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Port Mill

Water-source heat pump feasibility study

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Introduction

Executive summary

This report summarises the feasibility of a water-source heat pump installation at Port Mill. The site is due for redevelopment shortly, which will require the plant room to be relocated, providing an opportunity to upgrade and decarbonise the heating system.

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% (27-46 tonnes per year) with a payback period of 14.5 years. 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.

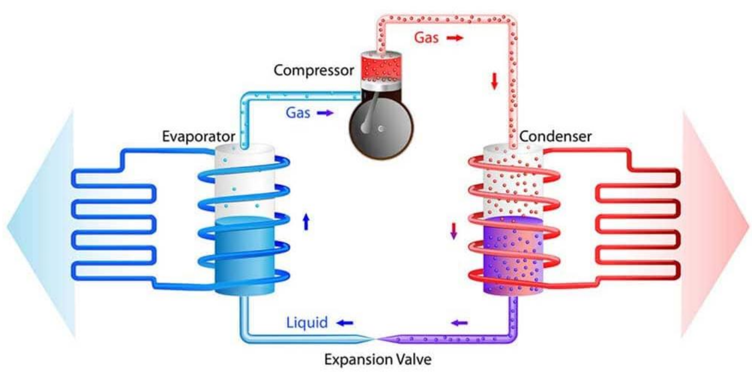
Heat pump technology

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 water bodies 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 not recommended.

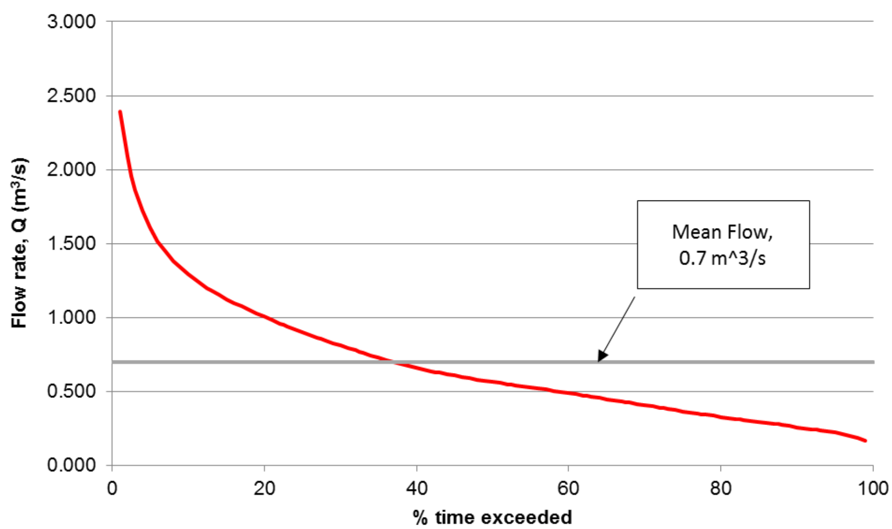
Resource

Watercourse flow
The Frome was gauged at Chalford during 2005-8, with mean flow 0.34 m^3/s and catchment size 57.5 km^2. Using this, the 76 km^2 catchment at Brimscombe Mill gives an estimated mean flow of 0.45 m^3/s. However, no recent information could be found on this gauging station, which may have been discontinued.

The Frome has been gauged at Ebley Mill since 1969, with mean flow 2.59 m^3/s and catchment size 198 km^2. Using this, the 76 km^2 catchment at Brimscombe Mill gives an estimated mean flow of 0.99 m^3/s. Due to the long measurement period this is considered to be more accurate.

We estimate the mean flow at the site as 0.7 m^3/s +- 0.2 m^3/s. Figure 2 shows the flow duration curve.

Figure 2 – Flow duration curve

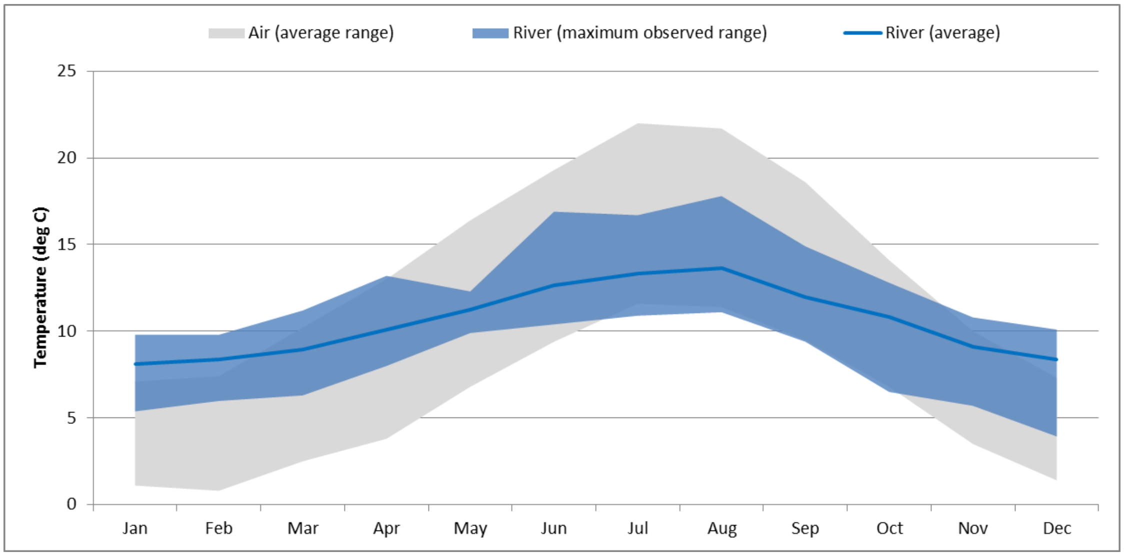


Environment Agency guidance stipulates a maximum drop in river temperature of 2 degrees. The graph above indicates that the lowest flow expected at the site is around 0.2 m3/s. This is the 'Q99' flow i.e. will be exceeded 99% of the time. Reducing 0.2 m^3/s by 2 degrees would yield around 840 kW. It 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.

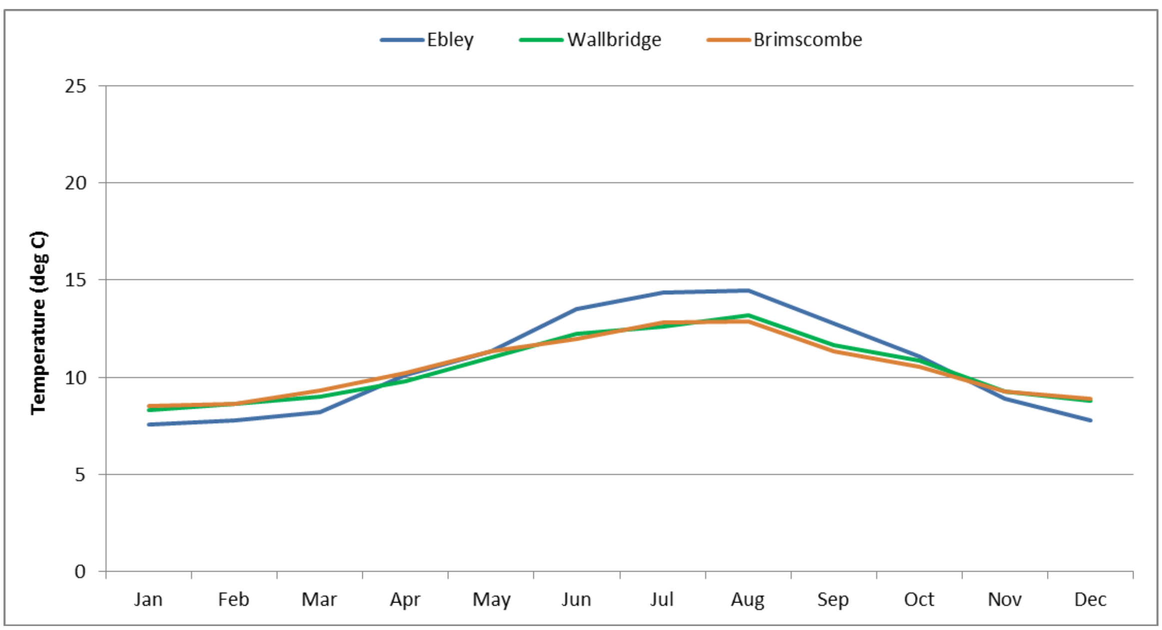
Parameter	Data type	Source	Period	Location
Air temperature	Daily min/mean/max	Met Office	1981-2010	Cirencester
River temperature	Spot measurements	EA 'WIMS'	2000-2015	Ebley, Brimscombe, Wallbridge

Figure 3 – Local temperature data



As shown in Figure 4, more extreme temperatures are seen at Ebley than at Brimscombe and Wallbridge. This may be due to contributions from the Painswick and Nailsworth streams, or site-specific factors such as shading.

Figure 4 – Comparison of average river temperature by location

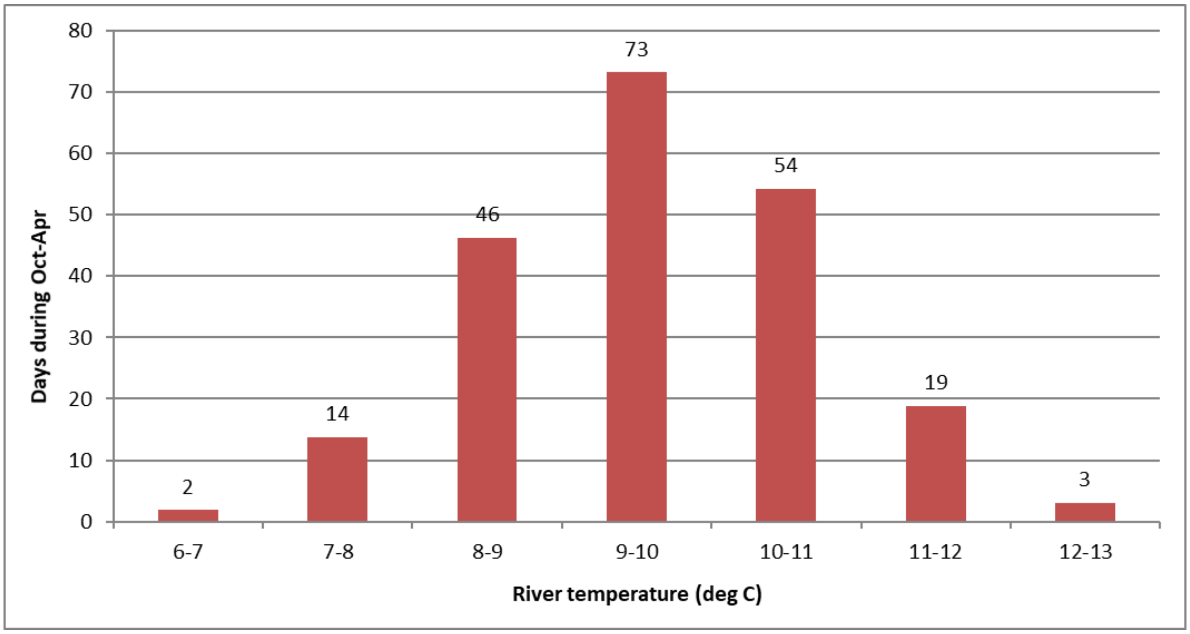


Of the readings taken at Brimscombe, the lowest temperatures recorded are:

Date / time	Temperature (C)
08/01/13 10:55	6.80
04/02/09 11:55	7.17
09/01/09 15:10	7.33

In summary, the local temperature data show that river temperature often falls to around 7 degrees C during Dec-Jan. Using a Gaussian model, we estimate that the following distribution on average during the main heating period:

Figure 5 – River temperature: days per heating season (Oct-Apr)



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 coefficient of performance are given later in this report.

As the river is relatively fast-flowing, it is well-mixed and there is no significant variation in water temperature across the site. This was confirmed by on-site measurements during summer 2019.

Building details

Construction
'Port Mill' or 'The Mill', dates from the early 19th century when it was used as a cloth mill. It is Grade II listed both for architectural reasons as a high-quality stone-built mill and for historic reasons given its background in local canal and textile traditions.

The building has three storeys with three main sections:

East wing	Next to the river (11 x 15 m)
South wing	Extends to the SW (24 x 9 m)
West wing	Extends to the NW (21 x 11 m)

Total floor area including communal areas: 1,800 m^2
Total volume including communal areas: 5,400 m^3

The limestone walls are around 450 mm thick and include large single-glazed windows with small panes and metal frames. The building has a suspended floor and a pitched slate roof. Approximately 200 mm of insulation (conductivity 0.044 W/mK) was recently fitted across most sections of the floor of the roof cavity, which would give it a theoretical U-value of around 0.2. However, there are several uninsulated sections used as walkways or for storage, so in practice the U-value may be higher than this. It is unclear whether there is also a gap below the boarded floor in the roof cavity, which could lead to significant ventilation losses.

An EPC assessment was carried out in 2009 and returned a D rating.

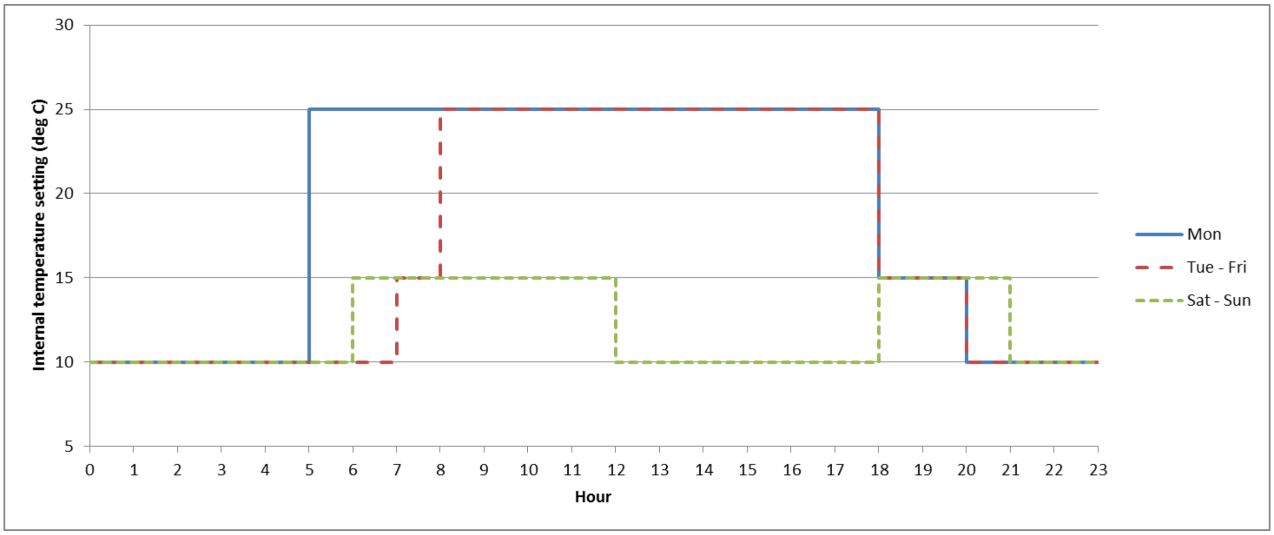
The Brimscombe Port area is planned to be completely redeveloped, with construction expected to start in the next 1-2 years. As a result, the plant room location will need to be moved, providing an opportunity to make cost-effective improvements to the heating system.

Heating system
The plant room is currently situated in 'The Old Port House', a separate building north-east of the main building entrance. This building will be demolished; the plant room will be moved to the main mill building, exact location to be confirmed.

Existing heating equipment:

Equipment	***Specification***	***Notes***
Gas boilers	*3 x 120 kW* Strebel S-CB boilers (gas) Manufacturer's gross seasonal efficiency 96% EESI Ltd 2016 test gross efficiency 88%	Flow temperature 75C
Hot water heater	19.5 kW Andrews RFF 190 Manufacturer's gross efficiency 63% EESI Ltd 2016 test gross efficiency 82%	Flow temperature 50-55C
Radiators	High temperature Mostly 40 x 110 cm 1p / 60 x 160 cm 2p All radiators fitted with TRVs	Approximately 15 kW total output per office
Control system	Dated system No zoning controls Internal and external temperature sensors	Location of internal sensor unclear Weather compensation set to ON/OFF only Heating pattern shown in figure below

Figure 6 – Existing heating control pattern



Heat demand

Occupancy

The building was recently fully occupied with the exception of the ground floor west wing, with approximately 60 staff working full-time Mon-Fri (max. occupancy 120). Currently, only the east and south wings of the ground floor are occupied. All communal areas are heated with the exception of the rear stairwell, where The Chapel adjoins the main building. The Chapel has a separate heating system.

Hot water demand

The peak hot water demand is estimated as 19.5 kW in line with the existing hot water heater.
The average hot water demand is estimated as:

Occupancy	Usage (litres/day)	Temperature rise (deg)	Daily usage (kWh)	Working days per year	Annual usage (kWh)
60	8	45	25	253	6,325

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 (occupancy = 60):

Item	**Number**	**Unit heat gain rate (W)**	**Total heat gain rate (kW)**
Lighting in use	(500 m^2)	(20 W/m^2)	10.0
Computers in use	70	100	7.0
Occupants	60	90	5.4
Fridges	6	150	0.9
Photocopiers in use	1	800	0.8
Printers in use	4	100	0.4
TOTAL			**24.5**

Solar heat gain rate (winter average):

Aspect	Area (m^2)	Number	Unit heat gain rate (W/m^2)	Total heat gain rate (kW)
NE/NW-facing	2.1	15	39	1.2
SE/SW-facing	2.1	18	60	2.3
TOTAL				**3.5**

Fabric heat loss rate:

Element	Description	Area (m^2)	U-value (W/m^2K)	Heat loss rate (kW/K)
Windows	Single pane, metal frames	179	5.2	0.93
Walls	450mm limestone	1395	1.4	1.95
Roof	200mm insulation (80% coverage)	603	0.3	0.18
Floor	Suspended timber	574	0.5	0.29
Doors	Solid wood	24	2	0.05
TOTAL				**3.40**

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, using degree-day analysis.

Degree-day analysis explained

Degree-day analysis is a method for estimating energy demand (kWh) over a certain period using external temperature data. During each day, the number of degrees C of heating required changes as the external temperature changes. This heating requirement is summed up across the day, with units of 'degree-days'.

Due to casual and solar gains, the heating requirement can be zero even if the external temperature is slightly below the target internal temperature. The external temperature at which the rate of casual and solar heat gain equals the heat loss rate is called the 'base temperature'. At this site the total heat gain rate is 28 kW and total heat loss rate is 9.1 kW/K. Using the proposed internal 'high' temperature of 21 C, this means the base temperature is 21 – (28 / 9.1) = 17.9 C.

Degree-days are then calculated relative to the base temperature, and multiplied by the total heat loss rate (14.4 kW/K) to give a total energy demand figure in kW-days. This is multiplied by 24 to give the result in kWh.

Please also note:

- The ground floor west wing (L0 west) was unoccupied during the period of gas bills reviewed. When matching the model with historical data, the effect of this empty office was approximated by ignoring heat losses from this area.
- A gas-to-heat efficiency of 90% was assumed
- 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 3.2, as shown in Figure 7.

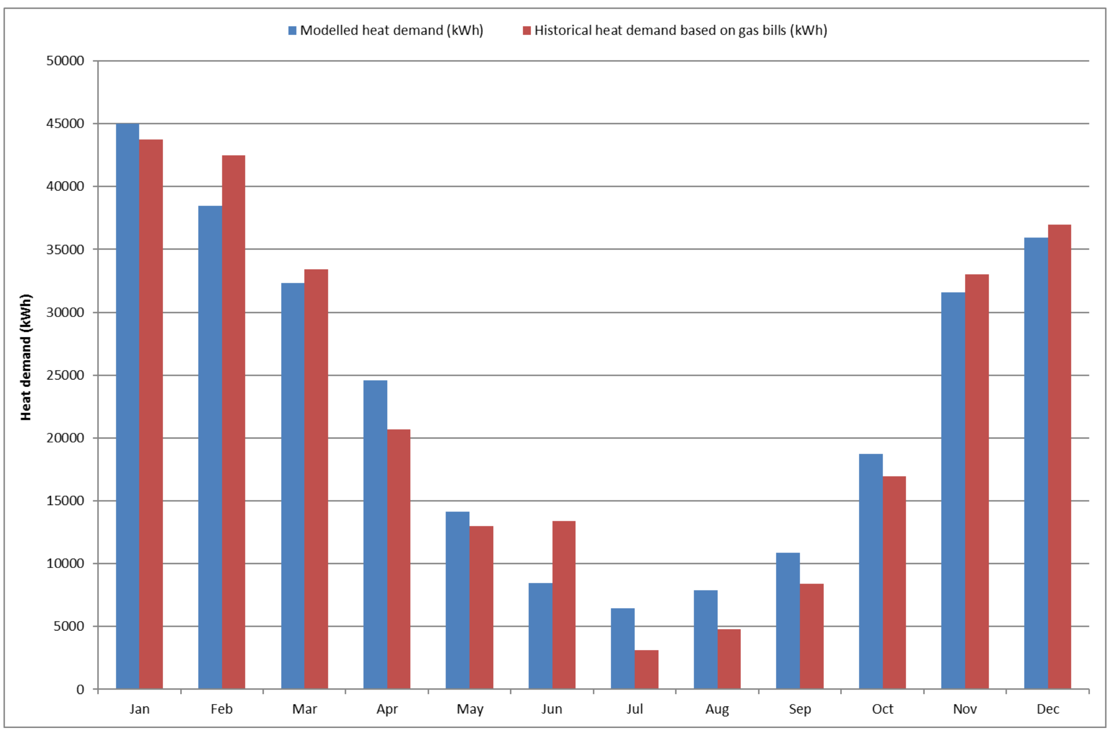
The low historical usage in Jul-Sep may be due to underestimation of solar gains, which were modelled using typical winter values. The high historical usage in June is likely to be an anomaly as the gas bill in June 2013 was particularly high.

Including heat losses in L0 west in this model (i.e. assuming this area is occupied), the overall peak space heating demand is 265 kW, based on an internal temperature of 25C and external temperature -4C. Setting solar gain to zero (which is conservative) and subtracting 25 kW of casual gains, the net peak space heating demand is **240 kW**. This is noticeably lower than the capacity of the existing boilers, which is 320 kW. There are two likely reasons for this:

1. A larger capacity has been used to reduce warm-up times
2. The boilers have been over-sized as a contingency measure

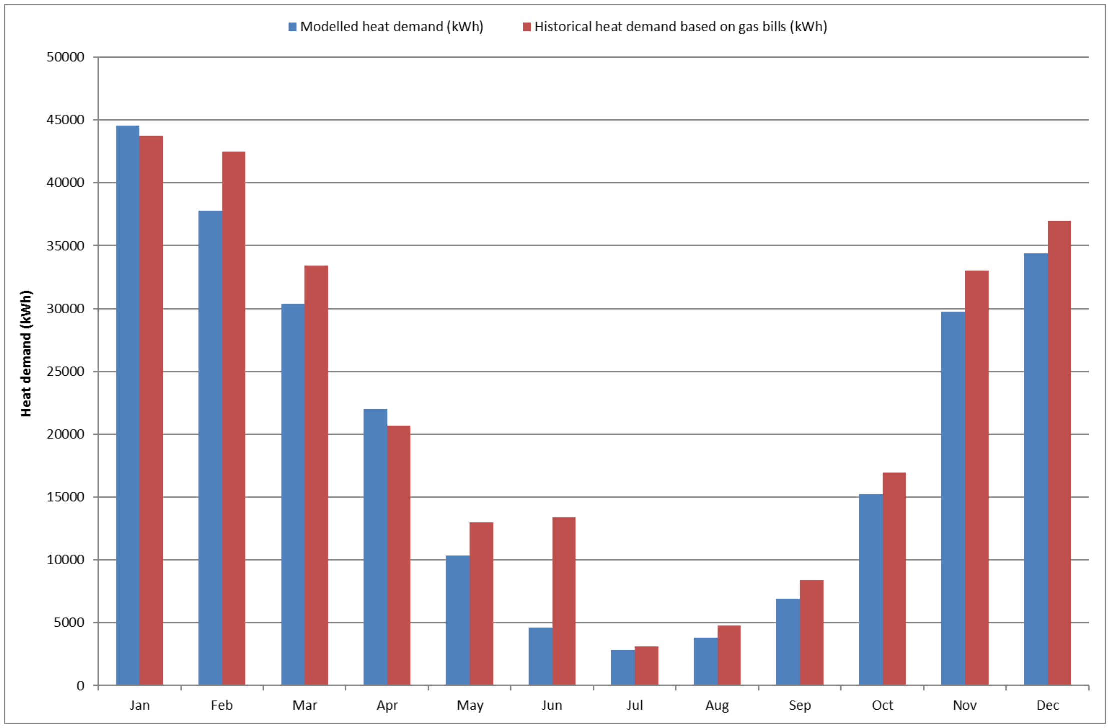
To demonstrate the first point: the overall heating system has a volume of around 1,500 litres. Heating from 10C to 75C at 150kW would take approximately 45 minutes, so a larger capacity of around 300kW would arguably be worthwhile to reduce the warm-up time to 23 minutes.

Figure 7 – Existing monthly heating profile



The predicted future heating profile was adjusted slightly to set the 'high' internal temperature to 21C instead of 25C. All offices were assumed to be heated, including L0 west, with the occupancy remaining at 60. All other factors were unchanged. This gives the modelled heating profile as shown in Figure 8.

Figure 8 – Predicted monthly heating profile



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

Section	Fabric (kW/K)	Ventilation (kW/K)	Total (kW/K)	Total (kW)
L0 east	0.25	0.27	0.52	13
L0 south	0.42	0.56	0.97	24
L0 west	0.35	0.62	0.98	24
L0 communal	0.17	0.38	0.56	14
L1 east	0.24	0.34	0.59	15
L1 south	0.38	0.59	0.97	24
L1 west	0.27	0.63	0.90	22
L1 communal	0.11	0.40	0.51	13
L2 east	0.28	0.39	0.66	17
L2 south	0.44	0.60	1.04	26
L2 west	0.37	0.62	0.99	25
L2 communal	0.12	0.32	0.43	11
TOTAL:	**3.40**	**5.73**	**9.13**	**228**

As shown above, the predicted peak space heating demand is 228 kW, based on an internal temperature of 21C and external temperature -4C. This figure ignores any gains so overestimates the actual demand. Subtracting casual gains (but ignoring solar gains, which are intermittent), the net peak space heating demand is **204 kW**. The total including hot water requirements is therefore **224 kW**.

Summary of heating demand

		Existing		Proposed
L0 west status		Unoccupied	Occupied	Occupied
Maximum internal temperature (C)		25	25	21
Space heating	**Annual (kWh)**	274,100	307,000	242,300
	Peak (kW)	212	240	204
Hot water	**Annual (kWh)**	6,300	6,300	6,300
	Peak (kW)	20	20	20
TOTAL	**Annual (kWh)**	280,400	313,300	248,600
	Peak (kW)	232	260	224

As discussed above, the ventilation rate has been estimated by matching the model to historical gas bills. These bills show a consumption of around 319,000 kWh per year. Applying a 90% efficiency reduces this to 287,500 kWh delivered in total, of which 6,300 kWh is hot water and 281,200 kWh is space heating. There may also be a small amount of additional heat loss via pipework in the plant room or other unheated areas.

Emitters

Theoretical radiator outputs for part of the property are shown below. Each radiator type is categorised according to the number of panels (p), number of convectors (c) and its dimensions.

Type	**1p 1c**	**1p 1c**	**1p 1c**	**2p 2c**	**2p 2c**	**1p 1c**	**2p 2c**	**2p 1c**	**1p 1c**	
Height (m)	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.60**	**0.60**	**0.46**	**0.60**	
Length (m)	**1.20**	**1.49**	**1.64**	**1.20**	**1.49**	**1.65**	**1.65**	**1.49**	**0.88**	
										TOTAL
L0 south										
Number	7		5							
Power (kW)	7.60		7.42							**15.0**
L0 west										
Number		2		3	3					
Power (kW)		2.70		5.56	6.91					**15.2**
L0 com.										
Number						1	2	1	1	
Power (kW)						1.85	6.32	1.91	0.99	**11.1**

Based on these figures, the radiators appear to only be capable of delivering approximately 150 kW across the property. However, in January 2020, a test of the heating system was carried out to provide further information on this. The results suggested that the radiators are capable of emitting a greater output and are unlikely to be a significant limiting factor in heat delivery for the building.

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 will be reduced to 21C. As shown above, this will reduce the space heating demand by approximately 27,000 kWh or 10%.

We estimate that over 60% of heat losses in the building are via ventilation, so infiltration testing and draught-proofing is recommended. A reduction in air change rate of 25% would reduce energy usage by around 15%. Other improvements that should be considered include secondary glazing, with panels fitted inside the window alcoves, and additional loft insulation, particularly to fill any gaps.

No 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.

Using the existing radiators with a flow temperature of 45C instead of 75C would reduce their output by approximately 70%. Whilst the existing radiators at 75C can maintain an internal temperature of 21C during an external temperature of around 2C, reducing the flow temperature to 45C would mean the heating is insufficient below 13C.

Replacing the radiators with low-temperature models is relatively straightforward. The existing 460 x 1200mm 1p1c radiators provide around 1086 W at a flow temperature of 75C; a low temperature model (Jaga Strada DBE) measures 500 x 1000mm and provides 1143 W at 45C. Low-temperature radiators also warm up much more quickly than traditional steel radiators.

The number and size of emitters does not need to change significantly as a result of the heat pump installation. The new radiators will be able to transmit the full output from the heat pump.

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.

If a bivalent system is used, there will be a certain external temperature below which the heat pump is insufficient and backup heating is required. There will also be a certain temperature at which the backup heating would be more cost-effective.

In terms of cost, even at very high flow temperatures the heat pump will provide a COP of around 2, which corresponds to a running cost of around 7 p/kWh. Including the RHI, the effective running cost is around 4 p/kWh. It is therefore likely that using the heat pump will always be cheaper than using the gas boilers, at least during the RHI period.

To ensure the maximum possible carbon reduction, we recommend heating the building entirely using heat pumps. Three 75 kW heat pumps would have an actual output of 225 kW (@ river 6C) and would provide 100% of the annual heat usage. The actual output would also be noticeably more at around 270 kW. This arrangement helpfully also avoids the need for a new gas supply in the relocated plant room.

We recommend specifying an additional smaller heat pump to provide hot water for the site. Although the existing heater is rated at 19.5 kW, a slightly lower rated capacity may be suitable. For example, the Kensa Evo 15 kW has a higher COP than larger models but can still provide 18.8 kW at 50C and a lower output at up to 63C.

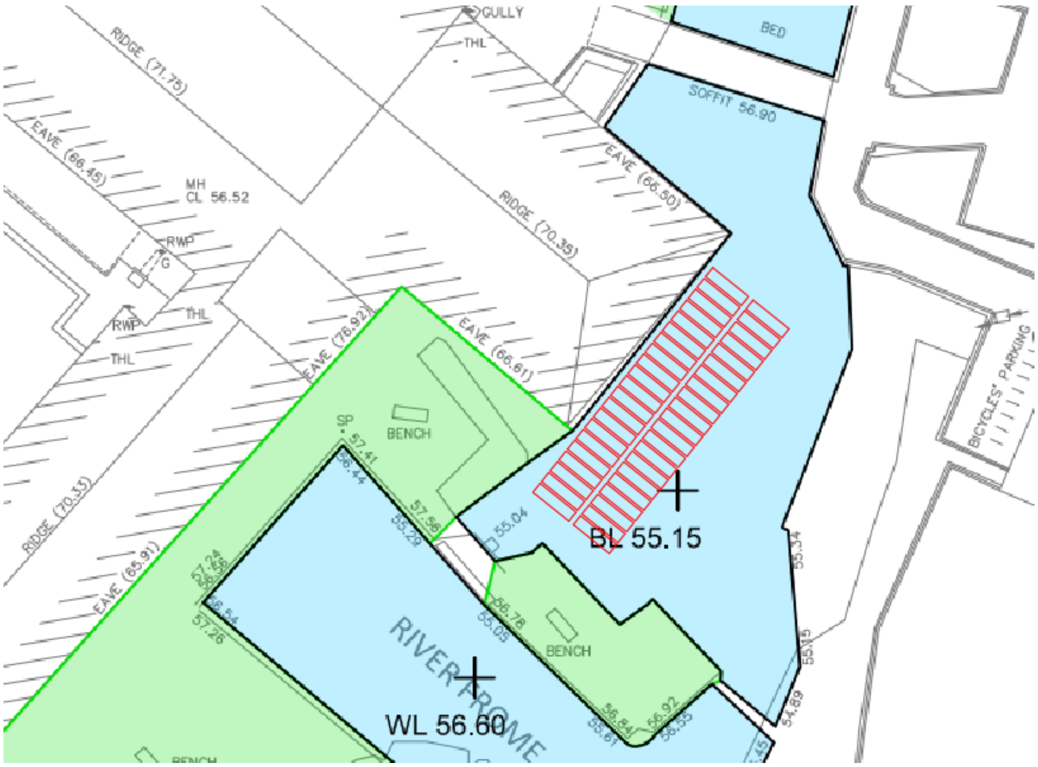
Collector specification
There are two types of heat collector commonly used for water-source heat pumps: HDPE 'pond mats' and steel flat plate collectors. In this case, we recommend the use of flat plate collectors, which are smaller and better-suited to sites with flowing water.

Some flat plate collectors (e.g. 'SlimJim') consist of several plates mounted vertically on a single frame. Whilst these have a small footprint, we would recommend that flat plates are mounted against the channel bed or walls only, to avoid ongoing maintenance issues due to debris.

We are currently prototyping and testing a flat plate heat collector that can be mounted in this way, which will enter the market shortly. Our results indicate that the collector plates will provide approximately 6 kW per m^2, based on a 6C river temperature and the typical river speed at the site of 0.1-0.2 m/s. Therefore, to provide 225 kW a total collector area of approximately 40 m^2 would be required.

An example layout is shown in Figure 9. This avoids interaction with the Brimscombe Port redevelopment.

Figure 9 – Suggested collector layout



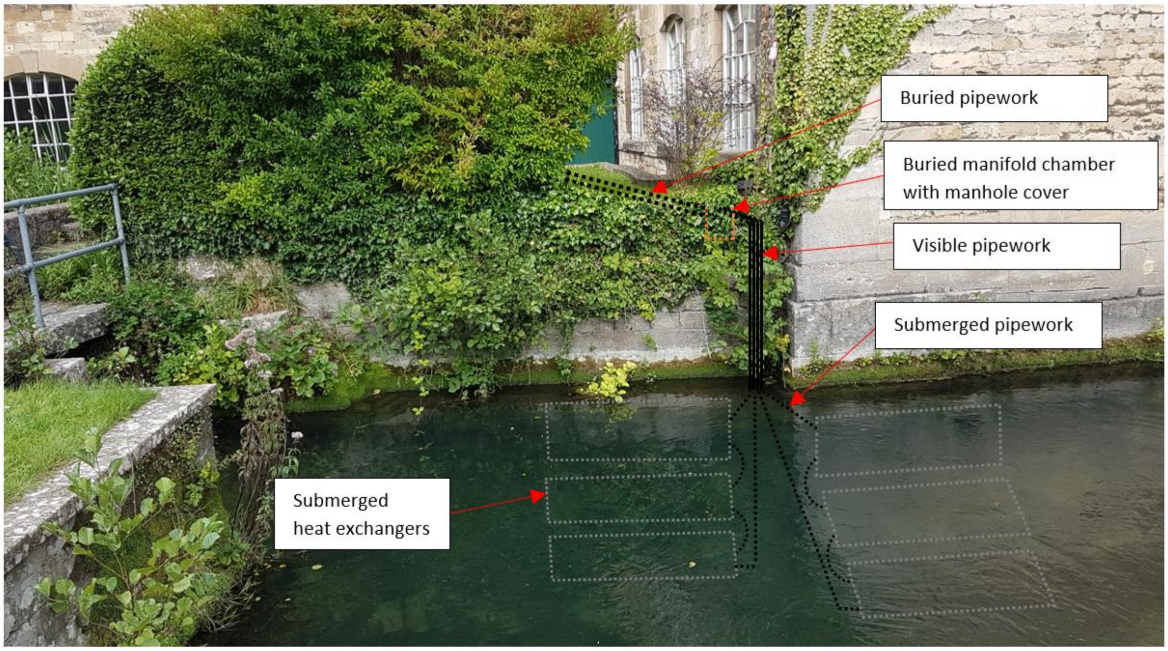
The overall collector loop flow rate would be approximately 10 litres/second. The flow rate through each collector plate should be approximately 1 litre/second; the plates would be arranged into ten groups accordingly. Within each group the collectors would be connected in series, whilst overall the groups would be connected in parallel.

The collectors will be mounted on a steel frame and secured using ground anchors.

If the collector footprint is considered too large, an alternative is to use an open-loop heat pump system. These are uncommon as they require intake filters and an additional heat exchanger that needs to be maintained and replaced quite regularly. However, the visual impact would be smaller. An abstraction rate of around 13 litres per second would be required. This has not been considered further in this report.

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. An example routing is shown below:



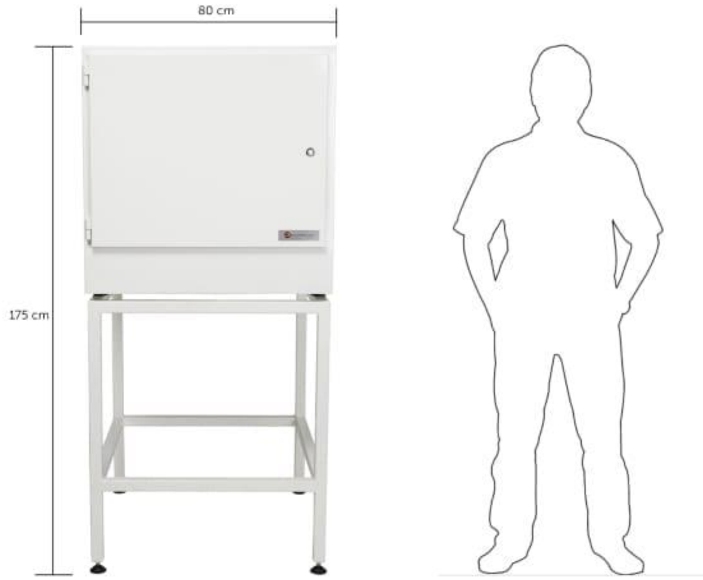
Suggested pipe diameters and pressure loss calculations are as shown below. The power required for circulation pumping is discussed later in this report.

Element	**Flow rate**	**Pipe OD**	**Flow speed**	**Length**	**Pressure drop**
	l/min	mm	m/s	m	mWs
Collectors					2.55
Pipes to manifold	60	40	1.2	15	1.95
Manifold to plant room	600	110	1.6	25	1.30
Elevation changes					3.00
Additional bends/fittings					1.50
				TOTAL	**10.30**

Grid connection

The new plant room area will be in the main mill building, exact location to be confirmed. To minimise circulation pumping, it would ideally be on the ground floor. Heat pumps are a similar size to gas boilers: a 75 kW heat pump is shown below as an example:

Figure 10 – Heat pump size diagram



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. A 225 kW heat pump system would require approximately 75 kW.

Metering

Electricity is currently metered both for the site as a whole and also individually for each tenant. Heating is not currently re-billed to tenants individually. If this general arrangement continues, the council would pay for the electricity required to run the heat pump and would also receive the full benefit of the RHI payments. However, other charging structures could be considered.

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

Control system

A dedicated control system will be provided by the heat pump manufacturer. We recommend adjusting the 'high' internal temperature setting to 21C and using weather compensation that adjusts flow temperature based on the external temperature.

Predicted performance

The performance of the heat pump system is shown below, based on 3no. Kensa P750-H with a total rated capacity of 225 kW. This assumes heating to 45C and ignores any auxiliary power requirements such as circulation pumping.

River temperature (C)	Heat power output (kW)	Coefficient of Performance (COP)
6	270	3.72
8	288	3.90
10	308	4.07

This shows that the heat power output will generally be significantly above the nominal rated capacity. Based on the minimum river temperature of 6C, a nominal heat pump rating of 225 kW would actually deliver 270 kW output.

The seasonal coefficient of performance (SCOP) for the heat pump across the year is estimated as 3.8. This reflects the stable river temperature at 9-10C, but also that the heat pump may be required to operate slightly above 45C in order to achieve 45C at the radiators, due to heat losses, cold water mixing and so on.

The circulation pumping requirement, based on the pressure drop stated above, is estimated as 2.1 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 11%. This equates to 2,100 kWh for circulation pumping. The total heat delivered is around 242,300 kWh, so if this is done at a SCOP of 3.8 the electricity used for the heat pumps is 63,800 kWh. Adding circulation pumping increases the electricity usage to 65,900 kWh, bringing the SCOP to 3.7. This adjusted figure is usually instead referred to as the seasonal performance factor (SPF).

There will be some additional auxiliary loads that will reduce the SPF a little further, however these are relatively minor so have not been assessed here. The overall SPF is estimated as 3.5.

Environment & consenting

Environmental impacts

During installation, the river bed will be 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 and channel walls, but will not present any physical obstruction. The total area occupied is small at around 40 m^2 only, so any impact on habitats would be very limited.

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 Q99 flow of around 0.2 m^3/s, the maximum heat extraction rate of 225 kW would reduce the average river temperature by less than 0.3 degrees.

The thermal transfer fluid within the collector plates is typically non-toxic ethylene or propylene glycol. Both were recently confirmed 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 EA was contacted to confirm the relevant fee; the relevant activities are likely to fall under categories 1.1.2 and 1.1.3, with total fee £501.

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

Planning permission

Although the building is listed, due to the very minor impact on the listed structures it is likely that the project would be considered to be permitted development. The impact on the building itself would be limited to a small number of pipework entries. The visual impact as viewed from the adjacent footpath would be very minor: the collectors will be visible on the river bed but will be inconspicuous and will not affect the character of the building.

A response to our request for pre-application advice was received in October 2019. The project is deemed to not require full planning consent, however Listed Building Consent would be required.

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)

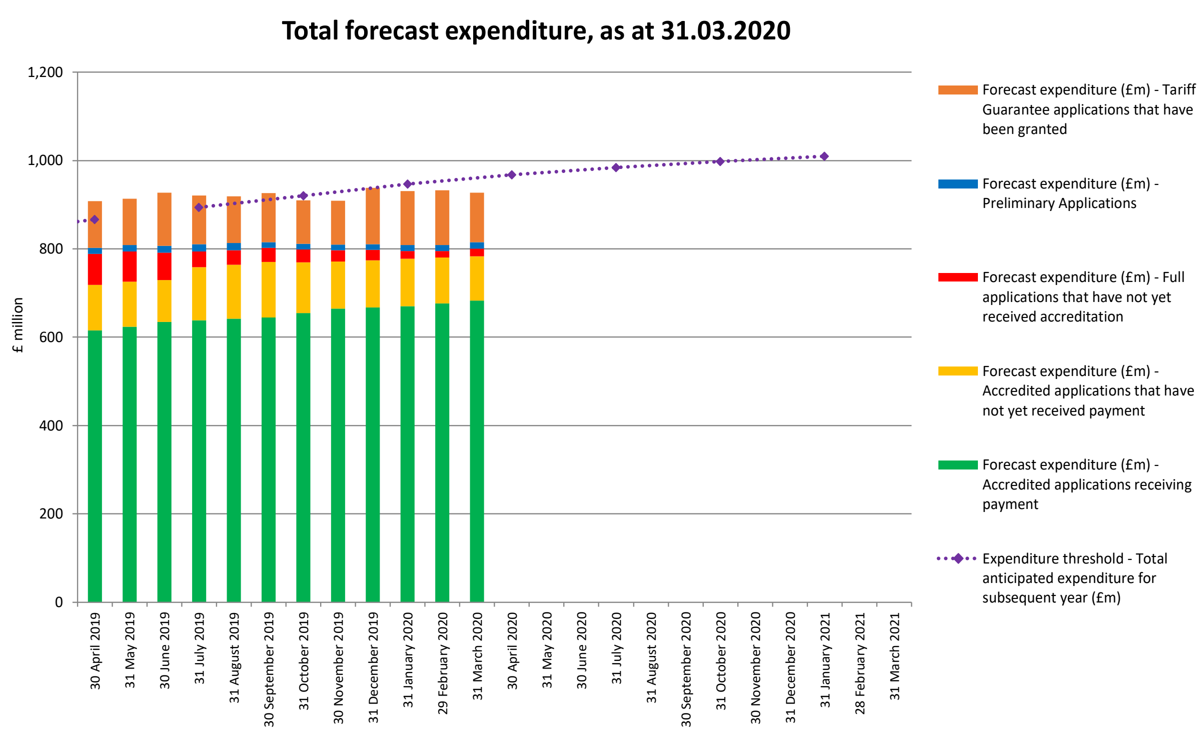
Stage 3 application:
- To be made upon commissioning

<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.



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	Unit price	Qty	Price
75 kW plant room heat pump	£17,237	3	£51,711
15 kW Evo heat pump	£7,875	1	£7,875
400L hot water cylinder	£1,460	1	£1,460
Collector pipe 40mm PE100 SDR11 HDPE, 100m	£237	3	£711
Other fittings (reducers, elbows, etc)	£485	1	£485
Subterranean manifold	£1,365	1	£1,365
Anti-freeze drums, 25L	£97	30	£2,910
Circulation pumps	£2,000	3	£6,000
Header pipe 110mm MDPE, 50m length	£405	1	£405
1000L two-connection buffer tank	£2,850	1	£2,850
Flat plate heat collectors with mounting frame	£1,220	38	£46,360
Heat & power metering	£1,960	1	£1,960
Low-temperature emitters	£750	100	£75,000
Detailed design & consenting	£25,000	1	£25,000
Installation & commissioning	£28,000	1	£28,000
RHI application	£950	1	£950
Contingency		*15%*	*£37,956*
TOTAL			**£290,998**

The heat pump and emitter parts of this costing are based on quotes received from Kensa and Jaga, partly previous quotes for this project and more recent quotes for another project we are working on. The price for collector plates is a budget estimate at this stage.

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 has an expected lifetime of 20-25 years.

The costs above do not include any distribution-side works, such as works to relocate the plant room.

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.

Both space heating and hot water production are eligible for RHI payments, so the total eligible amount is estimated as 248,600 kWh. The overall system, totalling 245 kW installed capacity, has an estimated capacity factor of 11%. The installation will therefore make full use of the higher RHI rate.

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

Running costs
Gas supply is currently via Total Gas & Power with a unit price of 4.402 p/kWh. The climate change levy (CCL) applies at the 2019 rate 0.339 p/kWh. Based on the reduced demand of 248,600 kWh, gas heating would cost around £11,780 per year.

The current cost for electricity is around 11.3 p/kWh. The climate change levy (CCL) applies at the 2019 rate 0.847 p/kWh. Based on a seasonal performance factor (SPF) of 3.5, the electrical demand for a heat pump system would be 71,000 kWh at a cost of around £8,630 per year.

The heat pumps do not require any more maintenance than the existing gas boilers require, so no additional allowance has been made for this. However, a small sum of £450 per year has been estimated for performance monitoring and any minor maintenance of the collector plates.

The effective income by comparison of gas and electricity costs would therefore be £2,700 per year. In addition to this, the project would receive RHI payments of approximately £17,350 per year, giving an overall effective income of around £20,050.

Financial return
The initial outlay of £290,998 is offset against an effective income of £20,050. The resulting payback period is 14.5 years with a 20-year project IRR of 3.3%.

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

- Natural gas 0.1839 kg CO_2e / kWh (gross CV)
- Electricity 0.2556 kg CO_2e / kWh

Based on the reduced heating demand, the carbon footprint is estimated as 45,750 kg CO_2e. By switching from gas to heat pumps this would reduce to 18,160 kg, a reduction of 60%. Alternatively, a 100% renewable tariff could be used (at additional cost) to eliminate the carbon footprint entirely.

Other benefits
In addition to the financial and environmental benefits of switching to a heat pump system, the heat pump system will also allow a certain extent of cooling, with minimal operational costs, by running the circulation pumps only.

Summary & next steps

Key findings
The building is currently heated to 25C, which with a typical occupancy of 60 results in a peak space heating demand of 240 kW. By reducing the internal temperature to 21C, the peak space heating demand is expected to reduce to 204 kW. In addition to the space heating demand is a hot water demand of up to 20 kW. This brings the total predicted peak heating demand to 224 kW.

The site is suitable for a water-source heat pump installation and is not constrained by the available heat resource in the river. Steel flat place collectors would be situated in the river, with pipework running to a new plant room location on the ground floor of the main mill building.

Any heat pump installation would require replacement of the radiators with low-temperature models, allowing a flow temperature of around 45C. This will be more cost-effective than using a higher flow temperature.

We recommend installation of a main heat pump system rated at 225 kW heat pump system, which would meet 100% of the space heating demand at the site. A further 15-20 kW heat pump is recommended for provision of hot water. This would operate using the same heat collector.

The total project cost is estimated as £290,998 + VAT with a predicted payback period of 14.5 years and 20-year project IRR of 3.3%. A CO2e saving of 60-100% of the building's heating (27-46 tonnes per year), 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 historic 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
The following step would be to begin the detailed design & consenting. We understand that this is likely to form part of a design & build contract.

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 being technically and financially feasible. We hope to work with you to deliver the remaining stages of this project.