HARLEY HADDOW

Warrens, Bramshaw

Heating Options Appraisal

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Contact
124-125 Princes St
Edinburgh, EH2 4AD
enquiries@harleyhaddow.com

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PLANNING	16.12.21	Updated for Planning	RL	GWR

Contents

Executive Summary

Harley Haddow have carried out a review of a range of options and technologies in order to highlight the optimum heating system upgrade for Project Warren. The assessment has been undertaken based on the preliminary scheme design information for the existing and proposed options on the site.

The table below summarises the **indicative** energy/carbon savings of potential space and hot water heating solutions compared to the existing oil-fired boiler system.

Scenario	Option	Energy Consumption[1]		Carbon Emissions[2]		Running Cost[3]	
		Total (kWh)	% Saving	(tonnesCO_2/yr)	% Saving	(£/annum)	% Reduction
Existing	Existing Oil	548,998	-	138.73	-	£40,014	-
1	New Oil	427,356	22.2%	107.10	22.8%	£34,175	14.6%
2	New LPG	421,607	23.2%	97.42	29.8%	£39,088	2.3%
3	New HT Heat Pump	241,453	56.0%	56.26	59.4%	£33,803	15.5%
4	Existing Oil + PV	528,502	3.7%	133.95	3.4%	£37,145	7.2%
5	New Biomass	442,848	19.3%	39.02	71.9%	£43,749	-9.3%
6	New Direct Electric Heating	401,630	26.8%	93.58	32.5%	£56,228	-40.5%
7	New HT Heat Pump + PV (100m^2)	220,958	59.8%	51.48	62.9%	£30,934	22.7%
8	New HT Heat Pump + PV (500m^2)	138,978	74.7%	32.38	76.7%	£19,457	51.4%

Table 1. Indicative Total Consumption and Running Costs Summary

The analysis identifies that significant savings to energy consumption (through a reduction in demand and efficiency improvements) and sourcing energy from low carbon and renewable sources will reduce overall carbon emissions from the property. This can be achieved with improvements to insulation in the floor and roof, improvements made to the heating system and indicates that a heat pump system supplemented with a large photovoltaic (PV) array offers the greatest reduction in both energy consumption and carbon emissions when compared to replacing the existing system with an oil boiler system.

It is recommended that a high temperature (HT) heat pump system, (either Air or Ground Source) is considered as a replacement heating option for Warren's, as an all-electric system, a heat pump solution will future proof the house in line with the transition to 'net zero' emissions due to the progressive decarbonisation of grid electricity.

By incorporating on site renewable energy via an onsite PV array additional reductions in energy consumption, CO_2 emissions and running costs would be achieved due to reducing the amount imported energy.

Heating via biomass boilers also offers a significant reduction in CO_2 emissions and the Warrens property is potentially well suited to this type of system. Careful consideration of the system arrangement such as fuel type, delivery and storage, plus the onsite maintenance requirements should be fully assessed in the design stage in order to avoid the issues with biomass boilers Harley Haddow have encountered in previous biomass installations.

The below table summarises the Advantages and Disadvantages of the heating options assessed in this report.

Option	Heat Source	Key Advantages	Key Disadvantages
Baseline	Oil Boiler	• Current solution • Low complexity	• High CO_2 • Low future flexibility • Fuel storage/deliveries • High fuel/maintenance costs • Unsecure heat supply
1	New Oil Boiler	• Low complexity • Improved efficiency over existing system	
2	LPG Boiler		
3	Heat Pump	• Low CO_2 • Future-proof option • Energy efficient plant • Will continue to decarbonise	• Visual impact with ASHP • Capital cost > Oil/LPG Boiler • Noise concerns with ASHP • Borehole/groundwork for GSHP • LV Power Upgrade Required
4	Move existing oil boiler and supplement with PV	• Current solution • Low complexity • Supplemented electrical energy via PV production.	• High CO_2 • Low future flexibility • Fuel storage/deliveries • High fuel/maintenance costs • Unsecure heat supply
5	Biomass Boiler	• Low CO2 • High temperature • Improved efficiency over existing system	• Fuel storage/deliveries • High fuel/maintenance costs • Unsecure heat supply
6	Direct Electric	• Easy to install • Low maintenance • Familiar technology • Will continue to decarbonise	• High CO_2 & running costs • LV Power Upgrade Required

Table 2. Options Summary

The results of this report demonstrate that following systems provide the greatest reduction in carbon emissions and annual running costs and therefore considered as suitable heating replacement options in design stage of the project;

- High Temperature Heat Pump (Air or Ground Source)
- Woodchip/Pellet Biomass Boilers
- Onsite renewable energy generation via Photovoltaic Array

To fully assess the suitability of each option each system it is recommended that Harley Haddow develop the system designs in conjunction with the Architects in order to confirm the impact of each option to the property and wider estate.

As part of the heating options review for Warrens, the measures considered for the project followed the 'Lean', 'Mean' and 'Green' Energy Hierarchy approach where feasible.

The incorporation of 'Lean' building fabric upgrades will help reduce heat losses and associated energy required to maintain a comfortable environment from the buildings' heating system. Any fabric improvements of the property need to be sensitively considered in relation to the Grade II* listing, using guidance from the Historic England 'Energy Efficiency and Historic Buildings' document and the emerging New Forest Design Guide. 'Green' actions to improve thermal performance, such as dealing with drafts, providing additional loft insulation in pitched roofs and adding rugs or carpets to uninsulated ground floors shall be provided where appropriate. Many of the windows benefit from the installation of internal wooden shutters to help reduce heat loss and fabrics could be added where there are no curtains or soft furnishings elsewhere which the interior designers are reviewing. No 'Amber' or 'Red' actions are being proposed or developed at this time as the strategy is to mitigate any impacts to the listed structure and its wider landscape setting, its fabric and maintain a sensitive conservation led approach to the project as a whole.

The new 'Garden Room' extension is required to comply with Part L1B of the Building regulations, there are no specific carbon reduction targets required for the extension but new thermal elements will be required to comply with Section 5 of Part L1B of the building regulations which states maximum allowed U-values for new thermal elements. In summary the extension shall include the following measures to reduce energy use;

- High performance building fabric with U values which exceed the minimum values stated in Part L1B.
- Provision of an extended eaves detail or 'brise soleil' to provide shade
- Solar control glazing to limit overheating
- Low temperature underfloor heating within the lime floor screed utilising thermal mass to provide efficient storage of and release of radiant heat energy

The Garden room shall also make use of local materials and sustainable building techniques to reduce the associated carbon emissions of the construction and to provide a positive impact on the natural and historic environment.

The 'Mean' measures comprise of using new high efficiency heating plant. High temperature systems would be required in order to integrate with the existing pipework and radiators as replacing the internal heating system to operative at lower temperatures could incur significant cost and disruption to the property. New heating controls and low temperature underfloor heating will be provided in the renovated bathrooms within the Master Suite as well as the new Garden Room.

The 'Green' measures consist of the potential use of a heat pump system as the primary heat source for the building and the use of PV to offset the total electricity consumption.

1.0 Introduction

1.1 General

Harley Haddow have carried out a high-level appraisal for Warrens, located just outside Bramshaw, Hampshire to determine suitable heating option upgrades for the property. This will consider the energy and carbon impact for each option alongside the technical considerations. The impact on the move to net zero and forthcoming changes to legislation will also form a key part of the appraisal.

The Warrens was built in the early 1800s, designed by architect John Nash. Soon after construction the building was extended with a wing to the Southeast. Further modifications to the house were carried out in the late 1800s which included a staff wing (demolished in 1980 including the chapel), re-appropriating the conservatory into a common room and internal alterations to the southern wing and service range. It is currently listed as a Grade II* heritage asset and sits within Forest Central (north) Conservation Area. The Warrens Estate also includes a Stable range 20 metres south west of Warrens House (also Grade II Listed) which is dated back to the C18th/ C19th, with a rendered brick, slate roof, brick and tile roof addition and accommodates the estate office within this building; Two unlisted cottages of Gardeners Cottage and Chauffeur's Cottage, of which the Chauffeur's Cottage is deemed to be curtilage listed; and the Red Lodge. The idea is to focus on the main house in this first phase and for the findings to be applied to the remaining buildings within the estate in the longer term.

Figure 1. The Warrens Site Location

1.2 Objectives

The objective of this analysis is to identify and assess different potential heating replacement options for the site. This involves the following key elements:

- Review existing building and proposed heating options.
- Review and model energy and carbon savings related to each proposed option.
- Review and comment on the feasibility and any risks of low and zero carbon technology.
- Using a fabric first approach address energy efficiency and low carbon measures suitable for the property.

1.3 The Energy Strategy Approach

Harley Haddow shall adopt a comprehensive 'whole building approach' to address the energy efficiency measures and renewable technologies proposed on the project and assess their suitability for inclusion.

The strategy shall follow the 'Lean', 'Mean' and 'Green' Energy Hierarchy approach where applicable in order to reduce overall energy consumption and demand.

- **Lean** measures consider building fabric improvements: U-values and lower air permeability rates.
- **Mean** measures consider energy efficient supply of energy, via high-efficiency plant, controls and lighting.
- **Green** measures consider the integration of renewable (zero carbon) technologies.

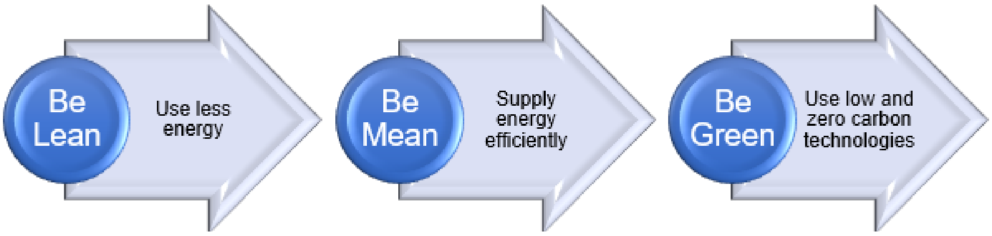


Figure 2. Energy Hierarchy Approach

Due to the Grade II* listing of the property a sensitive and considered approach is required to ensure that energy efficiency improvements are provided where ever possible but without affecting the integrity of the building or harming the heritage values of the architecture. In order to propose suitable energy saving measures Harley Haddow have referenced the Historic England, 'Energy Efficiency and Historic Buildings' guidance to propose suitable building fabric improvements and energy efficient heating systems upgrades that both increase the thermal performance of the building and support the conservation led approach to renovating the property.

Indicative energy strategy calculations have been undertaken based on energy modelling to assess existing carbon dioxide (CO2) emissions and energy consumption and identify the most appropriate energy efficiency measures and low and zero carbon (LZC) technologies.

1.4 Local Planning Policy

New Forest National Park Authority provides guidance on the levels of sustainable design required on each project as outlined within the Adopted Core Strategy, its Development Management Policies, and emerging New Design Guide. As the building is existing, there is no requirement to meet the carbon reduction targets set out in the current English Building Regulations.

However, the Core Strategy states that existing buildings should be made more energy efficient where possible and supports the development of new LZC solutions. Energy efficiency improvements should be made where technically feasible to reduce the peak heating load and energy demand of the property.

All new mechanical or electrical systems shall comply with the Building Services Compliance Guide 2018.

The proposed works include a Garden Room extension to the main building within the 3-sided walled garden. The following sustainability measures have been included in the design:

- The design employs 'fabric first' highly insulated floor, wall and roof to minimise heat loss in winter and heat gain in summer.
- New thermal elements will be required to comply with Section 5 of Part L1B building regulations which states maximum allowed U-values for new thermal elements, despite the extension not being required to meet any specific carbon reduction targets.
- The proposed glazing area of the extension is expected to exceed the guideline recommended 25% of the floor area plus any covered/removed existing openings as per Part L1B. As part of Building Regulations, a compensatory calculation will be required in order to prove that compliance has been met.
- The use of local materials and sustainable building techniques having a positive impact on the natural and historic environment
- The design provides a 'brise soleil' and includes solar control glazing to reduce overheating

1.5 Future-Proofing

The UK Government currently aims to achieve Net Zero carbon emissions in full by 2050 with a 78% CO_2 reduction by 2030.

As part of this process, there will be policies and targets put in place which will push new and existing developments to move away from fossil-fuel based heating systems such as gas.

Potential alternatives will include electric solutions which will be supplied by a largely decarbonised electricity grid due to the significant contribution from renewable technologies onto the network.

1.6 Grid Decarbonisation

The impact of grid decarbonisation encourages the consideration of electrical solutions such as heat pumps to future-proof the carbon footprint of the dwelling. As the electrical grid is now being produced more and more by renewable power sources rather than gas or coal fired power stations the grid is decarbonising and as such the carbon emission factor for electricity as a fuel is due to be revised. We have therefore considered the impact in this forthcoming revision in the consideration of potential heating options for the project.

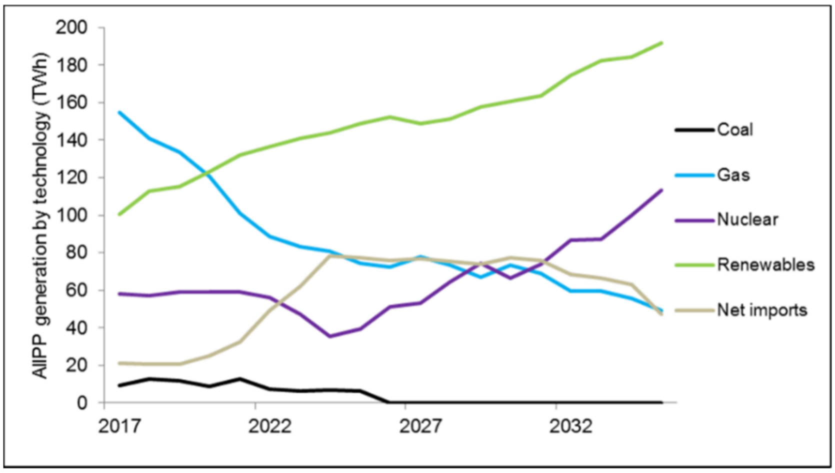


Figure 3. Grid generation breakdown

The following fuel emissions factors have been used in the calculations:

Fuel	Current CO_2 Emission Factor (kgCO$_2$/kWh)	2022 CO_2 Emission Factor (kgCO$_2$/kWh)
Natural Gas	0.216	0.210
Grid supplied electricity	0.519	0.233
Grid displaced electricity	0.519	0.233

Table 3. Carbon Dioxide Emissions Factors

At the moment the carbon emission factor for electricity is 0.519kgCO$_2$/kWh this will be updated to 0.233 kgCO$_2$/kWh next year thus greatly effecting the impact of electrical heating solutions in regard to carbon reduction.

The revised 2022 CO_2 factors are detailed as above and have been included in the carbon review.

2.0 Energy Modelling

2.1 Dynamic Simulation Modelling (DSM)

Dynamic simulation is a sophisticated form of building energy modelling, it has been carried out in order to predict the annual energy consumption and demand for the building. Integrated Environmental Solutions (IES) Version 2021 DSM software has been used. The software can base its performance calculations upon incremental time steps as low as 2 minutes. This allows realistic variations in fabric thermal storage (thermal mass effects), weather conditions, occupancy, internal and solar gains to be considered and their implications upon building/plant operation to be modelled effectively.

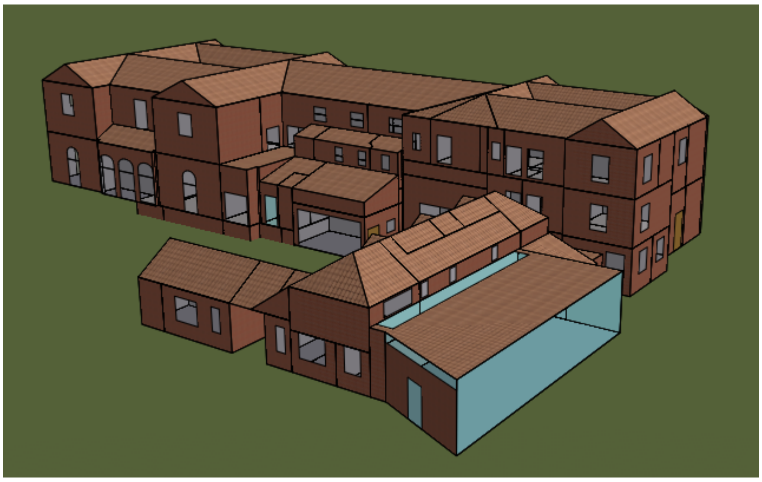


Figure 4. IES Model Image

2.1.1 Weather Data

To accurately model the dynamic nature of the building's thermal response, hourly recorded weather data is used in dynamic thermal simulations. Such weather data contains records of radiation, temperature, humidity, sunshine duration and additionally wind speed and direction. Weather data for Southampton has been used in this case, taking cognisance of 10 years of historical weather data.

2.2 Model Parameters

Harley Haddow have carried out the energy analysis based on assumed historical U-Values for the existing building and Part L1B Conversion U-Values for the new extension and new glazing. The U-values applied to the models are as listed in the table below and an infiltration rate of 1.0 ACH has been applied based on the specified levels within CIBSE Guide A Table 4.24. The operational profile and set points of the building are based on the National Calculation Method (NCM) to obtain energy figures.

Fabric U-values (W/m^2K)		
	Existing	**Extension**
Walls	1.7	0.28
Floor	0.71	0.22
Roof	1.4	0.8
Glazing	5.6 (g=0.85; LT=0.9)	1.6 (g=0.4; LT=0.71)
Doors	2.56	-
Infiltration	1.0 ACH, based on an air permeability of $20m^3h/m^2$ @ 50Pa	

Table 4. Building Fabric Performance

System	Performance Parameters
Artificial Lighting	Existing lighting assumed.
Ventilation	Natural Ventilation with Local Extract fans to the Bathrooms/Toilets/Laundry and Kitchen Extract Hoods.
Heating	**Option 1 New Oil Boiler** Efficiency 95% Boilers serving radiators throughout
	Option 2 LPG Boiler to replace existing Efficiency 97% Boilers serving radiators throughout
	Option 3 HT Heat Pump to replace existing Seasonal CoP of 2-3 (200-300%) serving radiators throughout.
	Option 5 Biomass Boiler to replace existing Efficiency 90% Boilers serving radiators throughout
	Option 6 Direct electric boiler to replace existing Efficiency 100% Boilers serving radiators throughout
Domestic Hot Water	1,000 litre hot water cylinder served by main heating system with (70mm factory insulation to new systems) uninsulated to existing system.
Photovoltaics	**Option 4 Supplementary PV with existing oil boiler** $100m^2$ Module Nominal Efficiency of 0.2010, Electrical Conversion Efficiency 0f 0.96.
	Option 7 & 8 Supplementary PV with heat pump solution $100m^2/500m^2$

Table 5. System Parameters

All heating set-points, internal gains and operational profiles have been applied based on the NCM profiles.

The profiles applied, as developed by the BRE are used to give a high-level representation of the potential annual energy usage associated with space heating and domestic hot water in-line with the templates used for Building Regulations related calculations. It should be noted that actual operational energy will vary in practice depending on actual occupancy and usage patterns.

3.0 Heating Options Appraisal

3.1 Overview

This report aims to highlight a range of potential options for further discussion to determine the options worth pursuing for further detailed analysis. Four options have been considered as usable for the dwelling and shall be considered for the building's heating source. These are:

- Replace existing oil boiler with new higher efficiency model.
- Replace existing oil boiler with LPG.
- Replace existing oil boiler with a LZC solution (heat pumps).
- Relocate existing oil boiler and supplement with PV.
- Replace existing oil boiler with biomass boiler.
- Replace existing oil boiler with direct electric boiler.
- Supplement heat pump solution with PV (2 potential areas).

3.2 Existing Heating Provision

A detailed survey of the existing heating system at Warrens was undertaken by Guy Willis-Robb (Director), Andrew Jones (Electrical Technical Director) and Rob Lewis (Principal Mechanical Engineer) on 27th September 2021.

During the visit it was confirmed that the primary heating system is provided by 3No oil fired boilers each with a heating capacity of 40kW located in a dedicated plantroom to rear of the property. The boilers are installed in a cascade arrangement serving heating circuits for space heating and the domestic hot water calorifiers. Existing records of the install were limited but it was identified from the primary heating circuit that the system is designed to operate at a minimum flow temperate of ~75°C which is typical for a heating system of this type. At the time of inspection, the boilers were operational and with the correct maintenance can be expected to keep functioning for the short term but the boilers and associated pipework and pumps etc are in the region of 20-30 years old and are in need of replacement.

Within the property it was identified that significant internal renovation had been undertaken in previous 1-5 years and in regards to the heating system new emitters (primarily cast-iron radiators) have been installed along with new branch pipework connections in the majority of areas along with some new local heating controls.

Although the survey did not allow for intrusive opening up of concealed pipework etc it was recognised that the works were undertaken to a high standard. In consideration with the proposed internal works, it is understood that it would be the preference that any internal changes are kept to a minimum i.e. keep the existing radiators and heating pipework, this would then require any new heating system to achieve the ~75°C flow temperature the buildings existing heating system is designed to operate on.

3.2 Oil or LPG-fired Boiler

New high efficiency oil or LPG fired boilers would provide a conventional replacement to the existing oil boilers and would integrate easily with the existing internal heating system. New Oil or LPG boilers offer both running cost and emissions savings when compared to the existing system but would also tie the property into long term reliance on fossil fuels and without significant onsite renewable generation or carbon offsetting adopting replacement boilers of this type would not be compatible with an ambition for ‘net zero ‘emissions.

Furthermore, in the future the UK Government carbon reduction targets and policies will look to push existing buildings away from the use of fossil fuels.

3.3 Air Source Heat Pump

An Air Source Heat Pump (ASHP) works by extracting available heat from the external air and upgrading this to a higher temperature which can be used in the building for heating using compressor technology.

Figure 5. Example ASHP System

To maximise efficiency ASHPs typically operate at flow temperatures of 45-55°C which is lower than conventional heating systems, in this temperature range the Coefficient of Performance (CoP) is typically ~3 i.e. every 1kW of electricity consumed to drive the heat pump system generates 3 kW of heat energy from the outside air to heat the building.

The existing radiators and pipework at Warrens are designed to operate at the higher temperature of a conventional system (~75°C) if these are to be retained then high temperature (HT) heat pumps capable of operating in this range would be required.

HT ASHPs are currently available and could be utilised in this application but the CoP of the system is negatively affected as more electrical energy is required to achieve the higher heating temperature. Measures such as weather compensation controls and inverter driven variable temperature pumps can reduce the periods that the heat pump is operating at peak output. The seasonal CoP for a HT AHSP would be in the region of 2-2.5. This is a significant reduction compared to a low temperature system but still offers a substantial improvement in efficiency when compared to the existing heating system.

ASHPs require evaporator units to be exposed to ambient air. This is most effectively achieved by mounting the units externally to the building. Any planning implications would have to be assessed prior to installing external units.

A key consideration for an ASHP system is the acoustic performance of the external unit, if this option is to be developed it is recommended that an acoustic consultant is appointed to ensure that appropriate measures are taken to limit the effects of noise breakout from the fans.

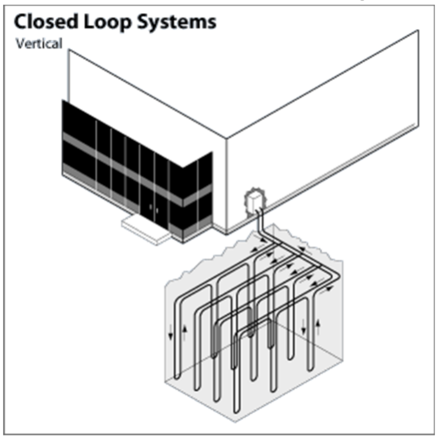
This type of system is deemed feasible for the building, an air source heat pump solution provides significant annual running costs and carbon emissions savings when compared to the existing oil boilers. As an electrically driven heating system served by a decarbonising electricity grid an ASHP shall also future proof the property in line with future net zero targets.

The existing Low Voltage power supply serving the building is insufficient to power a heat pump system and will need to be upgraded, an application to UKPN shall be required in order assess the local LV provision and provide a cost for the upgrade works.

3.4 Ground Source Heat Pump

Ground source heat pump (GSHP) systems utilise the same heat pump technology as a ASHP but rather than extracting heat from the air they utilise an array of below ground pipework to adsorb heat from below the surface. The most common configuration are borehole installations where the energy is transferred from the ground to a pipe loop down to a depth of approximately 100-150 meters. This type of system collects both solar energy and geothermal energy for use within the building through the heat pump. Alternatively, a horizontal ‘slinky’ system can be installed which is designed to cover a large area of ground and collect solar energy absorbed by the ground near the surface, this arrangement has a reduced installation costs but has a lower efficiency than the vertical bore hole system.

Vertical Borehole GSHP System



Horizontal ‘Slinky’ GSHP System

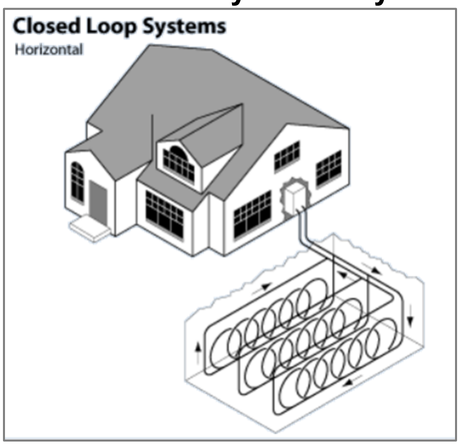


Figure 6. Typical GSHP Configurations

To maximise efficiency GSHPs typically operate at flow temperatures of 45-55°C which is lower than conventional heating systems, in this temperature range the Coefficient of Performance (CoP) is typically 3 to 4 (i.e. for every 1kW of electricity consumed to drive the heat pump system, 3 to 4 kW of energy would be transferred from the ground to heat the building.

The existing radiators and pipework at Warrens are designed to operate at the higher temperature of a conventional system (~75°C) if these are to be retained then high temperature (HT) heat pumps capable of operating in this range would be required.

HT GSHPs are currently available and could be utilised in this application but the CoP of the system is negatively affected as more electrical energy is required to achieve the higher heating temperature. Measures such as weather compensation controls and inverter driven variable temperature pumps can reduce the periods that the heat pump is operating at peak output. The seasonal CoP for a HT GHSP would be in the region of 2-3. This is a significant reduction compared to a low temperature system but still offers a substantial improvement in efficiency when compared to the existing heating system

Due to the large areas of open landscaping and gardens adjacent to the property it can be assumed that the there is ample external space for a ground array utilising either boreholes or the slinky type configuration. A detailed geothermal investigation by a specialist engineer would be required to determine extent of the ground array.

This type of system is deemed feasible for the building, a ground source heat pump solution provides significant annual running costs and carbon emissions savings when compared to the existing oil boilers. As an electrically driven heating system served by a decarbonising electricity grid a GSHP shall also future proof the property in line with future net zero targets.

The existing Low Voltage power supply serving the building is insufficient to power a heat pump system and will need to be upgraded, an application to UKPN shall be required in order assess the local LV provision and provide a cost for the upgrade works.

3.5 Biomass

A biomass heating installation uses a renewable fuel source such as wood pellets, wood chips or logs to provide heat to the building. In addition to being a renewable fuel source, the CO_2 emissions associated with utilising biomass systems are relatively low compared to using fossil fuels or grid supplied electricity.

The majority of biomass boilers will be designed to burn one fuel type due to the moisture content within each fuel. Biomass systems differ from other renewable sources because they emit carbon dioxide when they burn fuel. However, the amount is equal to the carbon absorbed when the biomass material was growing. The carbon intensity of biomass will remain constant and will not decarbonise further, unlike electricity, so would only be conversant with net zero if combined with other technologies.

The primary considerations when adopting a biomass system is the adequate provision of the associated woodchip/pellet storage facilities and suitably trained onsite staff to operate and manage the system which can be labour intensive, also, due to the large number of mechanical systems required to feed the chip/pellets into the burners regular breakdowns are possible and part replacement (usually from manufactures based in Austria for example) can take time to arrive. In the majority of biomass installations LPG boilers are also included as a back up to cover these downtimes.

The high delivery water temperature from biomass boilers would allow for the system to integrate into the existing heating system at Warrens and the property also benefits from having large grounds to house dedicated facilities for fuel storage.

It should be noted Harley Haddow have previously been employed to rectify issues with biomass systems and in some instances replace existing biomass installations with alternative heating systems due to regular breakdowns and would therefore recommend that this option is carefully considered during the design stage.

3.5 Direct Electric Heating

Direct electric heating is a simple technology with few moving parts associated with the plant and no flues. The infrastructure is primarily electrical, the operation and management of the equipment is well understood with specialists' maintenance and service personnel available nationally and locally depending on the issue.

Due to the nature of the technology, the Coefficient of performance is typically 1 (i.e. for every 1kW of electricity consumed, 1 kW of energy would be transferred from the heating system).

This type of system will have high running costs and high initial related CO2 emissions despite the future decarbonising electricity grid but will offer the future proofing of the property towards the net zero target but it is very rarely utilised due to the resulting high energy costs.

The existing Low Voltage power supply serving the building is insufficient to power a direct electric heating system and will need to be upgraded, an application to UKPN shall be required in order assess the local LV provision and provide a cost for the upgrade works.

3.6 Photovoltaic Panels

Solar photovoltaic panels work by converting energy from the sun into electricity. As a result, the system will displace grid electricity and in so doing realise carbon emissions savings. It should be noted that the electricity grid carbon factor is reducing all the time with the introduction of large-scale renewable fuel sources, however the carbon savings which can be achieved with a PV installation are still worthwhile.

Figure 7. Photovoltaic Panels

Photovoltaic panels can be used in conjunction with any building system as the additional electricity generated by the panels can be fed into the building or exported to the national grid. PV panels will require cleaning in order to maintain maximum generating efficiency but this may only be required annually.

From an initial review of the current building form, there is deemed to be adequate space on the Southeast roof of the main building and the roof of the extension to accommodate an array of panels without obstruction (shading) from surrounding buildings and trees. Planning (and Listed Building Consent) would have to be sought prior to the installation of solar panels. Due to the extensive grounds of the Estate, it would also be possible to provide a large ground array located away from but still connected to the building.

4.0 Energy Analysis Results

4.1 Dynamic Simulation Modelling

IES Dynamic Simulation modelling was used to produce estimated the energy requirement for the building. This was used to predict energy consumption, carbon emissions and running costs associated with each heating option. These are summarised in the table below;

Scenario	Option	Energy Consumption[1]					Carbon Emissions[2]		Running Cost[3]	
		Fuel Type (kWh)	Electricity (kWh)	Grid Displaced (kWh)	Total (kWh)	% Saving	(tonnesCO_2/yr)	% Saving	(£/annum)	% Reduction
Existing	Existing Oil	400,496	148,502	-	548,998	-	138.73	-	£40,014	-
1	New Oil	278,855	148,502	-	427,356	22.2%	107.10	22.8%	£34,175	14.6%
2	New LPG	273,105	148,502	-	421,607	23.2%	97.42	29.8%	£39,088	2.3%
3	New HT Heat Pump	-	241,453	-	241,453	56.0%	56.26	59.4%	£33,803	15.5%
4	Existing Oil + PV	400,496	148,502	-20,495	528,502	3.7%	133.95	3.4%	£37,145	7.2%
5	New Biomass	294,347	148,502	-	442,848	19.3%	39.02	71.9%	£43,749	-9.3%
6	New Direct Electric Heating	-	401,630	-	401,630	26.8%	93.58	32.5%	£56,228	-40.5%
7	New HT Heat Pump + PV (100m^2)	-	241,453	-20,495	220,958	59.8%	51.48	62.9%	£30,934	22.7%
8	New HT Heat Pump + PV (500m^2)	-	241,453	-102,475	138,978	74.7%	32.38	76.7%	£19,457	51.4%

Table 6. Indicative Total Consumption and Running Cost Summary

(1) Energy figures based on IES modelling.
(2) Based on current DEFRA CEFs of 0.233 kgCO_2/kWh for electricity, 0.260 kgCO_2/kWh for oil, 0.230 kgCO_2/kWh for LPG and 0.015 kgCO_2/kWh for biomass.
(3) Running costs based on typical tariffs for oil (4.8 p/kwh), LPG (6.8 p/kwh), biomass (7.8 p/kWh) and electricity (14.0 p/kWh).

Along with the simulated heating demand generated in the IES modelling of the property the performance of each option is based on typical system efficiencies, fuel tariffs and associated carbon emissions to provide a comparison of energy consumption, CO_2 emissions and running costs for each option. The results of the assessment are indicative only and the figures could vary significantly in practice considering actual operation and management.

The results of the analysis indicate that a heat pump solution coupled with a 500m^2 PV array provides the most significant reductions in both running costs (51%) and carbon emissions (77%) when compared to the existing system. The energy consumption of a heat pump solution is shown to be significantly less than any other option, this is due to the heat pump being considerably more efficient when compared to the other proposed boiler types.

A biomass heating option offers similar significant reduction in emissions (72%) but has potentially increased running costs when compared to the existing oil heating system, although this cost could vary depending on the fuel type or bulk purchase.

Direct electric boilers provide emissions reductions of over 30% but due to the high unit cost of electricity compared to oil running costs can be expect to increase in the region of 40%.

New high efficiency oil or LPG fired boilers offer a similar reduction in energy consumption (22% and 23% respectively) carbon emissions are lower for LPG as it a cleaner fuel saving close to 30% compared to 23% oil. Fuel savings of 15% can be expected for a new oil system but limited for a replacement LPG system (just 2%) due to the increased per kWh unit cost of the fuel.

Although the installation of PV could be difficult due to the condition of the building, an initial analysis has been conducted to present the potential electricity generation based on 100m² of PV being installed on the Southeast roof. A larger ground mounted array of 500m² sited within the ground offers the greatest potential to offset carbons emissions at the property this would be most affective when adopting an all-electric powered heating system. Battery storage would provide additional flexibility in utilising electricity generated onsite although this is not covered in this report.

4.2 Summary of Viable Heating Options

Below is a summary of the key advantages and disadvantages associated with each of the potential heating options highlighted within this study.

<table>
<tr><th>Option</th><th>Heat Source</th><th>Key Advantages</th><th>Key Disadvantages</th></tr>
<tr><td>Baseline</td><td>Oil Boiler</td><td>• Current solution
• Low complexity</td><td rowspan="3">• High CO_2
• Low future flexibility
• Fuel storage/deliveries
• High fuel/maintenance costs
• Unsecure heat supply</td></tr>
<tr><td>1</td><td>New Oil Boiler</td><td rowspan="2">• Low complexity
• Improved efficiency over existing system</td></tr>
<tr><td>2</td><td>LPG Boiler</td></tr>
<tr><td>3</td><td>Heat Pump</td><td>• Low CO_2
• Future-proof option
• Energy efficient plant
• Will continue to decarbonise</td><td>• Visual impact with ASHP
• Capital cost > Oil/LPG Boiler
• Noise concerns with ASHP
• Borehole/groundwork for GSHP
• LV Power Upgrade Required</td></tr>
<tr><td>4</td><td>Move existing oil boiler and supplement with PV</td><td>• Current solution
• Low complexity
• Supplemented electrical energy via PV production.</td><td>• High CO_2
• Low future flexibility
• Fuel storage/deliveries
• High fuel/maintenance costs
• Unsecure heat supply</td></tr>
<tr><td>5</td><td>Biomass Boiler</td><td>• Low CO2
• High temperature
• Improved efficiency over existing system</td><td>• Fuel storage/deliveries
• High fuel/maintenance costs
• Unsecure heat supply</td></tr>
<tr><td>6</td><td>Direct Electric</td><td>• Easy to install
• Low maintenance
• Familiar technology
• Will continue to decarbonise</td><td>• High CO_2 & running costs
• LV Power Upgrade Required</td></tr>
</table>

Table 7. Options Summary

7.0 Conclusion

As part of the heating options review for Warrens, the measures considered for the project followed the 'Lean', 'Mean' and 'Green' Energy Hierarchy approach where feasible.

The incorporation of 'Lean' building fabric upgrades will help reduce heat losses and associated energy required to maintain a comfortable environment from the buildings' heating system. Any fabric improvements of the property need to be sensitively considered in relation to the Grade II* listing, using guidance from the Historic England 'Energy Efficiency and Historic Buildings' document and the emerging New Forest Design Guide. 'Green' actions to improve thermal performance, such as dealing with drafts, providing additional loft insulation in pitched roofs and adding rugs or carpets to uninsulated ground floors shall be provided where appropriate. Many of the windows benefit from the installation of internal wooden shutters to help reduce heat loss and fabrics could be added where there are no curtains or soft furnishings elsewhere which the interior designs are reviewing. No 'Amber' or 'Red' actions are being proposed or developed at this time as the strategy is to mitigate any impacts to the listed structure, its fabric and maintain a sensitive conservation led approach to the project as a whole.

The new 'Garden Room' extension is required to comply with Part L1B of the Building regulations, there are no specific carbon reduction targets required for the extension new but thermal elements will be required to comply with Section 5 of Part L1B building regulations which states maximum allowed U-values for new thermal elements. In summary the extension shall include the following measures to reduce energy use;

- High performance building fabric with U values which exceed the minimum values stated in Part L1B.
- Provision of an extended eaves detail or 'brise soleil' to provide shade
- Solar control glazing to limit overheating
- Low temperature underfloor heating within floor screed utilising thermal mass to provide efficient storage of and release of radiant heat energy

The Garden room shall also make use of local materials and sustainable building techniques to reduce the associated carbon emissions of the construction to provide a positive impact on the natural and historic environment.

The 'Green' measures consist of the potential use of a heat pump system as the primary heat source for the building and the use of PV to offset the total electricity consumption.

The analysis indicates that a heat pump system supplemented with a large photovoltaic (PV) array offers the greatest reduction in both energy consumption and carbon emissions when compared to replacing the existing system with an oil boiler system.

It is recommended that a high temperature (HT) heat pump system, (either Air or Ground Source) is considered as a replacement heating option for Warren's, recognising that operating heat pumps at this higher temperature reduces the system efficiency, measures such as weather compensation and inverter driven pumps should be provided as part of the system upgrades to limit the periods at which the heat pumps operate at peak loads.

It is also recommended that back up LPG boilers are provided to ensure a continuity of the heating provision in case of failure or maintenance of the main heat pump system.

As an all-electric system, a heat pump solution will future proof the house in line with the transition to 'net zero' emissions due to the progressive decarbonisation of grid electricity. By incorporating on site renewable energy via an onsite PV array additional reductions in energy consumption, CO_2 emissions and running costs would be achieved due to reducing the amount of imported grid supplied energy.

Heating via biomass boilers also offers a significant reduction in CO_2 emissions, the Warrens property is potentially well suited to this type of system and therefore can be considered a feasible replacement to the existing heating system. Careful consideration of the system arrangement such as fuel type, delivery and storage, plus the onsite maintenance requirements should be fully assessed in the design stage in order to avoid the issues with biomass boilers Harley Haddow have encountered in previous biomass installations.

The results of this report demonstrate that following systems provide the greatest reduction in carbon emissions and annual running costs and therefore considered as suitable heating replacement options;

- High Temperature Heat Pump (Air or Ground Source)
- Woodchip/Pellet Biomass Boilers
- Onsite renewable energy generation via Photovoltaic Array

To fully assess the suitability of each option each system it is recommended that Harley Haddow develop the system designs for the above options in conjunction with the Architects in order to confirm the impact of each option to the property and wider estate.

HARLEY HADDOW

The Multi-disciplinary Engineering Consultancy

Edinburgh | London | Glasgow

Contact
124-125 Princes St
Edinburgh, EH2 4AD
enquiries@harleyhaddow.com