Feasibility Study: Renewable Energy Technologies

St. Mary the Virgin Primrose Hill – Installation of photovoltaic technology

Introduction

1. This note has been prepared by MRDA Architects and Conservation Consultants with support from the PCC in support of planning application Ref. 2020/0964/P. It explains why the Church arrived its decision to explore installing solar panels on its south facing roof.

2. The primary objectives of this development are to enable the Church to become carbon neutral[1] and to provide a clean source of energy to the national grid. The Church arrived at the decision to install solar panels after considering and implementing strategies to reduce its energy usage to the greatest possible extent, and after considering and excluding other potential sources of green energy.

3. This note considers the following topics:

    1. The strategies the Church has undertaken to reduce its energy usage and other strategies that are not suitable here;
    2. The options for providing a green energy source;
    3. The other green initiatives the Church has taken;
    4. New policy supportive of these proposals.

Part 1: Energy usage

4. The Church has already undertaken extensive measures to reduce the extent of its energy consumption. These measures have included the replacement of lighting with lower energy bulbs as well as steps to reduce the extent of heat loss (through insulation and glazing and reducing air leakage) to reduce the need for heating.

<u>Low energy light bulbs</u>

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[1] Carbon neutrality, or having a net zero carbon footprint, refers to achieving net zero carbon dioxide emissions by balancing carbon emissions with carbon removal or simply eliminating carbon emissions altogether.

5. Most building incorporate electric lighting in order to supplement natural daylight and provide a source of light after the sun has set. Electric light bulbs range in their power rating and can be costly if high wattage bulbs are used. All the lighting in the church, except in the parish room and the sacristy, has been replaced with low energy LED lighting as recommended by the Government. The remaining non-LED lights will be replaced over the next two years. There is no further scope to reduce the energy consumption from artificial lighting within the church.

Insulation

6. Materials such as rockwool with low conductivity can serve to improve a thermal barrier between indoor and outdoor areas. Heat naturally dissipates through diffusion, moving from volumes with higher pressure to volumes of lower pressure. Thermal bridging is where a conductive material bypasses the thermal barrier and allows heat to escape. Prior to insulating, the building has to be analysed for any thermal bridges than can be modified to prevent conductivity. Insulation reduces the heating demand, therefore reducing the quantity of gas or electricity needed to heat the building, which in turn lowers the carbon footprint of the building and the energy bills.

7. There are no thermal bridges that can feasibly be modified within the church of St. Mary the Virgin Primrose Hill, however, there are various roofs that can be modified, without altering the significance of the building, to incorporate an insulating material. The church's entrance porches have all been modified to reduce loss of heat out of the building. The glass elements have been replaced with double glazing and the porch ceilings have been insulated with rockwool. The church office, located in the transept, has had its roof insulated with rockwool as well. Further to retro-fitted insulation already applied in the church, the south and north aisle roofs will become insulated over the coming years as part of planned maintenance works, during which high efficiency thin layer products will be applied without creating a thicker envelope nor compromising the significance of the building.

8. Thermal transmittance is the rate of transfer of heat through matter. The thermal transmittance of a material or an assembly is expressed as a U-value. The U-value of all the roofs is being evaluated, and where possible insulation added to reduce the thermal transmittance.

Glazing Specification

9. Heat flows through windows and can flow in both directions, either into or out of the building. Solar heat and light can be transmitted through the windows to help raise

the air temperature and reduce heating requirements. Depending on the U-value of the glazing, heat is also lost. The heat loss has to be lower than the heat gained in order to benefit from passive solar heating.

10. Replacing single glazed windows for double or triple glazed windows creates a significant change in the heat loss of a building as can be seen from the following U - values of glass:

    - Single pane glass – 5,2 W/m^{2}K
    - Insulating glass – 2,7 W/m^{2}K
    - Coated insulating glass – 1,2 W/m^{2}K
    - 3 Pane highly insulating glass – 0,8 W/m^{2}K

11. St Mary the Virgin Primrose Hill has replaced all the entrance porches' single glazed windows for double glazed and opted for low U-value glass throughout the St. Mary Centre when it was constructed. The remaining windows are of historic stained glass. These cannot be replaced without altering the significance of the heritage asset. Professional glazing consultants have advised that it is not feasible to incorporate further low U-value panels in front or behind of the stained glass, which would also significantly alter the appearance and compromise the heritage asset. It has been concluded that no further modifications can be made to the church's windows.

<u>Air leakage</u>

12. Permeability of the building fabric allows air to escape. If the air has been heated through artificial means then energy is being lost that has been paid for.

13. The soft red bricks used in the construction have long been a cause for concern, requiring repairs to faces, replacement, indentation and re-pointing. The bricks are porous and are vulnerable to saturation which subsequently supports the development of algae, thus marring the appearance of the walls and leading to accelerated deterioration. The poor condition is due to a number of factors including:

    - Under fired bricks
    - Erratic quality of bricks
    - Failed pointing
    - Local saturation
    - Short-term repairs

14. Local re-pointing and brick repair works have been carried out continuously since the millennium, ensuring the permeability of the walls is reduced as far as possible. The roof maintenance programme has, and continues to ensure the roofs are airtight. There is no further scope for reducing air leakage.

<u>Potential additional steps that are not feasible here</u>

15. Potential additional steps to reduce energy usage include steps to increase the thermal energy of space, natural daylight, thermal mass, green roofs and earth sheltering. These options however do not provide feasible solutions for St Mary's Church to further reduce its energy usage.

Solar Gain

16. In theory the thermal energy of a space, object or structure can be increased as it absorbs incident solar radiation. The amount of solar gain a space experiences is a function of the total incident solar irradiance and of the ability of any intervening material to transmit or resist the radiation. Objects struck by sunlight absorb its visible and short-wave infrared components, increase in temperature, and then re-radiate that heat at longer infrared wavelengths. Though transparent building materials such as glass allow visible light to pass through almost unimpeded, once that light is converted to long-wave infrared radiation by materials indoors, it is unable to escape back through the window since glass is opaque to those longer wavelengths. In buildings, excessive solar gain can lead to overheating within a space, but it can also be used as a passive heating strategy when heat is desired.

17. In order to take advantage of solar gains that would contribute towards heating the church, the fabric would have to be significantly altered in order to incorporate a large expanse of new double or triple glazing. This cannot be achieved without significantly altering the appearance of the grade II listed church. Planning would not be granted, therefore the church has very little scope for making use of solar gains.

Natural Daylighting

18. Natural daylighting lowers the need for artificially produced light, which is typically produced through the use of electricity. The church cannot be modified to allow more light to penetrate without significantly altering the appearance, which planning would not allow, therefore the church has very little potential for making use of increased natural daylighting and reducing its electric lighting.

19. The St. Mary Centre, a 21st century eastern annex to main church building, is predominantly lit by natural daylight throughout the day. Glazing was used to full effect in order to take advantage of this potential.

Exposed Thermal Mass

20. Thermal mass describes a material's capacity to absorb, store and release heat. Materials that have a high capacity for storing heat are said to have a high thermal mass, in contrast, materials that have a low capacity are said to have a low thermal mass. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass.

21. Old churches typically feature walls with high thermal mass. This property ensures they remain cool in the hot summer weather with The same effect in winter causing the expansive buildings to become uncomfortably cold. In London the sun's heat can take all day to penetrate thick walls and heat the interior. In winter, the temperature rarely rises high enough for the walls to radiate any heat at all

22. High thermal mass materials absorb and release heat slowly under ordinary climatic conditions in the United Kingdom. The principal activity for which the main body of the church, comprising the nave, aisles, transept, chapel and chancel, has to be heated for are the services, held once or twice a day for no longer than 2-3 hours. The other parts of the church are also used intermittently. Therefore, the church has to be heated quickly and for a limited time period.

23. The church has a substantial amount of high thermal mass and would not benefit by further addition. Reducing the thermal mass of the building would be more beneficial as it would allow for faster heating and reduce the cooling effect, but this cannot be achieved without compromising the structural integrity of the building.

Green Roofs

24. Green roofs, as the name implies, are roofs that incorporate planting, typically sedum or grasses. These areas of planting reduce thermal transmittance and create a habitat for flora and fauna. Unfortunately, the roofs of St Mary's church cannot support the extra load that would be imposed if they were to be modified to accommodate vegetation. The change in visual appearance would also compromise the fabric of the heritage asset and create substantial harm, especially as the installation would not be reversible.

Earth sheltering

25. Earth sheltering uses thermal mass properties of earth to help stabilise internal conditions. It reduces peak cooling loads in hot weather and reduces peak heating demand in cold weather. It can also help reduce the visual impact of a structure, which in the case of the church of St Mary the Virgin Primrose Hill, is the opposite of what is desired. The church cannot be surrounded by added masses of earth for obvious reasons.

Part 2: forms of clean energy

26. As explained above, the Church has taken steps to reduce its energy usage to the greatest possible extent. However, no measures will remove entirely the need for energy within the Church. In order to become carbon neutral the Church must secure a clean source of energy. By analysing the available sources of clean energy against the site specific requirements at St Mary the Virgin, we have come to the conclusion that the installation of solar panels is the only option that will meet the Church's energy needs in a way that is both feasible and is respectful of the other interests, especially the heritage interest of the Church and the Conservation Area.

<u>Combined Heat and Power (CHP)</u>

27. CHP or cogeneration units burn fuel, either fossil or renewable, in order to drive a combustion engine, gas or steam turbine. Waste heat is reclaimed through a heat recovery boiler. Biomass CHP units typically use woodchip or wood pellets that can be sustainably sourced and are often waste materials from other processes. If a fuel source is not readily available then the feasibility is severely reduced. The output is the same throughout the year.

28. Conventional electricity generation lets heat escape into the atmosphere, wasting around two-thirds of the energy the fuel produces, while additional energy is wasted during the electricity distribution process. CHP units capture the heat that would not be used otherwise and helps to cut down on waste during the distribution process. Because of this, CHP systems easily achieve efficiencies upwards of 80 percent. Compared to conventional systems that use grid electricity and on-site heating, which are usually only 50 percent efficiency. Most CHP units burn fossil fuels and therefore can reduce but not eliminate greenhouse gas emissions.

29. There are four main types of CHP unit:

- Reciprocating Engines

- Microturbines
- Gas Turbines
- Fuel Cells

30. Reciprocating internal combustion engines are similar to car engines and are used for power generation, transportation, and a variety of other purposes. Reciprocating engines, which are often fuelled with natural gas. CHP sizes range from 1.5 kilowatts to more than 10 megawatts (MW). As natural gas for heating purposes Is planned to be phased out by Camden Council, a reciprocating engine is not feasible for use at the church of St Mary the Virgin Primrose Hill.

31. Micro turbines are smaller combustion turbines that are powered by natural gas. Their use in CHP systems began in the 1990's, though their larger gas counterparts had been used in that capacity for much longer. Much like their name implies, micro turbines have a size range of 30 kW to 200 kW, though they can be combined to create modular packages that exceed that capacity. For the same reason as with the reciprocating engine, this option is unfeasible.

32. Gas turbines are available in a range of 1 MW to over 50 MW, they typically have better economics in sizes greater than five MW. Gas turbines are great for CHP industrial applications because the high-temperature exhaust can be used for heating and drying or to generate high-pressure steam. When used for CHP, gas turbines typically run on natural gas. For reasons mentioned previously, gas turbines are unfeasible for generating heat and power for the church of St Mary the Virgin Primrose Hill.

33. Unlike traditional combustion technologies that burn fuel, fuel cells undergo a chemical process to convert hydrogen-rich fuel into electricity. Fuel cells do not need to be periodically recharged like batteries, but instead continue to produce electricity as long as a fuel source is provided.

34. A fuel cell is composed of an anode, a cathode, and an electrolyte membrane. A fuel cell works by passing hydrogen through the anode of a fuel cell and oxygen through the cathode. At the anode site, the hydrogen molecules are split into electrons and protons. The protons pass through the electrolyte membrane, while the electrons are forced through a circuit, generating an electric current and excess heat. At the cathode, the protons, electrons, and oxygen combine to produce water molecules. Due to their high efficiency, fuel cells are very clean, with their only

by-products being electricity, excess heat, and water. In addition, as fuel cells do not have any moving parts, they operate near-silently.

35. Fuel cells are scalable, which means that individual fuel cells can be compiled on one another to form stacks, in turn, these stacks can be combined into larger systems. Fuel cell systems vary greatly in size and power, from portable systems for smartphone battery recharging, to combustion engine replacements for electric vehicles, to large-scale, multi-megawatt installations providing electricity directly to the utility grid. Unfortunately, there is not a space that can accommodate an interior or exterior installation of fuel cells, therefore fuel cells cannot be employed at the church of St Mary the Virgin Primrose Hill.

<u>Solar Hot Water Generator</u>

36. This technique involves water exposed to radiation, typically travelling through tubes exposed to sunlight. As the water travels through the casing it is warmed and then collected in a hot water tank. Efficiency depends on positioning, orientation and angling. Tracking can improve upon these variables but requires electrical power. A heat exchanger inside the hot water tank transfers energy to piped water systems. Although highly desirable, this method only contributes towards lower costs for heating water. The principal aim of the church is generate renewable 'green' electricity in order to heat and light the church, which is not possible by installing a solar hot water generator.

<u>Ground Source Heat Pumps</u>

37. Ground source heat pumps, otherwise known as geothermal heat pumps, extract low temperature heat from the ground. The heat is essentially stored solar energy. Low temperature energy is reclaimed using a refrigerant. The technique takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems. Although widely used and highly desirable from a sustainability perspective, the ground directly below and around the church building cannot be disturbed due to structural problems faced by the church in the past. The risk of further movement in the structure is unacceptable.

<u>Wind Turbines</u>

38. A wind turbine, or alternatively referred to as a wind energy converter, is a device that converts the wind's kinetic energy into electrical energy. Wind turbines are manufactured in a wide range of vertical and horizontal axis. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or

caravans or to power traffic warning signs. Larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of intermittent renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

39. In order for a wind turbine to generate an electric current there has to be a good supply of wind and it has to be large enough to make a significant contribution towards the electrical supply of the church. The church is located in a built up area surrounded by areas of higher ground, which means it is largely sheltered from the type of high kinetic energy wind that would justify a wind turbine. A worthwhile wind turbine in this location would have to be enormous, which would create an unacceptable visual impact and has the potential for noise pollution. The cost would also make it unfeasible with 100 kW turbines costing in the region of £345,000 and 10kW turbines costing in the region of £50,000 for the turbine alone.

Hydroelectric

40. Small scale hydroelectric techniques can be used to supply electricity to buildings. The process involves the conversion of potential energy contained in water held at height to kinetic energy as the water moves. A microturbine is coupled with an electrical generator. The electric power output is typically 10 kW and required a significant head differential and a watercourse with sufficient flow. Neither of these are available to St. Mary's church, which means the technique is unfeasible in supplying sustainably generated electricity to the church.

Photovoltaics

41. Analysis above of alternative sources of clean energy reveals that they are not suitable for St Mary the Virgin, leaving the Church with the only option of introducing solar panels.

42. Photovoltaics are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons by the photovoltaic effect. Photovoltaic power generation makes use of solar modules, each composed of a number of solar cells containing a semiconductor material. A current inverter creates an alternating current (AC) from the direct current (DC) that is generated. Electricity can be used to charge batteries allowing the stored energy to power electrical appliances in the future.

43. The church of St. Mary the Virgin has a south facing nave roof that is exposed to sufficient sunlight to make a photovoltaic installation generate a significant current. The cost would be in the region of £30,000 and would typically pay back on the investment after 10 years. The electric current generated would not require the burning of any fossil fuels and would therefore be a 'green' supply of energy, ideal for mitigating climate change. All the electrical needs of the church can be met with the potential for surplus to charge batteries and/or feed back into the grid, thus creating a highly desirable revenue stream. There is also strong support and encouragement for photovoltaic technology from the Government, the Church of England, Camden Council, Historic England and countless other organisations (new supportive policy is outline below in part 4).

44. Array of photovoltaic panels can be mounted to slate roofs, such as the nave roof at the church, through the use of reversible slate hooks. These hooks are clamped to the roof timbers without damaging or altering them. The hooks can be removed at a later date returning the roof to its original appearance, highly desirable from a conservation point of view.

45. In pre-application discussions the Church proposed several options with respect to the number of solar panels to the Council for its consideration:
Option 1 – 4x rows of 14 panels (56 total) towards the right hand side of the roofslope
Option 2 – 2x rows of 29 panels (58 total) towards the bottom of the roofslope
Option 3 – 4x rows of 29 panels (116 total) covering the majority of the roofslope

46. Option 4 which consists of a single row of 29 panels on the bottom of the roofslope is favoured in the Council's pre-application response dated 9 April 2020.

47. However, this option was discounted in pre-application discussions as unfeasible. It would produce capacity of only 9.1 kWp, significantly less than the Church's need for electricity. As explained in the Design & Access Statement at [47] the Church's use for electricity in 2017 was 15,126kWh. As explained above, this need is expected to rise with the shift from gas to electric heating in future and which has been reduced to the greatest extent possible through the initiatives considered above.

48. Option 2 by contrast would provide approximately 18.3 kWp, meeting the Church's current need for electricity whilst allowing for some surplus that will contribute towards the Church's transition its heating to electricity in the near future.

49. Option 2 furthermore overcomes the visual impact, and resulting affect on the significance of the heritage assets, that the Council identified in relation to the previously refused planning application (Ref. 2018/4741/P). In that regard, the Council's pre-application advice speaks more favourably about Option 2 with respect to its visual impact:

> "Option 2 is preferred on the basis that it allows for a good proportion of the original slate roof to remain visible, particularly in longer-range views of the church. Furthermore, the 2x rows of panels have a horizontal emphasis that is in keeping with the horizontal emphasis of the roofslope and it is considered that the panels would be viewed as a later addition that respects the character and appearance of the host building. (This would be more the case with 1 row of solar panels.)"

Part 3: Other green initiates the Church has taken

50. It is also worth mentioning that the Church has undertaken other strategies to reduce its carbon impact beyond energy consumption, including through reducing its water usage.

<u>Rainwater Harvesting</u>

51. Rainwater harvesting involves collecting rainwater in tanks for later use. The church has installed water butts in order to collect rainwater and irrigate the gardens during periods of low rainfall. Although it lowers the requirement for water, it does not help contribute towards heating the building in a sustainable way. It does however lower the carbon footprint of the church in a minute way as less water is consumed from the Thames Water network.

<u>Grey Water Recycling</u>

52. As with rainwater harvesting, rainwater can be collected and stored in tanks for use within the church. Water has to be filtered, and if stored underground, pumped to where it is needed. The water also has to be filtered so that it can be used for washing up, etc. There is currently no space above ground on the church site that can accommodate a tank large enough to have an impact. Installing a large tank below ground may have an adverse effect on the structure, which has experienced movement in the past. Due to structural instability, the church reinforced its structure

at crypt level during Victorian and Edwardian eras. Introducing further ground movement would be an unacceptable risk.

Part 4: Policy

53. The Design & Access Statement at [52-57] provides an overview of relevant planning and other policy that is very supportive of the present proposals in so far as they create a green energy source for the Church. Those policies are not repeated here. Here we summarise two new material policies that is supportive of this development.

54. First, the Church of England has set to cut its carbon emissions to net zero by 2030. This means that the Church of England will have to implent actions such as introducing LED lights, insulation and draught proofing to buildings, as well as moving heating of churches from gas and oil to sustainably generated electricity.

55. Second, the United Kingdom has become the first major economy to pass net zero emissions law. The new target will require the UK to bring all greenhouse emissions to net zero by 2050.

Conclusion

56. The Church has already undertaken extensive measures to reduce the extent of its energy consumption. It has introduced LED lighting in every room except the Parish Room and the sacristy with plans to overhaul the lighting in these rooms in the next two years. All the windows that are not of stained glass have been double glazed. Insulation has been retrofitted to the entrances' porch ceilings and the office roof with further plans to insulate the south and north aisle roofs during the upcoming roof maintenance work.

57. The measures that have been implemented to date have caused the energy bills to drop by 40%. The next logical step for the Church to take to improve upon its sustainability is to create a green energy supply to meet its energy needs. The only feasible method is to use photovoltaic technology mounted on the south facing slope of the nave roof, as it has the best orientation and inclination with minimal shadowing. UK Solar Generation advised that other church roofs would have the benefit outweighed by the cost due to a lack of the sun's energy reaching the PV panels.

58. The technology allows the church to transition away from gas for its heating needs. Generated electricity could be stored for future use with the potential to feed surplus generated electricity into the grid, contributing towards lowering the carbon footprint of the National Grid and helping the Government reach its net zero carbon target by 2050 as well as helping the Church of England reach its net zero carbon by 2030.

59. Chris Dunham's report commissioned by Camden Council entitled Camden Carbon Scenarios for 2025 to 2030 – an Update to the 2010 Study concludes that in order for Camden to meet the Council's ambition of securing net zero carbon by 2030 "a vast increase in solar PV capacity would be needed on Camden's buildings" (p 6).

60. Similarly, the Camden Citizens' Assembly on the Climate Crisis published a report in September 2019 recommending that solar panels be fitted on as many homes as possible in the Borough. One of the actions listed under this recommendation is that Camden "consider planning permission to allow as many people to install as possible" (p25).

61. Whilst presented as a recommendation applying only to homes, the text at p25 implies the Assembly recommends solar panels be installed on other buildings too. For example, another action suggested is for "Camden to install on council blocks, schools, public buildings. → funding for community projects from any export payback". It is notable that the potential for "conservation areas changing their visual views" is specifically noted at p26 as a potential impact of this recommendation. Thus, the Assembly took account of the potential for impacts on conservation areas but found that, at least at a general level, this should not outweigh the importance of installing solar panels on an enormous scale in the Borough. It is also relevant to note the support for solar panels proposals within Historic England's guidance 'Energy Efficiency and Historic Buildings: Solar Electricity (Photovoltaics) (October 2018).

62. It is therefore recommended that the church pursue the use of photovoltaic technology in order to help meet the net zero carbon targets mitigate climate change as well as having local energy resilience and lowering energy bills, making the church more economically sustainable as well as environmentally sustainable.

63. The only option as to the number of solar panels that meets the objectives of these proposals whilst minimising their perceived visual impact is Option 2.

Sources

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