



MSc Engineering Project Management
Masters Project
ACFA 7003

A Solar Photovoltaic Farm Proposal
At Morriston Hospital,
Swansea Bay University Health Board

Mark Davies

1650901

January 2026

Executive Summary

This research proposal aims to provide a solution for Swansea Bay University Health Board to combat and achieve their Net Zero Carbon (NZC) emission targets. Hospitals are classed as one of the heaviest energy consumers in the UK which is down to the dated engineering services and the requirements to control the patient environment.

Healthcare in the UK must adhere to strict guidance and regulations to maintain their mechanical space heating, cooling, and ventilation. Due to the dated age on plant equipment then it is deemed as matter of concern to address non economical and non-eco-friendly equipment and services. By reducing the size on plant equipment could have a positive effect on greenhouse gas emissions of the site.

Prior to the research study, the author considered a range of renewable energies to propose to SBUHB, however the most suitable renewable energy is photovoltaic (PV) panels. The author will go into further detail throughout the thesis and explain the reason behind choosing PV panels and the solar farm.

Research was carried out by means of a literature review, this entailed reviewing relevant and documented articles in journals, websites / articles and professional blogs. Research was also obtained by contacting the Estates and Energy Department for Morriston Hospital. The research relied on existing data from the Energy Dept as it is important to note how much energy is consumed monthly / annually by Morriston Hospital.

The author aims to provide the reader with a clear understanding of PV panels and how they work in a solar farm, what type of PV panels should be installed and how they operate. The reader will also gain an understanding of what measurements need to be place for the solar farm to operate efficiently with a productive outcome. In order to ensure that the author was able to achieve each objective then specific literature was chosen and reviewed in-depth to make sure it was beneficial to the research. The author chose specific case studies which assisted this proposal, the case studies concentrated on Solar Photovoltaic (PV) panels, and how they can have an impact on healthcare sites.

Keywords:

Photovoltaic, Solar Farm, UK Healthcare, Energy

Acknowledgements

I would like to take this opportunity to thank Mr. Andrew Thorn, Lecturer at the University of Wales Trinity St David, whose support, guidance and advice have made this dissertation possible.

Most importantly, I would like to thank my wife Sarah, for continually supporting my efforts, even in times of despair her encouragement has never diminished. To my children, Carter and Sophia, who have given my life a sense of purpose and direction.

Further to this, I would like show gratitude to my current employer Swansea Bay University Health Board for allowing me the time to complete my Master's degree, with a special thanks to Mr. Tony Jones and Mr. Mark Parsons.

Declaration



Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the regulations of the University of Wales, Trinity Saint David. The work is original except where indicated by special references in the text and no part of the dissertation has been submitted for any other degree.

Any views expressed in the dissertation are those of the author and in no way represent those of the University of Wales, Trinity Saint David.

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List of Abbreviations

• SBUHB	-	Swansea Bay University Health Board
• A&E	-	Accident & Emergency Department
• PV	-	Photovoltaic
• WG	-	Welsh Government
• NZC	-	Net Zero Carbon
• ASHP	-	Air Source Heat Pumps
• GSHP	-	Ground Source Heat Pumps
• UK	-	United Kingdom
• NHS	-	National Health Service
• CSP	-	Concentrated Solar Power
• MW	-	MegaWatt
• MWh	-	Megawatt Hour
• KWhs	-	Kilowatt Hours
• NASA	-	National Aeronautics and Space Administration
• MVHR	-	Mechanical Ventilation Heat Recovery
• WHBNs	-	Welsh Health Building Notes
• WHTMs	-	Welsh Health Technical Memorandums
• HBNs	-	Health Building Notes
• HTMs	-	Health Technical Memorandums
• BESS	-	Battery Energy Storage System
• GHG	-	Greenhouse Gases
• Opex	-	Operational Expenditure
• Capex	-	Capital Expenditure
• OJEU	-	Official Journal of European Union
• LCDP	-	Low Carbon Delivery Plan
• NAWCC	-	National Assembly for Wales Climate Change
• ECS	-	Energy Control System
• ADSL	-	Asymmetric Digital Subscriber Line
• LV / HV	-	Low Voltage / High Voltage
• BESS	-	Battery Energy Storage Systems
• DPPs	-	Defined Performance Parameters
• LID	-	Light-Induced Degradation

Chapter One

1. Introduction

Swansea Bay University Health Board (SBUHB) consists of six hospitals, these are Morriston, Singleton, Neath Port Talbot, Gorseinon, Cefn Coed and Tonna Hospital plus local Mental Health and GP clinics.

Morriston Hospital is one of the largest hospitals in Wales. It is the regional acute tertiary hospital for Southwest Wales, offering a range of specialist services, including trauma and orthopaedics, renal medicine, neurology, oral and maxillofacial surgery. Morriston Hospital has one of the busiest emergency departments (A&E) in Wales.



Figure 1: Morriston Hospital. (SBUHB, 2025)

Morriston Hospital's monthly consumption of electricity fluctuates between 1,233 MWh's and 1,547 MWh's (season depending). The reason for these incredibly high volumes of electricity being consumed is down to the dramatic increase in services to all departments since the Covid-19 pandemic. SBUHB will have to consider new ways to save energy consumption and be initiative taking in their approach to reduce costs.

SBUHB currently spends £8.4m per year on electricity, gas, water and sewerage treatment across its estate including £3m spent purchasing 18.6m kWh of Electricity for Morriston. This is predicted to rise year on year at a rate higher than inflation.

SBUHB have started decarbonising their high energy resources such as removing old gas boilers and replacing with air source heat pumps (ASHPs), they are replacing their petrol / diesel fleet cars with electric vehicles, they have replaced all halogen theatre lights with LED lights to name but a few.

Due to Morriston Hospital's ideal geographical location then solar energy is a suitable key sustainable energy source. Solar energy benefits from South / Southwest or East facing, open space and exposure to gain maximum energy. There could be an argument to use wind turbine instead of solar power through PV panels. The author suggests that without exploring in-depth detail, then a valid reason wind turbines was not chosen is because of the emergency flight path of the air ambulances, as the wind turbines could be a potential hazard. Another contributing factor could be their high procurement and maintenance costs.

1.1 Project Proposal

This project proposal will focus on and propose the provision of solar power and how it contributes to SBUHB achieving their Net Zero Carbon (NZC) emission targets. Solar energy can be obtained directly from sunlight; the sun's organic energy is absorbed into the photovoltaic panels and then converts into electricity. Solar energy is rapidly gaining popularity rapidly due to it generating sustainable electricity and heating.

There are two ways to generate solar power, these are achieved by using solar photovoltaic (PV) and concentrated solar power (CSP). PV uses solar cells / panels to convert sunlight directly into electricity where CSP uses mirrors to concentrate solar rays. These rays heat fluid, which creates steam to drive a turbine and generate electricity. (Irena, 2025).

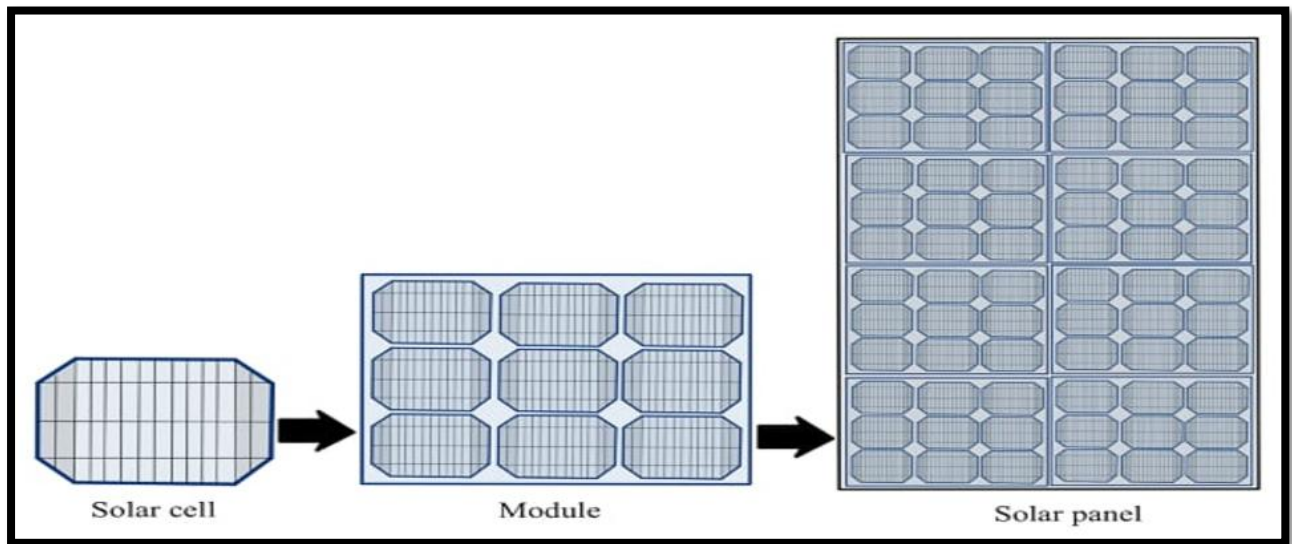


Figure 2: Calculating the efficiency of Solar Panels, JA Building Document. (Thorn, A 2025)

Figure 2 demonstrates how the size of a solar panel can range from a single module to multiple modules; the range will vary to suit the consumer and the extent of the area it needs to cover. For the SBUHB solar farm to be productive then it will require thousands of modules.

As part of this proposal, the author will investigate the positive and negative impact of a 4MW solar farm and how it could benefit the energy consumption of Morriston Hospital. The author will take into consideration the changes in energy tariff prices and how they are evaluated, and to analyse the potential payback period of installation.

The chosen land is Brynwhillach Farm, Felindre, Swansea. The identified land is approx. 3km far from Morriston Hospital. The solar farm will require 3km of private wire connection to the hospital. Significant ground works/ infrastructure would be required to provide compliant trenches for the cabling; this will no doubt influence traffic management and costs. However, from substantial capital investment then SBUHB will financially benefit as well as reduce purchasing of electricity from the national grid, it will also provide additional benefits such as:

- Reducing carbon emissions from the Health Board Estate by a further 1,000 Tco_{2e} per annum and over the lifetime of the farm 20,000 Tco_{2e}.

- Contributing to the Health Boards Statutory Requirements under the Environment (Wales) Act 2016 and the Wellbeing of Future Generations Act 2015.
- Demonstrating a proactive and sector leading approach to energy and carbon reduction within the health sector.

SBUHB would need to appoint a suitable and recognised renewable energy company to undertake an Investment Grade Proposal for a ground mounted solar PV array at Brynwhillach Farm.

The size of the farm is suitable for this proposal as it maximises the amount of electricity that can be produced and used within the hospital to offset purchased electricity. It needs to be noted that there will be times when the farm output is above the demand of the hospital.

There needs to an agreement set in place with Western Power Distribution to allow for surplus electricity to be exported by SBUHB during peak production months. To add to this, SBUHB will need to research into storage units to store surplus electricity.

The PV Solar Farm will produce zero-carbon electricity to reduce current grid demand and associated future cost uncertainties. The use of Solar PV will also help offset the costs associated with the planned heat decarbonisation projects associated with the electrification of heat.

1.2 Aim

The aim of this project evaluates how a solar farm can contribute to SBUHB to achieving a Net Zero Carbon status by 2030. The author believes this assessment will benefit the Health Board and Local Government, as it will provide detailed information and data into the performance of a solar farm for Morriston Hospital. The researcher is aiming to achieve the feasibility of this task by conducting the following objectives.

1.3 Objectives

The aim will be managed via the following key objectives:

- 1) In-depth review of how a 4 MW (Megawatt) Solar Photovoltaic Farm can benefit Morriston Hospital, SBUHB.
- 2) Analytical review of Morriston Hospital's energy consumption and uncover the potential revenue to be generated including payback period from the proposed solar farm.
- 3) To critically analyse the solar farm proposal for Morriston Hospital and how much of an impact the proposed solar farm can have on reducing greenhouse gas emissions.

1.4 Research Proposal Structure

To achieve the Aim and Objectives of this project, then the author will need to conduct a literature review. The literature review will allow the reader to gain a better understanding of solar photovoltaic power, and a proposed solar PV farm for Morriston Hospital. The literature review will support the author's conclusion on the topic.

Main Body Chapters will follow on from the Literature Review, this chapter breakdowns the variations of methods available to conduct research on solar photovoltaic power. The author will address the advantages and disadvantages of the chosen project and its method.

Following on from Main Body Chapters will be the Conclusion, this chapter demonstrates what the author has discovered throughout the project proposal, it will provide the opportunity for the author to present the research findings. The chapter explains how the results will be compiled and how the analysis will be conducted. The author will be able to provide a review of the project proposal, whether the aims and objectives were achieved, if so how and if not then why not. This chapter highlights what the author has learned from the project proposal, what recommendations would be suggested for future similar research projects and where should further research be focused on.

Chapter Two

2. Literature Review

This literature review will assist the author to gather information on solar photovoltaic power and how the solar PV farm will benefit Morriston Hospital. In order for the author to address the aims of this dissertation then the findings from this secondary research (literature review) will be compared with the results from the primary research of this study.

The author will conduct a literature search for information related to the subject matter of the research. The author will make use of the Learning Resource Centre (LRC), mostly through electronic means. This will involve searching through numerous journals & reports for any relevant articles; the author predicts that the most useful source of information will come from the Welsh Government website and primary research.

2.1 Decarbonisation

The Welsh Government faces huge challenges to decarbonise their Health public sector buildings, to retrofit renewable or clean energy sources onto existing buildings in order to decrease their carbon footprint. There are many factors to consider, such as cost, age and location of buildings, what impact it has on the services, does the Welsh government have the resources to conduct such tasks.

The European commission states “that it is estimated that over the next decade then investment in energy saving building components and equipment will need to be increased by up to €200 billion euros.” (European Commission, 2022)

The Welsh Government advised that “a crucial way to mitigate the impacts of climate change is reduce carbon emissions.” In March 2021, following advice from the Climate Change Committee in December 2020, the Welsh Government set new targets for a 63% carbon reduction by 2030, an 89% reduction by 2040, and a 100% reduction by 2050. (All Wales Low Carbon Delivery Plan, 2025)

These targets are incredibly ambitious but at the same time they can be achievable and offer productivity. By setting the targets then it is making the public think about the environment and to be more conscious of their actions by reserving energy rather than wasting it. (Wales-Audit, 2024)

It remains unclear whether these targets will be met by 2030. We are only 4 years away from this date, the author believes that there are still many old aging buildings under the public sector that have not been revamped to reduce their energy consumption.

2.2 Solar Photovoltaics

Solar Photovoltaics harvests the sun's natural energy, by using the sun's energy then this could have a dramatic effect on reducing the demand for fossil fuels which will reduce the effects of carbon dioxide. As each country receives a different impact from the sun's energy due to its geographical location, for countries that are closer to the equator line then they will benefit more from harvesting solar power than countries that are further away from it.

The UK is not near the equator line but is close enough to benefit from solar power.

Solar power does not overly rely on bright sunshine all the time, however that obviously helps. Solar panels require a certain degree of sunlight to generate electricity, it does depend on the amount of direct sunlight, and the quality of the PV panels. Kabir et al states *"The UK is shortcoming on Solar Power, due to that Solar Power energy can only be harnessed during the day and works most efficiently when it's sunny. Thus, solar energy is likely not the most reliable source of energy in regions with unsustainable weather or climate conditions."* (Kabir, 2018)

SBUHB will be able to get weather predictions and seasonal data from Mumbles Weather Station in Swansea. The impact of seasons will affect the level of energy the PV panels generate, in the UK a typical day of sunlight in the summer would be from 8am – 8pm and in the winter, it would average between 9am – 4pm.

It is known that solar panels can be less efficient in hot temperatures. According to Solar Energy UK, 2025 "then solar panel performance falls by 0.34 percentage points for every degree that the temperature rises above 25°C." (Solar Energy UK, 2025)

PV systems are most effective when the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow.

PV technology is a cornerstone of solar energy conversion, enabling the direct conversion of sunlight into electrical energy. PV systems consist of solar panels composed of interconnected solar cells, which are the fundamental building blocks responsible for converting light energy into electricity.

The electricity that is produced at this stage is in a form known as a direct current (DC) and needs to be converted to an alternating current (AC) to be suitable for Morriston Hospital, for this to happen then a solar inverter needs to be installed. The solar inverter takes the DC electricity and changes it to AC electricity ready to be sent to the electrical substation. The electric that isn't used can be stored in battery storage or / alternatively, the surplus electricity can be sold to the National Grid.

The operation of PV cells relies on the PV effect. When photons from sunlight strike the surface of a PV cell, they transfer energy to the atoms within the cell's semiconductor material, causing the release of electrons. (Hasan, 2023).

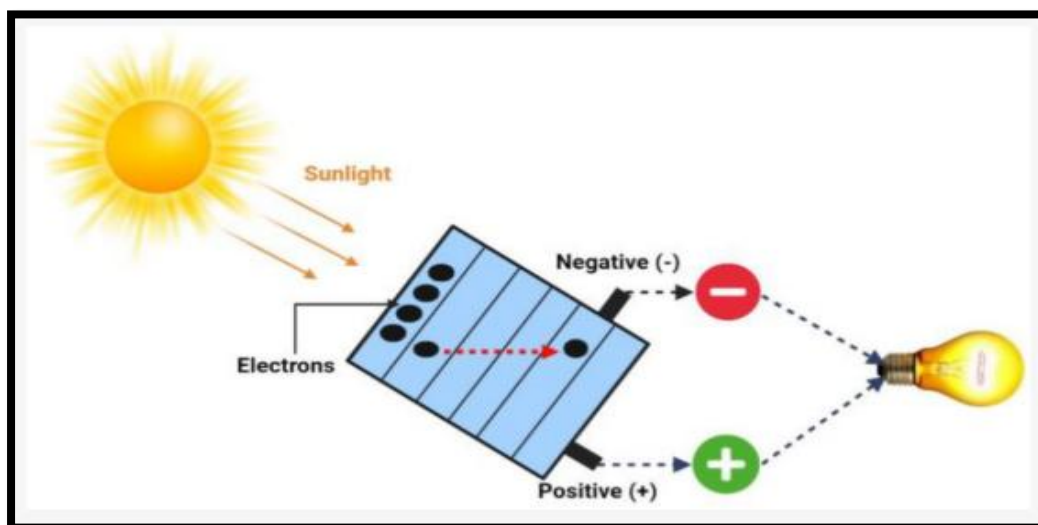


Figure 3: The working principles of a typical PV cell. (Hasan, 2023)

The UK is ranked 16th in the world for solar power generation capacity.

The solar power for electricity generation is measured in terawatt-hours (TWh) per year, the table below illustrates where the UK is as a solar power user. (Our World Data, 2024).

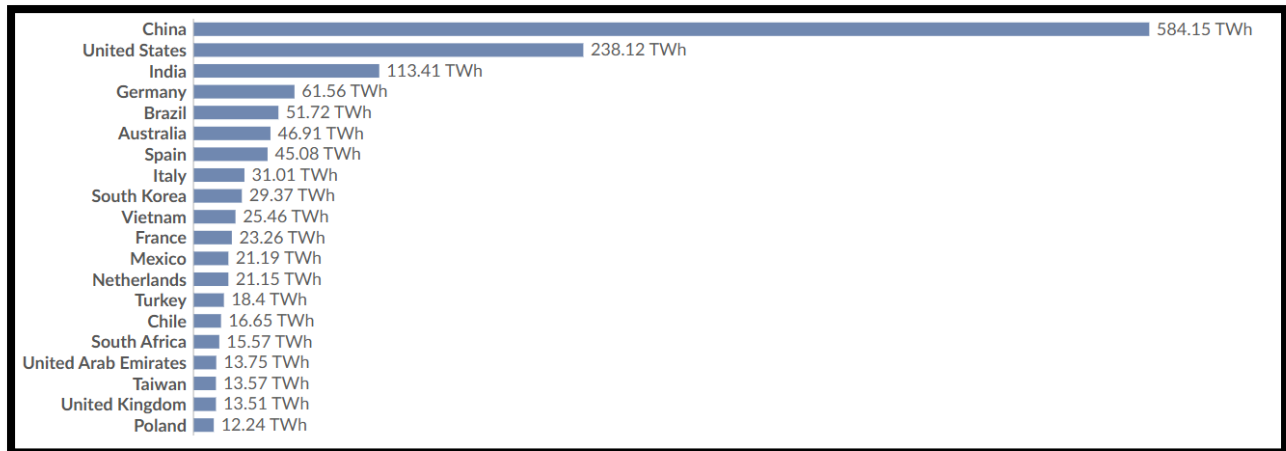


Figure 4: UK Global ranking in solar power usage. (Our World Data, 2024)

However, when you compare the solar power usage to wind turbine usage then there is a significant difference. In Figure 4, it shows that currently the UK is ranked fifth in the world as the largest wind turbine user. According to Our World Data then in 2023 the UK's offshore and inshore wind capacity is the largest in Europe, this would make sense as UK is an island where the majority of Europe is inland.

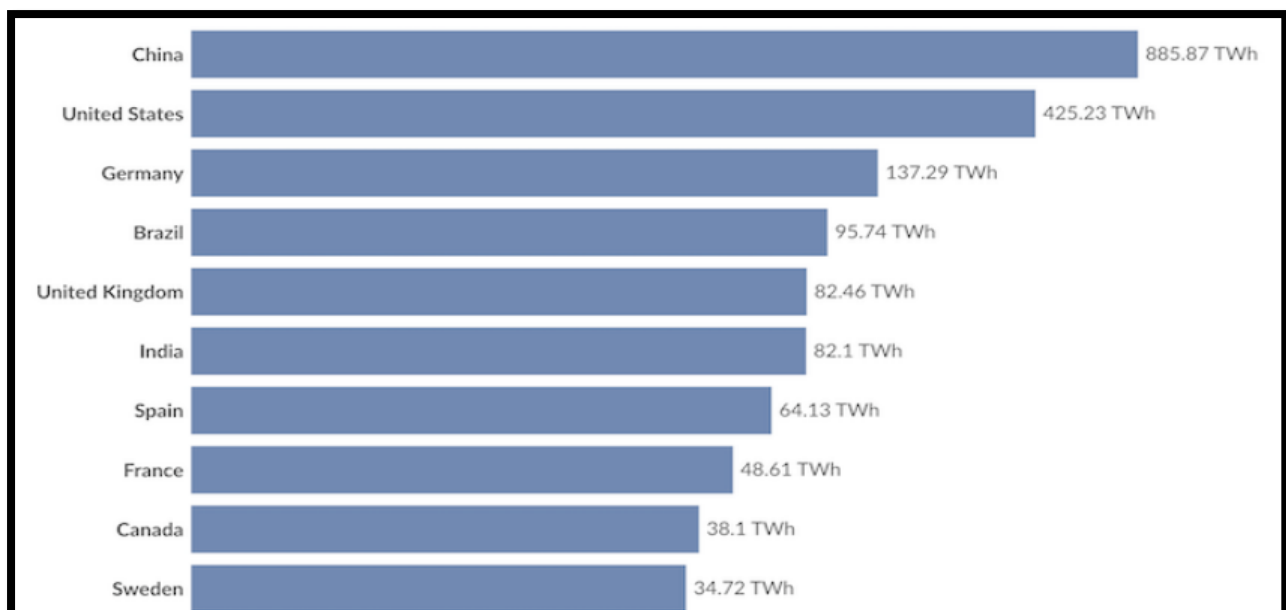


Figure 5: UK Global ranking in Wind Power usage. (Our World Data, 2024)

2.3 Solar Energy Guidance in Healthcare

According to NHS Wales Shared Services Partnership (NWSSP, 2025) then Healthcare properties are required to have a fully ventilated patient space, whether this be by natural or mechanical ventilation. This guidance requires a high demand on electricity; this is increasing annually. NWSSP abide by the Welsh Health Technical Memorandums (WHTMs) and Welsh Health Building Notes (WHBNs). The WHTMs states that alternative power should be provided to offset the increase in demand of electricity (WHTM 06-01, 2018).

The Welsh Health Building Notes and Welsh Health Technical Memorandum's provides guidance and advice on engineering and technical services to NHS Wales and their Health Boards. NHS Wales Shared Services Partnership provides guidance via the WHTMs and WHBNs to SBUHB on all technical engineering and building services. There are suitable WHTMs and WHBNs that SBUHB can adhere to for guidance on the Solar Farm, such as:

- WHBN1.1.1 (11-01) states "The following factors should be considered in order to minimise energy consumption: · use of natural lighting and ventilation, wherever feasible; · use of passive solar design, including the use of solar heating panels, the use of reflective glass and/or blinds to minimise solar gain, where appropriate, and locating heat-sensitive accommodation away from south-facing fascias".
- WHBN 00-01(61) states "General design guidance for health care buildings need to consider passive summer cooling, minimising solar gain, high thermal insulation and engineering systems should be flexible, efficient and economic in use, and in use of resources".
- WHTM 1.1.3 (00) states" Use of presence detection, appropriate local switching, photocell and multi-circuit systems to control lighting. Use of a Building Management System to provide automatic time-control switching (to shut down plant when not required)." [12] (WHTM, 2025)

According to 'Vourdoubas, (2022)' the author discusses that solar PV generation can significantly reduce the energy consumption by hospitals. On average, hospitals can consume approximately 2.5 times more energy than other buildings, the use of solar PV systems can reduce their annual electricity bills allowing them to invest more funds on

patients' care. There is an opportunity to combine with other low or zero carbon emission energy technologies, like wind turbines and co-generation systems. (Vourdoubas, 2022)

However, 'Vourdoubas,(2022)' did not state whether the research did not extend to analysing actual recorded PV generation from hospital sites and analysing any anticipated growth.

The author believes that from reviewing 'Vourdoubas, (2022)' research into renewable energies such as solar PVs, then this concept could be used to power high energy consuming plants systems such as chillers, air source heat pumps (ASHP's) plus small power and lighting throughout the hospital. By using the solar PVs then they would reduce the dependency on the electric grid and reducing costs for the health board.

Solar energy guidance can be seen in different formats such as Passive Solar Design, Renewable Energy Sources, PV Power, Solar Thermal Hot Water Systems plus other solar applications like solar chillers and hydrogen fuel cells to generate "green" electrical energy.

Passive Solar Design: Several documents emphasize the use of passive solar design to benefit from natural daylight and minimize solar gain. This includes locating areas like wards, recovery units, and offices where they can benefit from natural light, and using blinds or reflective glass to control heat gain.

Renewable Energy Sources: Healthcare projects should consider clean energy (renewable or "green" energy) from the outset, covering the energy source, technology integration, and supplier choice.

Photovoltaic (PV) Power: PV cells can be a useful supplementary energy source, particularly for smaller healthcare premises or dedicated small applications within larger ones. They generally have low maintenance costs and can save more CO₂ per installed capital cost compared to other renewable technologies.

Solar Thermal Hot Water Systems: The use of solar-thermal hot water heating panels is well-established and can make a useful contribution to pre-heating domestic hot water, even in winter.

Other Solar Applications: Examples include solar chillers, solar tube chimneys for daylight harvesting, and linking solar PV systems with hydrogen fuel cells to generate "green" electrical energy.

Sustainability and Energy Efficiency: Engineering services should use renewable energy sources where feasible, and energy consumption should be minimized through low/zero carbon solutions and energy-saving devices. (CompliMind, 2025)

2.4 Solar Farm Case Studies

To provide further support to the solar farm proposal then the author will conduct research into existing case studies of solar farms for hospitals in the UK. The first case study will review the Royal Wolverhampton NHS Trust Solar Farm, then followed by Clatterbridge Cancer Centre NHS Foundation Trust and lastly followed by Hull University Teaching Hospital to finish.

2.4.1 Case Study 1 – Royal Wolverhampton NHS Trust Solar Farm

Case Study 1 - This trust, in partnership with Wolverhampton City Council, is building a solar photovoltaic farm on a former landfill site. This 22-football-pitch-sized farm is designed to generate 6.9MWp at peak times, powering New Cross Hospital for approximately 288 days a year. This project is expected to save the trust £15-20 million over 20 years, or about £1 million annually, which will be reinvested into frontline healthcare.

More than 15,000 electricity generating solar panels are being installed at a new city solar farm to help power the whole of New Cross Hospital and save 1,450 tonnes of carbon a year.

The trust received almost £10m in funding from Salix Finance in 2021, and it received a further £33m to carry out green energy works as part of the Department of Business, Energy and Industrial Strategies Public Sector Decarbonisation Scheme (PSDS).



Figure 6: Royal Wolverhampton Trust – Solar Farm. (Carbon and Energy Fund, 2025)

2.4.2 Case Study 2 – Clatterbridge Cancer Centre NHS Foundation Trust

Case Study 2 - Clatterbridge Cancer Centre NHS Foundation Trust

This trust generates “green” electricity locally with its onsite PV solar farm.

The Clatterbridge Cancer Centre NHS Trust had £730k of funding to install solar panels at its Wirral site from the UK government investment of £200m in Great Britain Energy. Although Clatterbridge have been awarded this funding, to date the works to the solar farm have not been started, and no start has been officially announced.

The £730,000 awarded to The Clatterbridge Cancer Centre will be used to install approximately 1,000 solar panels (also known as photovoltaic panels) on the roofs of Clatterbridge Cancer Centre - Wirral, which opened in 1958 and is therefore the least energy-efficient of its three main sites.

It is estimated that the panels will produce an average of 300 MW/h of solar energy, saving around 70 tonnes of CO2 emissions each year and contributing towards the The Clatterbridge Cancer Centre's goal of delivering greener, more sustainable specialist cancer care.

The panels will also significantly reduce energy costs at Clatterbridge Cancer Centre - Wirral and the resulting savings will be reinvested into frontline services and support for patients.

Work on the panels is expected to start in Autumn 2025 and to be complete by late Spring 2026. The project will be led by The Clatterbridge Cancer Centre's estates subsidiary company.



Figure 7: Clatterbridge Cancer Centre Proposed Solar Farm. (Clatterbridge Cancer Centre, 2025)

2.4.3 Case Study 3 – Hull University Teaching Hospital

Case Study 3 - In 2022, Hull University Teaching Hospitals NHS Trust installed 11,000 solar panels on a dedicated solar farm at Castle Hill Hospital, becoming self-sufficient in daytime power during summer, saving hundreds of thousands monthly. They received a £4.2m grant from the Public Sector Decarbonisation Scheme.

Report benefits are:

- Provides daytime power for the entire hospital during the summer.
- Saves around £250,000 monthly in energy bills during the summer.
- Generates over 4.2m (kWh) annually.
- Innovate motive – The trust purchased 51 sheep to manage the grass cutting which helps reduced maintenance landscape costs and also enhances biodiversity.

The panels are now generating around 26MWh per day for May, with the expectation that this will almost double to 50MWh per day at peak Summertime. Yorkshire Bylines have stated that “At present, the solar field is generating an equivalent amount of power that is consumed daily by 3,250 average UK households.” (Yorkshire Bylines, 2025)



Figure 8: Hull University Teaching Hospital Solar Farm. (NHS England, Hull Hospital, 2022)

2.5 RETscreen Expert Energy Data

RETScreen Expert is a clean energy management software system for energy efficiency, renewable energy, and co-generation project feasibility analysis, as well as ongoing energy performance analysis.

RETScreen Expert empowers professionals and decision makers to rapidly identify, assess, and optimize the technical and financial viability of potential clean energy projects. This decision intelligence software platform also allows managers to easily measure and verify the actual performance of their facilities and helps find additional energy savings/production opportunities. (US Climate Toolkit, 2024).

By the author using RETScreen Expert then the current carbon emissions will be estimated using hospital consumption data provided by SBUHB. The greenhouse gas emissions reduction can then be forecast over the next several year period which is highlighted in Objective 3.

RETScreen Expert software uses data provided by National Aeronautics and Space Administration (NASA) on the location of the solar farm, as well as metrological conditions. RETScreen Expert uses data to calculate the anticipated energy from the solar farm annually. RETScreen Expert also counts for daily radiation, which is calculated monthly, this is demonstrated in Appendix 3.

Another advantage of RETScreen Expert software is that it conducts a payback calculation based on energy consumption by Morriston Hospital. The author will look at the actual Capital Expenditure (Capex) and Operational Expenditure (Opex) financial information based on Morriston Hospital relating to the PV solar farm.

RETScreen Expert uses a benchmark comparison tool, this allows the author to evaluate and compare the difference in the energy consumption of the hospital. The author will be actual data which has been recorded by SBUHB Energy Dept, the annual energy consumption data of Morriston Hospital to provide accurate results.

2.6 Morrison Hospital's Energy Data

The electricity used in Morrison Hospital is significantly high. There needs to be a reduction in the baseline costs and usages. The table below illustrates the electricity usage, costs and CO₂ emissions associated with the hospital. The original electricity demand of Morrison Hospital was 18,826,278 kWh. This has been reduced by 3,594,802 kWh to reflect the electrical savings from the Building Management System (BMS), a baseline for Morrison Hospital has been revised to 15,231,475 kWh. (Vital Energi, 2022).

Building	Usage		Cost		CO ₂ Emissions	
	kWh	%	£/Yr	%	TCO ₂	%
Morrison Hospital	18,826,278		£2,450,566		5,220.5	
Reduction by ECMs (provisional)	3,594,802		£467,926		996.8	
Nett Total	15,231,476		£1,982,640		4,223.7	

Table 1: Morrison Hospital's energy usage and cost 2022. (Vital Energi, 2022)

Table 2 below looks at the data from 2024 on the electricity usage in Morrison Hospital

2024 Month	Electricity Usage (KWh)
January	144,020
February	193,793
March	279,508
April	364,778
May	426,363
June	404,219
July	418,607
August	392,109
September	305,893
October	226,522
November	164,733
December	123,287
Total (kWh)	3,443,834

Table 2: Morrison Hospital Energy Production. (RETScreen, 2024)

2.6.1 Predicted Morriston Solar Farm Energy Generation 2026/27

Month	Theoretical Generation	Actual Generation	Difference	Solar Utilisation (kWh)	Export (kWh)
Apr 26	351,750	340,050	-3.33%	280,930	59,120
May 26	492,640	474,370	-3.71%	403,720	70,650
Jun 26	542,460	534,280	-1.51%	474,660	59,620
Jul 26	446,440	471,010	5.50%	436,500	34,510
Aug 26	403,440	439,930	9.04%	406,710	33,220
Sep 26	293,380	326,380	11.25%	296,820	29,560
Oct 26	206,740	266,980	29.14%	244,560	22,420
Nov 26	77,620	89,440	15.23%	89,440	-
Dec 26	41,120	51,020	24.08%	51,020	1
Jan 27	114,090	105,010	-7.96%	105,010	0.01
Feb 27	144,880	127,510	-11.99%	127,510	-
Mar 27	402,180	318,880	-20.71%	318,880	-

Table 3: Total Project Prediction Energy Generation. (Estates Dept, SBUHB, 2025)

The annual monthly consumption averages at 1,348 KWh's this is highlighted in Table 4 below. The table identifies the difference between daytime and night-time consumption; it provides the baseline to assess the impact the solar farm will have on the hospital's consumption taken from the Distribution Network Operator electrical intake supply. The table below predicts the solar development costs and energy savings from the 4MW Solar Farm based on readings for 2025 and proposed for 2026.

Table 4 below looks at the tariff rates for Morriston Hospital and what savings will be generated from the solar farm. For the use of this exercise, the author is assuming that the daily rate forecast will be 21p per KWh.

2026 Month	Anticipated PV Generation (MWh)	Daytime Consumption (KWh)	Night-time Consumption (KWh)	Morriston Hospital Total Consumption (MWh)
January	98.68	931,719.60	358,069.90	1,289.79
February	170.27	777,909.20	325,055.90	1,102.97
March	421.81	681,762	355,982.50	1,037.74
April	500.97	566,726	344,370.30	911.10
May	513.78	619,596.30	361,696.80	981.29
June	529.32	591,663.50	353,222.50	944.89
July	562.54	667,599.70	386,602.50	1,054.20
August	543.24	695,161.60	390,881.80	1,086.04
September	366.73	718,465.20	358,490.40	1,076.96
October	286.47	802,325.70	368,026.50	1,170.35
November	127.88	893,975.50	351,573.30	1,245.55
December	90.39	926,215.10	352,414.40	1,278.63

Table 4: Predicted Morriston Hospital Grid Consumption 2026. (Estates Dept, SBUHB)

The above prediction is based on data from 2025; this has been collated by the SBUHB Energy Department. Only time will tell whether these predictions come true, however the history tells us that energy consumption is increasing every year.

2.6.2 Welsh Hospital Size and Consumption 2024 Data

Welsh Health Board	Hospital Site	Gross Internal site floor area (m2)	Electricity consumption (KWh)	Gas consumption (KWh)
Betsi Cadwaladr UHB	Ysbyty Glan Clwyd	107,754	14,916,918	26,628,709
Hywel Dda LHB	Glangwilli General Hospital	51,294	7,299,812	17,127,288
Swansea Bay UHB	Morrison Hospital	99,640	8,497,667	28,507,490
Cardiff and Vale UHB	University Hospital of Wales	213,073	11,640,320	90,989,263
Cwm Taf LHB	Princess of Wales Hospital	56,743	8,010,413	14,967,824
Aneurin Bevan LHB	Royal Gwent Hospital	73,880	8,183,279	17,613,308

Table 5: Welsh Hospital Size and Consumption Data. (RETScreen, 2025)

From the solar farm there can be guaranteed energy savings that can be defined as 'avoided energy use' against an agreed set of parameters, generally for Energy Performance Contracts the baseline consists of two key parameters:

- Energy use (kWh) during the reference year against which the energy savings are achieved.
- The factors (independent variables & static factors) during the reference year which drive energy use.

Please see Appendix 4 for Morrison Hospital's Energy Consumption 2021-2023.

2.6.3 Overview of Solar Development Costs and Energy Savings

Building		Morrison Hospital
Location		Brynwhilach Farm
System Size	kWp	3,998
System Size	M ²	20,122
No of Modules		9,996
No of Inverters		20
Total Installed Cost (ex VAT)	£	£4,326,590
VE Profit (ex VAT)	%	7.5%
	£	£324,494
Total Base Cost (ex VAT)	£	£4,651,084
CCS Fees	%	0.025%
	£	£1,163
IGP Cost	£	£23,000
Total Project Cost (ex VAT)	£	£4,675,247
Annual Service Costs (ex VAT)	£	£41,170
Savings		
Electricity	kWh	£3,593,318
	%	23.6%
Grid Gas	kWh	-
	%	0.0%
Total Annual CO ² Saving	TCO	996.4
	%	10.0%
Total Annual Energy Saving	kWh	3,593,318
	%	7.7%
Energy Cost Savings	£	£487,254
Additional Financial Benefits	£	£0
Main Cost Savings	£	£0
Total Net Annual Energy Cost Saving	£	£487,254
	%	17.9%
Net Payback	Years	9.5
Salix Pers. Factor	Yrs	22.5
Lifetime Tonnes of CO ²		20,165
Lifetime £/Tonne of CO ²		£231.09

Table 6: Total Project Costs, savings and paybacks for the Solar Farm. (Estates Dept, SBUHB, 2025)

Table 6 above, confirms the location of the proposed solar farm, it states the size of the farm and the system size, how modules and inverters will be installed. The table also highlights the capital and revenue costs for the project. This will also be acknowledged in **Table 9: SBUHB Re:Fit Phase 1 Financial Summary** on Page 56. Table 9 predicts what the expected savings are from the solar farm and how long it is predicted for the payback in years.

2.7 Research Summary

The author has conducted extensive literature research into PV solar farms, and what benefits and negatives they may bring. Unfortunately, as PV solar farms are new, especially to the UK Health care then it has been challenging to find the relevant and accurate information to support the case.

The author does acknowledge that there are case studies available from other countries which could be pursued in depth. Countries with a warm climate (closer to the equator line) can be studied further and then compare their reports with each other.

At the beginning of the proposal the author set out objectives, which have been met, however further research is required to gain an accurate understanding over a long duration period.

The literature review did in value the author's research to find out what impact the solar farm has created on reducing the GHG within its community. The literature sways more to the benefits rather than the draw backs of PV solar farm's, the green impact it has and how the solar farm is reducing energy costs.

Chapter Three

3. Main Body Chapters

This chapter will discuss the methods in which the data for the primary research was obtained along with an explanation of how the secondary research (literature review) was collated.

The two principal approaches to research are through, 'quantitative' and 'qualitative' methods. The main differences between quantitative and qualitative research is *"rather like the difference between counting the shape and types of design of a sample of greenhouses as against living in them and feeling the environment."* (Naoum, 1998).

	Qualitative	Quantitative
Conceptual	Concerned with understanding human behaviour from the informant's perspective.	Concerned with discovering facts about social phenomena.
	Assumes a dynamic and negotiated reality.	Assumes a fixed and measurable reality.
Methodological	Data are collected through participant observation and interviews.	Data are collected through measuring things.
	Data are analysed by themes from descriptions by informants.	Data are analysed through numerical comparisons and statistical inferences.
	Data are reported in the language of the informant.	Data are reported through statistical analyses.
Source: Adapted from Minichiello <i>et al.</i> (1990, p.5)		

Table 7: Key differences between Qualitative and Quantitative data. (McLeod, 2017)

3.1 Chosen Research Method - Primary Data

The author will be focusing this study of PV solar farms in the Healthcare based on quantitative research. The author will investigate the energy usage by Morriston Hospital and then analyse what the production of the solar farm will generate energy and cost savings for the Heath Board.

This study will benefit from quantitative collection of data, as this data is readily available. The author will collect this data from the SBUHB Energy Department. The author will also be looking to use the computer software called RETScreen.

The energy consumption of Morriston Hospital will be collated prior to and following the installation of the PV solar farm. The author will need to review and analyse the data, taking into consideration the seasonal changes, and any additional services that may increase energy consumption. The computer software RETScreen will be used to analyse the energy consumption by Morriston Hospital.

3.2 Brynwhillach Solar Farm

SBUHB is advised to apply for funding via the Re:fit Cymru Programme Implementation programme for the proposed 4 MW solar PV farm.

Re:fit Cymru is a framework for Energy Conservation Retrofits within Public Sector buildings in Wales. It allows public bodies to include multiple buildings and saving measures within a single OJEU procured energy performance contracting framework providing energy reduction and alternative energy schemes which have scale and can be expedited within months. [28] (GEP Environmental, 2025).

The PV farm provides SBUHB the opportunity to reduce carbon emissions, achieve substantial guaranteed energy savings, and cut costs through energy efficiency and energy generation measures.

SBUHB undertook a phased programme of capital energy conservation measures with the support of the Welsh Government and Salix funding. The Welsh Government was the first parliament in the world to pass a Climate Emergency declaration and have set a target to

achieve NZC emissions by 2050 as part of its goal to decarbonise the public sector. The Wales Funding Programme requires an overall payback period of 8 years and a maximum expenditure of of £200 / tCO₂e per lifetime of CO₂ saved based on Salix persistence factors. [29] (Vital Energi, 2020).

3.2.1 Proposed Development and Site Location

The solar farm will occupy 9No fields at Brynwhilach, covering an area of approximately 29 hectares. The site is approximately 1km north of Junction 46 of the M4 Motorway, near postcode SA5 7PE

Access is gained from a minor road to the south of the site which connects to the B4489. The B4489 runs along the western boundary and un-named minor road along the southern boundary.

There are two primary substations adjoining the site, one to the northeast and the other to the southwest, with high voltage overhead lines distributing from the substations.

The proposed development comprises row of solar panels (arrays) placed in an east-west direction dictated by the need to gather maximum daylight. The low edge of the arrays will be above 800mm above ground level, and sensitive equipment will be sealed or raised appropriately above ground. Please Appendix 3 for example of solar farm setup.



Figure 9: Proposed site for the SBUHB Solar Farm. (Google Maps, 2025)

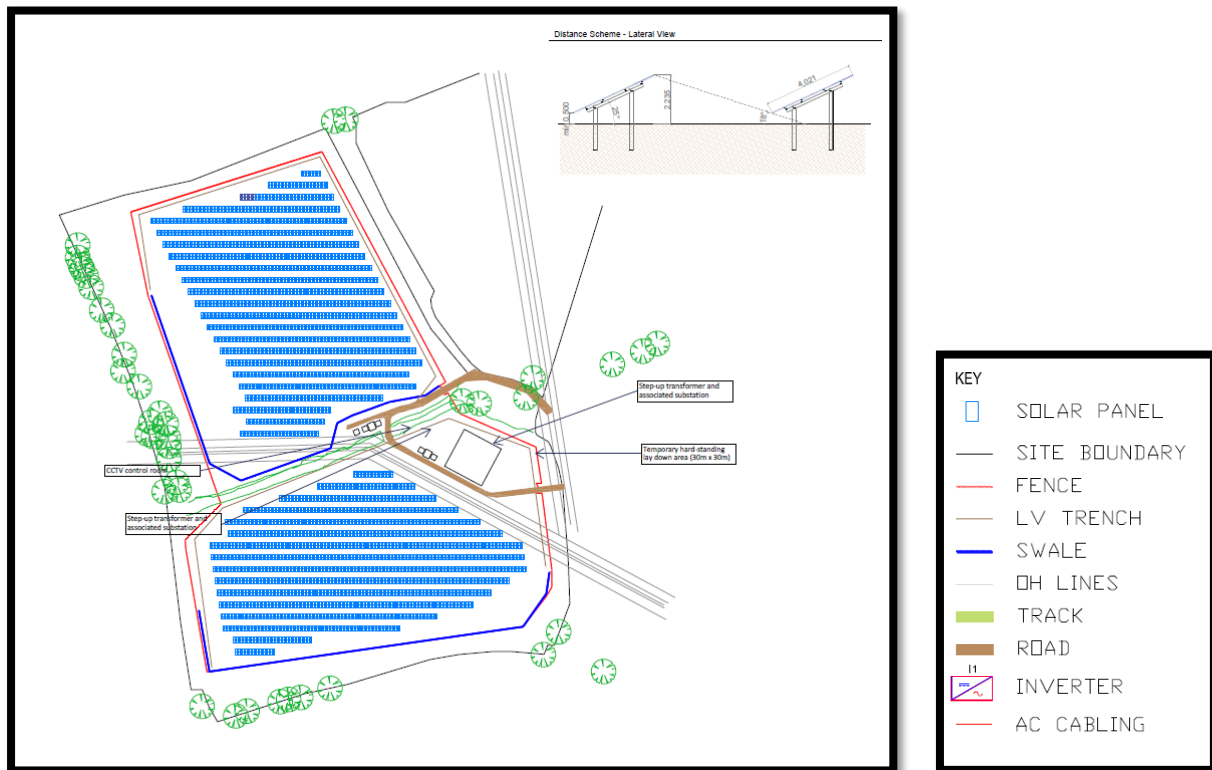


Figure 10: Proposed solar farm site layout. (Capital Planning, SBUHB, 2025)

3.3 Solar Cell Efficiency

Solar cell efficiency measures how well a solar cell converts sunlight into usable electrical energy and is a percentage of the total amount of energy from sunlight into electrical energy by the solar cell. [32] (Thorn, A (2025) Calculating the efficiency of Solar Panels, JA Building Document). There is a term called the *Shockley-Queisser* limit which equates the maximum limit for the photovoltaic cells. “According to some estimates, every hour, the Sun provides planet Earth with more energy than humankind consumes in a whole year. Part of this energy has been essential to ensure living conditions and to generate electricity by means atmospheric (aeolian). The photovoltaic PV conversion of solar radiation into electricity represents a very elegant method of power generation that causes minimum environmental disturbance.” (A.R Zanatta, 2022)

On average the maximum efficiency of top-grade solar panels is between 20-25%, especially in the UK as the weather is inconsistent. As with any technology, over time it will lose its maximum output and the efficiency will diminish through wear and tear, which could be age-related. The harsh winter months in the UK will take its toll on the best quality of

solar panels. The cold and wet weather can corrode metals, and cables and panels. The panels will need to be cleaned regularly as bird droppings can accumulate on the panels which might result in blocking sunlight which in theory could reduce the energy production.

According to “Maghami et al, 2016 then the power output delivered from a photovoltaic module highly depends on the amount of irradiance, which reaches the solar cells. Many factors determine the ideal output or optimum yield in a photovoltaic module. However, the environment is one of the contributing parameters which directly affect the photovoltaic performance.” (Magami et al, 2016)

Newly solar panels need to be cared for to prevent light-induced degradation (LID), as soon as new solar panels are exposed to intense sunlight for the first time then it is a chance that some of their silicon cells can react in a way that reduces their initial output, which in turn can cause a drop in their efficiency. A good way to prevent LID is by purchasing high quality panels which are pretreated.

Another lack of efficiency can be down to poor installation and handling, the panels will obviously need to be installed by a certified (Microgeneration Certification Scheme), highly qualified contractor. The panels will need to be installed South (West) facing, as poor placement or angling can make the panels less efficient. The panels will lose its ability to absorb the sunlight from poor instalment. Poor instalment and faulty wiring can lead to energy losses and possible system damage, poor handling can lead to damaged panels with micro-cracks, which degrade the panels performance over time or even cause cells to disconnect.

It is recommended that SBUHB purchase high-quality panels, this in theory should enhance efficiency and the lifespan of the solar panels. Installing low quality panels could be less efficient as they are built under less stricter standards which increases the chances of damage or failure.

According to “Eco Experts, 2025” “Solar panels typically degrade at an average rate about 0.5% - 0.8% per year this is according to most manufacturers’ specifications. This rate might be higher during the first year (around 2-3%) due to LID” (Eco Experts, 2025)

The diagram below is captured from the “Shockley-Queisser” theory and the conversion efficiency of silicon-based solar cells. In 1961 Walter Shockley and Hans Queisser proposed a model according to which the maximum efficiency of a solar cell is determined by both the solar spectrum and the properties of the semiconductor material. Since the Shockley-Queisser limit has experienced some major improvements and became a reference in the PV field. This goes to show that silicon and silicon-based solar cells have been around for centuries, modern technology is optimizing the potential of solar energy.

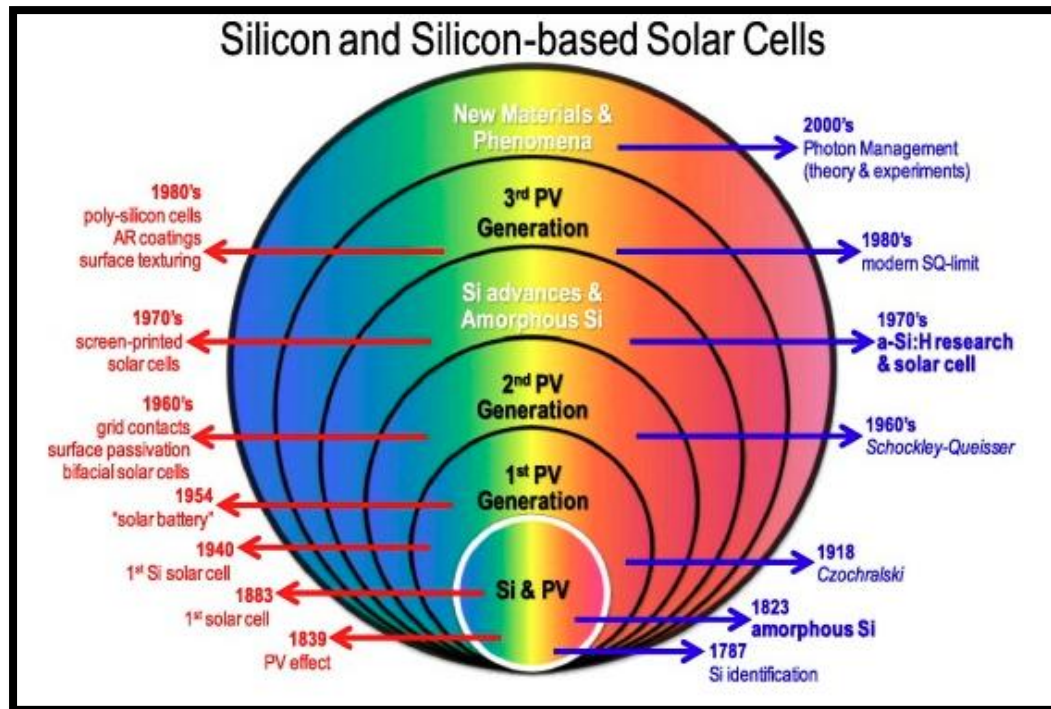


Figure 11: Silicon and Silicon-based Solar Cells Overview. (Shockley-Queisser, 2016)

Solar cell efficiency measures how well a solar cell converts sunlight into usable electrical energy and is a percentage of the total amount of energy from sunlight into electrical energy by the solar cell. At present there exists a theoretical maximum limit for the efficiency of PV cells, which is referred to as the Shockley-Queisser limit (as above), the limit stands at 33.7% for PV cells composed of ideal materials.

Please see formula in Figure 12 to determine Solar Cell Efficiency.

$\text{Efficiency } (\eta) = \frac{\text{Output electric energy per second}}{\text{Incident light energy per second}}$ $\eta = \frac{P_{max}}{P_{in}} = \frac{I_{SC} \times V_{OC} \times FF}{P_{in}}$	I_{SC} = Short circuit current V_{OC} = Open circuit voltage I_M = Maximum Current V_M = Maximum voltage generated FF = Fill factor P_{in} = Irradiance
--	--

Figure 12: Calculating the efficiency of Solar Panels, JA Building Document. (A, Thorn, 2025)

3.4 P-n Junction

A P-N junction is the boundary where an p-type material is mixed with an n-type material, the p-type material is positive material where there are fewer electrons than in a normal “neutral” state. The n-type material, negative material is opposite to P, where you add phosphorous atom to a group of silicon atoms adds one extra electron. Solar cells absorb light using the junction’s electric field to separate charge and generate power.

According to Smith 2018 “the p-n junction can drive a current, operating as a solar cell. There are two fundamental currents generated at the p-n junction, the drift current and the diffusion current, which flow in opposite directions. Under “dark” conditions i.e. when the solar cell is not in sunlight, these currents balance each other and no net current flows. (Smith, 2018)

This is important to note because a solar cell is an electronic device designed to harness energy from photons of light and convert it into electrical energy. The P-N junction has the ability to control electric current which enables the functions of DC – AC conversion.

According to [39] J Castle, 2014 “*Solar PV and wind power energies are much cheaper to source than fossil fuels and are much more attractive to invest in for energy companies on a global scale.*”

Technology year	2015	2025	2040	2050
Solar Large-scale PV (Photovoltaic)	80	44	33	41
Onshore Wind	62	46	44	–
Offshore Wind	102	57	40	51
Biomass	87	87	98	125
Nuclear PWR (Pressurized Water Reactor)	93	93	93	98
Natural gas combined cycle gas turbine	66	85	125	–
CCGT with CCS	110	85	82	79

Table 8: Forecast costs for UK power generation technologies in £/MWh. (Castle, Hendry, 2024)

From examining Table 8 above, then the author can see that large scale solar power is more cost effective and more popular in recent times in the UK. The UK is suffering from high end energy costs and consumers are more open to innovative energy providers.

The author has done extensive research in the quest to find information on renewable energies studies for hospitals in the UK, unfortunately there is little information available for solar PV systems or renewable energies. Morriston Hospital will be the first hospital in the UK to have its very own 4 MW Solar PV farm, this is shown in Appendix 1.

A study has taken place in Greece where they have installed solar PV systems on building roofs to provide energy for a hospital. According to [13] 'Vourdoubas, 2018' then "*The Solar PV energy is used for electricity generation in the hospital. Generated electricity is fed into the grid, achieving attractive feed-in tariffs.*"

According to Irena, 2022 then Solar PV is the fastest-growing renewable energy technologies and is playing an increasingly key role in the global energy transformation. The total installed capacity of solar PV reached 710 GW globally at the end of 2020. About 125 GW of new solar PV capacity was added in 202, the largest capacity addition of any renewable energy source.

Irena also states that the cost of manufacturing solar panels has decreased significantly over the past 10 years, they have become much more affordable and accessible. Irena states that the solar module prices fell by up to 93% between 2010 and 2020. (Irena, 2022).

3.5 Battery Energy Storage System

Battery storage harvests the increasing levels of renewable solar energy generated from the solar farm; the batteries can then supply the stored power back to the Grid. Solar energy is not always produced at the time energy is needed the most, being based in Swansea then energy is used most at during the winter months, so it is important to store unused energy during the summer months.

Industrial energy storage batteries have a 20-year shelf life, depending on the battery manufacturer. A battery project is not realistic without a connection to the Grid; it is vital that the Distribution Network Operator (DNO) / National Grid has a direct connection to the solar farm.

It should be noted that the use of batteries for energy storage is not economically feasible as it is expensive to procure and maintain and requires a long period of investment and commitment.

There is potential for the solar farm to generate more energy than required, the question is where this energy goes when it is not being used. By generating surplus energy then the power grid could be overloaded. [40] Palmer et al, 2017 states that *“Potentially, there could be overloads on the UK National Grid. Situations may arise where there is excess of power produced at times when it is not utilised or in places where demand is relatively low.”* The author acknowledges that the existing Distribution Network Operator electrical infrastructure is insufficient to keep up with the demand of large-scale solar farms.

According to a report by the International Renewable Energy Agency (IRENA), energy storage can increase the self-consumption of solar energy by up to 50% and significantly reduce grid reliance and curtailment of solar power.

Battery-based storage systems, particularly lithium-ion batteries, have gained significant attention due to their high energy density, efficiency, and cost effectiveness. These systems store excess solar energy in the form of chemical energy and release it as electricity when needed.

A study by Vieira et al. evaluated the performance of a lithium-ion battery energy storage system integrated with solar PV installations. The study found that the battery system improved self-consumption of solar energy from 30% to 60% and reduced the reliance on grid electricity. Roberts et al. analysed the performance of a Battery Energy Storage System (BESS) integrated with a solar PV system. The study found that the BESS increased the self-consumption of solar energy from 30% to over 70%, resulting in a significant reduction in grid electricity purchases. (Hasan, 2023).



Figure 13: Proposed Battery Storage for Brynwhillach Farm. (Estates Dept, SBUHB, 2025)

Solar photovoltaic (PV) systems combined with battery energy storage systems (BESS) are increasingly studied to address the intermittency of solar power and improve the reliability and efficiency of renewable energy integration. One key aspect is the sizing and operation of battery storage to deliver constant power output over monthly periods, which can enhance energy availability and increase PV penetration in the grid. Identifying an optimal storage size is critical, as beyond a certain "inflection zone," additional storage capacity yields diminishing returns in reducing energy unavailability. This approach supports capacity credit levels above 95%, indicating a reliable supply of constant power from PV-BESS systems.

In terms of system design, integrating batteries directly at the Direct Current (DC) link of solar inverters can improve overall system capacity and reduce power curtailment. A configuration using a single DC-DC converter that simultaneously manages battery charging and maximum power point tracking (MPPT) can enhance conversion efficiency and simplify the addition of storage to existing PV farms. This setup allows excess PV energy, which would otherwise be clipped due to inverter Alternate Current (AC) capacity limits, to be stored and later supplied to the grid during low irradiance periods. Methodologies for sizing such DC-bus connected batteries have been developed based on annual PV generation profiles to minimize energy curtailment.

For rural electrification, solar PV integrated with battery storage controlled via bidirectional DC-DC converters can manage load variations and solar insolation changes effectively. The system maintains voltage for MPPT and regulates frequency and voltage in the load network using advanced control algorithms, improving power quality and system stability under dynamic conditions.

Optimal planning of PV and battery storage with energy management systems (EMS) under different tariff schemes has been explored, showing that rule-based EMS can reduce the cost of electricity compared to net metering. Sensitivity analyses considering insolation, temperature, load, and grid constraints inform the optimal capacity of PV and battery storage for grid-connected households.

Additionally, hybrid storage frameworks combining batteries and supercapacitors have been experimentally validated to address fluctuating power in hybrid renewable systems. This hybrid approach leverages the high energy density of batteries and the high-power density of supercapacitors, potentially improving overall system efficiency, though its application in power grids is still emerging.

In summary, solar PV combined with battery storage involves considerations of optimal sizing, system configuration, control strategies, and economic planning to enhance reliability, efficiency, and cost-effectiveness in various applications from utility-scale plants to rural electrification.

In order to assist the solar PV panels, a weather station will be installed onsite to monitor the site-specific conditions and to measure against system performance. The weather station will be located on the roof of the southern LW Switchboard enclosure. The power feed for the weather station will come off the way made low voltage substation.

The recommended weather station manufacturer is Davis Instruments, Wireless Vantage Pro Plus 2 model.

PV Weather Station, Davis Instruments



Figure 14: PV Weather Station. (Davis Instruments, 2024)

3.6 Solar Panels Selection

There are 4 No major type of solar panels suitable for the solar farm:

- **Monocrystalline** – Also known as single-crystal panels, these are made from a single pure silicon crystal that is cut into several wafers. Since they are made from pure silicon, they can be readily identified by their dark black colour. The use of pure silicon also makes monocrystalline panels the most space-efficient and longest-lasting among all three solar panel types. However, this comes at a cost as a lot of silicon is wasted to produce one monocrystalline cell, sometimes reaching over 50%. There are many positives about Monocrystalline, however there are some drawbacks too, such as they are very expensive to manufacture, their efficiency can decrease slightly in extremely high temperatures – although this wouldn't be an issue for the Morriston location.
- **Polycrystalline** – come from different come from different silicon crystals instead of one. The silicon fragments are melted and poured into a square mold. This makes polycrystalline cells much more affordable since there is hardly any wastage and gives them that characteristic square shape. However, this also makes them less efficient in terms of energy conversion and space, since their silicon purity and construction are lower than monocrystalline panels. They also have lower heat tolerance, which means they are less efficient in high-temperature environments. Similar to Monocrystalline, Polycrystalline have negative impacts such as they can be less efficient than monocrystalline as you need more panels for the same power, they don't perform as well in low-light conditions so this will be not suitable for Morriston.
- **Passivated Emitter and Rear Cell (PERC)** – Are an improvement of the traditional monocrystalline cell. This relatively new technology adds a passivation layer in the rear surface of the cell that enhances efficiency. It reflects light back into the cell, increasing the amount of solar radiation that gets absorbed. PERC reduces the natural tendency of electrons to recombine and inhibit the flow of electrons in the system. PERC allows greater wavelengths of light to be reflected. Light waves over 1,180nm can't be absorbed by silicon wafers and simply pass through, so they end up heating the cell's metal back sheet and reduce its efficiency. The passivation layer reflects these higher wavelengths and stops them from heating up the back sheet. They can suffer from degradation such as LID (Light-induced Degradation) and PID (Potential-induced Degradation).

- **Thin-film** – Are characterised by very fine layers that are thin enough to be flexible. Each panel does not require a frame backing, making them lighter and easier to install. Unlike crystalline silicon panels that come in standardized sizes of 60, 72, and 96-cell counts. However, they are less efficient than typical silicon solar panels. Thin-film solar panels convert sunlight to electricity less effectively, due to their lower efficiency then they take up more space. They typically have a shorter lifespan of 15-20 years whereas Monocrystalline, Polycrystalline and PERC are typically 25-30 years. (Aurora, 2025)

3.6.1 Chosen Solar Panels

It would be advisory for SBUHB to go with the Passivated Emitter and Rear Cell (PERC) solar panels. PERC technology is used to improve the efficiency of solar cells by capturing as many extra photons as possible without fundamentally changing how a solar cell works. *“In ordinary crystalline silicon solar cells, electricity is produced when photons hit a layer of silicon, knocking electrons loose and then directed to flow along a wire.”* (Solar Reviews, 2025)

PERC technology is an excellent improvement that allows solar cells to achieve higher efficiencies. PERC PV's can be used on residential, commercial, and industrial applications. PERC technology can be used for ground PV power stations, which can be combined with bifacial technology and Building Integrated Photovoltaics (BIPV). Please see PERC solar module images on Page 37.

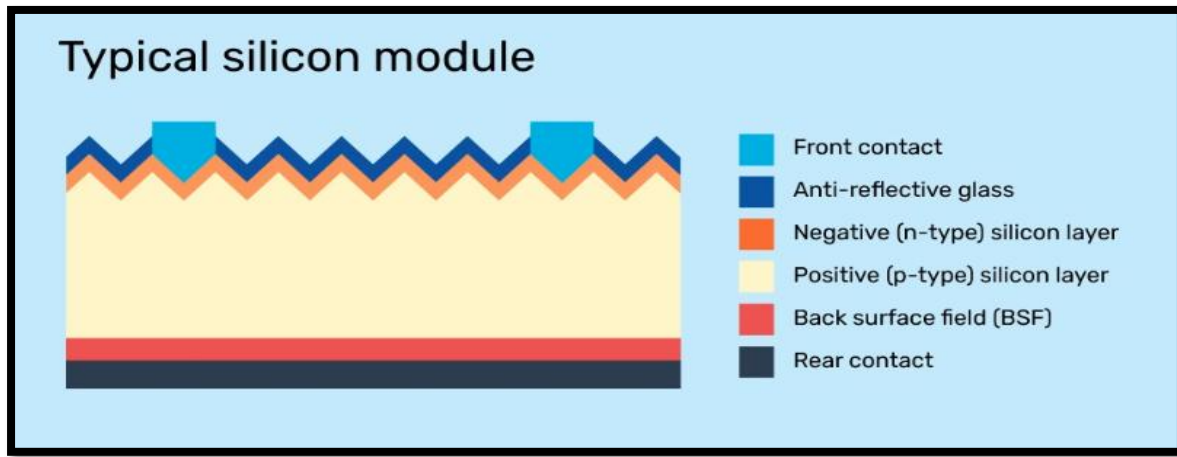
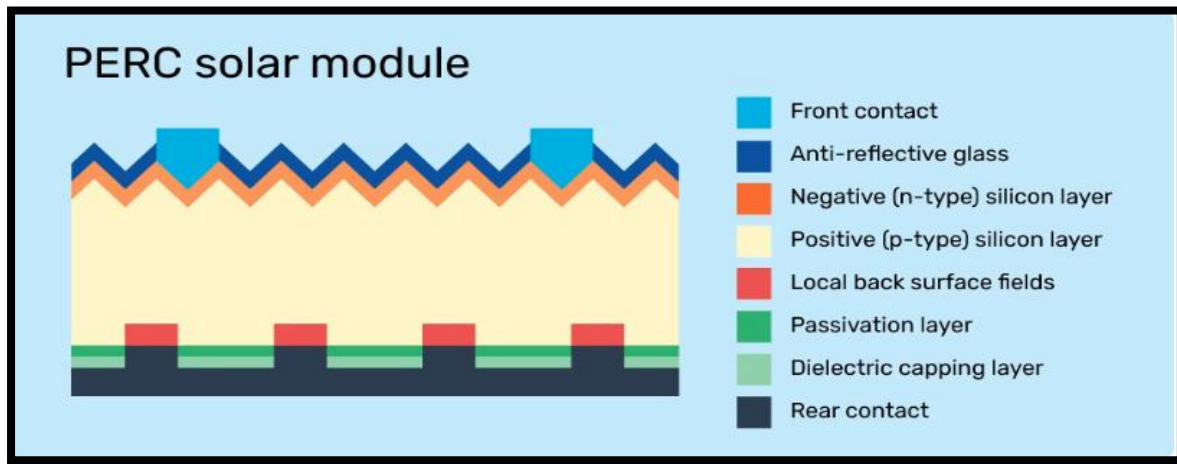


Figure 15 & 16: Typical PERC solar module compared to a typical silicon module. (Solar Reviews, 2025)

To make a PERC solar cell, a manufacturer takes standard monocrystalline silicon cells and adds a passivation layer to the back that is designed to reflect photons back through the silicon layer. The cells are then micro-etched with chemicals or a laser to cut through the passivation layer so that the back contacts can reach it. A dielectric capping layer is added over the passivation layer to insulate the solar cell. PERC cell technology makes it so that more photons are captured by the silicon, meaning each cell makes a little more electrically than it would without the PERC layers. The maximum efficiency of PERC cells is about 23% compared to 21% for traditional monocrystalline silicon cells. [45] (Solar Reviews, 2025)

Advantages of PERC

- Up to 1% more efficiency than traditional c-Si solar panels.
- Reduced heating absorption, allowing PV systems to perform better at high temperatures.
- Operation on a wider light spectrum.
- Better usage of the available space.
- Cost-effective technology.
- Prices for PERC solar panels will get reduced as the technology becomes more popular.
- PERC solar cells can be combined with IBC or Bifacial technology.

Disadvantages of PERC

- Relatively larger cost than traditional technologies.
- Light-Induced Degradation (LID) and Potential-Induced Degradation (PID) were a problem in the past for the technology.

There are large variety of brands on the market such as Canadian Solar, Jinko Solar, Q Cells and REC solar to name but a few, however the Jinko Cheetah HC 72M 390–410-Watt mono perc half-cell module appears to be the leading PV. These solar panels have a positive power tolerance of 0~+3%. Their unique features are:

- Higher module conversion efficiency (up to 20.38%) benefit from half-cell structure (low resistance characteristics).
- Excellent Anti-PID performance guarantee limited power degradation for mass production.
- 5 Busbar Solar Cell adopts new technology to improve the efficiency of modules, they offer a better aesthetic appearance, making it perfect for rooftop installation.
- Advanced glass and cell surface textured design ensure excellent performance in low-light environment.
- Certified to withstand wind load (2400 Pascal) and snow load (5400 Pascal).
- High salt mist and ammonia resistance certified by TUV NORD.
- The Jinko solar panels offers a 12-year product warranty and a 25-year linear power warranty. (Jinkosolar.com, 2025)

Please Appendix 1 for Jinko Solar Panels specification and schematic design.

3.6.2 Description of Operation – Control System

In order to control the output of the solar farm then the contractor will need to install their own Energy Control System (ECS) package which performs the SCADA role across the site. This system is responsible for monitoring the hard-wired states and communicated values at the HV switchboard and across each of the two solar fields. The ECS continually monitors the two main incomer transducers and provides a demand to each of the Huawei Smart Loggers controlling the solar inverters, in line with the site export agreement, external constraints and active network management from WPD. Plant data is displayed on the graphics package, remotely accessible via VNC viewer or a secure webpage.

3.6.3 Network Overview

SBUHB will need to provide a dedicated Asymmetric Digital Subscriber Line (ADSL) broadband line for connection to the solar farm. A dedicated router and switch provide a static external IP address to allow secure remote access. A fibre converter allows communication across the physical site via the stand-alone fibre to the communication panel in the LV switch room. In the communications panel fibre converter is connected to a Cisco Meraki switch which separates the connection onto two VLANs, allowing segregation of the ECS controller communication from that of the Modbus, CCTV and Huawei equipment. Separate screened Cat 5 cables connect these two VLANs to individual network switches in the ECS panel for onward communication across the site via a combination of Ethernet and single-mode fibre. Please see diagram below.

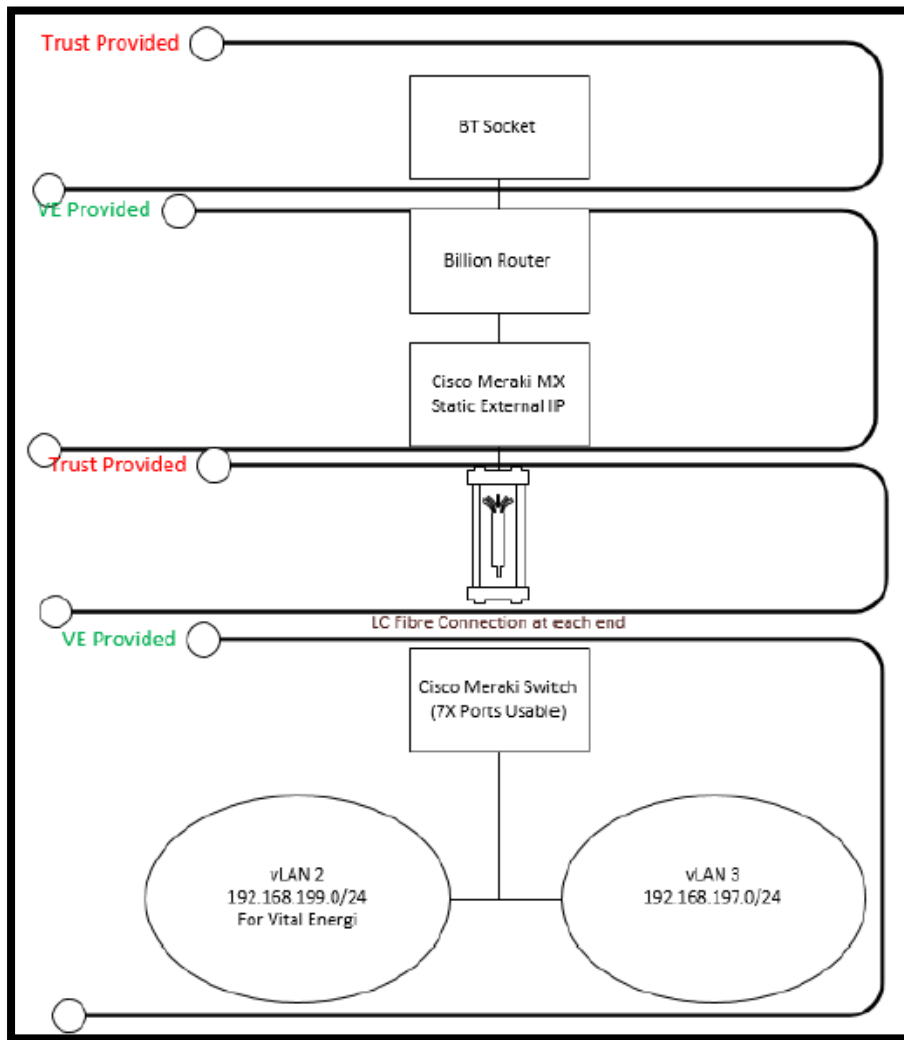


Figure 17: Typical Energi Network Overview. (Vital Energi, 2024)

3.6.4 System Architecture

The ECS has a distributed architecture across three panels. The main panel will be located in the Health Board's LV switch room, the network connections to the local communications cabinet and I/O and Modbus connections through the wall into the adjacent HV switch room. Under the main panel is a separate enclosure housing the graphics/report server and UPS giving protection to the server and panel supplies.

The main panel controller should have hard-wired connections to the constraint panel. The Modbus module connects across the segregated networks to take data from the transducers, P341 relay and solar farm generated meters. By communicating across the networks, the Modbus module takes data from the Huawei Smart Loggers in the two

remote panels and sends a value for the active energy demand to each Smart Logger so that they can modulate the output of the inverters.

The two remote panels are located in the GRP enclosures in the solar field. Each panel has a bank of distributed I/O to allow the ECS to monitor the states of the LV switchboard, transformer, fire alarm and the outside air temperature, as well as giving a VFC output to enable the Smart Logger control. The south RMU also has an output to trip the RMU. Each remote panel has unmanaged switch for each VLAN, communicating back to the main panel, as the diagram below illustrates.

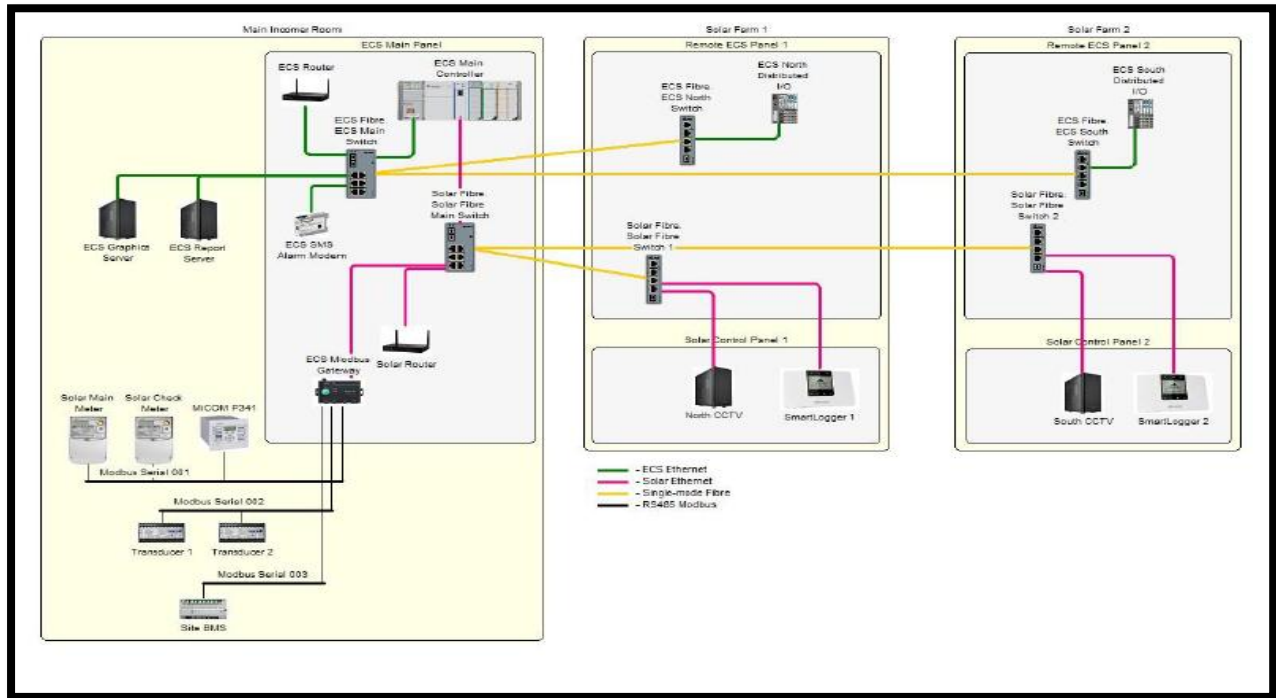


Figure 18: Typical Energi Network Illustration [48] (Vital Energi, 2024)

3.6.5 Control Description

The ECS controller monitors the two transducers in the HV panel and calculates the site total import and export values around a margin set to account for fluctuation in the site demand. The lower value of the site export licence and the TANM reduction is taken and demand to the solar fields will be reduced to keep the site export this value. In the event of a constraint panel stage 1 enable being registered, confirmation of receipt will be transmitted to the constraint panel via a VFC.

3.7 Solar Inverters

Solar PV panels generate DC electric power, SBUHB will need to convert this DC power to AC power, to do this then they need to install inverters. There are losses that occurring during the DC to AC process. There are various types of inverters available such as String Inverters, Microinverter, Hybrid Inverters, Optimised Inverters & Optimisers and Inverter Monitoring. Inverters convert DC (direct current) electricity generated by wind turbines, photovoltaic modules or stored in batteries into 230V 50Hz AC (alternating current) power required to run conventional appliances and for connection to the grid.

3.7.1 String Inverters

These convert the DC power from PV panels directly into AC power to be fed into the grid. String inverters wire the PV panels together in a string to obtain the required DC input voltage. Storage batteries are not used, as any power produced that is not consumed by the owner's electrical loads is fed into the grid to be used elsewhere. (Wind & Sun, Powering the Future, 2025)



Figure 19: Array of String Inverters. (Greentech Renewables, 2025)

3.7.2 Microinverters

Microinverters offer clear advantages in solar setups with shading and complex layouts. Converting power at the panel level ensures consistent performance, even when one panel underperforms. However, the higher upfront cost, complex installation, and risk of “clipping” make them best suited for specific conditions. (Energy Sage, 2025)

Microinverters has the potential to generate more electricity than using string inverters, they are ideal for generating electricity in low light and don't always need to be south facing. A microinverter is attached to each solar panel within the system, allowing for the independent conversion of each panel's output locally.

The UK hasn't got the sunny climate that the Mediterranean countries offer, however the microinverter are essentially mini-solar systems, then they can generate electricity with low voltage (typical 22 volts), whereas string inverters requires at least 200 volts to even begin energy generation.

3.7.3 Inverter Recommendation

It is recommended that the solar farm of this size and magnitude to go with the string inverters. There are many manufacturers who supply inverters, but for this exercise then the appropriate manufacturer is Huawei, and the model is SUN2000-185KTL-H1 which is a Smart String Inverter.



Figure 20: Huawei SUN2000-185KTL-H1 Smart String Inverter. (Huawei Solar, 2025)

Benefits:

- 9 MPP Trackers
- 99% Max. Efficiency
- String-level Management
- Smart I-V Curve Diagnosis Supported
- MBUS Supported
- Fuse Free Design
- Surge Arresters for DC & AC
- IP66 Protection

More benefits can be seen in Appendix – 1.0 for Technical Specifications

A Solar PV inverter monitoring system will be installed with inverter to monitor and maintain performance. It is recommended that a Fusion Solar Utility Smart PV solution is connected in tandem with the Smart 1000V Logger, this will continually optimise the system for generation and performance. Please see figure 23 for Fusion Solar Smart PV Solution.

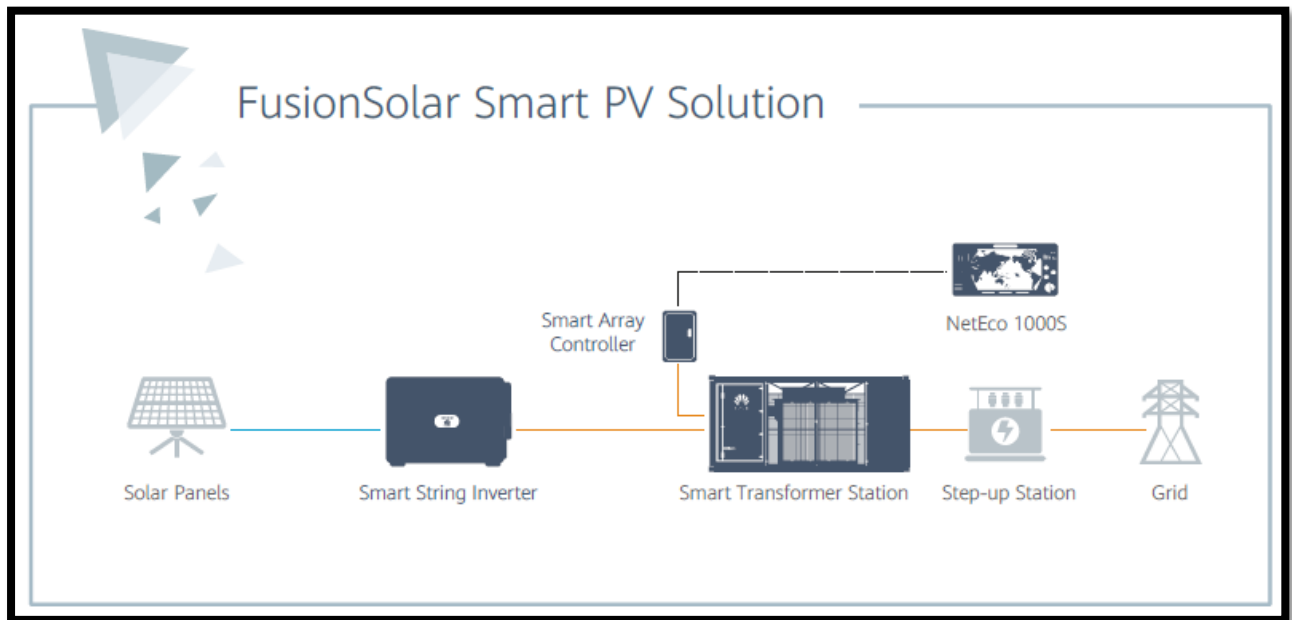


Figure 21: Fusion Solar Smart PV Solution. (Huawei Smart PV Solution, 2025)



Figure 22: Huawei Smart Logger 1000 [54]. (Huawei Smart Logger, 2025)

The SmartPID2000 Module Logger is installed in the Smart ACU2000B cabinet to reduce the negative effect of the Potential Induced Degradation (PID), and support 1000V DC system. Please see Figure 25 SmartPID2000 Solution Diagram to gain an understanding of the schematics.

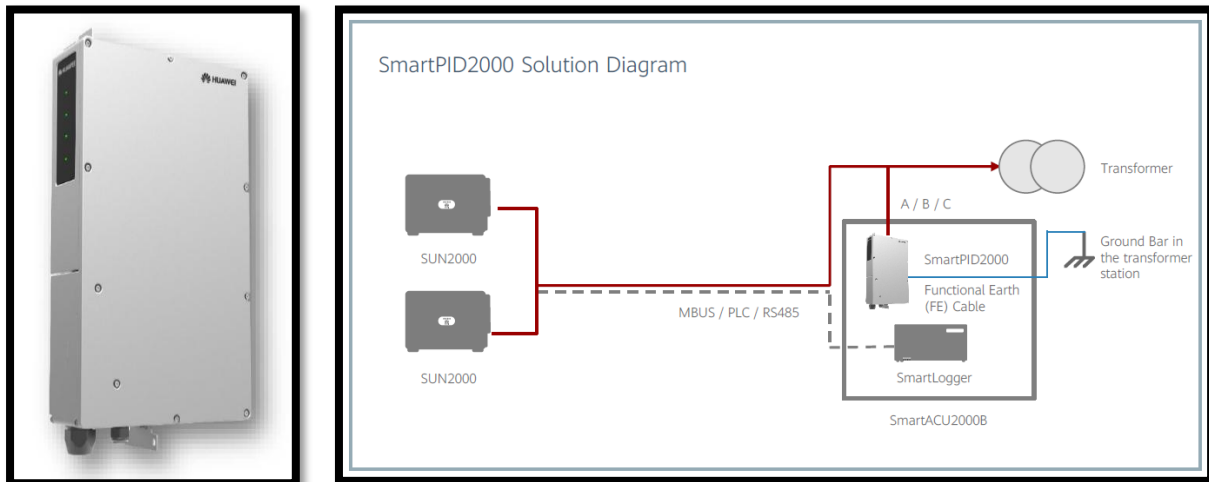


Figure 23: Huawei SmartPID2000 Solution Diagram. (Huawei Smart PID Module, 2025)

The Network and Smart I-V Curve Diagnosis is able to carry out online I-V curve analysis on entire strings with advanced diagnosis algorithm. The scanning would help to find out and identify the strings with low performance or malfunction, which would help to achieve proactive maintenance, higher O&M efficiency and lower operation cost. The Smart inverter will send fault messages directly to the operatives' Smart phone via the App or by text message with a full diagnosis.

Please see figure 26 for a breakdown in the Network Structure and the Smart I-V Curve Diagnosis.

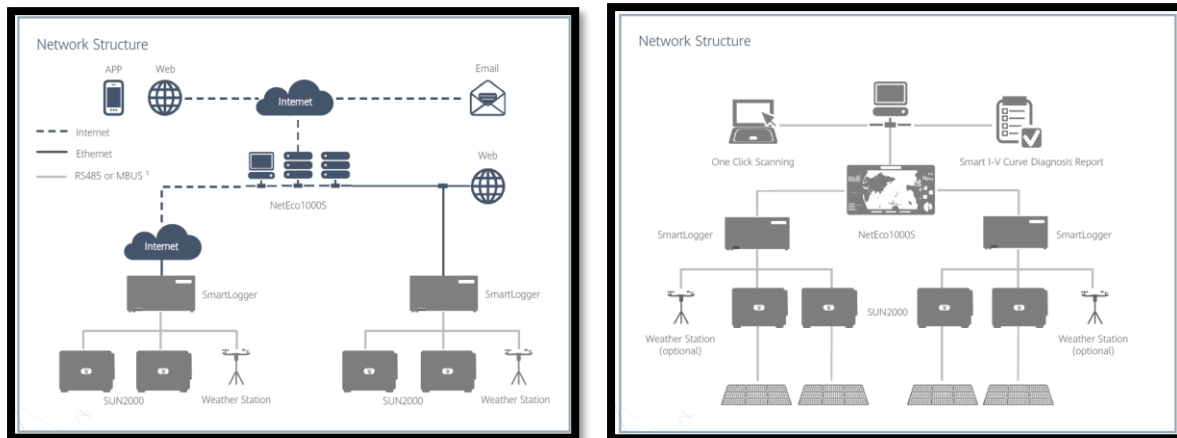


Figure 24: Fusion Solar Smart PV Solution. (Huawei Fusion Solar Solution, 2025)

3.7.4 Recommended Inverter Layout

The illustration below demonstrates how the string inverters would be positioned and installed in the solar farm. The AC system operates at an approximate line voltage of 800V, and the DC system operates at voltages up to 1100V.

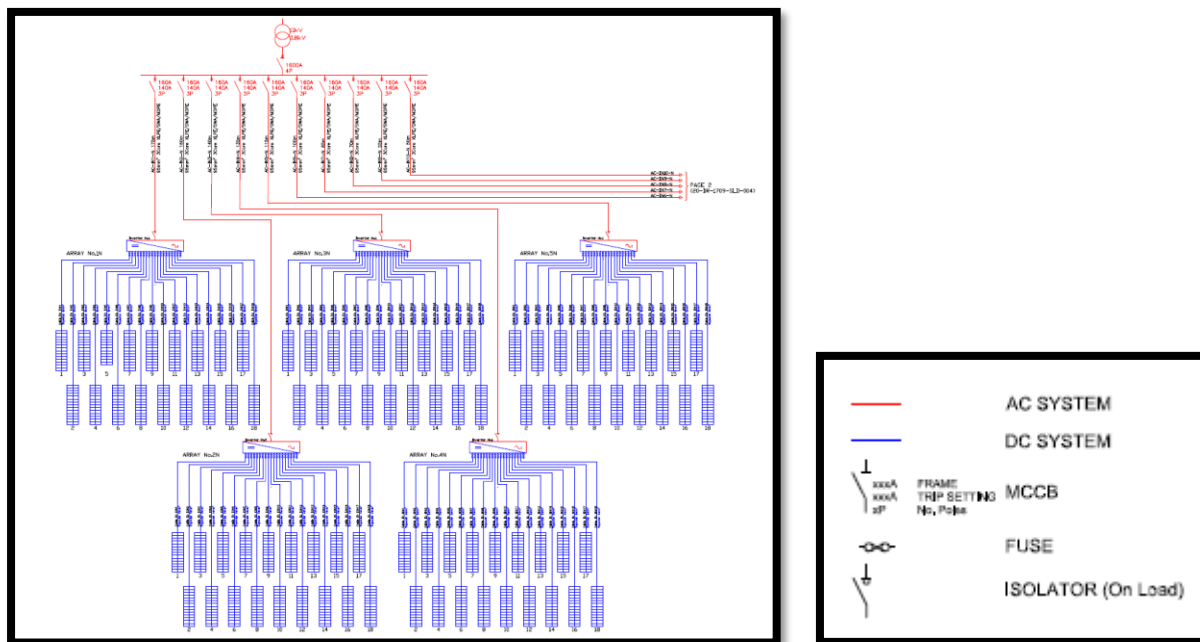


Figure 25: Solar Farm Inverter String Arrangement layout. (Capital Planning, SBUHB, 2025)

The illustration below demonstrates the inverter weatherproof cabinet

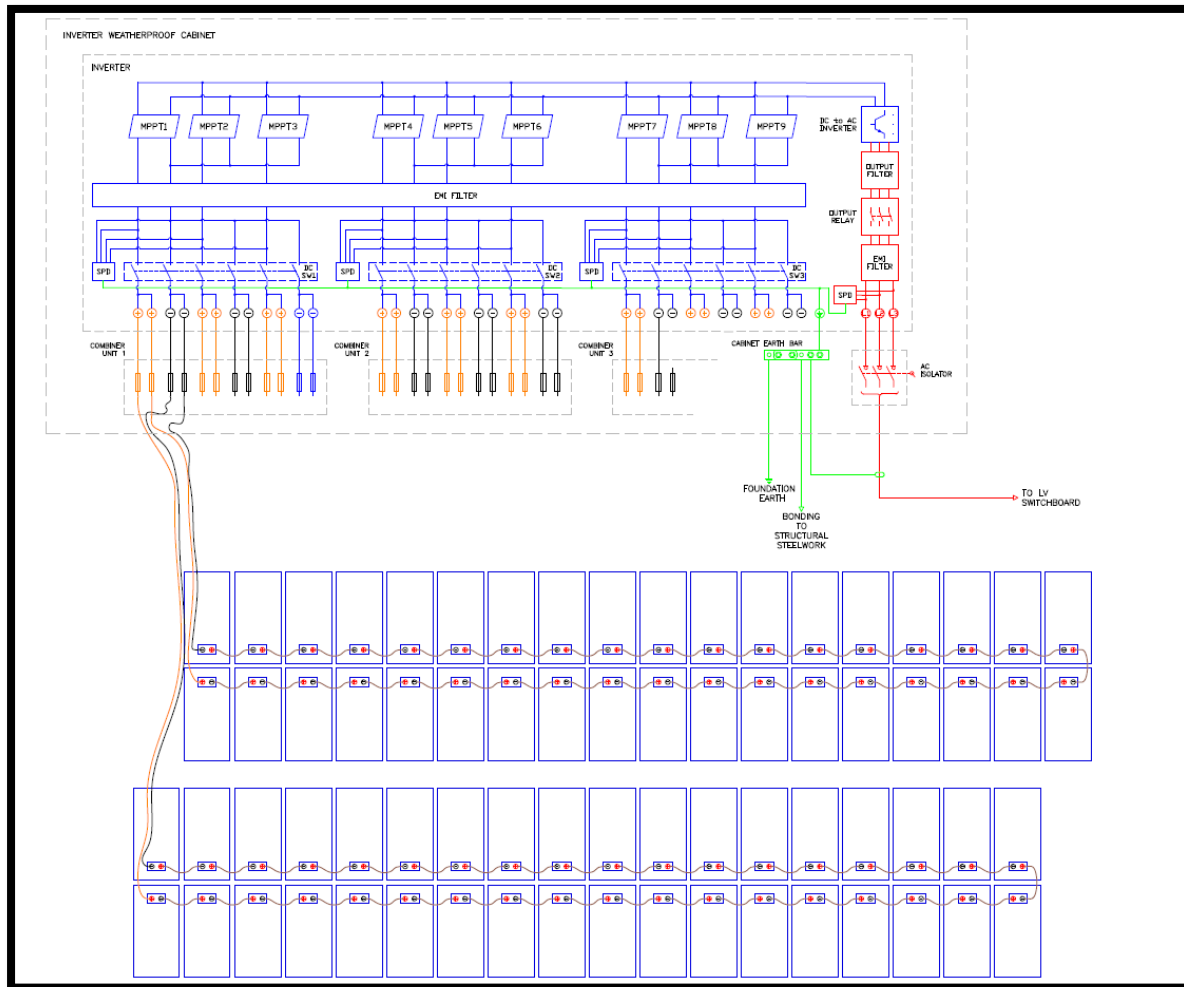


Figure 26: Inverter Weatherproof Cabinet schematic layout. (Estates Dept, SBUHB, 2025)

3.8 Solar Irradiance Test

A solar irradiance test would need to be conducted for solar panels, as it measures the intensity of sunlight (solar energy per unit area, in Watts per square meter) having direct contact on the panel which then determines the strength and power output. This can be assessed by practising with solar powered tools like pyranometers or irradiance meters, crucial for site assessment, and ensuring panels meet specifications and performance measures, especially as the sunlight will be variant.

Solar irradiance is the output of light energy that is received from the Sun and measured on Earth, and therefore it is the amount of light energy that reaches the Earth.

Solar irradiance is measured in the form of electromagnetic radiation per unit area and in the wavelength range of the measuring instrument being used, this is usually measured in watts per square metre. (TIS,2025)

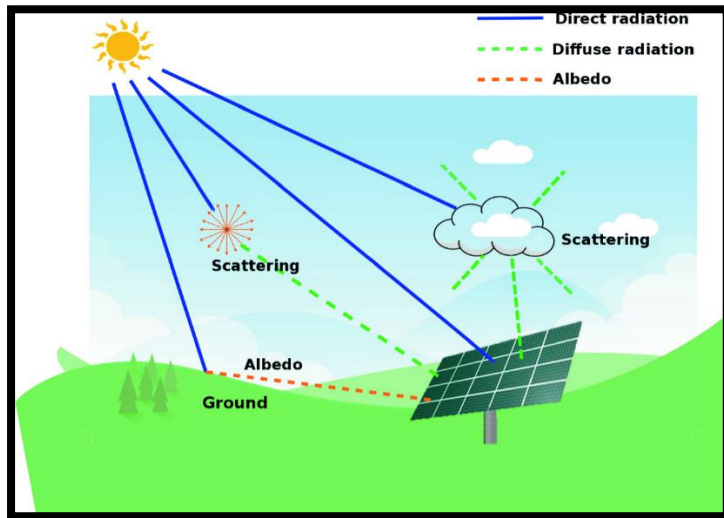


Figure 27: Solar Irradiance. (Solar Spectre, 2020)

Solar Irradiance (W/m^2) measures the solar panel performance of electrical output (volts, amps, watts) by collecting data which optimises system design and predict energy yield.

It is important to consider the Standard Test Conditions of the panels that are rated at 1000 W/m^2 irradiance. The temperature, air pollution and the sun's angle (air mass) and the low irradiance testing which assess performance under low-light conditions.

Guiheneuf (2017) states that “with the growth of on-grid PV systems, identifying degradation mechanisms and their impact on the PV system performances have become expandingly crucial. To secure a long warranty period (25 years or more), research in reliability and lifetime of PV modules is becoming growingly important and the feedback from consumers are essential to the deployment of PV energy.” (Guiheneuf, 2017)

This is important to note as the UV exposure from the solar irradiance test highlights the power of natural sunlight, and how much of an impact it has for photovoltaic energy. The author advises SBUHB to carry out a solar irradiance test to predict the effectiveness of the solar farm. The table below shows what a solar irradiance test looks like.

The formula in Table 9 below shows a typical Solar Irradiance test, this information is predicted for 2026 but was based on data from 2024 by SBUHB Estates Dept.

Date	Test Day	Hours >300W/m ²	Σ Solar Irradiance (kWh/m ²)	E _{ideal} (kWh)	E _{real} (kWh)
01/02/2026	1	8	1.47	5,912	5,147
02/02/2026	2	2	1.33	5,345	5,308
03/02/2026	3	1	0.84	3,374	2,904
04/02/2026	4	18	2.74	11,000	10,476
05/02/2026	5	2	0.93	3,726	3,612
06/02/2026	6	2	1.16	4,656	3,991
07/02/2026	7	0	0.52	2,098	1,935
08/02/2026	8	0	0.82	3,278	3,056
09/02/2026	9	0	0.69	2,782	2,617
10/02/2026	10	21	3.07	12,330	12,554
			Σ	54,504	51,600
				PR _{STC}	95%

Solar Farm Nominal Power (kWp)	4,014.36
--------------------------------	----------

$$PR_{STC} = \frac{\sum E_{Real}}{\sum E_{Ideal}} \times 100\%$$

$$E_{Ideal} = \frac{H_{DAY}}{1000 \text{ W/m}^2} \times P_{STC}$$

Table 9: Predicted typical layout of a PAC Test – Solar Irradiance Test

3.9 Cabling Details

Due to the proposed location of the solar farm and the distance it is from Morriston Hospital then a trench will need to be excavated. The red line in the image below demonstrates the length of cable and the geographic location where it travels through. The image on Page 50 illustrates the red line for cable route.

Proposed cable route from solar farm to Morriston Hospital.

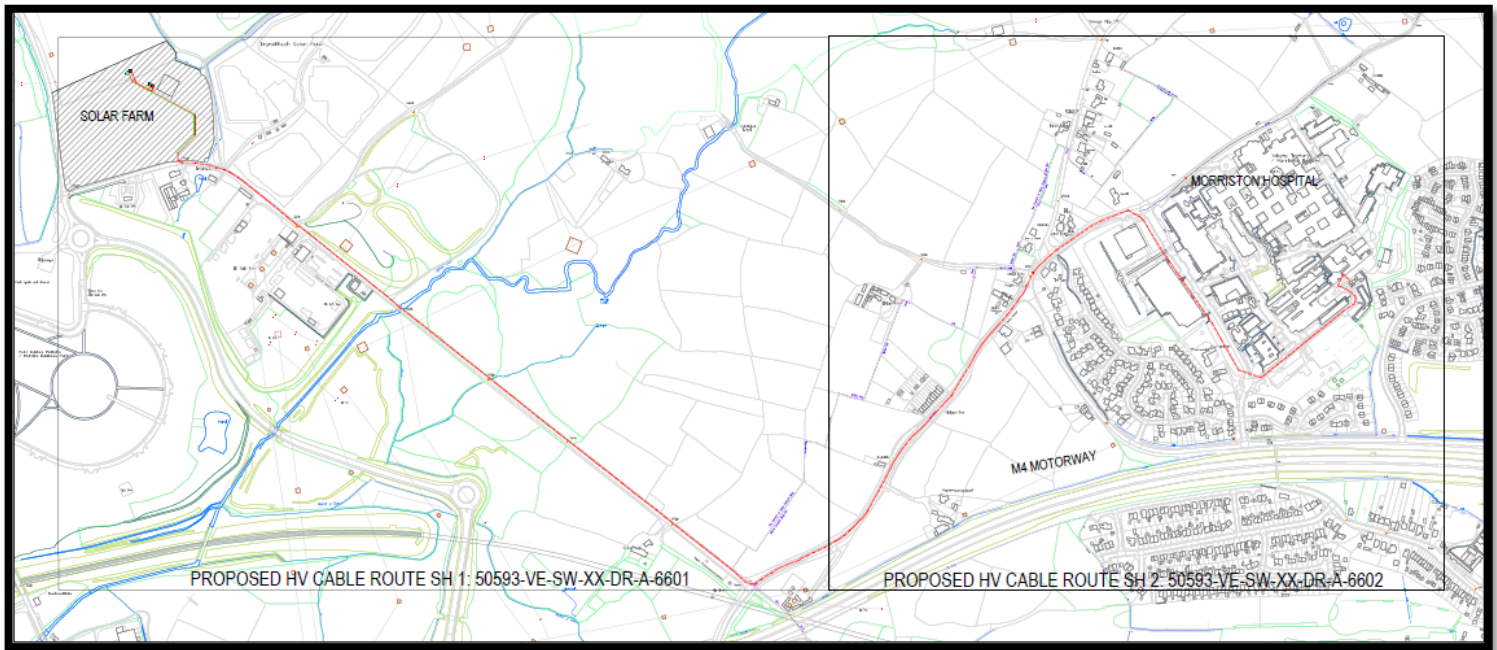


Figure 28: Proposed cable route from the Solar Farm to Morriston Hospital

It is recommended that a single trench with a width of 0.66m and a depth of 0.985 with 100mm diameter communication duct and 160mm diameter HV cable duct will be laid in parallel.

The total length of the required cable trench route from the solar farm to the electrical substation in Morriston Hospital is 2.9km, of which a 1.26km in private road / verge from the solar farm, and a 1km in public highway along Pantlasau Road and Mynydd Gelli Wastad Road and then 0.65km on Morriston Hospital private grounds. Please see image below for the proposed trench section.

Proposed trench section

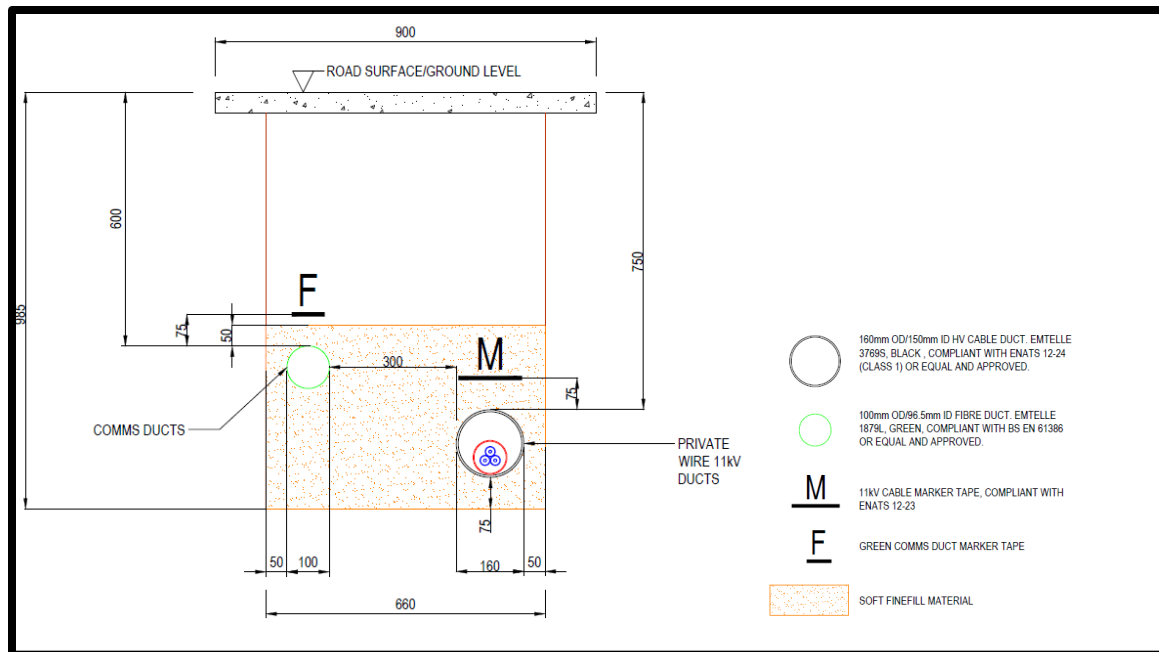
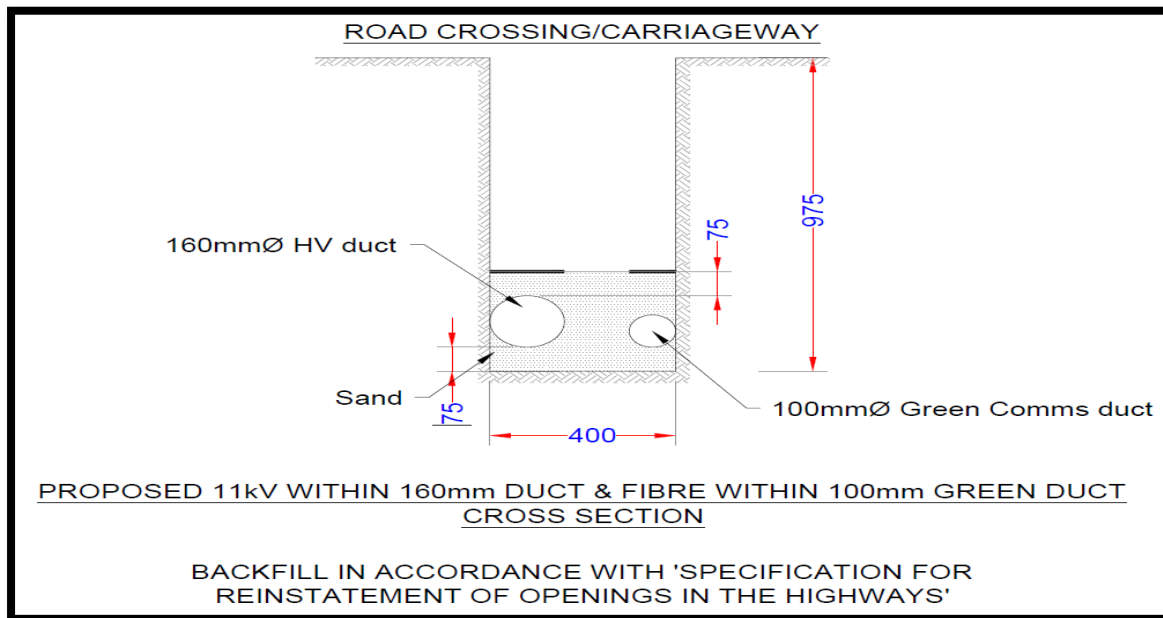


Figure 29: Proposed Trench Section for Road Crossing. (Smith Brothers, 2021)

The trench and cable route will require a planning permission from Swansea City Council, in the application will need to include a SUDs (Sustainable Urban Drainage) application plus surveys i.e. ecological and arboriculture. These surveys will look at local wildlife / birds / amphibians and reptiles, and tree protection order.

It is also important to consider the grounds on which the solar farm will be placed; a topographical and ground investigation survey will need to be carried out. This will be able to detect the make-up of the ground, and propose an invasive weed management plan, such as Japanese knotweed & Himalayan Balsam. These types of invasive weeds are listed on Schedule 9 of the Wildlife & Countryside Act 1981. Japanese knotweed and Himalayan Balsam are not easy plants to control as the extensive underground rhizome system sustains the plant even when the top growth is removed.

3.9.1 Power Shortage in Cabling

There are concerns over the length of cabling used to carry the power from the solar farm to the electrical substation in Morriston Hospital. Due to the extraordinary length of 2.9km cabling then there is a strong possibility that there could be a voltage drop. This happens as the electric current flows through this resistance, some electric is converted into heat and lost, which results in reducing the voltage at the receiving end. To overcome these issues then it is advised that the design engineers to increase the wire gauge, such as increasing the cable thickness. They could use higher quality materials such as high-quality copper wire, as this is more secure, clean connections and prevent additional resistance at terminals. By doing this, then it should reduce performance risk, any safety hazards and energy waste. The electrical design engineers will design to the British Standards 7671.

3.10 Collection of Data

The author is fortunate enough to be employed by SBUHB and has direct access to the Energy Department and energy data. The author will obtain energy data from the Morriston Hospital from January 2021 - December 2024. This includes electrical energy consumption of the Hospital from half hourly (HH) metered data.

By collecting the data on the excel spreadsheets then the author will be able to compare the anticipated generation against the actual generation to ascertain the accuracy of RETScreen Expert.

The author will also collect information from reviewing literature, researching into existing studies on PV solar farms throughout the UK and globally. Key data information will be obtained from Welsh Government and SBUHB.

3.11 Data Reliability

The reliability of the data that the author is aiming to gather will be a key attribute to the primary research. It is important that the data collected is dependable, this is to ensure that the stated results in the Results and Analysis section of this research can be checked against actual data recordings.

3.12 Ethical Considerations

Ethical research is 'to do things the right way,' it is vital that the author is expected to bring integrity, fairness, and honesty to the research. To take into the considerations of the people this research is aimed at and to take in the considerations of whom participated in gaining the research. Consent and confidentiality are always adhered to.

The ethical considerations about the solar farm would be to consider the land it will be built on, what measures will be put in place to protect the habitant wildlife and agriculture. If the farmland was being used for actual farming and what is the consequences of stopping the farming for the solar farm. In this instance, the farmland is unused and unoccupied, however it doesn't belong to SBUHB so they will have to lease the land which can be very costly. This will need to be considered to see if the return from the solar farm is financially rewarding.

3.13 Cost Considerations

The cost implications to research this topic is low compared to other research which might be based on overseas projects. The topic of this dissertation is based on Morriston Hospital, all the information which is collated can be either collected locally or via electronically means. The author will delve into the costs of the proposed project in the next chapter.

Chapter Four

4. Discussion of Findings

This chapter will concentrate on what findings were discovered and discussed of the potential data which will be collected throughout the study. To do this, an in-depth analysis of the key areas of the primary research will be outlined and discussed individually.

4.1 Findings

The author will set out to achieve the aim and objectives of the proposal, if for certain reasons that the objectives are not achieved then the author will need to state why.

The author predicts that by conducting an analytical review of how effective the solar farm has been for Morriston Hospital then it will demonstrate the difference prior and post completion.

The study will look at the revenue generated by the solar farm and determine the length of time it will take for SBUHB to payback the funding from Welsh Government. The study will also investigate the impact the solar farm has created on reducing GHG emissions to date, this will be predicted by the RETScreen Expert software.

The author is predicting that the use of the RETScreen Expert software then it will be possible to model the anticipated PV generation of the 4 MW solar farm at Morriston Hospital. The table below illustrates the anticipated monthly generation from the solar farm.

Month	Daily Solar Radiation (KWh/m ² /d)	Electricity rate (£/KWh)	RETscreen calculated Electricity Generation (KWh)
January	1.42	0.21	144,020
February	2.13	0.21	193,793
March	2.8	0.21	279,508
April	3.82	0.21	364,778
May	4.38	0.21	426,363
June	4.33	0.21	404,219
July	4.38	0.21	418,607
August	4.11	0.21	392,109
September	3.28	0.21	305,893
October	2.31	0.21	226,522
November	1.71	0.21	164,733
December	1.22	0.21	123,287
Total		Total	3,443,834

Table 10: RETScreen Expert predicted energy generation (RETScreen Expert, 2025)

Table 10 shows an estimated annual energy generation of 3,443,834 KWh annually from the solar farm. This information was extracted from the SBUHB Energy Department database. This is based on the average daily radiation per month and the weather data collated from RETscreen Expert. The author will be reviewing their database and analysing the comparison or difference in previous years of energy consumption.

	Daytime Tariff Cost (per KWh)	Daytime Generation (MWH)	Cost Saving from generation	Cost Saving from CCL at 0.775p per KWh	Total Cost Saving
Jan-26-Mar 26	6.629	690.76	£45,790.48	£5,353.39	£51,143.87
Apr 26-Oct 26	5.304	3016.58	£159,999.40	£23,378.50	£183,377.90
Oct 26-Mar 27	7.101	1091.49	£77,506.70	£8,459.05	£85,965.75
Apr 27-Oct 27	8.142	2667.06	£217,152.03	£20,669.72	£237,821.74
Oct 27 – Mar 28	21.8085	861.13	£187,799.54	£6,673.76	£194,473.29
Apr 28 – Oct 28	21.8085	2667.06	£581,645.78	£20,669.72	£602,315.50
Oct 28 – Mar 29	21.8085	861.13	£187,799.54	£6,673.76	£194,473.29

Table 11: Predicted savings generated from the solar farm (RETScreen, 2025)

Table 11 looks at the payback calculation for the Capex and Opex of the solar farm. Part of this data information is part accurate and assumption.

			Year 1	Year 2	Year 3-10
	Cost	Annual Charge	FY 2026/27	FY 2027/28	2028- 2036
Capital Cost	£5,763.980				
Revenue					
Land Costs (Lease)		£31,447	£31,447	£31,447	£251,576
Operations and Maintenance		£49,404	£49,404	£49,404	£395,232
Utility Saving			-£269,343	-£432,295	-£6,374,310
Revenue Saving			-£188,492	-£351,444	-£5,727,502
Total Saving at 10 years	£6,267,438				
Payback Period	9.5 years				
Annual Savings after 10 years	-£715,938				

Table 12: Predicted Capex / Opex payback calculation (Capital Planning, SBUHB 2024)

The author has predicted a payback rate of 21.8p per KWh, the payback calculation is based on table 4. The predicted capital expenditure for the solar farm is £5,763,980 this will include professional designer / PM fees.

4.2 Results Summary

The proposed solar farm will generate a prediction of 4,090,000 KWh of electricity if which 3,593,318 KWh will displace on-site electricity consumption. The difference between these two figures includes private wire losses and aligning of generation profile with hospital consumption profile.

It is predicted that the solar farm project will deliver annual cost savings of £487,254 or 17.9% of Morriston Hospital baseline costs. The total predicted project cost is £4,660,097 (Exc VAT) and has a payback period of 9.5 years. The project will also deliver CO₂ savings of 996.4 tonnes per year this is based on Salix persistence factors; this equates to 10% of Morriston Hospitals energy related carbon emissions. Annual CO₂ savings come from the project kWh saving x BEIS conversion factors for electricity. The payback is based on the Total Project Value and Net Savings. The Salix Persistence Factors are key metrics to assess the long-term carbon savings of public sector energy efficiency projects, helping to ensure that the project meets financial and carbon reduction targets. Table 4 shows the costs and savings plus services fees. The payback period of 9.5 years has been calculated using the annual savings, nett of the annual Operation and Maintenance costs. The M&V costs are included within the capital sum.

The Phase 1 proposal predicts:

- Project Capex - £4,660,097
- Annual Service Fees - £41,170
- Net Annual Savings - £446,084
- Payback – 9.5 years
- Average Cost per Tonne of CO₂ over lifetime - £231 this is calculated as Project Cost / Annual CO₂ saved x Salix Preference Factor for Solar PV)

Table 13 contains the high-level commercial summary for the works included within the solar farm proposal. This information was extracted from the Vital Energi proposal pack.

Item	Value	Units
Guaranteed Annual Energy Savings against Baseline	3,593,318	kWh per annum
Energy Savings over project lifetime (Salix PF)	72,720,695	kWh
Guaranteed Annual Energy Saving against Baseline	7.7%	%
Cost of Guaranteed Energy of Baseline	£487,254	£ per annum
Maximum Project Capital Sum (Capex ex VAT)	£4,660,097	£
Maximum Project Capital Sum (Opex ex VAT)	£41,170	£/Year
Simple Payback (excluding Opex)	9.5	Years
CO ₂ Saving against Baseline	996.4	Tonnes Per Annum
CO ₂ Saving	10%	% against Baseline
CO ₂ Cumulative Savings over project lifetime (Salix PF)	22,101	Tonnes
Total Measurement & Verification Costs (ex VAT), one off cost included in Capex	£21,455	£
Total IGP Costs (ex VAT), included in Capex	£23,000	£
Average Cost per Tonne of CO ₂ over lifetime	231.09	£/Tonne of CO ₂

Table 13: Commercial summary of the solar farm (SBUHB, 2025)

Table 14: SBUHB Re:Fit Phase 1 Financial Summary

SBUHB – Phase 1 Solar Farm PV Installation Financial Summary					
Year ending 31 st March	Previous Years	2026	2027	2036	10 Year Total
Re:fit Works		£4,660,097			£4,660,097
Enabling Costs		£38,081			£38,081
Project Management & Supervision		£69,337			£69,337
Rolled-up Development Cost		£59,446			£59,446
VAT on Costs	£0	£937,019			£937,019
Total Capital Cost		£5,731,380			£5,731,380
Welsh Government Funding		£5,763,980			£5,763,980
Net Capital Cost / (Benefit)	£32,600	£32,600			
Revenue					
Anticipated Savings on Utilities Cost			£487,254	£487,254	£4,872,540
Value of Exported Electricity			£14,900	£14,900	£149,005
Land Charge			£25,447	£25,447	£254,470
Land Maintenance Charge			£5,000	£5,000	£50,000
Operation & Maintenance of Solar Farm by Private Contractor			£41,170		
Net VAT on Revenue Costs			£91,197		
Repayment of Welsh Government Funding Programme Grant			£576,378	£576,378	£5,763,980
Net Revenue Cost / (Benefit)			£54,664	£54,664	£546,637
Payback Assessment			Annual Saving (inc VAT) Payback		£521,734

Table 14: SBUHB Re:Fit Phase 1 Financial Summary. (Estates Energy Dept, 2025)

Key items in **Green** are incomings / savings and **blue** are outgoings.

The table above proposes what the financial outcome will be for the solar farm, the table highlights how much it initially costs SBUHB to install the solar farm, what the enabling costs are i.e. feasibility and design, surveys and planning applications. There are costs associated with project management, SBUHB will have a design team to deliver the project which will include senior management. The table draws attention to the funding from Welsh Government and what the repay structure is.

The figures highlighted in red demonstrates what savings and benefits the Health Board can expect from the solar farm. It shows what the anticipated savings can be on the utility's costs. Due to the nature of the environmental project then SBUHB can expect to receive a return on Net VAT for Revenue Costs. The table does also show's what the Operation and Maintenance costs for the solar panels. It is important to note that the solar panels will require cleaning and care during their life span. The grounds need to be always maintained and accessible. The infrastructure of cabling needs to be considered, to make sure that the power is fully functional throughout the year.

The software RETscreen Expert can further be used to generate anticipated Greenhouse gas (GHG) emission savings of the renewable energy project. As a result of inputting the existing hospital electricity data and the solar farm project information, the baseline case is estimated to be 1,918 tCO₂. The GHG emissions of the proposed case following the installation of the 4 MW solar farm is expected to be approximately 290 tCO₂ which is a significant saving of 1,629 tCO₂ or 84.9%. Please see Figure 32 below.

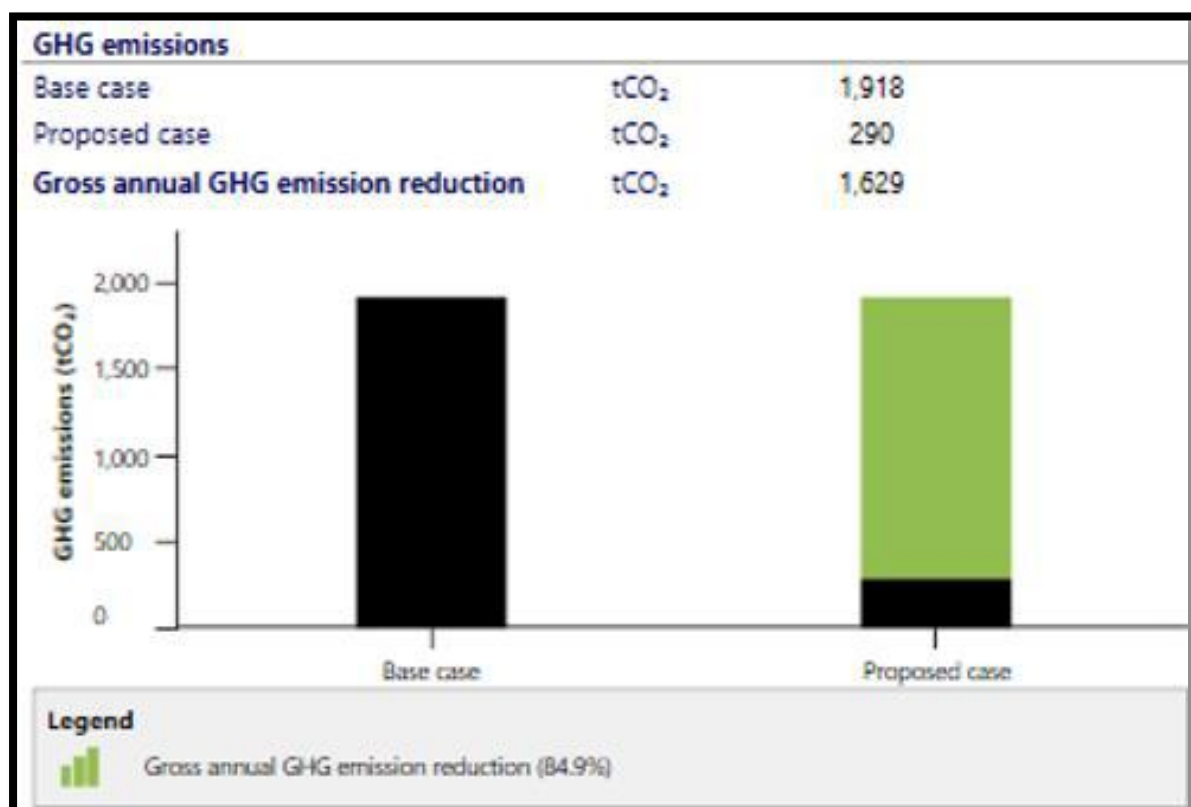


Figure 30: RETscreen Expert anticipated GHG emission saving. (RETscreen Expert 2025)

This project needs to consider the ever-increasing energy tariff costs and that they will differ over the next few years. The payback on the solar farm can be predicted but will not be accurate until closer to the time of recording the data. Energy tariffs have doubled in recent years and who can tell if the costs will reduce in time.

According to WHTM 06-01, 2018 states that the electrical demand in the healthcare sector is typically growing at a rate of between 3% and 6% every year. Looking back at recorded data then Morriston Hospital had an annual electricity consumption of 16,181.32 MWh's in 2022, 17,392 MWh's in 2023, and 17,592 MWh's in 2024. This calculates to an increase by 7.48% between 2022 and 2023, and a 1.14% increase between the years 2023 and 2024. Due to the increasing working hours of services in the hospital then this is expected to increase over the next several years.

Chapter Five

5. Time Plan

A Gantt chart was set out for this project proposal to outline when the author aims for each milestone / activity to be achieved. This is demonstrated in Figure 31.

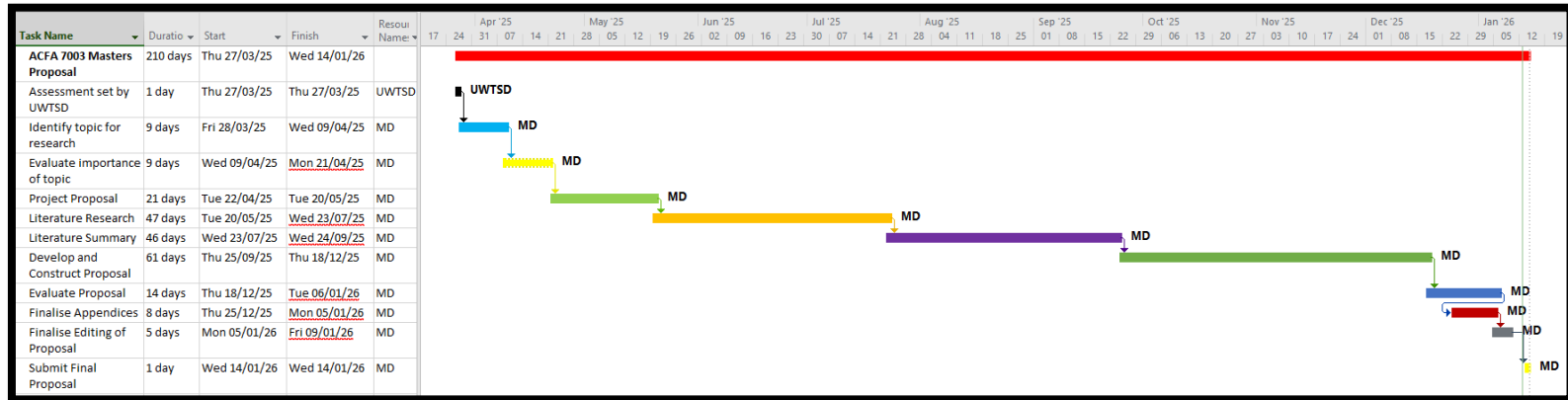


Figure 31: Initial Gantt Chart for Project Proposal

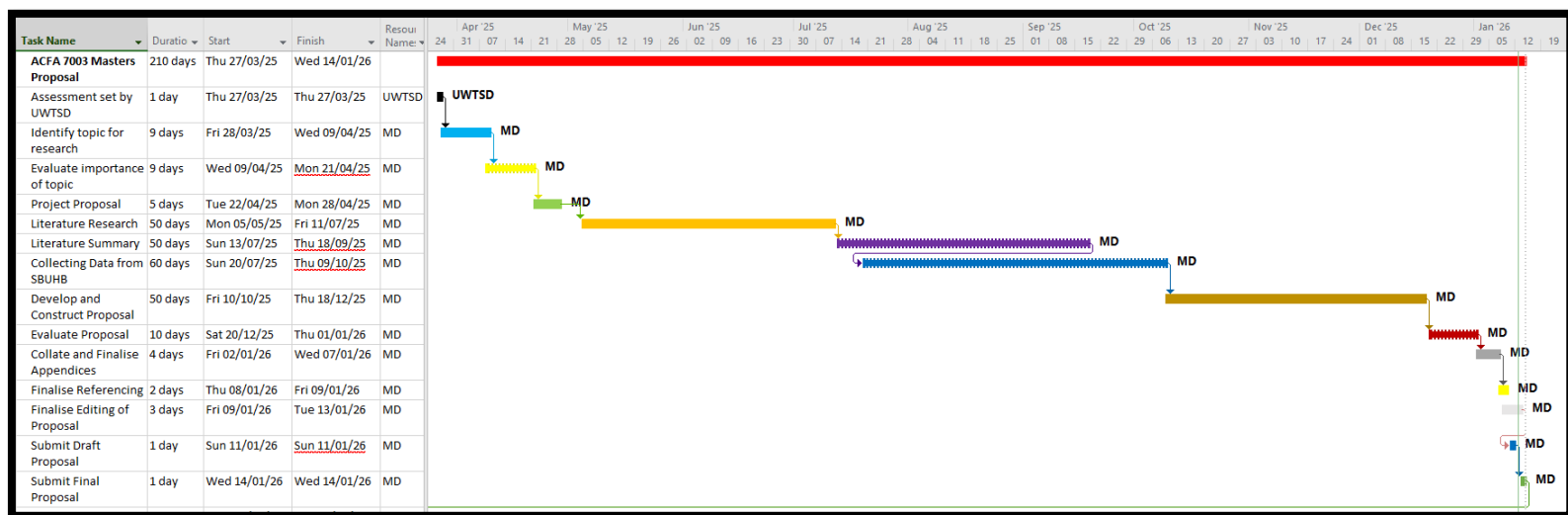


Figure 32: Revised Gantt Chart for Project Proposal

The author discover that the milestones set out in Figure 31 were not robust enough. The author should have made greater allowances for each milestone as the level of research exceeded the initial timescale. Figure 32 illustrates additional milestones and demonstrates a true reflection of when each milestone was achieved.

Chapter Six

6. Conclusion

To conclude, the author has investigated and conducted in-depth research for the PV solar farm proposal. The author acknowledges that prior to this proposal then he had minimum knowledge of the photovoltaics, however the author feels that this project proposal will have positive impact and benefit for SBUHB and Local Government.

The author did research other renewable technologies such as wind turbines, ground and air source heat pumps, however through intensive research then PV panels are apparent to offer the most potential for energy saving and efficiency. The author's aim was to gain an advance understanding of PV panels and solar panels, for this to be achieved then extensive research was conducted through literature papers, articles, journals, and accredited websites.

It is apparent that the UK does not have the resources that other countries who are situated in sunnier climates and longer daylight conditions have, so in terms of expertise and knowledge the UK is currently behind these countries.

The SBUHB 4MW solar farm will be the first in Wales and the UK of this size, it will provide accurate data for other NHS Health Boards and Trusts to follow. The author's aim to propose a solution for SBUHB to achieve a Net Zero Carbon status by 2030 can't be achieved in full due to the timescales, however if the proposal does go ahead and when accurate data which is recorded on a yearly basis then as 2030 approaches then the Health Board will be in a strong position to predict their target.

The author has enjoyed putting this proposal together, the studying and researching of international solar farms has been an informative one. The researched solar farms have been based on industrial usage and not hospitals, as there are very few solar farms used within the NHS sites.

The author has developed a good sense of how the 4MW solar farm will perform as well as providing an estimate for potential payback. The author used the RETScreen software to provide the GHG emission reduction as part of the modelled solar farm. The software

was influential in the productiveness of this research, as it provides clear and non-bias information. The author advises other Health Boards to use the RETScreen software if they are to pursue the idea of installing a solar farm on their sites.

By conducting the research into the solar farm then it is evident that battery storage is essential, this is necessary as the storage provides an outlet for the excess energy generated by the solar farm. The battery means that excess power generated during daylight hours can be stored and then used by the hospital after sunset.

The battery storage will be stored for the times when Morriston Hospital will need it the most. It is ironic that the solar farm will generate high volumes of electricity in the spring / summer months but will not need it until the winter months, and during those seasons then generate the least electricity.

The 4 MW solar farm has the potential to be the first of its kind in the UK to directly power a hospital, it has the potential to power a third of the hospital's power and could save high volumes of the SBUHB energy budget over the years to come, without failing to mention the potential payback to the national grid.

The author found the dissertation to be time absorbing and difficult to reach milestone, this was down to a busy work and family life. Finding the time to carry out the dissertation and work around family life to be challenging and stressful. However, the incentive of completing the dissertation and submitting a valuable proposal was valuable.

Overall, the solar farm proposal is an exciting project which will provide clean energy, job creation, financial savings, and energy reduction for SBUHB. It does require heavy investment from the Welsh Government, but the term investment should be emphasised and embraced. The solar farm has the potential to highlight SBUHB's commitment, drive, ingenuity, and creativity to reduce carbon emissions. The proposed land of Brynwhillach Farm is unused and has not been farmed for 10+ years, by installing the 4 MW solar farm at this site then it is putting the land back into use, provides shelter for habitation and enhances the ecological environment.

6.1 Limitations of Study

The author will need to conduct further investigations into the energy consumption of SBUHB, this would be recommended to be done over the next few years. By doing so, the reader will be able to gain a better understanding of the 4 MW solar farm performance.

As this project is a proposal then there is only so many predictions to be made, and as much as they aim to be accurate then only time will tell on how well the solar farm has performed. It is predicted that the revenue generated from the solar farm to assist the payback from Welsh Government be less than the 9.5 years expected at the feasibility stage, following more research than it is expected to be less than 8 years payback.

The author acknowledges that the initial time plan for the proposal was not strictly adhered to, the literature review required more time than first given. There were limitations to the access of energy data from SBUHB. The Estates and Energy Dept are constantly under pressure with the running of Morriston Hospital, so there was delay in receiving information, the author should have allocated more time in requesting information.

There were other limitations to the study which challenges the research such as the accuracy of the data obtained by SBUHB. It would be fair to comment that the data needs to be analysed daily to get a true record. AS SBUHB is the first and only Healthcare to have a 4 MW solar farm then it is difficult to compare them to any other healthcare organisation.

Chapter Seven

7. Recommendations

The recommendations from this proposal will be to review more case studies and follow up on how various solar farms around the world are operating. For this proposal then the author studied the RETScreen Expert software and concluded that it will benefit the proposal significantly, the software will provide data on the hospitals energy consumption plus also targets the GHG emissions reduction from the solar farm.

Another benefit of the study would be to investigate whether it is possible to install a solar farm for another hospital site which belongs to SBUHB, to investigate what geographical factors / restraints need to be taken into consideration. SBUHB have 3 major healthcare premises these are Morriston Hospital, Singleton Hospital and Neath Port Talbot Hospital (NPTH), although NPTH is a Private Finance Initiative site where SBUHB does not have ownership until the PFI contract expires in 2030. Unfortunately, both Singleton Hospital and NPTH does not have the land or space to install a solar farm nearby.

The author studied the use of battery storage and whether it is worthwhile for the Health Board to invest in large battery storages units. The proposed solar farm will be recommended to have its own dedicated battery storage unit but there could be a case to install more over time, especially if the solar farm is a success and generates large amounts of excessive energy.

For future research, SBUHB should compare and share their findings / information / statistics with the Welsh / UK Government, which will be the case. It will be interesting to see if Welsh Government is in more of an advance position than its counterparts.

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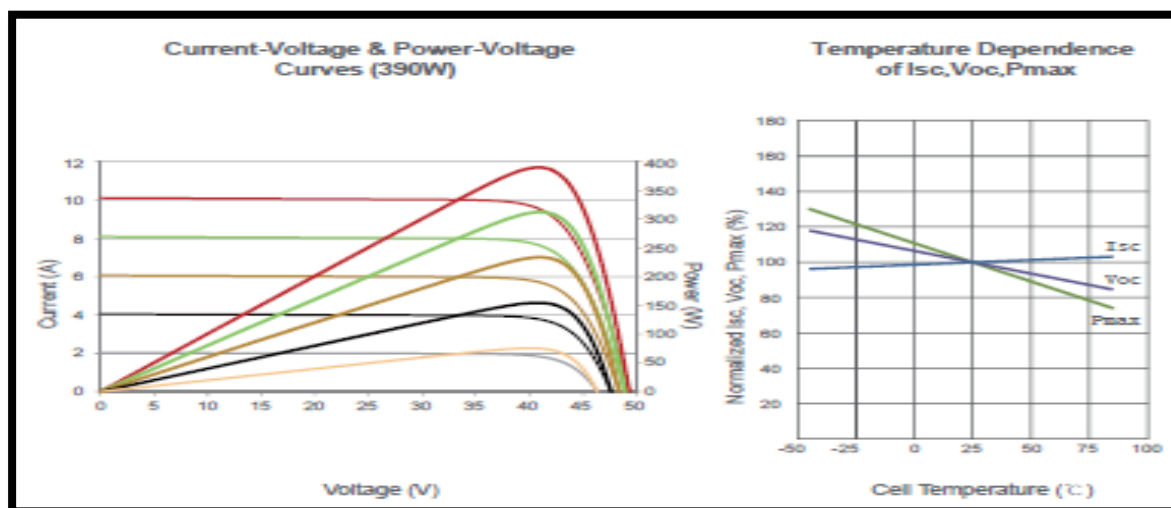
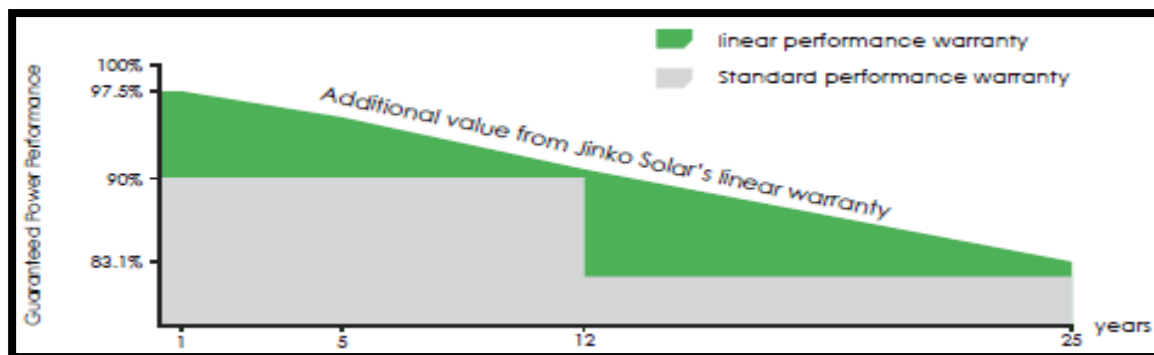
Appendices

Appendix 1 – Jinko Solar Power Panels

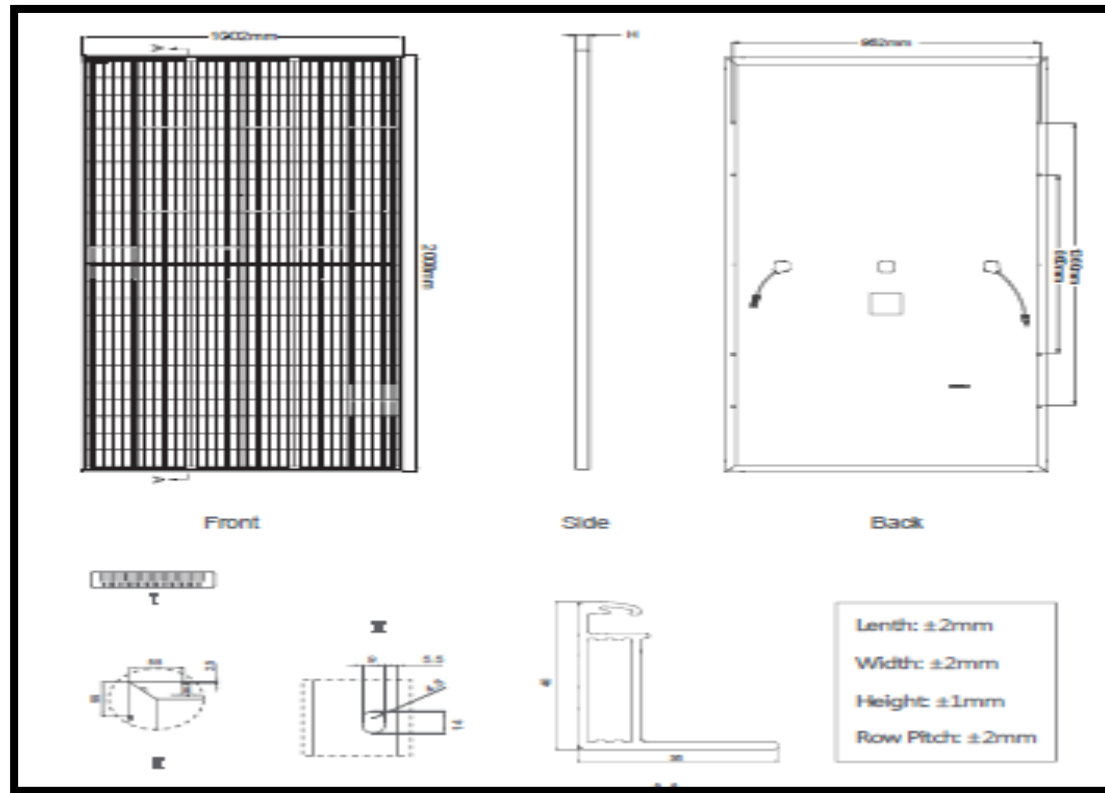
Jinko Solar Panel Mechanical Characteristics

Cell Type	Mono PERC 158.75×158.75mm
No.of Half-cells	144 (6×24)
Dimensions	2008×1002×40mm (79.06×39.45×1.57 inch)
Weight	22.5 kg (49.6 lbs)
Front Glass	3.2mm, Anti-Reflection Coating, High Transmission, Low Iron, Tempered Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP67 Rated
Output Cables	TÜV 1×4.0mm ² , (+) 290mm, (-) 145mm or Customized Length

Electrical Performance & Temperature Dependence



Jinko Solar Panel Engineering Drawings



Jinko Solar Panel Specifications

Module Type	JKM390M-72H		JKM395M-72H		JKM400M-72H		JKM405M-72H		JKM410M-72H	
	JKM390M-72H-V		JKM395M-72H-V		JKM400M-72H-V		JKM405M-72H-V		JKM410M-72H-V	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	390Wp	294Wp	395Wp	298Wp	400Wp	302Wp	405Wp	306Wp	410Wp	310Wp
Maximum Power Voltage (Vmp)	41.1V	39.1V	41.4V	39.3V	41.7V	39.6V	42.0V	39.8V	42.3V	40.0V
Maximum Power Current (Imp)	9.49A	7.54A	9.55A	7.60A	9.60A	7.66A	9.65A	7.72A	9.69A	7.76A
Open-circuit Voltage (Voc)	49.3V	48.0V	49.5V	48.2V	49.8V	48.5V	50.1V	48.7V	50.4V	48.9V
Short-circuit Current (Isc)	10.12A	8.02A	10.23A	8.09A	10.36A	8.16A	10.48A	8.22A	10.60A	8.26A
Module Efficiency STC (%)	19.38%		19.63%		19.88%		20.13%		20.38%	
Operating Temperature (°C)	-40°C~+85°C									
Maximum System Voltage	1000/1500VDC (IEC)									
Maximum Series Fuse Rating	20A									
Power Tolerance	0~+3%									
Temperature Coefficients of Pmax	-0.35%/°C									
Temperature Coefficients of Voc	-0.29%/°C									
Temperature Coefficients of Isc	0.048%/°C									
Nominal Operating Cell Temperature (NOCT)	45±2°C									

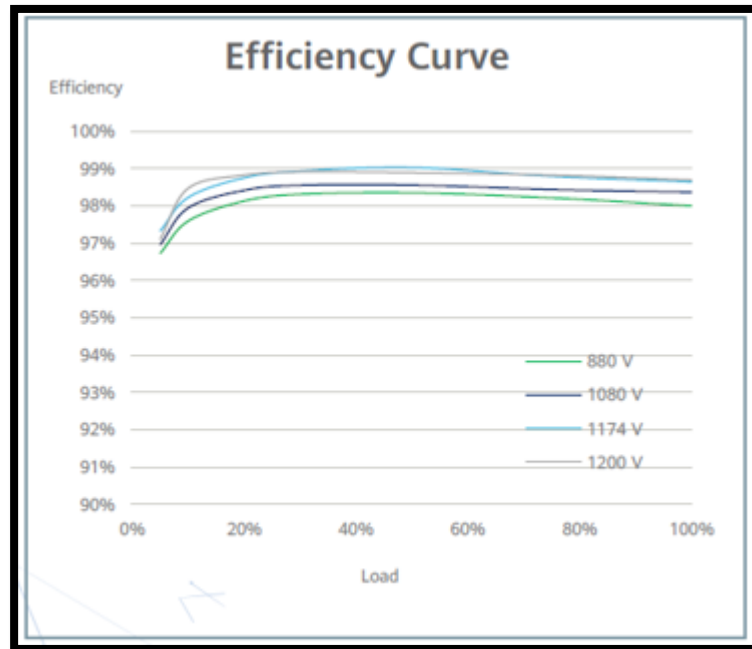
Appendix 2 – SUN2000 Solar Inverters

SUN2000-185KTL-H1

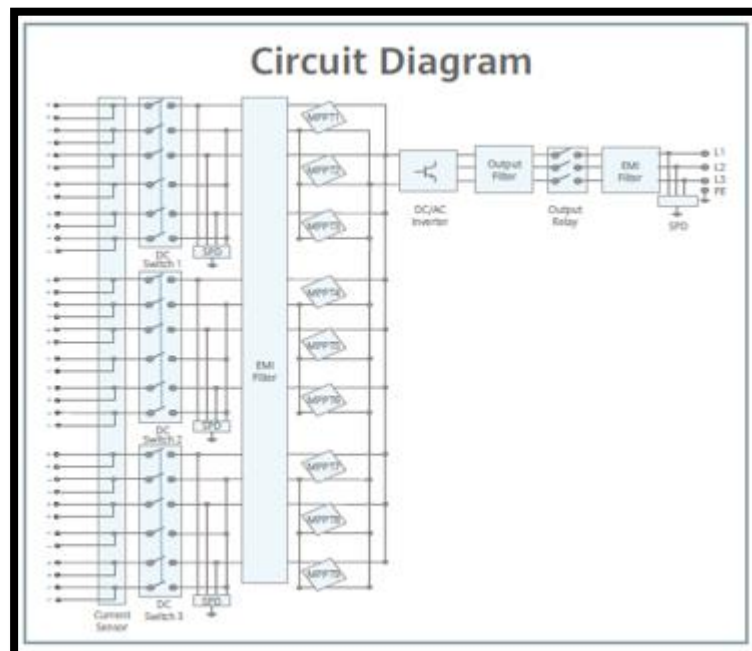
Technical Specifications

Efficiency	
Max. Efficiency	99.03%
European Efficiency	98.69%
Input	
Max. Input Voltage	1,500 V
Max. Current per MPPT	26 A
Max. Short Circuit Current per MPPT	40 A
Start Voltage	550 V
MPPT Operating Voltage Range	500 V ~ 1,500 V
Nominal Input Voltage	1,080 V
Number of Inputs	18
Number of MPP Trackers	9
Output	
Nominal AC Active Power	175,000 W @40°C, 168,000 W @45°C, 160,000 W @50°C
Max. AC Apparent Power	185,000 VA
Max. AC Active Power (cosφ=1)	185,000 W
Nominal Output Voltage	800 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Nominal Output Current	126.3 A @40°C, 121.3 A @45°C, 115.5 A @50°C
Max. Output Current	134.9 A
Adjustable Power Factor Range	0.8 LG ~ 0.8 LD
Max. Total Harmonic Distortion	< 3%
Protection	
Input-side Disconnection Device	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Monitoring Unit	Yes
Communication	
Display	LED Indicators, WLAN + APP
USB	Yes
MBUS	Yes
RS485	Yes
General	
Dimensions (W x H x D)	1,035 x 700 x 365 mm (40.7 x 27.6 x 14.4 inch)
Weight (with mounting plate)	84 kg (185.2 lb.)
Operating Temperature Range	-25°C ~ 60°C (-13°F ~ 140°F)
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
DC Connector	Staubli MC4 EVO2
AC Connector	Waterproof Connector + OT/DT Terminal
Protection Degree	IP66
Topology	Transformerless
Standard Compliance (more available upon request)	
Certificates	EN 62109-1/-2, IEC 62109-1/-2, EN 50530, IEC 62116, IEC 60068, IEC 61683, IEC 61727, P.O. 12.3, RD 1699, RD 661, RD 413, RD 1565, RD 1663, UNE 206007-1, UNE 206006

Appendix 2.1 – SUN2000 inverters Efficiency Curve



Appendix 2.2 – SUN2000 inverters Circuit Diagram



Appendix 3 – Potential Solar Farm Layout

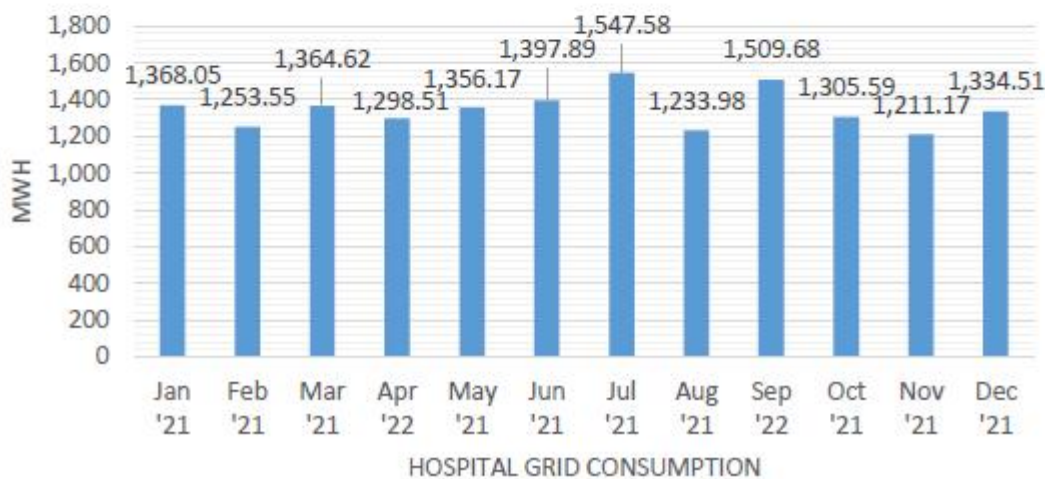


Appendix 4 – Morriston Hospital Energy Consumption 2021-2023

Morriston Hospital Energy Consumption 2021

Month	Daytime Consumption (KWh)	Night-time Consumption (KWh)	Hospital Total Consumption (MWh)
Jan '21	1,015,475.80	352,575.10	1,368.05
Feb '21	931,592.90	321,961.00	1,253.55
Mar '21	1,013,425.00	351,199.20	1,364.62
Apr '22	960,962.40	337,551.70	1,298.51
May '21	1,001,846.70	354,321.50	1,356.17
Jun '21	1,040,901.80	356,988.20	1,397.89
Jul '21	1,159,218.50	388,362.00	1,547.58
Aug '21	909,953.10	324,029.70	1,233.98
Sep '22	563,354.50	191,484.50	1,509.68
Oct '21	931,320.40	374,272.90	1,305.59
Nov '21	862,765.20	348,408.90	1,211.17
Dec '21	972,082.40	362,431.70	1,334.51

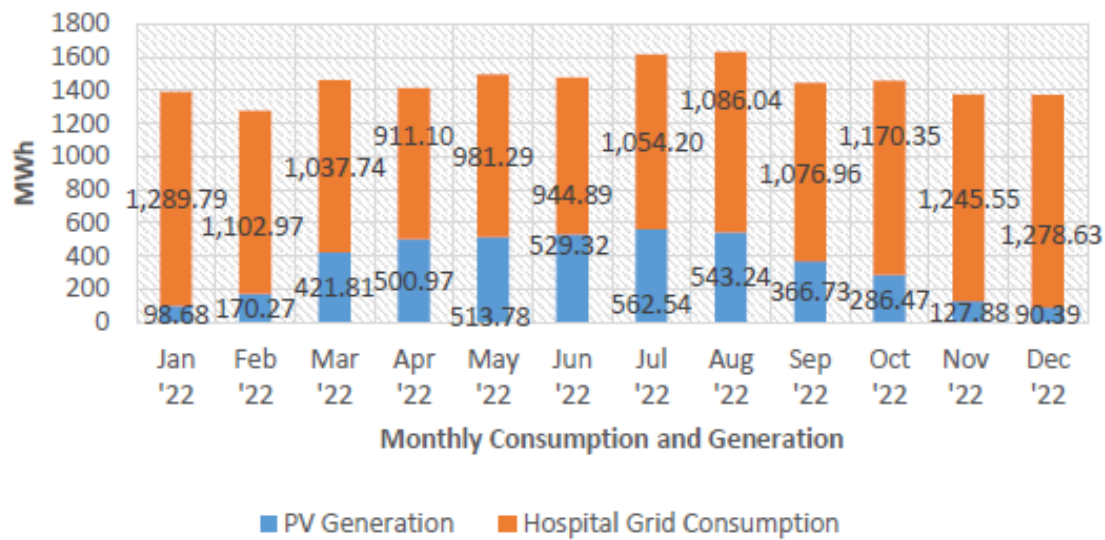
Hospital Consumption 2021



Morrison Hospital Energy Consumption 2022

Daytime consumption (KWh)	Night-time consumption (KWh)	Hospital Total Consumption (MWh)
931,719.60	358,069.90	1,289.79
777,909.20	325,055.90	1,102.97
681,762.00	355,982.50	1,037.74
566,726.00	344,370.30	911.10
619,596.30	361,696.80	981.29
591,663.50	353,222.50	944.89
667,599.70	386,602.50	1,054.20
695,161.60	390,881.80	1,086.04
718,465.20	358,490.40	1,076.96
802,325.70	368,026.50	1,170.35
893,975.50	351,573.30	1,245.55
926,215.10	352,414.40	1,278.63

Hospital Consumption 2022



Morrison Hospital Energy Consumption 2023

Daytime consumption (KWh)	Night-time consumption (KWh)	Hospital Total Consumption (MWh)
893,881.50	352,008.40	1,245.89
738,158.00	319,656.20	1,057.81
813,788.80	352,470.20	1,166.26
617,419.10	344,892.50	962.31
492,114.00	351,181.80	843.30
564,160.30	367,379.80	931.54
745,303.70	379,265.90	1,124.57
968,942.20	387,082.50	1,356.02
817,149.30	393,994.40	1,211.14
904,597.30	395,702.40	1,300.30
944,531.40	374,973.60	1,319.51
1,030,279.90	381,158.10	1,411.44

Hospital Consumption and Generation 2023

