Solar PV Feasibility Study

Client:	Cadwyn Clwyd and Energy Service Wales
Project:	Canolfan Ceiriog Centre
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poverty, create jobs and drive sustainable economic development. It is part of the Welsh Government Rural Communities – Rural Development Programme 2014 – 2020, which is financed by the Welsh Government and European Agricultural Fund for Rural Development (EAFRD). The project is match funded by the Centre, who were successful in drawing down funding through the Welsh Government Energy Service.

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Statement of Vested Interest:

Dulas Ltd are a worldwide-recognised supplier and installer of a range of renewable energy systems and as such have a commercial interest in some of the recommendations contained within the report. In some cases, cost estimates have been given based on current quotations for similar equipment supplied by Dulas Ltd and may not be the only equipment available.

However, it is our opinion that the study offers an appropriate level of detail in view of the resources available and information provided. The authors have no expectation of any order being placed with them and would welcome questioning of the choice and costs of any equipment.

Table of Contents.

1 Executive Summary

Dulas Ltd has undertaken a feasibility study examining the potential of generating electricity from a solar photovoltaic (PV) system at the Canolfan Ceiriog Centre. The study has confirmed that the site is suitable for the installation of a solar PV system on four of the roof aspects of the building. If all the available roof areas were utilised, then there is potential to install a maximum array capacity in the order of 49kWp based on a 330Wp 60-cell module.

Examination of the Scottish Power Energy Networks (SPEN) grid heat map has confirmed that the primary substation based at Llangollen is providing electricity to the Centre. This substation is classified in the red zone and there is a constraint on the upstream generation headroom from this substation. In practice this could mean that a zero-export constraint could be placed on any new PV system exporting significant quantities of electricity to the grid. A formal G99 grid connection application was made to SPEN and a grid connection offer has been received for an export capacity of up to 18kW. The SPEN cost for making this connection would be £300 including VAT; a copy of the connection offer is provided in Appendix 1. An alternative option would be to install a smaller PV system with a maximum electrical output of below 16A per phase. This would mean that the PV system could be grid connected under the G98 protocol and would not require prior approval from SPEN before being connected. It would also avoid the £300 connection charge. All individual roof mounted systems considered in this report would comply with the G98 requirements apart from the larger system on the Lower west facing roof and if more than one roof were combined to make a larger overall installation.

The site uses significant electricity during the winter months as space heating and hot water are provided by a ground source heat pump system. Electricity consumption is significantly less during the summer months when the heat pump system is running in summer mode. Simulation of the energy yield from the PV systems against the estimated electrical demand profile of the site highlights that significant quantities of PV generated electricity would be exported to the grid during the summer months when the site electrical demand is low. The main benefit to the Centre from installing the solar PV system would be the saving from offsetting incoming grid electricity. Therefore, best value for money will be achieved by designing the array size to best complement the electrical requirements of the site and/or find alternative ways of using the excess PV generated electricity.

The structural capability of the roofs, both upper and lower, to carry the additional load from the solar arrays has been assessed by Tier Consult, the original structural consultants involved with the design of the building. They have confirmed that both roofs have the capacity to hold the additional weight of the solar modules; their report is provided in Appendix 2.

In terms of selecting a preferred roof for the PV installation then the Lower south facing roof above the main site entrance would provide best value for money based on a simple return on investment calculation. It will be the easiest roof to install on as it is closest to the point of grid connection and the easiest roof to access for installation and maintenance purposes. Being at the front of the building it would also be the most visible to the public. It is estimated that an array capacity of 9.90kWp could comfortably be installed on the viable area of this roof whilst maintaining permitted development requirements. The system would generate in the order of 8,634kWh of electricity per annum of which 5,746kWh would be consumed by the building, providing just over 20% of the annual electrical requirements of the site. This would provide an electricity bill saving of circa £933 per annum based on the current tariff rate paid for incoming electricity. The balance of electricity exported to the grid could potentially be utilised to generate revenue via the Smart Export Guarantee (SEG). This could generate in the order of £115 per annum based on the current Scottish Power SEG tariff of 4p/kWh. It should be noted that the main electrical meter at the site would need to be changed to one that measures exported electricity at half hourly frequency in order to be eligible for the SEG and that also slightly higher SEG tariffs may be available from other providers.

The study has focussed on methods of improving the self-consumption level of the PV generated electricity to improve the project financial viability. This has included increasing the utilisation of the existing electric vehicle (EV) charging points, incorporation of battery storage, and the potential of supplying electricity to the adjacent doctor's surgery.

Increasing the utilisation of the EV charging points would improve the self-consumption of PV generated electricity and consequently improve the financial performance of the solar project. Significant improvements to the project finances could be made if there was a way of encouraging more EV charging during daylight hours. This would be a low-cost way of making the project work better for the investment and the community.

Adding standalone battery storage to the PV system offers no financial benefit unless the consumption pattern of the site changed significantly in the future. The relatively high cost of the battery system, coupled with the low electrical demand of the site overnight in the summer months, makes this option not worth pursuing under the current circumstances.

There is potential to couple an independent PV system mounted onto the Centre's roof to the adjacent doctor's surgery. There is some risk in this strategy as the surgery could change use, become unoccupied or issues could arise if there was a dispute between both parties in the future. The surgery is only utilised for 16 hours a week and as such electrical demand will be limited and restricted to these operating hours. Initial discussions with the Betsi Cadwaladr University Health Board estate department has confirmed that the NHS in Wales purchases electricity through an all Wales contract and the supply of electricity from a 3rd party could cause contractual issues under the current arrangements. It is therefore suggested that this option is not considered further at this stage.

Conclusions and recommendations: The Canolfan Ceiriog building is considered viable for the generation of solar PV electricity and there are four individual roofs that could be considered for this purpose. The roof above the entrance to the building is considered the most viable due to ease of installation and operation of the system, and the best return on investment of those roofs considered.

There appears to be little benefit in installing a maximum sized array based on the current electrical consumption pattern of the site. A 9.90kWp array installed on the Lower south facing roof will provide the best fit to the electrical requirements of the site and best value for money. It can also be connected under G98 and therefore not require prior approval from SPEN for the grid connection which would also save a £300 grid connection fee.

Increasing the use of the two EV chargers would increase the use of PV generated energy and we would recommend that this facility is promoted locally and particularly for daytime use if the PV system were installed.

Adding battery storage to the PV system provides no added value. This is due to the high cost of the battery system and the small electrical demand of the site outside of business hours in the summer months when the PV system is producing most energy.

Our recommendation would be to install a 9.90kWp PV system on the South facing roof as the first option. This could be increased in capacity slightly with the use of a higher power density module but it would be important to keep the inverter capacity at 10kW or less in order to be able to connect under a G98 agreement. If there was a desire to install a larger system, then we would recommend using the Upper West facing roof as well. The combined system could then be electrically connected under the G99 grid connection offer obtained from SPEN.

2 Introduction

The Canolfan Ceiriog Centre is a community owned and operated facility. It provides a range of sporting facilities and an event venue for the local area. The site consists of a large sports hall, exterior floodlit tennis courts, changing facilities with showers, a café area, and a licensed bar.

Dulas were contracted to provide a feasibility study of the viability of introducing solar PV generating capacity on the site.

3 Site Assessment

3.1 Site Details

The Canolfan Ceiriog Centre is situated at the heart of Glyn Ceiriog, the largest village within the Ceiriog Valley in the county of Wrexham. The Centre is located just off the main B4500 road which passes through the village and is indicated by the red circle in Figure 1 below.

Figure 1 Site location, Canolfan Ceiriog Centre, Glyn Ceiriog (courtesy Bing Maps)

The Centre was completed in early 2007 and appears to have been constructed with a good thermal envelope which would have at least met building regulations at the time. The site consists of a large double height steel portal frame building which forms the main sports hall, this is adjoined on all four sides by single storey timber framed extensions which house the supporting facilities. All roofs are finished with standard Kingspan Secret-Fix trapezoidal roofing sheets. The Centre is enclosed within a steep sided valley with altitudes extending to more than 350 metres above sea level. The area directly around the Centre is mainly open with tennis courts to the west, car parking and a grassed area to the south, domestic properties to the north and east. There is also a single storey doctor's surgery adjacent to the Centre to the south east. The site location, marked by a red rectangle, and major features are highlighted on the aerial photograph shown in Figure 2.

Figure 2 Canolfan Ceiriog Centre and major site features, (courtesy Bing Maps)

A site survey was undertaken by Chris White of Dulas Ltd on the 8th of February 2021. The site visit sought to identify suitable locations for the integration of solar PV technology into the site infrastructure.

3.2 Site Electricity Consumption

The site is primarily powered by electricity. Space heating and domestic hot water are provided by a ground source heat pump which has a direct electrical back up system to cover emergencies and planned maintenance periods.

The site monthly electricity consumption profile has been determined from regular meter readings that were taken in 2015 and 2016. This consumption profile has been used to refine the quarterly consumption data provided for 2019, the last full year of operation of the Centre before the Covid-19 restrictions were implemented. The typical monthly consumption pattern for the site used in this report is summarised in Figure 3 below.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Consumption (kWh)	3,698	3,779	3,817	2,640	1,771	1,320	1,125	950	1,091	1,902	2,349	3,772
Mean base load (kW)	4.97	5.62	5.13	3.67	2.38	1.83	1.51	1.28	1.51	2.56	3.26	5.07

Figure 3 Table of monthly site electricity consumption, Canolfan Ceiriog Centre

The mean electrical baseload profile for the site is represented graphically in Figure 4.

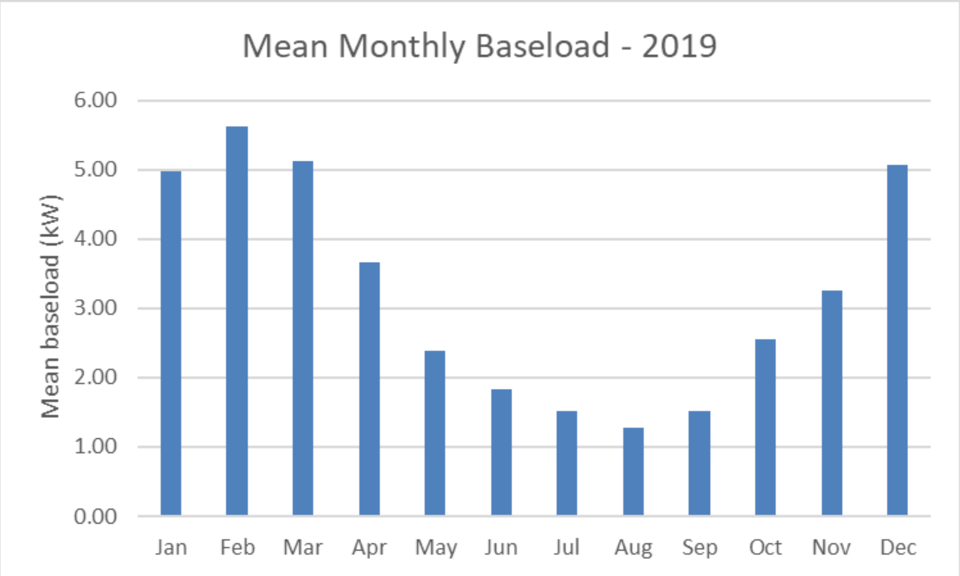

Figure 4 Bar chart of monthly mean electrical baseload, Canolfan Ceiriog Centre

The graph is typical of an electrically heated building demonstrating high consumption in the heating months and a significantly reduced consumption rate in the summer.

For the purpose of the study it has been assumed that the electrical consumption will be dominated by the ground source heat pump system in the heating months and the operation of the heat pump will be distributed evenly over the full 24 hours of the day during this time. Therefore, the continuous mean electrical base load determined for the site in each of the heating months has been used in the grid electricity offsetting calculations from the PV system.

During the summer months of June, July, August, and September, it is assumed that the heat pump would be working in summer mode and providing domestic hot water only. Electrical consumption from the heat pump system would be significantly reduced as the above graph confirms and electrical consumption from other facilities will become more significant. The electrical consumption data has been skewed in these months to represent greater consumption during the likely periods of building occupation, 10am in the morning to 9pm in the evening in this case.

3.3 Site Electrical Infrastructure

The site is connected to a 400V 3-phase supply. Electricity is distributed around the site from a main Hager distribution board; this would be the point of grid connection for any future solar PV installation. There are suitable spare ways available in this distribution board for the connection of the solar PV system up to a Miniature Circuit Breaker (MCB) rating of 63A.

4 Generation of Electricity from a Solar PV System

4.1 Grid Connection

In general, any type of embedded generation that connects to the national electricity system requires assessment of the potential impacts, even where no export of energy is planned. This is because even export limited schemes can have effects on the local distribution network if there is a fault and normal protection measures fail.

Due to the proliferation of embedded generation in recent years, most of the Distribution Network Operators (DNOs) in the UK are taking an increasingly hard line in relation to embedded generation. There is a legal requirement to notify the DNO of any grid connected embedded generator.

The DNO responsible for the grid local to the Centre is SPEN. The village of Glyn Ceiriog is fed from the Llangollen T1 primary substation and examination of the SPEN grid heat map confirms that there is a high voltage circuit constraint on the feed from this substation. Based on this information it is possible that any new PV installation with an electrical output of more than 16A per electrical phase may require a zero-export limitation device to be fitted to prevent excess electricity being exported to the grid. However, PV systems with a maximum output below 16A per phase could be grid connected under a G98 agreement and consequently not require prior approval from SPEN.

A G99 grid connection application for a 21.78kWp array with a maximum of 18kW (26A per phase) of AC export was made to SPEN. SPEN have approved this application and provided a grid connection offer which is attached in Appendix 1. The cost to make this connection would be £300 including VAT, whereas there would be no costs associated with connecting a smaller PV system under G98.

4.2 Planning Requirements

It is believed that the Canolfan Ceiriog Centre building is not listed and is not in a conservation area, and as such there is unlikely to be a requirement for planning permission under the Town and Country Planning Act 1990, except where the panels would materially affect the listed status of any nearby building and provided that the solar array is installed in compliance with permitted development guidance, as set out below.

Under Statutory Instrument 2012 No. 2318 (W. 252) The Town and Country Planning (General Permitted Development) (Amendment) (Wales) (No. 2) Order 2012, the solar array as non-domestic use would be permitted development under Part 43 Class A subject to the following criteria:

Permitted development.

A. The installation, alteration or replacement of solar PV or solar thermal equipment on a building other than a dwelling, house, or a block of flats.

Development not permitted.

A.1 Development is not permitted by Class A if—

(a) the solar PV or solar thermal equipment would be installed on a wall or pitched roof and would protrude more than 20 centimetres beyond the plane of the wall or the roof slope when measured from the perpendicular with the external surface of the wall or roof slope.

(b) the solar PV or solar thermal equipment would be installed on a flat roof and would protrude more than 1 metre above the plane of the roof.

(c) the solar PV or solar thermal equipment would be installed on a roof and within 1 metre of the external edge of the roof.

(d) the solar PV or solar thermal equipment would be installed on a wall and within 1 metre of a junction of that wall with another wall or with the roof of the building.

(e) in the case of a building on article 1(5) land or on land within a World Heritage Site, the solar PV or solar thermal equipment would be installed on a wall or roof slope which fronts a highway.

(f) the solar PV or solar thermal equipment would be installed on a building within the curtilage of a listed building or

(g) the solar PV or solar thermal equipment would be installed on a site designated as a scheduled monument.

Conditions

A.2 Development is permitted by Class A subject to the following conditions—

(a) solar PV or solar thermal equipment must, so far as practicable, be sited so as to minimise its effect on the external appearance of the building.

(b) solar PV or solar thermal equipment must, so far as practicable, be sited so as to minimise its effect on the amenity of the area and

(c) solar PV or solar thermal equipment no longer needed for or capable of microgeneration must be removed as soon as reasonably practicable.

A design of the PV system would need to conform to these requirements to be deemed permitted development which we believe is achievable in this case.

The Wrexham Borough Deposit Draft (March 2018) of the Local Development Plan sets out policy support for small scale and/or community-based proposals less than 5MW where they are in appropriate locations and where impacts to the landscape arising from scale, size and design are acceptable. It is believed this is the case with the Canolfan Ceiriog site.

The updated Renewable Energy Assessment for the Council (September 2019) identifies in Section 4.9 on Building Integrated Renewables the potential for up to 27 Megawatts of roof-top potential for the Borough. Much of this potential would be taken up by small scale schemes, such as Canolfan Ceiriog, which itself could provide up to c. 50kW of this capacity.

4.3 Solar PV Generator Opportunities

The site survey identified several roofs on the building that could potentially be utilised for the installation of solar PV arrays as indicated in Figure 5.

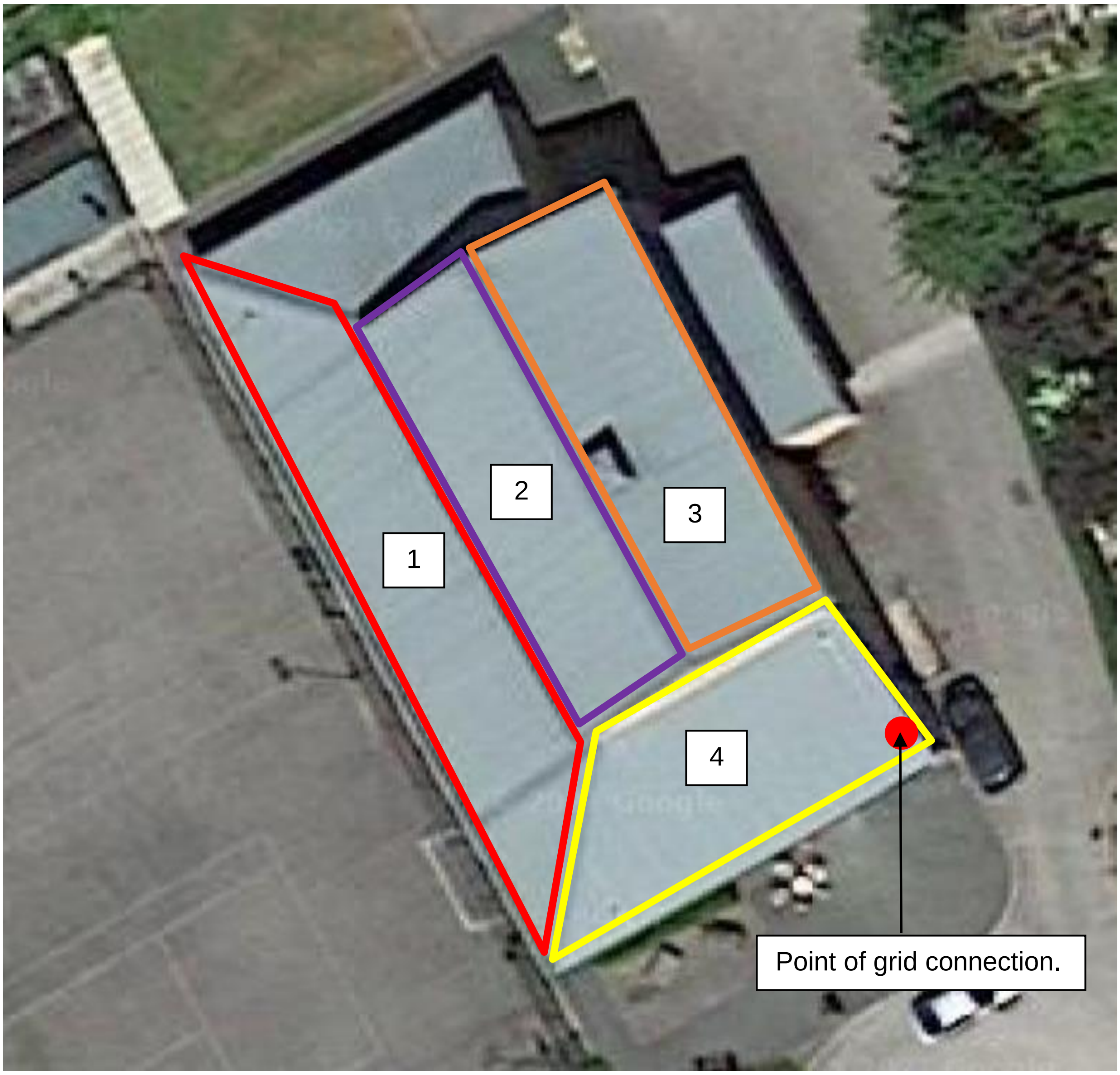

Figure 5 Potential viable roof areas for solar PV installation, Canolfan Ceiriog Centre, (courtesy Bing Maps)

The roofs are referred to as 1 Lower west facing roof, 2 Upper west facing roof, 3 Upper east facing roof, and 4 Lower south facing roof, elsewhere in the report.

All roofs are inclined at a pitch of 20 degrees to the horizontal. There is a passive ventilation stack on the upper east facing roof that will cause some shading of this roof aspect and limited shading on the adjoined west facing roof during the morning. Both lower roofs have several small ventilation pipes that protrude the roof surface, these are relatively insignificant, and will only cause limited shading losses. The building itself will cause some self-shading of all roof aspects at certain times of the day, the lower west facing roof will be particularly susceptible to this in the morning as a result of shade arising from the higher building to the east.

Shade will also be created by features local to the building. The location of the site in a deep sided valley will cause some shading losses in winter and at the start and end of each day. There are also two floodlight stanchions to the west of the building which will also cause some shading of the two lower roofs in the late afternoon and early evening.

All the roofs are finished with the same Kingspan Secret Fix insulated trapezoidal profiled metal panel system. The solar module mounting system would be secured to the roof structure by fixing to the outer skin of the roofing panels. The location of the fixings on the trapezoidal profile will be dependent on the manufacturer of the solar mounting system, but the system will be either fixed to the crowns (top) of the profile or the web (sides) of the profile. The solar module mounting system should comply with the latest version of the Microgeneration Certification Scheme standard MCS012. Figure 6 shows a photograph of a typical compliant trapezoidal roof mounting system where the fixing plates are secured to the web of the roof profile.

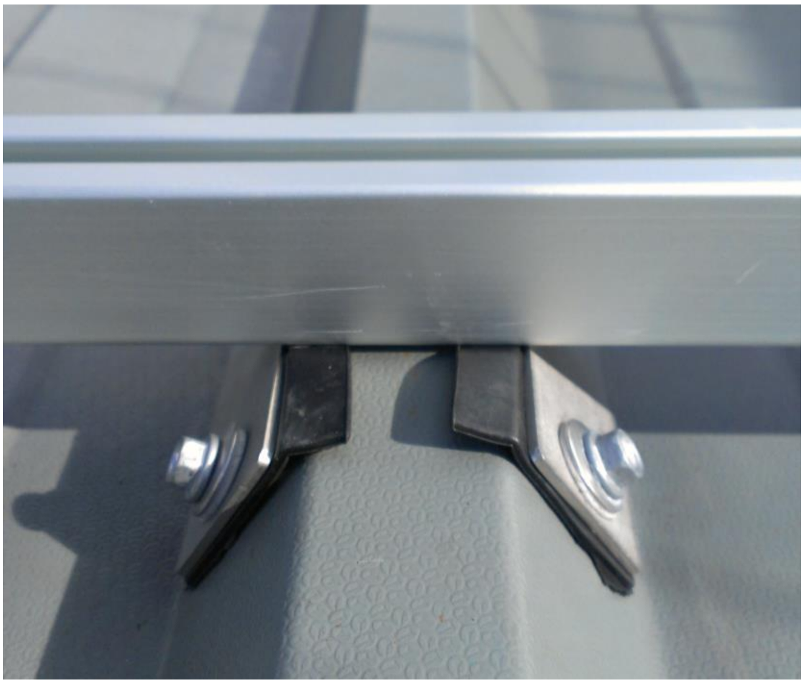

Figure 6 Trapezoidal roof solar mounting system fixings

Installation of a solar system on the Canolfan Ceiriog Centre roof could reduce the remaining warranty that may be outstanding on the roofing sheets. This is likely to be the case with the Kingspan roofing system that has been used on the building. On a newly installed roof, Kingspan would generally maintain their warranty if a Kingspan solar module mounting system is used. This could be a way of retaining any outstanding warranty on the Centre roof but there could be a price implication as Kingspan generally charge a premium for their solar mounting systems. However, the roof on the Canolfan Ceiriog building is 15 years old and will be nearing the end of the Kingspan warranty anyway, so this is less of an issue than if the roof had been newly laid. It would still be prudent to consult the original roof provider to determine the length of any outstanding warranty on the roof and the likely impact on this warranty from installing a solar array.

A structural assessment of the suitability of the upper and lower roofs to accommodate the solar arrays has been made by Tier Consult who were the structural engineers involved with the original design of the building. They have confirmed that both the upper and lower roofs can support the additional loads implied by the proposed solar arrays; their report and calculations are provided in Appendix 2.

4.3.1 Determination of PV system generating capacities.

The array layouts and system capacities have been determined using a 60-cell module of dimensions 1,657mm by 996mm, with a 330Wp power output. The module locations have been determined based on avoiding on roof obstructions and the requirement to be compliant with the permitted development guidance of being at least 1 metre away from the edges of the roof. PV system capacities have been determined for each individual roof to assess the relative performance ratio of each roof aspect and to examine energy yield distributions relative to the electrical demand requirements of the site. The individual roof systems have also been combined to determine a maximum sized system that could be installed on the building. There is potential to install a total system capacity in the order of 49kWp based on the 330Wp module used in this exercise. Figure 7 provides a simulated appearance of how the maximum sized system would appear on the building.

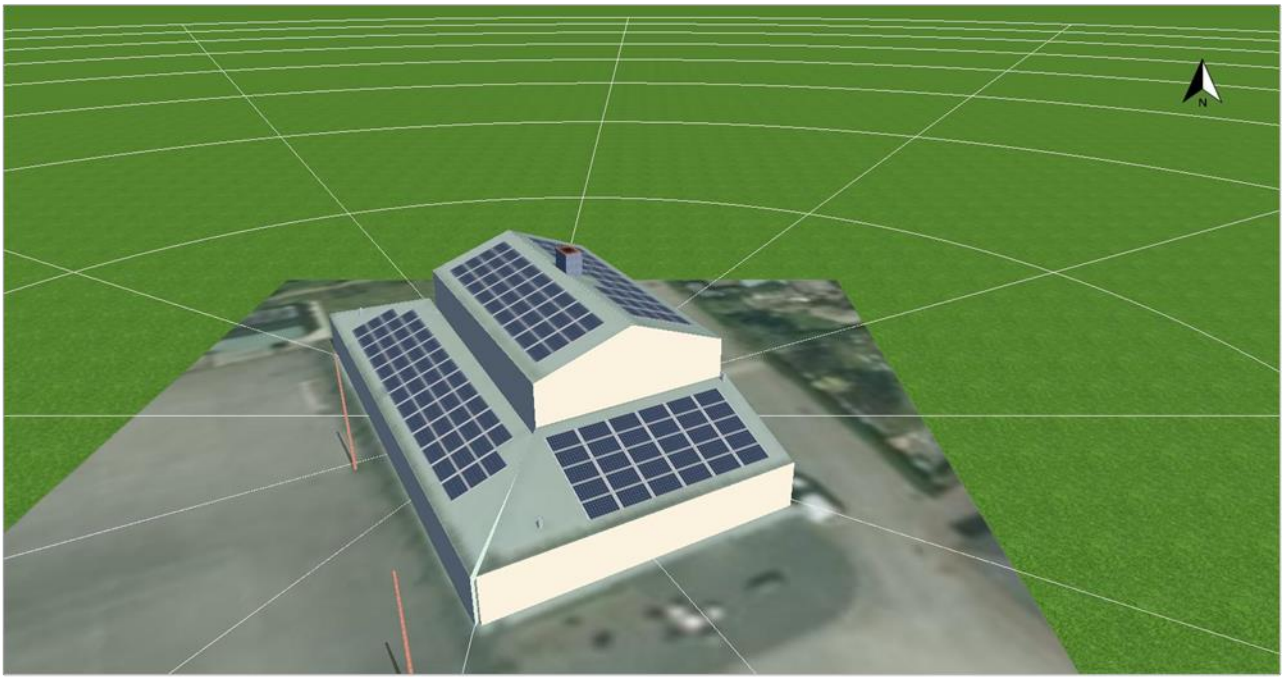

Figure 7 Simulated appearance of maximum sized solar array on the Canolfan Ceiriog Centre.

Electrically the DC output from the solar arrays would be converted to grid compatible AC electricity using inverters, the number of inverters required would depend on the capacity of the array and the number of roofs utilised. Based on the maximum sized 49kWp array and a 40kW inverter capacity, the peak AC current output would be approximately 60A per phase. This would require the circuit to be protected by a 63A MCB in the main site distribution board.

4.3.2 Estimated Energy Yield

The estimated energy yield from the proposed PV systems has been determined using proprietary PVSol simulation software. This software enables the array to be modelled in 3D space, allowing significant site features to be considered in terms of potential shading of the PV arrays. The programme uses weather station measured climate data, typically over a period of 10 years, in the energy yield calculations. In this case the climate data was simulated for the exact site location based on the closest weather station data.

The table in Figure 8 summarises the predicted annual energy yield from the PV systems.

Reference	System Capacity (kWp)	Estimated Annual Energy Yield (kWh)	Yield Ratio (kWh/kWp)	CO_2 offset per annum (Kg)	Shading Losses (%)
Lower west	16.50	12,951	784	3,019	11.2
Upper west	11.88	10,413	875	2,427	1.1
Upper east	10.89	7,851	719	1,830	3.3
Lower south	9.90	8,634	870	2,012	6.3
Combined system	49.17	40,029	813	9,332	5.7

Figure 8 Roof mounted solar PV details.

The quantity of CO_2 offset per annum has been determined using the Defra conversion factor (July 2020) of 0.23314KgCO_2/kWh for UK grid electricity.

The table of results highlights that the most efficient roofs in terms of converting light into solar electricity are the Upper west facing roof which has limited shading losses and the Lower south facing roof. It is surprising that the Lower south facing roof has 6.3% shading losses but this is due to shading from the higher part of the building to the north, particularly in the afternoon and to a certain extent in the morning as well.

4.3.3 Estimated On-site Consumption of PV Electricity

An estimation of the proportion of electricity generated from the solar PV systems that would be consumed directly by the site has been simulated based on the electricity consumption profile determined from the electricity bills provided. The results are presented in the table in Figure 9.

Reference	Annual PV Energy Generated (kWh)	PV Energy Consumed Directly on Site (kWh)	Proportion of PV Energy Generated Consumed on Site (%)	Proportion of Site Electricity Requirement (%)
Lower west	12,951	6,955	53.7	24.6
Upper west	10,413	6,445	61.8	22.8
Upper east	7,851	5,176	65.9	18.3
Lower south	8,634	5,746	66.5	20.4
Combined system	40,029	9,683	24.1	34.3

Figure 9 Table of the estimated PV energy generation and consumption data for various system capacities.

The analysis confirms that the site will only consume a maximum of 66% of the solar generated energy from any of the systems examined and this would provide in the region of 20% of the annual electricity requirements of the site. This is mainly due to spill-over of excess PV generated electricity in the summer months when the electrical demand of the site is relatively low. There would appear little value in increasing the capacity of the PV installation by combining more than one roof, as the increase in proportion of PV energy consumed on site would be insignificant, when compared to the increased energy yield from the PV system. The graphs provided in Figures 10 and 11 illustrate how the PV energy generated from the 9.90kWp Lower south facing system would be utilised by the site and how much of the site electrical requirement would be covered by the PV generated electricity.

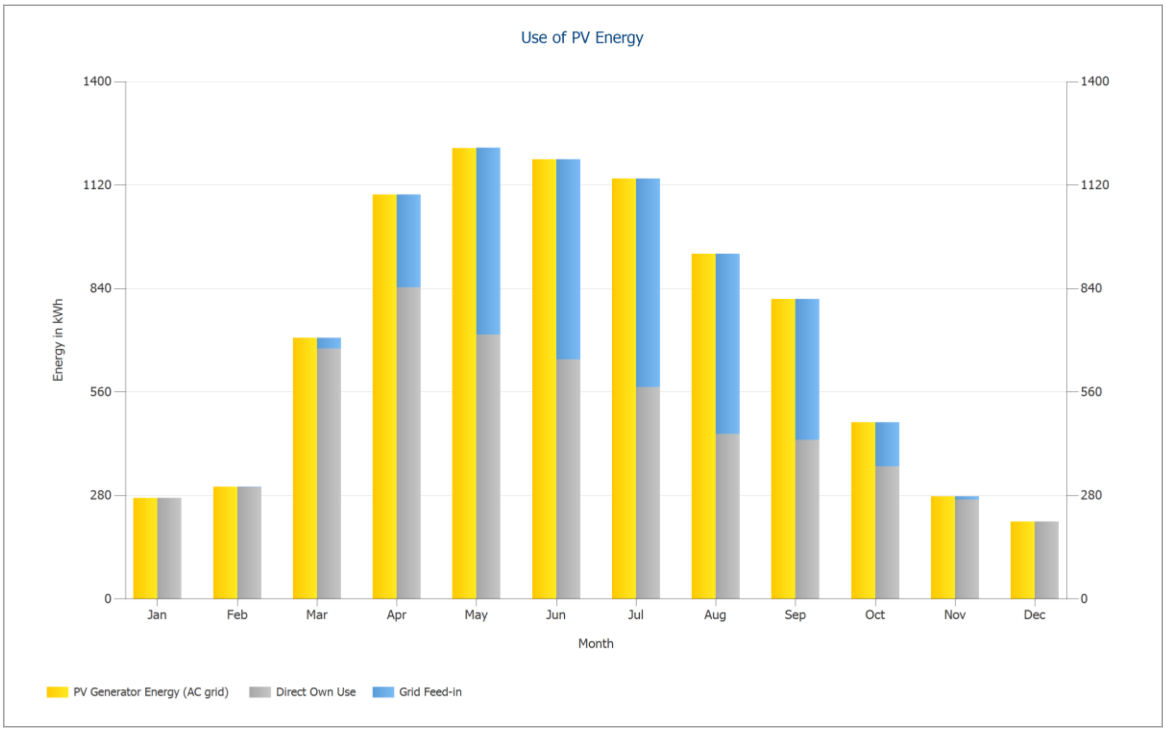

Figure 10 Graphical representation of use of PV generated energy from 9.90kWp system on Lower south facing roof.

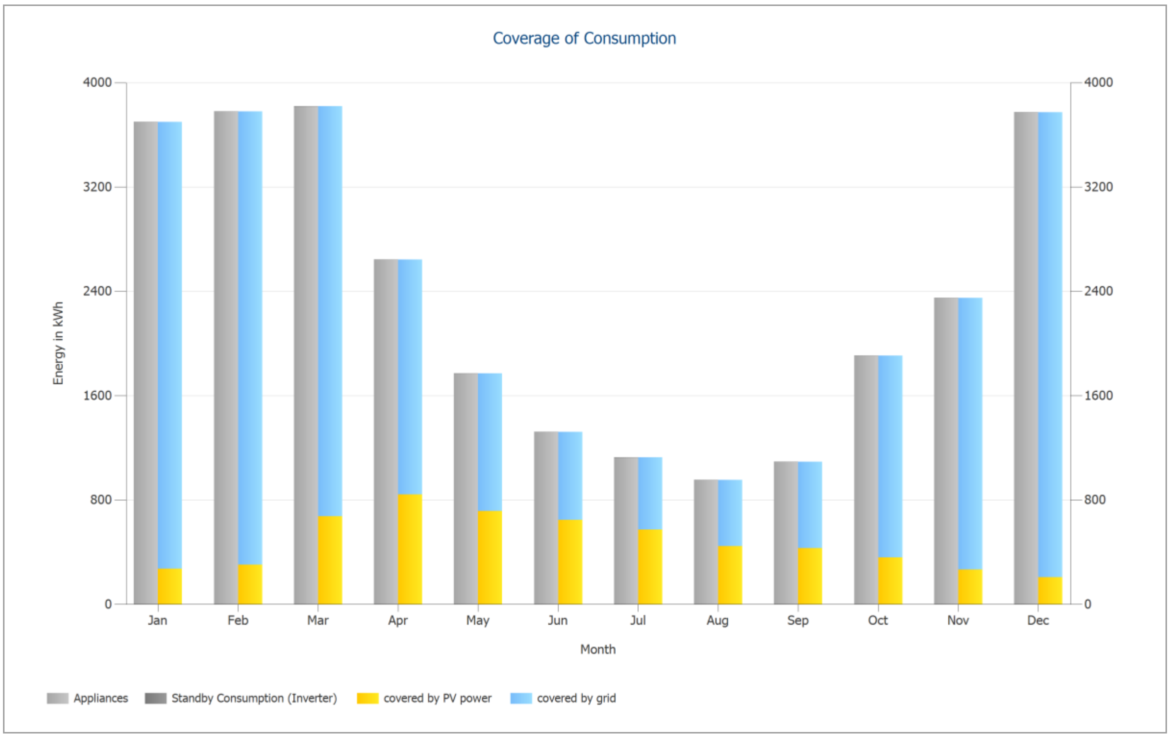

Figure 11 Graphical representation of coverage of site consumption from PV generated energy from 9.90kWp system on Lower south facing roof.

4.3.4 Financial Analysis

The estimated installation cost for the PV system options based on current component prices and the practicalities of installing the systems are summarised in Figure 12. Prices allow for use of a mid-price range solar module, a high-end German or Austrian inverter and a high-end German mounting system. They also include DNO costs for grid connection where applicable and a 15 to 20% contractor's mark-up on component costs.

Item	Roof/System				
	Lower west	**Upper west**	**Upper east**	**Lower south**	**Combined**
Array capacity	16.50kWp	11.88kWp	10.89kWp	9.90kWp	49.17kWp
Modules	£3,722.40	£2,679.28	£2,462.44	£2,242.80	£10,957.32
Inverter(s)	£1,911.60	£1,672.80	£1,672.80	£1,575.60	£6,302.40
Mounting system	£1,386.00	£997.92	£914.76	£831.60	£4,130.28
Electrical grid connection	£2,580.00	£2,400.00	£2,400.00	£1,200.00	£9,360.00
Scaffolding and roof access equipment	£1,500.00	£3,500.00	£3,500.00	£750.00	£9,250.00
Site labour	£2,500.00	£2,500.00	£2,500.00	£1,800.00	£9,000.00
Project management	£500.00	£500.00	£500.00	£500.00	£500.00
Total ex. VAT	**£14,100.00**	**£14,250.00**	**£13,950.00**	**£8,900.00**	**£49,500.00**

Figure 12 Budget installation costs for various system options.

A simple payback calculation for each project option has been determined based on the following criteria.

- System capital costs based on above figures.
- Electricity bill savings based on the estimated consumption levels determined in PVSol.
- Electricity offset savings at a rate of £0.1624/kWh.
- No income generated from exported electricity.

Reference	Estimated Capital Cost (£)	PV Energy Consumed Directly on Site (kWh)	Annual Saving from Offsetting Grid Electricity (£)	Simple Payback Year
Lower west	£14,100	6,955	£1,129	12.5
Upper west	£14,250	6,445	£1,046	13.6
Upper east	£13,950	5,176	£840	16.6
Lower south	£8,900	5,746	£933	9.5
Combined system	£48,500	9,683	£1,572	30.8

Figure 13 Table of relative financial performances by project option.

The PV systems should be eligible for some revenue generation through the Smart Energy Guarantee (SEG) scheme. The SEG scheme makes payments for exported electricity generated from appropriately accredited renewable energy installations. There would be a requirement to change the existing site incoming electricity meter to one that can measure exported electricity on a half hourly frequency. It should be noted that changing the meter type may result in additional administration charges and this should be checked with the current electricity provider before committing to a SEG contract.

Unlike Feed in Tariff contracts, SEG contracts are generally shorter term, more variable and can be market driven. Some SEG providers offer fixed rate tariffs over short-term contracts of one to two years, some offer variable rate tariffs where the prices goes up and down over time and a few providers offer variable rate tariffs over shorter time frames where the tariff is calculated from the day-ahead wholesale prices.

There is no obligation to sign up to a SEG contract with the existing electricity provider and the Centre would be free to search the market for the best available deal at the time of system commissioning. However, most SEG providers offer higher SEG tariff rates to clients with an existing supply contract. Best fixed rates are typically around 5.5p/kWh for clients with a supply contract reducing to around 3p/kWh for clients who receive electricity through a 3rd party supplier. Scottish Power, the current electricity provider to the Centre, is offering a variable rate SEG tariff of 4p/kWh for exported electricity. The table in Figure 14 indicates the potential revenue that could be generated from each PV system via the current Scottish Power SEG tariff.

Reference	Estimated Capital Cost ex. VAT (£)	Annual Saving from Offsetting Grid Electricity (£)	PV Energy Exported to Grid (kWh)	Estimated Annual Income from SEG Contract (£)	Simple Payback Year
Lower west	£14,100	£1,129	5,996	£239	10.3
Upper west	£14,250	£1,046	3,968	£159	11.8
Upper east	£13,950	£840	2,675	£107	14.7
Lower south	£8,900	£933	2,888	£115	8.5
Combined system	£48,500	£1,572	30,346	Subject to a larger G99 grid connection agreement	

Figure 14 Table of relative financial performances by project option including SEG income.

4.3.5 Conclusion

There is potential to install solar PV arrays on four different roof aspects on the building.

The energy yield profile from the PV systems will be almost the inverse of the electricity consumption profile of the Centre. This will mean that the PV system will under produce relative to the requirements of the building in the winter and overproduce in the summer months. Therefore, there is little value in oversizing the PV arrays with the current electrical consumption requirements of the site.

The installations on the lower roofs would be easier to install compared to those on the upper roofs. They will also provide better value for money as the fixed cost of scaffolding and roof access equipment required to work safely on the upper roofs are high, relative to the overall system cost. The high roof access costs should also be considered in the light of any maintenance requirements of the PV systems; future access to the array may be required if there was a DC string fault for example or the solar modules needed cleaning.

The system on the Lower south facing roof would be the easiest to install overall as it is adjacent to the point of grid connection. It will provide best value for money as well, due to providing a higher energy yield ratio than the system on the Lower west facing roof. It would also be the most prominent installation in terms of promoting the environmental benefits to the wider community.

The smaller systems on both Upper Roofs and the Lower south facing roof could be electrically connected under a G98 connection agreement. This would enable the PV systems to be grid connected without prior approval from SPEN and save on the connection cost. The larger system on the Lower west facing roof and any combination of two roof systems could be connected using the G99 connection offer received from SPEN. Combinations of three or more roofs would require a new G99 connection application to be made.

The PV systems could generate limited income to the community Centre via the SEG scheme. To receive this income, there would be a requirement to change the main electricity meter at the Centre to one that can measure export on a half hourly basis. Income from the SEG would typically be in the order of £100 to £150 per annum from the PV systems that could be connected under G98 and larger PV systems could potentially generate more income.

4.4 EV Charging Points

The site car park has two 7kW electric car charging points which were installed in March 2020 and are electrically supplied from the main Centre building. Readings from the meters inside the chargers taken at the end of January 2021 confirmed that the combined usage on both chargers amounted to 37kWh since the time of installation. Increased usage of the charge points would obviously increase site consumption, which we understand would be compensated for by the EV charger operator. It would also help to improve site consumption of PV generated energy. The impact of two theoretical EV charging scenarios has been simulated based on the Lower south facing PV system and using the following assumptions:

- Scenario 1:
    - Typical car charging periods would fall within 17:00 and 07:00 and 12:00 and 14:00 on weekdays and all day on weekends.
    - Both existing 7kW chargers would be available for use.
    - The chargers would typically service two Nissan Leaf e+ cars of battery capacity 62kWh.
    - The cars would complete 350km per week in 10 journeys of 35km.
- Scenario 2:
    - Car charging periods would be optimised for PV energy output anytime between 09:00 and 17:00 daily.
    - Both existing 7kW chargers would be available for use.
    - The chargers would typically service two Nissan Leaf e+ cars of battery capacity 62kWh.

- The cars would complete 350km per week in 7 journeys of 50km.
- Charging would be optimised for PV energy generation.

4.4.1 Estimated on Site Consumption of PV Electricity

Figure 15 highlights the increased self-consumption levels of solar generated electricity from the Lower south facing system if the EV chargers were utilised with the above scenarios.

Reference	Annual PV Energy Generated (kWh)	PV Energy Consumed Directly on Site (kWh)	PV Energy Used to Charge Vehicles (kWh)	Proportion of PV Energy Generated Consumed on Site (%)	Proportion of Site Electricity Requirement (%)
Standard charging	8,634	5,330	2,172	86.9	21.1
PV optimised charging	8,634	2,526	5,521	93.2	22.4

Figure 15 Table of the estimated PV energy generation and consumption data for the Lower south facing PV system using two EV charging scenarios.

The analysis confirms that self-consumption of PV generated electricity would significantly increase if the EV chargers were utilised beyond current levels. In terms of overall consumption of PV generated energy then there would be a small additional benefit if the charging periods were optimised for PV generation. The contribution levels from the PV system to the overall operation of the site would be reduced due to the increased electrical demand resulting from the chargers. However, we understand that the costs of the additional electricity consumed by the chargers would be met by the EV charger operator.

4.4.2 Financial Analysis

The simple payback calculation has been modified taking into consideration the additional consumption of PV electricity due to the greater utilisation of the EV charging points during PV generation periods. The analysis has been based on both charging pattern scenarios and no capital allowance has been added to the project cost for the EV chargers as they are already in situ.

Reference	Estimated Capital Cost ex VAT (£)	Total PV Energy Consumed (kWh)	Annual Saving from Offsetting Grid Electricity (£)	Simple Payback Year
Standard charging	£8,900	7,502	£1,218	7.3
PV optimised charging	£8,900	8,047	£1,306	6.8

Figure 16 Table of financial performance for the Lower south facing PV system with two EV charging scenarios.

4.4.3 Conclusion

The analysis confirms that increasing the usage of the EV chargers at the site would improve the financial viability of the solar PV installation. Publicity of the charging facilities and potentially an incentivisation scheme to promote the usage of the EV chargers during daytime hours may help to increase utilisation which would in turn benefit the financial return from the PV system if it were installed.

4.5 Standalone Battery Storage

The assessment was broadened to look at the impact of including a standalone battery storage system with the solar PV installation. The battery would collect excess PV generated electricity at times of overproduction for use at other times when the PV system was not generating, for example overnight. The assessment has been completed for the PV system on the Lower south facing roof as this is considered the most viable and easy to install and maintain option. Results for the assessment of the other PV systems considered in this report will be broadly like those below.

4.5.1 Estimated on Site Consumption of PV Electricity

The assessment has been completed based on the inclusion of a 15kWh Li-Ion battery system that would be connected over the three phases of the site supply. This would effectively provide 5kWh of storage on each phase of the electrical system.

Figure 17 highlights the increased self-consumption levels of solar generated electricity if a 15kWh battery system were added to the solar PV system on the Lower south facing roof.

Reference	Annual PV Energy Generated (kWh)	PV Energy Consumed Directly on Site (kWh)	PV Energy Used to Charge Battery (kWh)	Proportion of PV Energy Generated Consumed on Site (%)	Proportion of Site Electricity Requirement (%)
Lower south	8,634	5,737	1,892	88.3	26.3

Figure 17 Table of the estimated PV energy generation and consumption data with 15kWh of battery storage.

The table confirms that an extra 1,892kWh of solar generated energy would be consumed by the site if a 15kWh battery was installed over the three phases of the electrical system.

4.5.2 Financial Analysis

The additional cost for adding a battery, battery inverters and controls to the PV system on the Lower south facing roof are provided in Figure 18. Pricing for the battery system allows for use of a Chinese manufactured Li-Ion battery, high-end German battery inverters and controls, and a 20% contractor's mark-up on component costs.

Item	**South facing**
Array capacity	9.90kWp
PV system cost	*£8,900.00*
Li-Ion battery (15kWh)	£3,240.59
Battery stands	£1,036.46
Battery inverters	£2,748.25
Controls	£274.70
Electrical connection	£600.00
Site labour	£300.00
Total ex. VAT	**£17,100.00**

Figure 18 Budget installation cost of Lower south facing PV system with 15kWh battery system.

The simple payback calculation in Figure 19 has been modified taking into consideration the additional cost of the 15kWh battery system and the added consumption of PV generated electricity resulting from having a battery in situ.

Reference	**Estimated Total System Capital Cost PV + Battery ex. VAT**	**Total PV Energy Consumed (kWh)**	**Annual Saving from Offsetting Grid Electricity (£)**	**Simple Payback Year**
Lower south	£17,100	7,629	1,238	13.8

Figure 19 Table of financial performance of Lower south facing solar array with 15kWh battery included.

4.5.3 Conclusion

The analysis confirms that adding a battery to the PV system will increase the self-consumption of PV generated energy. However, the high cost of the battery system relative to the amount of excess energy that will be captured and then used, will make the project less financially attractive. There is no value in using a battery to capture excess PV generated electricity for use at times when the PV system is not operating under the current circumstances. There would be greater value in trying to increase the use of the EV chargers if the PV system were installed.

4.6 Electricity Supply to the Adjacent Surgery

It is technically possible to install a PV system on the Canolfan Ceiriog building to supply electricity to the adjacent doctor's surgery. However, it would not be possible to directly interconnect the electrical systems of the two buildings from a safety perspective as both sites would then have two independent points of grid connection. The PV system providing energy to the surgery would have to be electrically independent of the Canolfan Ceiriog building and would be installed on one of the roofs and connected directly into the electrical distribution system of the surgery. This could be achieved by splitting one of the roofs into two independent PV systems or installing PV systems on two independent roofs. The capacities of the arrays required would be sized to best fit the electrical requirements of each site.

There are some risks associated with this approach which could result in the surgery PV system becoming redundant. These could include a dispute between the Centre and the surgery, a change of ownership of the surgery building with the new building occupier not wanting electricity supplied from a 3rd party PV provider, or if the building was left unoccupied. In each of these cases the PV system supplying electricity to the surgery could be disconnected at the Centre and then reconnected to the Canolfan Ceiriog building. It should be noted however that a new grid connection application would have to be made to SPEN and there may be some risk of this being rejected based on the state of grid conditions at the time of application.

The selling price of the PV energy to the surgery and the consumption level of the supplied electricity will be critical to the viability of this option. The surgery is small in area, heated by Calor gas and has limited opening hours, 08:30 to 12:30 Tuesday to Friday, so electricity consumption levels will likely be limited.

Initial enquiries regarding electrical supply to the surgery have been made to Stephen Phillips of the Estates Department of the Betsi Cadwaladr University Health Board. Stephen was able to confirm that the invoiced annual electrical consumption for the surgery in 2020 was 6,926kWh, although he stated that many months were overestimated. Whilst he expressed some interest in making operational savings at the surgery, he confirmed that they would have to take legal advice before committing to the idea as the surgery was contractually supplied as part of an All Wales energy consortium. The requirements of supplying energy to the NHS outside of their existing supply contract are likely to be challenging and would involve legal costs in terms of setting up the contractual framework. It is felt that the time and costs associated with doing this would outweigh the small benefit that would be provided by supplying electricity to the surgery. It is therefore recommended that this option is parked at this stage unless there is an appetite within the Canolfan Ceiriog management group to pursue this further.

5 Business Case

5.1 Project financing

The following options could be considered for funding the solar PV installation:

- Direct funding using existing reserves.
- Debt finance.
- Grant funding.

- Community share issue.

In terms of the above options, Grant Funding, either full or partial, is likely to be the preferable option as it would limit the drain on any existing reserves which may be earmarked for rainy days or higher priority projects and avoid taking out project finance. Current potential grant funding options could include The National Lottery Community Fund Wales and the MCS Charitable Foundation.

Debt finance could be interesting if the debt repayments could be structured so that they were covered by the energy cost savings from the PV system and any potential revenue through the SEG.

It is unlikely that the project would be viable for a Community Share Issue Fund as the PV system would be generating limited revenue (circa £150 per annum) and most of the benefit would result from energy savings. However, it may be worth considering this option from a philanthropic perspective as there may be local funders who may be prepared to provide finance in return for a plaque on the wall in the site entrance or a free cup of coffee a week/month during the first year of operation for example.

5.2 Operational Costs

The operational costs from running the PV system will be relatively small. Potential areas where costs could be incurred would include:

- Replacing system components.
- System servicing.
- Increased site insurance.
- Increased business rates.

Solar PV modules have an excellent longevity record and there are modules in Japan that are now in their fifth decade of energy production. Solar modules are covered by both a manufacturer's product and performance warranty. A typical product warranty would cover the first 10 years of operation with high-end modules being covered for as long as 25 years. There is an inevitable performance degradation over the lifetime of the module which is covered by the manufacturer's performance warranty. This warranty is generally split over several milestone years and would include a minimum output guarantee after 1, 10 and 25 years of operation for example. The module surface glass could be damaged by projectile impact such as a golf ball or a thrown stone, so it would be important to include the PV system in the site insurance as the it would be unguarded for significant periods of time.

The most likely component within the PV system that will requirement replacement is the inverter. Inverters come with a five-year manufacturer's warranty as standard across the industry, and some manufacturers provide longer 10 or 12 year warranties as standard. It is also possible to extend the inverter warranty for as long as 20 or 25 years at the time of installation by purchasing an extended agreement from most manufacturers. An allowance for replacing the inverters should be built into the business model if the solar modules are to operate for more than 30 years. The system energy meter could expire at some point in the project lifetime, but the replacement cost is small at around £50 and will have limited impact on the business model.

The choice whether to service the PV system or not ultimately comes down to the system owner. There are limited preventative actions that can be undertaken to extend the life or improve the performance of the PV system. The AC circuit of the PV system should be included in the 5-yearly periodic inspection and testing of the building electrical circuits, and cleaning of the solar array could be added to a window cleaning contract. The cost of adding these extra activities to existing contracts would be insignificant. In our experience, most PV system owners undertake no preventative maintenance and wait for a system component, such as the inverter, to fail before acting. However, some insurance companies can request that the whole PV system is inspected on an annual basis by a competent solar engineer. This is particularly relevant on installations on commercial properties or buildings with historical significance.

Adding a PV system to a building should be notified to the building insurer and can result in an increase to the annual insurance premium. However, many policies cover solar PV systems as standard, and it is difficult to quantify any extra premium that might be payable without speaking to the existing insurer of the building first. We would recommend that the Canolfan Ceiriog management group speak to their current building insurer to determine the impact (or not) of installing the PV system before committing to the project.

Installing a PV system on a commercial building can result in an increase in business rates however Jim Mills has confirmed that the Canolfan Ceiriog Centre is exempt from business rates.

5.3 Business Model

A cash flow model has been constructed to examine the business case of the project based on the PV system being purchased outright using existing capital reserves and if some of the capital costs were borrowed via a commercial loan. The following parameters were used to build the model which has been based on the PV system on the Lower south facing roof over a 25-year project lifetime:

Costs:

- **Capital cost**: £10,680 including VAT.
- **Inverter replacement**: The cost for replacing the inverter has been included in year 10 and year 20 of the model but in practice this cost could be incurred anytime outside of the manufacturer's warranty and could be at a shorter or longer frequency than those modelled. We have inverters in the field which now have more than 15 years of operation under their belt for example.
- **System servicing**: An allowance of £500 for an inspection of the PV system by a solar engineer has been included in year five and then inflated and repeated at five-yearly intervals to reflect the periodic inspection and testing requirements of the building.

Benefits:

- **Electricity cost savings:** The savings have been based on the offset level of 5,746kWh per annum provided in the table in Figure 9 and an initial tariff rate for incoming electricity of 16.24p/kWh.
- **Revenue from SEG**: It has been assumed that the site would have a Smart meter installed which would be capable of measuring exported electricity from the site. A SEG

contract would be in place with Scottish Power, the existing electricity provider, paying a tariff rate of 4p/kWh for the electricity that would be exported.

Other factors:

- **Degradation in solar module output:** The energy yield from the solar PV module has been degraded in line with the manufacturer's performance warranty. It should be noted that this would be a worst-case scenario as the PV module will in all probability outperform the warranty in practice. It has been assumed that the yield reduction will not affect the quantity of electricity consumed by the site but instead will reduce the amount of electricity that would be exported from the building to the grid. The degradation figures used in the module are a 2% reduction in year 1, a maximum of 10% degradation after 10 years and a maximum of 20% degradation after 25 years. This is considered a standard warranty and many premium modules would offer improved warranty levels.
- **Impact of inflation:** It has been assumed that the average rate of inflation on project costs over the course of the project lifetime would be in line with the Bank of England target of 2% per annum. However, the future cost of electricity has been inflated by 4.2% per annum based on figures from the Office of National Statistics since 1988.

5.4 Business Case Results

Option 1: Outright Purchase using Capital Reserves.

Payback in year	13
Net profit at 25 years	£19,393
Internal Rate of Return (IRR)	8.8%

Figure 20 Business case, capital reserve purchase of Lower south facing system over 25 year period.

The internal rate of return (IRR) is a financial measure used to assess the attractiveness of a particular investment opportunity. The IRR for an investment estimates the rate of return of the investment after accounting for all projected cashflows together with the value of money over time. When selecting between several investments, the investor would select the investment with the highest IRR, provided it is above the investor's minimum threshold.

Option 2: Partial Debt Finance with balance from Capital Reserves.

£4,260 is borrowed at an APR of 7.8% over five years with the balance of £6,420 provided from capital reserves. The debt finance is modelled to be cash neutral against the electricity bill savings and income from the SEG over the five-year loan period.

Payback in year	16
Net profit at 25 years	£14,234
Internal Rate of Return (IRR)	5.4%

Figure 21 Business case, part capital reserve purchase, part debt finance of Lower south system facing over 25 year period.

Breakdown of the project cash flows are provided in Appendices 3 and 4.

6 Appendices

Appendix 1 – Scottish Power Energy Networks G99 Grid Connection Offer

Appendix 2 – Tier Consult Structural Assessment of PV Module Roof Loadings

Appendix 3 – Project Cash Flow Outright Purchase with Capital Reserves

Appendix 4 – Project Cash Flow Partial Debt Finance with balance from Capital Reserves

Appendix 5 – PVSol Report Lower West Facing Roof with Site Consumption

Appendix 6 – PVSol Report Lower South Facing Roof with Site Consumption

Appendix 7 – PVSol Report Upper West Facing Roof with Site Consumption

Appendix 8 – PVSol Report Upper East Facing Roof with Site Consumption

Appendix 9 – PVSol Report Maximum Sized System with Site Consumption

Appendix 10 – PVSol Report Lower South Facing Roof with EV Chargers

Appendix 11 – PVSol Report Lower South Facing Roof with EV Chargers – PV Optimised

Appendix 12 – PVSol Report Lower South Facing Roof with Battery Storage