year
Area required per borehole		850	m²
Borehole construction		12,000	£/borehole
Contingency cost		15%	of total capex
Cost of oil		0.42	£/l
Cost of biomass (woodchips)		123	£/tonne
Cost of power – base case		14 (day rate) 11 (night rate)	p/kWh
Cost of power – scenario 1		11.8 (day rate) 8.4 (night rate)	p/kWh
Cost of power – scenario 2		12	p/kWh
Operation and maintenance costs: Oil boilers Biomass boiler (large) Biomass boiler (small) Heat pump (large) Heat pump (small) Electric boilers		Variable/Fixed 0 / 2,571 3 / 2,571 3 / 1,928 2.3 / 1,928 2.3 / 693 1 / 1,390	 £/MWh / £/year
Technical assumptions			
Oil boiler efficiency		80%	
Biomass boiler efficiency		98%	

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ASHP efficiency (coefficient of performance)		270%	
Biomass-ASHP hybrid efficiency (coefficient of performance)		300%	
GSHP efficiency (coefficient of performance)		400%	
Calorific values: Oil Biomass (woodchips)		 10.30 4.1	 kWh/l kWh/kg
Carbon conversion factors: Oil Biomass (woodchips) Electricity		 0.2466 0.0155 0.2331	 kg/kWh kg/kWh kg/kWh

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