Hydro, Wind & Heat Pump Consultancy, Design & Installation

Ebley Mill

Water-source heat pump feasibility study

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Renewables First Ltd, The Mill, Brimscombe Hill, Stroud, Glos GL5 2QG
Phone +44 (0)1453 88 77 44
Email info@renewablesfirst.co.uk
www. renewablesfirst.co.uk

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Introduction

Executive summary
This report summarises the feasibility of a water-source heat pump installation at Ebley Mill, which houses the main offices of Stroud District Council. The council is exploring options to decarbonise the heating of this building, in line with its aim to make the district carbon neutral by 2030.

Our assessment reviews the available resource, heating demand and existing emitters, before recommending an outline system specification and next steps to progress the project.

Overall, the project would enable a CO2e reduction of 60-100% (70-110 tonnes per year). The project would not quite recover its installation costs within its lifetime, unless the capital cost can be reduced. In order to avoid further RHI rate reductions, the project would need to progress very quickly to obtain the necessary consents during the Jul-Sep tariff period.

Heat pump technology
Heat naturally flows from hot to cold. A heat pump is a device that moves heat in the opposite direction: it pumps heat from a cooler 'source' to a warmer 'sink'.

Domestic fridges use this principle to transfer heat from the interior into the surrounding room. In a similar way, it is possible to transfer heat from the external environment into a building's heating system.

The most common type of heat pump is an electrical compression heat pump. The heat pump works by allowing a refrigerant to absorb heat, which causes it to evaporate, then using electricity to compress the refrigerant, which causes it to condense and release its heat. This allows heat to be moved, by absorbing it from one location and releasing it in another.

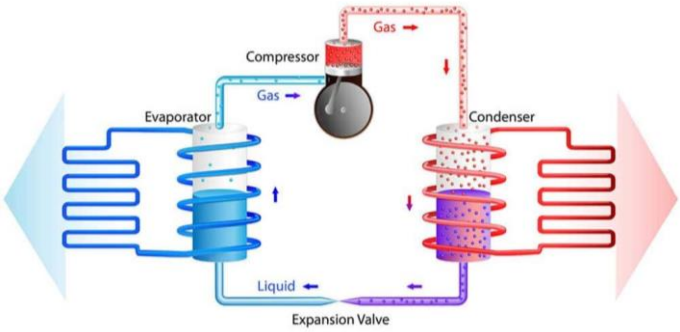


Figure 1 – Heat pump operation

All heat pumps operate most efficiently when the source and sink temperatures are similar. This is characterised by the coefficient of performance (COP), which is the ratio of heat power output and electrical power input.

Rivers, lakes, and other bodies of water are heated by the sun and so provide a source of renewable heat that can be used in homes and businesses. Water has a high heat capacity and a relatively stable temperature throughout the year, which results in water-source heat pumps typically having a much higher COP than air- or ground-source heat pumps.

Most water-source heat pump systems use a 'closed loop' to circulate a thermal transfer fluid (antifreeze mixture) between the heat pump and the water. Inside the heat pump, heat exchangers transfer heat to the refrigerant and then on to the building heating system.

‘Open-loop’ systems that abstract water are possible, however water quality issues mean an intermediate heat exchanger is required, with higher maintenance requirements. These systems are generally better suited to large scale applications.

Resource

Watercourse flow
The Frome has been gauged at Ebley by the Environment Agency since 1969. Figure 2 shows the flow duration curve based on the most recent 20 years.

The mean flow is 2.81 m^3/s with a 'Q95' flow of 0.89 m^3/s. This means that the flow in the river at this point will be above 0.89 m^3/s for 95% of the time. In practice, flows below this level will always occur during summer.

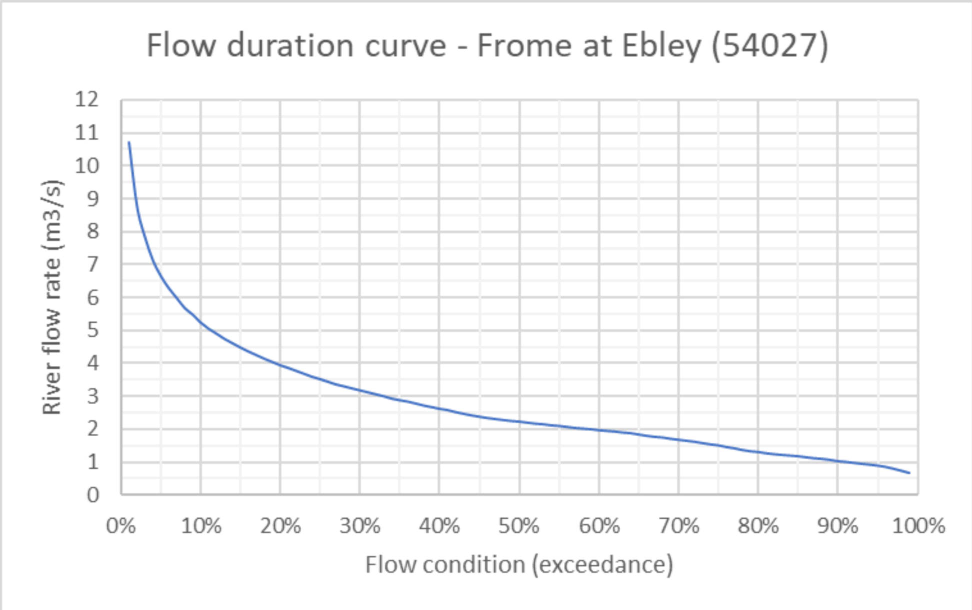


Figure 2 – Flow duration curve

Environment Agency guidance stipulates a maximum drop in river temperature of 2 degrees. Extracting 2 degrees from the Q95 flow of 0.89 m^3/s would yield around 7 MW. It is therefore very unlikely that low river flow will limit heat power here.

Climate & river temperature
Air and river temperature data were obtained as follows. The findings are shown in Figure 3.

Parameter	Data type	Source	Period	Location
Air temperature	Daily min/mean/max	Met Office	1981-2010	Cirencester
River temperature	Spot measurements	EA 'WIMS'	2000-2015	Ebley

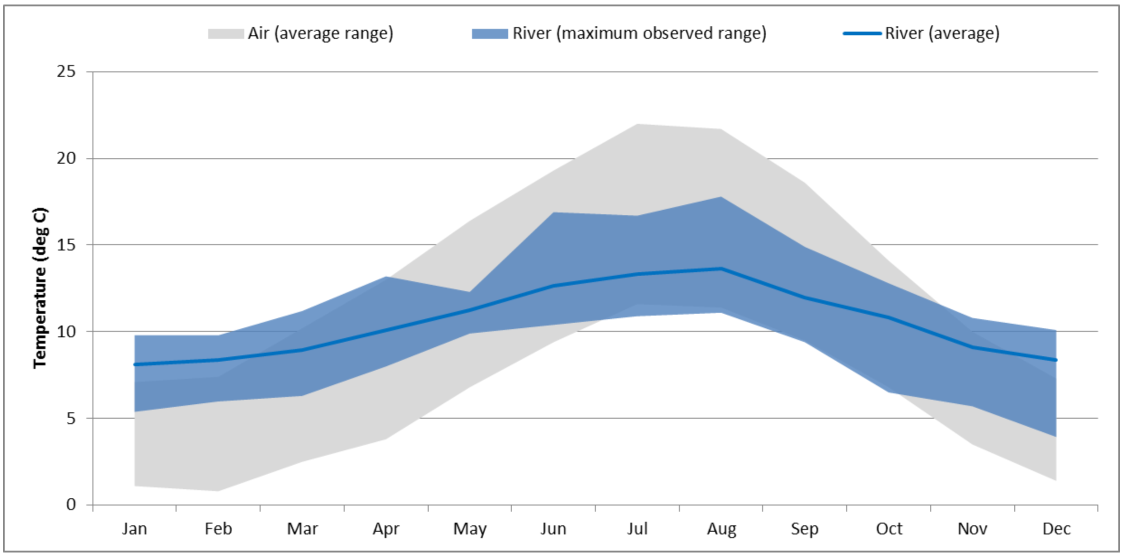


Figure 3 – Local temperature data

The lowest river temperatures recorded are:

Date / time	River temperature (°C)
03/12/2010 14:50	3.93
11/12/2008 08:45	5.00
09/01/2009 14:20	5.38

In summary, the local temperature data show that river temperature typically falls to around 7°C during Dec-Jan and occasionally below 4°C.

During periods when the river temperature is low, the heat pump will continue to work effectively, however the efficiency will be reduced. Details of the system performance are given later in this report.

As the river is relatively fast-flowing, it will be well-mixed with no significant variation in water temperature across the site.

Building details

Construction
Ebley Mill is a former wool mill that was converted for offices in 1990. It is of limestone construction with Welsh slate roof tiles and large arched windows. Historically, the mill was powered by up to five waterwheels, and later with steam power.

The building has three main sections:

Bodley Block	The north end of the building. Five floors, with an additional area on the ground floor
Long Block	The central section, with five floors
New Block	The south end of the building, with two floors. Newer construction

Total floor area: 5,313 m^2
Total volume: 19,991 m^3

In general, the walls are solid stone construction around 450 mm thick and include large single-glazed windows with small panes and metal frames. The windows are double glazed throughout New Block and on one floor of Long Block. Elsewhere the vast majority of windows are fitted with secondary glazing. The building is assumed to have a suspended floor throughout and has a pitched tiled slate roof, with dormer windows throughout Long Block. The roof is insulated with 2L2 foil bubble insulation.

An EPC assessment was carried out in 2019 and returned a D rating.

Heating system
The main plant room is on the ground floor of Bodley Block, which houses three gas boilers (installed 1987) that supply Bodley Block and Long Block. New Block has its own heating circuit using two newer gas boilers located in a plant room on the ground floor.

Existing heating equipment:

Equipment	***Specification***	***Notes***
Gas boilers	*3 x 235 kW Hoval SR800 boilers (gas)* *2 x 120 kW Concord CXA/H boilers (gas)* *[exact model unclear but 120kW assumed]*	Flow 80°C (when external -1°C) Flow 80°C (assumed)
Hot water heaters	Point-of-use electrical heaters only	We do not propose any changes to the hot water system
Emitters	Traditional high-temperature radiators All radiators fitted with TRVs Council chamber has four larger wall-mounted convector heaters	
Control system	Internal and external temperature sensors Weather compensation	Heating on 06:00-15:30 Mon-Thu, 06:00-15:00 Fri, off Sat/Sun Some zoning, but possibly faulty
Air-conditioning	A Daikin air conditioning unit serves the council chamber only. Small additional units also operate in the server room.	There is also a ducted air cooling system which is no longer used.

Heat demand

Occupancy

The building is fully occupied with the exception small areas undergoing refurbishment. During 2019 the building was fully occupied with the exception of a three-month period when Long Block was refurbished, one floor at a time (each taking one month).

Hot water demand

Hot water demand is not included in this assessment due to the use of electrical heaters at point of use.

Space heating overview

Space heating can be broken down as:

Emitter heat power + casual heat gain rate + solar heat gain rate = Fabric heat loss rate + ventilation heat loss rate

Casual heat gain rate:

Item	Unit heat gain rate (W/m^2)	Area (m^2)	Total heat gain rate (kW)
Lighting in use	12	6367	76.4
Equipment	14	6367	89.1
Occupants	6	6367	38.2
TOTAL			**203.7**

Solar heat gain rate (winter average):

Aspect	Area (m^2)	Unit heat gain rate (W/m^2)	Total heat gain rate (kW)
NE/NW-facing	435	39	17.0
SE/SW-facing	546	60	32.8
TOTAL			**49.8**

Fabric heat loss rate:

Element	Description	U-value (W/m²K)	Area (m²)				Heat loss rate (W/K)			
			New	*Long*	*Bodley*	*Total*	*New*	*Long*	*Bodley*	*Total*
Walls	450mm limestone, uninsulated	2.23	751	1797	804	3352	1674	4007	1794	7474
Windows / glazed doors	Double glazed	2.80	149	83	0	232	416	233	0	649
Windows	Single pane, metal frames, with secondary glazing	2.70	0	333	351	684	0	900	948	1847
Skylights	Single pane, wooden frames	4.80	0	0	66	66	0	0	315	315
Doors	Solid wood	3.00	28	14	9	51	84	43	26	153
Wood panelling	Solid wood	3.00	18	0	0	18	55	0	0	55
Roof	Slate tiles with 2L2 insulation (R=1.5)	0.67	893	734	625	2251	595	489	416	1501
Floor - NB	Suspended timber, uninsulated	0.30	783	0	0	783	233	0	0	233
Floor - LB	Suspended timber, uninsulated	0.36	0	581	0	581	0	208	0	208
Floor - BB	Suspended timber, uninsulated	0.29	0	0	602	602	0	0	176	176
TOTALS							**3057**	**5880**	**3675**	**12613**

Please note the figures above do not include losses due to thermal bridging or ground conduction.

Ventilation heat loss rate & overall demand:
The ventilation heat loss rate depends on the number of air changer per hour (ACH), which can only be directly measured using infiltration testing. To estimate the ACH value, the fabric heat loss rate was compared with existing overall consumption based on gas bills.

Hourly temperature data during 2019 was obtained for the weather station at Gloucestershire Airport, which should have a similar temperature profile to Ebley Mill. This was used to establish the temperature differential between the internal and external temperatures.

Taking into account the heating profile, which is typically 06:00-15:30 weekdays, the overall demand was modelled on an hourly basis. These results were summed for the periods shown on the gas bills for comparison and determination of the ventilation rate.

The gas consumption as stated on the bills was adjusted by a factor of 83% to provide the actual heat delivered. This accounts for the estimated efficiency of the heating system.

Please also note:

- A gas-to-heat efficiency of 83% was assumed
- The heating demand use for comparison with bills was reduced to account for the council chamber being heated by a separate system (electric convectors)
- Year-to-year variation in heat demand has not been estimated
- Solar gains are modelled as constant throughout the year, therefore the model will slightly over-estimate heat demand in summer and slightly under-estimate in winter
- Each floor of Long Block was unheated for a period of up to one month per floor during renovation in 2019. This may have reduced gas consumption by 8-10% during that period. However, it is not known exactly when this was carried out, so no adjustment has been made.
- The effects of thermal mass and warm-up / cool-down periods have not been assessed
- This analysis assumes that ACH is constant, whereas in reality it will vary according to factors such as wind speed/direction, occupant behaviour and internal/external temperature

The model gives the closest fit with gas bills data when ACH is set to 4.75, with results as shown in Figure 4.

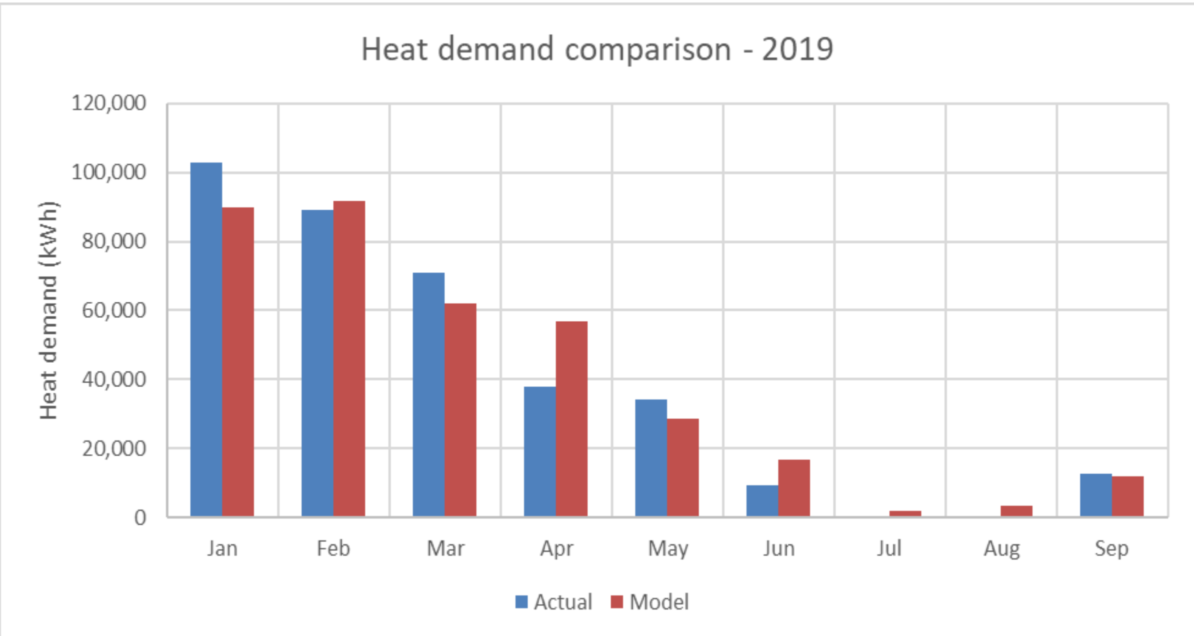


Figure 4 – Monthly heat demand comparison (Months approximate based on bill periods)

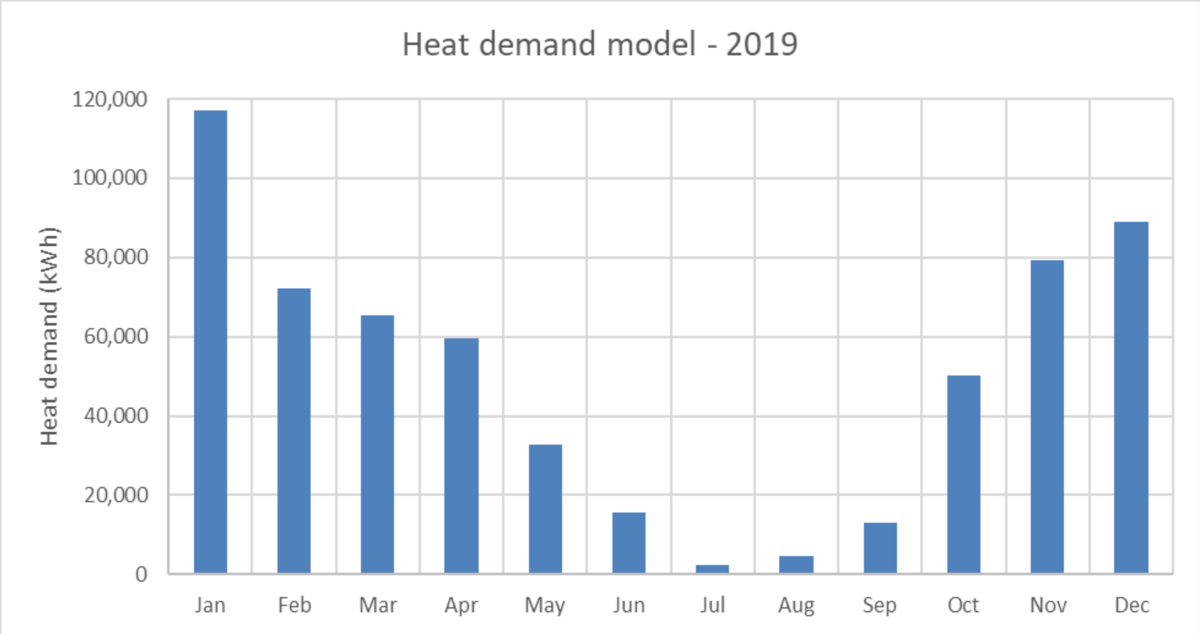


Figure 5 – Modelled heat demand profile (Months exact)

The predicted overall section-by-section heat loss rates are as shown below:

Section	Fabric (kW/K)	Ventilation (kW/K)	Total (kW/K)	Peak heat loss [dT=25K] (kW)
New Block	2.96	6.61	9.57	239
Long Block	5.87	14.24	20.11	503
Bodley Block	3.75	10.78	14.53	363
TOTAL:	**12.59**	**31.62**	**44.21**	**1105**

The overall peak space heating demand, ignoring gains, is 1105 kW. This is based on an internal temperature of 21C and external temperature -4C. Accounting for gains, the peak heat demand is approximately **850 kW**. This is relatively similar to the capacity of the existing boilers, which is 945 kW.

Please note that the secondary glazing is likely to have reduced the heating demand by around 10%, so before this was installed the peak heat demand (after gains) would have been approximately 900 kW.

The rating of the existing boilers will have been determined based on not only the peak heat losses but also the desired warm-up time for the building. Any heat pump installation would also need to ensure the warm-up times are acceptable.

The peak heat demand per unit floor area, based on the result above, is 208 W/m^2 before gains and 160 W/m^2 after gains.

The annual heating demand of the property including the council chamber, based on analysis from 2019, is approximately **600,770 kWh**.

Emitters
Within Long Block, typical emitter provision is one radiator per window, with a shorter radiator at the front (NW side) and a longer radiator at the rear (SE side). The heat output of these radiators is estimated as:

Position	Type	Dimensions (cm)	Flow/return/internal temperature (C)	Estimated heat output (W)
Front window	2p1c	85 x 40 (x 5.5)	80/60/20	849
Rear window	2p1c	128 x 40 (x 5.5)	80/60/20	1278
Total				**2127**

The floor area served by these radiators is approximately 33 m^2, giving a heat output of approximately 64 W/m^2. This will be increased when the building is warming up, for instance if the internal temperature is 15°C the expected output would increase by a factor of 1.13.

Nevertheless, this is significantly below the required peak heat demand estimated above, which suggests that the peak demand for the building may be lower than 850 kW. To resolve this difference, a more accurate model of heat demand may be required, in particular to account for intermittent heating.

Testing
A simple test of the heating will be carried out to provide valuable data on both the overall building heat loss. The test will involve monitoring gas consumption and external temperature over a period of several hours, while the internal temperature is stable. This will allow an estimate of the building heat loss (kW/K) that is more accurate than the methods used so far, as it provides higher resolution gas data and uses actual external temperature data from the site, instead of data from a nearby weather station. This test will require monitoring of internal temperatures or ensuring that the temperature control settings (including for TRVs) are known.

The above test will be carried out by Renewables First with results added as an appendix to this report.

Another useful test would be monitoring the gas consumption first thing on a Monday morning, to estimate the maximum heat output of the radiators. Alternatively, this test could be done by reviewing half-hourly gas consumption data (if available). This test would require all radiators to be turned on throughout the property.

Energy efficiency improvements
Any energy efficiency improvements will be valuable not only by reducing heating requirements but also by allowing lower flow temperatures to be used, which will improve heat pump efficiency.

As part of this assessment it has been assumed that the internal temperature is 22°C and this will be maintained. Please note that reducing the internal temperature by just 1 degree to 21°C would reduce heating demand by around 13%.

We estimate that around 70% of heat losses in the building are via ventilation, so draughtproofing is recommended. A reduction in air change rate of 25% would reduce energy usage by around 30%.

A thermal imaging survey could be carried out to identify key areas for draughtproofing, which would also identify areas where additional insulation would be most effective. This can be carried out at a relatively low cost.

No changes in internal temperature or improvements to airtightness or insulation have been assumed as part of this assessment.

System design

Emitters
Although heat pumps are capable of delivering high flow temperatures, it is generally more cost-effective to use a lower flow temperature and replace the radiators with low-temperature models. The RHI also places restrictions on the minimum system efficiency to qualify, which would not be met using the existing flow temperature of 80°C.

Using the existing radiators with a flow temperature of 50°C instead of 80°C would reduce their output by approximately 60%. It will therefore be essential that the radiators are replaced with low surface temperature (LST) fan-assisted radiators, which have a much greater heat output.

Replacing the 128x40 radiators Long Block with LST radiators of a similar size would allow use of flow/return temperatures of approximately 50/40°C. This would therefore enable a relatively high heat pump efficiency whilst minimising disruption.

Please note that the replacement radiators require a power supply, so some electrical works are required throughout the building. In some cases, it may be possible to upgrade the radiators by increasing the number of panels and/or convectors, instead of installing fan-assisted models.

Heat pump sizing
The heat pump size affects various factors including efficiency, carbon savings, RHI payments and practicalities. A smaller system would be less expensive but would require bivalent operation (alongside retained gas boilers) whereas a larger system could provide the entire heating load (a 'monovalent' system).

Consideration of bivalent system
The main attraction of using a bivalent system is to avoid the need to replace the existing radiators, by using the heat pump to provide low-level heat only, with the retained gas boilers taking over when it becomes cost-effective to do so. This point (known as the 'bivalent point') will in practice be the point at which the system COP drops below 2.9, which is the required standard for RHI.

This is expected to correspond to a maximum flow temperature of 60°C, at which point the heat output from the radiators would be around 55% of their existing output. Annually, we would expect the heat pump system to provide 50-60% of the space heating requirements.

As the reduction in heat output is similar to the reduction in heat pump rating, the project payback would be relatively similar. The key differences would be the reduced capital cost and reduced carbon saving. In the interests of meeting CO_2 reduction targets as quickly as possible, we therefore do not recommend using a bivalent system in this case.

Another consideration is that the lifetime of the heat pump system is expect to be at least 20-25 years, so it is likely to extend beyond the RHI period. After the RHI ends, the COP required for the heat pump to be cost-effective would increase, requiring a lower flow temperature. At this point it may be decided to upgrade radiators and increase the heat pump capacity. Installing a monovalent system now will ensure that it continues to work effectively beyond the RHI period.

Recommendation
We recommend heating the building entirely using a heat pump system for the following reasons:

- To ensure the maximum possible carbon reduction
- To maximise the heating system efficiency
- To avoid over-complication of the heating system
- To maximise financial benefits by making use of the high RHI tariff for heat pumps
- To ensure that the heat pump system continues to be cost-effective after the RHI ends

Plant room

Either of the existing boiler rooms could potentially be used for the heat pumps, however there is more space available in the Bodley Block boiler room.

The new plant room area is therefore expected to be located in the existing main plant room in Bodley Block. Each of the four proposed heat pumps will have a footprint of approximately 2000 x 900 (x1650h) mm, which is similar in scale to the existing gas boilers.

Ideally the New Block heating circuit would be connected to the Bodley/Long Block circuit, so that the heat pump system works entirely from the plant room in Bodley Block. Alternatively, a separate heat pump system with separate collector circuit could be installed in the New Block boiler room.

Collector type

At this site both open-loop and closed-loop systems could be considered.

An open-loop system would require some in-river works to create the abstraction and discharge points. The abstraction flow rate required to meet the 850 kW demand, based on reducing the temperature by 3 degrees, is 68 litres per second. This would require an intake structure approximately 10 m wide incorporating four Rotorflush pumps, which could be located along the bank of either the canal or the main river. A single discharge pipe would then discharge into the river. This is likely to discharge below the water surface, after passing through an underground silt trap chamber.

The abstracted water would be hydraulically separated from the heat pump by use of an intermediate plate heat exchanger located in the plant room. The maintenance requirement of the abstraction pumps, heat exchanger and outfall structure adds an operational cost when compared to a closed-loop system.

A closed-loop system would require some in-river works to mount stainless steel heat exchange plates to the channel. The canal walls provide a convenient surface but, due to the very low flow rate in this section, either a large number of panels or a pumped system to increase flow over the panels would be required. The preferred location is in the main river, with panels mounted onto the natural river bed. It should be relatively easy to fix the panels in place using ground anchors, provided this is done in summer during low river flows.

A kay advantage of a closed-loop system is the reduced maintenance requirements. In addition, there would be no requirement for an abstraction licence, which can take several months to obtain.

We would not recommend the use of pond mats or 'energy blade' type collectors at this site, as these are susceptible to damage and blockages from river debris.

Flat heat exchange panels can extract around 6 kW per m^2, based on a flow speed of 0.25 m/s passing over the panel. During June 2019 when the river depth was surveyed, the average depth was around 50cm giving a total channel cross-section area of around 5 m^2. Based on a Q95 flow of 0.83 m^3/s the average flow speed would be 0.17 m/s. We have therefore assumed that a minimum of 4 kW could be extracted per m^2 of heat exchange panel. For a heat demand of 850 kW, the required panel area would be approximately 140 m^2. An example layout is shown in Figure 6.

The overall collector loop flow rate would be approximately 50 litres/second. The flow rate through each collector plate should be around 1 litre/second; the plates would be arranged into 50 groups accordingly. Within each group the collectors would be connected in series, whilst overall the groups would be connected in parallel. The collectors will be mounted on a steel frame and secured using ground anchors, as shown in Figure 7.

Overall, we recommend using a closed-loop system as this will minimise operation & maintenance requirements, while also being more straightforward to install and consent.

Figure 6 – Suggested collector layout

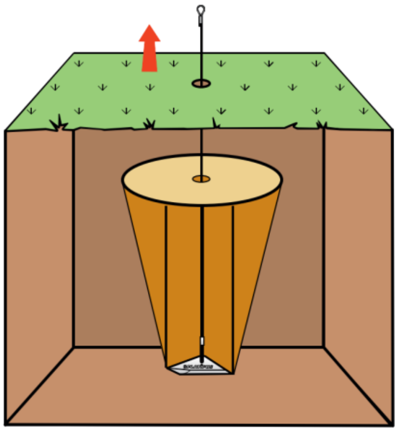


Figure 7 – Ground anchor diagram

Collector pipework

Pipework would pass from the collectors into an underground manifold chamber on the bank. From here, larger diameter flow/return pipes would carry the glycol mixture to the plant room.

Suggested pipe diameters and pressure loss calculations are as shown below. The power required for circulation pumping is discussed later in this report.

Element	**Flow rate**	**Pipe OD**	**Flow speed**	**Length**	**Pressure drop**
	l/min	mm	m/s	m	mH2O
Collectors	60	-	-	-	2.04
Pipes to manifold	60	40	1.2	20	2.60
Manifold to plant room	3000	225	1.9	50	1.35
Additional bends/fittings					2.00
Total pumped head					**7.99**

Grid connection

The maximum import capacity of the grid connection is currently unknown. The heat pump will require an import capacity of at least one-third of the rated heat power output. In this case the expected maximum import power is 290 kW. A load survey and application to WPD will be required as part of the project.

Metering

The heat pump system will include a MID-approved heat meter, which is a requirement for claiming RHI payments.

Control system

A dedicated heat pump control system will be provided by the heat pump manufacturer. This will include a weather compensation function, adjusting the flow temperature accordingly.

A separate building management system will be required to control zoning. We recommend a separate review of temperature sensors and motorised valves used for zoning.

Predicted performance

The performance of the heat pump system is shown below, based on 4no. Viessman Vitocal 300-G RedAstrum units with a total rated capacity of 850 kW. This does not include auxiliary power requirements such as circulation pumping.

Source inlet temperature (C)	5		10	
Heating outlet temperature (C)	45	55	45	55
COP (heating)	4.21	3.38	4.71	3.82

Based on the expected flow temperature of 50°C and river temperature 8°C, the expected COP is approximately 4.08. The COP will be significantly above the minimum required for RHI, which is 2.9.

The circulation pumping requirement, based on the pressure drop stated above, is estimated as 8.2 kW. This will apply whenever the heat pump is operating. The proportion of time that the heat pump and circulation pump are operational can be approximated to the capacity factor, which for the overall system is 8%. This equates to 5,770 kWh for circulation pumping. The total heat delivered is around 600,770 kWh, so if this is done at a COP of 4.08 the electricity used for the heat pumps is 147,248 kWh. Adding circulation pumping increases the electricity usage to 153,019 kWh, bringing the overall COP to 3.93.

This COP is defined at a flow temperature of 50°C and river temperature 8°C. In practice, the conditions will often be better than this, as weather compensation control will reduce the flow temperature.

This overall performance of the heat pump across the year, taking into account circulation pumping and variations in temperature, typically referred to as the seasonal performance factor (SPF). Overall, the SPF for this site is estimated as 4.08.

There will be some additional auxiliary loads that will reduce the SPF a little further, however these are minor so have not been assessed here.

Environment & consenting

Environmental impacts

During installation, the river bed may be slightly disturbed as the heat collectors are secured in place. Any ecological impact will be minor and very localised.

During operation, the collector plates will take up space on the river bed, but will not present any physical obstruction. The total area occupied is relatively small and being situated upstream of the weir minimises any impact on fish habitats.

The surface of the collector plates may be noticeably cooler than the river temperature, and as the collector fluid contains antifreeze it may be slightly below 0°C. This is not expected to have any adverse impact on ecology.

As mentioned in the Resource section, the river flow is more than sufficient to ensure that the river temperature does not reduce by more than 2 degrees, in line with EA guidance. Even during a Q95 flow of around 0.83 m^3/s, the maximum heat extraction rate of 648 kW would reduce the average river temperature by less than 0.2 degrees.

The thermal transfer fluid within the collector plates is typically non-toxic ethylene or propylene glycol. Both are classified as non-hazardous pollutants under the Water Framework Directive; they do not bioaccumulate, they biodegrade quickly and are non-toxic in aquatic environments. The impact of any leaks into the watercourse would therefore be very limited. Any leaks would be apparent due to the drop in water pressure within the circulation loop, allowing the problem to be fixed promptly.

EA consents

Closed-loop heat pump systems do not require an abstraction or impoundment licence from the Environment Agency. A flood risk activity permit (FRAP) will be required, which will permit both the temporary and permanent works in and near the river. Despite the name, this permit relates not only to flood risk but also environmental impacts. In particular, the permit will require a Water Framework Directive (WFD) assessment to be submitted, as well as a detailed method of work for construction. The permit typically takes around 3 months to be determined.

We expect the FRAP to be relatively straightforward to obtain as the impact on flood risk and the environment is extremely minor. The relevant activities are likely to fall under categories 1.1.2 and 1.1.3, with total fee £501.

If an open-loop scheme is progressed, this will require an Environment Agency abstraction licence, as well as a FRAP for any works in or near the river and Land Drainage Consent for any works in or near the canal.

A third-party ecological appraisal may be required as part of the EA consenting process.

Planning permission

Full planning permission is not expected to be necessary, however listed building consent is expected to be required as the building is Grade II* listed. This would be partly due to minor visual impact of the heat collectors as well as slight changes to the building structure to accommodate new pipework. The determination period for listed building consent is eight weeks.

Renewable Heat Incentive (RHI)

General requirements

Various documents are required in order to qualify for the non-domestic RHI scheme, including:

- Evidence that the installation is new
- Commissioning certificate & photos
- Metering (MID) certificate & photos
- Detailed schematic diagram
- Evidence of non-domestic status
- Heat pump manufacturer's specification & installer declaration to ensure SPF > 2.5
- Evidence that any public grants have been repaid
- External pipework heat loss calculations

Please note that whilst the domestic RHI requires loft or cavity wall installation if recommended on the EPC, the non-domestic RHI has no such requirements.

Degression

The RHI tariff rate may be degressed (reduced) based on forecast expenditure for each technology and for the RHI scheme as a whole. These are compared against the anticipated levels for expenditure, and for the rate of increase in expenditure, as published in advance.

- A degression of 10% was recently applied to large heat pumps (>=100kW), effective from 1 April 2020
- We expect a further 20% degression effective from 1 July 2020. There is a small chance this will be 25%
- We expect a further degression of 10% effective from 1 October 2020. There is a chance this may increase to 15%, 20% or 25%

The tariff rate assigned to the project will be the applicable rate at the time that a Stage 1 Tariff Guarantee application was made, subject to that application being approved successfully.

Deadline & tariff guarantees

The current official deadline for installation and commissioning of heat pump projects under the Non-Domestic RHI scheme is 31 March 2021. This is unlikely to be achievable.

During the 2020 budget it was announced that the government will create 'a new flexible allocation of Tariff Guarantees under the Non-domestic RHI, allowing plants to commission after 31 March 2021'. A public consultation was issued on 28 April 2020, which shows that the government intention is as follows:

- Installation & commissioning may take place after 31 March 2021 (until 31 March 2022), providing that 'stage 2' (financial close) information has been submitted by 31 March 2021
- However, no RHI payments will be made beyond 31 March 2041. This means that a system commissioned on 31 September 2021 would receive 19.5 years of RHI payments instead of 20 years

Please note that this follows the existing 'tariff guarantee' process:

Stage 1 application:

- Information requires includes:
  - Capacity of the system (kW) (must commission within 10% of this)
  - Evidence of planning permission & environmental permits
  - Expected commissioning date (cannot commission before this)
- At this stage the project will be checked against the Tariff Guarantee budget. If there is no budget available, the project will not progress and will be placed in a queue
- Upon approval, Ofgem will issue a Provisional Tariff Guarantee Notice (PTGN)
- No financial information needs to be submitted, but should be ready in preparation for Stage 2

Stage 2 application:*

- Once Stage 1 has been approved, Stage 2 application must be submitted within 3 weeks
- Evidence that sufficient funds to cover all project costs have been committed to the project, with this evidence verified by an independent auditor
- Upon approval, Ofgem will issue a Tariff Guarantee (TG)

Stage 3 application:

- To be made upon commissioning

<u>Budget caps</u>

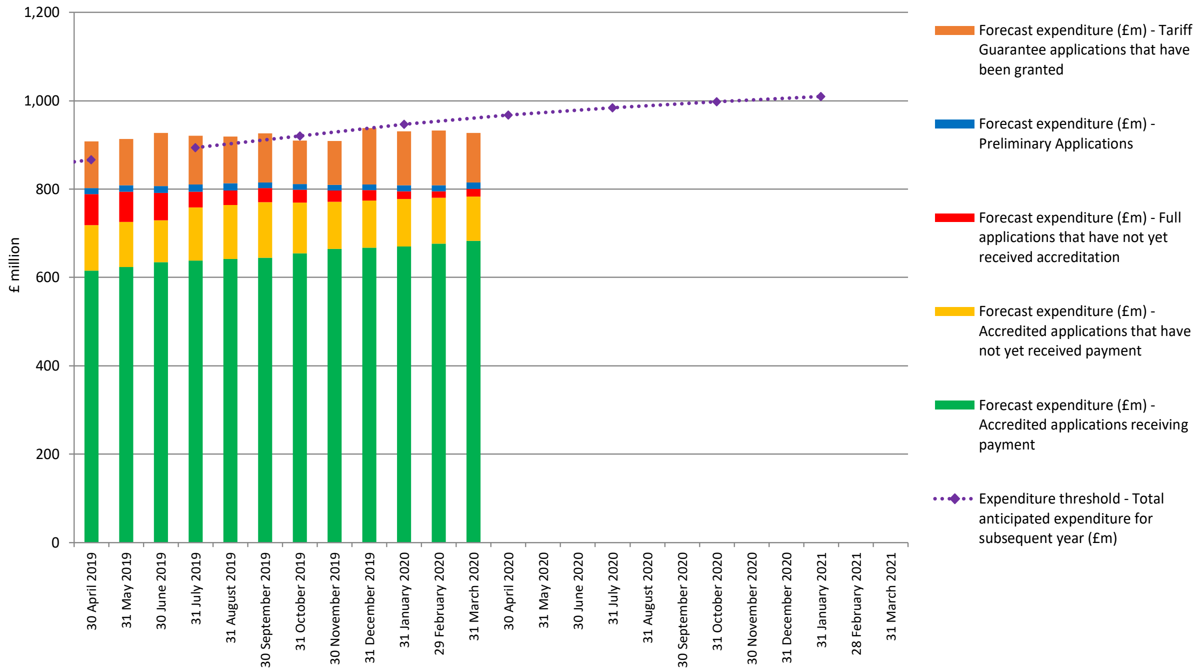
In addition to the overall deadline and tariff guarantee timescales, the RHI scheme includes budget caps on expenditure: one for the overall scheme and one for tariff guarantee applications. The budget caps and expenditure are assessed as a 12-month forecast, so they do not necessarily always increase.

If the overall scheme budget cap is reached, it is likely that the RHI will close entirely for all new applicants. This will be subject to parliamentary approval. The overall budget cap for 2020/21 is £1,150m.

If the TG budget cap is reached, no further TG applications will be accepted. This is written into RHI legislation. The legislation does allow BEIS to increase the TG budget cap; no increases have been made to date and it is unclear whether this would be done in future. The TG budget cap for 2020/21 is £150m.

The chart below shows the overall RHI expenditure (12-month forecast) at around £900m and the TG expenditure (orange) at around £110m. Both are relatively stable, however given the upcoming closure of the RHI scheme, we can assume that both are likely to increase, which means it is possible that one or both of the caps will be met.

Total forecast expenditure, as at 31.03.2020



Summary
The RHI rate was degressed by 10% in April 2020 and is expected to be reduced further. The project will be able to secure an RHI rate upon submission of a Stage 1 TG application. This requires that full consents are in place, so is expected to be during the Jul-Sep tariff period. We expect a further degression of 20% to take place, giving tariff rates for this project of 6.98 p/kWh (tier 1) and 2.08 p/kWh (tier 2).

There is a risk that the overall RHI budget will be met, which would mean that RHI support cannot be obtained.

There is a risk that the TG budget cap will be met, which would mean that further degressions would apply to the project, resulting in lower tariff rates. This would also increase exposure to the risk of the overall RHI budget being met.

If the project is commissioned after 31 March 2021, the overall period of RHI payments would be reduced accordingly. For example, if commissioned on 31 June 2021, the project would receive 19.75 years of RHI payments.

Other certifications
Microgeneration Certification Scheme (MCS) regulations do not apply here, as the installation will have a thermal output of more than 45 kW.

Other certification registrations will be required, such as Part P & G3, GasSafe and OFTEC for the electrical, hot water, gas and heating installation works respectively.

Finances

Budget cost

Item	Price
Building simulation & outline design	£8,800
Detailed design & consenting	£34,500
Viessman Vitocal 300-G heat pumps	£194,084
Heat exchange panels, frame, ground anchors	£250,585
Collector pipework	£100,995
Radiator replacement	£218,203
Other internal heating works	£35,910
Installation & commissioning	£72,600
Accreditation	£950
Grand total	**£916,627**

The heat pumps and emitter parts of this costing are based on quotes received from Viessman and Jaga. The price for collector plates is based on supply by Renewables First.

This cost estimate does not take into account the benefits associated with not needing to relocate the existing boilers and gas supply, or replace the boilers at the end of their lifetime. The heat pump system has an expected lifetime of 20-25 years.

Except for emitter upgrades, the costs above do not include any distribution-side works, such as works to relocate the plant room or improve zoning controls.

RHI payments

The expected non-domestic RHI rate, as discussed in the previous section, is 6.98 p/kWh within tier 1 and 2.08 p/kWh within tier 2. The tier 1 rate is paid for all heat delivered up to an equivalent of 1,314 hours per year at peak output (15% capacity factor). The tier 2 rate is paid for heat beyond this. Payments are CPI-linked and guaranteed for 20 years.

All heat delivered by the heat pump system will be eligible for RHI payments, so the total eligible amount is estimated as 600,770 kWh. The overall system, totalling 850 kW installed capacity, has an estimated capacity factor of 8%. This low capacity factor is due to the intermittent heating profile of the building. As the capacity factor is below 15%, the installation will fall entirely within the higher RHI rate.

Please note the comments on RHI deadlines in the previous section.

Running costs

Gas supply is currently via Regent Gas with a unit price of 2.829 p/kWh, with a standing charge of £15.82 per day. The climate change levy (CCL) also applies; the latest rate is 0.339 p/kWh.

The existing cost for electricity via HavenPower (from 2018 bill) is around 14.281 p/kWh during 07:00-24:00 and 11.094 p/kWh during 00:00-07:00. The climate change levy (CCL) also applies; the latest rate is 2019 rate 0.847 p/kWh. In addition, a monthly availability fee of £1.52 per kVA applies with a connection rating of 220 kVA, plus monthly standing / data aggregation charges totalling around £50.

The heat pumps do not typically require any more maintenance than the existing gas boilers require. However, a small sum of £900 per year has been included to allow for additional performance monitoring and any minor maintenance of the collector plates.

The long-term cost effectiveness of the heat pump system depends largely on future fuel prices. Oil and gas prices are particularly volatile, whereas electricity prices have been falling, relative to inflation, quite steadily in recent years. However, it is very difficult to predict what fuel prices will be 10 or 20 years from now.

Performance summary
The overall expected project performance is shown below. The cost to run the heat pump system will be similar to the existing gas-fired system, and the project is expected to recoup its capital cost in approximately 16 years.

Item	Value	Units
Heat pump system rating	850	kW
Heat supplied by heat pump system	600,770	kWh/yr
Total project cost (ex. VAT)	**-£916,627**	
Units of heat per unit of electricity (SPF)	4.08	
Electricity price	15.1	p/kWh
Existing fuel price	3.2	p/kWh
RHI rate	6.98	p/kWh
RHI annual payments	**£41,934**	
RHI period	20	years
Annual cost to run existing heating system	-£23,210	
Annual cost to run heat pump system	-£23,176	
Annual fuel saving	**£35**	
Payback period	-	years
Project IRR (20 years)	-	
Potential annual carbon saving	110,566	kg CO2e

Based on current fuel prices and the initial estimates above, the project would not quite pay for itself within its lifetime. To achieve project payback within 20 years, the capital cost would need to be reduced to £830,000. This may be possible, particularly if further work demonstrates that a slightly lower system rating would be sufficient.

Please also note that the cost of replacing the existing gas boilers has not been taken into account.

Carbon footprint
The current government conversion factors for greenhouse gas reporting are:

- Natural gas 0.1840 kg CO2e / kWh (gross CV)
- Electricity 0.2556 kg CO2e / kWh

The existing carbon footprint is estimated as 110,566 kg CO2e. By switching from gas to heat pumps using a standard electricity tariff this would reduce to 40,198 kg, a reduction of more than 60%. Alternatively, a 100% renewable tariff could be used (at additional cost) to eliminate the carbon footprint entirely.

Summary & next steps

Key findings

Ebley Mill has a total peak heat demand, after gains, of approximately 850 kW. The building is heated during weekday daytimes only, with an overall annual heat demand of approximately 600,770 kWh in 2019.

Our initial assessment of emitter specification suggests that the peak demand may be lower than 850 kW. To resolve this difference, a more accurate model of heat demand may be required, in particular to account for intermittent heating.

The existing heating system consists of five gas-fired boilers with a total rated output of approximately 945 kW, in addition to electric convector heaters in the council chamber. All hot water is electrically heated at the point of use.

The adjacent canal and river both provide opportunities for installation of a water-source heat pump. This could be an open-loop system, abstracting water via a series of pumps, filters and intermediate heat exchangers, or a closed-loop system using stainless steel heat exchange panels.

Due to the lower maintenance requirements and ease of consenting, we recommend a closed-loop installation, with panels fixed onto the river bed using ground anchors. Collector pipework would then lead through the building to the proposed plant room, which is the existing boiler house in Bodley Block.

The heat pump system would provide all space heating requirements for the building, with a recommended flow temperature of 50°C to ensure a high system efficiency, providing around 4.1 units of heat per unit of electricity. This will require replacement of most radiators throughout the building, either with higher output traditional radiators or low-temperature fan-assisted radiators.

Ideally the New Block heating circuit would be connected to the Bodley/Long Block circuit, so that the heat pump system works entirely from the plant room in Bodley Block. Alternatively, a separate heat pump system with separate collector circuit could be installed in the New Block boiler room.

A bivalent system was considered, which would retain the existing gas boilers for use during cold weather. However, this arrangement would not improve the project payback and would significantly reduce the carbon savings, so is not recommended unless there is a strong driver to minimise capital costs.

The total project cost is estimated at approximately £917,000. Based on current fuel prices and the initial estimates above, the project would not quite pay for itself within its lifetime. To achieve project payback within 20 years, the capital cost would need to be reduced to £830,000. This may be possible, particularly if further work demonstrates that a slightly lower system rating would be sufficient. Please also note that the cost of replacing the old boilers has not been taken into account.

A CO_2e saving of up to 110 tonnes per year could be achieved, which would be a significant contribution to reducing the council's carbon footprint. The project would also pave the way for further similar installations at other buildings within the Stroud area.

If the council wishes to carry out this installation, it is critical that the project should be developed quickly in order to secure the highest possible RHI rate. To minimise the effects of RHI degression, consents for the project would need to be obtained during the Jul-Sep tariff period.

Next steps
To obtain additional real data on the building heat loss and emitter outputs, we will test the heating as described in the 'building details' section above. This will provide useful data to validate the heat demand estimates.

The following step would be detailed design, starting with using a building physics software package to model the heat demand in greater detail, including a more accurate representation of how factors such as intermittent heating and solar gains affect the heat demand.

If preferred, this software modelling could be completed as a standalone item prior to the main design and build contract. The benefit of this would be to identify whether the overall project finances can be improved, before entering the formal tender process. However, if the project finances are acceptable, it would be simpler to include this step as part of the design and build contract, providing there is flexibility to allow the installation scale to be varied as required.

The project timeline is expected to be as follows:

Jun 2020	Detailed design & consent applications
Sep 2020	Consents granted
Sep 2020	Stage 1 Ofgem application
1 Oct 2020	*RHI degression (if Stage 1 Ofgem application not submitted)*
Oct 2020	Stage 2 Ofgem application*
Nov 2020	Completion of remaining design work
Dec 2021	Place order for main components
May 2021	Installation & commissioning
May 2021	Stage 3 Ofgem application

**please note that arrangements for project financing need to be finalised by this point.*

We feel this report demonstrates that the project will provide significant environmental benefits whilst also repaying the vast majority of its installation costs. We hope to work with you to deliver the remaining stages of this project.