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Renewable Energy Feasibility Study

18 Greville Place
13 November 2023

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Renewable Energy
Feasibility Study

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Contents

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Revision Log

Section	Revision	Author	Reviewer	Issue	Date
	For review and comment			Draft	08/11/23
	Change the strategy from bivalent to ASHP or Gas boiler			RevA	10/11/23
	Incorporate cast iron radiators with UFH			RevA	13/11/23

1 Introduction

1.1 Overview

Tobias Munte and Elinor Bashan have been working closely with Noel Wright Architects on 18 Greville Place, where they are planning to renovate an existing house and review the heating system.

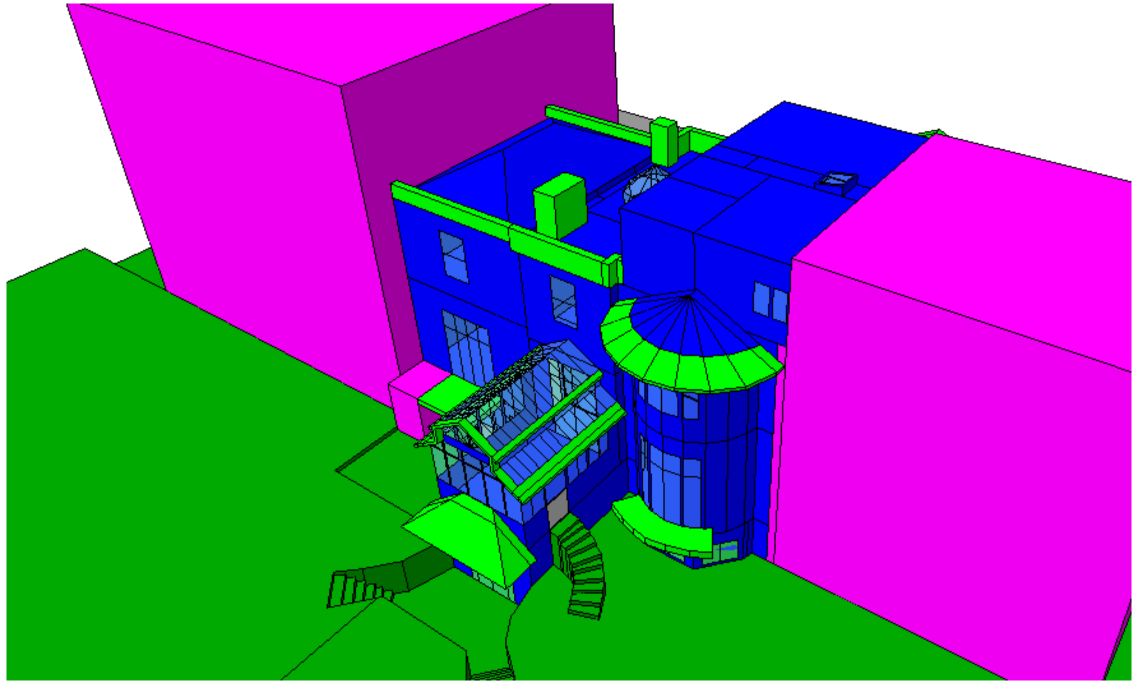

Figure 1: IES dynamic thermal model of the property

Mesh Energy have been commissioned to review and refine a range of renewable heating and hot water solutions to simplify the choices for Tobias and Elinor, to help them to understand the practical feasibility, key economic considerations, and long-term benefits of a final system strategy.

The purpose of the document is to identify the most practical and best suited low carbon options and to ensure minimal ongoing running costs for an acceptable capital investment.

The technologies considered within this document are:
Air Source Heat Pumps (ASHP), Bivalent Systems, Domestic Hot Water, Underfloor heating (UFH), Solar Photovoltaics (PV), and Solar thermal.

2 Executive Summary

The findings of the report conclude there are several renewable energy options that would reduce the heating and hot water running costs.

2.1 Recommendations

- An ASHP delivering 21.23kW for delivering all hot water and space heating at -3.5°C design temperature and 45°C water flow temperature.
- Wet underfloor heating throughout the property.
- New radiators to be installed in some spaces as a backup for heating demand.
- Towel rail warmer connected to hot water system for heating all the bathrooms.
- A 2.96kWp (8 x 370W) Solar PV array.
- Solar Diverter controller.

2.1.1 Summary

Heating energy demand

- Upgrading the thermal building fabric is resulted in a 42% reduction in annual heating demand and CO2 emissions, showcasing its positive impact on both energy efficiency and environmental sustainability.

Heating and DHW system

- An ASHP heating system delivers 21.23kW of heat. The ASHP system is an efficient, non-fossil fuel-based system providing the lowest carbon emissions. The ASHP will also deliver all the hot water for the property.
- Electricity supply is a consideration for any heat pump installation. This site is currently served by a three-phase supply which is sufficient for a heat pump of this size.
- A domestic hot water tanks covering 420 litres, designed for 7 inhabitants. DHW usage is calculated for 65lt/person/day based on Building Regulations Part G. A storage allowance of 60lt per person is made for heat pump heated DHW.

Heat emitters

- The recommended temperature for the central heating system is 45°C, ensuring the most cost-effective operation of the Air Source Heat Pump (ASHP) throughout the year. This temperature is ideal for installing a wet underfloor heating in screed system on the lower ground floor and UFH with a metal conductor system on the other floors. Additionally, consider incorporating cast iron radiators in spaces where the heat output of the underfloor heating may not fully meet the heating demand.
- Mesh recommends installing new radiators on dining, lobby, and lounge spaces of the ground floor and the master east bedroom on the first floor. The additional heat load required has been detailed in the heat emitters section 7.
- Careful consideration will need to be paid to floor coverings in certain rooms to ensure comfortable and efficient heat distribution into the spaces, this has been detailed in the heat emitters section 7.

Bivalent system - ASHP/gas hybrid

- Employing a bivalent system composed of a 7kW air source heat pump (ASHP) catering to the heating needs of the lower and second floors through underfloor heating emitters, alongside a new 21.23 kW gas boiler providing heat for the ground and first floors via cast iron radiators, as well as meeting all domestic hot water demands. However, caution is advised due to concerns related to technical intricacies, control, and maintenance factors.

Gas boiler

- The gas boiler can work with any type of heat emitters.
- Gas boilers can provide higher water temperatures, which is more compatible with the lower heat output and slower response time of cast iron radiators.

Solar Photovoltaic (PV) panels

- The limiting factor for PV is the available desired roof space.
- 2.96kWp (8 x 370w) could be installed as indicated in figure9
- Based on this array size there is likely to be almost no excess generation exported to the grid and most of the energy generated will be consumed during the day by the normal day to day running of the property. It will provide £790 savings each year, paying back in around 7.5 years. It will also save around 315kg of carbon emissions.

Solar thermal

- This scheme of 2 solar thermal panels will likely provide 13% of the property's DHW demands for 7 people. It will cost around 4800£ and save around 175£ per year, paying back in 27 years, leading to choose the PV panels over the solar thermal panels.

Solar Diverter controller

- The Solar Diverter will use any electricity excess from the solar PV system that isn't used in the building to heat water in the DHW cylinder. It offers a relatively low-cost way to utilise excess onsite generation and is a good investment in this case.

Energy tariffs

- A rate of 34 p/kWh has been applied for electricity.
- A rate of 9 p/kWh has been applied for gas.

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In summary, the running cost reduction benefits of embracing a range of renewable energy technologies are shown in the table below:

Technology	Feasible	Recommended	Capital cost, £	Annual running cost, £*	Annual CO_2 emissions savings, Kg	20-year total cost , £*
Gas	✓	✗	2,500	5,815	N/A	118,850
ASHP, 21.23kW	✓	✓	30,830	5,485	11,380	140,540
ASHP7kW /Gas 21.23kW Hybrid	✓	✗	16,030	5,425	4,210	124,530
Solar PV array 2.96kWp (8 x 370W)	✓	✓	5,900	-790	315	-9,900
Solar thermal	✓	✗	4,800	-175	410	1,270
Under floor heating	✓	✓	10,600	-	-	-

3 Predicted Home Energy Use

Before this report considers suitable renewable technology solutions it is critical to consider the likely overall consumption of energy required by the property.

3.1 Space Heating

The space heating requirements are expressed in two ways:

Annual space heating

Which refers to the total energy over the year required to keep the building comfortable throughout the year. These calculations are based on average weather data based on geographic location.

Peak heat loss

Which refers to the amount of energy needed for the home to stay comfortable on the coldest day of the year. System designers use this figure to ensure the correct sizing of heating plant installed. These design temperatures and weather files are based on the property's geographic location and altitude and are specified CIBSE. For this property the design temperature used for peak heat loss is -3.5°C.

In order to establish the space heating requirements of the property a dynamic thermal model was created in the IES Virtual Environment software using the fabric heat loss from the methodologies described in CIBSE Guide A Chapter 5. The results of the heat loss calculations are summarised in Appendix A. This process allows individual room elements to be analysed and an optimised heating system to be specified later in development.

Noel Wright Architects have established a set of potential insulation improvements to the building fabric. These potential improvements have been incorporated in arriving at Mesh recommendations. It should therefore be noted that Mesh recommendations are based on the assumption that these improvement works are all carried out. A reduced level of improvements should be expected to cause a further review of our recommendations.

These insulation improvements are:

Windows/doors/glazing: The performance of all glazing has been upgraded to a level comparable to typical good modern double glazing. This is to be achieved either by installing secondary glazing, or replacing the window glass with 'Fineo', a special form of thin vacuum sealed glazing units. (U Value 1.6W/m2K). Draught proofing work has also been assumed.
Roofs, flat and pitched: all are in need of renewal and the renewal works will incorporate good levels of thermal insulation (U-value of 0.18 W/m2K flat roofs, 0.18 W/m2K pitched roofs)

Lower Ground floors: proposals include taking up these floors and remaking to include insulation as well as underfloor heating. (U-value of 0.22 W/m2K)
Outside walls: it is considered that scope exists to incorporate a degree of insulation applied to the inner surface of the outside walls. This insulation. The extent and quality of this insulation is limited and has been assessed on a room-by-room basis. Care has been taken to retain space and character. The provision arrived at will cover approximately 60% of the internal wall area. (U-value of 0.5 W/m2K)

Note: the conservatory and the garage have been treated as unheated spaces and are excluded from the assessment of heating demand.

The following table shows the U-values for constructions discussed and agreed with Noel Wright Architect:

Construction Element	**U-Value** (W/m^{2}K)
Ground floors	0.22
Existing External Walls	1.35
Improved External Walls	0.5
New External Walls	0.2
Flat roof	0.18
Slated roof	0.15
Windows	1.6
Roof light	1.8
Existing windows	4.7
External doors	1.5
Existing Infiltration Rate	12.5m^3/h.m^2@50Pa

3.2 Domestic Hot Water (DHW) Requirements

The DHW storage requirements for the dwellings have been calculated as 45lt per person at full occupancy based on a gas boiler heating the water to 60ºC. Full occupancy is assumed to be two persons occupying the master bedroom and single persons occupying the remaining bedrooms.

3.3 Electricity Use

The estimated annual electrical load for dwellings of this size and occupancy is 6,860kWh per annum based on 15kWh per m^2 of floor area. This excludes any electricity associated with space heating, domestic hot water, and includes consumer goods, cooking appliances, lighting, and other likely typical electrical loads in the home.

3.4 Predicted Use Summary

The table below details the expected energy requirements for 18 Greville Place

	Annual demand, kWh th	**Peak demand, kW***
Space heating	43,084	19.8
Domestic hot water heating	13,780	1.4
Electricity (appliances, cooking and lighting) kWhe	6,860	-

** Peak heating demand at -3.5°C externally*

3.5 Benchmark Heating System

This benchmark heating scheme relies upon a single modern Gas boiler providing 21.23kW heat energy to deliver all space and DHW heating, without the need for backup.

Benchmark heating system	**Gas**
Capital cost, £	2,500
Annual running cost, £	5,815
20-year total cost, £	118,850
Annual CO2 emissions, Kg	13,570

4 Energy Efficiency Methodology

Before starting to look at energy efficiency and renewable energy technology options it is worth explaining the general energy strategy steps employed on modern low energy homes to ensure money is well spent on the most beneficial and cost-effective areas.

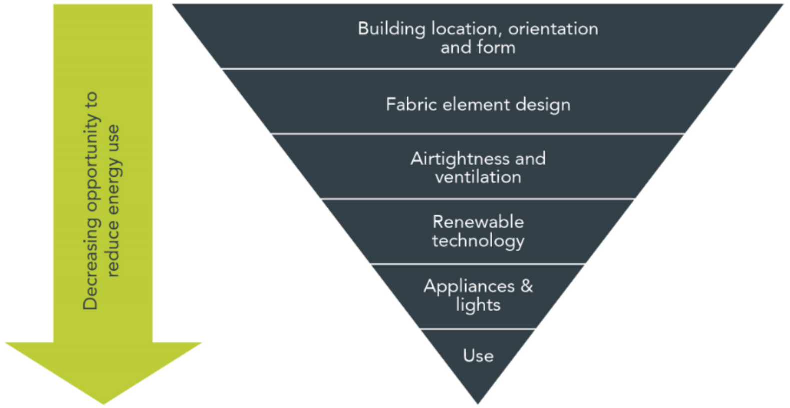

Figure 2: The Energy Hierarchy

Step 1: Reduce elemental building fabric heat loss
Step 2: Reduce unnecessary ventilation and air heat losses
Step 3: Harvest energy more efficiently to heat home and produce hot water
Step 4: Incorporate micro-generation to generate electricity and power efficient technology
Step 5: Store surplus locally generated electricity to reduce imported electricity from the grid

Most successful construction projects start with a fabric first approach and aim to reduce the amount of energy the building loses through windows, doors, walls, floors and ceilings. Heat can escape through the fabric itself and through small gaps in the thermal envelope. Minimising fabric losses is easier when designing a new building than when planning renovations to existing building. The older the original building, typically the less thermally efficient the original building materials and greater the air infiltration will be.

Increasingly, the most efficient heating solutions finding their way into homes are electrically powered and installing electrical micro-generation technologies in the home only assist further in reducing household electrical costs.

It is with this methodical approach in mind that the remainder of the report addresses various aspects of the building and internal low carbon systems to achieve a cost effective, progressive and low carbon home.

5 Technology Review Methodology

For each of the technologies and measures within the scope of this feasibility we will include a section containing detail on the following areas:

5.1 Technology introduction

This will give a brief overview of the technology, how it works, and the opportunities and challenges associated with it. Where appropriate complimentary technologies have been included for your information and where possible indicative costs have been included.

5.2 Installation considerations

This is specific to your property; it will consider where is most appropriate on your site to place each technology and the space required.

5.3 Economic considerations

This section details the economic elements to be considered when installing a new heating system:

5.3.1 Capital cost

The costs presented below consider best estimated values for all capital equipment required, ground works, installation labour and commissioning costs. Where any associated costs cannot be easily estimated, and therefore have not been included, this will be noted. The costs are presented do not include VAT; they also do not include the standard fees usually added by main contractors; so be aware that additional fees are usually added when projects are tendered in this way.

5.3.2 Running costs

The costs presented below are the fuel costs for the various technologies. It is assumed that when installed well all systems will require a similar level of maintenance. Running cost savings are calculated as a comparison to the existing heating system and assume low flow temperatures of 50.0°C

5.3.3 Payback

This has been calculated as how many years the capital cost will take to be re-paid by the running cost saving.

5.3.4 20-year total cost

This has been calculated as the total capital cost, plus 20 years of running costs, minus any subsidy payments. 20 years has been selected as, beyond this point, parts would likely need to be replaced, regardless of the system chosen. For simplicity, and to avoid speculation, today's prices have been used throughout and inflation has not been applied.

5.3.5 Annual carbon emission

These have been calculated based on the fuel input amount and type, associated with each technology, and conversion figures published within the UK SAP 10.1. Carbon emissions are compared to the existing heating system for ease of comparison.

While Mesh makes every effort to ensure that the costs presented are an accurate representation of the market, variation will always apply.

6 Ventilation Technology

Ventilation losses in modern and well insulated homes can account for up to 50% of the home's total energy costs per year. Increasingly, high quality, airtight buildings benefit from devices that control the movement of air and recycle waste heat to minimise these losses and improve overall air quality in the home.

6.1 Technology Introduction

The aim of this section is to briefly introduce the available ventilation technologies. We will outline the technology's key points and comment on practical feasibility before moving on to the financial analysis.

6.1.1 Mechanical Extraction and Trickle Ventilation

Mechanical extraction is the use of a fan unit, typically in bathrooms and kitchens, to remove warm, moist air or odour from the property. To avoid condensation however, extraction of warm, moist air is not enough, it must be in conjunction with input of fresh air, yet this is often overlooked for several different reasons. The fresh air not only creates a fresh atmosphere, it also promotes air movement to ensure that air is circulated around the property.

Trickle Vents, known also as background ventilators, are natural ventilation devices which can be integrated into façades or window systems as an alternative to operable vents. As the name suggests, the vent is designed to allow a trickle of air to pass through. This helps provide 'natural' ventilation within a home. Some types of vents incorporate a sliding switch to increase or decrease the ventilation.

There can be issues with this sort of ventilation, however. Trickle vents may still allow draughts through, even when turned to a 'closed' position. Even the small gaps used for trickle vents will affect the home's energy-efficiency to a certain degree, allowing some heat to dissipate.

Advantages

- Low cost
- Improved indoor air quality.

Disadvantages

- Allows uncontrolled heat loss.

7 Heat Emitter Technology

7.1 Technology Introduction

Low central heating flow temperatures allow heating systems to operate more efficiently. This is particularly true when installing heat pump technology, which works best with flow temperatures of between 35-45°C. Conventional radiators with conventional sizing are not compatible with these low temperatures and will not keep properties comfortable. This section introduces the alternatives.

7.1.1 Underfloor Heating

The installation of wet low temperature (35-45°C) underfloor heating can bring several comfort benefits that may prove worthwhile:

- Declutters the walls of a room as the emitter is under the floor.
- Provides a gentle all-round heat effect.
- Provides warmth throughout the room and avoids hot and cold spots.
- Relies on heat radiation rather than air convection meaning you will instantly feel warm when coming in from outside in the winter.
- Provides superior and controllable zonal heating.

The approximate costs of installing a good quality wet underfloor heating (UFH) system are £40/sqm installed (excluding insulation and screed).

Old and new homes are constructed in a wide variety of ways and modern underfloor heating solutions can be adapted to ensure that they function successfully around the building structural elements. UFH can be installed on solid concrete floors, in structural concrete floors, in suspended floors between rafters/joists and even in walls. Usually, UFH sits on top of an insulation layer and just below the finished floor level ensuring that heat is emitted into the room and minimal losses are incurred into the ground or structure below.

In new homes the integration and installation of UFH is relatively easy but for older homes there are a selection of low-profile products and lightweight products available to ensure they do not compromise space or weight limitations of older structures; these are more expensive to install and less efficient at transferring heat into the room.

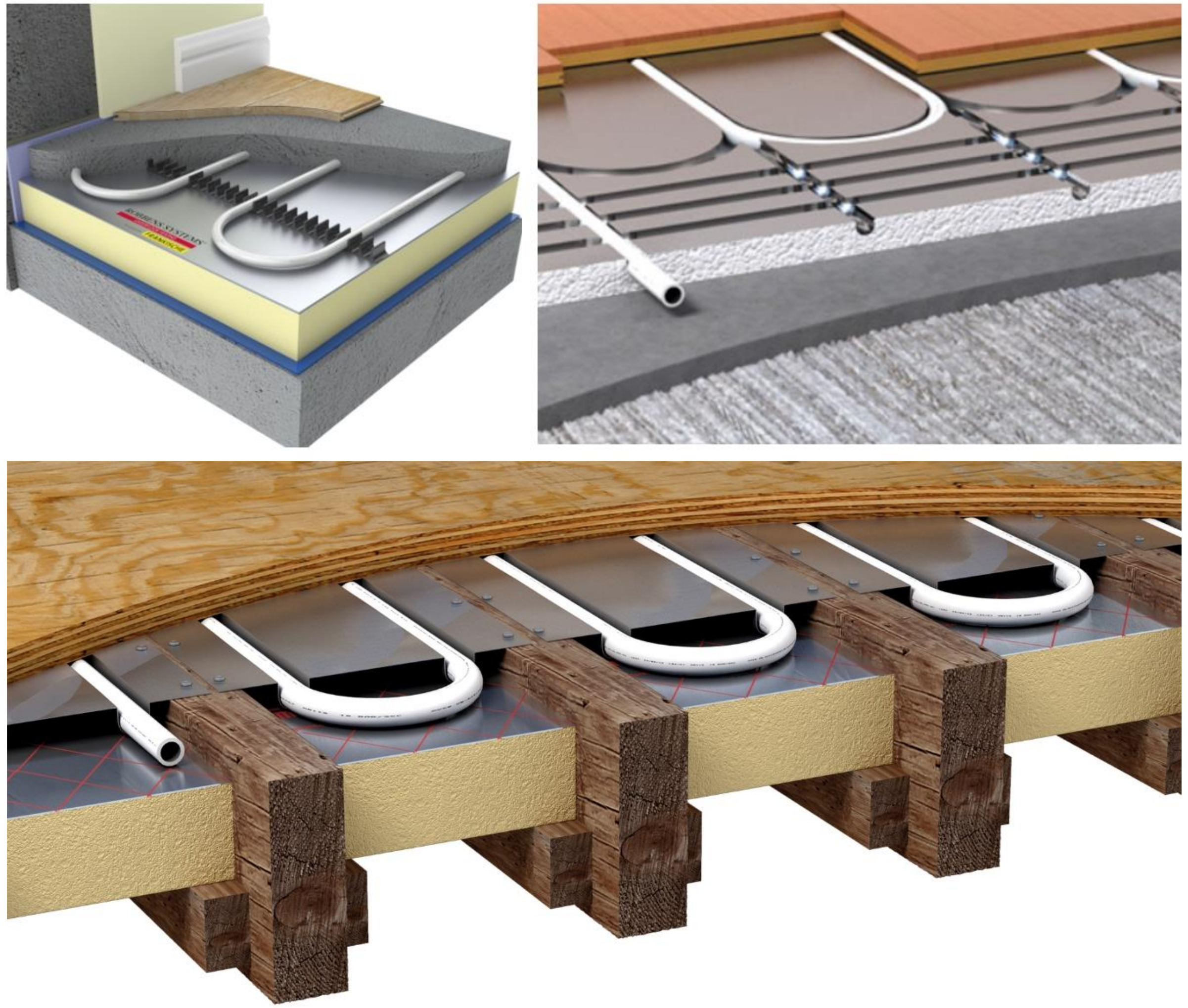

Figure 3: UFH (clockwise) in screed, overlay, and metal conductor systems

7.2 Radiators

Radiators have been used for many years in British homes and are still a viable option where existing plumbing cannot be changed, client preference dictates, or floor structures cannot take the additional loads of UFH.

With modern multi-panel and finned radiators allowing higher outputs than older designs, lower water flow temperatures can still produce respectable radiator outputs. Twinned with more efficiently insulated homes and different heating durations, traditional pressed steel radiators can be used with lower temperature heat sources, whilst still maintaining adequate room heating during the coldest days of the year.

A range of products have been developed to allow radiators to be used in homes where heating systems are running at a low temperature and wall space is at a premium. These radiators use aluminium fin construction and sometimes convection fans to produce comparable emitter outputs to those of traditional radiators at flow temperatures of 45°C rather than more traditional 65°C from conventional boiler systems. Companies such as Jaga are market leaders in bespoke low flow temperature radiator design and production.

Modern heating systems, and particularly heat pump systems, are optimised by using weather compensation which adjusts heating circuit flow temperature based on outdoor temperatures. In winter the flow temperatures are at their highest but in spring and autumn months these temperatures are reduced.

For drying towels, to combat 'luke-warm' radiators during summer months when the home heating is not operational; often dual fuel systems are often suggested. These systems use timed and thermostatically controlled electric immersion heaters to boost radiator temperatures to that desired by the client all year round. While these offer a simple installation a more efficient alternative is to heat towel rails via the domestic hot water circuit, reducing the losses associated with direct heating elements.

Cast iron radiators are traditional heating devices known for their durability and classic design. They efficiently distribute heat through their large surface area and retain warmth even after the heating system is turned off. These radiators are popular for their aesthetic appeal and ability to provide consistent, long-lasting warmth in homes.

Figure 4:Example for cast iron radiator

Figure 5: Example for low flow temperature radiator

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7.3 Installation considerations

Mesh has conducted a comprehensive analysis of the heat loss in the property and have determined that the optimal flow temperature for the underfloor heating system is 45°C. This recommendation takes into account the installation of wet underfloor heating in screed on the lower ground floor and UFH on the other floors with a metal conductor system.

Based on our calculations, it is feasible to install underfloor heating throughout the property, considering 1 tog carpet or hardwood flooring. Ceramic materials and stone tiles will also provide an efficient thermal conductivity and could be used in any of the areas.

Some spaces on the ground and first floor need additional heat support as the underfloor heating may not meet the heating demand. Mesh recommends installing a new radiators on dining, lobby, and lounge spaces of the ground floor and the master east bedroom on the first floor.

Mesh recommends including towel rail warmer connected to hot water system in all the bathrooms to provide more responsive heating system in this area.

The table below shows the heat loss and cost of under floor heating system for each room on the property. In addition to the heat loss of the backup radiators.

Room name	Floor area, m^2	Heat loss,W	Heat loss w/m^2	Heat emitter	Rads Heat Loss, W	Cost estimate, £
L00: Dining	25.3	2037.3	81	UFH+Rad	848.2	569.3
L00: Kitchen	23.2	812.4	35	UFH	-	522.0
L00: Lobby	19.7	1047.6	53	UFH+Rad	121.7	443.3
L00: Lounge	37.3	2758	74	UFH+Rad	1004.9	839.3
L00: WC	2.6	295.2	114	UFH+Rad	173	58.5
L01: Bedroom 01	19.9	807	41	UFH	-	447.8
L01: Bedroom 02	24.3	1261.7	52	UFH+Rad	119.6	546.8
L01: Bedroom 03	20.8	867.6	42	UFH	-	468.0
L01: Bedroom 04	14.9	692.2	46	UFH	-	335.3
L01: Landing	10.2	431.3	42	UFH	-	229.5
L01: Lobby 01	1	15.2	15	UFH	-	22.5
L01: Lobby 02	3.1	64.2	21	UFH	-	69.8
L01: Bathroom 01	9	778.3	86	UFH+Rad	355.3	202.5
L01: Bathroom 02	10.2	670.4	66	UFH+Rad	191	229.5
L02: Bedroom 05	10.6	389.8	37	UFH	-	255.0
L02: Bedroom 06	20.1	824.5	41	UFH	-	265.0
L02: Kitchen	3.9	108.9	28	UFH	-	502.5
L02: Bathroom 05	5.1	358.4	70	UFH	118.7	42.5
LG: Play room B	8	452.8	57	UFH	-	288.0
LG: Bed- sitting room	23.2	1509.4	65	UFH	-	835.2
LG: Play room A	24.5	1668.6	68	UFH	-	882.0
LG: Utility	19.6	858.5	44	UFH	-	705.6
LG: Hallway	15.5	334.4	22	UFH	-	558.0
LG: Bathroom	6.8	446.6	66	UFH	-	244.8
L02- Lobby	1.2	27.9	23	UFH	-	30.0
Total						**9,590**

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8 Heating Technology

This section explores the space and domestic hot water heating plant available for your property. We'll introduce the technology; highlight any practical considerations you'll need to make and summarise the economic costs and benefits.

8.1 Air Source Heat Pumps (ASHPs)

8.1.1 Technology Introduction

Air source heating uses electricity to convert energy gathered from the air into low temperature water for heating and domestic hot water use. The energy is collected externally via a fan unit which can be either be adjacent to the property using a "monobloc" unit or up to 50m away using a "split" unit design. Depending on the availability of outside space and the location of individual properties' social areas split units can reduce noise and visual concerns. The operation of the fan within ASHPs, can be considered as a nuisance noise, but if they are not immediately adjacent to living spaces, they are unlikely to pose a nuisance.

Internally a monobloc heat pump requires no additional equipment, except for a manifold connecting it to your central heating circuits and a domestic hot water (DHW) cylinder as the external fan unit houses the refrigeration circuit which converts the heat to a useable form.

When installing a split system, an additional unit, approximately the size of a conventional gas boiler, is installed internally and it is this unit which houses the compressor and condenser.

In both cases a DHW cylinder will also be required, along with heating "buffer" cylinder. ASHP installations are therefore a good option when space is at a premium.

In special cases it may also be desirable to site a monobloc heat pump some distance from a property, for example if both external and internal plant positions were constrained. In this case highly insulated buried pipework would connect the external unit to the heating circuit within the property. This would add approximately £100/m to the cost of installation.

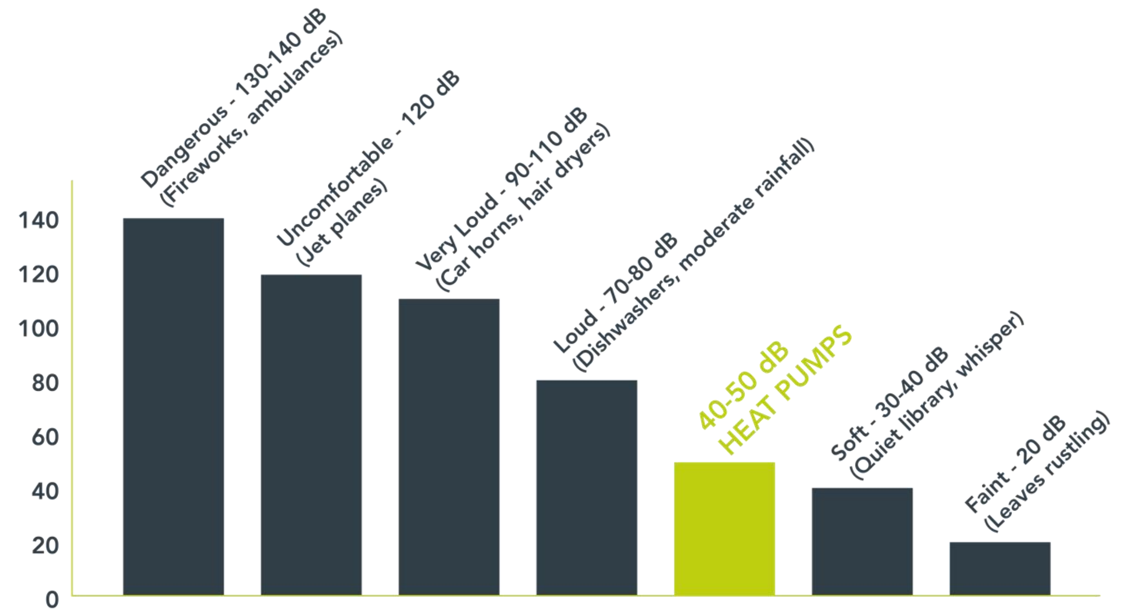

Figure 6: ASHP decibels compared

Advantages
- Significant carbon savings
- Reduced running costs
- Ideal to use with underfloor heating

Disadvantages
- External unit required
- Low level noise during operation

Figure 7: Left to right typical air source plant room installation, typical outdoor small fan unit, example cover for aesthetic purpose

8.1.2 Installation Considerations

ASHPs are considered permitted development under planning law providing they are:

- the first ASHP unit (or wind turbine) installed onsite, if multiple units recommended then planning permission is required
- over 1m away from the property boundary
- a minimum of 500mm clearance to the rear and side of the ASHP
- a minimum of 150mm clearance around the plant room cylinders

On land within a Conservation Area or World Heritage Site ASHPs must not be installed:

- on a wall or roof which fronts a highway
- nearer to any road than the building

On land not within a Conservation Area or World Heritage Site ASHPs must not be installed on any part of that wall is above the level of the ground storey

Permitted development rights do not apply for installations within the curtilage of a Listed Building or within a site designated as a Scheduled Monument

A monobloc system is considered to be most appropriate for this site, as the rear wall of the play room provides an ideal location to site the fan unit, with clear access in to the building. A monobloc system, with a fan unit sited adjacent to the external wall of the property would allow internal space to be maximised, as only an external fan would be required. Figure 8 illustrates the location considered to be the most appropriate for this site, this seems natural as in this location it is unlikely to disturb any socialising that may take place. This unit could be placed at any external wall of the main building, if there is felt to be a more suitable position, as long a good air flow can be maintained around the unit.

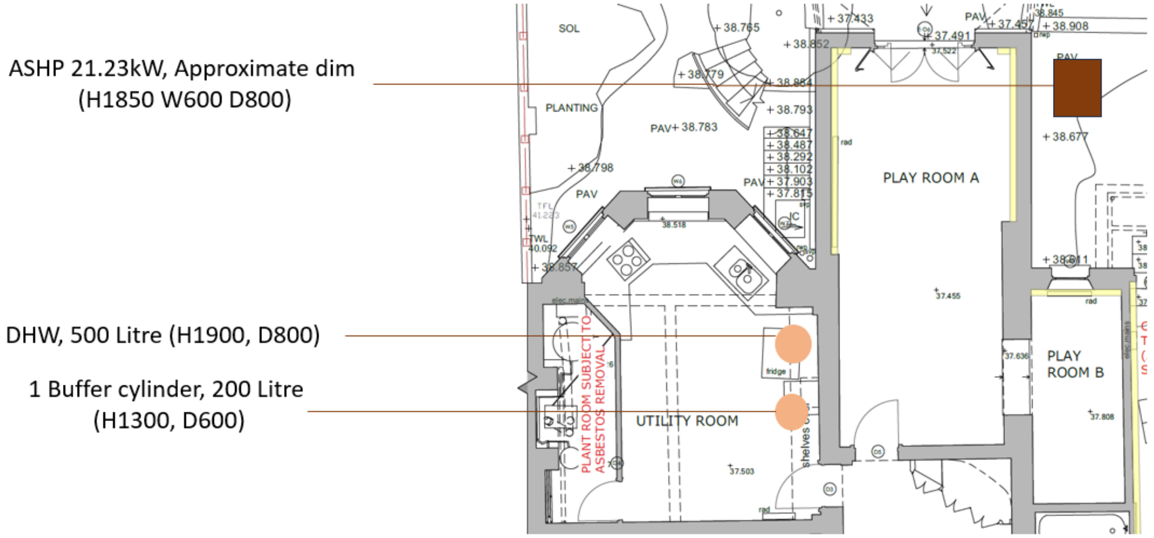

Figure 8: Potential location for external fan unit and internal plant locations

Internally a monobloc system would connect directly to a domestic hot water cylinder, buffer cylinder and a central heating manifold. Additional items would not be required. The 420-litre domestic hot water (DHW) cylinder proposed for this property has been sized based on the likely full occupancy of the property being one bedroom occupied by 2 people and the remaining occupied singly. This is based on the 60 litres per occupant as per the CIPHE design guide when utilizing an ASHP to provide the domestic hot water demands.

Electricity supply is a consideration for any heat pump installation. This site is currently served by a three-phase supply which is sufficient for a heat pump of this size.

8.1.3 Economic Appraisal

This scheme relies upon an ASHP heating system delivering 21.23kW of heat at -3.5°C. Powering this system would cost £330 less each year than Gas.

ASHP	
Capital cost, £	30,830
Annual running cost saving, £	5,485
20-year total, inc BUS £	133,040
Annual carbon emissions saving, Kg	11,380

8.2 Bivalent Systems

Bivalent systems utilise a secondary boiler, which is designed to support a heat pump in providing heat on the coldest of days. They can also provide additional heat to radiators in a mixed emitter heating system. This can be of benefit for retrofit projects and older buildings where heat pumps are required, due to the size of existing radiators, to run with higher than optimum flow temperatures (<45°C) and peak heat loss is high. The capital cost of providing heat pump equipment able to cover the full heating load in these cases can be expensive.

A heat pump 7kW sized to heat the lower ground floor and second floor via underfloor heating emitters, working in parallel with gas boiler which is providing the other heating demand for the ground and first floor via cast iron radiators in addition to provide the domestic hot water for the property. The gas boiler will provide a backup for the heating system of the whole property.

Advantages

- Reduced heating capacity
- Reduced capital cost
- Reduced area required for ground loops
- Back-up and peace of mind

Disadvantages

- Increased running costs compared to single system

8.2.1 Economic Considerations

Bivalent	ASHP
Capital cost, £	16,030
Annual running cost, £	5,425
20-year total, £	124,530
Annual carbon emissions saving, Kg	4,210

8.3 Heating Technology Summary

We recommend installing an ASHP/Gas hybrid heating system, because this system offers the best consistent strategy with design limitation and carbon reduction.

The table below summarises the economic information:

Technology	Capital cost, £	Annual running cost, £	Annual carbon emissions saving, Kg	20-year total,£
Gas	2,500	5,815	N/A	118,850
ASHP	30,830	5,485	11,380	140,540
ASHP/Gas Hybrid	16,030	5,425	4,210	124,530

9 Solar Technology

9.1 Solar Photovoltaics (PV)

9.1.1 Technology Introduction

Solar photovoltaic panels are employed to reduce the amount of energy used by the household from the main electricity network and in turn reduce the overall electricity bill for the home. Photovoltaic systems have minimal internal components to consider and can easily be integrated into the home electricity supply.

Roof mounted panels on most homes outside of conservation areas are within permitted development rights and can be installed without planning permission. Panels are now available in all types of colours, finishes and roof integration formats and so for more aesthetically sensitive areas there is often an acceptable solution. Black panels and solar slates are often used in aesthetically sensitive areas.

Advantages

- Substantially lowers electricity bills
- Little maintenance
- May be roof mounted or ground array depending on site location

Disadvantages

- May not be suitable due to orientation of the roof or heavy shading

Figure 9: Solar installation examples clockwise from top left: In roof, tile in-roof, typical flat roof, flat green roof

9.1.2 Installation Considerations

The most suitable location for a solar PV array is illustrated in Figure 10. Usually, the limiting factor on solar PV at this site is the availability of suitable roof space. The potential roof space discussed is orientated towards South and unshaded. In this example conventional 370w panels have been used as they offer a good level of energy density. The roof would allow up to 8 panels, which equates to 2.96kWp of installed capacity. In this position annual generation is estimated to be 785kWh per kWp of capacity installed.

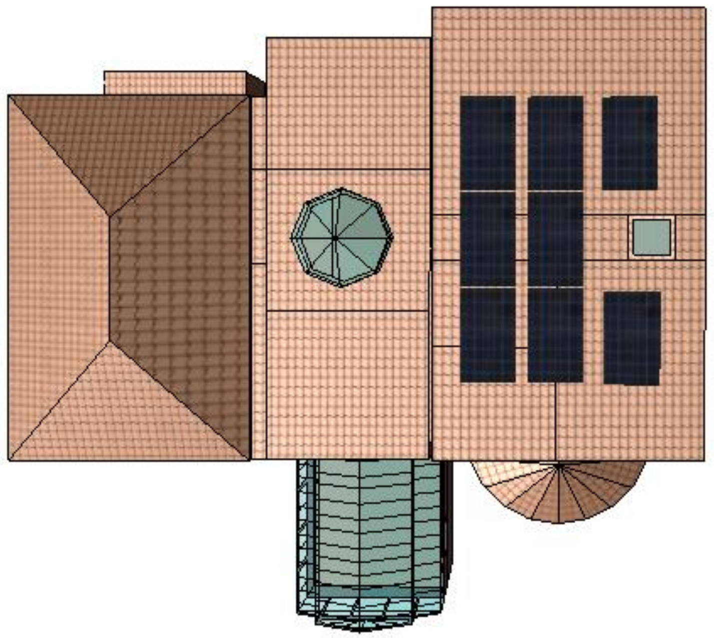

Figure 10: Solar PV array (black) location

Under G98 regulations, generation capacity is limited to 16amps per phase of incoming electrical supply. This roughly equates to 4kWp per phase, which can be installed without additional permissions from the local District Network Operator (DNO). The property is served by a three-phase connection, and this allows up to roughly solar PV array of 12kWp to be installed.

9.1.3 Economic Appraisal

To assess the likely benefit of a solar PV array we must first understand the likely building electricity consumption. Based on a ASHP system providing heating and hot water, the expected annual electrical consumption is estimated to be 22,710kWh and 7,250 when utilizing a gas boiler. Figure 11&12 shows the likely distribution of energy consumption amongst the key uses within the property and the following table describes how these consumptions have been assumed to be distributed between daylight and darkness hours.

Item	Time of use	Day	Night
Heating	Even Split	50%	50%
DHW	Even Split	50%	50%
Cooking	Even Split	50%	50%
Other appliances	Even Split	50%	50%
Lighting (& night specific)	Night only	0%	100%

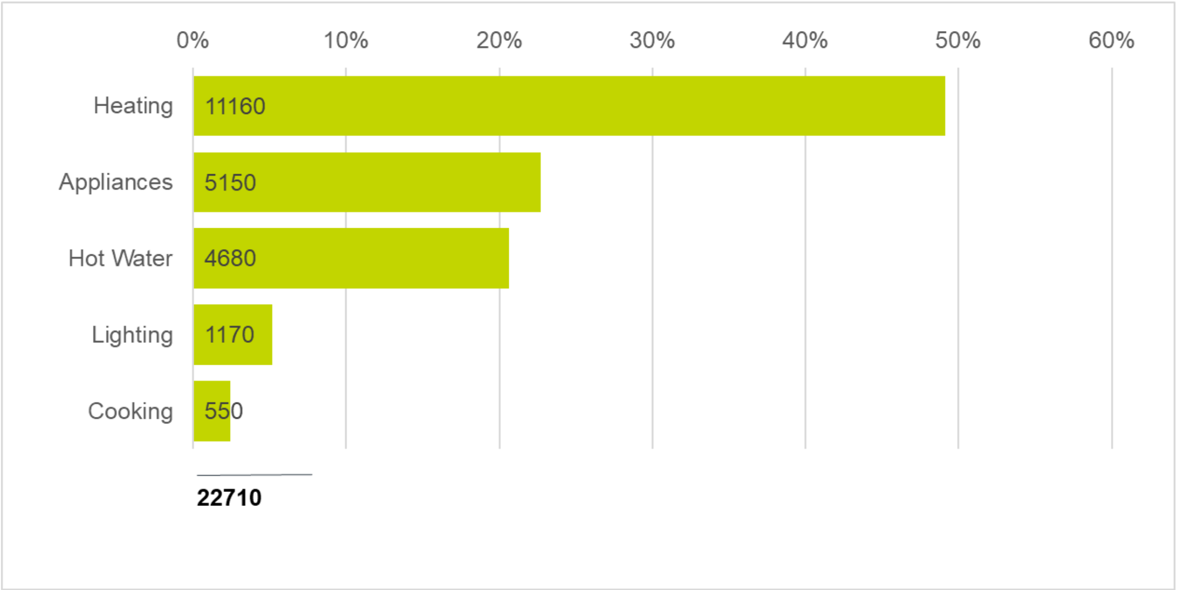

Figure 11: Likely end use electricity consumption Based on a ASHP system providing heating and hot water

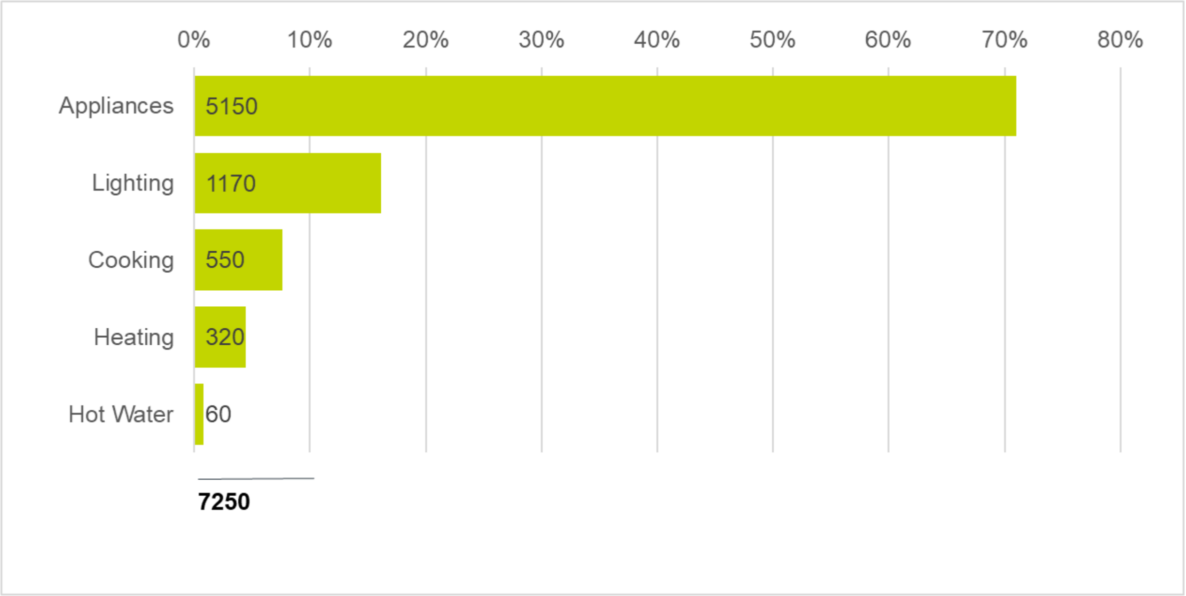

Figure 12: Likely end use electricity consumption Based on a gas boiler system providing heating and hot water

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Figure 13&14 demonstrates the monthly daily average of energy generated and consumed onsite, based on the optimum array size for this property – 2.96kWp. You'll see from this graph that the energy generated by the 2.96kWp system never exceeds the daytime load of the property, even in the height of summer when utilising an ASHP and there is a small excess in the summertime when utilising the Gas boiler. With this size of array, it is likely that most of the energy generated will be consumed during the day by the normal day to day running of the property; without any excess being export to the grid. The 2.96kWp array proposed is sized to best suit the expected loads of the property, providing a balance between covering winter lows in PV generation and minimising wasted excess to the grid.

When utilising a gas boiler as a source of heat, solar diverter controller will be an efficient solution to divert any electricity generated by the solar PV system that isn't used in the building to an immersion heater to heat water.

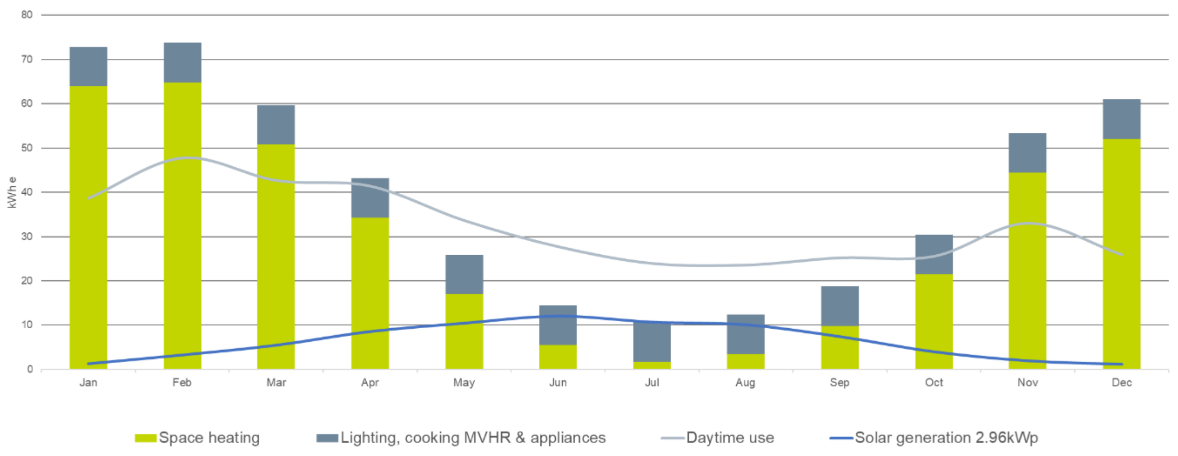

Figure 13: Average daily electricity production and usage by month Based on a ASHP system providing heating and hot water.

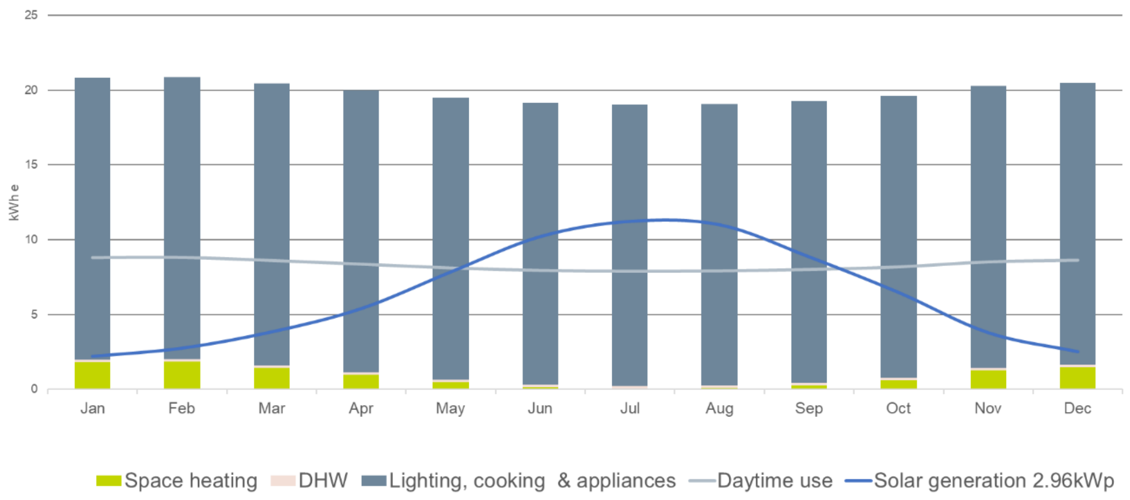

Figure 14: Average daily electricity production and usage by month Based on a gas boiler system providing heating and hot water.

Based on these figures the table below demonstrates the costs and savings associated with a 2.96kWp PV array considering an ASHP providing heating and hot water:

Solar PV	
PV Size, kWp	2.96
Capital cost, £	£5,900
Estimated first year benefit, £*	£790
Payback, yrs.	7.5
Annual excess kWh	0
Annual carbon emissions saving, Kg	315

the table below demonstrates the costs and savings associated with a 2.96kWp PV array considering a gas providing heating and hot water:

Solar PV	
PV Size, kWp	2.96
Capital cost, £	£5,900
Estimated first year benefit, £*	£600
Payback, yrs.	9.8
Annual excess kWh	640
Annual carbon emissions saving, Kg	230

9.2 Complementary Solar PV Technologies

9.2.1 Hot Water Immersion Controllers

Immersion heater power diverters are devices which can optimise the use of electricity generated by a solar PV system thus increasing savings. These devices divert any electricity generated by the solar PV system that isn't used in the building to an immersion heater to heat water. This electricity would otherwise be exported to the grid. The benefit therefore is the difference between the payment received for export and the cost of buying electricity from the grid.

To install such a system that would intelligently control the power to an immersion heater when there was spare electricity available would cost approximately £400.

Figure 15: Example of a solar PV hot water immersion controller – iBoost

9.3 Solar Thermal

9.3.1 Technology Introduction

Solar thermal uses panels or vacuum tubes orientated towards the sun that absorb energy. The glycol solution within the panels or tubes is heated and then pumped down to a hot water cylinder or thermal store to exchange heat via an indirect secondary coil in the water cylinder. Solar thermal systems are predominantly used to supplement domestic hot water but can also be used for swimming pool heating and space heating using thermal stores.

Figure 16: Solar thermal installation examples left in-roof, right – vacuum tube

A standard system can be expected to deliver the entire home's hot water during the summer months and 50-60% of hot water needs on average throughout the year. Vacuum tubes or panels can be installed and, other than aesthetic differences, the vacuum tubes do allow a certain element of 'tuning' as they can be rotated to face south making them more productive year-round.

9.3.2 Installation Considerations

Solar thermal panels and solar PV share the same principles when it comes to considering where to locate them. Therefore, the only suitable roof is that which was highlighted in the PV section within **Error! Reference source not found.**. Solar thermal panels are sized based on the likely DHW usage, oversizing can lead to inefficiencies and therefore should be avoided.

9.3.3 Economic Appraisal

This scheme of 2 solar thermal panels offers the best payback period, and will likely provide 13% of the property's DHW demands for 7 people.

Solar Thermal	
Capital cost, £	4,800
Running cost saving against Gas, £	176

Payback, yrs	27
20-year total cost, £	1,270
Annual carbon emissions saving, Kg	412

** Subject to local supplier/installer pricing*

9.4 Solar Technology Summary

There is a limited roof space at this property to size a solar array. A 2.96kWp PV array is the maximum size for this site. Including battery storage within the PV system does not improve the economic viability of the scheme.

Solar Technology	Capital Cost	Payback, Yrs
Solar PV - 2.96kWp	5,900	8.6
Solar diverter control	400	4
Solar Thermal	4,800	27

** Subject to local supplier/installer pricing*

10 Summary & Recommendations

Heating energy demand

– Upgrading the thermal building fabric is resulted in a 42% reduction in annual heating demand and CO2 emissions, showcasing its positive impact on both energy efficiency and environmental sustainability.

Heating and DHW system

– An ASHP heating system delivers 21.23kW of heat. The ASHP system is an efficient, non-fossil fuel-based system providing the lowest carbon emissions. The ASHP will also deliver all the hot water for the property.
– Electricity supply is a consideration for any heat pump installation. This site is currently served by a three-phase supply which is sufficient for a heat pump of this size.
– A domestic hot water tanks covering 420 litres, designed for 7 inhabitants. DHW usage is calculated for 65lt/person/day based on Building Regulations Part G. A storage allowance of 60lt per person is made for heat pump heated DHW.

Heat emitters

– The recommended temperature for the central heating system is 45°C, which provides the most cost-effective operation of the ASHP all year round. This temperature is suitable when installing wet underfloor heating system on the lower and second floors and new efficient radiators on the ground and first floors.
– Mesh verified that UFH is suitable only for the lower and second floor. Careful consideration will need to be paid to floor coverings in certain rooms to ensure comfortable and efficient heat distribution into the spaces, this has been detailed in the heat emitters section 7.
– Mesh recommends installing new radiators on the ground and first floors in design with the recommended temperature flow of 45°C, which is the optimal for running the heating system efficiently.

Bivalent system - ASHP/gas hybrid

– Employing a bivalent system composed of a 7kW air source heat pump (ASHP) catering to the heating needs of the lower and second floors through underfloor heating emitters, alongside a new 21.23 kW gas boiler providing heat for the ground and first floors via cast iron radiators, as well as meeting all domestic hot water demands. However, caution is advised due to concerns related to technical intricacies, control, and maintenance factors.

Gas boiler

- The gas boiler can work with any type of heat emitters.
- Gas boilers can provide higher water temperatures, which is more compatible with the lower heat output and slower response time of cast iron radiators.

Solar Photovoltaic (PV) panels

- The limiting factor for PV is the available desired roof space.
- 2.96kWp (8 x 370w) could be installed as indicated in figure9
- Based on this array size there is likely to be almost no excess generation exported to the grid and most of the energy generated will be consumed during the day by the normal day to day running of the property. It will provide £790 savings each year, paying back in around 7.5 years. It will also save around 315kg of carbon emissions.

Solar thermal

- This scheme of 2 solar thermal panels will likely provide 13% of the property's DHW demands for 7 people. It will cost around 4800£ and save around 175£ per year, paying back in 27 years, leading to choose the PV panels over the solar thermal panels.

Solar Diverter controller

- The Solar Diverter will use any electricity excess from the solar PV system that isn't used in the building to heat water in the DHW cylinder. It offers a relatively low-cost way to utilise excess onsite generation and is a good investment in this case.

Energy tariffs

- A rate of 34 p/kWh has been applied for electricity.
- A rate of 9 p/kWh has been applied for gas.

In summary, the running cost reduction benefits of embracing a range of renewable energy technologies are shown in the table below:

Technology	Feasible	Recommended	Capital cost, £	Annual running cost, £*	Annual CO_2 emissions savings, Kg	20-year total cost , £*
Gas	✓	✗	2,500	5,815	N/A	118,850
ASHP, 21.23kW	✓	✓	30,830	5,485	11,380	140,540
ASHP7kW /Gas 21.23kW Hybrid	✓	✗	16,030	5,425	4,210	124,530
Solar PV array 2.96kWp (8 x 370W)	✓	✓	5,900	-790	315	-9,900
Solar thermal	✓	✗	4,800	-175	410	1,270
Under floor heating	✓	✓	4,700	-	-	-

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11 Appendix A – System design assumptions

Benchmark Assumptions:	
Boiler efficiency, %	0.88
Cost, p/kWh	9
kWh/kWh	1.0
Cost p/kWth	10.2
ASHP Assumptions:	
Efficiency, SCOP	3.41 (341%)
Cost, p/kWhe	34.0
Cost, p/kWth	10.0

12 Appendix B – Room type thermal template

Set back	Heating set back design temp. and profile (˚C), with heating set back 23-07hrs	CIBSE TM59 Internal Gains
Ancillary / Cupboard / Store	Two-value: 18.0; 16.0	Lighting
Bathroom	Two-value: 22.0; 16.0	Lighting
Dining room	Two-value: 21.0; 16.0	Lighting and people
Double bedroom	Two-value: 18.0; 16.0	Lighting, people, and equipment
Dressing room	Two-value: 21.0; 16.0	Lighting and people
Hallway / Lobby / Stair	Two-value: 18.0; 16.0	Lighting
Kitchen	Two-value: 18.0; 16.0	Lighting, people, and equipment
Kitchen / Family room	Two-value: 18.0; 16.0	Lighting, people, and equipment
Living room / Snug	Two-value: 21.0; 16.0	Lighting, people, and equipment
Plant room	Unheated	
Single bedroom	Two-value: 18.0; 16.0	Lighting, people, and equipment
Studio bedsitting	Two-value: 21.0; 16.0	Lighting, people, and equipment
Study / Office	Two-value: 21.0; 16.0	Lighting, people, and equipment
Utility / Boot room	Two-value: 18.0; 16.0	Lighting
Void	Unheated	
Voids and garages	Unheated	
WC	Two-value: 21.0; 16.0	Lighting

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13 Appendix C – Peak and annual heating loads

Address	18 GREVILLE PLACE LONDON NW6 5JH
House type	5+ bed semi detached
Date	03/11/2023
IES weather file	LondonTRY05
Floor area	458m^2
Dwelling volume	1280m^3
Outdoor design temperature	-3.5°C

The figures below are based on building heat loads calculated in the IES Virtual Environment software using the fabric heat loss from the methodologies described in CIBSE Guide A Chapter 5.

Room	Design temp (˚C)	Floor area (m^2)	Heat loss, (W)	Normalised heat loss, (W/m^2)	Annual thermal energy consumption, (kWh th)
L00: Conservatory	-60	14.2	-	-	-
L00: Dining	21	25.3	2037	81	5260
L00: Kitchen	18	23.2	812	35	976
L00: Lobby	18	19.7	1048	53	1567
L00: Lounge	21	37.3	2758	74	6909
L00: Stair	18	2.4	60	25	53
L00: Store	18	2.6	55	21	61
L00: WC	21	2.6	295	114	799
L01: Bedroom 01	18	19.9	807	41	1569
L01: Bedroom 02	18	24.3	1262	52	2124
L01: Bedroom 03	18	20.8	868	42	1406
L01: Bedroom 04	18	14.9	692	46	1219
L01: Landing	18	10.2	431	42	496
L01: Lobby 01	18	1.0	15	15	34
L01: Lobby 02	18	3.1	64	21	91
L01: Roof Void	-60	36.5	-	-	-
L01: Stair	18	3.3	53	16	103
L01: Bathroom 01	22	9.0	778	86	2282
L01: Bathroom 02	22	10.2	670	66	1918
L02: Bedroom 05	18	10.6	390	37	707
L02: Bedroom 06	18	20.1	825	41	1724
L02: Kitchen	18	3.9	109	28	79
L02: Stair	18	1.7	67	39	121
L02: Bathroom 05	22	5.1	358	70	1024
LG: Play room B	21	8.0	453	57	1073
LG: Plant room	-60	5.2	-	-	-
LG: Bed- sitting room	21	23.2	1509	65	4205
LG: Cupboard 01	18	1.5	54	36	81
LG: Cupboard 02	18	1.5	27	18	31
LG: Play room A	21	24.5	1669	68	3936
LG: Utility	18	19.6	859	44	1350
LG: Hallway	18	15.5	334	22	447
LG: Bathroom	22	6.8	447	66	1397
L02- Lobby	18	1.2	28	23	44
LG: Garage	-60	28.2	-	-	-
Total		457	19,834		43,084

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