

A modern office interior featuring a reception desk with a white top and wood base. The background wall is covered in vertical wood paneling. Three copper-colored, faceted pendant lights hang from a ceiling with a grid of recessed lights. Large windows on the left show an outdoor area with red planters. Two computer monitors are on the desk.

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Bringing buildings to life
QVS1 Reading
Low Zero Carbon (LZC) Study
WA0305-TBA-Q1-XX-RP-N-00003

15th July 2022

PROJECT
QVS1 Reading

PROJECT REF
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1.0 Introduction

This report investigates the feasibility of a number of low and zero carbon (LZC) technologies which could be used to support the evolving energy strategy for the proposed development at 138-144 Friar Street in Reading comprising of a new apart hotel and retail units. In line with the BREEAM scope set out in TBA-XX-RP-N-00002 QVS1 Energy and BREEAM Statement, the proposed building, with the exception of the listed part, is subject to a bespoke assessment under BREEAM RFO 2014.



Fig. 1 Location of proposed building within Reading

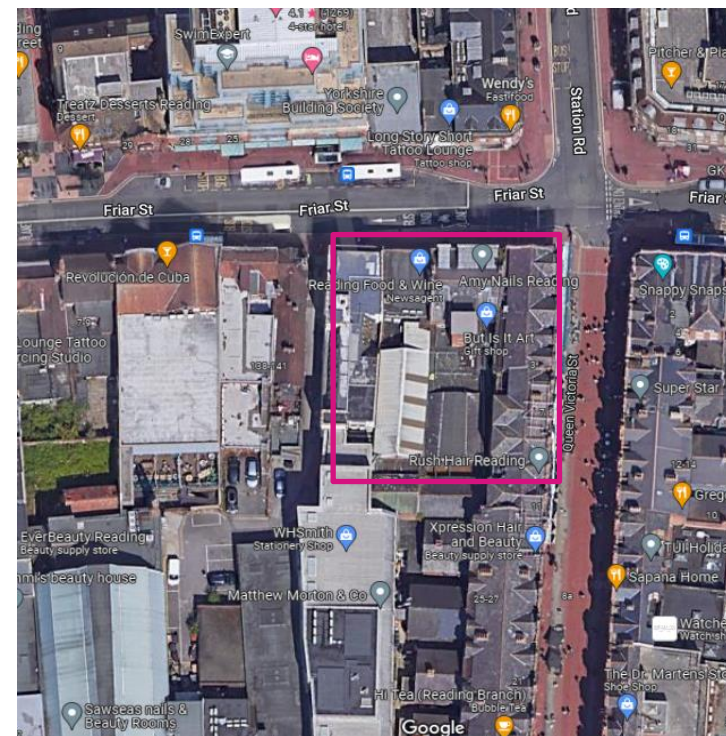


Fig. 2 Site boundary and proposed new buildings

This report has been structured in compliance with the BREEAM RFO 2014 Ene04 credit: 'Low and zero carbon feasibility study' and has been undertaken at RIBA Stage 1. In accordance with these standards the following is reported:

- A baseline energy strategy for the buildings – including its energy consumption, CO₂ emissions and an outline estimation of cost
- An overall assessment on the appropriateness of LZC technologies for the site
- Explanations for excluding a number of technologies are given in Appendix A
- Feasibility of exporting heat/electricity from the system
- For the technologies that are feasible the following is reported:
 - The energy demand of the development (see note below)
 - The annual energy provided by the LZC energy source
 - The expected carbon reductions from the LZC energy source
 - Site constraints
 - Noise impact
 - Payback
 - Whole life cost impact of potential specification in terms of carbon emissions
 - Any planning considerations
 - Any available grants/income schemes
 - Reasons for excluding other technologies

In order to satisfy the requirements of the BREEAM Ene 04 credit, it is recommended that the LZC technology specified for the building

should provide a 'meaningful' reduction in regulated CO₂ emissions. As a guide it is recommended that the specified LZC provides a minimum contribution of 5% of overall regulated CO₂ emissions for the building. This guidance will be taken into consideration when reporting on potential technologies assessed for this development.

Further investigation is recommended by the project team during the detailed design to assess the most practical way to accommodate the energy strategy chosen for the building, and in coordination with the designers and manufacturers, estimate the exact performance of the chosen system(s) in detail.

It is also recommended that a further detailed review of the anticipated thermal and electrical load profiles for the building is undertaken to confirm appropriate sizing and viability of LZC technology at this site.

The energy performance of the building was calculated using the Apache module of IES Virtual Environment 2021.

Policy drivers

The UK government has committed to sourcing 15% of its energy from renewable sources by 2020. UK100 Clean Energy Commitment has pledged to take appropriate action by shifting to 100% clean energy by 2050.

The Reading Borough Local Plan (2019) mandates that all major non-residential developments meet BREEAM Excellent and minor developments meet BREEAM Very Good. Non-residential developments over 1,000m² shall consider inclusion of decentralised energy provision within the site, unless it can be demonstrated that the scheme is not suitable, feasible or viable for this form of energy provision.

The Sustainable Design and Construction Supplementary Planning Document (2019) defines non-residential developments of > 1000m² as major (BREEAM Excellent).

Objectives

The report evaluates the suitability of LZC technologies to provide value to the development in terms of meaningful energy or CO₂ savings and economic viability. The review considers both the technical capacity of the technology, as well as existing site constraints and demand patterns of the building which may preclude the technology from operating at the site.

The following technologies were included for review:

- Air source heat pump
- GSHP
- Biomass
- Wind
- District Heating
- Solar Thermal
- Photovoltaic array
- Combined Heat and Power

All technologies listed above underwent an initial review of suitability for the site. Those deemed to be unsuitable for the site are briefly described in Appendix A with justifications as to why they were excluded from further consideration.

Appropriate sources have been referenced throughout this document in order to provide an outline estimation of costs associated with particular energy technologies, and to draw overall comparisons between strategies. However, as the costs provided are estimates, and are not directly linked to any particular product or manufacturer, they should not be used to gauge an accurate reflection of actual costs likely to be incurred but can be used to enable comparisons to be made.

2.0 Baseline scenario

Baseline energy strategy

The indicative energy strategy forming the baseline scenario for the building is as follows:

- Natural Gas boiler to provide LTHW space heating.
- Domestic Hot Water – Gas-fired water heaters
- Ventilation – MVHR to all spaces
- Cooling – DX cooling to all bedrooms, lobbies, restaurant
- Lighting – presence/absence detection throughout, daylight dimming to perimeter rooms

The assumed thermal performance of the main fabric elements is shown in Table 1. An air permeability of 5m³/h/m² was assumed for the whole building including the retained retail unit

	Building Element	U-value in W/m ² K
External wall	New Build	0.15
	Refurbished	2.1
Ground Floor	New Build	0.1
	Refurbished	1.2
Roof	New Build	0.1
	Refurbished	0.18
Windows	New Build	1.3
	Refurbished	1.8

Table 1 Fabric performance of baseline building

Baseline energy consumption and carbon emissions

The above strategy was the result of preliminary dynamic simulations using IES 2022 in order to optimise the passive design features for low energy consumption and CO₂ emissions. A breakdown of energy consumption and associated CO₂ emissions for the buildings is provided in Table 2. While BREEAM 2018 prescribes that the carbon factors from the prevailing Building Regulations are used, i.e. Part L (England), we have included a comparison with the SAP10.2 carbon factors which are more reflective of current carbon factors.

	Energy Consumption in kWh/a	CO ₂ Emissions			
		SAP10.2		Part L 2013	
		in kg CO ₂	in %	in kg CO ₂	in %
Heating	107,260	22,524	15%	22,524	12%
Hot Water	570,642	119,835	78%	119,835	65%
Cooling	3,788	515	0%	1,966	1%
Auxiliary	40,895	5,562	4%	21,224	12%
Lighting	35,114	4,775	3%	18,224	10%
Total	757,697	153,212		183,773	

Table 2 Predicted energy consumption and CO₂ emissions of the proposed buildings

BREEAM and Building Regulations Approved Document Part L2A 2013 only take into consideration 'regulated' carbon emissions of the building. This excludes any emissions associated with equipment. Energy and carbon emissions associated with the building's equipment usage have therefore been excluded from the calculations presented in this report.

Figs. 3 and 4 demonstrate the impact of the set of carbon factors on the relative CO₂ emissions. Under both SAP10.2 and Part L 2013, DHW is the biggest carbon emitter (78% and 65%, respectively) followed by space heating (15% and 12%, respectively under SAP10.2 and Part L 2013 and auxiliary (fan and pump, 4% and 12% under SAP10.2 and Part L 2013, respectively). Therefore, the most favourable LZC technologies will need to include heat generating LCZs for the

provision of space heating and DHW and electricity displacement.

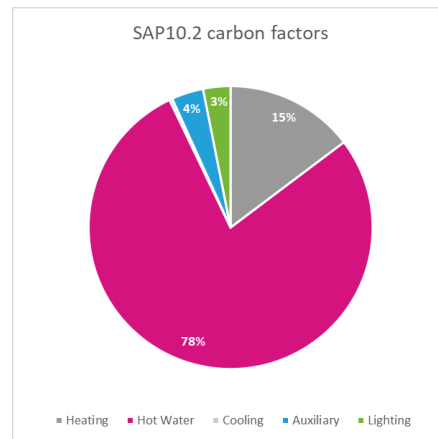


Fig. 3 Percentage contribution to CO₂ emissions using BEIS carbon

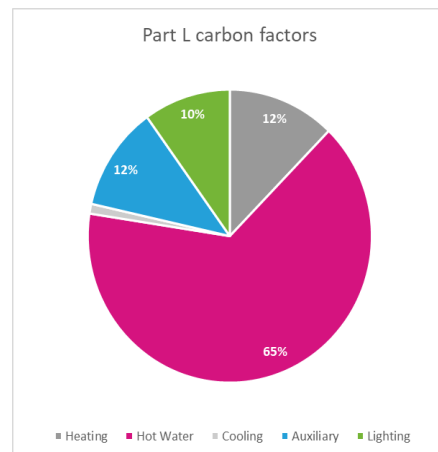


Fig. 4 Percentage contribution to CO₂ emissions using Part L 2013 carbon factors

Installation cost estimation

In order to compare the cost implications and potential savings that could be achieved through alternative technologies it is important to establish an estimation of costs associated with delivering the services strategy associated with the baseline scenario. As DHW and heating represent a significant proportion of the energy consumption of the buildings, heat generating technologies are focused on.

- Capital costs: ¹
Gas boiler at 186.8kW² at £100/kW = £18,680
Gas-fired water heater 147.4kW at £120/kW=£17,688
- Maintenance costs per annum: 334.2kW at £5 per kW = £1,671

It is estimated that gas fired boilers and water heaters will have a life span of approximately 15 years

Fuel costs

The baseline annual fuel costs for the space heating and DHW is £26,777³.

This figure has been calculated using the most recent publication on gas prices for small consumers in UK (£0.0395/kWh).

¹ DECC – 2050 Working Assumption Cost Source – available at http://2050-calculator-tool-wiki.decc.gov.uk/cost_sources/61

² The plant sizes were pro-rata'd to reflect the area under BREEAM assessment

³ Taken from BEIS Gas and electricity prices in the non-domestic sector Q4 2021 available at: <https://www.gov.uk/government/statistical-data-sets/gas-and-electricity-prices-in-the-non-domestic-sector>

3.0 Air source heat pumps

Introduction

Air-source heat pumps (ASHPs) take naturally occurring low-level heat from the external air and convert it to high level heat (approx. 35-50°C) using a pump driven by an electrically powered compressor. The heat generated by this pump can be used to provide space heating for the building. Heat pumps operating at higher temperatures are suitable for DHW generation, but at a lower COP.

ASHPs can either transfer the heat from air to air, where the heat is delivered through an air conditioning system to the building. Alternatively, this heat can be transferred from air to water and delivered around the building via emitters such as radiators or underfloor heating.

The benefits associated with ASHPs include generally having low maintenance requirements, no fuel deliveries are required, and reversible heat pumps are capable of providing cooling as well as heating.

Site constraints

The only site constraints are the acoustic restrictions. Depending on the location of the ASHPs, there may be visual or acoustic disturbance.

Planning constraints

There are no known planning constraints.

Model scenario

The gas boilers and DX cooling were exchanged for a VRF heating and cooling system with a SCOP of 5.5 and SEER of 6.5⁴. A further ASHP with SCOP of 2.9 provides the pre-heat for 80% of the DHW, with 20% topped up by gas-fired water heaters. This top-up is necessary to meet the peak DHW demands of the hotel.

Energy consumption

Table 3 shows a 51% energy reduction when ASHPs are deployed for space heating and DHW pre-heat.

Item	Energy Consumption [kWh/annum]
Baseline Scenario	757,697
ASHP	372,221
Percentage Reduction	51%

Table 3 Energy consumption of the ASHP compared with the baseline scenario.

CO₂ emissions

When ASHPs are deployed for space heating and DHW, they save 73% CO₂ against SAP10.2 carbon factors and 49% under Part L2013 carbon factors (due to the electricity carbon factor being so much higher than the gas carbon factor).

⁴ E.g. Mitsubishi R2 Series with high efficiency heat recovery

Item	CO ₂ Emissions [kgCO ₂ /annum]	
	SAP10.2 carbon factors	Part L 2013 carbon factors
Baseline Scenario	153,212	183,773
ASHP	40,844	93,166
Percentage Reduction	73%	49%

Table 4: CO₂ reduction associated with ASHP compared with the baseline scenario.

Costs

The capital cost associated with ASHPs capable of handling the peak space heating and half the DHW demand, in addition to costs associated with its annual maintenance, are provided below:

- Capital cost VRF: 187kW at £1,222/kW = £228,412
- Capital cost ASHP for DHW pre-heat: 147kW @£600/kW=£41,799
- Annual Maintenance costs: 334kW at £6 per annum = £2004

Fuel cost savings

When ASHPs are used for space heating and DHW pre-heat, fuel costs will increase by £6,680 per annum.

This figure has been calculated using the most recent publication on gas (£0.0395/kWh) and electricity (£0.1889/kWh) prices for small consumers in UK.

Renewable heat incentive (RHI)

The RHI is closed to new applicants, and no replacement scheme has been announced.

Simple payback

The ASHPs would not pay for themselves within their 20-year lifespan.

Item	
Capital Cost	£272,638
Simple Payback Cost	£177,064
Annual Cost Savings	£-8,243
Life Span	20 years
Simple Payback	Never

Table 5: Simple pay back model for installation of ASHP.

Life cycle cost (LCC) and carbon

The LCC of the ASHP option is £3,082,283 (Table 6) over the 60-year lifespan of the building

Item	Lifespan of technology	Lifespan of the building
Installation cost	£272,638	£817,914
Total energy costs	£683,444	£2,050,331
Total maintenance costs	£71,346	£214,038
Life cycle cost	£1,027,428	£3,082,283

Table 6 Life Cycle Cost for installation of ASHP

Conclusion

Replacing the baseline gas boilers and chillers for space heating/cooling with a VRF system for space heating and cooling and ASHP for DHW pre-heat reduces energy consumption by 51% and CO₂ emissions by 73% and 49%, with SAP10.2 and Part L 2013 carbon factors, respectively.

An investment in ASHP would not pay for itself within the lifetime of the installation at the 2021 gas and electricity tariffs. However, if the price gap between gas and electricity narrows in the future, this may change the balance in favour of the ASHP. LCC is £3,082,283 over the lifespan of the building.

ASHP is highly recommended from a CO₂ reduction perspective.

4.0 Ground Source Heat Pumps

Introduction

Ground source heat pumps (GSHPs) take naturally occurring low-level heat stored in the ground or ground water and convert it to high level heat (approx. 45-50°C) using a pump driven by an electrically powered compressor. The heat generated by this pump can be used to provide space heating for the building. DHW generation can also benefit from GSHP, by pre-heating DHW from the space heating plant with electrical or gas top-up.

GSHPs can either transfer the heat from the ground or groundwater to the air or to an LTHW heating system.

There are three principal types of GSHP:

- In open loop boreholes, ground water is abstracted from one borehole⁵, heat extracted by a heat pump and cooler water returned to a second borehole. Thus, the space requirements for this technology are minimal
- In vertical closed-loop boreholes, vertical loops are sunk to a depth of 50-200m. The loops act as heat exchangers with the surrounding ground. Each loop can extract on average 75W per metre depth and loops need to be 10m apart
- Horizontal (slinky-type) ground loops are laid in trenches 2.0m below ground and exchange heat with the surrounding ground. Each loop can extract on average 100W per metre depth and loops need to be 5m apart

⁵ Assuming that ground water is available at the right depth and abstraction rate at the site.

The benefits associated with GSHPs include generally having low maintenance requirements, no fuel deliveries are required and reversible heat pumps are capable of providing cooling as well as heating.

Site constraints

The feasibility of GSHP as a main heat source depends on the area of ground available for the heat exchangers. The presence of existing basements and retained building structure, constrains the area available for a GSHP array to an area of approx 16m x 28 m under the courtyard and new builds. Table 7 shows the capacities available with the three types of GSHP. None of these options are able to meet the predicted 186kW space heating demand (pro-rata'd from the total building space heating load by area).

Vertical closed loop 12 piles, 100m deep	Vertical open loop system at 10l/s abstraction rate	Horizontal slinky 112m combined length
45kW	126W	11.2kW

Table 7 Heat capacities of the three systems

As the site cannot meet the space heating demand from GSHP, no further carbon or economic analysis was undertaken.

5.0 Photovoltaics

Introduction

Photovoltaic (PV) panels utilise the sun's energy to produce direct current electricity via semiconducting materials that absorb solar radiation. There are a number of different PV types including monocrystalline, polycrystalline, amorphous silicon (thin film) and hybrid panels. Panels are either mounted onto a roof or form an integral part of the roof or vertical façades.

In order to gain the most out of these panels in the UK the optimum position is tilted at 30° facing south. They can either be mounted on a pitched (on roof or integrated into roof) roof or independently tilted on a flat roof. In reality, panels on flat roofs are generally mounted at 10° to reduce wind loads.

PV is generally maintenance free. Once installed, PV will typically operate for 20+ years without needing any significant maintenance regime. Only the inverters may need to be replaced after approx. 15 years.

Site constraints

The feasibility of installing PV is highly dependent on suitable roof space and possible over shading of the building from adjacent structures.

Planning constraints

There are no known planning constraints in place at this site that would prohibit the installation of PV panels on the building. However, this should be officially confirmed if this LZC option is selected. There is no noise impact associated with PV that needs to be considered.

Model scenario

A 130m² (28.6kWp) south-facing PV array with 10° inclination and 22% efficiency was modelled. A roof plan showing the proposed layout of the PV array is shown in Appendix B.

It is assumed that all PV-generated electricity can be used on-site or exported, but this will need to be confirmed. All other details relating to the building services strategy for the building have been modelled as per the baseline scenario.

Energy consumption

Table 7 demonstrates that there is small reduction of 3.3% in regulated energy consumption.

Item	Energy Consumption [kWh/annum]
Baseline Scenario	757,697
130m ² PV	733,024
Percentage Reduction	3.3%

Table 7 Energy consumption with PV compared with the baseline scenario.

CO₂ reduction

The regulated CO₂ emissions are 2.2% and 7.0% lower than the baseline scenario with SAP10.2 and Part L 2014 carbon factors, respectively (Table 8). While these SAP10.2 CO₂ savings are lower than the targeted 5% threshold, they nevertheless contribute some CO₂ savings.

Item	CO ₂ Emissions [kgCO ₂ /annum]	
	SAP10.2 carbon factors	Part L 2014 factors
Baseline Scenario	153,212	183,773
130m ² PV	149,856	170,968
Percentage Reduction	2.2%	7.0%

Table 8 Carbon reduction associated with PV compared with the baseline scenario.

Costs

An approximate capital cost associated, in addition to cost associated with annual maintenance is provided below:

- Capital costs: 28.6kW at £900/kW = £25,740⁶
- Annual maintenance costs: 28.6kW at £5/kW = £143⁷

Fuel cost savings

If all generated electricity could be deployed on-site, the annual electricity savings would amount to £4,661.

This figure was calculated using an assumed consumption-related electricity price of £0.1889/kWh.

⁶ Pro-rata'ed from recent budget quotation

⁷ http://2050-calculator-tool-wiki.decc.gov.uk/cost_categories/27

Feed in tariff (FiT)

As of April 2019, FiTs and export tariffs are no longer available. The scheme was replaced in January 2020 with the Smart Export Guarantee (SEG), under which utilities are obliged to offer a tariff to eligible producers of renewable electricity⁸. However, as there are no published tariffs, SEG payments are not taken into consideration in this report but could benefit the scheme.

Simple payback

The PV array would pay for itself in 6 years, which is within the lifespan of the installation (Table 14).

Item	
Installation Cost	£25,740
Simple Payback Cost	£25,740
Annual Cost Savings	£4,518
Life Span	20 years
Simple Payback	6

Table 9 Simple payback for PV

⁸ <https://www.ofgem.gov.uk/environmental-programmes/smart-export-guarantee-seg/about-smart-export-guarantee-seg>

Life cycle cost

Provided that all electricity is used on-site, the 130m² array would generate £193,844 in revenue over the lifespan of the building.

Item	Lifespan of technology	Lifespan of the building
Installation cost	£25,740	£77,220
Total energy costs	-£93,215	-£279,644
Total maintenance costs	£2,860	£8,580
Life cycle cost	-£64,615	-£193,844

Table 10 Life Cycle Cost for installation of PV

Conclusion

The 130m² (28.6kWp) PV array reduces regulated energy consumption by 3.3% and CO₂ emissions by 2.2% and 7.0% with SAP10.2 and Part L 2013 carbon factors, respectively. It pays back within 6 years and generates £193,844 over the lifetime of the building.

While the CO₂ emissions reduction target of 5% is not met with the SAP10.2 carbon factor, PV is highly recommended for this project on account of the energy cost savings.

7.0 Conclusion

ASHP, GSHP and PV were considered as potentially suitable LZC technologies for this development.

Due to insufficient accessible heat capacity in the ground under the proposed QVS1 building, GSHP was not taken forward for carbon or economic assessment.

The ASHPs generated the highest reduction in regulated energy consumption (51%) followed by the 130m² PV array (3.3%).

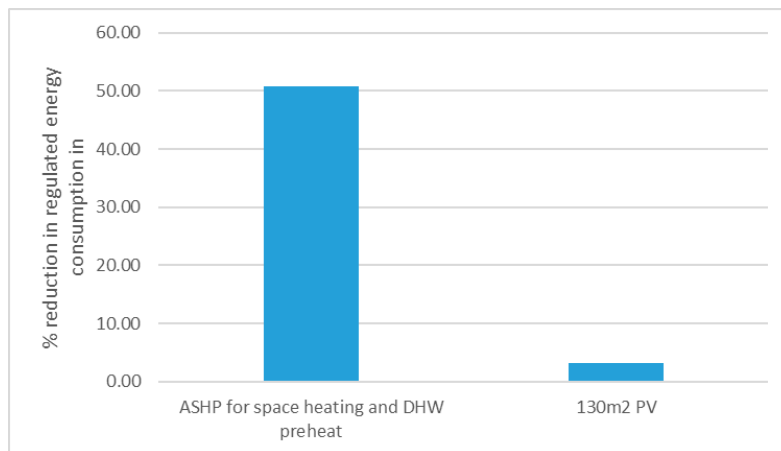


Figure 5. Bar chart showing total building energy consumption association with each LZC scenario.

The ASHP met the 5% carbon improvement target (Fig.6) both with SAP10.2 and Part L 2013 carbon factors and provided the highest regulated CO₂ savings with SAP10.2 (73%) and PV provided the highest CO₂ savings with the Part L 2013 carbon factors (7.0%). While the PV array did not reach the 5% target with the SAP10.2 carbon factor, it makes a contribution to CO₂ and decentralised energy supply.

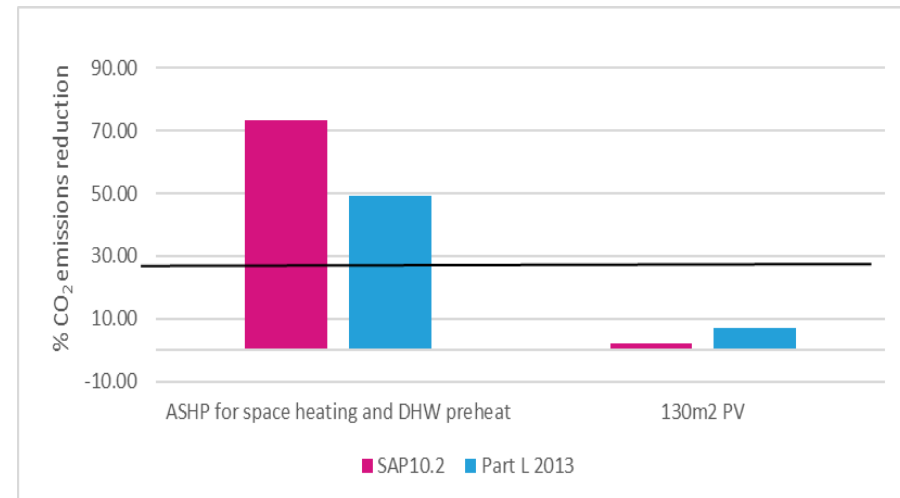


Figure 6. Bar chart showing total regulated building CO₂ emissions association with each LZC scenario

PV was the only technology to pay back within its lifetime (Fig. 7).

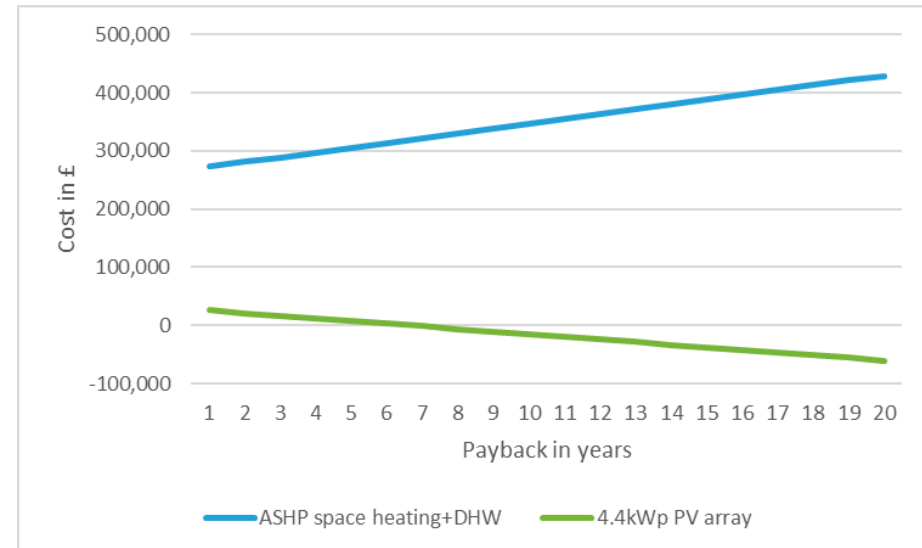


Figure 7: Line graph showing the payback periods associated with each scenario over 20 year lifespan.

In terms of LCC, the heat pump options are very expensive while PV generates a modest revenue (Fig. 8).

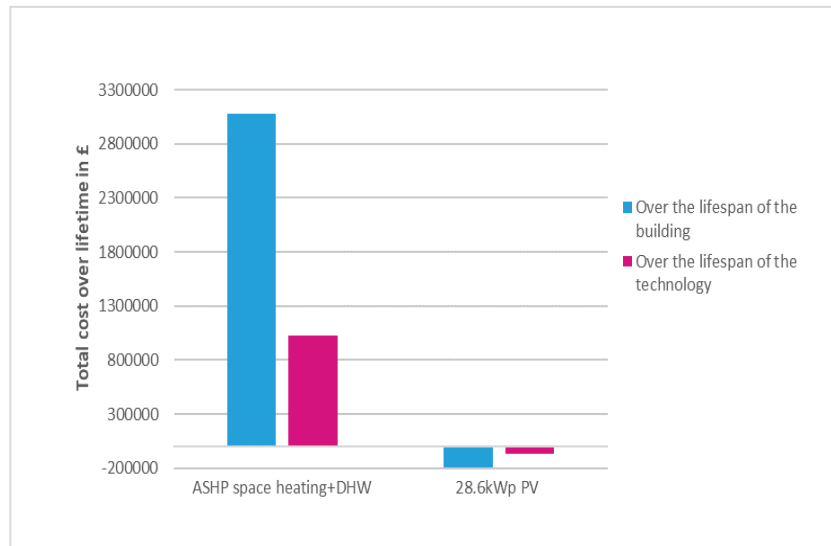


Figure 8 LCC of the LZC technologies

Overall, installation of the VRF heating and cooling system and PV are recommended.

ASHPs can generate significant energy and CO₂ savings but have high capital and operational costs associated with them. They are recommended from a CO₂ reduction perspective only.

The 130m² PV array produces small energy and carbon savings relative to the high energy consumption and CO₂ emissions of the basecase building but provide useful energy cost savings.

It should be noted that for the purpose of this study each LZC technology was looked at in isolation and the combined effect of compatible technologies was not considered.

APPENDIX A - Discounted LZC technologies

District / community energy networks

To establish whether the creation or the adjoining to an existing heat network is feasible, national mapping data was interrogated⁹.

For a new district system to be feasible, a considerable and consistent annual energy demand would be required. The advantage of the district system is the high efficiencies which can be delivered when the energy is generated and distributed from a central source.

Figure 9 highlights significant national existing energy networks in the UK. In the situation where there is an existing network, it may be possible to investigate further whether a connection to the network could be made.

Figure 10 confirms that there are no heat networks in the vicinity of the proposed development, therefore connection to an existing network can be ruled out.

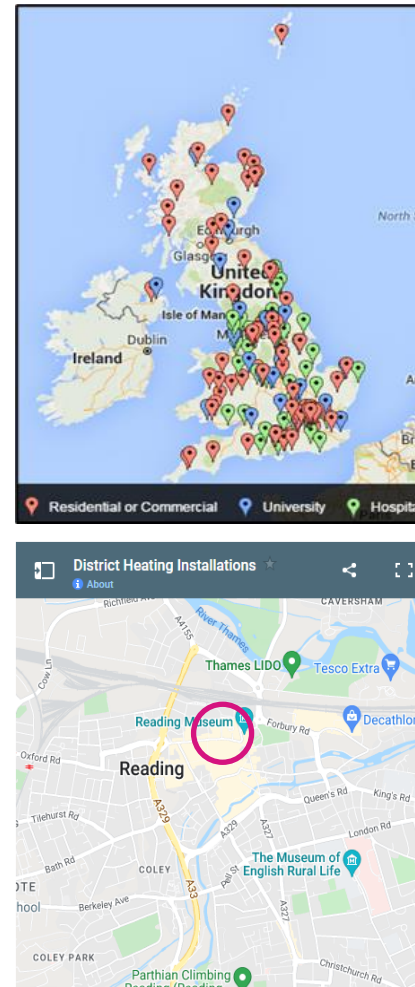


Figure 9: District Energy Network Map – from The Association for Decentralised Energy

Figure 10 confirms no significant heat networks local to the project, so connection to existing networks can be ruled out.

⁹ District Energy Network Map – from The Association for Decentralised Energy www.theade.co.uk

However, the Reading Borough Council Sustainable Design and Construction SPD envisages a Reading Town Centre heating network in four clusters. The proposed development would straddle the Station Hill cluster and Old Civic Building cluster, but without direct adjacencies to the core schemes and the extensions (see Fig. 11). As no details are given on how the proposed schemes will generate heat, no calculations on energy and carbon savings could be undertaken.

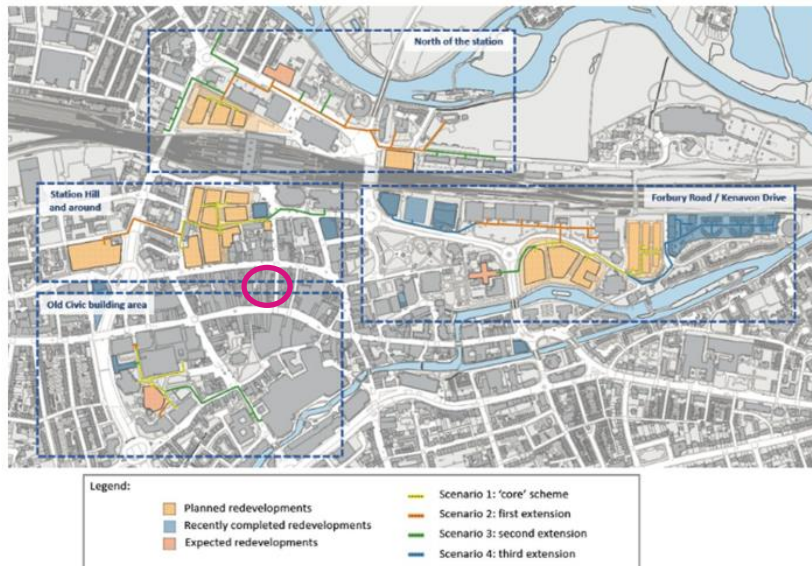


Fig. 11 Reproduction of the map of proposed DHN clusters from the Sustainable Design and Construction SPD

Biomass heating system

Biomass boilers can make an impact in buildings with high and constant space and DHW heating loads, which is the case with this building. However, the particulate emissions from biomass boilers make them unsuitable for high density urban areas.

Wind turbine

Wind turbines are only suitable for areas with frequent wind speeds above the cut in speed of the turbines and which are remote from residential areas

as they can create noise problems. Given the developments location in a densely populated urban area is not considered to be a suitable option for this development.

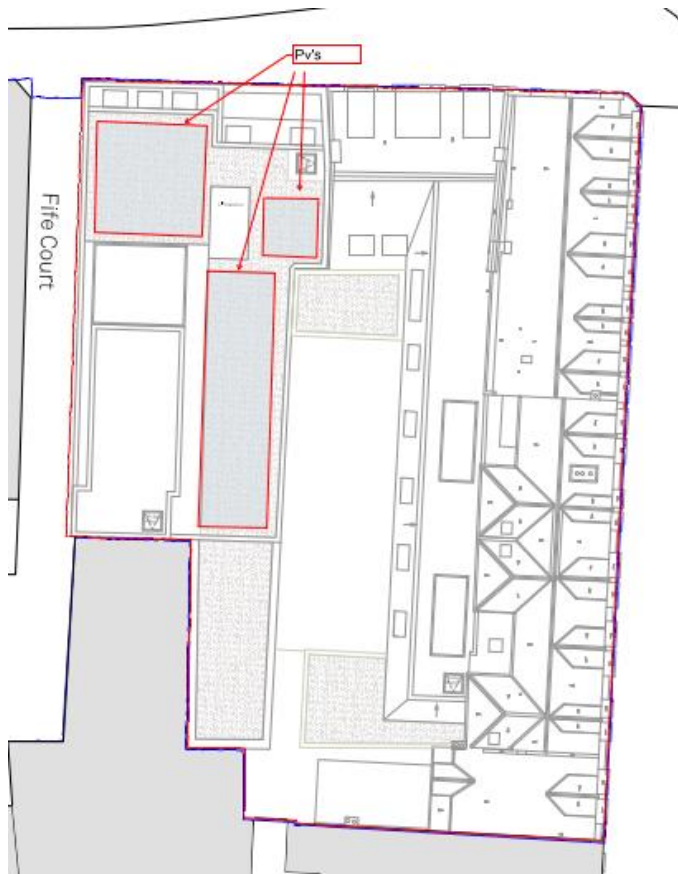
Solar thermal

Solar thermal can have an impact in buildings with high baseline DHW demand, which is the case in this building. However, a solar thermal array would compete with the PV array for the limited roof space.

Combined Heat and Power (CHP)

CHP was excluded from consideration because the rapid drop in the electricity grid's carbon intensity has made this technology non-viable from a carbon saving perspective.

APPENDIX B – Proposed location of roof PV



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