No. 53 Fitzroy Park

Energy Strategy

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-	29.09.14	First issue	-	CMS	GMW
-	10.12.14	Revised Issue	Layout	CMS	GMW
-	22.01.15	Revised Issue	GSHP Review	CMS	GMW

1 Summary

The report sets out the energy strategy for the building, which follows the “Be Lean, Be Clean, Be Green” approach, with a focus on the building fabric. External elements should be highly insulated, with low U-values, and accredited construction details should be used to minimise thermal bridges. An air tightness of $3m^3/m^2/hr$ should be achieved. Efficient building services, including lighting, lighting controls, condensing boilers, low energy fans and pumps, and energy-saving controls and monitoring, should be implemented. Finally, an LZC solution of Air Source Heat Pumps and Photovoltaic Solar Panels is recommended as the best means of meeting the Code for Sustainable Homes Level 4 energy target, while being a cost-effective and appropriate solution for the building.

2 Introduction

The report will set out the energy strategy for the redevelopment of No.53 Fitzroy Park, with consideration of the building fabric, building services and low and zero carbon technology. Recommended measures will be set out for building fabric standards, and efficiency of building service systems. Finally, an analysis of low and zero carbon (LZC) technology will be carried out to establish a suitable solution which meets the energy requirements for Code for Sustainable Homes Level 4.

3 Targets & Compliance

3.1 Energy & Carbon Emissions Targets

3.1.1 Building Regulations: Part L1A

The new building must comply with Part L (2013), which requires a calculation of the building’s carbon emissions using an approved methodology and software (SAP)

3.1.2 Code for Sustainable Homes

According to local planning requirements, the building must comply with the Code for Sustainable Homes, and must achieve at least Code Level 4. This requires that the calculated carbon emissions for the building be 19% lower than the building regulations minimum standard, as calculated using the approved methodology and software.

4 Energy Strategy

4.1 Approach

The energy strategy has been based on the “Be Lean, Be Clean, Be Green” step-wise approach;

Building Fabric (Be Lean):
Minimise energy demand through the design of the building fabric; high insulation levels, careful detailing, good air tightness. This approach incorporates energy efficiency into the building fabric itself, with such measures typically enduring through the life of the building.

Building Services (Be Clean):
Use highly efficient systems to provide energy to the building including efficient lighting, boiler plant, ventilation systems. These services are essential and should be provided efficiently.

Low & Zero Carbon Technology (Be Green):

Use Low and Zero Carbon technology (LZC) to supply energy to the building. This should be the final part of the approach as such technology is more expensive and lasts only a proportion of the building life.

4.2 Building Fabric

Energy efficiency should primarily be achieved by the most enduring component of the building- the fabric itself. High levels of insulation should be provided, with good airtightness to minimise infiltration heat losses. Proposed fabric properties are shown in Table 1. These are subject to thermal modelling results.

Walls	U=0.11 W/m^2/K
Ground Floor	U=0.10 W/m^2/K
Roof	U=0.11 W/m^2/K
Glazing (including frame)	U=2.0 W/m^2/K[1]
Glazing g-value	0.65 generally, 0.4 for solar control (e.g., east facade)
Air tightness	3m^3/m^2/hr

Table 1: Proposed fabric properties

Thermal bridges should be designed out as far as possible through careful detailing. If not considered carefully, heat losses through these elements can negate the performance of insulation. The design should make use of accredited construction details to ensure that this is achieved.

Glazing g-value should be maximised to increase solar heat gains in winter, but this must be balanced against overheating.

4.3 Building Services

4.3.1 Ventilation Strategy

Mechanical ventilation with heat recovery will be used as the means of maintaining air quality throughout the building, supplying fresh air to living spaces, and removing stale air from bathrooms, WCs and the kitchen. Heat recovery ensures that the amount of heating carried out on the air is minimised, and that air is supplied at a comfortable temperature to the spaces.

The energy performance of the system shall be as follows;

- Heat recovery: >85%
- Specific fan power: <1.2 W/(l/s)

4.3.2 Heating Plant

Where gas boilers are used these shall be condensing type with a high gross seasonal efficiency (min. 90%). Pumps shall be high efficiency type with automatic speed control. Heating pipework shall be highly insulated to ensure heat is distributed efficiently.

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[1] Glazing U-value restricted by use of sash windows which are key part of building style.

4.3.3 Controls

A control system shall be implemented which shall operate plant efficiently and effectively;

- Weather compensation for heating circuits to improve heating plant efficiency and prevent spaces being over-heated.
- Pump speed control to match demand
- Deadband control of heating and cooling to prevent systems ‘fighting’
- Energy metering and monitoring to identify where energy is used
- Time scheduling of systems so that they are used only when required

4.3.4 Lighting

Efficient lighting shall be provided, with LED being used where suitable. Lighting controls should be implemented where appropriate to further reduce energy use;

- Automatic presence/absence detection
- Daylight dimming in well lit areas
- Photocell and timeclock control for external lighting

4.3.5 Hot Water

Hot water shall be generated and distributed efficiently. Cylinders shall be well insulated to minimise standing losses. Secondary distribution pipework shall be well insulated to reduce heat loss and prevent potential overheating in adjacent spaces.

4.3.6 Swimming Pool Plant

Plant serving the swimming pool should be highly efficient with the following considered;

- Heat pump technology to recovery heat
- Passive dehumidification using heat exchangers
- Demand control of ventilation rates
- Variable fresh air rates
- Set back temperatures

<u>It is highly recommended that a pool cover be installed and used as this can reduce pool energy requirements by over 20%.</u>

4.4 Low and Zero Carbon Technology

4.4.1 Targeted Approach

The use of low and zero carbon technology should focus on delivering savings in the key areas of energy consumption and carbon emissions.

Figure 1 shows a predicted breakdown energy consumption of for the building for a ‘baseline design’ using the measures outlined in sections 4.2 and 4.3, using condensing gas boilers for heating, and mains electricity, without the use of renewable energy.

As shown, heating (space heating, pool heating and domestic hot water) makes up the main energy use (totalling 69%). Space heating is the largest single consumer of energy, followed by pool heating.

However, when the energy use is considered from the aspect of costs, or CO_2 emissions, both of which are arguably more useful measures of energy efficiency, it is shown that electrical energy is just as significant as heating (Figure 4) as a result of the higher inherent costs and CO_2 emissions associated with electrical energy production.

The optimum solution would therefore be able to provide a contribution to both the heat and electrical demands of the building.

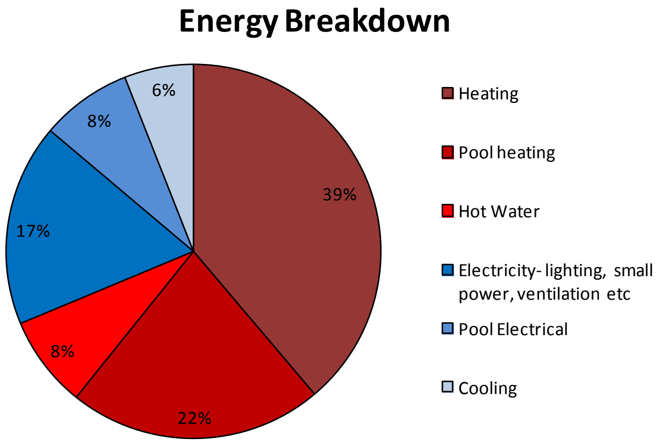

Figure 1: Energy Breakdown for baseline design without LZC

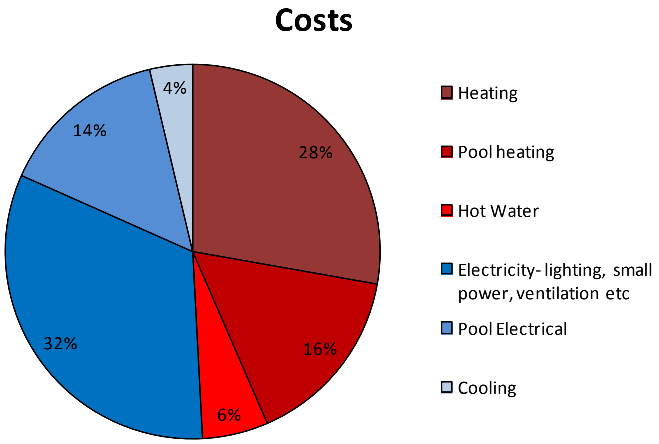

Figure 2: Energy Cost breakdown for baseline design without LZC

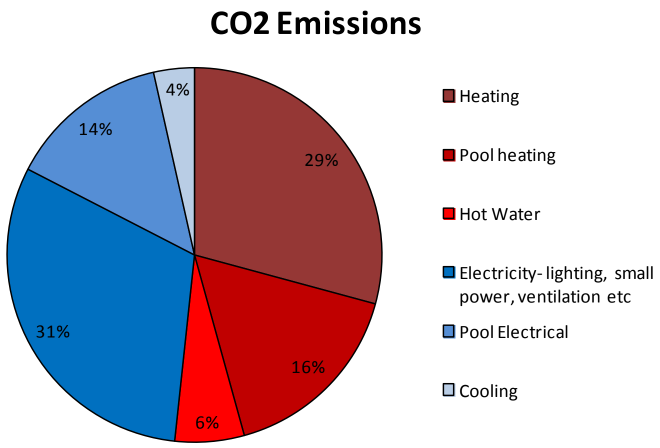

Figure 3: CO2 emissions breakdown for baseline design without LZC

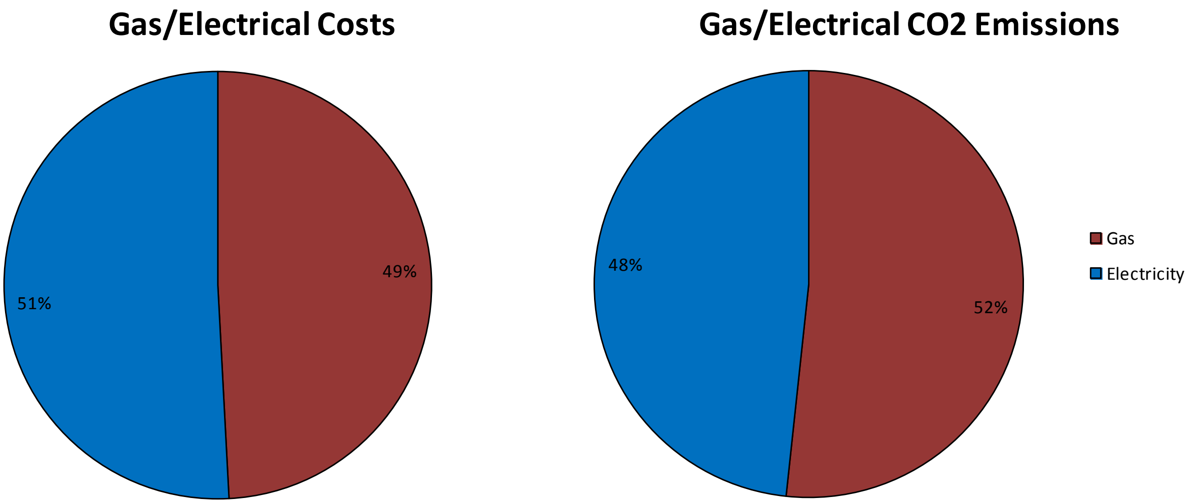

Figure 4: Gas and electrical costs and CO2 emissions comparison

4.4.2 Overview of feasible LZC Technology

An overview of the feasibility of various LZC technologies as given in Figure . Technologies which are worth further discussion and analysis are as follows;

- Solar Photovoltaic (PV)
- Solar Hot Water
- Air Source Heat Pumps
- Ground Source Heat Pump

Solar Photovoltaic (PV)

A solar PV system is feasible and can be mounted on the flat roof areas. Panels can be mounted at an angle of between 10 and 30deg facing south-east to south-west, and will reliably produce electrical energy for use in the building provided that they are located in an unshaded location.

Such systems typically recover their initial investment in around 8 years as result of electrical energy savings, export revenue to the grid, and the government's feed-in tariff which generates revenue for every kWh produced by the system.

Maintenance requirements for PV arrays are extremely low as a result of the lack of moving parts, although inverters may need replacing every 10-15 years.

Solar Hot Water

Solar hot water systems capture energy from the sun which is used to heat water. They are typically used for generating domestic hot water, but rarely so for space heating since the majority of available solar energy occurs outside of the heating system. In the case of Fitzroy Park the system can also be used to generate heat for the swimming pool in water and air heating.

Typically such systems are economical when designed to provide 100% of the summer hot water requirements, while provide a minimal amount during the winter. Overall, the system may be capable of provide around 60% of the heat demand for hot water and pool heating. Above this, during the summer the system will be oversized, and energy may need to be dissipated through dump radiators, wasting valuable heating, and reducing the cost effectiveness of the system.

Air Source Heat Pumps

Air Source Heat Pumps (ASHPs) extract heat from the external air using the refrigeration cycle, and put this heat into hot water for space heating and domestic hot water production. The performance of units is related to external air temperature and at lower temperatures the efficiency will drop significantly. However, if sized correctly, and with suitable design of internal heat emitters, ASHPs can provide a highly efficient means of heating a building, with significant savings compared to gas boilers.

An air source heat pump system would be able to provide heat for space heating, pool heating and domestic hot water.

ASHP units will generate noise from the operation of their fans, and this must be considered in their positioning. They should also be positioned to ensure good airflow around them, which will aid heat transfer.

Ground Source Heat Pumps

Ground Source Heat Pumps (GSHP) extract heat from the ground, via a horizontal trench or vertical borehole, using the refrigeration cycle and transfer this heat into hot water for space heating and domestic hot water production. The performance of the system is related to the length of horizontal trenches or number and depth of boreholes. Temperatures beneath ground under a certain depth are generally consistent and allow the system to provide a steady efficiency, assuming the system is sized correctly and has sufficient external space to meet the system demands.

A ground source heat pump system would be able to provide heat for space heating, pool heating and domestic hot water.

It is noted that the original planning proposal considers GSHP as part of the renewable technologies for the property.

GSHP systems require a large amount of external space to accommodate the trenches or boreholes, and the costs of the associated groundwork will need to be considered. This has been investigated further and to meet the buildings heat demand it is estimated that the following is required

- Horizontal trench system with a total length of 1600m
- 14 vertical boreholes, each 100m deep.

The above figures have been considered with the proposed building layout and can be seen as indicated on the following sketches.

Figure 5: Sketch Layout OF GSHP Boreholes

As shown, there is only sufficient suitable space on site for 7 boreholes, which is half of the total required to meet the buildings heat loss. Whilst a GSHP borehole system could be used to contribute to the renewable technologies of the property, it will be unsuitable to use without the assistance of another heat generator.

It has also been considered to utilise the buildings foundation piles as heat collectors, known as energy piles. This would increase the amount of usable space on site and could be the assistance required for the standard boreholes, however energy piles are generally much shallower than dedicated boreholes, so will have a lower output in comparison. For this to work the significant majority of the piles being used for the formation of the basement as put forward by the structural engineer will need to be energy micro-piles. However, due to the proximity of these piles they will quickly interfere with each other and the surrounding earth will be cooled by the demand for energy. Normally a micro-pile arrangement such as this would then utilise the cooling demand of the building to regenerate the 'heat-store'. There is enough energy within this location to provide energy for a year but there is no supply that will regenerate this 'energy store' over the summer months. This will result in the micro-piles removing more energy than can be restored and as such the surrounding earth will cool. This has proven severely problematic in certain locations in the UK, as the resulting effect is icing around the micro piles which when they melt result in an air pocket around the piles, which not only effectively means that there is an insulant around the piles resulting in a significant drop in efficiency but more importantly that the structural benefit of the piles is compromised. For this reason this technology is not viable on this particular project.

It should also be noted that a full geological survey will need to be carried out to establish the suitability of the ground for a GSHP borehole system for the deep energy boreholes. Alongside this, further investigation would be necessary to establish any regulations and permissions to drill in this area.

Figure 6: Sketch Layout OF GSHP Trenches

As indicated on the sketch above, there is only sufficient room for a total of 29m of horizontal trench space, which is considerably less than the required 1600m needed to meet the buildings heat loss. As with the borehole system, the horizontal trench system will be unable to meet the heat demands of the building by itself, and will require supplementary heating from another form of heat generation.

Another factor to consider with GSHP systems is the high cost associated with the required ground works for the collector arrays.

Consequently, a GSHP system has been ruled out as a suitable means of providing useful heat for the building.

Technology	Description	Advantages	Disadvantages	Conclusions
Biomass Boilers	Combustion of wood chips or pellets to provide LTHW for hot water & heating	Very high carbon savings Reliable heat generation. Eligible for renewable heat incentive (RHI). Fast returns on investment possible.	Particulate emissions can be a planning issue, particularly in an urban setting. Requires significant planning of building and site infrastructure from an early stage. Requires large storage space and suitable access for deliveries.	Not suitable for site- no suitable location for storage or space for boilers. Particular emissions not appropriate in urban setting.
CHP – small scale.	Produces both heat and electricity using gas-fired engine.	Large carbon savings from efficient generation of electricity. High LTHW temperatures reduce size of heat emitters and simplify hot water production. Effective with district heating. Excess power can be sold back to grid.	Requires steady base load to achieve significant saving. No government incentives available. High capital cost and maintenance costs. Slow return on investment if at all.	Not feasible due to lack of consistent electrical baseload during the day. High maintenance requirements not suited to domestic application.
Ground Source Heat Pumps (GSHP)	Extracts heat from ground using electrically powered refrigeration cycle.	High efficiency and performance relatively constant throughout year. Potential for free cooling from ground loops. Eligible for renewable heat incentive (RHI). Effective with underfloor heating.	High cost of ground works. External land space required. Performance may reduce if annual heat balance not achieved. Only partially renewable energy Large heat emitters required.	Suitable technology for providing heating, pool heating and domestic hot water. Dependant on available external space.
Air Source Heat Pumps (ASHP)	Extracts heat from air using electrically powered refrigeration cycle.	Potential for good carbon savings for well designed system. No ground works required. Effective with underfloor heating.	COP and output dependent on external temperature. COP lower than GSHP. Only partially renewable energy. Large heat emitters required. Can be noisy.	Suitable technology for providing heating, pool heating and domestic hot water. External location required.
Wind Turbines	Generate electrical power from the wind	Completely renewable energy Excess power can be sold back to grid. Eligible for feed-in tariff.	Major planning issues anticipated. Performance uncertain without extensive data collection.	Poor efficiency for small scale turbines. Major planning issue.
Solar Photovoltaic	Produces electrical power from solar radiation.	Completely renewable electricity. Good levels of carbon reduction. Excess power can be sold back to grid.	High capital cost compared to carbon savings. Requires large roof area for sufficient impact.	Suitable technology for building, requires roof space and must be incorporated into planning proposals.

		Eligible for feed-in tariff.		
Solar Hot Water	Generates heat from solar radiation for domestic hot water production.	Completely renewable energy. Low maintenance costs. Works well with GSHP- excess heat can be used to recharge ground. Eligible for renewable heat incentive (RHI). Very suited to building because of all-year hot water demand.	Contribution to hot water demand limited (normally up to 50%) to prevent excess heat in summer. Conflicts with other technologies- CHP, PVs.	Suitable technology for providing domestic hot water and contributing to swimming pool heating. Requires large area of roof which prevents PVs being used.

Figure 7: Summary of review of LZC technologies

4.4.3 Analysis of LZC Options

Various combinations of LZC have been analysed, taking into account annual performance, running costs and capital outlay. The results are shown in Figure , Figure and Figure .

4.4.3.1 Option 1: Air Source Heat Pump + PV Panels

The solution comprises an Air Source Heat Pump (ASHP) providing heat for space heating, pool heating and domestic hot water, and a solar PV panel array, mounted on the flat roof areas.

It has been assumed that the ASHP system can contribute 75% to the total heat demand of the building, including the swimming pool, space heating, and hot water. This would need to be achieved with careful sizing and the use of buffer vessels.

Analysis of the available roof area indicates that a 7kWp solar PV array can be accommodated if laid at a low elevation (approx 15deg from horizontal). ASHP units can be mounted on the roof, and should be positioned with good airflow around them.

The system is able to meet the requirements of Code for Sustainable Homes Level 4, and in addition offers a good financial return, paying back in 7-8 years, and reducing running costs by 58% compared to the baseline design. Of the compliant system, it also has the lowest capital cost.

4.4.3.2 Option 2: Solar Hot Water

For the purposes of the analysis, a $20m^2$ array has been deemed as appropriate given the building's likely demand and roof space available. This is predicted to generate around 40% of the combined energy demand for hot water and pool heating.

This system is unable to meet the code for sustainable homes energy requirement (see Figure) for several reasons;

1. The system can only contribute to domestic hot water (a small component) and pool heating, and cannot deal with space heating or electrical energy use.
2. The contribution is limited by the size of the array that is practical.

It is worth noting that heat produced by the SHW system that is used for the swimming pool would not be eligible for the Renewable Heat Incentive, which significantly the financial attraction.

In addition, the performance of the system is closely linked to the heat energy consumption of the swimming pool. This is highly unpredictable, and could be significantly overestimated, depending on the extent of usage by the occupants. Should the pool use be minimal during the summer (a realistic possibility), the SHW would become ineffective, and much of the heat gathered would be wasted. This could also pose a technical challenge of how to disperse this heat, which must be safely released to atmosphere.

4.4.3.3 Option 3: Air Source Heat Pump + Solar Hot Water

This solution comprises the Solar Hot Water system as per option 1, but with an ASHP system added to provide space heating and any remaining pool and domestic hot water heating.

The system performs well financially, paying back in under 10 years, with significant cost (65%) and carbon (20%) savings compared to the base line design.

However, the system fails to meet the Code for Sustainable Homes Level 4 requirements. This is a result of the limited performance of the SHW system and the fact that electrical consumption is not dealt with by this system.

The system also has a significantly higher capital cost than other options, with the highest cost per kgCO2 saved.

4.4.3.4 Option 4: Air Source Heat Pump + SHW + PV Panels

This solution combines Option 3 with a Solar PV system of around 3.5kWp, which corresponds to the available roof area left over after the SHW system has been employed.

The system is able to meet the Code for Sustainable Homes Level 4 requirement, and offers a good return on the investment. However, the overall system cost is significantly higher than other options, and suffers from the concerns highlighted for option 2.

Option	**Description**	**Estimated Capital Cost Increase above baseline**	**Annual cost saving over baseline (including government incentives)[2]**	**Simple Payback (for whole system)**	**£ per kgCO2 saved**
Baseline	Fabric improvements, Gas boilers	-	-	-	
1	ASHP + PVs (7kWp)	£33,000	£4,800	7-8 years	£4.50
2	SHW (20m^2)	£19,750	£2,500	8 years	£6.40
3	SHW (20m^2) + ASHP	£52,000	£5,500	9-10 years	£7.60
4	SHW (20m^2) + ASHP + PVs (3.5kWp)	£57,000	£6,190	9-10 years	£6.90

Figure 8: Cost analysis of LZC Options

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[2] Includes for renewable Heat Incentive, Feed-in Tariff based on rates available at time of writing.

Option	Description	CfSH Level 4 Compliant
Baseline	Fabric improvements, Gas boilers	NO
1	ASHP + PVs (7kWp)	YES
2	SHW (20m^2)	NO
3	SHW (20m^2) + ASHP	NO
4	SHW (20m^2) + ASHP + PVs (3.5kWp)	YES

Figure 9: Compliance with CfSH Energy Target

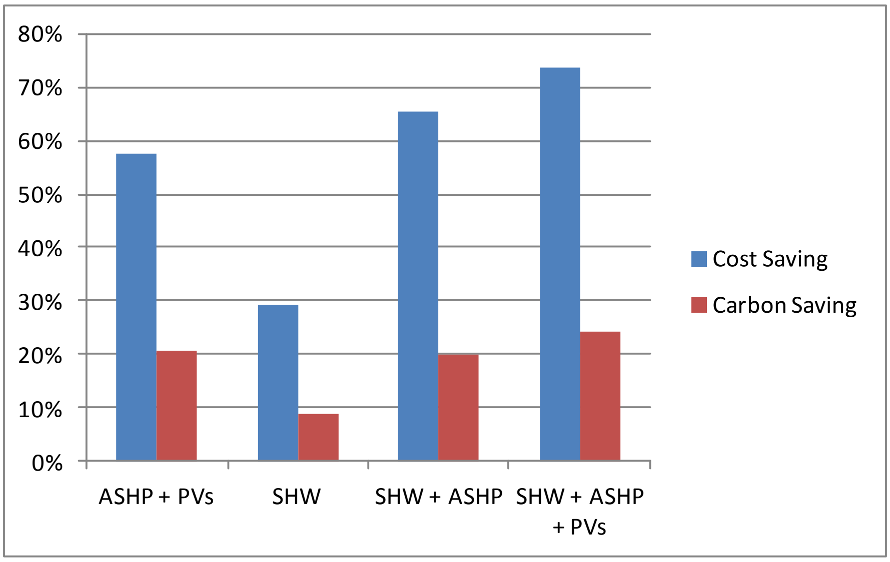

Figure 10: Comparison of options- carbon and cost savings

4.4.4 Recommended Strategy

The recommend strategy is as follows;

- **Air Source Heat Pump (ASHP)** sized to provide heat to space heating, swimming pool and hot water production.

Gas boilers should be provided for top-up and backup of system.

- **Solar Photovoltaic panels (PV)** should be installed on flat roof areas to provide electricity to the building. A minimum of 7kWp should be provided, but this should be maximized as budget and roof space allow to make best use of the feed-in tariff.

The strategy meets the requirements of Code for Sustainable Homes Level 4, as well as providing a technically feasible solution, with low running costs (58% lower than the baseline design), taking advantage of the RHI and Feed-in tariff. The system is also the most cost-effective of those considered in delivering a compliant solution.

Figure shows a possible location of solar PV panels and Air Source Heat Pumps mounted on the roof. The PV panels could be installed at a low elevation (approx 15deg) to minimise their visibility from ground level. The heat pump units could be located centrally on the roof plan to likewise minimise visibility.

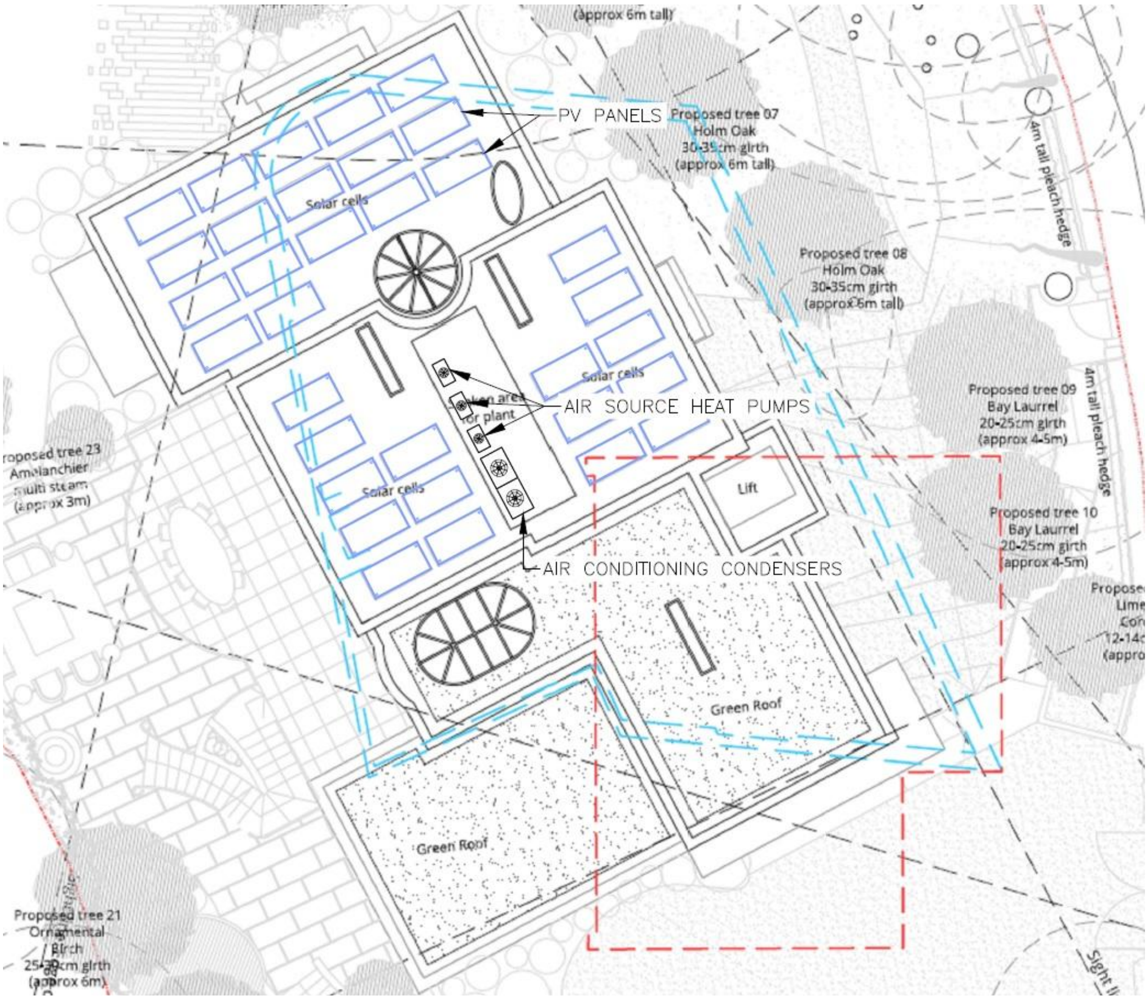

Figure 11: Possible location of Solar PV panels and Air Source heat pumps on roof