University of Southern Queensland
Faculty of Health, Engineering and Sciences

Feasibility Study of Off-Grid Electrical Infrastructure Required to Support a Carbon Farm

A dissertation submitted by

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Abstract

This feasibility study aims to assess the viability of supporting the establishment and maintenance of a carbon farm, utilising the 'Reforestation by Environmental or Mallee Plantings' carbon sequestration method, via off-grid electrical infrastructure. The study evaluates the energy consumption needs of the farm, considering federal and state regulations and drawing insights from a survey of a proposed project site located in South Australia. Its objectives include developing a plan for site transformation as the carbon sink forest matures, evaluating hardware needs, producing a mature detail design of a security, livestock/pest, and fire monitoring subsystem, proposing a whole of farm concept before analysing both designs for off-grid feasibility via a cost comparison and potential payback period.

Through research into legislative requirements, conduct of the topographic, climatic and physical site survey, and hardware assessments, this study constructs a plan for an off-grid carbon farm. The study's results confirm the feasibility of off-grid electrical infrastructure for the base station of a security and fire monitoring subsystem, documenting the feasibility of potential expansion opportunities before grid connection cost parity. Furthermore, the study confirms the viability of off-grid electrical infrastructure for the overall farm design, encompassing a residence/office and water transfer stations within a South Australian project. Importantly, it takes into careful consideration the distance-from-point-of-service factor, a crucial determinant of off-grid feasibility. Specifically, it highlights the consideration of payback period when determining off-grid feasibility for potential grid connected consumers, who incur lower initial setup cost when located within 100 metres of the point of service.

The research also highlights the need for careful consideration of off-grid feasibility for lower-demand consumers near the connection point where a distance-based decision-making framework is proposed for grid versus off-grid implementation. This framework streamlines decision-making for equipment located beyond a 100-metre radius from the connection point, gaining efficiency through the design process.

In summary, this study offers valuable insights into the systems and designs necessary for carbon farms in South Australia. It deepens the understanding of the feasibility of off-grid electrical infrastructure for various consumer loads, especially those situated beyond the 100-metre viability threshold. Furthermore, it lays the groundwork for further research into broader geographical feasibility and the strategic utilisation of smart farm technology in the context of the envisioned connected carbon farm.

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[redacted]

Jason Craige
Signature of Candidate

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Abbreviations

ACCU:	Australian Carbon Credit Unit
AP:	Access Point
ATO:	Australian Taxation Office
BoM:	Bill of Materials
ERF:	Emissions Reduction Fund
FullCAM:	Full Carbon Accounting Model
IP:	Ingress Protection
LCOE:	Levelized Cost of Electricity
Li-ion:	Lithium-ion
MDOD:	Maximum Depth of Discharge
OECD:	Organisation for Economic Cooperation and Development
POC:	Point of Connecton
PV:	Photovoltaic
SAPN:	South Australian Power Networks
STC:	Small-scale Technology Certificate
UniSQ:	University of Southern Queensland

Chapter 1: Introduction

1.1. Background

Climate change, in its various guises, is not a novel issue, it is far from a recent concern. In fact, it was back in 2007 when Kevin Rudd's opposition government, in recognition of Australia's vulnerabilities and potential, who took the initiative to address this pressing issue. With the backing of the states, they established the Garnaut Review to thoroughly examine the impacts of climate change on the Australian economy (Garnaut 2008). As seen in Figure 1, the report highlights the agriculture, forestry, and fishing sector as the largest emitter in Australia. On a per capita basis, Australia's emissions in this sector exceed the OECD average by more than four times, placing it as the third highest emitter within the OECD. To address this issue, the report introduces the concept of 'biosequestration' as a promising and cost-effective method for landowners to diversify their income while employing sustainable farming practices (Garnaut 2008).

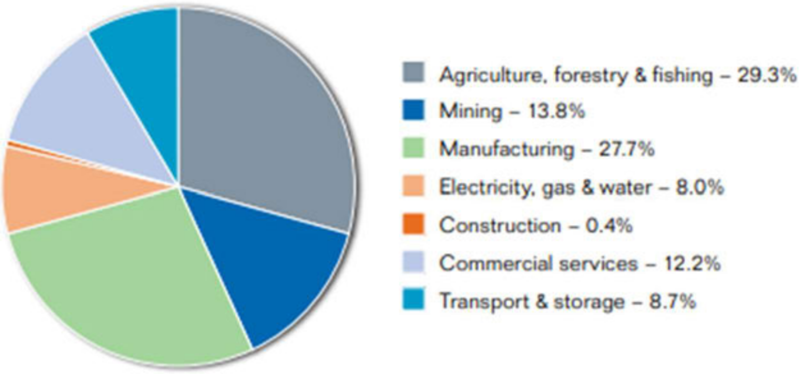

Figure 1: Emissions attributable to Australian industry by sector, 2006 (Garnaut 2008)

One notable aspect emphasised in the report is Australia's favourable position in terms of biosequestration. This is due to the abundance of available land and the country's forested areas, which are 20 times higher than the OECD average (refer to Figure 2) (Garnaut 2008). These factors provide Australia with a significant capacity for carbon credit production, estimated at 12 tonnes per hectare per year. Considering the current approximate spot price of Australian Carbon Credit Units (ACCUs) at $55.95 (Moore 2023), landowners engaging in biosequestration practices have the potential to earn around $671 per hectare per year. This economic value adds further incentive for existing and prospective landowners to explore and implement biosequestration methods, contributing to both emission reduction efforts and financial sustainability.

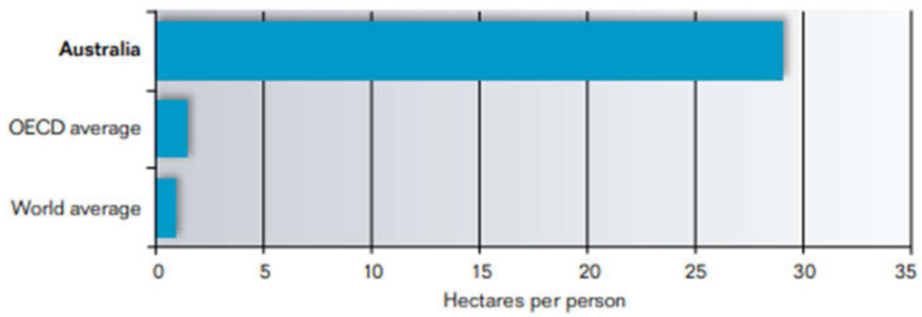

Figure 2: Per capita area of forested and wooded land, 2005 (Garnaut 2008)

In 2011, the Australian government enacted the Carbon Credits (*Carbon Farming Initiative*) Act, which outlined four specific activities related to deforestation avoidance and reforestation (Mitchell et al. 2012). Subsequently, regulations and rules were put in place to allow the registration of the first two projects in Queensland and Victoria, utilising a carbon capture vegetation methodology, in December of that year. The potential of these initiatives has rapidly gained momentum among both companies and landowners. According to the Emissions Reduction Fund Register (2023), 66 vegetation-based projects have been registered this year alone. Furthermore, across all Australian States and Territories, there are currently 859 registered vegetation projects, primarily concentrated in rural and remote areas, as seen in Figure 3 below. These vegetation projects constitute a substantial 56% of all projects registered, encompassing various methodologies (*Emissions Reduction Fund Register* 2023). This indicates a growing interest and participation in leveraging these opportunities for carbon farming and emission reduction efforts.

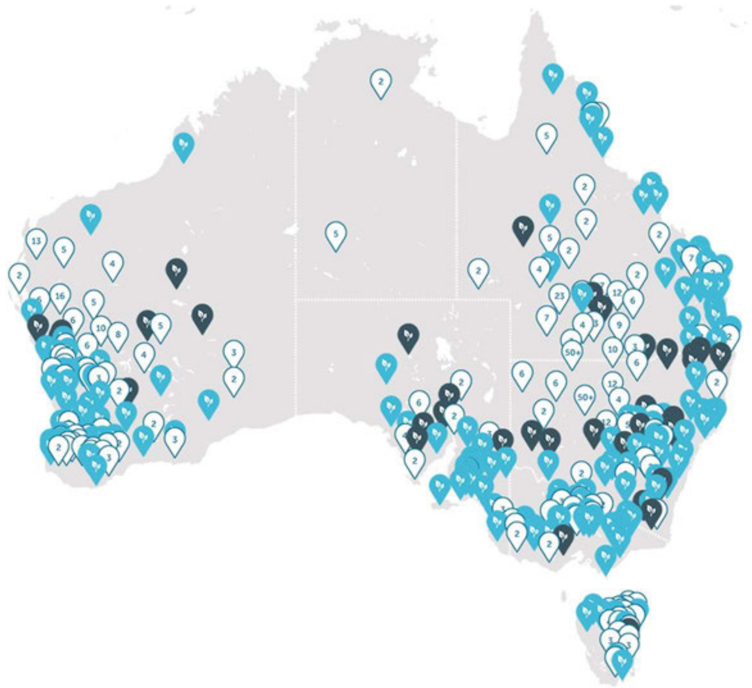

Figure 3: ERF project map, filtered for vegetation methodology only

Given Australia's extensive geography and the high probability of prospective biosequestration projects being situated in rural or remote areas, a critical aspect to consider when establishing a carbon farm is the necessary electrical infrastructure. This infrastructure plays a crucial role in supporting the management, maintenance, and protection of the carbon capture assets. One challenge in setting up a new rural business, that necessitates electrical infrastructure, is the accessibility and cost involved in connecting to the mains electricity grid. The remote nature of rural areas presents inherent challenges when it comes to accessing grid electricity. Extending power lines to these locations can incur substantial expenses, as indicated by the Price = Labour + Contractor Services + Materials + Margin formula and the accompanying fee and rate schedule outlined in the SA Power Networks Connections & Ancillary Network Services 2022/23 Manual No. 18 (2022). These cost factors, encompass the expenses related to labour, contractor services, materials, and profit margin. Considering the potential challenges involved, exploring alternative solutions for new rural infrastructure is a worthwhile undertaking. In this regard, McKenzie and Howes (2006) propose off-grid renewable energy systems as a practical and viable option, particularly in areas where access to the conventional electricity grid is unavailable. These systems provide a sustainable and self-sufficient approach to meeting the energy needs of rural areas, offering an effective solution to overcome the access and financial challenges of grid connection.

This feasibility study focuses on a specific section of land encompassing approximately 53 hectares, located in the suburb of Rockleigh, South Australia. The land, as depicted in Figure 4 below, has a previously been used for recreation and grazing, historically the land was cleared of the majority of trees, bushes, and shrubs to accommodate these activities. The property is divided by a quick-draining creek that maintains a nominal amount of fresh water throughout the year. Three structures are present on the site, with the machinery shed and small shack being the only functional ones. Water storage is available through two tanks, with a combined capacity of approximately 31,500L, capturing water from the main structures. However, there is no water distribution system in place for irrigation or sewage storage and processing. While mains electricity supplied by SA Power Networks is accessible at the northwest corner, just outside of the property line, it is approximately 450m away from the shack. On-site, the only available source of electricity is a transportable generator. Aside from the boundary fences, there is currently no security system or means through which to remotely monitor the site for invasive/destructive actors. The proposed plan for the carbon sequestration forest involves dividing the land into two plots, each spanning approximately 24 hectares. These plots will be positioned on either side of the creek, maximising the use of suitable land for the intended purpose.

Figure 4: Rockleigh carbon farming project site map (Source: Google Earth)

1.2. Aim

The aim of this feasibility study is to evaluate the feasibility of establishing and sustaining a carbon farm using the 'Reforestation by Environmental or Mallee Plantings' carbon sequestration methodology, with a specific focus on implementing suitable off-grid electrical infrastructure. The study will assess the energy consumption requirements of the farm, taking into account federal and state legislation and drawing insights from exemplary carbon farms. It aims to achieve carbon neutrality, promote sustainability, and identify the key technical factors that would contribute to the success of such a business.

1.3. Objectives

The primary objective of this feasibility study is to determine the potential success and viability of a carbon farm that utilises off the grid electrical infrastructure. The study will assess technical and economic feasibility of implementing such a system, whilst also identifying potential challenges and risks associated with the project. Ultimately, this study aims to provide a clear understanding of the viability of this approach to carbon farming and inform future decisions concerning similar projects. The detailed objectives that address the project aim are as follows:

1. Conduct initial research into the federal and state legislative requirements, codes of conduct and taxation guidelines in order to determine mandatory requirements, best practice and cost reconciliation of carbon farming supporting electrical infrastructure.
2. Conduct a site survey of the proposed carbon sink forest in order to determine the topography and natural resources that will inform the requirement for electrical supporting infrastructure.
3. Construct a future plan for the site, providing a view of how the topography (buildings and landscape) will change as the carbon sink forest reaches maturity.
4. Assess hardware requirements as derived from objectives 1-3.
5. Select commercially available hardware as a catalogue to inform carbon farm design.
6. Propose a system of off grid electrical infrastructure design concept that supports the proposed carbon farm.
7. Propose a security, livestock/pest and fire monitoring subsystem in accordance with the derived design constraints.

If time and resources allow, this project will strive to achieve a stretch target of successfully constructing and testing the proposed security, livestock/pest, and fire monitoring subsystem.

1.4. Motivation and Justification

The effects of climate change and the impact on our environment has become a globally prioritised concern. Australia, most notably, has been identified as one of the country's most at risk due to its increasing susceptibility to extreme weather events and vulnerability to droughts and bushfires (Head et al. 2014). In this context, the need for sustainable solutions that can mitigate the effects of climate change is never more important. One solution coming to the fore is the establishment of carbon farms, which aim to sequester carbon from the atmosphere by utilising a variety of sequestration methods as defined by the Clean Energy

Regulator (Evans 2018). However, due to the relative infancy of the industry, the viability of establishing new carbon farms with off-grid electrical infrastructure in Australia remains unclear, which calls for a feasibility study to evaluate the potential of this approach. There are several reasons why a feasibility study on supporting a carbon farm in Australia with off-grid electrical infrastructure is justified. Firstly, the Australian government has set ambitious targets to reduce greenhouse gas emissions, which requires the adoption of sustainable practices such as carbon farming (Albanese & Bowen 2022). However, due to the remote location of potential carbon farms, there is a lack of grid connected electrical infrastructure to support carbon farming. Therefore, the feasibility of off-grid electrical infrastructure to support carbon farming needs to be evaluated.

Secondly, the establishment of a carbon farm requires a significant investment, and the cost of electricity can be a significant component of the overall cost. Additionally, as net zero requirements are applied to businesses the use of off-grid electrical infrastructure, may reduce costs, mitigate need for operational offsets and increase the viability of carbon farming. However, it is necessary to assess the feasibility of off-grid electrical infrastructure, including the costs, technical feasibility, and potential benefits.

Finally, this study can provide valuable insights into the potential benefits and challenges of an off-grid design approach. It will assist in identifying potential barriers to implementation, including regulatory and policy issues, and provide recommendations to overcome them. Additionally, it can help evaluate the potential environmental, social, and economic benefits of carbon farming, such as reducing greenhouse gas emissions, increasing biodiversity, and creating employment opportunities in regional areas (Kragt et al. 2016).

1.5. Consequential Effects

The conduct of this feasibility study will yield several consequential effects. Firstly, it involves assessing the viability of implementing off-grid electrical infrastructure, considering factors such as site conditions and infrastructure costs, to determine its economic feasibility. One important outcome of implementing off-grid installations is achieving independence from reliance on the conventional electricity grid. By transitioning away from traditional fossil fuel generators and embracing on-site renewable energy sources, businesses can significantly reduce greenhouse gas emissions, aligning with sustainability goals. Relying on renewable energy sources also enhances resilience to natural disasters, as highlighted in the article by Pagliaro (2019). During grid failures, the off-grid electrical infrastructure continues to operate, ensuring uninterrupted power supply and supporting critical equipment, including those used by emergency services. Throughout the study, cost analysis will be conducted to assess the financial viability of off-grid technology in comparison to grid connection and ongoing costs within the context of the proposed carbon farm. Additionally, the feasibility study may uncover innovative methods for integrating renewable energy technologies specifically tailored for carbon farming operations.

In summary, the consequential effects of conducting this feasibility study encompass evaluating economic viability, reducing greenhouse gas emissions, enhancing resilience to natural disasters, analysing cost-effectiveness, and potentially identifying innovative approaches to implementing renewable energy technologies within the context of a carbon farm.

Chapter 2: Literature Review

This literature review aims to provide an understanding of the current state of knowledge regarding off-grid electrical infrastructure, with a specific focus on its feasibility and applicability to support carbon farming initiatives. To accomplish this objective, an examination of relevant academic research articles, industry reports, and policy documents has been undertaken. The review will explore various off-grid design drivers including legislation and taxation policy, investigate various off-grid technologies and design principles, whilst also identifying the relatively new technologies that constitute 'smart farming' for future research.

The findings from this literature review inform the methodology and results of the feasibility study, enabling an informed assessment of the potential for off-grid electrical infrastructure in supporting carbon farming initiatives. It is anticipated that the outcomes of this literature review will provide valuable guidance to future carbon farming business owners who might be considering the implementation of off-grid electrical infrastructure to support their venture. In aspiration, this research aims to support Australia's broader sustainability objectives towards a low-carbon future.

2.1. Review of the Requirements for Carbon Farming in Australia

Carbon farming in Australia is established under a legislative framework that is regulated by the Clean Energy Regulator under the Emissions Reduction Fund and allows landholders, communities and businesses to undertake projects that capture and store carbon, operating under the Carbon Credits (Carbon Farming Initiative) Act 2011 and the Carbon Credits (Carbon Farming Initiative) Rule 2015. Such participants can engage in these activities in order earn Australian carbon credit units (ACCUs). Each ACCU represents one tonne of carbon dioxide equivalent (tCO2-e) emissions stored by a project. ACCUs can be sold to generate income, either to the Australian Government through a carbon abatement contract, or to private buyers in the secondary market (*About the Emissions Reduction Fund* 2023).

2.1.1. Carbon Farming Legislation Design Drivers

In 2014, the Australian government introduced legislation known as the Reforestation by Environmental or Mallee Plantings—FullCAM methodology. This legislation serves as a framework for generating Australian Carbon Credit Units (ACCUs) by measuring carbon sequestration through the establishment of mallee plantings or mixed species environmental plantings. The *Carbon Credits (Carbon Farming Initiative) (Reforestation by Environmental or Mallee Plantings—FullCAM) Methodology Determination 2014* 2018) provides the specific requirements and guidelines for compliance with this methodology. While this study does not cover all the requirements outlined in the legislation, it is important to note certain notable requirements. These include regulations concerning plot arrangements and activities that are excluded from qualifying for carbon credits in order to understand the types and scale of supporting off-grid electrical infrastructure. The divisions of interest are summarised as follows:

Division 3.4 presents requirements pertaining to a variety of planting geometry and spacing methods however, for the purpose of this study mixed-species environmental planting methods are considered in detail. This method is split into two subsections that describe both narrow and wide linear plantings. For narrow linear plantings, the distance between the outermost trees or shrubs on either side must be less than or equal to 20 metres. The distance between the outermost trees or shrubs at the edge of the planting must be at least 40 metres from other plantings in the area. Material competition from adjacent trees should not affect the planting. For wide linear plantings, the distance between the outermost trees or shrubs must be greater than 20 metres and less than 40 metres. The other requirements for wide linear plantings are the same as for narrow linear plantings. This set of requirements denote the accessibility between linear planting plots and will be utilised to determine possible service routes including electricity and water.

Division 3.8 outlines the activities that are restricted on a carbon farm including; harvesting, grazing, thinning, and the use of lime or fertiliser in a carbon estimation area. Biomass cannot be removed from the area unless used in accordance with specific controls including; up to 10% of fallen timber can be removed for personal use. Other permitted removals include thinning for ecological purposes, debris removal for fire management, harvesting of fruits, nuts, seeds, or materials for non-commercial use, and harvesting in accordance with traditional indigenous practices or native title rights.

Grazing is allowed but must not impact forest cover, and evidence may be requested to demonstrate compliance. Thinning, the practice of removing select trees for ecological purposes and the use of lime or fertiliser should be selected depending on the desired FullCAM calibration method (specific or generic).

Division 4.14 of the regulations outlines the calculation method for determining project emissions, which is crucial in assessing the total carbon dioxide net abatement amount. This calculation plays a vital role in determining the quantity of carbon credits to be issued. By minimising the project's emissions throughout the carbon farming activities, the potential for issuing a greater number of carbon credits is maximised. This aligns with sustainability goals and serves as a driving factor in designing off grid electrical infrastructure, noting that the selection of electrified equipment may be a preferred option for many businesses who aim to minimise emissions and maximise the positive environmental impact.

Division 5.2 outlines the monitoring requirements for a project. The project manager is responsible for monitoring the project to ensure compliance with the legislative requirements. If the FullCAM specific calibration has been used, information must be collected to demonstrate compliance with the calibration requirements. The manager must also identify and record management events and disturbance events within each project area. On-ground observation and/or remote-sensing imagery can be used to meet these requirements and collect information for specific calibration compliance.

2.1.2. Carbon Farming Taxation Design Drivers

An objective of this feasibility study is to develop an understanding of the economic aspects related to establishing an off-grid carbon farm. In addition to conducting a cost comparison between on-grid and off-grid solutions, it is important to consider tax regulations and develop a tax strategy that can provide significant benefits to the business (Collardin & Vogele 2002). The Australian Taxation Office (ATO) has implemented a taxation policy that specifically addresses deductions related to "carbon sink forest expenses." This policy allows the business to claim the full capital expenditure associated with establishing the carbon sink forest across 14 years. These expenses are numerous however, the most relevant to this study are listed as:

- raising tree seedlings in pots and potting mixtures
- grafting trees and germinating seedlings
- allowing seeds to germinate (whether by broadcasting, deliberate regeneration or planting seeds directly)
- preparing the area for planting (for example, ploughing, scarifying, contouring, top dressing, fertilising, weed spraying, stone removal and top soil enhancement)
- planting the trees or seeds
- surveying the planted area.

(*Claiming a deduction for carbon sink forest expenses* 2019)

An additional scheme, currently offered by the ATO is the “GST and the Small-scale Renewable Energy Scheme” which enables the business owner to claim a GST credit when purchasing and installing a system for their business. The credit is based on the price of the installation before any discounts, minus personal use. Business owners who install renewable energy systems also have the opportunity to generate STCs, which serve as a form of renewable energy currency. These STCs can be assigned to a third party in exchange for a delayed cash payment or an up-front discount on the system purchase. This provides business owners with the flexibility to monetise the value of their STCs and leverage them as a financial benefit for their business. GST is applicable on the sale or assignment of STCs if the installed system is used for the business, and the GST amount is determined by the sale or the delayed cash payment/discount (*GST and the Small-scale Renewable Energy Scheme* 2020).

2.2. Off Grid Technologies

2.2.1. Solar Cells and Arrays

Solar PV arrays are the predominant form of renewable energy in Australia, accounting for 12% of total electricity generation in 2021 (*Renewables* 2023). Australia enjoys a significant advantage in terms of solar radiation, boasting the highest average solar radiation per square metre of land among all continents. Recognising this opportunity, successive governments have provided incentives and subsidies to encourage investment in solar energy (Bahadori & Nwaoha 2013). These policies have played a crucial role in the widespread adoption of solar PV systems across the country.

PV arrays generate electricity by utilising the phenomenon of charge carrier separation from a photon-absorbing material, which converts solar irradiation into electrical energy. Among the various types of solar cells available, the most commonly used are the mono and multi crystalline cells. These cells are manufactured from metallurgical grade silicon, which undergoes a processing and casting process to form multicrystalline ingots. These ingots are then sliced into thin wafers, which are subsequently incorporated into the solar cells as seen in Figure 5 below (Bagher et al. 2015; Sato 2015, p. 44).

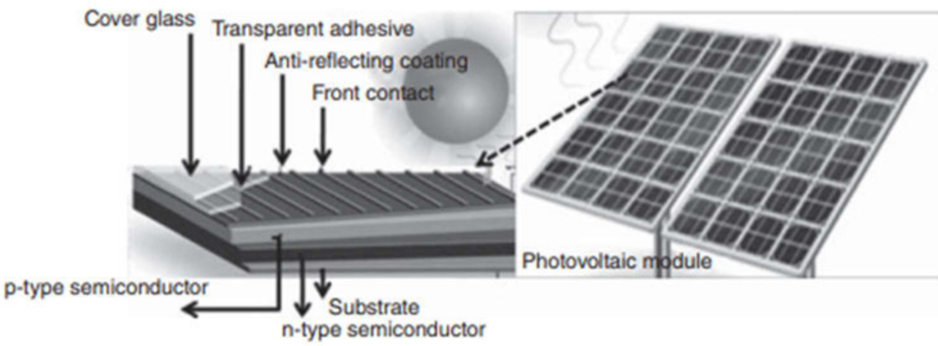

Figure 5: Typical multicrystalline silicon solar cell (Sato 2015, p. 44)

PV solar arrays consist of several components tailored to specific use cases, an example of which can be found in Figure 6 below. They function by harnessing the energy generated by a set of solar cells and storing it or converting it for practical purposes. In many cases, the generated energy is stored in batteries through a charging process, enabling its use during periods of low or no sunlight. Alternatively, the direct current (DC) electricity produced by the solar cells can be converted into alternating current (AC) electricity through an inverter, allowing for immediate use or export to the mains grid (Sato 2015, p. 44).

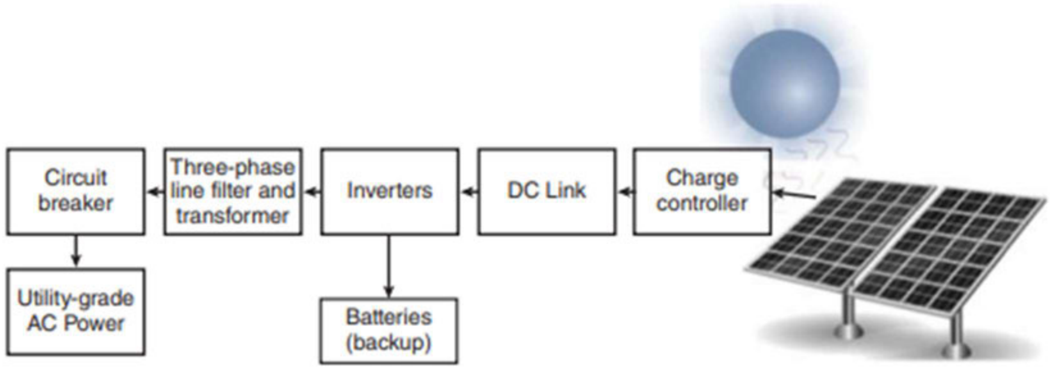

Figure 6: Block diagram of a solar array system (Sato 2015, p. 44)

For the purpose of this feasibility study and subsequent analysis and design, Victron Energy, a leading manufacturer in the industry, serves as an example. Known for offering both mono and multi-crystalline panels, Victron Energy are well renowned off-grid technology manufacturer. Their product range includes various panel sizes and performance characteristics, making them a suitable reference for assessing the feasibility and performance of solar arrays (Svarc 2023). The datasheets for the selected solar cells can be found in Appendix F.

2.2.2. Wind Turbines

Second to solar generation, wind-based generators account for 10% of Australia's total electricity generation and have been employed, at an industrial scale globally, since the 1970s. Wind turbines are the central component of wind-based machines, converting the wind's kinetic energy into mechanical energy, which is then transformed into electrical energy. The energy generated by wind turbines is dependent on the wind speed, with higher speeds resulting in increased available wind power (Sato 2015, p. 52). Small wind turbines, defined as those generating 100 kW or less, are commonly deployed in situations where grid connection is not available and in conjunction with a battery storage system. These compact turbines offer an alternative power source for off-grid locations or areas with unreliable grid access. Unlike utility-grade turbines, small turbines are available in vertical axis configurations as well, catering to specific application needs (Breeze 2016).

The inclusion of wind turbines in off-grid systems requires careful consideration alongside optimisation, as highlighted by Guerello et al. (2020) in their research on hybrid off-grid systems incorporating solar, wind, wood, and diesel as energy inputs. Each system instance necessitates specific optimisation measures in order to achieve the desired benefits such as resilience (Pagliaro 2019). It is important to note that wind energy, in terms of per kilowatt cost, was found to be approximately twice as expensive as solar energy. Therefore, the specific requirements and potential benefits of integrating wind as an energy source should be clearly defined and evaluated within the context of the off-grid system. This ensures that the use of wind turbines is optimised and economically viable for the given energy needs and objectives.

2.2.3. Converters

Converters play a crucial role in off-grid systems as they enable the conversion of renewable electricity into a format compatible with the required appliances. In the context of off-grid systems, the term "converter" encompasses the conversion of DC to DC (up or down) and the inversion of DC to AC. DC to DC downward conversion is employed to ensure a suitable voltage for charging storage batteries, ensuring efficient energy storage (Labouret et al. 2010, pp. 209-10). On the other hand, DC to AC inverters are utilised in off-grid systems to power regular household appliances, without the capability for exporting excess electricity, as seen in grid-connected systems (Labouret et al. 2010, p. 211). Converters are available in a large variety of sizes and specification, depending on the use case. Considering the types of application relating to this feasibility study, both small (up to 3kW inversion and 40A charge) and large (above 3kW inversion and 40A charge) should be considered in design.

2.2.4. Storage Batteries

Renewable energy storage batteries are essential components of off-grid systems. They capture surplus electricity generated by solar and wind sources and provide backup power during periods of low generation. Li-ion batteries are increasingly preferred over traditional lead-acid batteries for solar systems due to their significantly longer lifespan. While lead-acid batteries typically last for 300-500 cycles, Li-ion batteries can endure up to 2000 cycles (Diouf & Avis 2019). However, cost plays a significant role in determining the most appropriate battery chemistry. Li-ion batteries can be four times more expensive than lead-acid batteries, so factors such as immediate budget availability, specific use case requirements, and environmental considerations must be taken into account (Diouf & Avis 2019). It's worth noting that despite their higher cost, Li-ion batteries account for a significant portion of the total cost in an off-grid system due to their limited lifespan compared to other components (Labouret et al. 2010, p. 187).

Various commercially available batteries are widely used, with the top five rated by Wrigley (2022) predominantly utilising Li-ion chemistry. However, selecting the most suitable battery for an off-grid carbon farm requires considering several factors. These factors include cost, available sizing options, expansion and modularity capabilities, temperature performance, IP rating (for protection against dust and water), and specific consumption needs (Weniger et al. 2014). It's important to note that while Li-ion batteries are popular for solar systems, they may not always be the optimal choice for every electricity requirement on a carbon farm. Alternative chemistries such as lead acid may be more cost-effective and better suited for certain applications. Therefore, a thorough evaluation of these factors is necessary to determine the most appropriate battery chemistry for the specific needs of the off-grid infrastructure.

2.2.5. Petrol/Diesel Generators

Fossil fuel generators used in off-grid systems are predominantly either petrol or diesel-based, and the choice depends on the specific application. Research suggests that diesel generation is commonly preferred for larger off-grid systems (typically greater than 4 kW) that are regularly used as backup power sources (Kosmadakis & Elmasides 2021). On the other hand, in smaller off-grid applications, petrol generation may be more suitable due to its lower capital cost, smaller capacity, and absence of high load and charging requirements (Connolly 2014). These factors make petrol generators more cost-effective and efficient for smaller-scale off-grid setups. It is important to consider the size, usage patterns, and specific needs of each off-grid system when choosing between petrol and diesel generators. Larger systems that require frequent backup power typically benefit from the reliability, endurance and efficiency of diesel generators. In contrast, smaller systems may find petrol generators more economical and practical.

Ren et al. (2019) highlights the need for hybridized off-grid systems, incorporating petrol or diesel generation, to enhance the financial viability of such systems, despite their misalignment with sustainability goals. The study suggests that by offsetting 10% of a household's energy consumption with petrol-based generation, the overall payback period of the off-grid system, based on the Levelized Cost of Electricity (LCOE), can be significantly reduced. Table 1 (Ren et al. 2019) illustrates the findings, using House 1 as an example, it presents the average payback period for a photovoltaic (PV)/battery-based system under current global warming conditions, considering seven different cities. The average payback period is calculated to be 23.8 years.

Table 1: Payback periods for PV battery systems in current and future global warming conditions

City	Full day occupied			
	Current climate		Future global warming	
	House 1	House 2	House 1	House 2
Darwin	12.8	12.3	12.8	14.1
Alice Springs	20.7	21.0	13.9	19.7
Brisbane	18.2	20.0	13.9	16.0
Mildura	22.5	27.1	19.2	20.5
Sydney	22.3	35.0	15.7	16.7
Melbourne	21.7	59.1	20.1	24
Hobart	48.4	189.9	42.1	78.6

Table 2 (Ren et al. 2019) presents the results obtained when incorporating a generator, which accounts for approximately 10% of energy usage, into House 1's hybrid system. The inclusion of the generator leads to a significant reduction in the average payback period, from 23.8 years to 12.03 years, resulting in a decrease of 11.77 years. By excluding the outlier city, Hobart, from the analysis, the average payback period for a PV/battery system is calculated to be 19.7 years. In contrast, the average payback period for a hybrid system, including a generator, is 10.53 years. These findings indicate that incorporating a generator into the hybrid system can substantially shorten the payback period compared to a PV/battery system alone. The hybrid system proves to be more financially favourable, demonstrating its potential for increased cost efficiency and financial viability in off-grid applications. It is important to consider these results when evaluating the optimal configuration for off-grid systems, taking into account factors such as energy usage patterns, local conditions, and financial considerations.

Table 2: Payback periods for a hybrid petrol generator/PV battery system in current and future global warming conditions for House 1

City	Full day occupied			
	Current climate		Future global warming	
	Generator, PV/battery	Payback (year)	Generator, PV/battery	Payback (year)
Darwin	3.0 kVA, 8 kW/13.5 kWh	9.6	4.0 kVA, 8 kW/16 kWh	9.2
Alice Springs	3.5 kVA, 4 kW/11 kWh	10.2	3.5 kVA, 6 kW/8 kWh	10.9
Brisbane	2.5 kVA, 6 kW/8 kWh	9.7	3 kVA, 6 kW/7.5 kWh	10.0
Mildura	3.5 kVA, 8 kW/10 kWh	10.2	3 kVA, 6 kW/8 kWh	8.4
Sydney	3 kVA, 6 kW/7.5 kWh	10.3	2.5 kVA, 5 kW/7 kWh	8.9
Melbourne	3 kVA, 15 kW/11.5 kWh	13.2	4 kVA, 8 kW/9.5 kWh	10.4
Hobart	3.5 kVA, 15 kW/12 kWh	21	3.5 kVA, 10 kW/15.5 kWh	20.6

The implementation of a fossil fuel-based generator in the system introduces additional complexities beyond the cost analysis discussed by Ren et al. (2019). This is particularly relevant when considering the ACCU (Australian Carbon Credit Units) calculation method, which requires accounting for the total project emissions in order to determine the appropriate carbon credits to be issued. It is important to minimise the emissions generated by the project in order to maximise the number of carbon credits that can be obtained. Emissions generated within the project incur a double cost: the cost of the fuel itself and the opportunity cost associated with the additional emissions produced.

Therefore, when evaluating the inclusion of a fossil fuel-based generator in an off-grid system, it is crucial to carefully consider the environmental impact and the implications for carbon credit eligibility. Balancing the financial benefits of using a generator with the associated emissions and sustainability goals is an important decision-making factor in designing a system that aligns with both economic and environmental objectives.

2.3. Off Grid Design Principles

2.3.1. Project Design Limitations

Extensive research has been conducted on implementing off-grid energy systems as alternatives to traditional generators, exploring various optimal configurations. However, in the Australian context, a simple spot cost comparison is inadequate to assess their viability. Factors such as government policies, retailer competition, and available tariffs significantly influence the feasibility of different design configurations.

A study conducted by Powell et al. (2019) on a cotton farm irrigation system serves as an example. The study compared various supply configurations with grid connection, using the payback period as a measure of viability. The findings revealed that a grid/PV configuration offered benefits such as shorter payback periods and energy security during daylight hours. However, the economic viability of this configuration heavily relied on the price offered for surplus energy exported back to the grid. This study emphasises the importance of considering not only the initial costs but also ongoing operational factors, including emissions generation and revenue streams associated with off-grid energy systems. Government policies, available subsidies, market competition, and electricity pricing structures play pivotal roles in determining the overall economic feasibility of different off-grid design configurations when compared to grid-connected equivalents.

In this feasibility study, certain assumptions will be made due to its limitations. Government policies, incentives, and subsidies will be considered as they currently exist, and electricity prices will be taken as the current prices with nominal annual growth. Factors such as the cost of degrading global warming conditions and feed-in prices will be excluded as the study primarily focuses on the capital investment of each proposed solution, alongside sustainability goals and maximizing carbon farming revenue.

2.3.2. Design Process

Two studies conducted by Ghafoor and Munir (2015) and Al-Shamani et al. (2015) present similar processes for designing off-grid electrical systems. While these studies provide comprehensive approaches to system design, they have a limitation in that they restrict the design to renewable generation and storage, excluding the consideration of fossil fuel generators as a potential cost-saving measure.

Both studies follow a systematic process that starts with defining the energy demand of the installation using a load profile approach. They then proceed to select the block components of the system, as illustrated in Figure 7 (Al-Shamani et al. 2015). Finally, the design of each component part is determined.

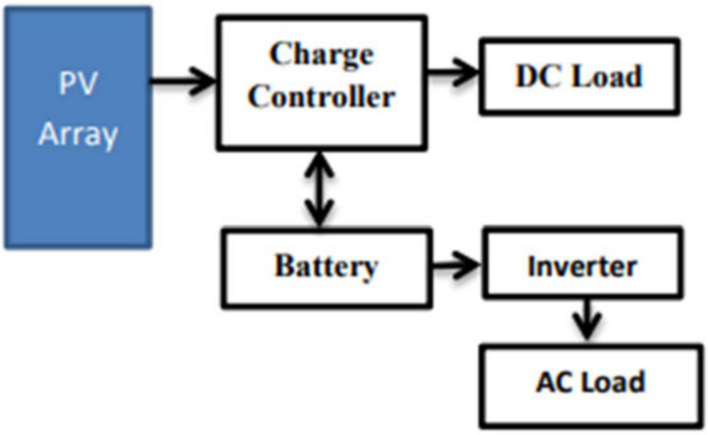

Figure 7: Example off-grid system block diagram

The final stage of the design feasibility process involves conducting a cost analysis, which is not included in the study by Al-Shamani et al. (2015) but is incorporated in the example design by Ghafoor and Munir (2015) and discussed in the book by Labouret et al. (2010).

The design procedure typically consists of seven stages, although it can be condensed to five depending on the desired outcome and the importance of cost considerations. The description and outcomes of each stage are as follows:

- Stage 1: Assess the energy demand of the installation, including supply voltage, power demand of each appliance, and duration of use. The output of this stage is a load profile obtained during the peak season.
- Stage 2: Size the PV array based on the location and geographical situation. The specific approach may vary, but the process outlined by Al-Shamani et al. (2015) determines the daily energy requirement, peak power, total current, number of parallel modules, number of series modules, and total number of modules.
- Stage 3: Size the storage battery based on the estimated energy required for storage during reduced or non-production hours. The output of this stage is the number of required batteries and their series/parallel configuration (Al-Shamani et al. 2015).
- Stage 4: Size the charge controller by considering the short circuit current of the PV module, number of panels, and applying a safety factor (typically 1.25) (Al-Shamani et al. 2015).
- Stage 5: Size the inverter based on the power required by concurrently operating devices, with an added safety factor of approximately 20% (Ghafoor & Munir 2015).
- Stage 6: Determine the wiring plan in accordance with local wiring rules.
- Stage 7: Perform a cost analysis, which can be done through lifecycle cost analysis, LCOE or, in the case of this study, by comparing capital investment, considering the payback period using nominal increases in grid connected electricity prices over time.

One significant omission in the aforementioned studies and off-grid design process is the consideration of alternative means of generation. Vick and Neal (2012) addressed this gap by examining a smaller-scale water pumping subsystem that incorporated wind power in the renewable energy mix. While wind power is an appealing option in terms of sustainability goals, the study identified several challenges when applied to a small-scale operation, particularly the variation in output voltage due to wind speed. This issue does not arise in on-grid designs, as the variable DC output can be inverted to a constant AC voltage used by the utility. It is important to note that the system examined in the study did not include any storage, was directly connected to a DC motor/pump arrangement, and did not involve any conversion in the off-grid configuration. In the context of this feasibility study, wind power should only be considered if the system design incorporates appropriate conversion components.

2.3.3. Cable Size Calculation Tool

A core element to any electrical infrastructure design is the network of power cables that distribute electrical energy from the point of supply to end consumers. Cable size calculators are software tools, available to electrical design professionals, for the purpose of increasing the efficiency of performing cable size calculations. Within Australia AS/NZS 3008:2017 (Standards Australia 2017) is utilised in reference to AS/NZS 3000:2018 (Standards Australia 2018) to determine appropriate cable sizing for electrical installations. There are a number of AS/NZS 3008:2017 based cable size calculator tools available via the internet. These cable size calculator tools enable quick determination of cable size based on a number of inputs provided by the user including:

- Load size (A): Current demand given in amperes
- Power factor: Typically given at 0.8
- Cable core count/configuration: Single/multicore with conductor vs earth arrangement
- Conductor type: Aluminium or copper
- Stranded/solid: Flexible or solid conductor variant
- Insulation type: Outer sheathing material variant
- Phase arrangement: 1 phase, 3 phase, DC, 2 phase variants
- System voltage (V): Typically, 230/415VAC, 12/24/48VDC
- Maximum voltage drop (%): As determined by customer and equipment parameters
- Cable distance: Distance from source to load in metres
- Installation type: Choice of environment and method which the cable is installed
- Number of parallel cables
- Additional derating options: Available as required

(*Cable Pro 2023* 2023; Staden 2023)

The following subsections provide an overview of two example tools that are available for use within a project such as this.

2.3.3.1. jCalc Cable Calculator

The jCalc cable calculation tool, developed by Staden (2023), is a cable size calculation tool designed utilising AS/NZS 3008:2017, it was and was last updated in September 2023. It is available online in both free and paid formats however, watermark free reports are only available via a yearly subscription of $265.00. It has a simple to use, single page user interface with all cable variant, supply type, installation method and derating features available to free users. Substantial reference information, that supports the input of all parameters is also available by selecting the corresponding information button. It generates detailed reports that comprehensively outline the parameters utilised in the calculations, along with the resultant cable requirements. Figure 8 below provides a view of the user interface.

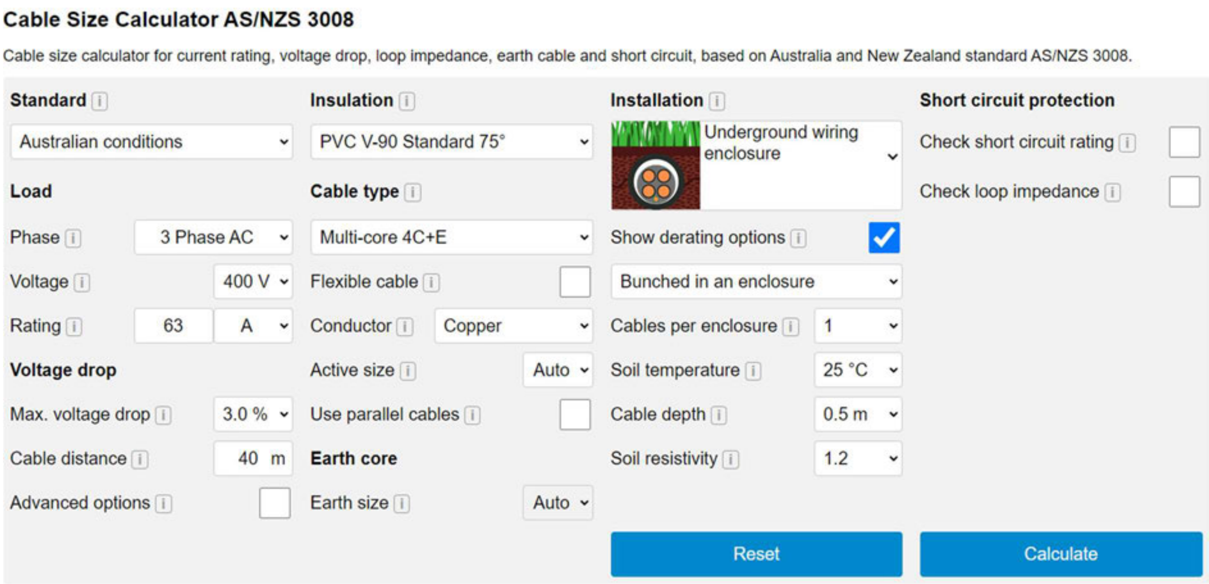

Figure 8: jCalc cable calculator user interface

2.3.3.2. Cable Pro 2023

Cable Pro, developed by Electrotechnik (*Cable Pro 2023* 2023), offers an alternative cable sizing software solution with capabilities similar to that of the jCalc tool. It provides users with a parallel range of features and options. The initial access to Cable Pro is facilitated through a 14-day trial, after which an annual licensing fee of at least $190.00 is required. The free trial version also includes the feature of generating cable sizing calculation reports. However, it's worth noting that these reports, much like those in the jCalc tool, come with watermarks.

Figure 9 overleaf, provides a view of the Cable Pro user interface, noting this may differ to the purchased version.

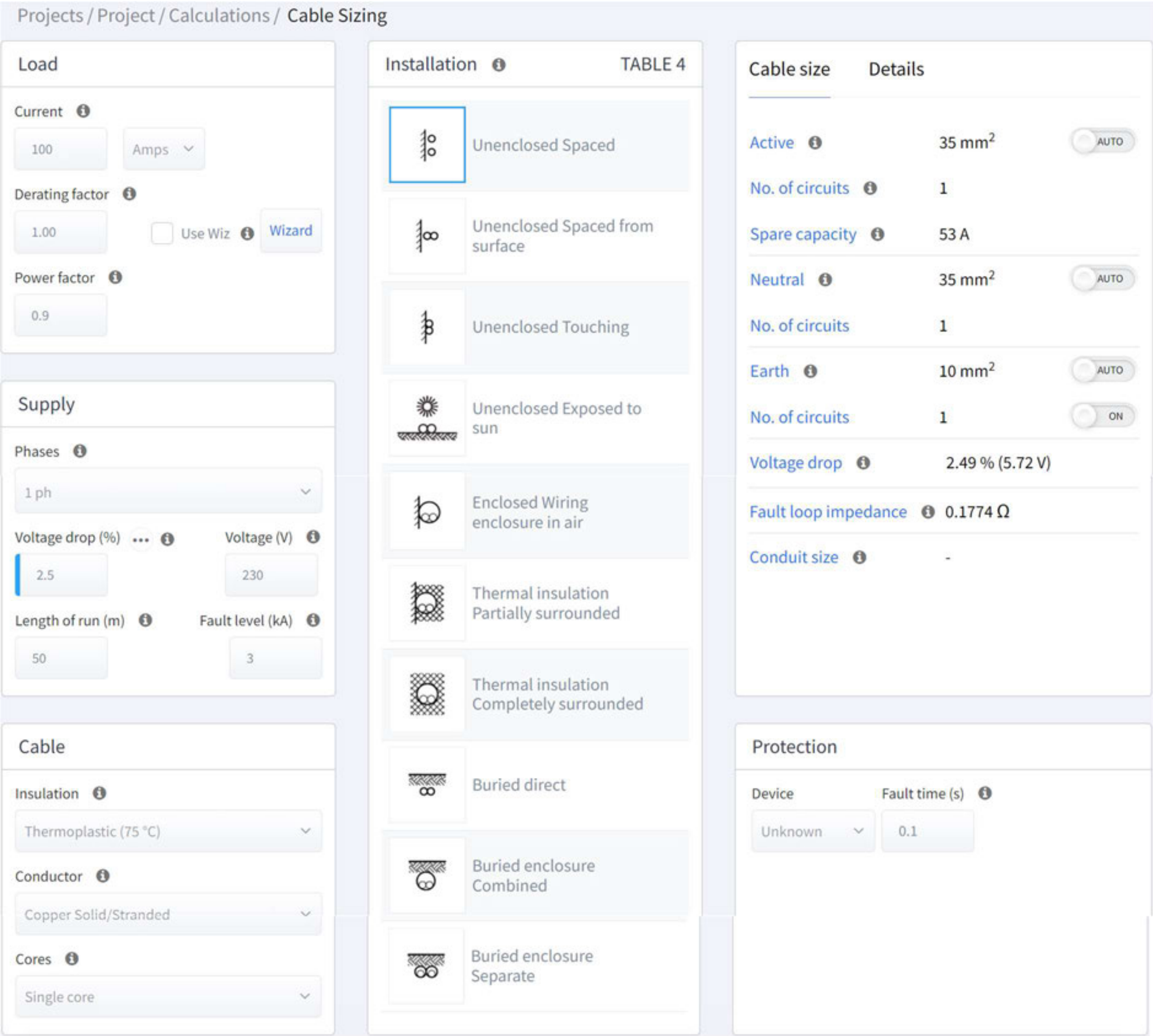

Figure 9: Cable Pro 2023 cable calculator user interface

2.4. Smart Farming Technologies

During the literature review, the emerging concept of "smart farming" has been identified as a relatively new technology category. Smart farming involves the adoption of digital innovations and revised farming practices to enhance farming efficiency. However, its widespread adoption has been hindered by ethical concerns, particularly in relation to livestock care, as highlighted by Knierim et al. (2018). These technologies encompass remote monitoring of farming infrastructure used in both crop and livestock production. They enable the centralised collection of information, allowing farmers to intelligently prioritise areas that require attention, such as water tanks, feeding troughs, and access gates (Idoje et al. 2021).

Although this feasibility study did not initially consider smart farming technology, it is recognised as a potentially valuable additional capability. Therefore, a decision regarding the inclusion of smart farming technology in the proposed carbon farm design will be made at the conclusion of the case study reviews. The feasibility and appetite for such capabilities will be assessed to determine the suitability of integrating smart farming technology into the overall design.

2.5. Knowledge Gap

This literature review highlights the existing research, case studies, and feasibility studies on renewable energy technology and system design. However, it identifies a crucial gap in the literature regarding the electrical infrastructure required to support a carbon farm. Furthermore, the specific design drivers unique to carbon farming, such as fire management, livestock incursion, capital asset security, and water distribution, have not been adequately considered in previous studies. Therefore, there is a pressing need for further review and analysis of these topics, particularly in light of upcoming case studies.

To address these gaps, an analysis and evaluation of renewable technologies in the context of off-grid carbon farming systems is necessary. This analysis should encompass several key aspects, including optimal configurations, performance characteristics, cost-effectiveness of different off-grid technologies for carbon farming applications.

Chapter 3: Methodology

The methodology for this project, is outlined in four sections as follows.

Section 1 of the methodology centres on mobilising and planning the remote activities, considering the unique logistical and site-specific challenges involved. Key considerations include factors such as weather conditions, which require thorough planning and preparation before initiating on-site activities. Additionally, this section encompasses the acquisition of necessary resources, ensuring their availability well in advance of the project's commencement alongside the activities associated with setting up the case study candidates.

Section 2 outlines the process of gathering requirements from the relevant legislation, codes of conduct, identified as a result of the literature review, as well as the conduct of a survey of the remote site.

Section 3 outlines the process of cataloguing the essential hardware items necessary for an off-grid carbon farm. This includes assessing the requirements for renewable electrical energy generation, security and monitoring hardware, water monitoring and movement hardware, as well as any additional hardware needed for the existing supporting structures.

Section 4 outlines the process of documenting the future plan for the carbon farm, encompassing various aspects such as topography analysis, carbon sink forest maturity assessment, and an indicative holistic electrical infrastructure design. Additionally, it includes the development of a fully engineered security and fire monitoring system with remote access capability.

3.1. Project Mobilisation and Planning

To ensure the safe and ethical execution of upcoming site survey and case study activities, careful planning and mobilisation are essential. This process involves several important steps. Firstly, it is crucial to acquire and account for all the necessary resources for the site survey. This includes identifying and obtaining the required equipment, materials, and personnel. Secondly, approvals must be sought for the project risk assessment. This approval ensures that potential risks are carefully assessed and appropriate measures are put in place to mitigate them. Once the necessary risk mitigation controls are accepted, a plan for the site survey can be developed. It is important to conduct the survey throughout the year to account for any seasonal variations that may impact the development of the off-grid design concept. By following these steps, the site survey can be conducted in a well-planned and safe manner, ensuring reliable results for the development of the off-grid design concept.

3.2. Collate Carbon Farming Requirements

3.2.1. Site Survey

The site survey will be conducted in three separate visits throughout the year, aiming to capture data during different seasons and account for seasonal variations. The surveys will be planned and executed in accordance with the controls identified in the project risk assessment to minimise the risk of incidents to a reasonably practicable level. Navigating the site will involve the use of all-terrain vehicle and walking, as needed, to collect relevant information crucial for developing the overall carbon farm site concept, with a specific focus on the optimal placement of electrical infrastructure. To aid in documentation, software tools like Google Maps will be utilised, complemented by topographic maps to assess landscape variations. Weather data from reliable sources, such as the Bureau of Meteorology, will also be gathered to address regional requirements pertinent to the carbon farm. Given the presence of existing buildings on the site, the information captured in Table 3 will be collected to support the design of off-grid infrastructure.

Table 3: Site structure survey details (template)

Title:	*Name of the structure*
Location:	*Name of the structure*
Topographic Height:	*XXX metres (m)*
Dimensions:	*LxWxH*
Connected Facilities:	*Name of facilities and detail*
External Ambient Temperature Summer:	*XX˚C*
Internal Ambient Temperature Summer:	*XX˚C*
External Ambient Temperature Winter:	*XX˚C*
Internal Ambient Temperature Winter:	*XX˚C*
Special Notes:	*Notes as required*

In addition to the aforementioned data collection methods, photos will also be taken during the site survey to provide visual documentation and support the development of requirements and subsequent design stages. Photos can serve as valuable references for understanding the existing infrastructure, layout, and conditions of the site. They can capture important details, such as the location of buildings, existing electrical systems, potential obstacles, and terrain features. These visual records will aid in assessing the feasibility of implementing off-grid infrastructure, identifying potential integration points, and informing the design decisions. By including photos as part of the site survey documentation, the project lead will have a visual reference that complements the gathered data and enhances the accuracy and effectiveness of subsequent requirement development and design processes.

3.2.2. Requirements Development

The development of requirements for this feasibility study will follow a process based on the methodology outlined by Robertson and Robertson (1999). Given the time constraints of the study, a detailed use case and scenario analysis will not be conducted. Instead, the requirements will be derived from available information and data gathered through the site survey. These requirements will be categorised into functional requirements, which define the system's necessary capabilities, and non-functional requirements, which specify the performance expectations of the system. Each requirement will be assigned a unique number and prioritised based on its importance in the design process. Verification activities will be focused on assessing the alignment of the design with the identified requirements and will be limited due to project time constraints. It should be noted that if the stretch goal of constructing the proposed subsystem is pursued, additional verification in the form of testing and demonstration will be necessary.

Requirements will be captured in a table such as the example provided below:

Table 4: Template requirements table

Requirement ID	Requirement Description	Priority	Verification Method
RID001	*Example description 1*	Must	Inspection
RID002	*Example description 2*	Should	Demonstration
RID003	*Example description 3*	Could	Test
RID004	*Example description 4*	Won't	Analysis

Where priority is defined by the MoSCoW method as quoted by Wiegers (2021):

- *"Must: The requirement must be satisfied for the solution to be considered a success.*
- *Should: The requirement is important and should be included in the solution if possible, but it's not mandatory to success.*
- *Could: It's a desirable capability, but one that could be deferred or eliminated. Implement it only if time and resources permit.*
- *Won't: This indicates a requirement that will not be implemented at this time but could be included in a future release."*

Requirement verification methods will be captured utilising the Inspection, Demonstration, Test and Analysis theory described by Adams (2010) where:

- Inspection: Non-destructive examination method used to evaluate a product or system. It involves utilising one or more of the five senses (visual, auditory, olfactory, tactile, taste) to assess the item. Inspection may also incorporate basic physical manipulation and measurements to gather information without causing any damage.
- Demonstration: Process of manipulating a product or system according to its intended use. The purpose of this manipulation is to verify and ensure that the achieved results align with the planned or expected outcomes.
- Test: The process of verifying a product or system by subjecting it to a controlled and predefined set of inputs, data, or stimuli. The objective of testing is to ensure that the product or system produces a specific and predefined output that aligns with the requirements defined for it.

- Analysis: The method of verifying a product or system using models, calculations, and testing equipment. Analysis enables the generation of predictive statements regarding the typical performance of the product or system based on confirmed test results from a sample set. It also allows for drawing conclusions about the product or system by combining individual test outcomes. Analysis is commonly employed to predict the breaking point or failure of a product or system by utilising non-destructive tests to extrapolate the point of failure

3.3. Author Off Grid Hardware Catalogue

In the design concept stage of the feasibility study, a hardware catalogue will be developed to capture and organise key fields relevant to each technology group of required off-grid hardware, as outlined in section 2.2. Traditionally, database input and storage are commonly used for cataloguing hardware. However, for this particular feasibility study, the number of products to be captured is relatively small, making the use of a database less suitable. Instead, a excel workbook will manage tables which will be inserted for each technology type to effectively organise and present the information. This approach allows for a more streamlined and manageable way of cataloguing the hardware. Each technology group will have its own dedicated sheet with fields gleaned from the supplier datasheets and will include relevant fields such as product name, technical specifications, suppliers, pricing, and any other necessary information.

By utilising this approach, the feasibility analysis can easily present and compare the information for each technology group for use within the design concepts. This method ensures a clear and organised representation of the hardware options without the need for a database setup. It is noted that key components of each subsystem design will be recorded within the hardware catalogue workbook. Sundry items such as fittings and fixings will only be recorded in the hardware catalogue if they present as a significant cost.

3.4. Propose Infrastructure Design Concept

Two infrastructure design concepts will be developed as part of this study. The first design will focus on a fully engineered solution for a security and monitoring subsystem which, through initial analysis, has been deemed necessary. This subsystem will be designed to operate off-grid and will include provisions for an internet connection, wireless network, lighting (including security lighting) and security cameras. The second design concept is a whole-of-site indicative design, which will outline the arrangement of planting plots, existing infrastructure, and future infrastructure requirements. This includes considerations for security and monitoring systems, water extraction and distribution, and commercial offices. This analysis will employ the load model methodology employed within UniSQ course ELE3803, alongside a set of assumptions and some indicative load values to understand what a whole of farm off-grid renewables mix might look like.

While drawing inspiration from the works of Al-Shamani et al. (2015) and Ghafoor and Munir (2015) both concept designs will adopt an integrated approach. However, the whole-of-site indicative design will rely on general assumptions to develop an approximate schematic of the off-grid electrical infrastructure and an estimated load profile as per Appendix D. This approach aims to provide a broad understanding of the system's requirements and capabilities. In contrast, the security and monitoring subsystem will employ a more rigorous approach to the load model in order to determine an optimised off-grid solution. This involves considering specific factors, such as energy demands, equipment specifications, and monitoring requirements.

As input to the detailed design subsections of the methodology, it is important to highlight that, given the constraints on available project resources and the limited availability of Cable Pro beyond its 14-day trial period, a decision has been taken to employ the jCalc cable sizing software for all cable sizing calculations. For future projects, it might be practical to explore alternative paid options that offer similar capabilities but come at a more cost-effective price point than the licensed version of jCalc.

3.4.1. Carbon Farm System/Subsystem Preliminary Design Methodology

Building upon the requirements established in prior activities, the core aim of the preliminary design phase is to identify the essential components needed to satisfy the specified requirements. This entails a two-step approach: initially, conceptualising the system's arrangement within the designated site through a site plot diagram, followed by the development of a subsystem block diagram. Subsequent subsections will provide an exhaustive breakdown of the specific criteria for each step in the design process.

3.4.1.1. Site Plot Diagram

The site plot diagram is designed to encapsulate the concept of operations, essential structures and components, as well as any key performance parameters that could guide subsequent design phases. The provided template diagram, captured in Figure 10, has been sourced from Google Maps, with delineated boundaries highlighted in gold. This template will be updated for each of the following system/subsystem designs.

Figure 10: Template site plot diagram

3.4.1.2. System Block Diagram

The methodology for creating the system block diagram draws inspiration from the example provided in Figure 7. However, recognising the inclusion of extra equipment and their corresponding interfaces, certain modifications have been applied to the template. Each system/subsystem block is treated as a "white box," revealing the internal details of its equipment groups and their associated interfaces. Within these equipment groups, individual pieces of equipment are similarly presented as "white boxes," detailing each equipment instance within the design. These block diagrams, identify the specific components for inclusion in the load model and following analysis.

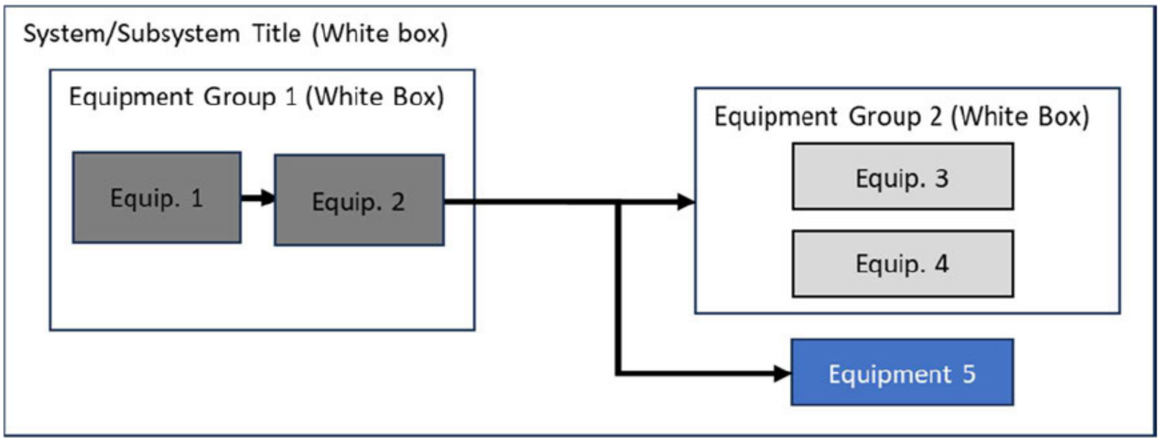

Figure 11: Template system block diagram

3.4.2. Carbon Farm System/Subsystem Load Modelling Methodology

A consistent methodology is employed for modelling load requirements across various system and subsystem elements under feasibility assessment. However, the precision of the load input parameters can vary, particularly when comparing the granularity between the security and fire monitoring subsystems and the whole farm concept. The representation of these load requirements may also differ within different design segments. However, for systems comprising multiple equipment components, a load profile graph must be included, displaying the total 24-hour usage and peak load.

The subsequent steps outline the utilisation of the template load model spreadsheet found in Appendix D.

Step 1: Identify all load components and their associated rate load as per Figure 12. Note colour coding used to easily identify certain load groups for use when considering optimisation options.

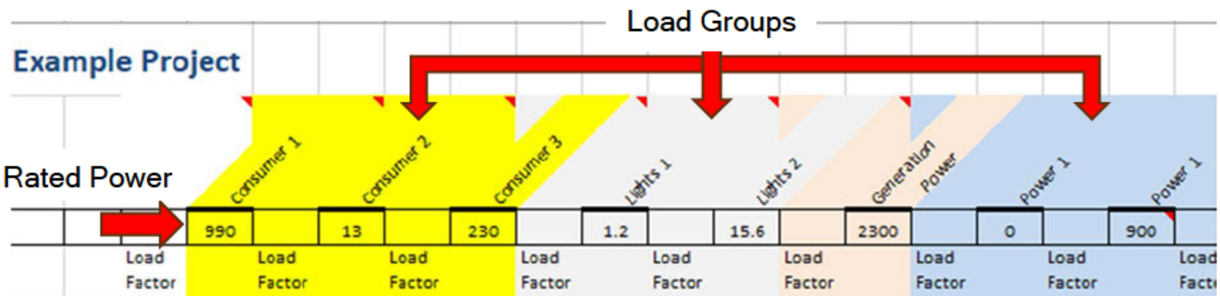

Figure 12: Load modelling process - identify load components

Step 2: Determine the load factor required per item and enter into associated column as a factor of 0 -1 across a 24-hour period in 30-minute intervals. The columns to the right will then calculate the required watthours required for that period.

Time (hr) (min)	Load Factor	Wh/30 min	Load Factor	Wh/30 min	Load Factor	Wh/30 min	Load Factor	kWh/30min	Load Factor	Wh/30 min	Load Factor	Wh/30 min	Load Factor	kWh/30min	Load Factor	Wh/30 min	L F
10 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	
11 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	
11 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	
12 00	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	

Figure 13: Load modelling process - determine load component load factor

Step 3: Review the total watthour requirement as a summation of each load component across row 58 as the first input to following detailed design.

Step 4: Consult the load model graph and extract the peak load figure required by the system as the second input to following detailed design.

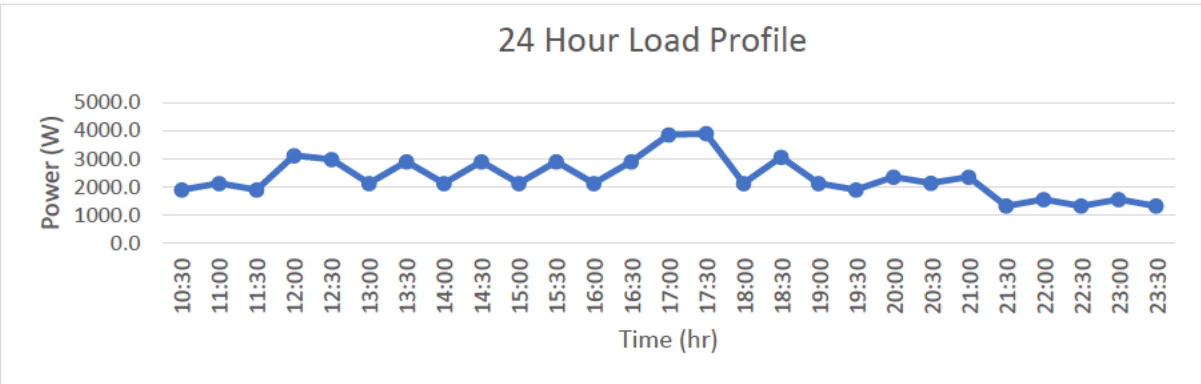

Figure 14: Load modelling process - peak load value

3.4.3. Security and Fire Monitoring Off-Grid Detailed Design Methodology

The subsequent detailed design phase integrates the outputs specified in the earlier design stages, incorporating them into detailed calculations. These calculations will, in turn, determine the exact specifications and capacity of the off-grid electrical infrastructure necessary to sustain a security and fire monitoring subsystem.

Stage 1: Assess the energy demand of the security and monitoring subsystem including prescribed equipment that accommodate an internet connection and Wi-Fi connectivity alongside the required monitoring cameras and security lighting. Record the results in the format provided in example by Table 5.

Table 5: Example load profile table (Ghafoor & Munir 2015)

Load profile					
Equipment in use	No. of equipments	Power of equipment	Total wattage, (W)	Daily appliances use (h)	Daily energy required (kW h d^{-1})
Lamps	5	40	200	6	1.20
Refrigerator	1	100	100	24	2.40
Washing machine	1	250	250	2	0.50
TV	1	100	100	6	0.60
Fans	2	100	200	0–6*	1.20
Total			850		4.70–5.90

Stage 2: The resultant power found at stage 1 is entered into the following average equipment efficiency derating formula to ultimately determine peak power (Al-Shamani et al. 2015):

$$P_p = \frac{daily\ energy\ consumption}{minimum\ peak\ sun} = \frac{E_r}{T_{min}} \tag{3.1}$$

The total current required can then be calculated:

$$I_{DC} = \frac{P_p}{System\ DC\ Voltage} = \frac{P_p}{V_{DC}} \tag{3.2}$$

The required series and parallel solar modules for each subsystem can then be determined by the following formulae:

$$N_p = \frac{I_{DC}}{Rated\ current\ of\ one\ module} \tag{3.3}$$

$$N_s = \frac{V_{DC}}{Module\ rated\ voltage} \tag{3.4}$$

The number of total solar modules can then be determined as:

$$N_m = N_s * N_p \tag{3.5}$$

Stage 3: Size the storage battery based on the estimated energy required for storage during reduced or non-production hours. The output of this stage is the number of required batteries and their series/parallel configuration (Al-Shamani et al. 2015). The number of days required to run autonomously (on battery power) determines a power demand:

$$E_{rou} \quad = E_r * number\ of\ days \tag{3.6}$$

Dividing this value by the maximum depth of discharge (MDOD) determines the safety factor concerning the required power:

$$E_{safe} = \frac{E_{roug}}{MDOD} \tag{3.7}$$

After selecting a battery and gleaning the rated voltage, determine the capacity of the battery bank:

$$C = \frac{E_{safe}}{Battery\ voltage\ V_b} \tag{3.8}$$

Next determine how many cells will be required by dividing the battery bank amp-hour rating by the amp-hour rating of each cell:

$$N_{batteries} = \frac{C}{C_b} \tag{3.9}$$

Now determine the series and parallel configuration:

$$N_s = \frac{V_{DC}}{V_b} \tag{3.10}$$

$$N_p = \frac{N_{batteries}}{N_s} \quad (3.11)$$

Stage 4: Size the charge controller by considering the short circuit current of the PV module, number of panels, and applying a safety factor (typically 1.25) (Al-Shamani et al. 2015).

$$I = I_{SC} * N_p * F_{safe} \quad (3.12)$$

Stage 5: Size the inverter based on the power required by concurrently operating devices, with an added safety factor of approximately 20% (Ghafoor & Munir 2015).

Stage 6: Develop a detailed single line diagram that can be utilised to develop the physical wiring solution in accordance with AS3000 and AS3008. Use the jCalc cable calculation tool (Staden 2023) to determine sizing, capture output reports as an appendix.

Stage 7: Perform a cost analysis, comparing the cost to install a submain to from the point of connection to the machinery shed where the security and monitoring subsystem will be located, to the proposed off-grid solution.

3.4.4. Whole-of-farm Concept Off-Grid Detailed Design Methodology

The detailed design for the entire farm adheres to a process similar to that in the preceding subsection. However, it's important to emphasise that load model input values and subsequent system design, are indicative only, based on estimates of typical load groups. It is not intended for implementation without undergoing further analysis. The methodology for the detailed design of each off-grid subsystem across the whole of farm concept is outlined as follows.

Stage 1: Review input requirements and develop a robust set of assumptions that will inform the load profile model. Assess the energy demand of each subsystem installation instance, including supply voltage, power demand of each appliance, and duration of use and input to the load model to determine per day energy usage. For the purpose of this study appliance usage will be assumed consistent across the seven days of the week.

Stage 2: Size the PV array based on the location and geographical situation. The resultant power found at stage 1 is entered into the following formula for each instance to determine peak power (Al-Shamani et al. 2015):

$$P_p = \frac{daily\ energy\ consumption}{minimum\ peak\ sun} = \frac{E_r}{T_{min}} \quad (3.13)$$

The total current required can then be calculated:

$$I_{DC} = \frac{P_p}{System\ DC\ Voltage} = \frac{P_p}{V_{DC}} \quad (3.14)$$

The required series and parallel solar modules for each subsystem can then be determined by the following formulae:

$$N_p = \frac{I_{DC}}{Rated\ current\ of\ one\ module} \quad (3.15)$$

$$N_s = \frac{V_{DC}}{Module\ rated\ voltage} \quad (3.16)$$

The number of total solar modules can then be determined as:

$$N_m = N_s * N_p \quad (3.17)$$

Stage 3: Determine the number of required batteries and their series/parallel configuration (Al-Shamani et al. 2015). The number of days required to run autonomously (on battery power) determines a rough power demand:

$$E_{rough} = E_r * number\ of\ days \quad (3.18)$$

Dividing this value by the maximum depth of discharge (MDOD) determines the safety factor concerning the required power:

$$E_{safe} = \frac{E_{rough}}{MDOD} \quad (3.19)$$

After selecting a battery and gleaning the rated voltage, determine the capacity of the battery bank:

$$C = \frac{E_{safe}}{Battery\ voltage\ V_b} \quad (3.20)$$

Next determine how many cells will be required by dividing the battery bank amp-hour rating by the amp-hour rating of each cell:

$$N_{batteries} = \frac{C}{C_b} \tag{3.21}$$

Now determine the series and parallel configuration:

$$N_s = \frac{V_{DC}}{V_b} \tag{3.22}$$

$$N_p = \frac{N_{batteries}}{N_s} \tag{3.23}$$

Stage 4: Size the charge controller by considering the short circuit current of the PV module, number of panels, and applying a safety factor (typically 1.25) (Al-Shamani et al. 2015).

$$I = I_{SC} * N_p * F_{safe} \tag{3.24}$$

Stage 5: Size the inverter based on the power required by concurrently operating devices, with an added safety factor of approximately 20% (Ghafoor & Munir 2015).

Stage 6: Develop simple single line diagrams to represent how the system might be wired. As per the determined design, use the jCalc cable calculation tool to determine the required cable sizes (Staden 2023).

Stage 7: Perform a simple cost analysis by calculating an estimated the capital cost of both off-grid electrical infrastructure and on-grid electrical connection in addition with an estimated payback period for any additional cost associated with an off-grid solution. Note that the electricity price will be taken as per the time of calculation plus a nominal 5% increase year on year.

3.4.5. Feasibility Analysis Methodology

The feasibility analysis will be executed through a two-step process. First, comparative material costs are analysed before, a payback period analysis is conducted to assess the time required to recoup the additional expenditure necessary to implement an off-grid design. It is upon these cost assessments and the subsequent payback period calculations that the feasibility of an off-grid design will be determined.

3.4.5.1. Material Cost Analysis

The initial phase of the cost analysis involves an examination of material expenses associated with both grid and off-grid designs. For every subsystem design instance, a pair of bill of material (BoM) tables, as outlined in Table 6, will be completed. This will provide a detailed breakdown of component-level costs alongside the overall cost.

Reiterating a factor mentioned in section 3.3, the key component BoM details will be sourced from the hardware catalogue. Sundry items like fittings and fixtures will only be documented in the hardware catalogue if they constitute a significant cost. Therefore, less significant items, those with a total cost below $100.00, will be individually researched and included in the BoM at their currently available prices.

Table 6: Template bill of materials

Item	Model	Quantity	Unit Price	Total Cost
Item description	*Item model/details*	*##*	*$#.##*	*$#.##*
				$#.##

3.4.5.2. Payback Period Analysis

When there is a positive cost difference between grid and off-grid design material costs, a payback period will be conducted.

First determine the cost difference between a grid and off-grid connected design. This will inform the rough number of payback years.

$$C_{\Delta} = C_G - C_{OG} \tag{3.25}$$

Using the template table below (Table 7), record the current daily supply charge and usage rate, for the three identified suppliers, as given on the Canstar Blue electricity rates comparison site for South Australia (Wrigley 2023).

Table 7: Template electricity usage cost table

Provider	Plan	Daily Supply Charge	Usage Rate	Cost Year 1	Cost Year 2	Cost Year 3
AGL	Value Saver	*$##.##*	*$##.##*	*$##.##*	*$##.##*	*$##.##*
Lumo Energy	Basic	*$##.##*	*$##.##*	*$##.##*	*$##.##*	*$##.##*
Simply Energy	Simply Energy Saver	*$##.##*	*$##.##*	*$##.##*	*$##.##*	*$##.##*

Next, determine the year one cost by multiplying the daily supply charge (D_{sc}) by the number of days in a year and adding the usage cost multiplied by the number of days used.

$$C_1 = (D_{SC1} * 365) + (U * E_r) * Days \quad (3.26)$$

Similarly, the year 2, year 3, year X... cost can be evaluated by the same equation, with 5% growth. Continue this until the cost difference is amount is absorbed by the rough number of payback years.

$$C_2 = C_1 * 1.05$$
$$\dots C_x = C_{x-1} * 1.05 \quad (3.27)$$

To determine the exact payback years, add up the full year costs before subtracting the cost delta. Then subtract the last years cost value (C_{LY}) before dividing by the last years cost.

$$Partial\ year = \frac{C_{LY} - ((C_1 + C_2 + \cdots) - C_\Delta)}{C_{LY}} \quad (3.28)$$

Add this to the number of full year costs, required to make up the difference to determine the exact payback period. Ie. 2 full year costs plus the partial year. Record the values in a table similar to Table 8.

Table 8: Template payback period table

Provider	Plan	Payback Period
Provide name	*Plan description*	*Payback years*

Chapter 4: Results

Chapter 4 is divided into five main sections that present the results captured during the execution of the methodology. Specifically, it documents key characteristics noted during the topographic, climate review and site survey as input to the hardware requirements that inform the various system designs and following off-grid feasibility analysis for this carbon farm project. The chapter concludes with a discussion of the results obtained from design and feasibility analysis, which will serve to address the aims of this study.

4.1. Site Survey

In accordance with the methodology a site survey was undertaken, encompassing on-site inspections, involving in-person audits of the proposed carbon farm, as well as examination of pertinent online resources. These resources included climate data from the Bureau of Meteorology, topographic maps, and Google Maps.

4.1.1. Topographic and Climate Review

The topographic heat map, depicted in Figure 15 below, offers valuable insights into the diverse elevation characteristics of the prospective carbon farming project. This data will inform the design of the wireless connectivity options across the entire farm. Prominent elevations are notably concentrated in two local regions, approximately to the north and south of the property, with the highest point reaching an elevation of 160 metres. Conversely, the lowest point is situated along the central creek that runs through the centre of the property, registering an elevation of 124 metres. This contrast yields a potential elevation difference of 36 metres within the farm's boundaries. Additionally, it's worth noting the significant elevation points where network equipment will most likely be installed; the machinery shed, positioned at 152 metres, and the shack, located at 136 metres.

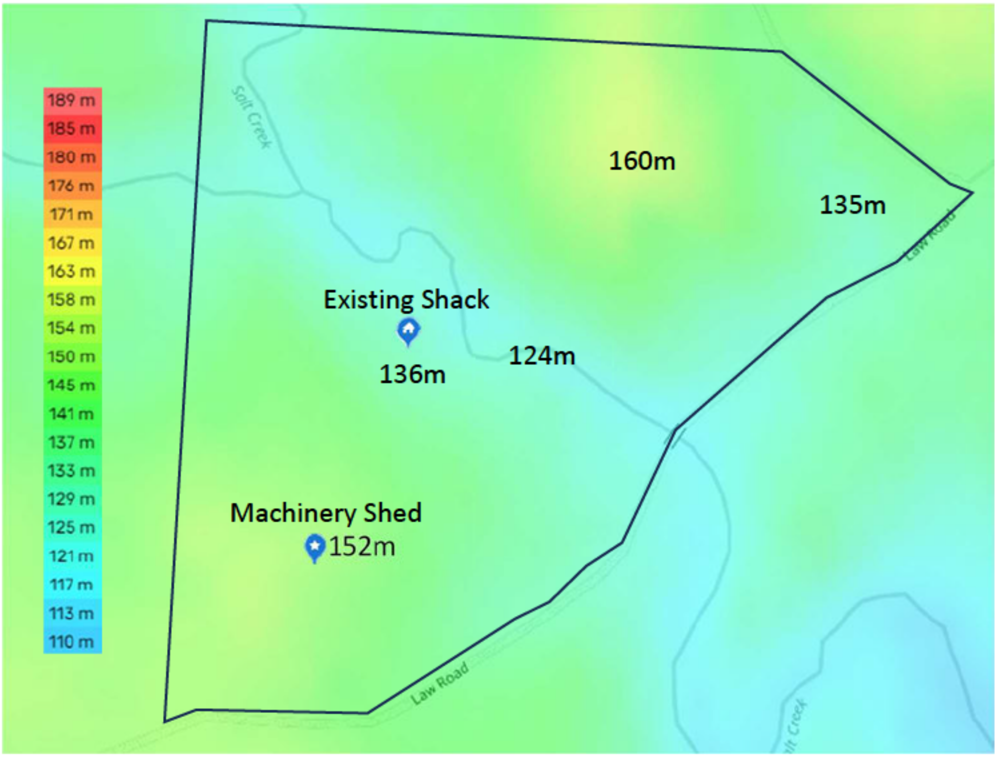

Figure 15: Topographic image of the proposed carbon farm (Australia topographic map 2023)

The sunshine hours heat map, as depicted in Figure 16 below, presents a view of the average daily sunshine hours across Australia. This data will serve as a key determinant in sizing the solar array for the prevailing off-grid designs. Specifically, for the carbon farm situated in the Adelaide region, the data reveals a minimum of 4 hours of sunshine per day (*Average daily sunshine hours - July* 2023).

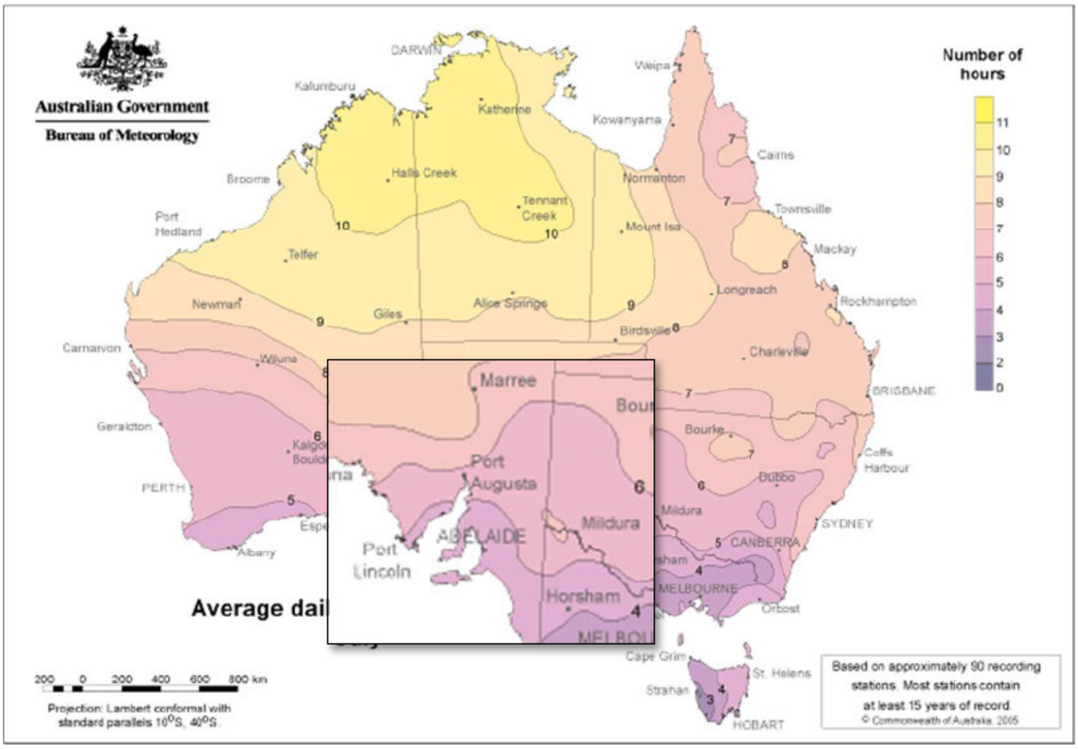

Figure 16: Minimum daily sunshine hours - Australia

4.1.1.1. Average Rainfall

Water captured and stored on the farm can be utilised for both firefighting and irrigation of new carbon sink forests. In order to size structure attached water storage solutions, data from the Bureau of Meteorology, summarised in Table 9 and Table 10 below (*Daily Rainfall* 2023), provides insight towards water captured via annual rainfall.

Table 9: Monthly mean and median rainfall at Rockleigh

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	23.7	25.1	25.6	37	47.2	58.4	67.5	69	59.2	43.1	30.6	31.7
Median	17	13.8	17.2	31.6	45	51.5	65.2	67.2	52.6	37.6	27.2	20

Table 10: Annual mean and median rainfall at Rockleigh

Statistic	Annual Total
Mean	518.1
Median	445.9

4.1.1.2. Average Temperature

Informing specific hardware requirements, various temperature metrics are utilised to determine the environmental operating conditions that the proposed hardware will encounter. Table 11 below presents the data obtained from two reports generated using the 'Climate Data Online' tool; accessible via the Bureau of Meteorology. This data records the highest and lowest daily, as well as mean monthly temperatures (*Climate Data Online* 2023).

Table 11: Average, highest and lowest temperatures at Rockleigh

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest Monthly Mean	30.6	29.5	27.4	23.5	19.1	16.1	15.7	17.1	20.2	23.9	26.8	28.8
Lowest Monthly Mean	13.5	12.7	10.7	7.6	5.3	1.3	3.0	2.5	3.1	6.0	8.4	11.1
Highest Daily	48.0	46.7	42.1	39.0	30.7	23.7	26.9	31.0	35.2	39.2	45.3	48.1
Lowest Daily	6.9	5.2	3.1	0.5	-4.1	-4.1	-4.6	-4.4	-3.1	-1.1	1.7	2.6

4.1.2. Structures

Presently, the proposed carbon farm comprises two structures. The first is a machinery shed, situated in the southwestern corner at an elevation of 152 metres. The second is a centrally located shack, positioned at an elevation of 136 metres. Importantly, neither structure has access to wired internet or grid electricity. Acknowledging the need for establishing a distributed wireless network across the property, an assessment at each facility location will be conducted to determine their suitability for housing base station equipment. Additionally, as a component of the summary off-grid design concept, water collection and storage capacity will also be surveyed.

4.1.2.1. Machinery Shed Survey

The machinery shed presents as an ideal candidate for the implementation of the security and fire monitoring system. Its elevation offers a vantage point for receiving and distributing a wireless internet signal. Furthermore, the shed possesses a large roof area, making it capable of accommodating a considerably larger solar array than might be required to support the modest power consumption of the security and fire monitoring system. One noteworthy aspect to address is the lack of current physical security, which might protect from both pests and potential theft. The installation of secure doors however, is an investment that will be required regardless, as the carbon farming business will require the storage of large machinery. The photos, coupled with information captured in Table 12, provide detail to inform forthcoming design.

Figure 17: Photo of the machinery shed

Table 12: Machinery shed survey

Title:	Machinery shed
Location:	South West corner
Topographic Height:	152 metres (m)
Dimensions:	12x6x4 metres (m) Roof Pitch: 12.5˚
Single Roof Aspect Area:	36.87m^2
Average Annual Rain Harvest:	38,209L
Connected Facilities:	22500L Water Tank Internal lighting - Powered via petrol generator
External Ambient Temperature Summer:	29˚C
Internal Ambient Temperature Summer:	31˚C
External Ambient Temperature Winter:	16˚C
Internal Ambient Temperature Winter:	17˚C
Special Notes:	Lack of security - No front doors

Figure 18: Machinery shed attached water storage (22,500L)

4.1.2.2. Shack/Office Survey

Although centrally situated, the shack is not the ideal candidate for the security and fire monitoring system. Its placement within a valley significantly restricts its ability to receive a consistent 4G signal, necessitating the need for supplementary infrastructure. However, the shack presents itself as a more fitting choice for an office setup. This is primarily due to the presence of a septic system, stored water resources, building security, and abundant roof space for accommodating a substantial solar array.

Table 13: Shack/office survey

Title:	Shack/Office Building
Location:	Centre
Topographic Height:	136 metres (m)
Dimensions:	15x9x2.7 metres (m) Roof Pitch: 6˚
Roof Area:	135m^2
Average Annual Rain Harvest:	69,944L
Connected Facilities:	9000L Water Tank Internal lighting - Powered via petrol generator
External Ambient Temperature Summer:	29˚C
Internal Ambient Temperature Summer:	34˚C
External Ambient Temperature Winter:	16˚C
Internal Ambient Temperature Winter:	18˚C
Special Notes:	Internal insulation poor 4G connectivity poor (no phone signal) Septic system available

Figure 19: Photo of the existing shack/office

4.1.3. Water Source

In years without drought conditions, Salt Creek, which runs through the centre of the property, serves as a reliable water source. This creek exhibits a rapid drainage pattern and contains multiple water catchment areas that can be estimated through rough volume calculations during non-flowing periods.

4.1.3.1. Approximate Average Capacity

During summer, there are 3 areas that retain water, all of which have been measured approximately 10m x 10m at an approximate depth of 0.5m, equating to 50,000L of storage across three catchments; 150,000L. It is also estimated that the creek flows to capacity, in each catchment, three time a year, equating to an approximate available retention of 450,000L, assuming each catchment is drained to empty. There is no existing pumping infrastructure through which to extract and transfer water between storage.

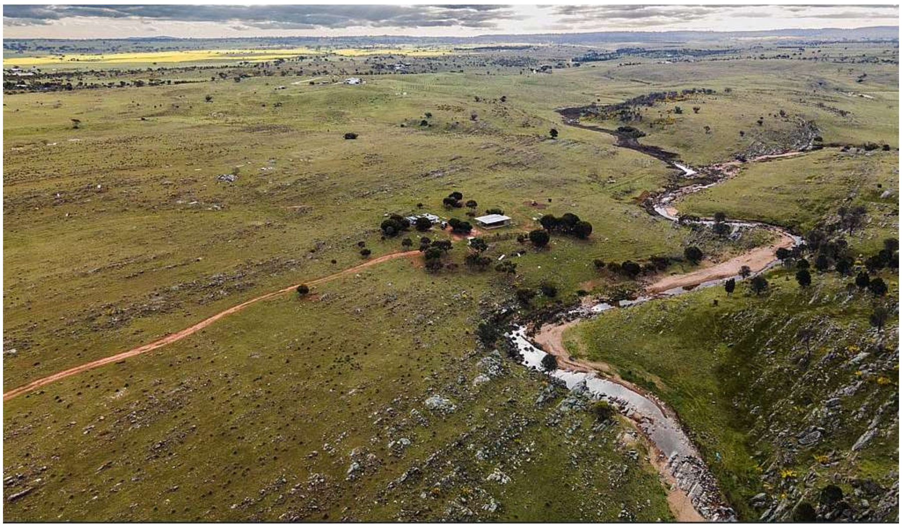

Figure 20: Aerial photo of the available water source

Figure 21: Photo of one example water catchment

4.2. Requirements

4.2.1. Rockleigh Carbon Farm Requirements

Table 14 below details the 'system' level requirements, as an output of the site survey and literature review, referenced in the development of the forthcoming design processes.

Table 14: Table of Rockleigh carbon farm requirements

Req. ID	Requirement Description	Priority	Verification Method
RID001	The carbon farming systems/subsystems design shall be constrained by the environmental planting flora native to Southern Murray Mallee region.	Must	Inspection
RID002	The security and fire monitoring subsystem must visually monitor localised fires and for pest and livestock incursions.	Must	Demonstration
RID003	The security and fire monitoring subsystem must visually monitor capital assets including farm equipment and carbon sequestration assets.	Must	Demonstration
RID004	The security and fire monitoring subsystem visual footage should cover the entirety of the farm.	Should	Demonstration
RID005	The security and fire monitoring subsystem must be accessible remotely.	Must	Test
RID006	The security and fire monitoring subsystem must be autonomous for a minimum of one day.	Must	Test
RID007	The water storage and transfer subsystem should store a water volume that is able to irrigate seedling plants and trees for one year of draught.	Should	Analysis
RID008	The water storage and transfer subsystem must store a water volume of a minimum 5,000L adjacent to major structure for the purpose of firefighting (Department Planning Transport and Infrastructure 2020)	Must	Inspection
RID009	The water storage and transfer subsystem must transfer water against a minimum head of 20m.	Must	Test
RID010	The carbon farming system should be fitted with a residence facility capable of housing up to three adults for up two nights in one week.	Should	Inspection
RID011	The residence subsystem must be autonomous for a minimum of 2 days.	Must	Test
RID012	Non-residence subsystems must be autonomous for a minimum of 1 day.	Must	Test
RID013	Solar array design must be constrained by a minimum of 4 sun hours per day.	Must	Inspection

4.2.2. Hardware Requirements

Upon conducting an initial evaluation of the available wireless security monitoring hardware, two viable connectivity options were identified: 4G and 2.4G Wi-Fi. It became evident that Wi-Fi cameras offer a more cost-effective solution, primarily because each 4G camera is more costly and requires its own SIM card, leading to recurring expenses. Taking this cost consideration into account and factoring in the results of the site survey, the following requirements have been determined.

Table 15: Hardware requirements table

Req. ID	Requirement Description	Priority	Verification Method
RID014	Hardware installed outside must continue to operate if subjected to a temperature of 48.1˚C +5%	Must	Inspection
RID015	Hardware installed outside must continue to operate if subjected to a temperature of -4.6˚C -5%	Must	Inspection
RID016	Hardware installed in a position where it is exposed to sunlight must be UV resistant.	Must	Inspection
RID017	Hardware installed in a position where it is exposed to weather must be constructed to a minimum IP44 rating.	Must	Inspection
RID018	Solar system design should use a maximum average solar hours exposure of 7 hours per day.	Should	Analysis
RID019	A network of 2.4GHz Wi-Fi must be made available to wireless hardware.	Must	Test
RID020	Off grid systems must be designed with a minimum of one day of redundancy.	Must	Analysis
RID021	Batteries subjected to temperature extremes should be insulated.	Should	Inspection
RID022	Batteries must be installed in a ventilated position.	Must	Inspection
RID023	When installed on the roof of a structure, solar array sizes must be constrained by the area of the roof.	Must	Analysis
RID024	Electrical wiring must comply with AS3000.	Must	Inspection
RID025	Wireless cameras should be positioned so as to monitor property entries and significant infrastructure.	Should	Inspection
RID026	Wireless cameras should be positioned so as to provide sight of approaching fires from all directions.	Should	Inspection
RID027	Water should be able to be transferred for a distance up to 200m.	Should	Inspection
RID028	Water should be able to be transferred against a head of up to 40m.	Should	Inspection

4.3. Security and Fire Monitoring Subsystem Feasibility

The design of the security and fire monitoring system is designed in such a way as to determine the load requirements and consequently, the scale of the off-grid electrical infrastructure. The objective is to establish a robust 2.4GHz Wi-Fi network across a substantial portion of the property, ensuring remote monitoring capabilities through a network of wireless cameras.

4.3.1. Security and Fire Monitoring Subsystem Assumptions/Exclusions

To guide the design and subsequent feasibility analysis, when compared to a grid-connected configuration, the following assumptions and exclusions have been identified.

Table 16: Security and fire monitoring system assumptions

Assumption/ Exclusion ID	Assumption Description
AE001	It is assumed that each access point shall provide 2.4GHz Wi-Fi connectivity up to 300m in diameter.
AE002	For the cost comparison, assume grid connection is available at the shack.
AE003	Labour costs are excluded from the cost comparison

4.3.2. Security and Fire Monitoring Subsystem Design

The design of the security and fire monitoring (SFM) system is evolved incrementally, starting from the site plot and progressing to calculations that guide component selection. Throughout this process, a comprehensive hardware catalogue is developed, capturing performance attributes and associated dimensions. This catalogue is the primary resource for component selection phase and subsequent cost analysis.

4.3.2.1. Preliminary Design - Site plot

The site plot, described in Figure 22, offers an overview of the security and fire monitoring system, presenting the intended distribution of a wireless network across the property. The 'base station' situated at the machinery shed will serve as both the internet connection point and access point. Meanwhile, strategically positioned repeaters, spaced approximately 250 metres apart, will extend the internet connection's coverage across the entire property. Solar powered Wi-Fi cameras have been strategically placed at key vantage points. These cameras are located to provide long-range visibility for fire detection and security surveillance.

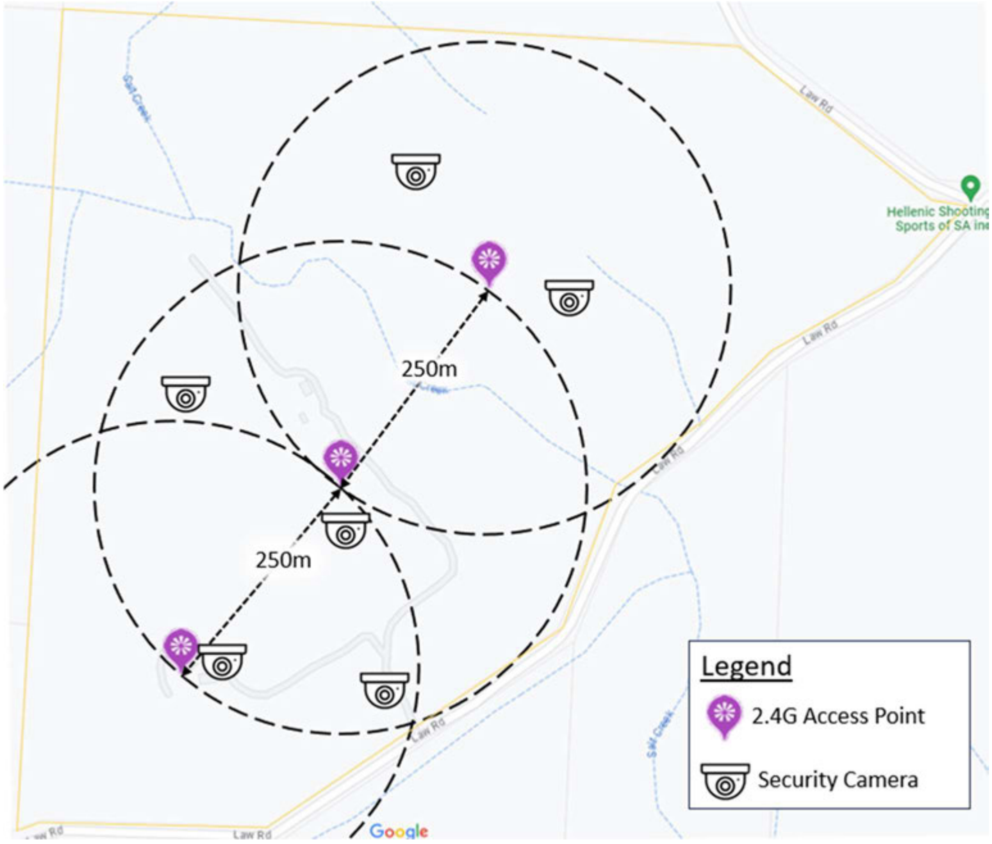

Figure 22: 2.4G wireless network and monitoring equipment layout

4.3.2.2. Preliminary Design - System Diagram

Figure 23 presents a system block diagram, providing a depiction of the key components within the security and fire monitoring system and how they interface with each other.

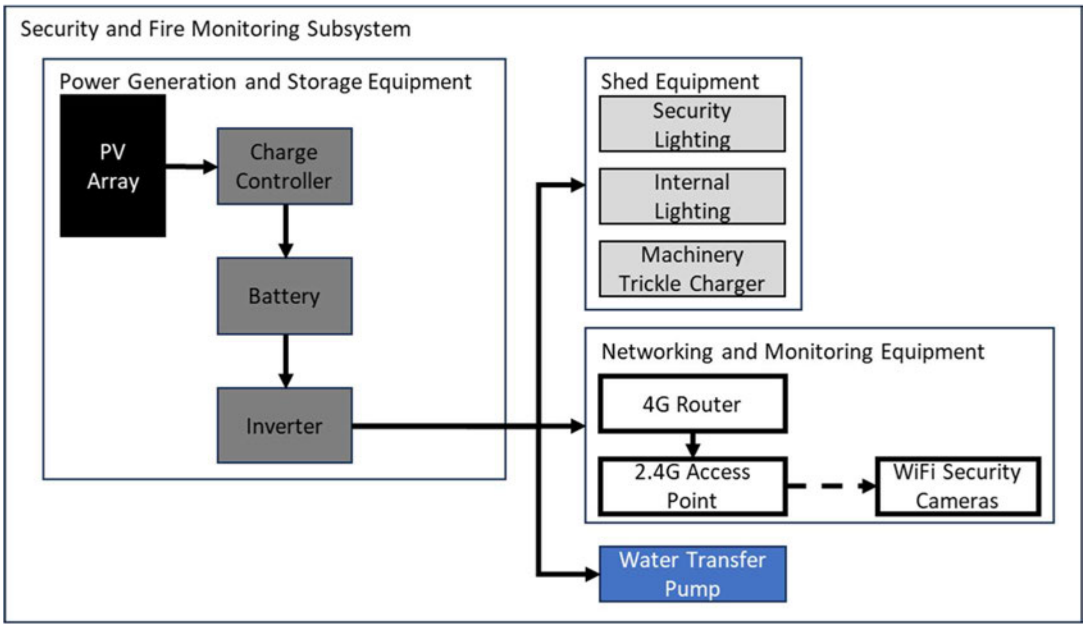

Figure 23: Security and fire monitoring subsystem diagram

4.3.2.3. Detailed Design - Off Grid Electrical Infrastructure SFM System Size Calculation

Stage 1: Assess the energy demand of the security and monitoring subsystem including prescribed equipment that accommodate an internet connection and Wi-Fi connectivity alongside the required monitoring cameras and security lighting.

Table 17, presented below, offers a summary of the equipment projected for this specific use case. For an understanding of the breakdown of the 24-hour consumption details over time, please refer to Figure 16, with source information available in Appendix E.

Table 17: Summary fire & security monitoring system load profile

Equipment	No. of equip.	Equip. power (W)	Total wattage (W)	Daily use (h)	Daily energy required ($kWhd^{-1}$)
4G Router	1	12	12	24	288
Wireless Access Point	1	20	20	24	480
Solar Charger (idle consumption)	1	1.2	1.2	24	28.8
Inverter	1	15.6	15.6	24	374.4
LED Flood Light	1	100	100	3	300
Linear LED	3	40	120	2.5	300
Water Transfer Pump	1	400	400	1	400
Trickle Charger (Charge)	1	138	138	0.5	69
Trickle Charger (Trickle)	1	128.8	128.8	14	1803.20
Total (W)			935.6		4043.40

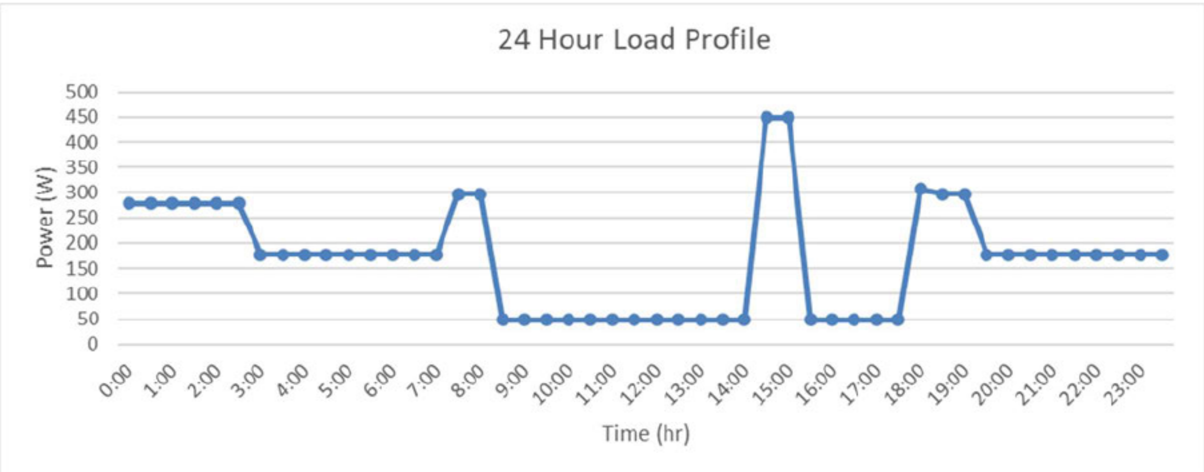

Figure 24: Fire & security monitoring system load model

Figure 25 identifies the various load categories and how, as a proportion, they contribute towards total consumption.

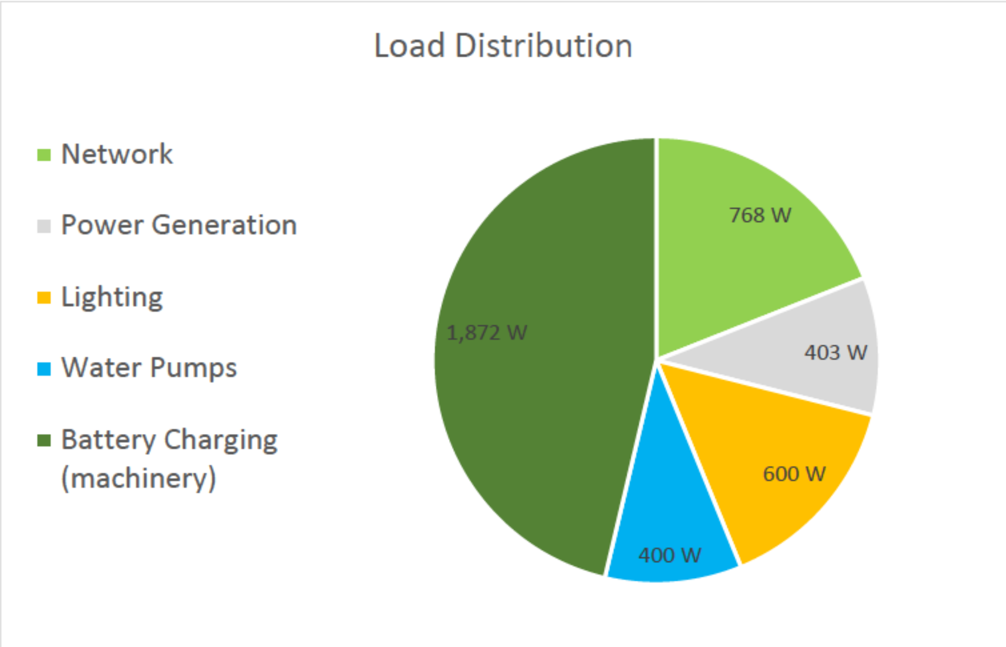

Figure 25: Fire & security monitoring system load distribution

Stage 2: The resultant power found at stage 1 is entered into the following formula to determine the minimum amount of power generated by solar energy (Al-Shamani et al. 2015):

Minimum annual peak sun hours in Adelaide Hills region of South Australia: 4 hours

$$P_p = \frac{daily\ energy\ consumption}{minimum\ sun\ hours} = \frac{4043}{4} = 1010.75Wh \tag{4.1}$$

The total current required can then be calculated:

$$I_{DC} = \frac{P_p}{System\ DC\ Voltage} = \frac{1010.75}{30.8} = 32.82A \tag{4.2}$$

Choosing WINAICO WST-333MG, 333W Monocrystalline Solar Panel (Appendix F), the required series and parallel solar modules for each subsystem can then be determined by the following formulae:

$$N_p = \frac{I_{DC}}{Rated\ current\ of\ one\ module} = \frac{32.82}{10.82} = 3.03 == 3 \tag{4.3}$$

$$N_s = \frac{V_{DC}}{Module\ rated\ voltage} = \frac{30.8}{30.8} == 1 \tag{4.4}$$

The number of total solar modules can then be determined as:

$$N_m = N_s * N_p = 3 * 1 = 3 \tag{4.5}$$

Stage 3: Size the storage battery based on the estimated energy required for storage during reduced or non-production hours. The output of this stage is the number of required batteries and their series/parallel configuration (Al-Shamani et al. 2015).

The number of days required to run autonomously (on battery power) determines a rough power demand:

$$E_{rough} = 4043 * 1 = 4043Wh \tag{4.7}$$

Choosing 12V ITECH120X 120Ah lithium battery (Appendix I) and dividing this number by the MDOD of 80%, to achieve greater than 2000 cycles, determines the safety factor concerning the required power:

$$E_{safe} = \frac{4043}{0.80} = 5053.75Wh \tag{4.8}$$

Reviewing the data sheet and taking the rated voltage, determine the capacity of the battery bank:

$$C = \frac{5053.75}{12} = 421.15Ah \tag{4.9}$$

Next determine how many cells will be required by dividing the battery bank amp-hour rating by the amp-hour rating of each cell:

$$N_{batteries} = \frac{421.15}{120} = 3.5\ batteries == 4\ batteries \tag{4.10}$$

Now determine the series and parallel configuration:

$$As\ the\ battery\ system\ voltage\ is\ 12VDC, the\ four\ batteries\ will\ be\ connected\ in\ parallel.$$

Stage 4: Size the charge controller by considering the short circuit current of the PV module, number of panels, and applying a safety factor (typically 1.25) (Al-Shamani et al. 2015).

$$I = I_{SC} * N_p * F_{safe} = 11.39 * 3 * 1.25 = 42.71A \quad (4.11)$$

The charge controller must also be able to withstand the maximum load current hence;

$$I_{max} = P_p/V_{DC} = 448.8/12 = 37.4A \quad (4.12)$$

The Renogy RNG-CTRL-RVR40 (Appendix G) is chosen as the charge controller due to its maximum rated solar input of 1040W at 24V (43.33A) and 40A rated charge current.

Stage 5: Size the inverter based on the power required by concurrently operating devices, with an added safety factor of approximately 20% (Ghafoor & Munir 2015).

Maximum power required is 448W (537.6W with safety factor). The Renogy INVT-PUH1-201235-AU, 2000W inverter (Appendix H) will be chosen to allow for future expansion which might include higher peak loads.

Stage 6: Develop a detailed single line diagram that can be utilised to develop the physical wiring solution in accordance with AS3000.

In order to determine the required cable sizes, the jCalc AS/NZS 3008 cable calculator was utilised (Staden 2023). The values for current are provided previously however, the maximum demand drawn from the battery is calculated by accounting for the maximum continuous output of the inverter at an efficiency of 90%: 2000W/12/0.9 = 185A. The summary output of each calculation found in Table 18 with each report generated is captured in Appendix K.

Table 18: Fire and security monitoring cable calculation summary (off-grid)

Cable	Current Draw	Voltage (VDC)	Type	Parallel Cables	Length (m)	Installation	Cable Size (mm^2)
Solar Panel Connection	37A	30.8	PVCV90	3	5	Touching Surface	6
Solar Charge Controller	40A	12	XLPEX90	1	1	Touching Surface	6
Battery Cables	185A	12	XLPEX90	1	1	Touching Surface	70

The single line diagram presented in Figure 26 below offers a detailed view of the key components, including circuit protection, of the off grid electrical infrastructure required to support the base station for a distributed Wi-Fi network and associated equipment identified in Figure 23.

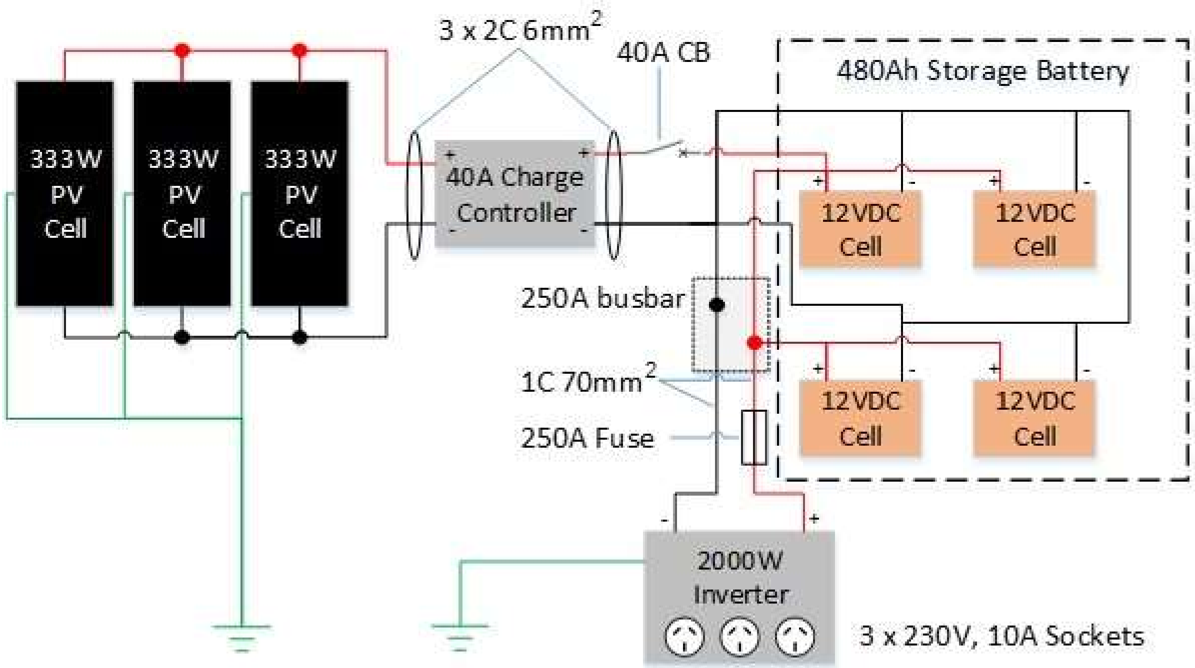

Figure 26: Fire and security monitoring subsystem single line diagram

4.3.3. Security and Fire Monitoring Subsystem Feasibility Analysis

Stage 7: Perform a cost analysis, comparing the cost to install a submain to from the point of connection to the machinery shed where the security and monitoring subsystem will be located, to the proposed off-grid solution.

The cost summary given in Table 19 details the key components, selected from the hardware catalogue, as required to construct the off-grid system designed in the previous steps. Note sundry items such as mounting hardware and cable supports are excluded from the cost breakdown.

Table 19: Off grid security and fire monitoring system cost summary

Item	Model	Quantity	Unit Price	Total Cost
Solar Panel	WST-333MG	3	$309.00	$927.00
Solar Angle Mount	Clenergy Tripod Adjustable 15-30 Degree	2	$70.00	$140.00
Solar Mounting Rail	CLENERGY PV-EZRACK CUTTER RAIL 4400MM	2	$49.00	$98.00
Solar Isolator	ZJ Beny 4 Pole 32A 1200V DC Isolator	1	$50.00	$50.00
Panel Clamps	Clenergy End Clamp 35mm	12	$3.50	$42.00
Battery	iTECH120X PRO	4	$899.00	$3596.00
Charge Controller	RNG-CTRL-RVR40-AU	1	$169.99	$169.99
Inverter	R-INVT-PUH1-201235-AU	1	$319.99	$319.99
Inverter Cable	Enerdrive Cable Kit to Suit up to 2000 Watt Inverters, 70mm 2 x 1.2m (Fused)	1	$309.00	$309.00
Battery Cable (Short)	400mm Red/Black Battery Lead 70mm^2	4	$29.90	$119.60
Battery Cable (Long)	600mm Red/Black Battery Lead 70mm^2	4	$34.90	$139.60
Earth Wire	6.0mm Building Wire Green / Yellow Earth (100mtr Roll)	1	$137.50	$137.50
Battery Isolator	Single Circuit On-Off 300A Mini Battery Switch	1	$36.00	$36.00
Solar Charger Cable	1000mm 6mm Sq Tinned Twin Core Cable	10	$6.50	$65.00
Solar Charger Circuit Breaker	40A Manual Reset Circuit Breaker	1	$34.95	$34.95
Bus Bar	Alvota Red/Black 250A busbar	2	$49.70	$99.40
Solar Connectors	Branch Solar Panel Parallel Connectors (Pair)	2	$19.50	$39.00
Connectors/Lugs	Cable Lugs 70Mm 8Mm Stud	10	$3.00	$30.00
				$6,353.03

Table 20 provides a concise summary of the cable size calculations for a grid-connected system, which is documented in each cable jCalc report catalogued in Appendix K.

Table 20: Fire and security monitoring cable calculation summary (grid connected)

Cable	Current Draw	Voltage (VAC)	Type	Parallel Cables	Length (m)	Installation	Cable Size (mm^2)
Mains	10A	230	XLPEX90	1	310	Exposed to sun	35
Power Point	10A	230	PVCV90	1	10	Touching Surface	1.5

Table 21 provides a breakdown of the essential components necessary to sustain a 10A electrical load situated 310 metres away from a hypothetical service point situated at the shack. The mains supply cable will be installed on a catenary wire, exposed to sunlight, and supported by steel galvanised stobie poles, installed at intervals of approximately 30 metres apart.

Table 21: Grid connected security and fire monitoring system cost summary

Item	Model	Quantity	Unit Price	Total Cost
Mains Cable	35mm XLPE Single Core (per metre)	610	$7.86	$4873.20
Power Cable	1.5mm Twin and Earth (100mtr Roll)	1	$97.90	$97.90
10A GPO	Clipsal Classic Quad Powerpoint	1	$37.40	$37.40
Earth Wire	6.0mm Building Wire Green / Yellow Earth (100mtr Roll)	1	$137.50	$137.50
Stobie Pole	Residential Power Pole / Private Pole 4 Inch x 6.5mtr	10	$341.00	$3410.00
Catenary wire	Catenary / Guy Wire 150mtr Roll	2	$59.40	$118.80
Cable Ties	250mm Black Cable Ties (100 Pack)	6	$5.50	$33.00
Concrete	20kg Concrete Mix	10	$8.27	$82.70
Switchboard	4 Pole Switchboard (Surface)	1	$9.50	$9.50
Circuit breaker	Clipsal RCD/MCB Safety Switch 1 Pole 10A	1	$28.60	$28.60
Main switch	Clipsal MAX9 1 Pole Main Switch 100A	1	$9.90	$9.90
Earth Stake	Standard Earth Stake / Rod	1	$10.45	$10.45
Earthing Accessories	Standard Earth Stake / Rod + Clamp + Warning Tag	1	$11.55	$11.55
				$8,860.00

4.4. Whole Carbon Farm Off Grid Design Concept

The design of the whole off grid design concept is designed in such a way as to determine approximate and example load requirements and consequently, the scale of the off-grid electrical infrastructure. The objective is to determine the feasibility of off-grid electrical infrastructure in support of a hypothetical electrical load demanded by a residence/office, machinery shed and water transfer system.

4.4.1.1. Assumptions/Exclusions

To guide the design and subsequent feasibility analysis, when compared to a grid-connected configuration, the following assumptions and exclusions have been identified.

Table 22: Carbon farm summary concept design assumptions

Assumption/ Exclusion ID	Assumption Description
AE004	It is assumed that the hot water service will be a solar, evacuated tube system type.
AE005	Labour costs are excluded from the cost comparison however, it is acknowledged that SA Power Networks will charge a fee for connection of submains.
AE006	Water transfer will be provided by some form of exotic supply (petrol powered machinery/off-grid electricity) and is excluded from the forthcoming load calculation.
AE007	The cost comparison will exclude internal cabling as this will be equivalent for each supply variant.
AE008	The following set of calculations and cost comparison will be conducted on the residence/office subsystem only. The remote water collection/distribution subsystem will be determined in within further research, with the determination of residence/office distribution versus off-grid configuration being compared.
AE009	It is assumed that there is enough physical roof space, available on the proposed structures, to install the required solar arrays.

4.4.2. Carbon Farm Summary Concept System Design

The design of the carbon farm summary concept system is evolved incrementally, through preliminary design stages that will identify the key subsystems that will be analysed for feasibility in detailed design. Throughout the process, the existing hardware catalogue referenced and further developed where required.

4.4.2.1. Preliminary Design - Site plot

Illustrated in Figure 27, the site plot provides an approximate depiction of the hypothetical farm-wide system, delineating the planned deployment of the security and fire monitoring system, water storage points, and key facilities. The key facilities, the machinery shed and house/office will serve as the primary sources of electrical demand, and their energy requirements will be driving to the forthcoming analysis. Additionally, for the scope of this analysis, water extraction and transfer systems will be treated as external to the office/residence subsystem, with off-grid feasibility determined separately.

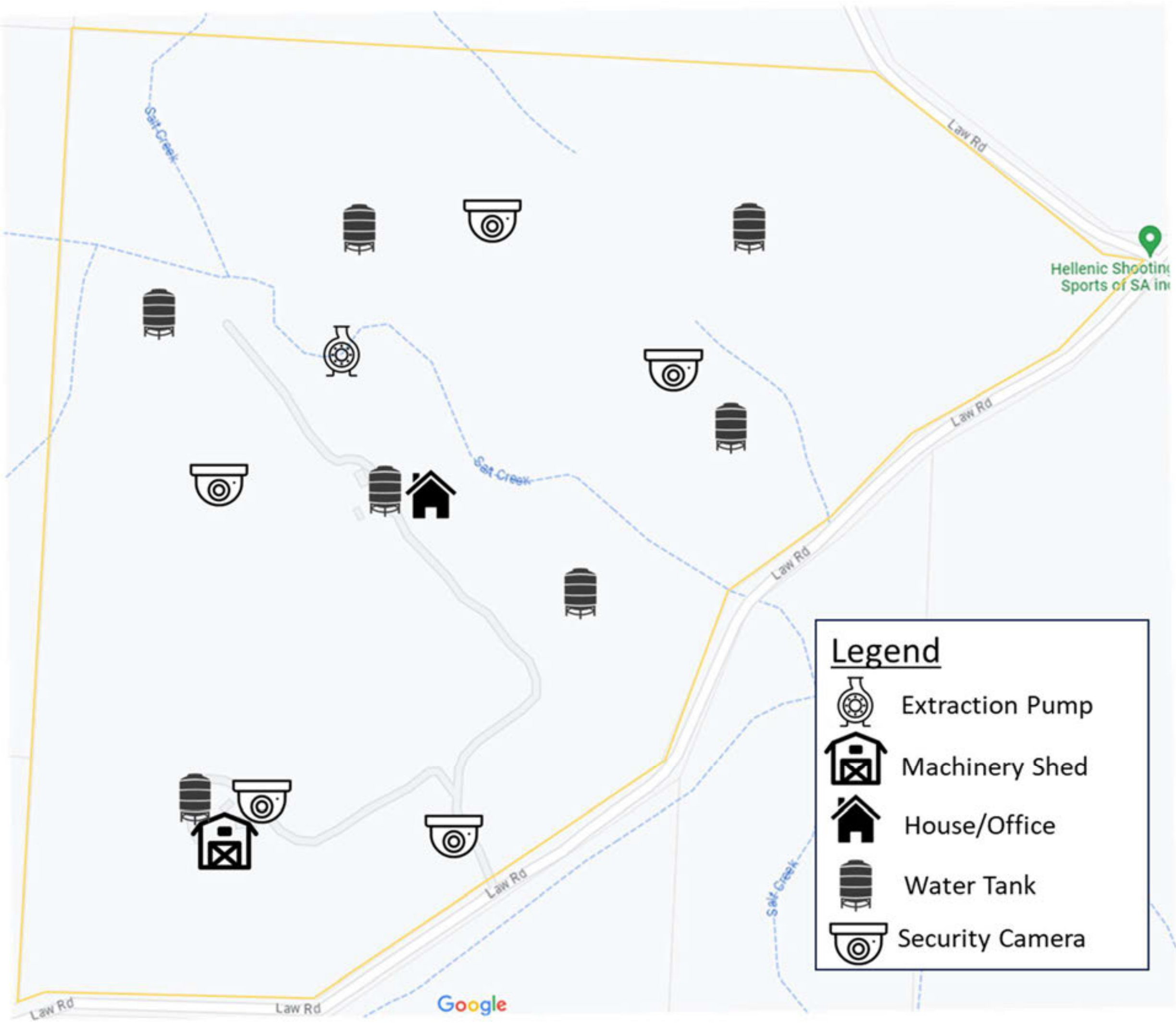

Figure 27: Carbon farm summary concept design equipment layout

4.4.2.2. Preliminary Design - System Diagram

Figure 28 details a summary concept design that might support a carbon farm through residence and office duties, security and fire monitoring and remote, distributed water collection and distribution subsystems. These subsystems are those which were determine, by analysis of the requirements conducted during the literature review, as necessity to maintain, protect and develop a prospect carbon farm in South Australia.

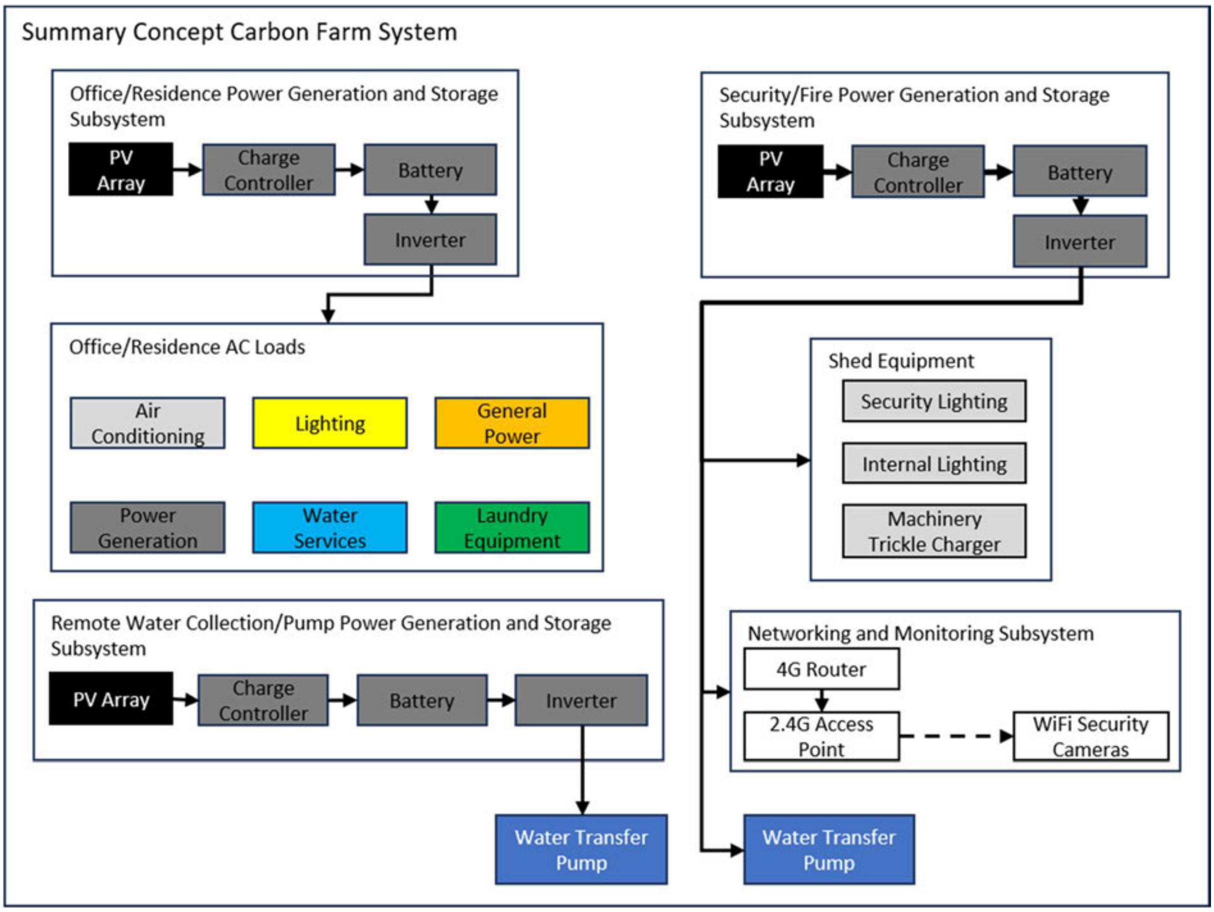

Figure 28: Summary concept carbon farm system diagram

4.4.2.3. Detailed Design Off Grid Electrical Infrastructure Residence Subsystem

Stage 1: Review input requirements and develop a robust set of assumptions that will inform the load profile model. Assess the energy demand of each subsystem installation instance, including supply voltage, power demand of each appliance, and duration of use and input to the load model to determine per day energy usage. For the purpose of this study appliance usage will be assumed consistent across the seven days of the week.

The load model presented below in Figure 29, provides breakdown of the 24-hour consumption details of the equipment and associated load factor identified in Appendix E.

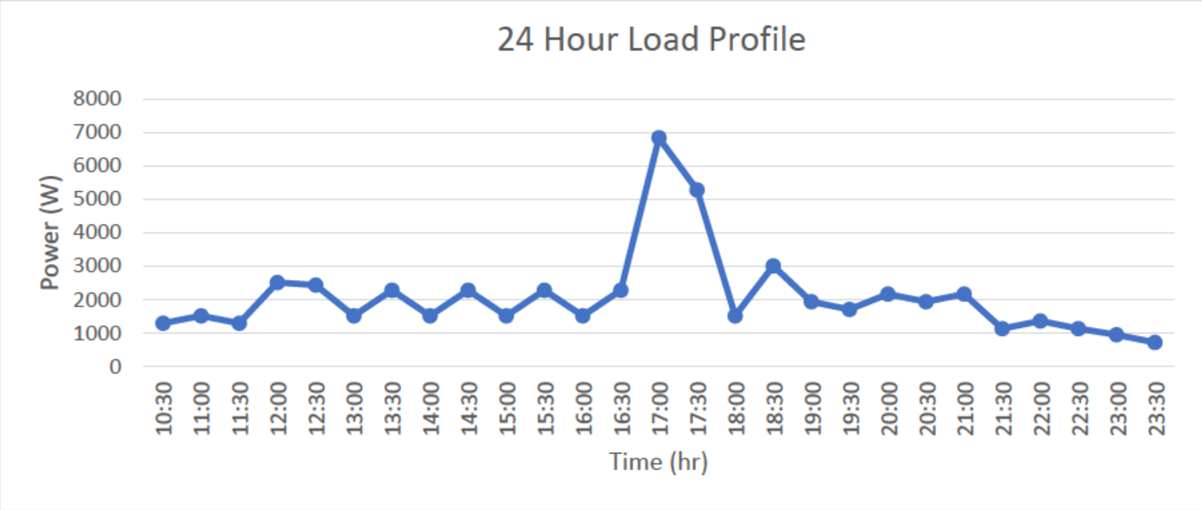

Figure 29: Carbon farm residence/office concept load model

Figure 30 identifies the various load categories and how, as a proportion, they contribute towards total consumption.

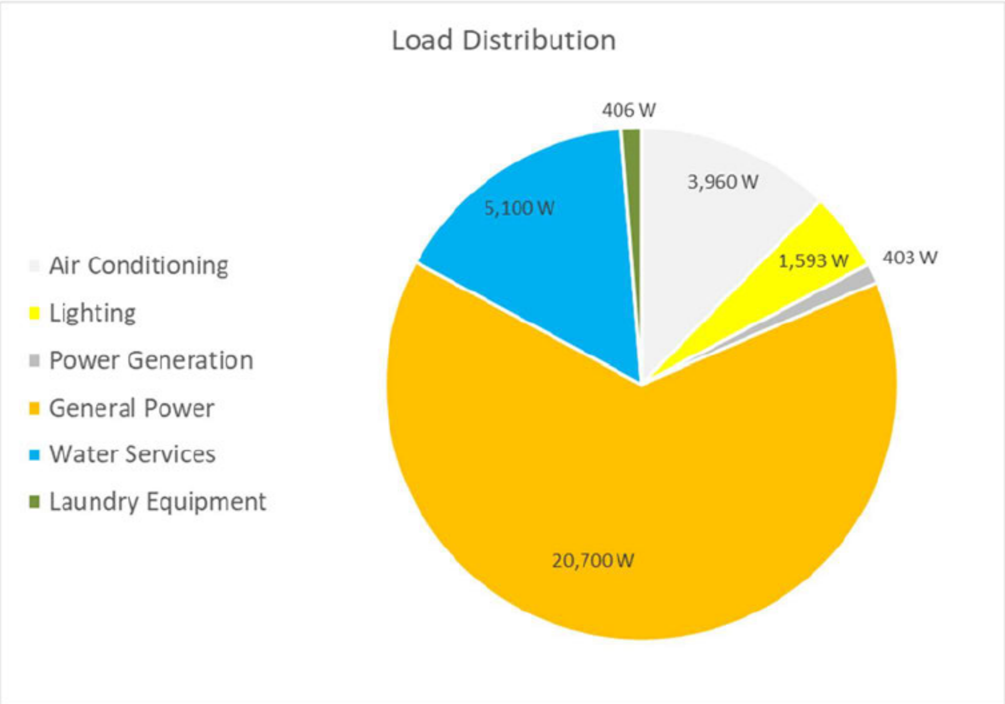

Figure 30: Carbon farm residence/office concept load distribution

Stage 2: Size the PV array based on the location and geographical situation. The resultant power found at stage 1 is entered into the following formula for each instance to determine peak power (Al-Shamani et al. 2015):

$$P_p = \frac{daily\ energy\ consumption}{minimum\ sun\ hours\ per\ day} = \frac{37552}{4} = 9388W \quad (4.13)$$

The total current required can then be calculated:

$$I_{DC} = \frac{P_p}{System\ DC\ Voltage} = \frac{9388}{210} = 44.7A \quad (4.14)$$

Choosing SPR-P6-410-BLK, 410W Sunpower Monocrystalline Solar Panel (Appendix F), the required series and parallel solar modules for each subsystem can then be determined by the following formulae:

$$N_p = \frac{I_{DC}}{Rated\ current\ of\ one\ module} = \frac{44.7}{13.73} = 3.26 == 4 \quad (4.15)$$

$$N_s = \frac{210}{29.9} = 7.02\ panels \quad (4.16)$$

The number of total solar modules can then be determined as:

$$N_m = N_s * N_p = 7 * 4 = 28\ \ panels \quad (4.17)$$

Stage 3: Determine the number of required batteries and their series/parallel configuration (Al-Shamani et al. 2015).

The number of days required to run autonomously (on battery power) determines a rough power demand:

$$E_{rough} = E_r * number\ of\ days = 37552 * 2 = 75{,}104kWh \quad (4.18)$$

Choosing 3.7VDC ELFOMO 50Ah lithium battery (Appendix I) and dividing this number by the MDOD of 80%, to achieve greater than 2000 cycles, determines the safety factor concerning the required power:

$$E_{safe} = \frac{75104}{0.8} = 93{,}880kWh \quad (4.19)$$

After selecting a battery and gleaning the rated voltage, determine the capacity of the battery bank:

$$C = \frac{93{,}880}{48} = 1955Ah \tag{4.20}$$

Next determine how many cells will be required by dividing the battery bank amp-hour rating by the amp-hour rating of each cell:

$$N_{batteries} = \frac{C}{C_b} = \frac{1955}{50} = 39.1 = 39\ batteries \tag{4.21}$$

Now determine the series and parallel configuration:

$$N_s = \frac{V_{DC}}{V_b} = \frac{48}{3.7} = 12.97 = 13\ batteries \tag{4.22}$$

$$N_p = \frac{39}{13} = 3\ parallel\ strings\ of\ batteries \tag{4.23}$$

Stage 4: Size the charge controller by considering the short circuit current of the PV module, number of panels, and applying a safety factor (typically 1.25) (Al-Shamani et al. 2015).

$$I = I_{SC} * N_p * F_{safe} = 14.63 * 4 * 1.25 = 73.15A \tag{4.24}$$

The charge controller must also be able to withstand the maximum load current hence;

$$I_{max} = P_p/V_{DC} = 6846/48\ =\ 142.65A \tag{4.25}$$

Choose two Victron Smart VICTRON-SSR250-85MPPT Solar Charge Controller (Appendix G), connected in parallel, with 85A of output each.

Stage 5: Size the inverter based on the power required by concurrently operating devices, with an added safety factor of approximately 20% (Ghafoor & Munir 2015).
Peak continuous power is estimated at 6846W. The Victron 3000VA Smart Pure Sine Wave Inverter (Appendix H) has a rated continuous output power of 2400W and a peak of 6000W hence, three inverters in parallel will be required, totalling 7200W of available continuous power.

Stage 6: Develop simple single line diagrams to represent how the system might be wired. Figure 31, overleaf, provides a representation of how the residence/office subsystem might be wired. Cable sizes have been determined using the jCalc tool with reports for identified cables catalogued in Appendix K. Note this diagram excludes details pertaining to the required circuit protection, this will need to be incorporated should the subsystem be implemented.

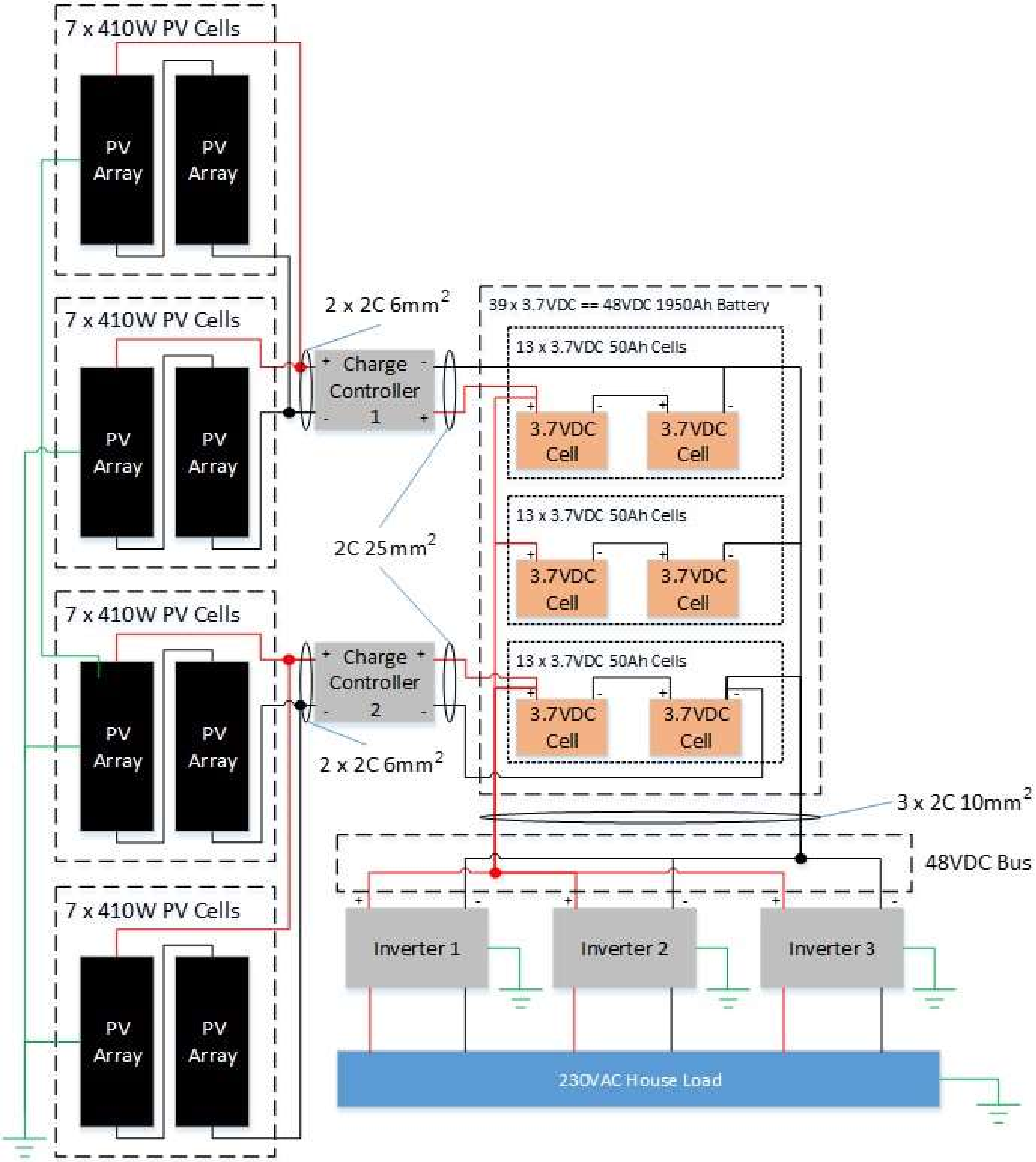

Figure 31: Carbon farm residence/office concept single line diagram

4.4.3. Carbon Farm Residence/Office Concept Subsystem Feasibility Analysis

Stage 7: Perform a simple cost analysis by calculating an estimated the capital cost of both off-grid electrical infrastructure and on-grid electrical connection in addition with an estimated payback period for any additional cost associated with an off-grid solution. Note that, providing off-grid infrastructure incurs a higher cost than grid connection, the electricity price will be taken as per the time of calculation plus a nominal 5% increase year on year. The maximum demand drawn from the battery is calculated by accounting for the maximum continuous output of each inverter at an efficiency of 90%: 2400W/48/0.9 = 55A. The summary output of each calculation found in Table 23 with each report generated is captured in Appendix K.

Table 23: Carbon farm residence/office concept cable calculation summary (off-grid)

Cable	Current Draw	Voltage (VDC)	Type	Parallel Cables	Length (m)	Installation	Cable Size
Solar Panel Connection	73.15A	210	XLPEX90	2	10	Enclosed in Air	6mm^2
Solar Charge Controller	85A	48	XLPEX90	1	5	Enclosed in Air	25mm^2
Battery Cables	55A	48	XLPEX90	1	5	Touching Surface	10mm^2

The cost summary given in Table 24 details the key components, selected from the hardware catalogue, as required to construct the off-grid system designed in the previous steps.

Table 24: Off grid carbon farm residence/office concept cost summary

Item	Model	Quantity	Unit Price	Total Cost
Solar Panel	SPR-P6-410-BLK	28	$420.00	$11,760
Battery	50NMC	39	$88.00	$3432.00
Charge Controller	VICTRON-SSR250-85MPPT	2	$1,399.00	$2,798.00
Inverter	V-PIN-3000-Smart	3	$1,670.00	$5,010.00
Solar Angle Mount	Clenergy Tripod Adjustable 15-30 Degree	10	$70.00	$700.00
Solar Mounting Rail	CLENERGY PV-EZRACK CUTTER RAIL 4400MM	14	$49.00	$686.00
Solar Isolator	ZJ Beny 4 Pole 32A 1200V DC Isolator	2	$50.00	$100.00
Panel Clamps	Clenergy End Clamp 32mm	112	$3.50	$392.00
Inverter/Battery Cable	10mm PV1-F Twin Solar PV Cable	30	$9.95	$298.50
Earth Wire	6.0mm Building Wire Green / Yellow Earth (100mtr Roll)	1	$137.50	$137.50
Battery Isolator	Single Circuit On-Off 300A Mini Battery Switch	1	$36.00	$36.00

Item	Model	Quantity	Unit Price	Total Cost
Solar Charger Cable	800mm Red/Black Battery Lead 25mm^2	4	$19.90	$79.60
Solar Charger Circuit Breaker	100A Circuit Breaker	2	$49.95	$99.90
Bus Bar	Alvota Red/Black 250A busbar	3	$49.70	$149.10
Solar Cables (to isolator)	10M 6MM Extension Solar Cables	2	$67.70	$135.40
Solar Cables (to Chargers)	1000mm 6mm Sq Tinned Twin Core Cable	10	6.50	$65.00
Connectors/Lugs	Cable Lugs 70Mm 6Mm Stud	4	$3.00	$12.00
				$25,891

Table 25 provides a summary of the cable size calculations for a grid-connected system, which is documented in each cable jCalc report catalogued in Appendix K. Note the maximum demand is calculated as peak load current of the residence plus the 10A draw demanded by the machinery shed.

$$I_T = I_{MS} + (P_P/V) = 10 + (6846/230) = 10 + 29.76 = 39.76A \qquad (4.26)$$

Note, as per the SA Power Networks Service and Installation Rules *Service and Installation Rules* 2023), the basic connection service is defined as 63A hence, the grid connected mains cable calculation will use this value for its current draw.

Table 25: Carbon farm residence/office cable calculation summary (grid connected)

Cable	Current Draw	Voltage (VAC)	Type	Parallel Cables	Length (m)	Installation	Cable Size (mm^2)
Mains	63A	230	XLPEX90	1	450	Exposed to sun	95

Table 26 provides a breakdown of the essential components necessary to sustain a 63A electrical load situated 450 metres away from the SA Power Networks point of service situated just outside of the North boundary. The mains supply cable will be installed on a catenary wire, exposed to sunlight, and supported by steel galvanised stobie poles, installed at intervals of approximately 30 metres apart.

Table 26: Grid connected carbon farm residence/office concept cost summary

Item	Model	Quantity	Unit Price	Total Cost
Mains Cable (@63A Service)	95mm XLPE Copper Single Core (per metre)	1800	$23.50	$42,300
Mains Cable (@32A Service)	70mm XLPE Copper Single Core (per metre)	1800	$17.17	$30,906
Earth Wire	6.0mm Building Wire Green / Yellow Earth (100mtr Roll)	1	$137.50	$137.50
Stobie Pole	Residential Power Pole / Private Pole 4 Inch x 6.5mtr	15	$341.00	$5115.00
Catenary wire	Catenary / Guy Wire 150mtr Roll	4	$59.40	$237.60
Cable Ties	250mm Black Cable Ties (100 Pack)	9	$5.50	$49.50
Concrete	20kg Concrete Mix	15	$8.27	$130.50
Earth Stake	Standard Earth Stake / Rod	1	$10.45	$10.45
Earthing Accessories	Standard Earth Stake / Rod + Clamp + Warning Tag	1	$11.55	$11.55
			Min. Cost	$36,598

4.4.3.1. Detailed Design - Off Grid Electrical Infrastructure Water Transfer Subsystem

The detailed design of the water transfer subsystem presented below draws upon inputs from two key preliminary design artefacts: the site plot (Figure 27) and the concept system block diagram (Figure 28). These outputs identify the major components of the subsystem and offer an initial estimate of the physical layout.

4.4.3.1.1. Water Transfer Subsystem Assumptions/Exclusions

To guide the design and subsequent feasibility analysis, when compared to a grid-connected configuration, the following assumptions and exclusions have been identified.

Table 27: Water transfer subsystem design assumptions

Assumption/ Exclusion ID	Assumption Description
AE010	It is assumed the subsystem will be required to pump water against a maximum head of 20m.
AE011	It is assumed that up to 2000L of water from each source will need to be transferred each day.
AE012	Assume the water tanks and associated water transfer equipment are located between 50 and 300m from the shack/residence point of service.

Stage 1: Review input requirements and develop a robust set of assumptions that will inform the load description required for this subsystem.

The load description presented below in Table 28, provides breakdown of the 24-hour consumption details pertaining to the operation of the water transfer pump. Note the Onga SPN100S pump was chosen for its high flow (60L/min at 40m head) and 54m head capacity. This requires an operating time of 50 minutes to pump 2000L at maximum head.

Table 28: Water transfer pump daily energy requirements

Equipment	No. of equip.	Equip. power (W)	Total wattage (W)	Daily use (h)	Daily energy required (Whd^{-1})
Water Transfer Pump (Onga SPN100S)	1	1100	1100	0.85	935
Total (W)			1100		935

Stage 2: The resultant power found at stage 1 is entered into the following formula to determine the minimum amount of power generated by solar energy (Al-Shamani et al. 2015):

Minimum annual peak sun hours in Adelaide Hills region of South Australia: 4 hours

$$P_p = \frac{daily\ energy\ consumption}{minimum\ sun\ hours} = \frac{935}{4} = 233.75Wh \quad (4.27)$$

The total current required can then be calculated:

$$I_{DC} = \frac{P_p}{System\ DC\ Voltage} = \frac{233.75}{30.8} = 7.59 \quad (4.28)$$

Choosing WINAICO WST-333MG, 333W Monocrystalline Solar Panel (Appendix F), the required series and parallel solar modules for each subsystem can then be determined by the following formulae:

$$N_p = \frac{I_{DC}}{Rated\ current\ of\ one\ module} = \frac{7.59}{10.82} = 0.7 == 1 \quad (4.29)$$

$$N_s = \frac{V_{DC}}{Module\ rated\ voltage} = \frac{30.8}{30.8} == 1 \quad (4.30)$$

Stage 3: Size the storage battery based on the estimated energy required for storage during reduced or non-production hours. The output of this stage is the number of required batteries and their series/parallel configuration (Al-Shamani et al. 2015).

The number of days required to run autonomously (on battery power) determines a rough power demand:

$$E_{rough} = 935 * 1 = 935Wh \tag{4.31}$$

Choosing 12V ITECH120X 120Ah lithium battery (Appendix I) and dividing this number by the MDOD of 80%, to achieve greater than 2000 cycles, determines the safety factor concerning the required power:

$$E_{safe} = \frac{935}{0.80} = 1168.75Wh \tag{4.32}$$

Reviewing the data sheet and taking the rated voltage, determine the capacity of the battery bank:

$$C = \frac{1168.75}{12} = 97.4Ah \tag{4.33}$$

Next determine how many cells will be required by dividing the battery bank amp-hour rating by the amp-hour rating of each cell:

$$N_{batteries} = \frac{97.4}{120} = 0.81\ batteries == 1\ batteries \tag{4.34}$$

Stage 4: Size the charge controller by considering the short circuit current of the PV module, number of panels, and applying a safety factor (typically 1.25) (Al-Shamani et al. 2015).

$$I = I_{SC} * N_p * F_{safe} = 11.39 * 1 * 1.25 = 14.24A \tag{4.35}$$

The Renogy RCC20RVRE-AU (Appendix G) is chosen as the charge controller due to its maximum rated solar input of 520W at 24V (23.33A) and 20A rated charge current.

Stage 5: Size the inverter based on the power required by concurrently operating devices, with an added safety factor of approximately 20% (Ghafoor & Munir 2015).

Maximum power required is 1610W (at full load). The Renogy INVT-PUH1-201235-AU, 2000W inverter (Appendix H) is chosen.

Stage 6: Develop a detailed single line diagram that can be utilised to develop the physical wiring solution in accordance with AS3000. Figure 32 below repurposes design from section 4.3.2.3 noting that the key components are broadly the same only scaled down.

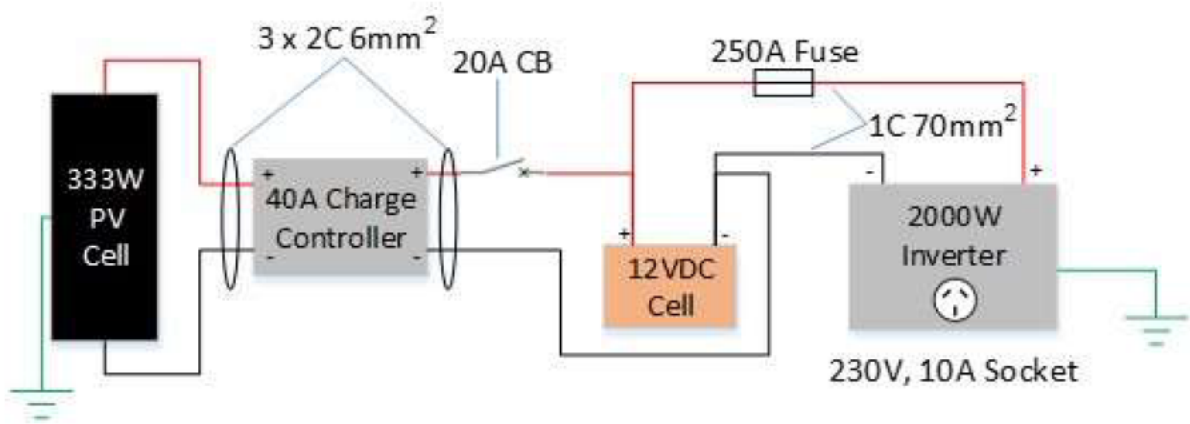

Figure 32: Water transfer subsystem single line diagram

4.4.3.2. Water Transfer Subsystem Feasibility Analysis

Stage 7: Perform a simple cost analysis by calculating an estimated the capital cost of both off-grid electrical infrastructure and on-grid electrical connection in addition with an estimated payback period for any additional cost associated with an off-grid solution.
The cost summary given in Table 29 details the key components, selected from the hardware catalogue, as required to construct the off-grid system designed in the previous steps. Note sundry items such as mounting hardware and cable supports are excluded from the cost breakdown.

Table 29: Water transfer subsystem off-grid cost summary

Item	Model	Quantity	Unit Price	Total Cost
Solar Panel	WST-333MG	1	$309.00	$309.00
Solar Angle Mount	Clenergy Tripod Adjustable 15-30 Degree	2	$70.00	$140.00
Solar Mounting Rail	CLENERGY PV-EZRACK CUTTER RAIL 4400MM	1	$49.00	$98.00

Item	Model	Quantity	Unit Price	Total Cost
Solar Isolator	ZJ Beny 4 Pole 32A 1200V DC Isolator	1	$50.00	$50.00
Panel Clamps	Clenergy End Clamp 35mm	4	$3.50	$14.00
Battery	iTECH120X PRO	1	$899.00	$899.00
Charge Controller	RCC20RVRE-AU	1	$145.99	$145.99
Inverter	R-INVT-PUH1-201235-AU	1	$319.99	$319.99
Inverter Cable	Enerdrive Cable Kit to Suit up to 2000 Watt Inverters, 70mm 2 x 1.2m (Fused)	1	$309.00	$309.00
Battery Cable (Short)	400mm Red/Black Battery Lead 70mm^2	1	$29.90	$29.90
Battery Cable (Long)	600mm Red/Black Battery Lead 70mm^2	1	$34.90	$34.90
Earth Wire	6.0mm Building Wire Green / Yellow Earth (100mtr Roll)	1	$137.50	$137.50
Battery Isolator	Single Circuit On-Off 300A Mini Battery Switch	1	$36.00	$36.00
Solar Charger Cable	1000mm 6mm Sq Tinned Twin Core Cable	5	$6.50	$32.50
Solar Charger Circuit Breaker	20A Manual Reset Circuit Breaker	1	$29.70	$29.70
Connectors/Lugs	Cable Lugs 70Mm 8Mm Stud	4	$3.00	$30.00
				$2,615.48

Table 30 provides a summary of the cable size calculations, at increasing distance from the source for a grid-connected system, with each cable jCalc report catalogued in Appendix K.

Table 30: Water transfer subsystem cable calculation summary (grid connected)

Cable	Current Draw	Voltage (VAC)	Type	Parallel Cables	Length (m)	Installation	Cable Size (mm^2)
Water transfer sub circuit	7A	230	PVCV90	1	50	Exposed to sun	2.5
Water transfer sub circuit	7A	230	PVCV90	1	100	Exposed to sun	6
Water transfer sub circuit	7A	230	PVCV90	1	150	Exposed to sun	10
Water transfer sub circuit	7A	230	PVCV90	1	300	Exposed to sun	16

Table 31 provides a breakdown of the essential components necessary to provide a full load current of 7A at 230V to a water transfer pump situated at distances of 50 to 300 metres away from a hypothetical service point situated at the shack. The mains supply cable will be installed on a catenary wire, exposed to sunlight, and supported by steel galvanised stobie poles, installed at intervals of approximately 30 metres apart.

Table 31: Grid connected water transfer subsystem cost summary

Item	Model	Quantity	Unit Price	Total Cost
Water transfer sub circuit @ 50m	2.5mm PVCV90 2c +E	50	$3.30	$165.00
Water transfer sub circuit @ 100m	6mm PVCV90 2c +E	100	$5.39	$539.00
Water transfer sub circuit @ 150m	10mm PVCV90 2c +E	150	$8.25	$1,237.50
Water transfer sub circuit @ 300m	16mm PVCV90 2c +E	300	$11.77	$3,531.00
Stobie Pole @ 50m	Residential Power Pole / Private Pole 4 Inch x 6.5mtr	2	$341.00	$682.00
Stobie Pole @ 100m	Residential Power Pole / Private Pole 4 Inch x 6.5mtr	4	$341.00	$1,364.00
Stobie Pole @ 150m	Residential Power Pole / Private Pole 4 Inch x 6.5mtr	6	$341.00	$2,046.00
Stobie Pole @ 300m	Residential Power Pole / Private Pole 4 Inch x 6.5mtr	10	$341.00	$3,410.00
Catenary wire	Catenary / Guy Wire 150mtr Roll	2	$59.40	$118.80
Cable Ties	250mm Black Cable Ties (100 Pack)	6	$5.50	$33.00
Concrete	20kg Concrete Mix	10	$8.27	$82.70
Total cost at 50m				$955.94
Total cost at 100m				$2,028.48
Total cost at 150m				$3,392.02
Total cost at 300m				$7,175.50

It's worth acknowledging that, when considering material costs alone, there are situations when opting for a grid connection can result in cost savings. Specifically, in cases where the distance to the connection point is relatively short, such as 50 and 100 metres, it becomes necessary to factor in the cost of electricity. This assessment can help determine the potential payback period for choosing a grid connection. To facilitate this evaluation, Table 32 details three provider plans available in South Australia, accounting for the supply and usage charge whilst also applying a nominal 5% increase year to year.

Table 32: South Australian electricity plans forecast

Provider	Plan	Daily Supply Charge	Usage Rate	Cost Year 1	Cost Year 2	Cost Year 3	Cost Year 4
AGL	Value Saver	$1.02	$0.44	$521.70	$547.79	$575.18	$603.94
Lumo Energy	Basic	$1.01	$0.44	$520.34	$546.35	$573.67	$602.36
Simply Energy	Simply Energy Saver	$1.21	$0.47	$601.00	$631.06	$662.61	$695.74

Hence, the payback period for a water transfer subsystem located at up to 100 metres away is calculated as:

Table 33: Water treatment off-grid payback period

Provider	Plan	Payback Period at 50 m	Payback Period at 100 m
AGL	Value Saver	3.025 years	1.119 years
Lumo Energy	Basic	3.032 years	1.122 years
Simply Energy	Simply Energy Saver	2.662 years	0.978 years

4.5. Discussion of Results

4.5.1. Security and Fire Monitoring System Feasibility Discussion

As the design and following cost comparison was progressed it was found that the intention to include a payback period, based on current electricity rates plus nominal growth, was not required to support feasibility. In this specific scenario, the viability of an off-grid system, priced at $6,353, as compared to a grid connection, priced at $8,860, clearly demonstrated its advantage when considering material costs alone. It is worth noting that the electrical capacity margins for this particular design are quite narrow, with the off-grid system providing very limited expansion opportunity. However, it's important to highlight that the cost difference of $2,507 provides opportunity for upgrade. This upgrade would accommodate a daytime peak load twice the size of current requirements whilst also increasing storage capacity by 25%, as costed in Table 34 below.

Table 34: Fire and security monitoring optional break-even capability upgrade

Item	Model	Quantity	Unit Price	Price Over Std.
Solar Panel	WST-333MG	3	$309.00	$927.00
Battery	iTECH120X PRO	1	$899.00	$899.00
60A Charge Controller	RNG-CTRL-RVR60-AU	1	$359.99	$190.00
Sundry items				$500.00
				$2,516.00

The focus of this analysis was also on what is described as the 'base station' within the design of the subsystem, categorised by its position in receiving the 4G internet signal and initial point of wireless distribution. To further extend the local network, in order to achieve the desired functional performance, it's essential to note that two additional access points would be necessary, as indicated in Figure 22. Taking into account the entirety of the subsystems design, a critical consideration arises regarding the most suitable electrical infrastructure for ensuring continuous power supply to these access points. The decision hinges on whether a grid connection or a micro-off-grid solution would be the most cost-effective choice in each instance.

In this section of the results, it's important to highlight a significant caveat regarding the feasibility of implementing an off-grid system in other setups with comparable electrical demands. Specifically, when considering material costs alone, there exists a cost inversion point, which is proportional to the distance from the point of service. To illustrate this point, take the example of the machinery shed. If the machinery shed were positioned 100 metres closer to the point of service, the savings realised in terms of cable costs, mounting hardware, and infrastructure expenses would bring the overall expenditure in close proximity to the cost of an off-grid equipment setup. Following this cost balance, it becomes essential to factor in ongoing electricity costs and the potential need for upgrades to the off-grid power source when assessing feasibility. It is therefore imperative to highlight that both the size of the load and the distance from the power source are substantial factors that demand thorough consideration during the design and implementation of subsystems like the one under discussion.

4.5.2. Carbon Farm Summary Off Grid Design Concept Feasibility Discussion

The results concerning the summary farm system need to be discussed in two distinct parts, given the nuanced feasibility of each consumer system/subsystem analysed within this study.

4.5.2.1. Residence Subsystem Feasibility Discussion

The residence and office facility, is located in place of the existing shack. This site is fixed due to its central positioning and its reliance on existing infrastructure, such as roads. Consequently, optimising its design feasibility through closer proximity to the SAPN connection point isn't a viable option. When assessing the feasibility of this particular design, it becomes clear that an off-grid configuration offers significant advantages. This holds true, even when stepping outside the SAPN service rules, towards a tailored lower-output service to the specific consumer needs. The cost savings, based solely on material considerations, amount to $10,707, equating to a 40% reduction in costs compared to the recommended grid-connected solution. Furthermore, if the standard 63A supply is adhered to (acknowledging its greater capacity over the load-specific off-grid design), the savings further increase to 85%, totalling $22,101. In either case, this analysis supports the viability of the off-grid design.

4.5.2.2. Water Transfer Subsystem Feasibility Discussion

To assess the viability of the water transfer subsystem, it's imperative to analyse each instantiation of the equipment individually. The results presented Table 31 clearly demonstrate that the viability of each instantiation, based solely on material costs, is contingent on its proximity to the point of service, which is assumed to be connected to the grid in this analysis. In a broader context, this analysis proves the feasibility of an off-grid solution for any water transfer subsystem located beyond 100 metres from the connection point when considering material costs alone. However, for installations situated within 100 metres or less from the connection point, the assessment must include an analysis of a payback period.

It's worth noting that even in the case of subsystems located as close as 50 metres from the connection point, as calculated in Table 33, the longest payback period extends just over 3 years. Supporting the case for off-grid feasibility where the lifespan of the key components, namely the panels and batteries, which are calculated to last for 5.47 years when continuously discharged to a depth of 80%, with panels having a performance warranty of 25 years. Hence, this analysis confirms the feasibility of the off-grid solution, given that the calculated payback period falls within, what might be considered, a reasonable timeframe and aligns with the expected performance lifespan of the key components.

Chapter 5: Conclusions

5.1. Conclusions

This research investigated the viability of supporting the electrical consumer needs of a carbon farm, as determined by the review and of multiple data sources and following review of the proposed site, with off-grid electrical infrastructure. The following conclusions are determined by the study.

- The results of the design and subsequent cost analysis prove the feasibility of employing off-grid electrical infrastructure to supply power to the fully defined base station component of the security and fire monitoring subsystem. However, it's crucial to recognise that the design margins and selected hardware, particularly the chosen charge controller, impose certain limitations on expansion opportunities. Opting for the next size up, a 60A controller, despite its higher cost at $359.99, facilitates substantial expansion possibilities by accommodating additional solar panels and batteries. It's worth noting that the inverter's sizing exceeds current requirements, providing room for scalability should consumer requirements demand it.

- The results of the design and cost analysis demonstrate the viability of off-grid electrical infrastructure required to support the concept design of a carbon farm situated in South Australia. It's important to highlight that this conclusion holds true despite not factoring in the connection fees imposed by SAPN or the expected additional labour necessary for the installation of approximately 450 metres of overhead mains supply cable.

- While the viability of off-grid solutions has been established for the example consumers, it's important, as the carbon sink forest expands, to conduct a thorough feasibility analysis for lower-demand consumers located closer to the connection point before committing to an off-grid design.

- The calculated cost differential between grid-connected and off-grid solutions not only validates the initial choice but also offers room for further expansion or capacity enhancement within the off-grid framework before reaching cost parity with grid connection. In cases where additional capacity isn't required, additional resilience and autonomy can be incorporated into the system through alternative methods of electrical power generation, such as wind or petrol/diesel generators.

This study has yielded valuable insights into the types of systems necessary to support a carbon farm in South Australia. The outcomes of the cost analysis have provided an enhanced comprehension of the feasibility of supplying power to diverse consumer loads using off-grid electrical infrastructure, particularly in the context of the crucial 50-metre distance threshold where viability becomes apparent. Thus, a distance based rapid, grid versus off-grid, decision making framework has been established. Additionally, exemplary design outputs have been produced that can serve as reference in the consideration of future carbon farm projects constrained by similar parameters to this South Australian based project.

5.2. Limitations and Further Research

Future work related to this study entails the construction and testing of the security and fire monitoring subsystem to further validate the chosen design methodology. Likewise, an analysis of the off-grid design and feasibility for micro consumers, such as the additional access points, should be conducted to assess their feasibility whilst also confirming the applicability of the 50-metre decision threshold.

In scenarios where the electricity at the connection point is set up as off-grid, the assessment of the off-grid feasibility for satellite consumers should encompass the expenses tied to the expansion of the central electricity source, if it is proposed to be connected via a sub mains to create a local grid. This procedure should also be incorporated into the design methodology whenever farming facilities and systems undergo expansion within the 50-metre threshold and are structured within a local grid configuration.

One notable limitation uncovered in this study pertains to the methodology, particularly the challenge of matching charge controllers with specific solar array configurations while adhering to hardware constraints. The approach of selecting the panels first necessitated careful consideration of voltage and overall power, often requiring a backtrack in the design process to ensure hardware compatibility when a charge controller was eventually chosen. For future studies, it is advisable to revisit the methodology to incorporate additional steps that guide the designer in verifying critical performance specifications.

Expanding the scope of this study could involve evaluating the feasibility of similar systems in different Australian states and territories. It's crucial to recognise that the suitability of such systems will heavily depend on the specific location of the carbon farm and the associated electricity costs, which vary significantly between regions.

Additionally, in the context of creating a connected farm, it is envisaged that future research could also explore the utilisation of smart farm hardware and informed farming strategies. This exploration aims to unlock the advantages of enhanced decision-making and increased efficiency, both of which can be achieved through the collection and analysis of farm equipment and resource data (Jakku et al. 2019).

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Appendix A: Project Specification

ENG4111/4112 Research Project
Project Specification

For: Jason Craige

Title: Feasibility Study of Off-Grid Electrical Infrastructure Required to Support a Carbon Farm

Major: Electrical/Electronics Engineering

Supervisors: Professor Paul Wen

Enrollment: ENG4111 – EXT S1, 2023

ENG4112 – EXT S2, 2023

Project Aim: Supporting a carbon sequester project, for implementation on a nominal 56-hectare farm requires supporting electrical infrastructure in accordance with legislation and site-specific needs. Initial research identifies the need for fire monitoring and security hardware, the capability to irrigate planted flora and charging infrastructure for electric farm equipment required to minimise the need for carbon offset and maximise output carbon credits. Typical remote sites do not have a viable connection to the electricity grid and therefore require an off-grid design. This project will investigate and propose off-grid electrical infrastructure required to support a carbon farm as given by the aforementioned requirements.

Programme: Version 2, 8th March 2023

1. Conduct initial research into the federal and state legislative requirements, codes of conduct and taxation guidelines in order to determine mandatory requirements, best practice and cost reconciliation of carbon farming supporting electrical infrastructure.
2. Review existing Australian carbon farming projects as example of existing electrical support systems.
3. Conduct a site survey of the proposed carbon sink forest in order to determine the topography and natural resources that will inform the requirement for electrical supporting infrastructure.
4. Construct a future plan for the site, providing a view of how the topography (buildings and landscape) will change as the carbon sink forest reaches maturity.
5. Assess hardware requirements as derived from points 1-3 of the programme.
6. Select commercially available hardware as a catalogue to inform carbon farm design.
7. Propose a system of off grid electrical infrastructure design concept that supports the proposed carbon farm.
8. Propose a security, livestock/pest and fire monitoring subsystem in accordance with the derived design constraints.

If time and resource permit:

1. Assess software requirements as derived from the future plan that might support centralised monitoring of all monitorable/controllable electrical infrastructure.

Appendix B: Project Risk Assessment

2411	RISK DESCRIPTION	TREND	CURRENT	RESIDUAL
	Conduct feasibility study of off-grid electrical infrastructure required to support a carbon farm		Medium	Medium

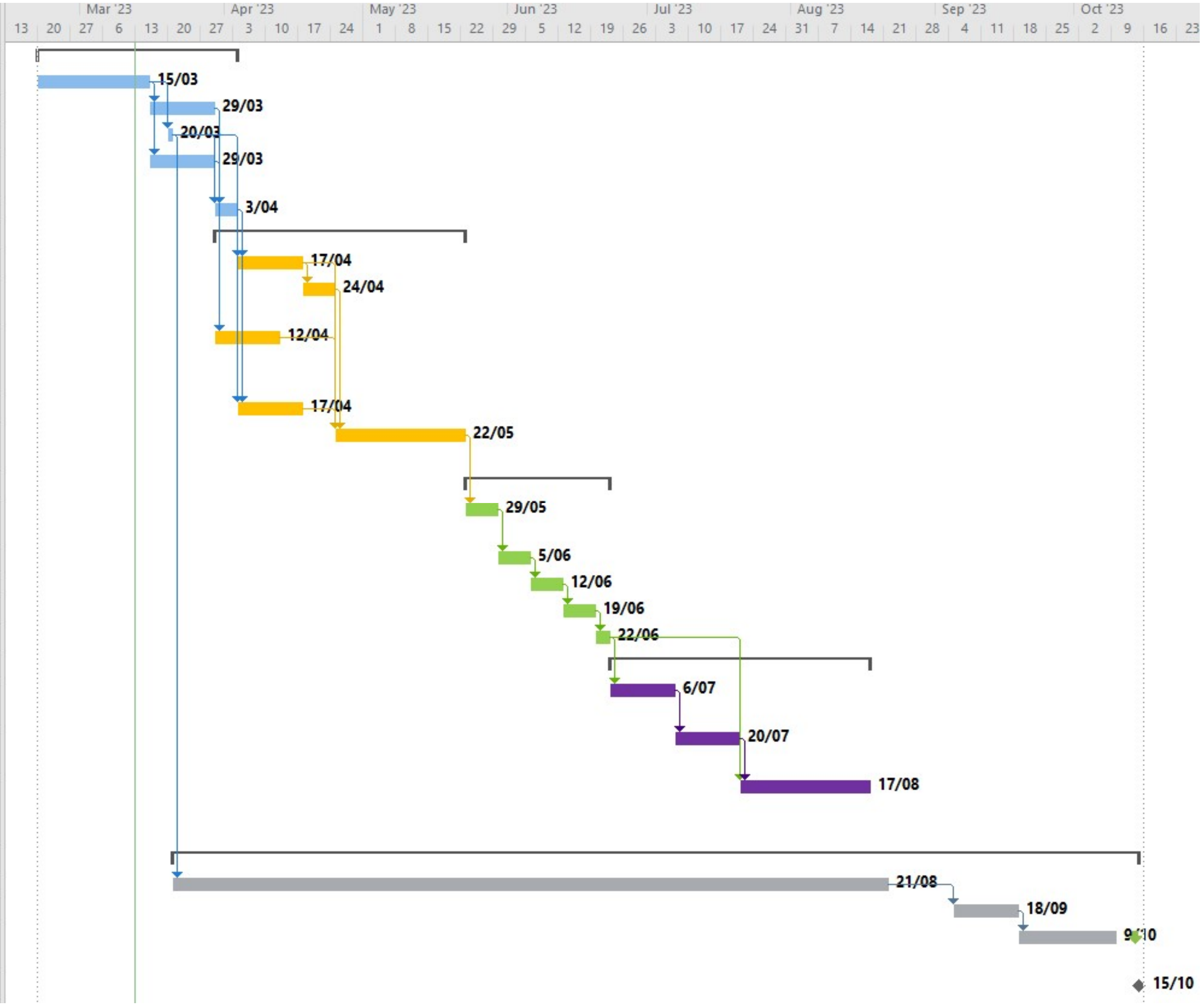
RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Jason Craige	14/05/2023		

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Sitting for prolonged periods performing analysis or report writing	Control: Regular breaks Set up workspace as per ergonomic recommendations Utilise sit/stand desk where possible Stretch neck/shoulders/legs	Medium	No Control:			Medium
Conducting site survey at the remote location. Walking across steep and rocky terrain during Winter, Autumn and Spring.	Control: Where correct PPE - ankle high boots, long trousers, long sleeve shirt, hat, sunglasses and sunscreen. Take water and food for one day. Take fully charged mobile phone and charger. Avoid excessively steep and/or rocky ground, use paths where possible. Control: Plan site visits around weather forecast. Attend site in pairs.	Medium	No Control:			Medium
Conducting site survey at the remote location where farm and wild animals will be present. (sheep, kangaroos, snakes)	Control: Where correct PPE - ankle high boots, long trousers, long sleeve shirt. Take fully charged mobile phone and charger for emergency phone calls. Keep clear of any sighted animals. Use clear pathways where possible. Avoid long grass and rocky areas (snake habitats) Control: Attend site in pairs. Plan evacuation in case of injury or snake bite.	Low	No Control:			Low

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Conducting site survey at the remote location during adverse weather conditions and risk of bush (grass) fires.	Control: Plan site visits around weather forecast. Attend site in pairs. Plan for evacuation in case of grass fire.	Low	No Control:			Low
Onsite vehicular traffic that might collide with pedestrians.	Control: Keep vehicular traffic to roads where possible, observing the site speed limit of 10km/hr. Pedestrians to wear high visibility clothing.	Low	No Control:			Low
Whilst conducting a survey at the remote site, fire may result from the operation of vehicles. Local grass fires are also common in the area.	Control: Do not operate vehicles or equipment in long grass. Monitor local fire warnings (CFS)	Low	No Control:			Low
*Construction of proposed off grid security system proposal in concept state requires manual handling of heavy materials (batteries, solar panels etc.) and use of hand tools.	Control: Where gloves when conducting manual handling activities or using hand tools. __________ Control: Implement correct lifting techniques. Only lift individual materials to avoid requirement for anything more than a single person lift. Review weights of lifted materials before attempting lift.	Low	No Control:			Low
*The construction of an off grid security system proposal, in concept state, will require expose the installer to voltages generated by a solar array and batteries.	Control: Wear safety glasses, gloves, long sleeve cotton clothing whilst working with potential energy sources. If conducting live testing, wear insulated gloves. __________ Control: Avoid live testing - connect test equipment prior to energization.	Medium	Install guards and insulated materials on any exposed live parts. Install equipment with exposed live parts into an enclosure		09/07/2023	Low
			Where possible, isolate equipment when conducting commissioning activities (including testing, installation etc.)		09/07/2023	

Appendix C: Project Schedule Gantt Chart

	WBS	Task Name	Start
1	**1**	**Phase 1 - Project Mobilisation and Planning**	**Mon 20/02/23**
2	1.A	Project mobilisation and defintion	Mon 20/02/23
3	1.B	Resource acquisition/provision	Thu 16/03/23
4	1.C	Site visit plan	Mon 20/03/23
5	1.D	Identify and contact any existing off grid Carbon Farming projects	Thu 16/03/23
6	1.E	Conduct risk assessment	Thu 30/03/23
7	**2**	**Phase 2 - Collate Carbon Farm Exemplars and Requirements**	**Thu 30/03/23**
8	2.A	Review state and federal legislation (including taxation policy)	Tue 4/04/23
9	2.B	Assess the applicable code of conduct and extract requirements	Tue 18/04/23
10	2.C	Survey any existing Carbon Farming projects for best practice and lessons learnt concerning electrical supporting infrastructure	Thu 30/03/23
11	2.D	Conduct on site survey for proposed Carbon Farm	Tue 4/04/23
12	2.E	Collate data and requirements into a format that supports the cataloging of potential hardware	Tue 25/04/23
13	**3**	**Phase 3 - Author Off Grid Hardware Catalogue**	**Tue 23/05/23**
14	3.A	Catalogue off grid electrical infrastructure (production, storage, conversion etc.)	Tue 23/05/23
15	3.B	Catalogue security and monitoring hardware	Tue 30/05/23
16	3.C	Catalogue water monitoring and movement hardware	Tue 6/06/23
17	3.D	Catalogue hardware for supporting structures (shed and office)	Tue 13/06/23
18	3.E	Finalise off grid electrical hardware catalogue	Tue 20/06/23
19	**4**	**Phase 4 - Proposal Infrastructure Design Concept**	**Fri 23/06/23**
20	4.A	Author future plan, including topography and mature carbon sink forest landscape	Fri 23/06/23
21	4.B	Develop proposal system to support an off grid carbon sink forest (indicative only)	Fri 7/07/23
22	4.C	Determine an off grid design for a security and fire monitoring system with remote access capability (Fully engineered solution)	Fri 21/07/23
23	**5**	**Phase 5 - Author Dissertation**	**Tue 21/03/23**
24	5.A	Draft dissertation and provide to the USQ supervisor	Tue 21/03/23
25	5.B	Present results as directed by the USQ supervisor (Conference)	Tue 5/09/23
26	5.C	Author final dissertation, incorporating supervisor critique and submit for marking	Tue 19/09/23
27	5.D	Final date for submission of dissertation	Sun 15/10/23



Appendix D: Load Profile Estimate Model

The embedded file below contains the load model to be utilised within both off-grid concept designs.

Load_Estimate_Model.xlsx

Appendix E: Load Models

Rockleigh Carbon Farming Project - Security and Fire Montoring System Load Profile

Time (hr) (min)	Wireless AP Load Factor	Wireless AP Wh/ 30min	4G Router Load Factor	4G Router Wh/ 30min	Solar Charger Load Factor	Solar Charger Wh/ 30min	Inverter Load Factor	Inverter Wh/ 30min	LED Flood Light Load Factor	LED Flood Light Wh/ 30min	Linear LED x 3 Load Factor	Linear LED x 3 Wh/ 30min	Transfer Pump Load Factor	Transfer Pump Wh/ 30min	Trickle Charger (Charge) Load Factor	Trickle Charger (Charge) Wh/ 30min	Trickle Charger (Trickle) Load Factor	Trickle Charger (Trickle) Wh/ 30min	Total kWhr	time	30 min demand (kW)
		20		12		1.2		15.6		100		120		400		138		128.8			
0 0	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	1.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	138.8	0:00	277.6
0 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	1.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	138.8	0:30	277.6
1 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	1.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	138.8	1:00	277.6
1 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	1.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	138.8	1:30	277.6
2 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	1.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	138.8	2:00	277.6
2 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	1.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	138.8	2:30	277.6
3 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	3:00	177.6
3 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	3:30	177.6
4 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	4:00	177.6
4 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	4:30	177.6
5 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	5:00	177.6
5 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	5:30	177.6
6 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	6:00	177.6
6 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	6:30	177.6
7 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	7:00	177.6
7 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	1.0	60.0	0.0	0.0	0.0	0.0	1.0	64.4	148.8	7:30	297.6
8 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	1.0	60.0	0.0	0.0	0.0	0.0	1.0	64.4	148.8	8:00	297.6
8 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	8:30	48.8
9 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	9:00	48.8
9 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	9:30	48.8
10 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	10:00	48.8

Rockleigh Carbon Farming Project - Security and Fire Montoring System Load Profile

Time (hr) (min)	Wireless AP Load Factor	Wireless AP Wh/ 30min	4G Router Load Factor	4G Router Wh/ 30min	Solar Charger Load Factor	Solar Charger Wh/ 30min	Inverter Load Factor	Inverter Wh/ 30min	LED Flood Light Load Factor	LED Flood Light Wh/ 30min	Linear LED x 3 Load Factor	Linear LED x 3 Wh/ 30min	Transfer Pump Load Factor	Transfer Pump Wh/ 30min	Trickle Charger (Charge) Load Factor	Trickle Charger (Charge) Wh/ 30min	Trickle Charger (Trickle) Load Factor	Trickle Charger (Trickle) Wh/ 30min	Total kWhr	time	30 min demand (kW)
		20		12		1.2		15.6		100		120		400		138		128.8			
10 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	10:30	48.8
11 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	11:00	48.8
11 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	11:30	48.8
12 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	12:00	48.8
12 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	12:30	48.8
13 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	13:00	48.8
13 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	13:30	48.8
14 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	14:00	48.8
14 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	1.0	200.0	0.0	0.0	0.0	0.0	224.4	14:30	448.8
15 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	1.0	200.0	0.0	0.0	0.0	0.0	224.4	15:00	448.8
15 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	15:30	48.8
16 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	16:00	48.8
16 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	16:30	48.8
17 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	17:00	48.8
17 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	17:30	48.8
18 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	1.0	60.0	0.0	0.0	1.0	69.0	0.0	0.0	153.4	18:00	306.8
18 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	1.0	60.0	0.0	0.0	0.0	0.0	1.0	64.4	148.8	18:30	297.6
19 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	1.0	60.0	0.0	0.0	0.0	0.0	1.0	64.4	148.8	19:00	297.6
19 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	19:30	177.6
20 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	20:00	177.6
20 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	20:30	177.6
21 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	21:00	177.6
21 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	21:30	177.6
22 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	22:00	177.6
22 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	22:30	177.6
23 00	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	23:00	177.6
23 30	1.0	10.0	1.0	6.0	1.0	0.6	1.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	64.4	88.8	23:30	177.6

Rockleigh Carbon Farming Project - Summary Concept

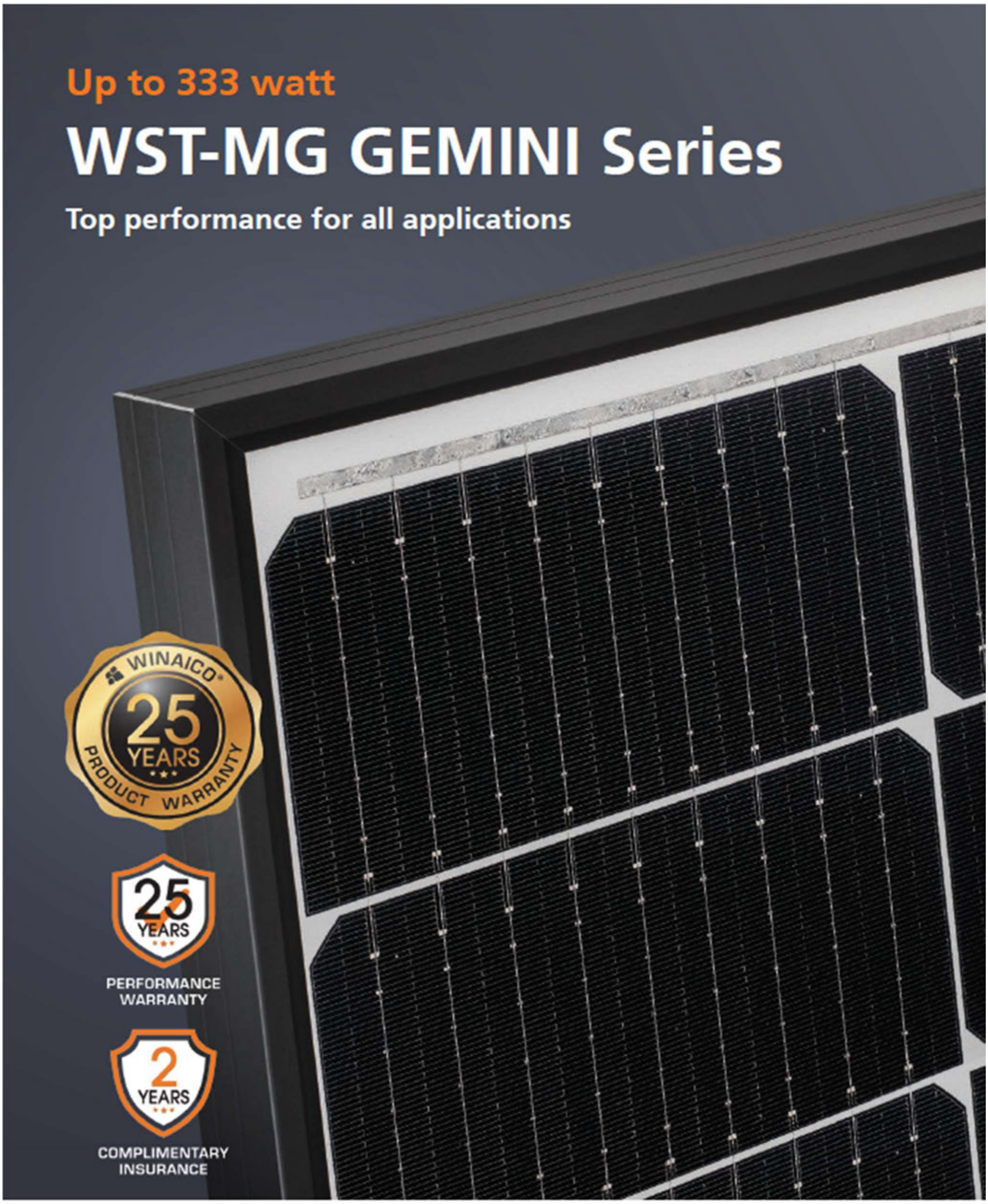
Time (hr) (min)	Load Factor Wh	Air conditioning 990 Wh/30min	Load Fa	Internal Lighting 13 208 Wh/30min	Load Factor	External Lighting 230 Wh/30r	Load Factor	Solar Charger 1.2 kWh/30min	Load Factor	Inverter 15.6 Wh/30min	Load Factor	General Power 2300 Wh/30min	Load Factor	Hotwater 0 kWh/30min	Load Factor	Constant Pressure Pump 900 Wh/30min	Load Factor	Waste Water Treatment 100 kWh/30min
0 0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
0 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
1 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
1 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
2 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
2 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
3 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
3 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
4 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
4 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
5 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
5 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
6 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
6 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
7 00	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
7 30	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	1.0	0.0	0.0	0.0	1.0	50.0
8 00	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	1.0	0.0	0.3	112.5	1.0	50.0
8 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0
9 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0
9 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0
10 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0

Time (hr) (min)	Load Factor	Fridge Freezer 28.65 kWh/30min	Load Factor	Microwave 1550 kWh/30min	Load Factor	Toaster 830 kWh/30min	Load Factor	Oven 3000 kWh/30min	Load Factor	Extraction Hood 126 kWh/30min	Load Factor	Induction Cook Top 2200 kWh/30min	Load Factor	Dishwasher 304 kWh/30min	Load Factor	Washing Machine 405.5 kWh/30m	Total kWhr	time	30 min demand (kW)
0 0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	0:00	945.5
0 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	0:30	720.5
1 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	1:00	945.5
1 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	1:30	720.5
2 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	2:00	945.5
2 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	2:30	720.5
3 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	3:00	945.5
3 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	3:30	720.5
4 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	4:00	945.5
4 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	4:30	720.5
5 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	5:00	945.5
5 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	5:30	720.5
6 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	6:00	945.5
6 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	6:30	720.5
7 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	680.7	7:00	1361.5
7 30	1.0	14.3	0.2	155.0	0.1	41.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	202.8	967.5	7:30	1935.0
8 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	202.8	883.5	8:00	1767.0
8 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	152.0	0.0	0.0	360.2	8:30	720.5
9 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	152.0	0.0	0.0	472.7	9:00	945.5
9 30	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	647.7	9:30	1295.5
10 00	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	10:00	1520.5

Rockleigh Carbon Farming Project - Summary Concept

Time (hr) (min)	Air conditioning		Internal Lighting		External Lighting		Solar Charger		Inverter		General Power		Hotwater		Constant Pressure Pump		Waste Water Treatment		Fridge Freezer		Microwave		Toaster		Oven		Extraction Hood		Induction Cook Top		Dishwasher		Washing Machine		Total kWhr	time	30 min demand (kW)
		990		13		230		1.2		15.6		2300		0		900		100		28.65		1550		830		3000		126		2200		304		405.5			
			Load Fa	208	Load Factor				Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor		Load Factor				
	Load Factor Wh	Wh/30min		Wh/30min		Wh/30r	Load Factor	kWh/30min		Wh/30min		Wh/30min		kWh/30min		Wh/30min		kWh/30min		kWh/30min		kWh/30min		kWh/30min		kWh/30min		kWh/30min		kWh/30min		kWh/30min		kWh/30m			
10 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	647.7	10:30	1295.5
11 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	11:00	1520.5
11 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	647.7	11:30	1295.5
12 00	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1255.2	12:00	2510.5
12 30	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.1	77.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1220.2	12:30	2440.5
13 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	13:00	1520.5
13 30	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1142.7	13:30	2285.5
14 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	14:00	1520.5
14 30	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1142.7	14:30	2285.5
15 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	15:00	1520.5
15 30	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1142.7	15:30	2285.5
16 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	16:00	1520.5
16 30	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1142.7	16:30	2285.5
17 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	1.0	1500.0	1.0	63.0	1.0	1100.0	1.0	152.0	0.0	0.0	3423.2	17:00	6846.5
17 30	1.0	495.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	1.0	1500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2642.7	17:30	5285.5
18 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	1.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	760.2	18:00	1520.5
18 30	1.0	495.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	1.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.2	155.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1505.7	18:30	3011.5
19 00	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	1.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	968.2	19:00	1936.5
19 30	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	855.7	19:30	1711.5
20 00	0.0	0.0	1.0	104.0	1.0	115.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1083.2	20:00	2166.5
20 30	0.0	0.0	1.0	104.0	1.0	115.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	970.7	20:30	1941.5
21 00	0.0	0.0	1.0	104.0	1.0	115.0	1.0	0.6	1.0	7.8	0.5	575.0	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1083.2	21:00	2166.5
21 30	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	568.2	21:30	1136.5
22 00	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	680.7	22:00	1361.5
22 30	0.0	0.0	1.0	104.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	568.2	22:30	1136.5
23 00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.3	112.5	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.7	23:00	945.5
23 30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.0	7.8	0.3	287.5	0.0	0.0	0.0	0.0	1.0	50.0	1.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.2	23:30	720.5

Appendix F: Solar Panel Datasheets



WINAICO®

Power to Perform

EUPD RESEARCH TOP BRAND PV MODULES 2020

EUPD RESEARCH TOP BRAND PV MODULES 2020

www.winaico.com.au

WST-MG GEMINI

333 W / 108 Cells

Stable long term investment
Reliability you can bank on for 25 years

Advanced cell technology
Better performance in any weather

High-density module technology
Half cell and multi-busbar design to increase power yield

Improved temperature performance
Reduced internal resistance and module degradation

Greater Value

Premium quality from solar module specialists

A solar system is a long term investment, which should last for over 20 years. You want to be able to trust that the solar panels you install will perform for their whole life. WINAICO specialises in premium quality solar that you can rely on.

Greater Customer Satisfaction

Thousands of satisfied system owners worldwide

Established in 2008 WINAICO is one of the world's oldest solar manufacturers. Since inception we have focused on building close relationship with our customers. WINAICO stands for quality, reliability and customer engagement, values we apply every day in our business. Working closely with our customers builds trust and understanding, a feeling shared by thousands of satisfied customers worldwide.

Greater Protection

3 in 1 insurance for your complete system

Photovoltaic modules from WINAICO are characterised by outstanding quality, innovative design, durability and safety. In order to protect your system against property damage, operational interruption and reduced yields, we offer comprehensive all-round protection for your complete photovoltaic system when purchasing WINAICO modules.

Ask your installer to check if you qualify for free complimentary insurance.

Greater Quality Awarded By Customers

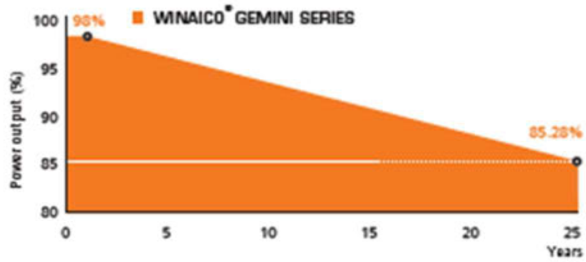
WINAICO is one of the few manufacturers to be awarded the EUPD Research "Top Brand PV" seal. The award centres around customer satisfaction from the performance of their solar systems in the real world. The EUPD Seal reflects WINAICO's customer focus and the positive consensus on lifetime performance.

Greater Durability Reliable Long Term Investment

WINAICO's solar panels are designed to last for a long time. They are backed by industry-leading 25-year product warranty to give you reliable and consistent returns.

Greater Performance Leading Module Technology

WINAICO combines half cell, multi-busbar and reflective wire designs to maximise efficiency and reduce internal resistance. The result is higher energy yield, lower module degradation, and market-leading 25 year power guarantee.



No more than 0.53% degradation per year from 2nd year to 25th year.

Greater Safety Tested to the Limits

WINAICO's modules are tested above and beyond international standards. Aiming to use lab conditions to simulate 25 years of service life, we push our modules to withstand conditions far above what they will likely experience on your roof. Be confident that your WINAICO panels will last the test of time.

Greater Quality Control 100% Inspection

We examine all cells and finished laminates for internal damage with a special electroluminescence test. In doing so, we can virtually eliminate all micro-cracks, hot spots, solder defects and other faults that cannot be seen with the naked eye. A type of "X-ray image" proves the 100% cell quality for each individual module, ensuring every WINAICO product is ready to perform on your roof.

Beyond Industry Standard Testing

Thermal Cycling (TC) Cycles between -40°C and +85°C	IEC Standard	200 Cycles
	WINAICO	3 times IEC standard
Damp Heat (DH) Constant +85°C and 85% relative humidity	IEC Standard	1,000 Hours
	WINAICO	3 times IEC standard
Mechanical Load (ML)	IEC Standard	5,400 Pa
	WINAICO	Follow IEC standard
Hail Impact	IEC Standard	25 mm ice ball at 83 km/h
	WINAICO	35 mm ice ball at 100 km/h

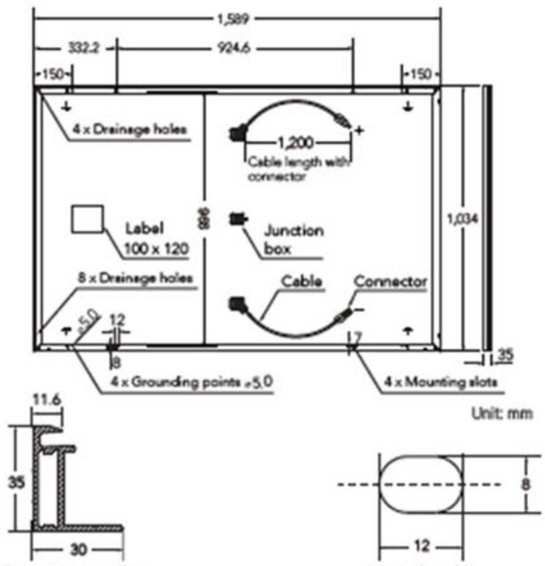
We test beyond the industry testing standards because at WINAICO we believe that our customers deserve complete peace of mind.

Enhanced Voluntary Quality Testing

Potential Induced Degradation (PID) (IEC TS 62804-1:2015)	96hours	1,000 V, 85°C, 85% relative humidity
Light and elevated Temperature Induced Degradation (LeTID)	Non-sensitive to LeTID	0.55A, 75°C, 162 hours
Dynamic Mechanical Load (DML) (IEC TS 62782:2016)	1000 Pa	10 push to pull cycles/minute, for 1000 cycles
Salt Mist (IEC 61701:2020)	Severity 6	40°C humid storage, 90% relative humidity, 56 days
Ammonia (IEC 62716:2013)	480 hours	20 cycles between 8 hrs of heating up and 16 hrs of cooling test sections

Our modules are voluntarily submitted to testing laboratories to push them to the absolute limits, guaranteeing your safety and return on investment.

Dimensions



Frame cross section

Mounting slot

Mechanical Data WINAICO WST-MG GEMINI

Cell	Monocrystalline silicon cells
Quantity of cells	6 strings x 18 cells
Dimensions	1,589 x 1,034 x 35 mm (62.56 x 40.71 x 1.38 in)
Weight	18.6 kg (41 lbs)
Glass thickness	3.2 mm (0.13 in)
Frame	Black anodised aluminium
Junction box	IP 68
Connector type	MC4 IP 68
Module fire performance	Type 4
Fire safety class	C

WINAICO PRODUCT WARRANTY

In order to activate our 25-year product warranty, please register your installation under https://www.winaico.com/warranty-registration/

Operating conditions	WINAICO WST-MG
Operating temperature	–40 °C to +85 °C / –40 °F to +185 °F
Maximum system voltage IEC/UL	1,000 V/1,000 V
Maximum series fuse	20 A
Maximum design load (push/pull)	3,600 Pa/1,600 Pa
Maximum test load (push/pull)	5,400 Pa/2,400 Pa
Nominal module operating temperature NMOT	43.85 ± 3 °C
Temperature coefficient of P_{MAX}	–0.35 %/°C
Temperature coefficient of V_{OC}	–0.28 %/°C
Temperature coefficient of I_{SC}	0.04 %/°C
Certifications	IEC 61215-1:2016, IEC 61215-2:2016, IEC 61730-1:2016, IEC 61730-2:2016

Electrical data (STC)		WST-333MG	
Nominal performance	P_{MAX}	333	Wp
Voltage at maximum performance	V_{MP}	30.80	V
Current at maximum performance	I_{MP}	10.82	A
Open circuit voltage	V_{OC}	36.72	V
Short circuit current	I_{SC}	11.39	A
Module efficiency		20.27	%
Power tolerance		-0/+5	

Electrical data applies under standard test conditions (STC): solar radiation 1,000 W/m² with light spectrum AM 1.5, with cell temperature 25 °C. Measurement tolerance of P_{MAX} at STC: ±3%. Accuracy of other electrical data: ±10%.

Electrical data (NMOT)		WST-333MG	
Nominal performance	P_{MAX}	243	Wp
Voltage at maximum performance	V_{MP}	28.28	V
Current at maximum performance	I_{MP}	8.59	A
Open circuit voltage	V_{OC}	34.60	V
Short circuit current	I_{SC}	9.00	A

Electrical data applies under Nominal Module Operating Temperature (NMOT), irradiance of 800 W/m², spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

Specifications included in this datasheet are subject to change without notice. 0623/WST-333MG–AUS 0621/agentur-bemberg.de

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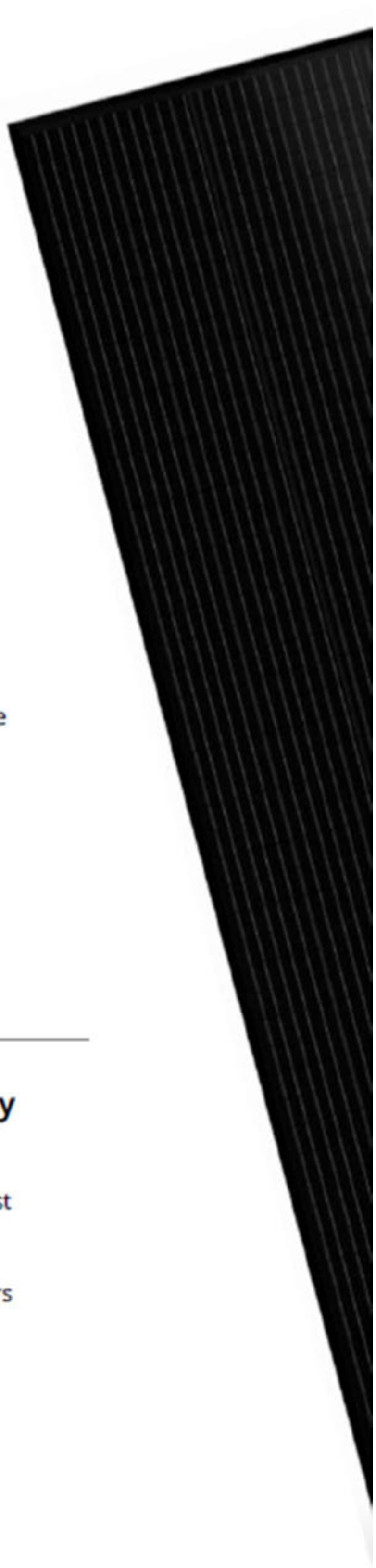
SUNPOWER | FROM MAXEON SOLAR TECHNOLOGIES



SPR-P6-XXX-BLK

PERFORMANCE 6 SOLAR PANEL

395-415 W | Up to 21.1% Efficient

Ideal for residential applications

Black backsheet, black frame

Enhanced Power Density

With high efficiency, LID-resistant solar cells (G12, 210mm), a lower temperature coefficient, and front-side conductive wires that support increased current collection, SunPower Performance panels are uniquely engineered to deliver more lifetime energy over standard solar panels.

Proven Reliability

A proprietary shingled-cell design maximises durability in all types of weather conditions—including reinforced cell connections that withstand the stresses of daily temperature swings, redundant electrical paths that alleviate the impact of cell cracks, and an advanced electrical architecture that is more resilient to the effects of shade and mitigates hot-spot formation.

SunPower Complete Confidence Warranty

Each SunPower Performance panel is manufactured with the absolute confidence to deliver more energy and greater reliability over time—and backed by one of the industry's most comprehensive warranties.

Product and power coverage	25 / 25 Years
Year 1 minimum warranted output	98.0%
Maximum annual degradation	0.45%

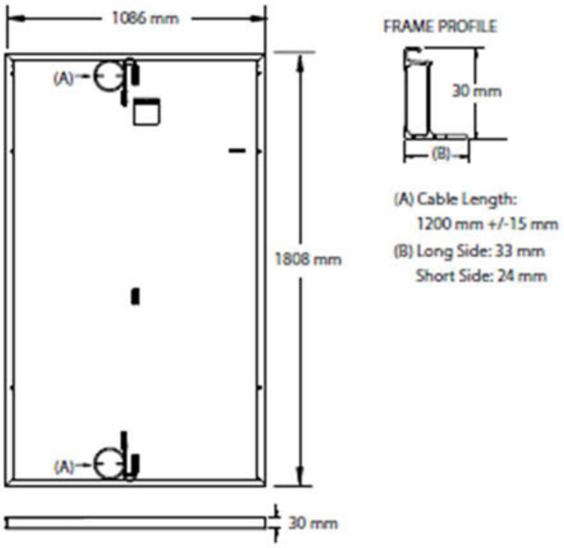
Learn more about the SPR-P6-XXX-BLK
sunpower.maxeon.com

Performance 6 POWER: 395-415 W | EFFICIENCY: Up to 21.1%

Electrical Data					
	SPR-P6-415-BLK	SPR-P6-410-BLK	SPR-P6-405-BLK	SPR-P6-400-BLK	SPR-P6-395-BLK
Nominal Power (Pnom) [1]	415 W	410 W	405 W	400 W	395 W
Power Tolerance	+3/0%	+3/0%	+3/0%	+3/0%	+3/0%
Panel Efficiency	21.1%	20.9%	20.6%	20.4%	20.1%
Rated Voltage (Vmpp)	30.2 V	29.9 V	29.6 V	29.3 V	29.0 V
Rated Current (Impp)	13.76 A	13.73 A	13.70 A	13.67 A	13.64 A
Open-Circuit Voltage (Voc) (+/-3%)	36.1 V	35.9 V	35.7 V	35.5 V	35.3 V
Short-Circuit Current (Isc) (+/-3%)	14.66 A	14.63 A	14.60 A	14.57 A	14.55 A
Maximum System Voltage			1000 V IEC		
Maximum Series Fuse			25 A		
Power Temp. Coef.			-0.34% / ° C		
Voltage Temp. Coef.			-0.27% / ° C		
Current Temp. Coef.			0.04% / ° C		

Operating Condition And Mechanical Data	
Temperature	-40°C to +85°C
Impact Resistance	25 mm diameter hail at 23 m/s
Solar Cells	Monocrystalline PERC
Glass	3.2 mm, Heat Strengthened Glass
Junction Box	IP-68, 3 bypass diodes
Connector	Stäubli MC4
Weight	21.0 kg
Max. Load[2]	Wind: 2400 Pa, 244 kg/m² front & back Snow: 5400 Pa, 550 kg/m² front
Frame	Black anodized aluminum alloy

Tests And Certifications	
Standard Tests	IEC 61215, IEC 61730
Fire Rating	Class C (IEC 61730)
Quality Certs	ISO 9001:2015, ISO 14001:2015
EHS Compliance	ISO 45001-2018, Recycling Scheme



(A) Cable Length: 1200 mm +/-15 mm
(B) Long Side: 33 mm
Short Side: 24 mm

Please read the safety and installation instructions.
Visit www.sunpower.maxeon.com/int/PVInstallGuideIEC
Paper version can be requested through
techsupport.ROW@maxeon.com

1 Standard Test Conditions (1000 W/m² irradiance, AM 1.5, 25° C). NREL calibration Standard: SOMS current, LACCS FF and Voltage.
2 Safety factor 1.5 included.

SUNPOWER
FROM MAXEON SOLAR TECHNOLOGIES

Designed in U.S.A.
Assembled in China
Specifications included in this datasheet are subject to change without notice.
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538667 REV A / A4_EN
Publication Date: July 2022

Appendix G: Charge Controller Datasheets

RENOGY

ROVER
20A/30A/40A MPPT
CHARGE CONTROLLER

RENOGY **ROVER 20A/30A/40A MPPT CHARGE CONTROLLER**

The Renogy Rover MPPT Charge Controller is an intelligent negative ground controller. Built with protections against reverse polarity, short-circuiting, overheating, and more, this MPPT controller is also capable of self-diagnosing itself in the event of an error. Its durable shell protects against general wear and tear, and aluminum heat sink allows for heat dissipation. The Rover can automatically detect 12V/24V systems and can handle various battery options such as GEL and Lithium. Pair this charge controller with the Renogy BT-1 and unlock monitoring features on the Renogy BT-1 APP or view your system's performance in real time via the Renogy DC Home App.

KEY **FEATURES**

- Automatically detects 12V/24V DC system voltages; Deep Cycle Sealed, Gel, Flooded, and Lithium option ready.
- Innovative MPPT technology with high tracking efficiency up to 99% and peak conversion efficiency of 98%.
- Electronic protection against reverse polarity, overcharging, over-discharging, overload, short-circuiting, and reverse current.
- LCD screen with multiple LED indicators for displaying system operation information, customizable parameters, and error codes.
- Features diverse load control; also capable of charging over-discharged lithium batteries.
- Unlock Monitoring features through the new Renogy BT-1 Bluetooth module

RENOGY.COM   2775 EAST PHILADELPHIA ST. ONTARIO, CA 91761

PARAMETERS

	RVR20	RVR30	RVR40
Nominal System Voltage	12/24V	12/24V	12/24V
Rated Load Current	20A	20A	20A
Max Solar Input Voltage	100V DC	100V DC	100V DC
Max Solar Input Power	12V/260W, 24V/520W	12V/400W, 24V/800W	12V/520W, 24V/1040W
Self Consumption		≤ 100mA/12V, ≤ 58mA/24V	
Charge Circuit Voltage Drop	≤ 0.26V		
Discharge Circuit Drop	≤0.15V		
Temperature Compensation	-3mV/°C/2V		
Dimensions	210 x 151 x 59.5mm, 8.27 x 5.94 x 2.34in	238 x 173 x 72.5mm, 9.37 x 6.81 x 2.85in	238 x 173 x 72.5mm, 9.37 x 6.81 x 2.85in
Mounting Oval	7.66 x 4.70mm / 0.30 x 0.18in		
Max Terminal Size	10mm² 8AWG	10mm² 8AWG	10mm² 8AWG
Net Weight	1.4kg / 3.08 lb	1.4kg / 3.08 lb	2.0kg / 4.41 lb
Operating Temperature	-35°C to +45°C , -31°F to 113°F		
Storage Temperature	-35°C to +75°C , -31°F to 167°F		
Humidity Range	≤ 95% (NC)		
Enclosure	IP32		
Altitude	< 3000m		
Communication	RS232		
Certification	FCC Part 15 Class B; CE; RoHS;		

BATTERY CHARGING PARAMETERS

Battery	GEL	SEALED	FLOODED	LI (LFP)	USER
Over-voltage Warning	16V	16V	16V	16V	9-17V
Equalization Voltage	—	14.6V	14.8V	—	9-17V
Boost Voltage	14.2V	14.4V	14.6V	14.4V	9-17V
Float Voltage	13.8V	13.8V	13.8V	—	9-17V
Boost Return Voltage	13.2V	13.2V	13.2V	13.2V	9-17V
Under Voltage Warning	12V	12V	12V	12V	9-17V
Under Voltage Recover	12.2V	12.2V	12.2V	12.2V	9-17V
Low Voltage Disconnect	11V	11V	11V	11V	9-17V
Low Voltage Reconnect	12.6V	12.6V	12.6V	12.6V	9-17V
Equalization Duration	—	2 Hours	2 Hours	—	0-10 Hours
Boost Duration	2 Hours	2 Hours	2 Hours	—	1-10 Hours

*Battery charging parameters in USER mode can be programmed using the Renogy BT App.

**Default charging parameters in LI mode are programmed for 12.8V LFP battery. Before using Rover to charge other types of lithium batteries, set the parameters according to the suggestions from battery manufacturer.

***Parameters are multiplied by 2 for 24V systems.

SmartSolar Charge Controllers 250V and 99% efficiency
MPPT 250/60, 250/70, 250/85 & 250/100

Ultra-fast Maximum Power Point Tracking (MPPT)
Especially in case of a clouded sky, when light intensity is changing continuously, an ultra-fast MPPT controller will improve energy harvest by up to 30% compared to PWM charge controllers and by up to 10% compared to slower MPPT controllers.

Advanced Maximum Power Point Detection in case of partial shading conditions
If partial shading occurs, two or more maximum power points may be present on the power-voltage curve.
Conventional MPPTs tend to lock to a local MPP, which may not be the optimum MPP.
The innovative SmartSolar algorithm will always maximize energy harvest by locking to the optimum MPP.

Outstanding conversion efficiency
No cooling fan. Maximum efficiency exceeds 99%.

Flexible charge algorithm
Fully programmable charge algorithm (see the software page on our website), and eight pre-programmed algorithms, selectable with a rotary switch (see manual for details).

Extensive electronic protection
Over-temperature protection and power derating when temperature is high.
PV short circuit and PV reverse polarity protection.
PV reverse current protection.

Internal temperature sensor
Compensates absorption and float charge voltage for temperature.

SmartSolar Charge Controller
MPPT 250/100-Tr
with optional pluggable display

SmartSolar Charge Controller
MPPT 250/100-MC4
without display

Bluetooth Smart built-in: dongle not needed
The wireless solution to set-up, monitor and update the controller using Apple and Android smartphones, tablets or other devices.

VE.Direct
For a wired data connection to a Color Control GX, other GX products, PC or other devices

Remote on-off
To connect for example to a VE.BUS BMS.

Programmable relay
Can be programmed (a.o. with a smartphone) to trip on an alarm, or other events.

Optional: pluggable LCD display
Remove the seal that protects the plug on the front of the controller, and plug-in the display.

SmartSolar Charge Controller	MPPT 250/60	MPPT 250/70	MPPT 250/85	MPPT 250/100
Battery voltage	12 / 24 / 48V Auto Select (software tool needed to select 36V)			
Rated charge current	60A	70A	85A	100A
Nominal PV power, 12V 1a,b)	860W	1000W	1200W	1450W
Nominal PV power, 24V 1a,b)	1720W	2000W	2400W	2900W
Nominal PV power, 48V 1a,b)	3440W	4000W	4900W	5800W
Max. PV short circuit current 2)	35A (max 30A per MC4 conn.)		70A (max 30A per MC4 conn.)	
Maximum PV open circuit voltage	250V absolute maximum coldest conditions 245V start-up and operating maximum			
Maximum efficiency	99%			
Self-consumption	Less than 35mA @ 12V / 20mA @ 48V			
Charge voltage 'absorption'	Default setting: 14,4 / 28,8 / 43,2 / 57,6V (adjustable with: rotary switch, display, VE.Direct or Bluetooth)			
Charge voltage 'float'	Default setting: 13,8 / 27,6 / 41,4 / 55,2V (adjustable: rotary switch, display, VE.Direct or Bluetooth)			
Charge algorithm	multi-stage adaptive			
Temperature compensation	-16 mV / -32 mV / -64 mV / °C			
Protection	Battery reverse polarity (fuse, not user accessible) PV reverse polarity / Output short circuit / Over temperature			
Operating temperature	-30 to +60°C (full rated output up to 40°C)			
Humidity	95%, non-condensing			
Data communication port	VE.Direct or Bluetooth			
Remote on/off	Yes (2 pole connector)			
Programmable relay	DPST AC rating: 240VAC / 4A DC rating: 4A up to 35VDC, 1A up to 60VDC			
Parallel operation	Yes (not synchronized)			
ENCLOSURE				
Colour	Blue (RAL 5012)			
PV terminals 3)	35 mm² / AWG2 (Tr models) Two sets of MC4 connectors (MC4 models 250/60 and 250/70) Three sets of MC4 connectors (MC4 models 250/85 and 250/100)			
Battery terminals	35 mm² / AWG2			
Protection category	IP43 (electronic components), IP22 (connection area)			
Weight	3 kg		4,5 kg	
Dimensions (h x w x d) in mm	Tr models: 185 x 250 x 95 MC4 models: 215 x 250 x 95		Tr models: 216 x 295 x 103 MC4 models: 246 x 295 x 103	
STANDARDS				
Safety	EN/IEC 62109-1, UL 1741, CSA C22.2			

1a) If more PV power is connected, the controller will limit input power to the stated maximum.
1b) The PV voltage must exceed Vbat + 5V for the controller to start.
Thereafter the minimum PV voltage is Vbat + 1V.
2) A PV array with a higher short circuit current may damage the controller.
3) MC4 models: several splitter pairs may be needed to parallel the strings of solar panels.
Maximum current per MC4 connector: 30A (the MC4 connectors are parallel connected to one MPPT tracker)

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Technical Specifications

Electrical Parameters

Model	RCC20RVRE-G1	RCC40RVRE-G1
Nominal system voltage	12V/24V Auto Recognition	
Rated Battery Current	20A	40A
Max. Battery Voltage	32V	
Max Solar Input Voltage	100 VDC	
Max. Solar Input Power	12V @ 260W 24V @ 520W	12V @ 520W 24V @ 1040W
Self-Consumption	≤1.5W	
Temp. Compensation	-3mV/℃/2V, excludes LI	

General

Model	RCC20RVRE-G1	RCC40RVRE-G1
Battery Types	SLD/AGM, GEL, FLD, LI	
Grounding Type	Common Negative	
Terminal Size	20-6 AWG	
Operating Temperature	-20℃ ~ 45℃ / -4°F ~ 113°F	
Storage Temperature	-40℃ ~ 80℃ / -40°F ~ 176°F	
Humidity Range	≤95% (NC)	
Dimensions	161.5 * 97.9 * 66.5 mm 6.36 * 3.85 * 2.62 in	199.5*130*76.7 mm 7.85*5.12*3.02 in
Weight	0.75 kg 1.65 lbs	1.364 kg 3.01 lbs
Enclosure	IP32	
Communication	RS485	
Certification	FCC Part 15 Class B; CE; RoHS; RCM	

Battery Charging Parameters

Battery	SLD/AGM	GEL	FLOODED	LI(LFP)
High Voltage Disconnect	16 V	16 V	16 V	16 V
Over Voltage Reconnect	15 V	15 V	15 V	15 V
Equalization Voltage	-----	-----	14.8V	-----
Boost Charge Voltage	14.6 V	14.2 V	14.6 V	14.4V User:12.0V-16V
Float Charge Voltage	13.8 V	13.8 V	13.8 V	-----
Boost Return Voltage	13.2 V	13.2 V	13.2 V	13.2 V
Over-discharge Recover	12.6 V	12.6 V	12.6 V	12.6 V
Over-discharge Warning	11.1 V	11.1 V	11.1 V	11.1 V
Equalization Interva	-----	-----	30 Days	-----
Equalization Duration	-----	-----	2 hours	-----
Boost Duration	2 hours	2 hours	2 hours	-----

RENOGY

PURE-SINE **WAVE**
BATTERY INVERTER

RENOGY
(ETL LISTED)
12V OFF-GRID PURE-SINE WAVE BATTERY INVERTER

The Renogy 12V Pure Sine Wave Inverter is a great addition to any off-grid solar power system. A power inverter is an electrical device that transforms the DC power stored in a battery bank into standard household AC power for a user's electronic needs. The Pure Sine Wave Power Inverter delivers superior performance for off-grid applications, providing stable power for applications that are sensitive to AC voltage variations. As a pure sine wave inverter, it is capable of producing cleaner, smoother, quieter, and more reliable electricity to operate tools, fans, lights, and other electronics without any interference.

- **Optimized for 12 VDC system voltage.**
- **Offers high quality waveform with little harmonic distortion.**
- **Overload protection for both DC input and AC output to prevent damage to the components and the unit.**
- **Special LED indicators for under-voltage and over-voltage protection,over-temperature protection, over-load protection, and short circuit indication.**
- **Two high-speed ventilation fans to help keep the inverter running at a low temperature.**
- **Includes Inverter Cables to connect the inverter to battery. (Not included in 3000W)**
- **Includes wired remote control**

Model Option ***700W 1000W 2000W 3000W***

RENOGY.COM   2775 EAST PHILADELPHIA ST. ONTARIO, CA 91761

Remote Switch

Inverter Cable

SPECIFICATION

Model	700W	1000W	2000W	3000W
Input	12V DC			
Output	115V AC			
Peak surge	1400W	2000W	4000W	6000W
Efficiency	> 90%			
Frequency	60Hz			
Total harmonic distortion (THD)	< 3%			
No load current draw	< 0.8A	< 1.0A	< 2.0A	< 2.5A
Battery low alarm	10.5V ± 0.5V DC			
Battery low shutdown	10.0V ± 0.5V DC			
Over voltage shutdown	16.5V ± 0.5V DC			
Cooling fan	Thermally controlled			
AC output sockets	2	2	3	3
USB power port	5V/2.1A			
Power output control	AC On/Off Switch			
Dimensions	12.2 × 7.4 × 3.3 in	12.9 × 6.8 × 3.3 in	17.8 × 8.6 × 4 in	18.9 × 9 × 4 in
Net weight (approximate)	5.6 lb	6.0 lb	11.7 lb	12.5 lb

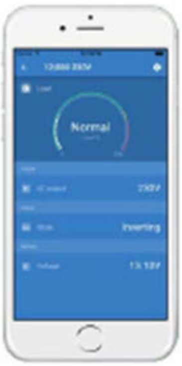
RENOGY.COM 2775 EAST PHILADELPHIA ST. ONTARIO, CA 91761

Phoenix Inverters Smart

1600 VA – 5000 VA

www.victronenergy.com

Phoenix Inverter Smart 12/3000



Bluetooth built-in: fully configurable with a tablet or smartphone

- Low battery voltage alarm
- Low battery voltage cut-off and restart levels
- Dynamic cut-off: load dependent cut-off level
- Output voltage: 210 - 245V
- Frequency: 50 Hz or 60 Hz
- ECO mode on/off and ECO mode sense level
- Alarm relay

Monitoring:

- In- and output voltage, load and alarms

VE.Direct communication port

The VE.Direct port can be connected to a computer (VE.Direct to USB interface cable needed) to configure and monitor the same parameters.

Proven reliability

The full bridge plus toroidal transformer topology has proven its reliability over many years.
The inverters are short circuit proof and protected against overheating, whether due to overload or high ambient temperature.

High start-up power

Needed to start loads such as power converters for LED lamps, halogen lamps or electric tools.

ECO mode

When in ECO mode, the inverter will switch to standby when the load decreases below a preset value. Once in standby the inverter will switch on for a short period every 2,5 seconds (adjustable).
If the load exceeds the preset level, the inverter will remain on.

Remote on/off

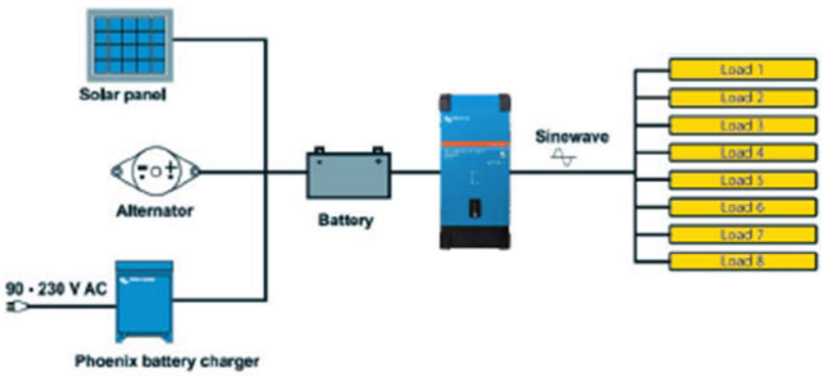
A remote on/off switch or relay contact can be connected to a two pole connector.
Alternatively, the H terminal (left) of the two pole connector can be switched to battery plus, or the L terminal (right) of the two pole connector can be switched to battery minus (or the chassis of a vehicle, for example).

LED diagnosis

Please see manual for a description.

To transfer the load to another AC source: the automatic transfer switch

For our low power inverters we recommend our Filax Automatic Transfer Switch. The Filax features a very short switchover time (less than 20 milliseconds) so that computers and other electronic equipment will continue to operate without disruption. Alternatively use a MultiPlus with built-in transfer switch.



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Phoenix Inverter Smart	12/1600 24/1600 48/1600	12/2000 24/2000 48/2000	12/3000 24/3000 48/3000	24/5000 48/5000
Parallel and 3-phase operation	No			
INVERTER				
Input voltage range	9.3 – 17V 18.6 – 34V 37.2 – 68V			
Output	Output voltage: 230 VAC ±2% 50 Hz or 60 Hz ± 0.1% (1)			
Cont. output power at 25°C (1)	1600 VA	2000 VA	3000 VA	5000 VA
Cont. output power at 25°C	1300 W	1600 W	2400 W	4000 W
Cont. output power at 40°C	1200 W	1450 W	2200 W	3700 W
Cont. output power at 65°C	800 W	1000 W	1700 W	2800 W
Peak power	3000 W	4000 W	6000 W	10000 W
Dynamic (load dependent) DC low shut down (fully configurable)	Dynamic cut-off, see https://www.victronenergy.com/live/ve.direct:phoenix-inverters-dynamic-cutoff			
Max. efficiency 12/ 24 /48 V	92 / 94 / 94%	92 / 94 / 94%	93 / 94 / 95%	95 / 96%
Zero load power 12 / 24 / 48 V	8 / 9 / 11 W	8 / 9 / 11 W	12 / 13 / 15 W	18 / 20 W
Zero load power in ECO mode	0.6 / 1.3 / 2.1 W	0.6 / 1.3 / 2.1 W	1.5 / 1.9 / 2.8 W	2.2 / 3.2 W
GENERAL				
Programmable relay (2)	Yes			
Stop & start power ECO-mode	adjustable			
Protection (3)	a - g			
Bluetooth wireless communication	For remote monitoring and system integration			
VE.Direct communication port	For remote monitoring and system integration			
Remote on-off	Yes			
Common Characteristics	Operating temperature range: -40 to +65°C (fan assisted cooling) Humidity (non-condensing): max 95%			
ENCLOSURE				
Common Characteristics	Material & Colour: steel (blue RAL 5012; and black RAL 9017) Protection category: IP21			
Battery-connection	M8 bolts	M8 bolts	12 V/24 V: 2+2 M8 bolts 48 V: M8 bolts	24 V: 2+2 M8 bolts 48 V: M8 bolts
230 V AC-connection	Screw terminals			
Weight	12kg	13kg	19kg	29kg / 28kg
Dimensions (hxwxd)	485 x 219 x 125mm	485 x 219 x 125mm	533 x 285 x 150mm (12 V) 485 x 285 x 150mm (24 V/48 V)	595 x 295 x 160mm (24 V) 555 x 295 x 160mm (48 V)
STANDARDS				
Safety	EN 60335-1			
Emission Immunity	EN 55014-1 / EN 55014-2/ EN-IEC 61000-6-1 / EN-IEC 61000-6-2 / EN-IEC 61000-6-3			
Automotive Directive	ECE R10-5			

1) Non-linear load, crest factor 3:1
2) Programmable relay that can a.o. be set for general alarm, DC under voltage or genset start/stop function.
AC rating: 230 V / 4 A
DC rating: 4 A / 35 VDC, 1A / 60VDC

3) Protection key:
a) output short circuit
b) overload
c) battery voltage too high
d) battery voltage too low
e) temperature too high
f) 230 V AC on inverter output
g) input voltage ripple too high

Phoenix Inverter Control
This panel is intended for remote on/off control of all Phoenix inverters Smart

Color Control GX and other GX devices
Provides monitoring and control.
Locally, and remotely on the VRM Portal.

VE.Direct to USB interface
Connects to a USB port.

Bluetooth wireless communication
Connects to a smart phone (both iOS and Android).

BMV-712 Smart Battery Monitor
The BMV Battery Monitor features an advanced microprocessor control system combined with high resolution measuring systems for battery voltage and charge/discharge current. Besides this, the software includes complex calculation algorithms, like Peukert's formula, to exactly determine the state of charge of the battery. The BMV selectively displays battery voltage, current, consumed Ah or time to go. The monitor also stores a host of data regarding performance and use of the battery.

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victron energy
BLUE POWER

ITECHWORLD
THE POWER EXPERT

iTECH120X

LITHIUM LIFEPO4 DEEP CYCLE BATTERY

12.8V | LIFEPO4 | IP67 WATERPROOF | 4000+ CYCLES

The iTECH120X Lithium Battery is the result of over ten years of design and development from our Australian engineers. A true drop-in lithium replacement for your existing system, the iTECH120X has 50% more useable energy, ten times greater lifespan, weighs 60% less and will charge up to ten times faster than the equivalent lead-acid battery. Fully IP67 waterproof, the iTECH120X can be submerged for up to 30 minutes.

Designed in Australia, iTechworld Lithium Batteries have are tested to withstand the unique Australian climate.

SUITABLE FOR

Caravans, Campervans, Boats, Under-bonnet, RV's, 4WD Canopies, Battery Boxes, Dual-Battery Systems

DIMENSIONS

SPECIFICATIONS

Nominal Voltage	12.8V	**BMS Operating Temperture**	-5 °C to 80 °C
Nominal Capacity (C20)	105Ah	**Battery Output Voltage Range**	10V to 14.6V (approx)
Cell Structure	A Grade Prismatic Cells	**Maximum Discharge Current**	275A (5 seconds)
Cell Technology	LiFePO4	**5 Minute Discharge**	175A
Cycle Life (100% DoD)	4000+	**Continuous Discharge**	150A
Cycle Life (50% DoD)	8000+	**BMS Charge Cut Off Voltage**	15.4V
Optimal Operating Temperature	+5 °C to +60 °C	**BMS Low Voltage Cut Off (Safe Mode)**	≤10V
Recommended Charge Voltage	14.2V to 14.6V	**Short Circuit Protection**	Yes
Standby (Float) Voltage	13.5V	**Waterproof Rating**	IP67
Maximum Charge Current	100A	**Vibration Proof**	Yes
Parallel Connection	Unlimited	**Weight**	10KG
Series Connection	24V Max	**Warranty**	5 Years
Terminal Type	M8 Terminal Bolts	**Dimensions**	255x170x215mm (LxWxH)

CERTIFICATIONS
IEC UL UN38.3 PASSED

Updated May 2023

ELMOFO E-CELLS POWERCELL

E-CELLS 50NMC TECHNICAL SPECIFICATION

ELMOFO E-CELLS 50NMC Lithium Ion Battery designed for power applications that require:

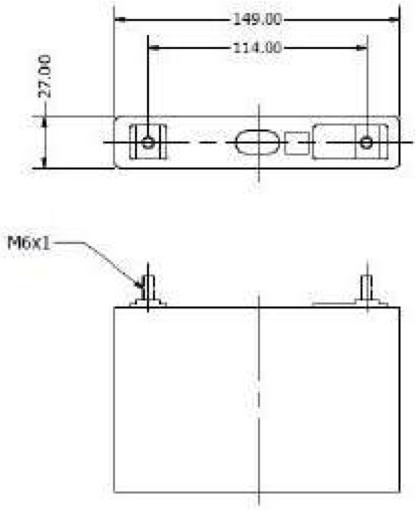
- High power output
- Light weight
- Long battery life
- High durability
- Excellent energy density
- Excellent power-to-energy balance

Items	Unit	Specification		Remarks
Nominal Capacity	Ah	50Ah		Standard Discharge
Energy Density	Wh/kg	205		
Energy Density	Wh/L	528		
Internal Resistance	MΩ	0.60~0.80mΩ		50% SOC
Weight	g	900±25g		
Cell Dimensions	mm	149x27x113(h)		Top of Stud
Voltage	V	2.80		Minimum
	V	3.70		Nominal
	V	4.20		Maximum
Recommended Voltage Range	V	3.40 - 4.10V		Long Life Voltage Range
Current	A	Cont	50A (1C)	Charge 23 °C<T<40 °C
	A	Cont	50A (1C)	Discharge
	A	3 min	150A (3C)	Discharge
	A	10 sec	400A (8C)	Discharge 23 °C<T<40 °C SOC>20%
Cycle Life	Cycles	≥ 2000		1C/1C to 80% DOD to 80% Remaining Capacity
Operating Temperature	°C	10~45 °C		Charging Temperature
	°C	-10~55°C		Discharging Temperature

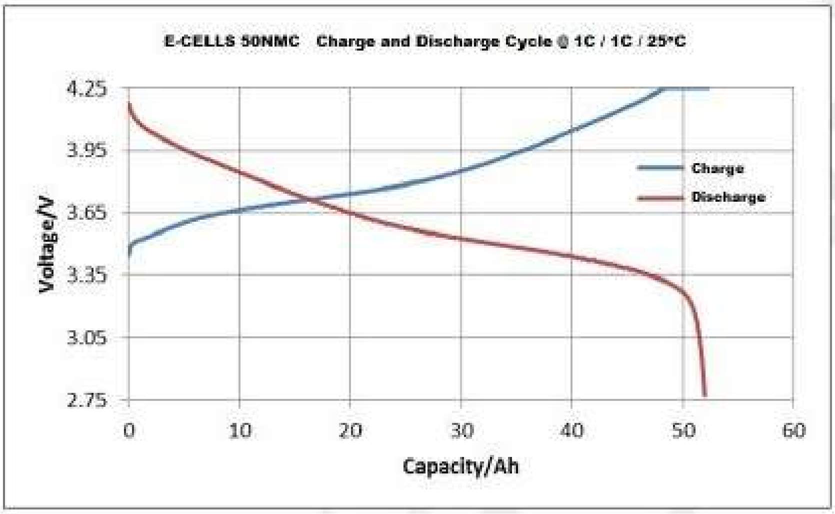
The information contained herein is provided solely for the purposes of general explanation and illustration and is subject to modification without notice. No warranty or guarantee is given in regards to the information contained herein or the referenced products. Please contact ELMOFO for the most current and relevant product information for your particular application.

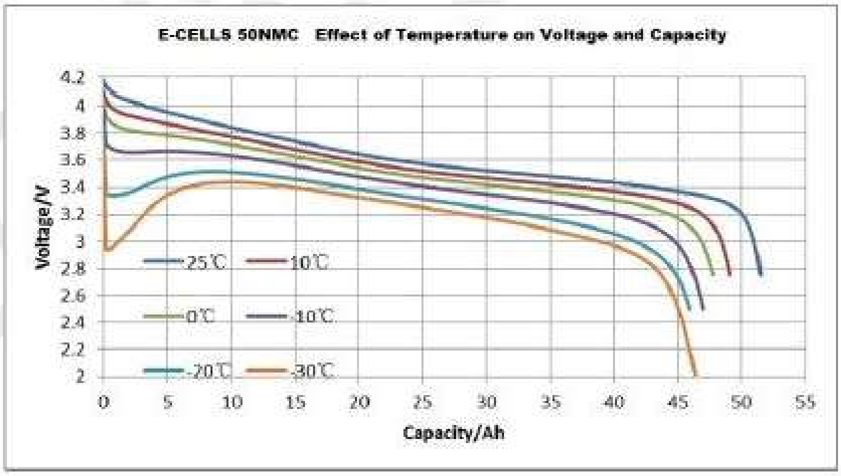
Mechatronic Pty Ltd T/a ELMOFO www.elmofo.com.au +61 2 4954 3310

ELMOFO E-CELLS POWERCELL



E-CELLS 50NMC Dimensions





Appendix J: Water Transfer Pump Datasheets

KEY FEATURES

- Easy installation and operation
- Quiet operation
- High efficiency twin impellers
- Rugged cast iron construction with brass impellers
- High quality mechanical shaft seal
- Threaded suction and discharge connections [2CP6S/2CP7S/2CP9T]:
  Suction 32mm [¼" BSPF]
  Discharge 25mm [1 " BSPF]
- TEFC motor, 2900rpm, 240V single phase or 415V 3 phase, IP44 enclosure
- 240 volt units supplied with 1.5m lead and 3 pin plug

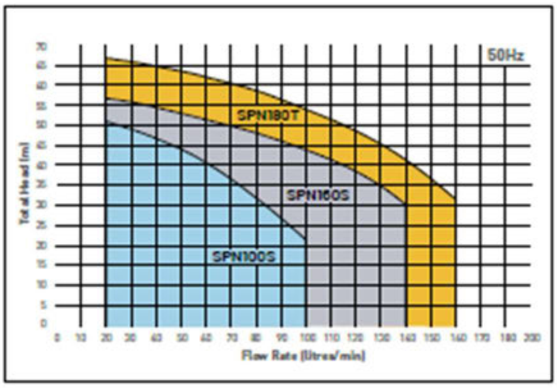
PUMP CONSTRUCTION MATERIALS

Component	Material
Pump casing:	Cast iron
Impellers:	Brass
Shaft Seal:	Ceramic / Graphite / NBR
Shaft:	Stainless Steel
Priming Plug:	Brass

APPLICATIONS

Washdown, heating and cooling systems.
Pressure boosting, agriculture and horticulture.

PERFORMANCE



OPERATING CONDITIONS

Capacity:	Maximum 160 l/min.
Max. Head:	65m
Liquid Temp.:	+0°C to +90°C
Max. Ambient Temp.:	+40°C
Pumped Liquid:	Clean Water

SPECIFICATIONS

Part Number (Transfer Pumps)	Part Number (Pump + Pressure switch)	Motor [Watts]		Full Load Amps		Pump Stages	Max. Head [m]	Max. Flow [L/min]	Inlet	Outlet	Length (mm)	Height (mm)	Width (mm)	Weight (kg)
		1x240V	3x415V	1x240V	3x415V									
SPN100S	SPN100SP	1100	-	7	-	2	47	100	32mm [1 ¼" BSPF]	25mm [1" BSPF]	382	225	200	20.1
SPN160S	SPN160SP	1500	-	10	-	2	54	140	32mm [1 ¼" BSPF]	25mm [1" BSPF]	407	263	225	24.6
SPN180T	SPN180TP	-	2200	-	5	2	65	160	32mm [1 ¼" BSPF]	25mm [1" BSPF]	407	263	225	26.1

PENTAIR

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0323

Appendix K: Cable Reports

Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

jCalc.NET

Project information	
Security and Fire Monitoring System - Solar Panel Connection Cables	
Date	2023-09-09
Compiled By	Jason Craig

Load	
Voltage	[illegible]1 V, DC
Load	37 A
Maximum voltage drop	2 %
Cable distance	5 m

Cable type	
Cable type	3 x Multi-core 2C+E
Live cores	3 x 6 mm²
Neutral cores	3 x 6 mm²
Earth cores	3 x 2.5 mm²
Conductors	Copper, Flexible
Insulation	PVC V-90 Standard 75°

Current rating	
Rated current	126 A = 42 A x 3, Table 10, col. 6
Derated current	87 A = 126 A x 0.70
Calculated operating temperature	4[illegible]°C
Maximum operating temperature	75°C

FREE PREVIEW
NOT FOR COMMERCIAL USE
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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop

Voltage drop	1.6%, 0.5 V
Voltage at load	30.3 V
Max distance	6 m for 2%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per core	3.8200 Ohm/km, Table 37, col. 8, 60°C

Impedance -earth

Resistance per core	9.2300 Ohm/km, Table 37, col. 8, 60°C

Installation

Cable installation

Touching surface

		Derating	Reference
Cable support	Bunched on a surface		
Number of cables	3	0.70	Table 22, row 2, col. 6
Air temperature	40°C	1.00	Table 27(1), row 5, col. 7
Total derating		0.70	

Protection

Protection device	MCB
Rating	40 A
Curve	C
Magnetic trip setting	300 A, Fixed

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Earth fault current at load	728 A

Fault rating -live and neutral	
Fault energy rating	443,556 A²s
Initial operating temperature	75°C, worst case.
Maximum fault temperature	160°C
Fault constant	111

Fault rating -earth	
Fault energy rating	77,006 A²s
Initial operating temperature	75°C, worst case.
Maximum fault temperature	160°C
Fault constant	111

Earth fault loop impedance	
Check loop impedance	Yes
Source impedance method	Estimate
Source impedance	0.0205 Ohm
Phase cable impedance	0.0064 Ohm
Earth cable impedance	0.0154 Ohm
Total fault loop impedance	0.0423 Ohm
Maximum allowable fault loop impedance	0.1 Ohm
Installed distance	5 m
Maximum allowable distance	19 m
Earth fault current at load	728 A
Minimum earth fault current required at load	300 A

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Project information

Security and Fire Monitoring System - Solar Charge Controller

Date	2023-09-09
Compiled By	Jason Craig

Load

Voltage	12 V, DC
Load	40 A
Maximum voltage drop	3 %
Cable distance	1 m

Cable type

Cable type	Single-cores
Live cable	6 mm²
Neutral cable	6 mm²
Earth cable	2.5 mm²
Live conductor	Copper, Flexible
Neutral conductor	Copper, Flexible
Earth conductor	Copper, Flexible
Live insulation	XLPE X-90 Standard 90°
Neutral insulation	XLPE X-90 Standard 90°
Earth insulation	XLPE X-90 Standard 90°

Current rating

Rated current	46 A, Table 5, col. 9
Derated current	46 A, 46 A x 1.00
Calculated operating temperature	78°C
Maximum operating temperature	90°C

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Cable Sizing Report

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Voltage drop

Voltage drop	2.8%, 0.3 V
Voltage at load	11.7 V
Max distance	1 m for 3%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per cable	4.2100 Ohm/km, Table 37, col. 5, 90°C

Impedance -earth

Resistance per cable	10.2000 Ohm/km, Table 37, col. 5, 90°C

Installation

Cable installation  Touching surface

Cable support: Bunched on a surface

		Derating	Reference
Number of cable groups	1	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		1.00	

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

All cables

	Active Size	Earth Size	Current Rating	Volt Drop
	mm²	mm²	A	%
	1	2.5	16	16.6
	1.5	2.5	20	[illegible]
	2.5	2.5	27	[illegible]
	4	2.5	[illegible]	4.2
X	6	2.5	46	2.8
	10	4	64	1.5
	16	6	85	0.9

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Cable Sizing Report

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Project information	
Security and Fire Monitoring System - Battery Cables	
Date	2023-09-09
Compiled By	Jason Craig

Load	
Voltage	12 V, DC
Load	185 A
Maximum voltage drop	2 %
Cable distance	1 m

Cable type	
Cable type	Single-cores
Live cable	70 mm²
Neutral cable	70 mm²
Earth cable	25 mm²
Live conductor	Copper, Flexible
Neutral conductor	Copper, Flexible
Earth conductor	Copper, Flexible
Live insulation	XLPE X-90 Standard 90°
Neutral insulation	XLPE X-90 Standard 90°
Earth insulation	XLPE X-90 Standard 90°

Current rating	
Rated current	225 A, Table 5, col. 9
Derated current	225 A, 225 A x 1.00
Calculated operating temperature	74°C
Maximum operating temperature	90°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop

Voltage drop	1%, 0.1 V
Voltage at load	11.9 V
Max distance	2 m for 2%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per cable	0.3320 Ohm/km, Table 37, col. 4, 75°C

Impedance -earth

Resistance per cable	0.9490 Ohm/km, Table 37, col. 4, 75°C

Installation

Cable installation		Touching surface
Cable support	Bunched on a surface	

		Derating	Reference
Number of cable groups	1	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		1.00	

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 2%.	Good
Minimum earth size AS/NZS 3000.	Good

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

All cables

Active Size mm²	Earth Size mm²	Current Rating A	Volt Drop %
1	2.5	16	76.8
1.5	2.5	20	[illegible]
2.5	2.5	27	[illegible]
4	2.5	[illegible]	19.5
6	2.5	46	13
10	4	64	7.5
16	6	85	4.8
25	[illegible]	114	3.1
35	[illegible]	141	2.2
50	16	[illegible]	1.5
✓ 70	25	225	1
95	25	271	0.8
120	35	322	0.6

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

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Project information

Security and Fire Monitoring System - Grid Connected Mains	
Date	2023-09-09
Compiled By	Jason Craig

Load

Voltage	230 V, 1 Phase AC
Load	10 A
Maximum voltage drop	2 %
Cable distance	310 m

Cable type

Cable type	Single-cores (mains)
Live cable	35 mm²
Combined earth and neutral cable	35 mm²
Live conductor	Copper, Flexible
Combined earth and neutral conductor	Copper, Flexible
Live insulation	XLPE X-90 Standard 90°
Combined earth and neutral insulation	XLPE X-90 Standard 90°

Current rating

Rated current	103 A, Table 5, col. 12
Derated current	103 A, 103 A x 1.00
Calculated operating temperature	40°C
Maximum operating temperature	90°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop	
Voltage drop	1.7%, 3.8 V
Voltage at load	226.2 V
Max distance	372 m for [illegible]%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live	
Resistance per cable	0.6090 Ohm/km, Table 37, col. 2, 45°C
Reactance per cable	0.1080 Ohm/km, Table 31, col. 7
Impedance per cable	0.6185 Ohm/km

Impedance -combined earth and neutral	
Resistance per cable	0.6090 Ohm/km, Table 37, col. 2, 45°C
Reactance per cable	0.1080 Ohm/km, Table 31, col. 7
Impedance per cable	0.6185 Ohm/km

Installation

Cable installation: Exposed to sun

Cable support: Bunched on a surface

		Derating	Reference
Number of cable groups	1	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		1.00	

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 2%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

	Active Size mm²	Earth Size mm²	Current Rating A	Volt Drop %
	10	10	48	5.7
	16	16	63	3.[illegible]
	25	25	83	2.3
X	35	[illegible]	[illegible]	1.7
	[illegible]	50	128	1.2
	70	70	161	0.9

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Cable Sizing Report

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Project information

Security and Fire Monitoring System - Grid Connected Power Outlet	
Date	2023-09-09
Compiled By	Jason Craig

Load

Voltage	230 V, 1 Phase AC
Load	10 A
Maximum voltage drop	2 %
Cable distance	10 m

Cable type

Cable type	Multi-core 2C+E
Live core	1.5 mm²
Neutral core	1.5 mm²
Earth core	1.5 mm²
Conductors	Copper, Flexible
Insulation	PVC V-90 Standard 75°C

Current rating

Rated current	17 A, Table 10, col. 12
Derated current	17 A, 17 A x 1.00
Calculated operating temperature	5[illegible]°C
Maximum operating temperature	75°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop	
Voltage drop	1.3%, 3.1 V
Voltage at load	226.9 V
Max distance	15 m for 2[illegible]
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral	
Resistance per core	15.4000 Ohm/km, Table 37, col. 8, 60°C
Reactance per core	0.1090 Ohm/km, Table 31, col. 9
Impedance per core	15.4004 Ohm/km

Impedance -earth	
Resistance per core	15.4000 Ohm/km, Table 37, col. 8, 60°C
Reactance per core	0.1090 Ohm/km, Table 31, col. 9
Impedance per core	15.4004 Ohm/km

Installation

Cable installation: Wiring enclosure in air

Cable support: Bunched in an enclosure

		Derating	Reference
Cables per enclosure	[illegible]	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 5, col. 7
Total derating		1.00	

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 2%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

	Active Size	Earth Size	Current Rating	Volt Drop
	mm²	mm²	A	%
	1	1	13	2.1
X	1.5	1.5	17	1.[illegible]
	2.5	[illegible]	23	0.8
	4	[illegible]	[illegible]	0.5

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Project information	
Carbon Farm Concept - Solar Connection Cables	
Date	2023-09-09
Compiled By	Jason Craig

Load	
Voltage	210 V, DC
Load	73 A
Maximum voltage drop	3 %
Cable distance	10 m

Cable type	
Cable type	2 x Multi-core 2C+E
Live cores	2 x 6 mm²
Neutral cores	2 x 6 mm²
Earth cores	2 x 2.5 mm²
Conductors	Copper
Insulation	XLPE X-90 Standard 90°

Current rating	
Rated current	92 A = 46 A x 2, Table 11, col. 11
Derated current	74 A = 92 A x 0.80
Calculated operating temperature	89°C
Maximum operating temperature	90°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop

Voltage drop	1.4%, 2.9 V
Voltage at load	207.1 V
Max distance	22 m for 3%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per core	3.9300 Ohm/km, Table 35, col. 5, 90°C

Impedance -earth

Resistance per core	9.4500 Ohm/km, Table 35, col. 5, 90°C

Installation

Cable installation

Wiring enclosure in air

Cable support: Bunched in an enclosure

		Derating	Reference
Cables per enclosure	2	0.80	Table 22, row 2, col. 5
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		0.80	

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

All cables

	Active Size mm²	Earth Size mm²	Derated Current Rating A	Volt Drop %
	2 x 1	2 x 1	26	9.4
	2 x 1.5	2 x 1.5	32	[illegible]
	2 x 2.5	2 x 2.5	44	[illegible]
	2 x 4	2 x 2.5	[illegible]	2.1
X	2 x 6	2 x 2.5	74	1.4
	2 x 10	2 x 4	100	0.8
	2 x 16	2 x 6	132	0.5

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Project information	
Carbon Farm Concept - Solar Charge Controller Cables	
Date	2023-09-09
Compiled By	Jason Craig

Load	
Voltage	48 V, DC
Load	85 A
Maximum voltage drop	3 %
Cable distance	5 m

Cable type	
Cable type	Multi-core 2C+E
Live core	25 mm²
Neutral core	25 mm²
Earth core	6 mm²
Conductors	Copper
Insulation	XLPE X-90 Standard 90°C

Current rating	
Rated current	110 A, Table 11, col. 11
Derated current	110 A, 110 A x 1.00
Calculated operating temperature	70°C
Maximum operating temperature	90°C

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Cable Sizing Report

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AS/NZS 3008.1.1:2017 Australian conditions

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Voltage drop

Voltage drop	1.6%, 0.8 V
Voltage at load	47.3 V
Max distance	10 m for 3%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per core	0.8840 Ohm/km, Table 35, col. 4, 75°C

Impedance -earth

Resistance per core	3.7500 Ohm/km, Table 35, col. 4, 75°C

Installation

Cable installation

Wiring enclosure in air

Cable support	Bunched in an enclosure		
		Derating	Reference
Cables per enclosure	1	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		1.00	

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

All cables

	Active Size	Earth Size	Current Rating	Volt Drop
	mm²	mm²	A	%
	1	1	16	47.8
	1.5	1.5	20	[illegible]
	2.5	2.5	28	[illegible]
	4	2.5	37	10.4
	6	2.5	46	7
	10	4	63	4.1
	16	6	82	2.6
X	25	[illegible]	110	1.6
	35	[illegible]	132	1.1
	50	16	[illegible]	0.8

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Project information	
Carbon Farm Concept - Inverter Cables	
Date	2023-09-09
Compiled By	Jason Craig

Load	
Voltage	48 V, DC
Load	55 A
Maximum voltage drop	3 %
Cable distance	5 m

Cable type	
Cable type	Single-cores
Live cable	10 mm²
Neutral cable	10 mm²
Earth cable	4 mm²
Live conductor	Copper
Neutral conductor	Copper
Earth conductor	Copper
Live insulation	XLPE X-90 Standard 90°
Neutral insulation	XLPE X-90 Standard 90°
Earth insulation	XLPE X-90 Standard 90°

Current rating	
Rated current	65 A, Table 5, col. 8
Derated current	65 A, 65 A x 1.00
Calculated operating temperature	76°C
Maximum operating temperature	90°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop	
Voltage drop	2.6%, 1.2 V
Voltage at load	46.8 V
Max distance	6 m for 3%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral	
Resistance per cable	2.2600 Ohm/km, Table 34, col. 5, 80°C

Impedance -earth	
Resistance per cable	5.8800 Ohm/km, Table 34, col. 6, 90°C

Installation

Cable installation

Touching surface

		Derating	Reference
Number of cable groups	1	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		1.00	

Cable checks	
Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

All cables

	Active Size mm²	Earth Size mm²	Current Rating A	Volt Drop %
	1	2.5	16	30.9
	1.5	2.5	20	[illegible]
	2.5	2.5	28	[illegible]
	4	2.5	37	6.7
	6	2.5	47	4.5
X	10	4	65	2.6
	16	6	86	1.5
	25	[illegible]	117	1

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

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Project information

Carbon Farm Concept - Grid Connected Mains Cables	
Date	2023-09-09
Compiled By	Jason Craig

Load

Voltage	230 V, 1 Phase AC
Load	63 A
Maximum voltage drop	2 %
Cable distance	450 m

Cable type

Cable type	Single-cores (mains)
Live cables	3 x 95 mm²
Combined earth and neutral cables	3 x 95 mm²
Live conductors	Copper
Combined earth and neutral conductors	Copper
Live insulation	XLPE X-90 Standard 90°
Combined earth and neutral insulation	XLPE X-90 Standard 90°

Current rating

Rated current	591 A = 197 A x 3, Table 5, col. 11
Derated current	414 A = 591 A x 0.70
Calculated operating temperature	41°C
Maximum operating temperature	90°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop	
Voltage drop	1.9%, 4.5 V
Voltage at load	225.5 V
Max distance	464 m for [illegible]%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live	
Resistance per cable	0.2130 Ohm/km, Table 34, col. 2, 45°C
Reactance per cable	0.1020 Ohm/km, Table 30, col. 7
Impedance per cable	0.2362 Ohm/km

Impedance -combined earth and neutral	
Resistance per cable	0.2130 Ohm/km, Table 34, col. 2, 45°C
Reactance per cable	0.1020 Ohm/km, Table 30, col. 7
Impedance per cable	0.2362 Ohm/km

Installation

Cable installation	Exposed to sun		
Cable support	Bunched on a surface		
		Derating	Reference
Number of cable groups	[illegible]	0.70	Table 22, row 2, col. 6
Air temperature	40°C	1.00	Table 27(1), row 3, col. 7
Total derating		0.70	

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 2%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

Active Size mm²	Earth Size mm²	Derated Current Rating A	Volt Drop %
3 x 10	[illegible]	102	17.5
3 x 16	3 x 16	135	[illegible]
3 x 25	3 x 25	180	7
[illegible]	3 x 35	[illegible]	4.8
[illegible]	3 x 50	267	3.6
[illegible]	3 x 70	336	2.6
3 x 95	[illegible]	414	1.9
3 x 120	3 x 120	480	1.6
3 x 150	3 x 150	549	1.4

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Project information

Water transfer subsystem at 50m from source	
Date	2023-10-01
Compiled By	Jason Craige
Approved By	Jason Craige

Load

Voltage	230 V, 1 Phase AC
Load	7 A
Maximum voltage drop	3 %
Cable distance	50 m

Cable type

Cable type	Multi-core 2C+E
Live core	2.5 mm²
Neutral core	2.5 mm²
Earth core	2.5 mm²
Conductors	Copper
Insulation	PVC V-90 Standard (5

Current rating

Rated current	20 A, Table 10, col. 8
Derated current	20 A, 20 A x 1.00
Calculated operating temperature	44°C
Maximum operating temperature	75°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop

Voltage drop	2.5%, 5.7 V
Voltage at load	224.3 V
Max distance	61 m for 3%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per core	8.1400 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.1020 Ohm/km, Table 30, col. 9
Impedance per core	8.1406 Ohm/km

Impedance -earth

Resistance per core	8.1400 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.1020 Ohm/km, Table 30, col. 9
Impedance per core	8.1406 Ohm/km

Installation

Cable installation — Exposed to sun

		Derating	Reference
Number of cables	[illegible]	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 5, col. 7
Total derating		1.00	

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Cable Sizing Report

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Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

	Active Size	Earth Size	Current Rating	Volt Drop
	mm²	mm²	A	%
	1	1	11	7.5
	1.5	1.5	14	4.[illegible]
X	2.5	2.5	20	2.5
	4	2.5	27	1.5
	6	2.5	34	1

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

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Project information

Water transfer subsystem at 100m from source

Date	2023-10-01
Compiled By	Jason Craig
Approved By	Jason Craige

Load

Voltage	230 V, 1 Phase AC
Load	7 A
Maximum voltage drop	3 %
Cable distance	100 m

Cable type

Cable type	Multi-core 2C+E
Live core	6 mm²
Neutral core	6 mm²
Earth core	2.5 mm²
Conductors	Copper
Insulation	PVC V-90 Standard (5[illegible]

Current rating

Rated current	34 A, Table 10, col. 8
Derated current	34 A, 34 A x 1.00
Calculated operating temperature	41°C
Maximum operating temperature	75°C

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Cable Sizing Report

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AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop	
Voltage drop	2.1%, 4.7 V
Voltage at load	225.3 V
Max distance	146 m for [illegible]
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral	
Resistance per core	3.3800 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.09[illegible] Ohm/km, Table 30, col. 9
Impedance per core	[illegible] Ohm/km

Impedance -earth	
Resistance per core	8.1400 Ohm/km, Table 35, col. [illegible], 45°C
Reactance per core	0.1020 Ohm/km, Table 3[illegible], col. 9
Impedance per core	8.1406 Ohm/km

Installation

Cable installation — Exposed to sun

		Derating	Reference
Number of cables	[illegible]	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 5, col. 7
Total derating		1.00	

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

	Active Size	Earth Size	Current Rating	Volt Drop
	mm²	mm²	A	%
	1	1	11	14.9
	1.5	1.5	14	9.[illegible]
	2.5	2.5	20	5
	4	[illegible]	27	3.1
X	6	2.5	34	2.1
	10	4	46	1.2
	16	[illegible]	60	0.8

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Cable Sizing Report

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Project information

Water transfer subsystem at 150m from source	
Date	2023-10-01
Compiled By	Jason Craig
Approved By	Jason Craige

Load

Voltage	230 V, 1 Phase AC
Load	7 A
Maximum voltage drop	3 %
Cable distance	150 m

Cable type

Cable type	Multi-core 2C+E
Live core	10 mm²
Neutral core	10 mm²
Earth core	4 mm²
Conductors	Copper
Insulation	PVC V-90 Standard (75°C)

Current rating

Rated current	46 A, Table 10, col. 8
Derated current	46 A, 46 A x 1.00
Calculated operating temperature	41°C
Maximum operating temperature	75°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop

Voltage drop	1.8%, 4.2 V
Voltage at load	225.8 V
Max distance	245 m for 5%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per core	2.0100 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.0906 Ohm/km, Table 30, col. 9
Impedance per core	2.0120 Ohm/km

Impedance -earth

Resistance per core	5.0600 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.1020 Ohm/km, Table 30, col. 9
Impedance per core	5.0610 Ohm/km

Installation

Cable installation — Exposed to sun

		Derating	Reference
Number of cables	[illegible]	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 5, col. 7
Total derating		1.00	

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

Active Size mm²	Earth Size mm²	Current Rating A	Volt Drop %
1	1	11	22.4
1.5	1.5	14	14.3
2.5	2.5	20	7.4
4	2.5	27	4.6
6	2.5	34	3.1
10	4	46	1.8
16	6	60	1.2
25	6	79	0.7

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Project information

Water transfer subsystem at 300m from source	
Date	2023-10-01
Compiled By	Jason Craige
Approved By	Jason Craige

Load

Voltage	230 V, 1 Phase AC
Load	7 A
Maximum voltage drop	3 %
Cable distance	300 m

Cable type

Cable type	Multi-core 2C+E
Live core	16 mm²
Neutral core	16 mm²
Earth core	6 mm²
Conductors	Copper
Insulation	PVC V-90 Standard (75°C)

Current rating

Rated current	60 A, Table 10, col. 8
Derated current	60 A, 60 A x 1.00
Calculated operating temperature	40°C
Maximum operating temperature	75°C

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Voltage drop

Voltage drop	2.3%, 5.3 V
Voltage at load	224.7 V
Max distance	390 m for [illegible]%
Option: Conductor temperature	Calculated
Option: Load power factor	Worst case

Impedance -live and neutral

Resistance per core	1.2600 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.0861 Ohm/km, Table 30, col. 9
Impedance per core	1.2629 Ohm/km

Impedance -earth

Resistance per core	3.3800 Ohm/km, Table 35, col. 2, 45°C
Reactance per core	0.0967 Ohm/km, Table 30, col. 9
Impedance per core	3.3814 Ohm/km

Installation

Cable installation

Exposed to sun

		Derating	Reference
Number of cables	[illegible]	1.00	Table 22, row 2, col. 4
Air temperature	40°C	1.00	Table 27(1), row 5, col. 7
Total derating		1.00	

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Cable Sizing Report

AS/NZS 3008.1.1:2017 Australian conditions

Cable checks

Current rating for live and neutral conductors.	Good
Voltage drop less than 3%.	Good
Minimum earth size AS/NZS 3000.	Good

All cables

Active Size mm²	Earth Size mm²	Current Rating A	Volt Drop %
1	1	11	44.7
1.5	1.5	14	28.7
2.5	2.5	20	14.9
4	2.5	27	9.2
6	2.5	34	6.2
10	4	46	3.7
16	6	60	2.3
25	6	79	1.5
35	10	97	1.1

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Appendix L: Catalogue

The embedded file below contains the catalogue utilised within both off-grid concept designs.

Catalogue.xlsx