University of Southern Queensland
Faculty of Health, Engineering and Sciences

Analysis of the Potential for 100% Renewable Energy supply to Groote Eylandt

A dissertation submitted by

Jayesh Patel

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Abstract

In past 200 years, Australia has witnessed a continual cycle of mining boom and bust which left over 50,000 abandoned mine sites. Many of the mines had closed due to various reasons and government allowed these mining operators to walk away with their operations. There is a severe effect of mine closure which includes social, economic and environmental. The social and economic effects of mine closure is depends on level of dependency of surrounded community on mines.

GEMCO (Groote Eylandt Mining Company) is a world largest and lowest-cost manganese ore producer in Australia. Community of Groote Eylandt is highly dependent on this manning operation for royalty income, employments and their energy need. Decrease in manganese demand, reduction in ore price, and high operation cost are the main factors, which will decide the future of this mine. This factors also affected Rio Tinto to cease their mining operation from Groote Eylandt in 2014. If rest of the mining operation is ceased in near future, Government of Northern Territory required to operate new power plant to meet the energy needs of this island. Power generation can be done with variety of different power sources such as diesel generators, Photovoltaic (PV) with battery bank, or combining it with diesel generators or biomass gasifier power generator. The key challenge is to choose the right power generation system to suit the geographical area of Groote Eylandt and meet their demand. Detail analysis conducted with HOMER by selecting each of the system and compared. This Comparison conducted on the base of initial cost, net present cost, cost of fuel, cost of operation and maintenance, and greenhouse gas emission (GHG). The key outcome of this project was demand of energy can be met by hybrid system comprise with PV-Battery bank and Biomass gasifier. This hybrid system will met the community energy demand with 100% renewable energy and the cost of this hybrid system is cheaper than any other system with or without fossil fuels. This hybrid system will not only provide power, but it has many other benefits which make it more attractive than others. This renewable project can create employment opportunities, more than 50% federal funding for its initial set up cost and reduction of GHG with earing carbon credits. The major advantage of this hybrid system will create Groote Eylandt community profile as first in the country to become 100% renewable.

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Limitations of Use

Certification of Thesis

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Jayesh Patel

Student Number: 0061056583

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List of Acronyms

GEMCO - Groote Eylandt Mining Company

PV - Photovoltaics

ALC - Anindilyakwa Land Council

ABS - Australian Bureau of Statistics

ABA - Aboriginal Benefits Account

CEC - Clean Energy council

SMES - Superconducting magnetic energy storage

CAES - Compressed air energy storage

NiCad - Nickel cadmium

NiMH - Nickel metal hydride

Li-ion - Lithium Ion

NREL - National Renewable Energy Lab

IES - Indigenous Essential service

NPC - Net Present Cost

MRF - Minimum renewable energy fractions

PWC - Power and Water Corporation

LCOE - Levelized cost of energy

ARENA - Australian government Renewable energy agency

Chapter 1: INTRODUCTION

1.1 Background and Justification

Australia has just been through one of the biggest mining booms in its history, which was the biggest since the gold rush of the mid-1800s. But unwinding of the boom has started, with thousands of mines now closed. Mining operations can have a beneficial effect on a community, and subsequent closure will have adverse effects. The effect of Groote Eylandt Mining Company (GEMCO) can be seen in the community of Groote Eylandt, which has become highly dependent on its operation for nearly five decades. Dependency is not only limited to royalty income but energy demand, employment, education, training and other welfare support which creates a perfect environment for researcher to study different problem area and propose solutions for future problems.

Figure 1.1 Groote Eylandt (Google Map)

Groote Eylandt is the third largest island in Australia, it situated at Western side of the Gulf of Carpentaria close to NT. It named Groote Eylandt (Great Island) by Dutch explorer Abel Tasman in 1644. It is home of Warnindilyakwan Aboriginal people and population of around 1500 with unemployment rate of 12%.

Many of the mines in Australia closed due to various reasons, and governments have let them walk away from their operations. If this situation arises in the islands community of Groote Eylandt, they will require many support services from government. The main priority would be to reinstate their basic life style by providing electricity, ahead of any other resources. However, the cost of electrification with fossil fuel has increased worldwide causing creation of a new power industry with renewable resources such as PV (Photovoltaics), wind, and bio gasification and battery banks. Popularity of this industry has been increasing worldwide, leading to decreased net investment costs. The uptake of these energy solution are providing sustainable energy to the people around the globe with minimum harm to nature.

The last couple of decades, have been an increase in development of medium to large scale PV farm, wind farms, hybrid systems which are combinations of PV-diesel, wind-diesel, PV-wind-diesel and PV-diesel-Biomass plant. The goal is to reduce fossil fuel use, and increase the capacity of renewable energy supply up to 100%. Utilization of PV systems for rural power supply is economically more feasible than using diesel generators or extension of power grid (Mahmoud, 2006). Many researchers found that hybrid power systems are less costly than diesel generation alone, even with government fuel subsidies for regional areas. Hybrid systems utilising battery banks increase efficiency of the total system and reduce diesel consumption with lower maintenance costs (Schmid, 2004).

1.2 Development of the Project Topic

The original project topic was load balancing with STATCOM power inverter with renewable power source in remote community of Groote Eylandt. But during our research we became aware of that the Groote Eylandt community would be in hard condition upon mining operations could be ceased in near future. Given this we decide it was a good idea to investigate further the current option to future proof the island community as it is a special place for local community even it is a mine site. We want to insure that should the price of manganese decline rapidly and in this very up and down market, mine could close and it will leave large clean up job without any energy supply to community. There is a federal government incentive program for large renewable project like this and this will assist forward thinking nature of this plan. We will present to those government bodies the analysis of this report. Hopefully this will leads to some investment and long term sustainability of Groote Eylandt community.

1.3 Problem Statement

Groote Eylandt is one of the largest island in the Gulf of Carpentaria. Due to its geographical location there is no grid connection available and energy is provide to the community by GEMCO mine by diesel generators since 1964. If mine operation closes its doors then government needs to find another option for energy supply.

1.4 Project Aim

The aim of this project is to investigate transiting from diesel power generator to 100% renewable and an economic case study of Groote Eylandt if the mining business were to close.

1.5 Project Objectives

The main objectives of the project are as follows:

1. Research and analysis the effect of mine closure in the remote community.
2. Based on research and analysis propose a power system model that can be sustainable, close to 100% renewable with minimum expenditure and efficient.
3. Feasible study of Load profile where system can be purpose to install, possible detail energy audit to get clear picture of Load profile to get accurate result of Load.
4. Create experimental model of the micro grid, battery bank, generator and wind turbine with fixed load and then analyses.
5. Cost effective ness and sustainable of the system model to the area under which system can be used in off grid situation in case of grid power is not available.

1.6 Limitations

This project will mainly focus on the analysis of the current power generation situation and what possibility exists to convert it to 100% renewable power resources. Much research of social and economic aspects of this community has been done, but for this project a brief discussion is done to outline the main effect of mine closure in regards to power distribution. Further research can be conducted for economic and sustainability of post mining effect in near future.

1.7 Thesis Overview

Chapter one of this dissertation introduces the motivation of the project and outlines the project aims and objectives. Chapter 2 contains a literature review to justify the techniques and comparisons between different renewable power resources. Chapter 3 of this dissertation outlines the methodology that was employed for the completion of this project while Chapter 4 has detailed discussion about different system approaches and comparisons of results to justify the conclusion that the final hybrid system is capable of achieving the desired result.

Finally, Chapter 5 gives some recommendations to achieve the maximum benefits from renewable resources and how the hybrid system will gives more opportunity to community in regards to local jobs, other project opportunity for future students.

Chapter 2: Literature Review

2.1 Overview

This chapter contains a summary of the reviewed literature that was required to understand how the mining activities to make communities to think about and adopt different approaches to survive and live sustainably with minimum harm to nature. It reviews the socio-economic impact of mine closure on the surrounding community of Groote Eylandt, comparison of different renewable resources, power storage technology, and peak demand limiting to reduce power demand.

2.2 Socio-Economic impact of mine closure

This research project is based on the community of Groote Eylandt in the Northern Territory. Anindilyakwa people are the traditional owner of Groote Eylandt by The Aboriginal Land Rights (Northern Territory) Act (1976) and the Native Title Act (1993). (Anindilyakwa Land Council (ALC), 2012). The Anindilyakwa People are an amalgamation of two cultures, the Warnindilyakwan, and the Nunggubuyu (ALC 2012).

GEMCO (Groote Eylandt Mining Company) has been operating its manganese mine service since 1960(ALC, 2012). Some other big companies such as BHP, Rio-tinto have joined and left this operation since it started. Currently, the GEMCO mine is operated and managed by Sough32 (60%) and Anglo American Plc (40%). The population of Groot Eylandt is around 1539 people, with an unemployment rate of 11.7 in 2006 with average taxable income over $58,000 in 2004(ABS, 2004).

Over 80% of local population is employed by mine and related business. The Northern Territory Government has been receiving over 20 million annually as royalty income from mining management company South32, but due to a slower global economy these royalties have been reduced by 50% during the last couple of years (ALC, 2012). Figure 2.1 explains the system of royalty income. After royalty income paid to NT Government, Federal Government pays its share to ABA (Aboriginal Benefits Account) where money gets divided between different parts and finally ALC gets its share. In 2015 they received only 12 million and in 2014 it's 11 million as part of royalty income. GEMCO also provides energy to local businesses and surrounding communities (NT Government, 2014). The mining operation has been participating in many local charity activities to improve education and sports in the local community, with additional funding also provided by them to support community services.

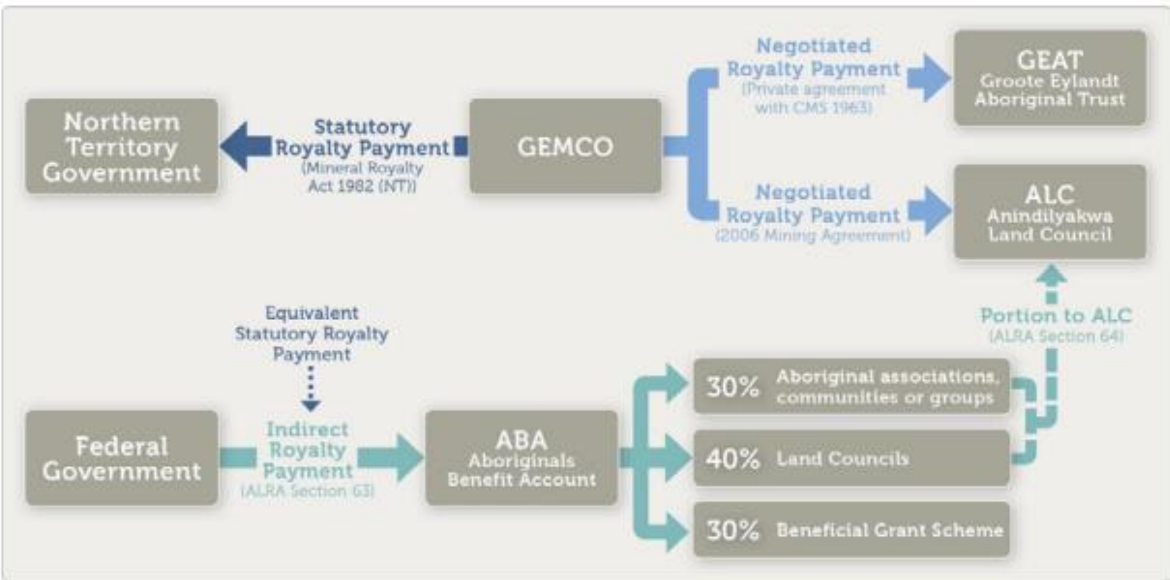


Figure 2.1 Royalty Arrangements (South32, GEMCO)

The mining sector was contributing around 8.5 percent to the GDP and constituted 50 percent of Australia's total export earnings. According to the Australian Bureau of Statistics, earnings from minerals and energy exports totalled AU$195 billion in 2014. Mine closures is one of the toughest sustainable development challenges for local government and mining companies. At the same time, it provides an opportunity for the industry to take up its responsibility for sustainable development by including socio-economic aspects in the mine planning process. Even though mining companies may not have sole responsibility for addressing the socio-economic impacts of mine closure. Mining has a large effect on local communities, and careful planning is required by mining companies at the outset.

Mines are notoriously vulnerable not only to planned closures as a result of diminished natural resources, metallurgical problems, environmental requirements and rising labour costs, but to sudden closure due to accidents, health and safety concerns, and natural disasters.(Keyes,1992). When actual work on mine closures then it indicates an inevitable, and significant negative economic impact, such as loss in local tax revenue, physical infrastructure, loss of local businesses, loss of mine royalty income (Laurence, 2006).

According to environmental scientist Peter Erskine of the University of Queensland, there are more than 50,000 abandoned mines in Australia since the early mining days, when firms were allowed to walk away after the profits started drying up. There are several literature reviews on mine closures that have focused predominantly on the nature of economic and social impacts such as rising crime and alcoholism in communities (Laurence, 2006). The extent of these economic, social and psychological impacts of mine closures in terms of effective community adaptation are dependent on the lifespan of the mine and the degree to which the local economy has become dependent on the mine (Warhurst et al., 1999). They are also dependant on the structuring policies and approaches of the mining company, unions, government and the community.

2.3 Sustainable Energy Concept

Energy has been the essential factor of the world economy and society, where power consumption of society has increased with its cost of production. The continued use of fossil fuels has become an important question of world economy, and today alternative energy sources have major growth in demand. Alternatives to fossil fuel, and especially renewable energy, have been the key focus for sustainable energy resources.

Figure 2.2 shows average diesel price in Northern Territory (NT). Groote Eylandt being an island which required special delivery of fuel with a storage facility to meet the demand of diesel. This extra resources can be added to present cost of fuel which will bring it too high than normal retail price. Groote is a tropical Island and filled with tropical forest which can provide verity of different energy source such as wind, solar, verity of biomass fuel, thermal etc.

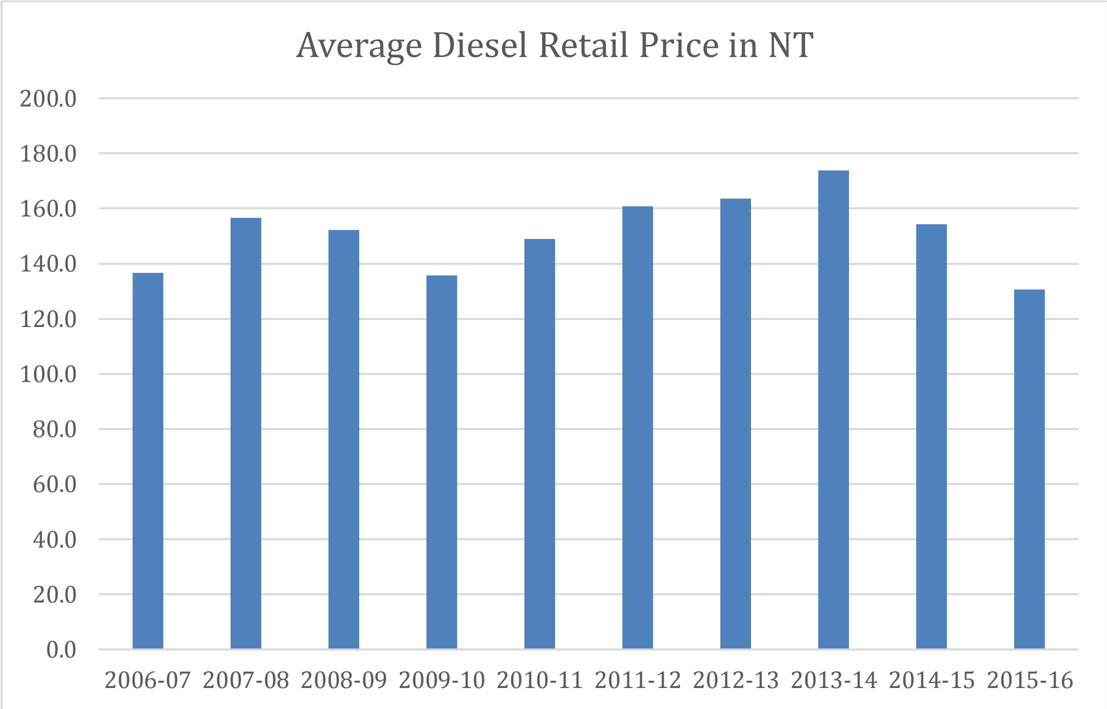


Figure 2.2 Average Retail Diesel Price in NT

2.3.1 Wind Energy

Wind energy is clean energy source and it is recognized one of the cheapest sources of large scale renewable energy. The value of wind energy is the kinetic energy of air flow and it is expressed as W= $\frac{1}{2}\rho v^3$, where ρ is air density and v is wind velocity. Wind turbines capture wind energy with in the area swept by their blades. This kinetic energy drives an electric generator that produces electricity for consumer, by exporting to main grid. Australia`s wind farms produced 33.7 percent of the country`s clean energy and supplied 4.9 per cent of its overall electricity demand during 2015. (Clean Energy Council, 2015).

Installing wind energy farms has potential economic benefits to the local community as well as a constant supply of clean energy. In a study conducted by CEC(Clean Energy council), a 50 MW of a wind farm can deliver direct employment of up to 48 construction workers, indirect employment during the construction phase of approximately 160 people locally,504 state jobs and 795 nationwide jobs. Large wind firms generates up to $250,000 per year for land rental income and over 80,000 on community projects each year (CEC, 2012).

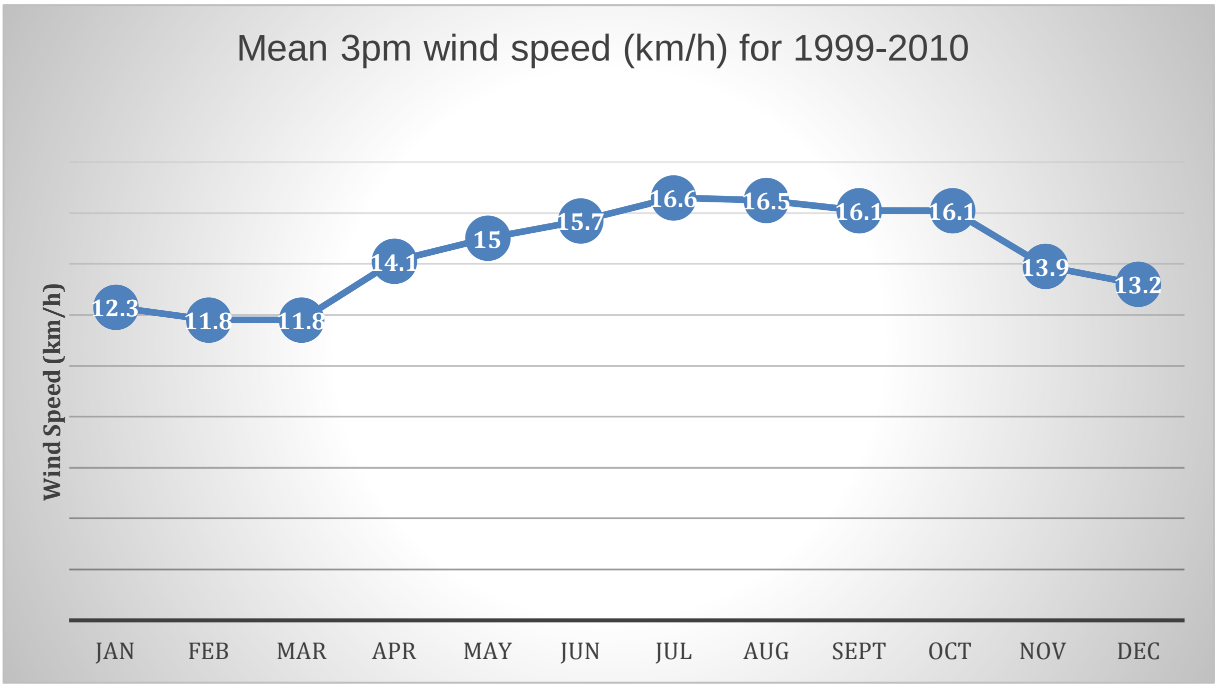


Figure 2.3 Mean Wind Speed

Groote Eylandt weather is topical where hot in summer and wet in wet season. History of Groote Eylandt shows it has been effected by many large cyclones. Regards to good wind speed and perfect weather for wind energy, economically wind energy is not suitable for Groote Eylandt. Cost of installation and maintenance can be increased for wind turbine on this island due to high cyclonic wind condition.

2.3.2 Solar Energy

Solar energy is energy harvested from the sun in the form of heat and light. The Sun`s radiant energy can be use as lighting, heating houses, and to produce electricity. With the help of technological advancement, solar energy has been harnessed to minimise the use of other electrical and mechanical energy.

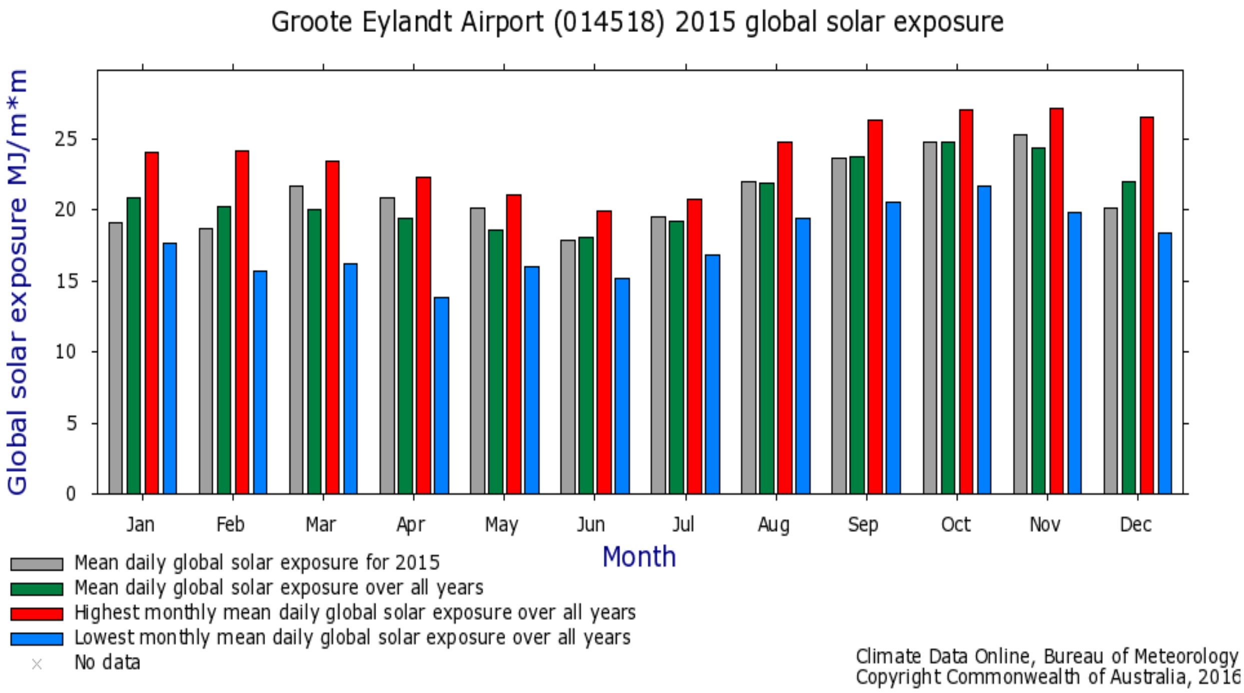


Figure 2.4 Solar Radiation (BoM, 2016)

Today, two main solar energy technologies, solar thermal and solar photovoltaic (PV), are highly in demand. This paper will discuss about PV only. Solar PV system converts the sunlight directly into direct current (DC) which can be inverted to AC (alternative current) and fed in to the grid. It can also be stored as DC and used when energy production is low and demand is high. PV systems can be installed on roof tops, as an integral part of a building design, on vehicles, and as large scale PV power plants. One of the major advantages of photovoltaics is that power generation with PV system does not produce any emissions during the process.

The Australian continent receives the highest solar radiation per square meter compare to any other part of the world. It receives an average of 58 million PJ of solar radiation per year which is 10000 times larger than its total energy consumption. (Australian Government, 2015). Where, Groote Eylandt receives the highest solar radiation per square meter compared to other parts of country.

As of June 2016, there are over 1.57 million PV installations completed in Australia, with combined capacity of over 5.4 gigawatts (APVI, 2016). The solar energy industry in Australia employ 7480 full time workers in 2014-15, which is 75 per cent of the total direct FTE employment in renewable energy activities (ABS, 2016).

2.3.3 Biomass Energy

Biomass power technologies convert renewable biomass fuel to heat and electricity using processes similar to that used with fossil fuel. There are four primary classes of bio power plants such as direct fired, Co-firing, Biomass gasifiers, and Modular systems. Biomass gasifiers is one the most efficient bio power plant. Biomass gasifiers operate by heating biomass in an oxygen limited environment where the solid biomass breaks down to form a flammable gas. This gas known as syngas or synthetic natural gas (SNG) can cleaned and filtered to remove chemical compounds. The final product gas can be used in more efficient power generation system. (US department of energy, 2011). The SNG can be stored in storage tanks and used when demand is high and required to operate multiple of generators.

Figure 2.5 Biomass gasifier system (Singapore University, 2015)

The gasification process offers technologically more attractive options and economically the lowest dependency on the feedstock cost (Hartanto et al., 2009). The majority of the research focused on the design and operation of the gasifiers and gasification process and the composition of syngas produced. But choosing a suitable feedstock is limited to its quantity of supply and availability (Vaezi et al., 2012).The efficient and clean utilisation of biomass has required necessary analysis. Higher heating value (HHV) of biomass materials determine the quantitative energy content of the fuel. HHV of biomass materials carbon, hydrogen, oxygen, nitrogen, sulphur and ash contents of material respectively, expressed in mass percentages on dry basis (Channiwala, 2002*).*

In remote area there will be more than a few types of biomass to choose from. There is a literature gap, where no one suggested any scientific criteria to implement the selection procedure. The research conducted by Vaezi and his team introduced a novel approach that can be utilized to choose an appropriate type of biomass to achieve certain syngas specifications.

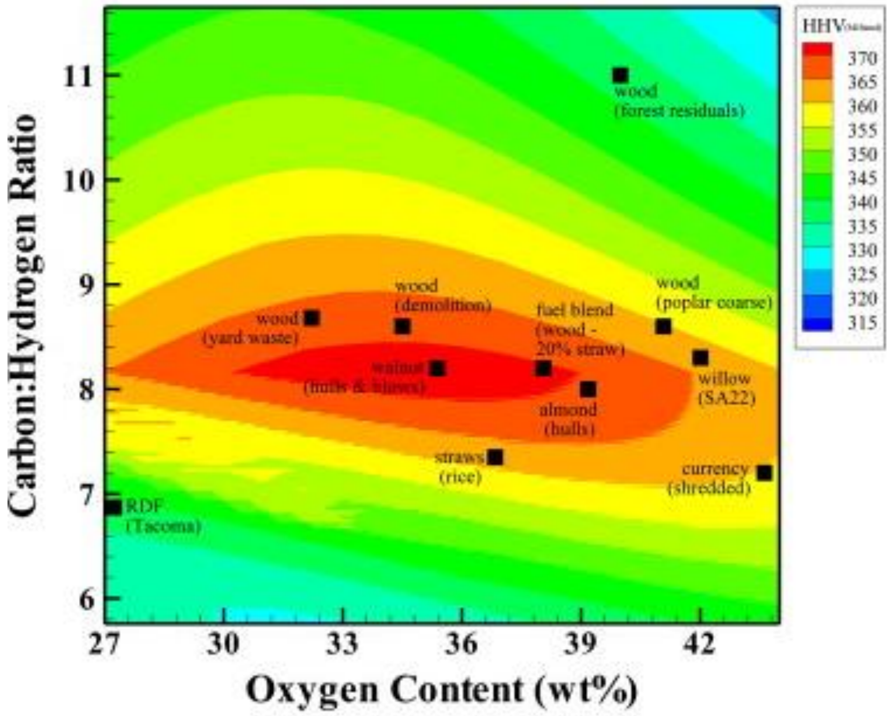


Figure 2.6 HHV plot (Vaezi et al., 2012)

Calorific value of the produced syngas (MJ/kmol) based on the oxygen content and C: H ratio of the biomass materials.

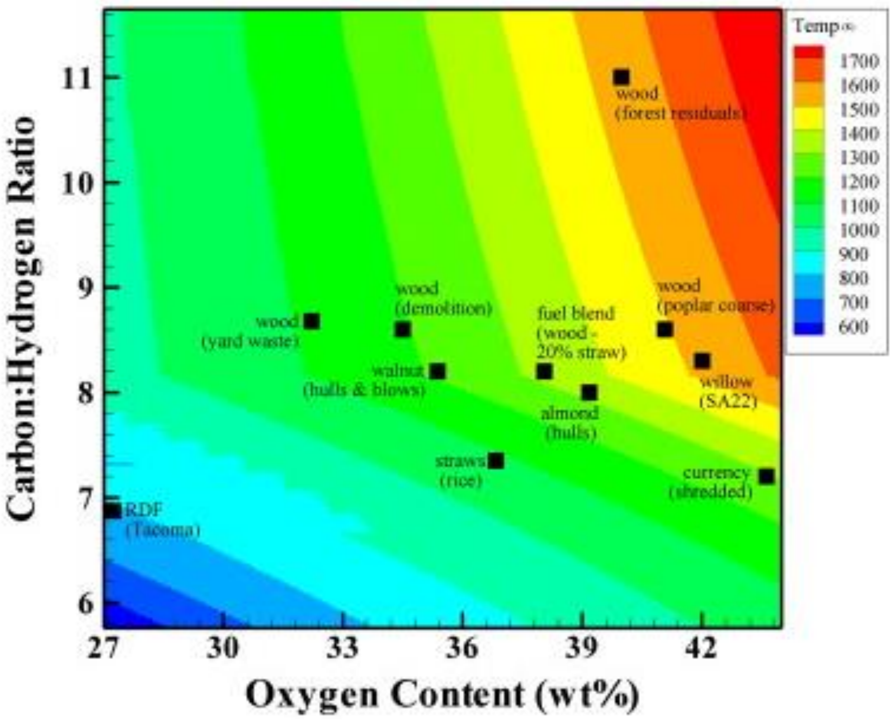


Figure 2.7 Temperature of biomass (Vaezi et al., 2012)
Variation of the produced syngas temperature (K) based on the C:H ratio and oxygen content of the biomass materials.

HHV plot (Figure 2.6), a syngas with calorific values of 370 MJ/kmol compared to a feedstock with 30 to 39wt. %. Temperature plot (Figure 2.7) shows different material with their biomass temperature where preferred materials to choose whose temperature range is around 1200 k. Table 2.1 can be utilise to find different material and their characteristic to utilise as biomass to produce efficient syngas. This materials can be found on Groote Eylandt. There are many other source for biomass fuel such as council solid waste, wood waste, dry sludge and wild grass which grows during the wet season and can be harvested in months of winters. These fuel sources are available freely so, it will not cost to community and will reduce the land fill to keep their island clean.

Table 2.1. Biomass Material and their comparison

	O2							
C:H	**37**	**38**	**39.5**	**40**	**40.5**	**41.5**	**42**	**43**
9			Pine Bark				Coconut Shells	
8.75								Pine Sawdust
8.5		Pine Chips	Urban Wood	Wood Pit	Furniture Waste	Wheat Straw		Eucalyptus Bark
8.25				Pine Pruning				Sugar Cane
7.25	Rice Straw							

Using Values of Table 2.1 and below equation gives value of HHV of every material which can be found on Groote Eylandt and can be used as bio fuel.

$HHV\ (MJ/kg) = 3.55C^2 - 232C - 2230H + 51.2C \times H + 131N + 20600$. (Friedl, 2005)

Biomass Energy industry makes a significant contribution to the total employment in renewable energy activity in Australia. In Queensland employment related biomass renewable energy activity rose from 1010 jobs in 2009-2010 to 1150 jobs in 2014-2015 (ABS, 2015)

2.3.4 Cost of Biomass plant

Cost of electricity generated from a biomass plants are highly depends on scale of the plant, biomass fuel costs and operation hours of power plant. Table 2.2 provides detail of each plant and its cost break down. A simple costing model is used to assess the required electricity selling price to make a bioenergy project economically viable. The model uses set of baseline assumptions, such as life of a project, construction period, inflation rate for costs and revenues, depreciation, financing rates for debt, feed purchase price etc. (Government of Australia, 2008). Average cost of Biomass plants is around 5000 kW/h.

Costing model of Biomass Gasifier power generation system:

Project life = 15 year from first investment

Construction Period = 6, 12 and 18 according to size of plant (1MW, 5MW, 30MW)

Inflation of costs and revenues each year = 3% for costs and revenue

Depreciation = straight after 15 years

Company tax rate = 30%

Interest on any borrowings = 10% with all loans repaid by the end of the 5th year

Feed purchase price = $30 per green tonne delivered to site or free

Plant operation = 8,000 hours per annum

Table 2.2 Cost of Biogas electrification plant (Government of Australia, 2008)

Electrical out put	**1 MW**	**5MW**	**30MW**
Gross Electrical Output (MWe)	1	6	30
Feed Requirements (green ktone/yr)	12.7	91.2	375.3
Capital Cost (M$S)	$5.3	$12.5	$47.4
Operation and Maintenance Cost (M$/year)	$0.3	$0.8	$2.9
Unit Capital Cost ($M/MW)	5.3	2.5	1.6
Cost of Energy (c/kWh)	20	15	10
Capital Costs	**1MW**	**5MW**	**30 MW**
Gasifier	$ 3,460,000	$ 2,910,000	-
Boiler	-	$ 2,550,000	$ 9,580,000
Steam Turbine	-	1,940,000	$ 9,990,000
Auxiliary Equipment	$ 200,000	$ 1,520,000	$ 11,820,000
Grid Connection	$ 260,000	$ 660,000	$ 2,900,000
Civil and Infrastructure	$ 260, 000	$ 260, 000	$ 4,210,000
Design and Project Management	$ 640,000	$ 1,490,000	$ 4,630,000
Contingency	$ 480,000	$ 1,130,000	$ 4,310,000
Total	$ 5,300,000	$ 12,460,000	$ 47,440,000

2.4 Energy storage technologies

Electricity can be stored by converting it to different form such as potential, chemical and kinetic energy. Many storage technologies can be found in the world today. These include storage media like batteries, flow batteries, fuel cells, flywheels, super capacitors, pumped hydro, superconducting magnetic energy storage (SMES), and compressed air energy storage (CAES). Energy storage technologies discussed in this paper are related to renewable energy integration i.e. PV for residential dwellings and commercial buildings. Energy Storage medium such as CAES and hydro are not suitable for this project. SMES and super capacitor battery banks will be not discussed in this paper due to high implementation and maintenance cost. Flywheels, fuel cells and flow batteries are suitable for medium to large scale renewable energy integration but they have high installation and initial setup costs compared to other batteries. Five types of battery energy storage technologies is discussed in this paper are: lead-acid, nickel cadmium, nickel metal hydride, lithium ion, and nickel ion. Selection of battery banks has to consideration area where it needs to install, simplicity in maintenance, recycle of batteries after end of life, and energy density with life of battery.

2.4.1 Lead –acid

Lead-acid batteries are widely used as important power storage device in automotive, UPS, and telecommunication system. These batteries consist of electrolyte, lead and lead alloy grid, lead organics and 35% sulphuric acid and 65% water solution (Zhang et al., 2016).

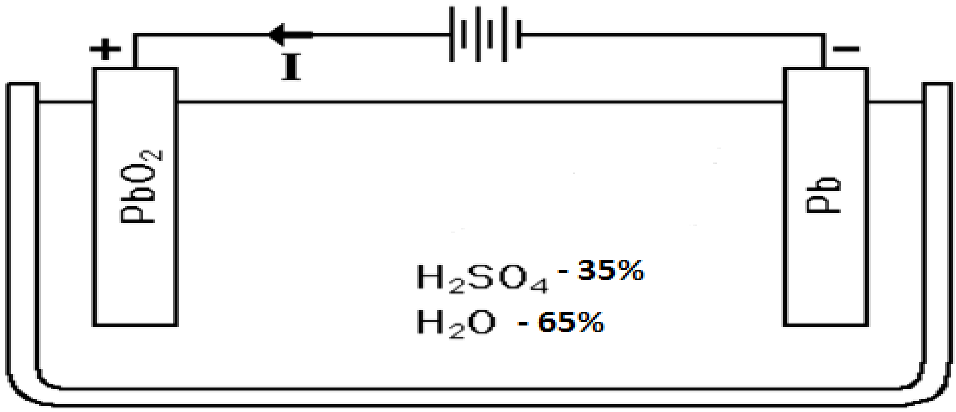


Figure 2.8 Lead Acid Battery

Lead-acid batteries is leading the global market due to the tried and true nature of this technology. These batteries can be discharge repeatedly as much as 80% of their capacity (Farret, 2006). Due to low implementation costs, lowest self-discharge of all rechargeable battery systems and low maintenance, they provide competitive solution to range of power storage requirements. Lead acid batteries have limited cycle life, poor performance at low and high ambient temperatures, short life, environmentally unfriendly lead and acid electrolyte which cause a large eco-footprint (Hadjipaschalis, 2009).

2.4.2 Nickel cadmium (NiCad)

NiCad batteries are robust and have longer life cycle, higher energy densities and low maintenance (Baker, 2008). It uses nickel hydroxide as the active material for the positive plate and cadmium hydroxide for the negative plate. These batteries uses an aqueous solution of potassium hydroxide with small quantities of lithium hydroxide as their electrolyte. This electrolyte is only used for ion transfer not chemically charged or degraded during charge/discharge cycle compared to lead acid battery. NiCad batteries have one of the longest cycle life with depth of discharge.

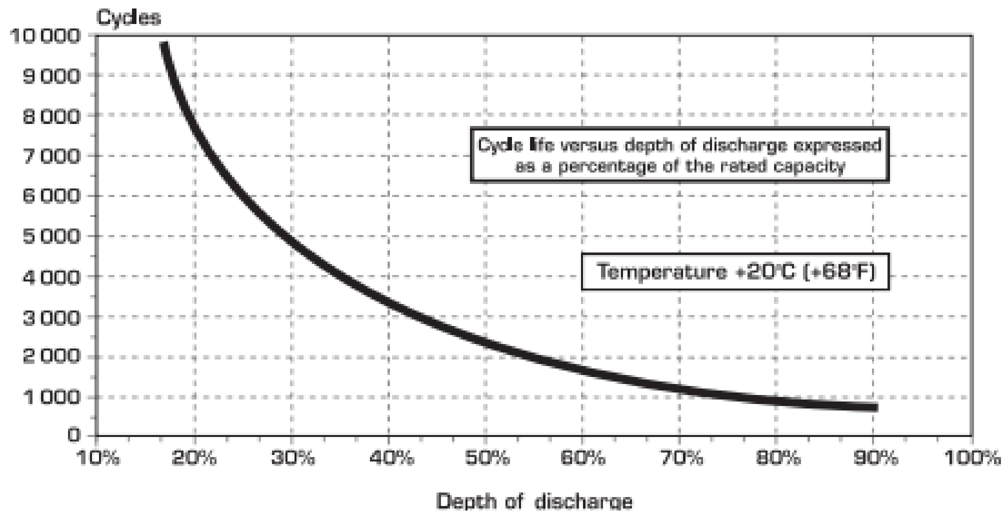


Figure 2.9 Typical cycle life vs depth of discharge (SAFT Battery Technical manual)

NiCad batteries offers many advantages but they contain toxic heavy metals which are undesirable and incompatible with a clean energy future. NiCad must be fully discharged before it is recharge (Hall, 2008).

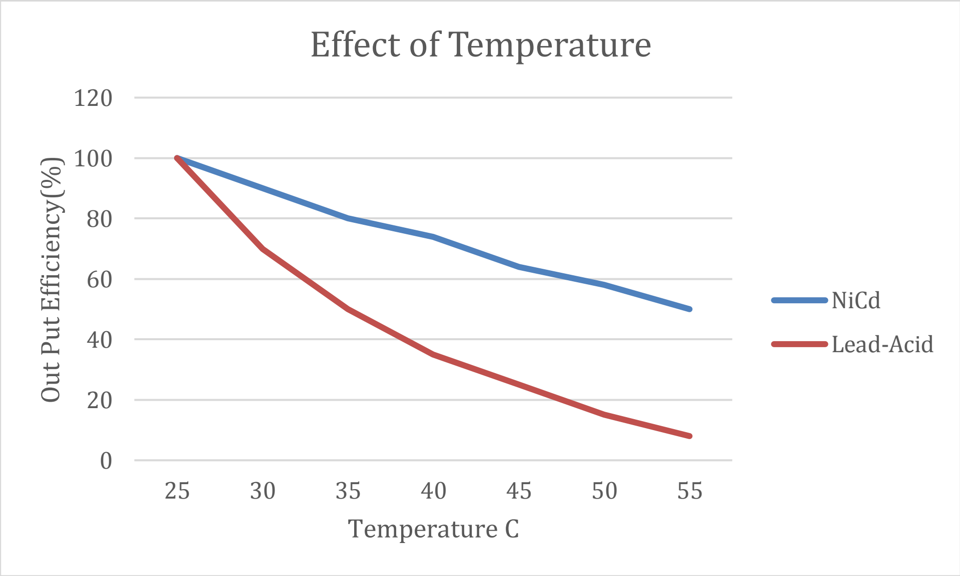


Figure 2.10 Effect of Temperature on Battery (Data: Alfa, 2009)

Every battery system decrease its life cycle as temperature increases. Figure 2.9 shows effect of temperature on NiCad and lead acid battery and reduction of its efficiency in twenty years. So, special consideration have to be taken into account when application of this battery in hot geographical area where temperature rise over 40 degrees.

2.4.3 Nickel metal hydride (NiMH)

Nickel metal hydride batteries have replaced the use of Lead-acid and Nickel cadmium in some use cases due to their improved performance and eco footprint. They does not contain any harm full substance compared to lead acid and NiCad batteries (Dunbar, 1994). NiMH cells has higher energy density compared to nickel cadmium cells. (Crompton, 2000). NiMH has 20% to 30% self-discharge a month, which makes them least favourable in renewable energy and inefficient for tong term energy storage purpose. If it compared to lead- acid and NiCad batteries, there are many good quality it has and lower cost compared to Li-ion batteries. NiMH batteries can be used in short term power storage with renewable energy integration. NiMH batteries stored at high temperature (above 30C) will self-discharge faster due to the increased reaction rated caused by the elevated temperature. NiMH batteries are difficult to charge in parallel due each of the battery cell cannot bee same. This means that it required separate charge circuit for each of the string in parallel pack. This makes more complicated charging system.

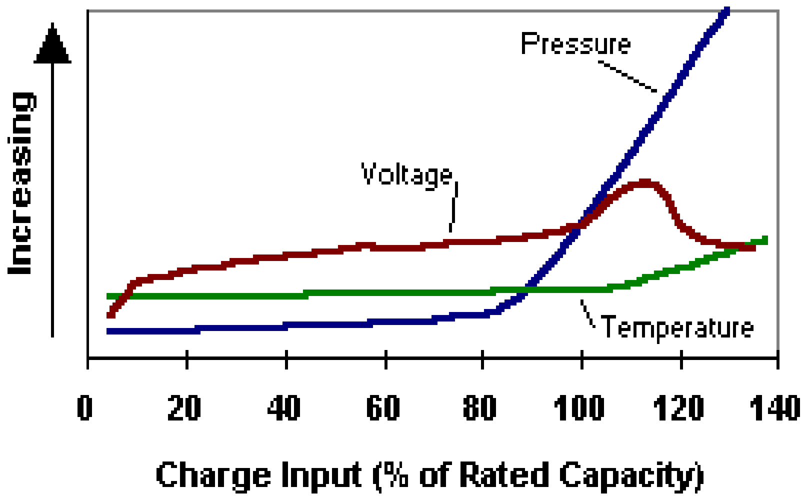


Figure 2.11 NiMh Charge Characteristics (Moltech Power systems, 2000)

High-current overcharge and cell polarity reversal during the discharge are main cause of failure of NiMH batteries. If batteries has been over charged, internal temperature and pressure will rise quickly as charging current is dissipated as heat. This situation will make the internal vents to open to reduce the pressure and gas to escape and prevent explosion of cell. This is main situation behind the failure of NiMh individual cell. Figure 2.9 Typical cycle life vs depth of discharge gives some reference to show when it should to stop the charging process to keep the battery healthy. (Texas Instruments, 2011).

NiMH batteries commonly used in Hybrid electric vehicles such as Toyota Prius and many more. Positive electrode are made of nickel oxyhydorxide and while their negative electrodes utilized to store hydrogen as metal-hydrate. Potassium hydroxide solution is the electrolyte in this batteries and nickel oxyhydorxide is generates from nickel hydroxide during discharge (Linden and Dough, 2002). Potassium hydroxide is a poisonous chemical which has side effect on human such as severs pain, vomiting, diarrhea and collapse while nickel hydroxide causes cancer in humans and animals (U. S. National Library, 2014).

2.4.4 Lithium Ion Battery (Li-ion)

Lithium Ion batteries possesses the greatest potential for future development and optimisation with efficiency of close to 60% to 70% with highest energy density. Although NiMH, Pb-acid, NiCad can also supply excellent power but due to low equivalent series resistance (ESR), they are large and heavy compared to Li-ion (Hall, 2008). Li-ion batteries has greatest scope for development of future application and many different type of energy storage, due to higher investment and demand price of Li-ion batteries are decreasing rapidly. In 2008 global investment in Li-ion research and development estimated at over $1 billion annually and keep increasing (Hall, 2008).

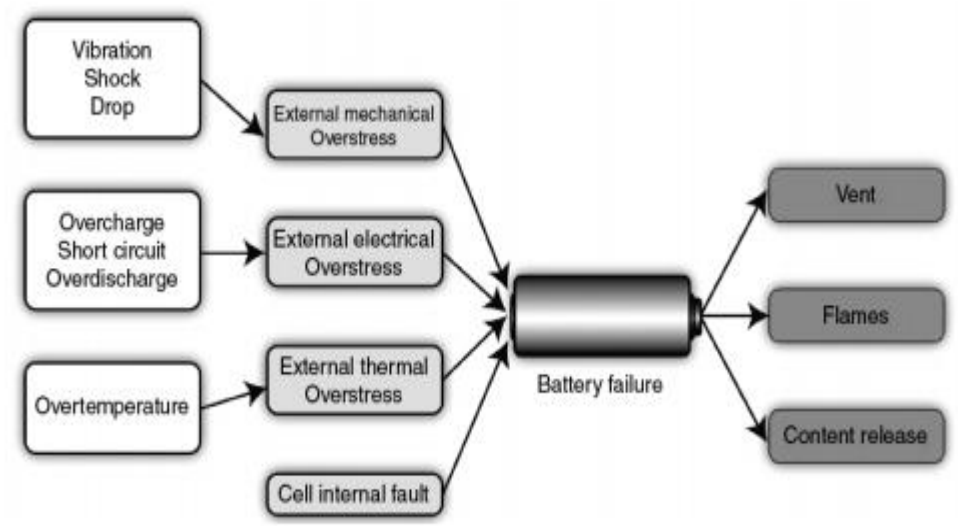


Figure 2.12 Cause of Ni-ion failure (Takahisa, et al.1997)

As a name of it Lithium, it uses lithium metal or lithium aluminium alloy as its negative electrode. Lithium polymer batteries required heat to create conductivity during the charge and discharge process. Over discharge below 1.5V Li-ion batteries will create electrochemically irreversible process, this process causes oxidization of Cu atoms to Cu2+ ion. Resulting in a potential internal shorts (Kaypmaz, 2008). This oxidization cannot be reverse through recharging. Similar process will occur if Li-Ion cell is charged too high voltage or over charged. Once this cell shorted, it catches fire which is hard to put it down and can cause severe damage to surrounding and can be fatal to human.

2.4.5 Nickel Iron Battery (Ni-Fe)

The Nickel Iron (Ne-Fe) battery was independently developed by Edison in US (Edison, 1900) and Junger in Sweden in 1901(Jungner, 1899). Battery uses nickel oxhydroxide (NiOOH) as positive electrode and iron at the negative electrode. The Ni-Fe battery is one of the most attractive system for its long charge-discharge cycle life which is more than 3000 cycles which is over 20 years of its life.

Figure 2.13 Ni-Fe Battery (Iron Edison 1.2 V)

Typical Ni-Fe battery is able to deliver specific gravimetric energy of ~30-50 Wh/kg and power of ~3-50 W/kg (Halpert, 1984). This battery known for its long cycle life in harsh condition, robust and durable power source. Ni and Fe both minerals are abundant elements of earth and they are relatively nontoxic. Which makes NI-Fe battery highly desirable for renewable energy storage.

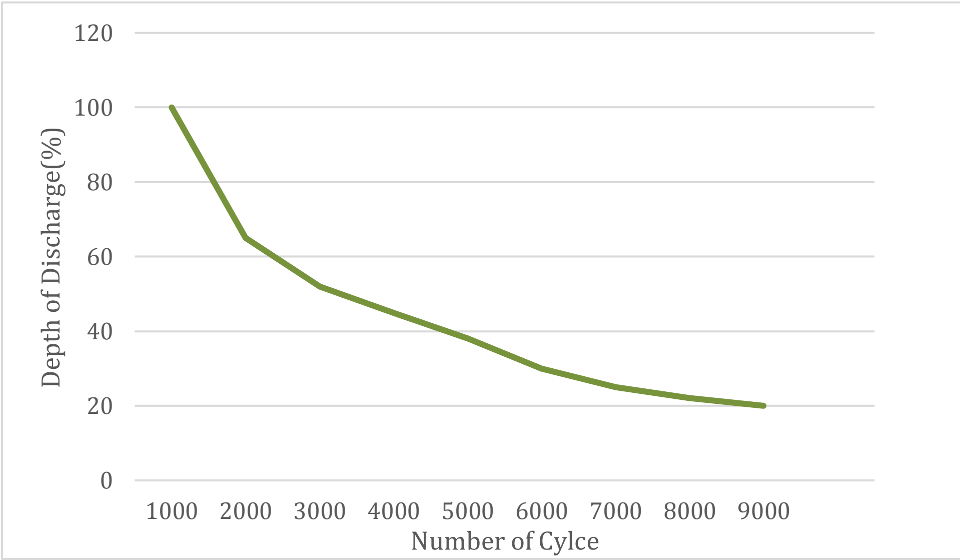


Figure 2.14 Ni-Fe Batteries depth of discharge

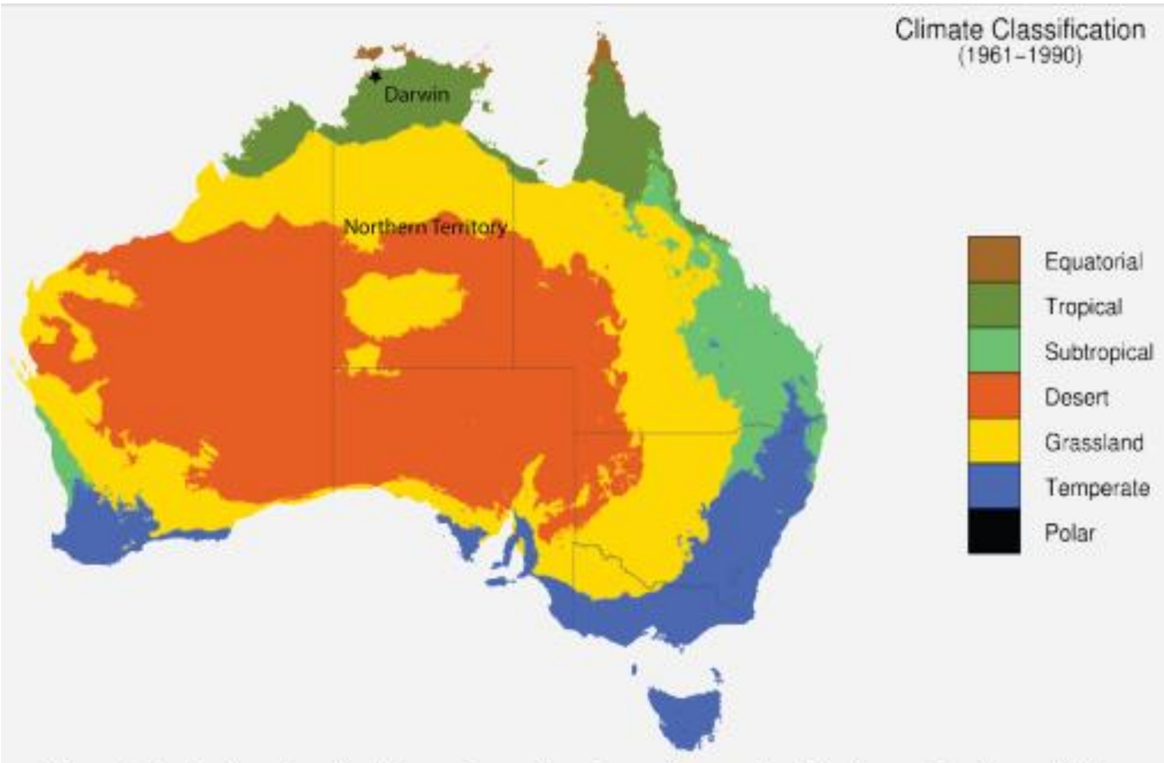
Ni-Fe batteries required minimum and cost-effective maintenance. When depth of discharge decreases below 70% it required to top up the electrolyte and sometime new Ni and Fe plates can boost the capacity of battery with extended life.

2.5 Peak Demand limiting

Peak demand limiting is the practice of reducing power loads during the peak hour when power is at higher rate. Limiting demand is differs from load shedding by reducing the amount of power to electrical equipment's versus turning equipment's off (shedding the load). A good example of demand limiting would be turning the fan off in stage or reducing the fan speed during the peak hours.

Electricity distribution network in Australia typically invest in infrastructure based on ensuring the network can meet the peak demand in the line with secure supply standard which demanded by local regulation and customs. For many networks, faces the challenges when the system maximum demand only occurs for short periods of time. For example, in regional Queensland, approximately 10% of the network capacity was used for less than 1.5% of the year (Ergon Energy, 2011). Geographical area, Season, climate and time of day are some of the key variables that contribute to peak demand. Peak demand risen small number of times in a year when very high amounts of electricity are used. Usually hottest days of summer when consumers increases cooling system. To meet the demand power network invest more into the new power plants to avoid blackouts and this new plants comes with at a considerable cost to consumers, even though thy might only be used for few hours a year. Over whole of 2012, the electricity network experienced peak demand for less than 40 hours (IPART, 2013).

The tropical zone is the part of the earth that lies between Tropic of Cancer (23.27`N) and the Tropic of Capricorn (23.27`S) (Ayoade, 1983). The tropical region is an uncomfortable climate zone that received large amount of solar radiation, higher temperature, and high level of humidity and long period of sunny days through the year (Greenup, 2002). Most of the cooling energy demands in the tropics are directly related to building materials and particularly the roofing area. Roofing system represents 70% of the total heat gain (Vijaykumar et al., 2007). Metal collarbone roof permits the high transmission of solar radiation that create sauna effect which is responsible of uncomfortable environment of house.



Map of Australia showing the major climate regions – the Northern Territory is the northern region in the middle of the map.
Credit: http://www.metvis.com.au/gallery/index.html (location labels added)

Figure 2.15 Climate regions of Australia

One of the sustainable approaches to cooling building by natural means is the passive cooling strategy (Kamal, 2012). Passive cooling strategies generally consist of all preventive measurement against overheating in the interior of buildings (Asimakopoulos, 1996). There are three level of such cooling strategies.

1. Prevent heat gain inside the building. The parameters that should consider is insulation, the solar shading of the façade and surface properties (colour of external surfaces) (Asimakopoulos, 1996).
2. Comfortable level of heat load should be permitted by modulating the required temperatures for the different uses of internal spaces during the design phase (Mumovic and Santamouris, 2009).
3. The heat in the building's interior should be controlled by natural or hybrid cooling through air infiltration (Al-Obaidi et al., 2014b and Al-Obaidi et al., 2014c). Surface property such as the colour of the internal surface and energy efficient equipment's can considerably reduce internal heat gain (Mumovic and Santamouris, 2009).

For this project we only discuss about first strategy to prevent heat gain inside the building through roof and external walls to reduce use of cooling. Replacing external wall and roof colours with light colours significantly reduce the infrared radiation and heat absorption. For example, rising solar reflectance of a typical residential dark room from 0.10 to 0.35 can reduce building cooling energy use by 7% to 15% (Akbari et al. 2006). Use of reflective roof colour for residential and commercial and industrial building has been increase, which is one of the most inexpensive solution to reduce indoor temperature. According to Parker et.al. (2008) and Suehrcke et al. (2008) shows that using reflective colours in hot climates can reduced need for space cooling by 20% to 70%.

Chapter 3: Methodology

This chapter is based on the methodology that was employed to design, simulate and implement the research to analyses the regional community can achieve 100 % renewable energy without effecting their lifestyle. This research project is discussed about community of Groot Eylandt. Due to fluctuation in market and decaling commodity demand internationally, there is no guarantee GEMCO will operate its mining operation in the future (ABC, 2016). If mine is closed, this community will required 4 GWh Energy (Energy Usage, 2014) per year to live. As they are far from main land, and there is no grid connection available. ALC has proposed a 15 year action plan, under this plan creating a self-manage solar plant to keep the energy demand met (ALC, 2012). The Geographical area of Northern Territory is Tropical which is hot and longest sunny days in the country.

To understand the load demand for Energy Efficiency, a detail energy audit conducted for a residential properties and community of Groote Eylandt. Based on demand of energy data, Homer a computer model developed by National Renewable Energy Lab (NREL) is used to analysis the economic and technical feasibility of stand-alone PV system with comprising of batteries and additional green energy sources. Analysis conducted with Homer will provide different model of system which can be economical, renewable and provide maximum benefit's to Groote Eylandt community to achieve 100% renewable goal.

3.1 Energy Audit

According to Average Household Energy consumption survey, average house of Groote Eylandt community consume around 19.18 kWh a day (ABS, 2014). This energy is divided according to the time of the day and equipment's which consume this energy for this energy audit. From energy audit it's found that 63% of energy was consume during the peak demand (day time). Community pays gazetted rate of 26.88 cents/kWh for their energy which was supplied by GEMCO mine (Government of NT, 2014). Energy audit conducted with a detail individual calculation of each equipment and time of operation. Detail Audit data is available in Appendix. Figure 3.1 and 3.2 is provides detail load profile of average house and community with their energy demands with time of the day.

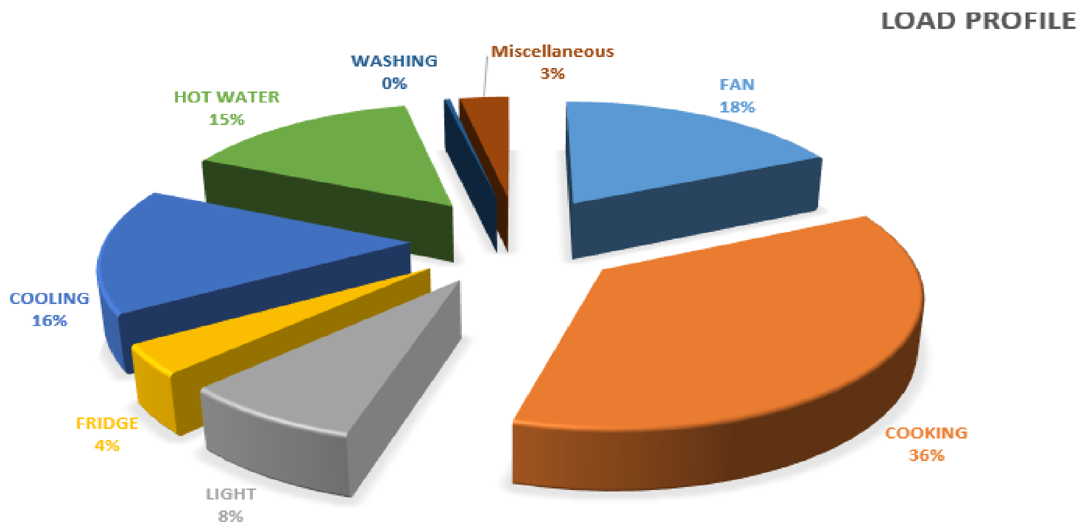


Figure 3.1 Residential Load Profile of Groote Eylandt

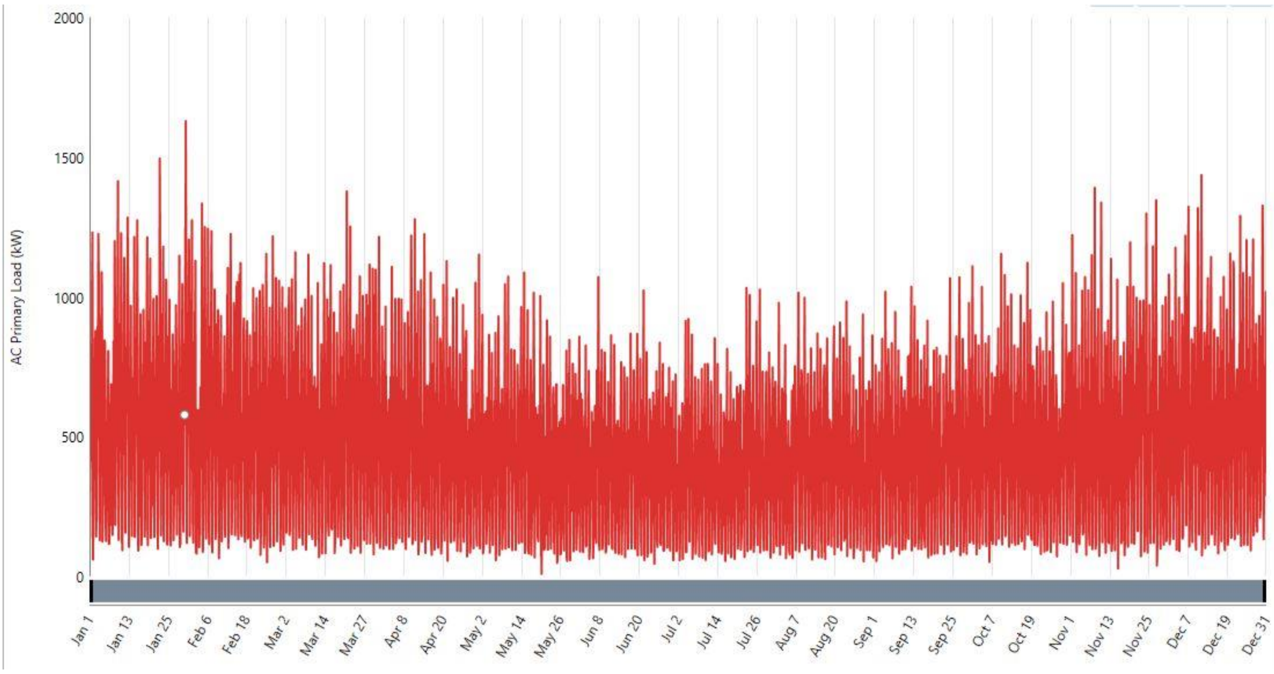


Figure 3.2 Community Load Profile of Groote Eylandt

Energy audit gives the results of an energy performance analysis carried out on the base of current energy consumption and cost. It estimates the likely potential for energy cost saving resulting from improved energy efficiency. Residential energy audit includes the equipment's used in normal house hold property such as Fans, Electric cook tops, lights, fridge, cooling system, hot water system, washing machine and miscellaneous equipment. Table 3.1 provide brief detail of equipment, power demand and load factor.

Table 3.1: Equipment characteristic of Residential load profile

Equipment	Efficiency	Demand(kW)	Hours of Operation	Load Factor
4 x fans	90%	0.288	All Day/24hr	0.5
5x 40 W Fluorescent Light	90%	0.22	Night/7hr	1
Electric Cook Top	-	7.5	Few time/7 hr	0.2
240L Fridge	-	0.044	All Day/24hr	1/0.5
Cooling	-	5	Few time/3 hr	0.25
2.4 kW Hot water	85%	2.82	Off Peak/4 hr	0.25
Miscellaneous (TV, Microwave etc.)	-	0.59	Any Time	0.25

3.2 Electricity Supply

GEMCO generates the electricity for the township of Alyangula and nearby Indigenous Essential service (IES) community Angurugu on Groote Eylandt. Power and Water Corporation (PWC) of NT is acting as a billing agent for this communities and paying GEMCO for electricity consumed by these customers and customers were charged by PWC at gazetted tariff which is 26.88 cents/kWh (Government of NT, 2014). GEMCO currently operating a 44MW maximum demand diesel power generation station and consume around 5738 kL Diesel annually for 13.4 GWh annual energy generation (Bailey, 2015). Figure 3.3 provides details information regarding present power delivering system of Groote Eylandt.

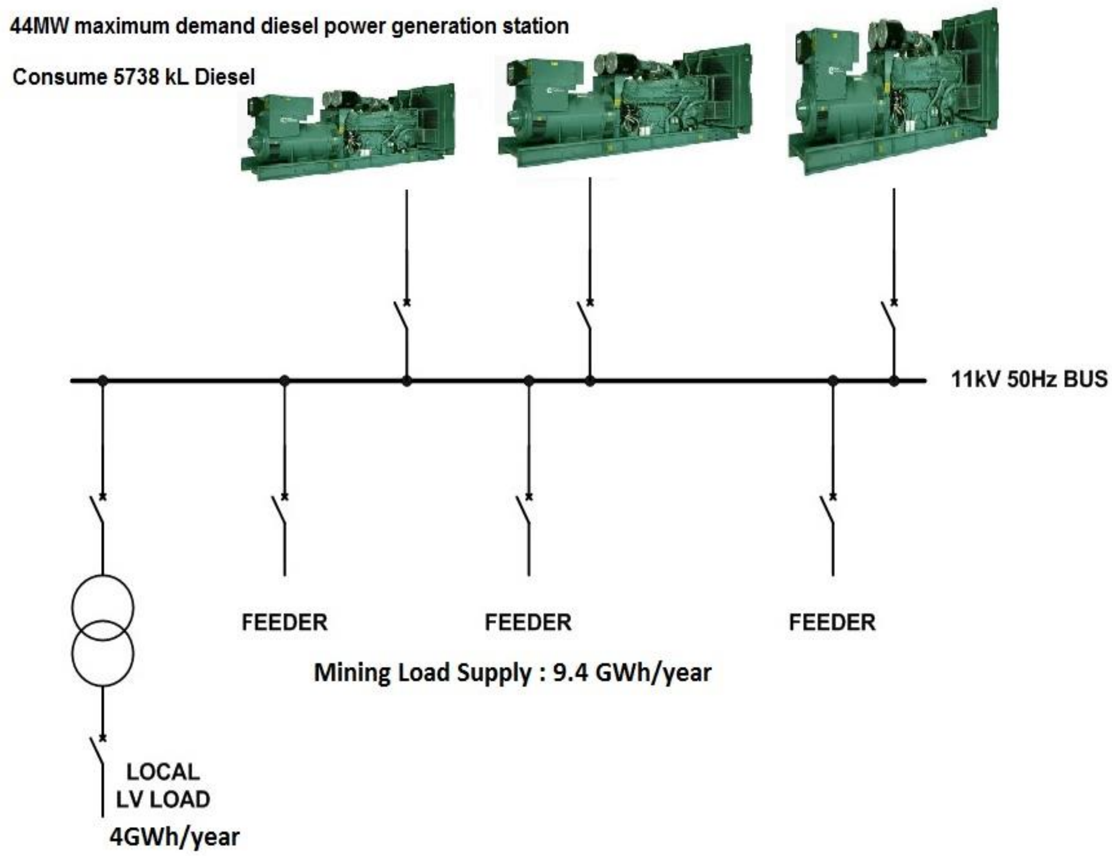


Figure 3.3 Schematic of Present power supply system

3.3 Homer Analysis

HOMER is an optimization software package which mainly simulates different energy resources and scale them on the base of net present cost (NPC). NPC is the total cost of installing and operating the power generating system over its life time (25 years). Homer system models simulate each of them by performing an hourly time –step simulation of its operation for project life time which includes initial set-up costs (IC), components replacements within the life of the project, operating and maintenance cost (O&M), and fuel cost. (Lambert, 2004).

3.3.1 Input Data

The main input data include the community load data, technical specification and cost of diesel generators, PV modules, power converters, batteries, system controls, economic parameters and system constraints.

3.3.1.1 Control parameters

Minimum renewable energy fractions (MRF) considered = 0% to100%

Annual real interest rate = 6%

Plant working life span = 25 years

Diesel price considered (A$/L) = 1.0

Dispatch strategy: cyclic charging

Apply set point state of charge = 80%

Operating reserve: as percent of load, hourly load =10%

As percent of renewable output, solar power output = 10% minimum

Photovoltaic sizes considered (kW) = 0 - 3000,

Cost of photovoltaic array (A$/kW) = 1900

Replacement cost of photovoltaic array (A$/kW) = 1900

Photovoltaic modules were considered as fixed

Working life of photovoltaic panels (years) = 25

3.3.1.2 Power converter

Power converter sizes considered (kW) =0 and 3000

Cost of power converter (AS$/kW) = 900

Replacement cost of power converter (A$/kW) = 300

Operation and maintenance cost of power converter (A$/kW/year) = 0

Working life span of power converter (years) = 15

Inverter efficiency (%) = 90

3.3.1.3 Batteries Li-Ion

Nominal capacity of each battery (Ah) = 255

Nominal voltage of each battery (V) = 4

Round trip efficiency (%) = 80

Number of batteries per stack = 10

Number of batteries considered = 0-1000

Minimum battery life (years) = 10

Maximum Capacity (Ah) = 276

Expected output (MWh) = 1828

Cost of battery (A$/kW) = 600

Replacement cost of battery (A$/kW) = 250

3.3.1.4 Batteries Ni-Fe

Nominal capacity of each battery (Ah) = 1000

Nominal voltage of each battery (V) = 1.2

Round trip efficiency (%) = 85

Number of batteries per stack = 10

Number of batteries considered = 0-1000

Minimum battery life (years) = 25+

Cost of battery (A$/kW) = 630

3.3.1.5 Diesel generators

Generator 1 sizes considered (kW) = 1800

Operating hours (hours/year) = 1200

Minimum load ratio (%) = 30

Capital cost (A$/kW) = 500

Replacement cost (A$/kW) = 250

Fuel consumption (kL) = 186.5

3.3.2 Homer Analysis system models

Homer Analysis was conducted in two scenario. One is at present situation where GEMCO providing power to Groote Eylandt community and installing PV system to minimize the diesel consumption. Where second scenario is when GEMCO close the mining production and remove their generators sets so PWC (Power and Water Corporation) has to find other option for power supply. Homer analysis was conducted with a complete autonyms hybrid system with targeting maximum use of green energy to minimize diesel consumption and reduce O&M cost.

There are four category of systems which was analysis on Homer.

1. Grid connected PV system
2. PV-Battery Bank System
3. Hybrid PV-diesel-battery system
4. Hybrid PV-Battery- Bio gasification plant

3.3.2.1 Grid connected PV system

At present, GEMCO mine is operational and providing sufficient energy to community of Groote Eylandt with the use of diesel power generators. Connecting the PV system to the main grid will not only save money but also reduce in diesel consumption during the day time.

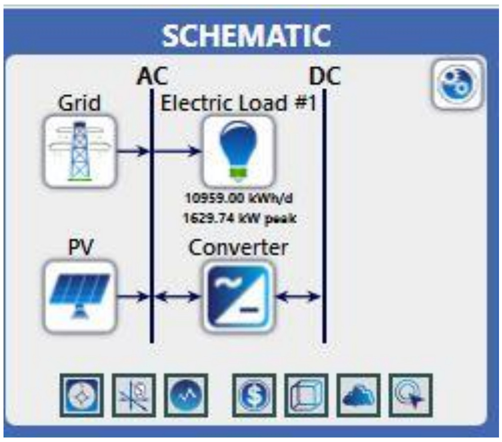


Figure 3.4 Grid connected PV system

3.3.2.2 PV-Battery Bank System

Complete autonomous PV-Battery bank system can meet the demand of energy. System design required large PV farm with sufficient battery bank to stored energy to meet the demand. This system provides 100% renewable energy as requirements of this project.

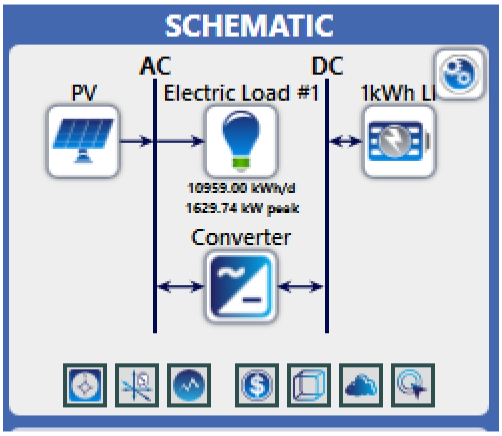


Figure 3.5 PV-Battery Bank Schematic

3.3.2.2 Hybrid PV-diesel-battery system

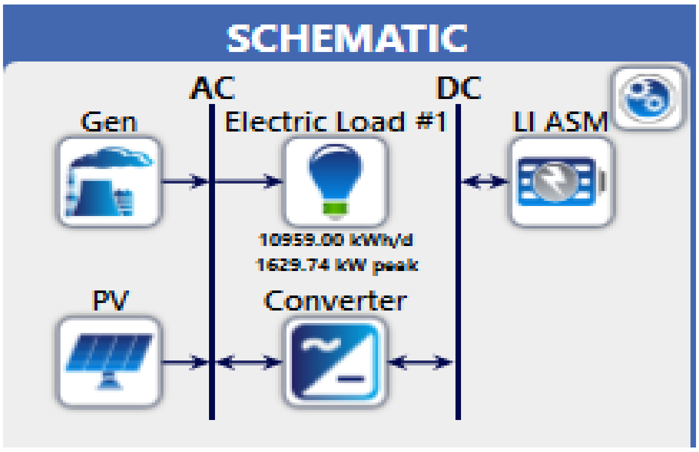


Figure 3.6 Hybrid system Schematic

When variation in the solar energy generation occurs due to weather condition and it does not match the time distribution of the demand, a secondary system is required. Therefore power generation system required battery backup system to smoothen the time distribution mismatch between the load and solar energy generation which also helpful during the maintenance time (Chowdhury, 1988). In simple system the diesel generators will runs continuously with minimum load to cover the power difference between PV and load demand. Some case generators will runs under no load condition. Efficiency of generators will drop tremendously when it operators under 40%

of full load capacity. For Fuel economy consideration generators should stop when average power of the PV is relatively high enough compare to load. This intermittent operations cause high start-stop frequency which will causes wear and damage to generators which required constant maintenance and will increase O&M (operation and maintenance) coast. During the high demand without any battery bank, generators must have enough spinning reserve to cover all possible sudden net load peaks when PV power drops. Many researcher advocate hybrid system to cope with above both scenario to balance demand and supply with achieving maximum efficiency of diesel generators.

3.3.2.3 Hybrid PV-Battery- Bio gasification plant

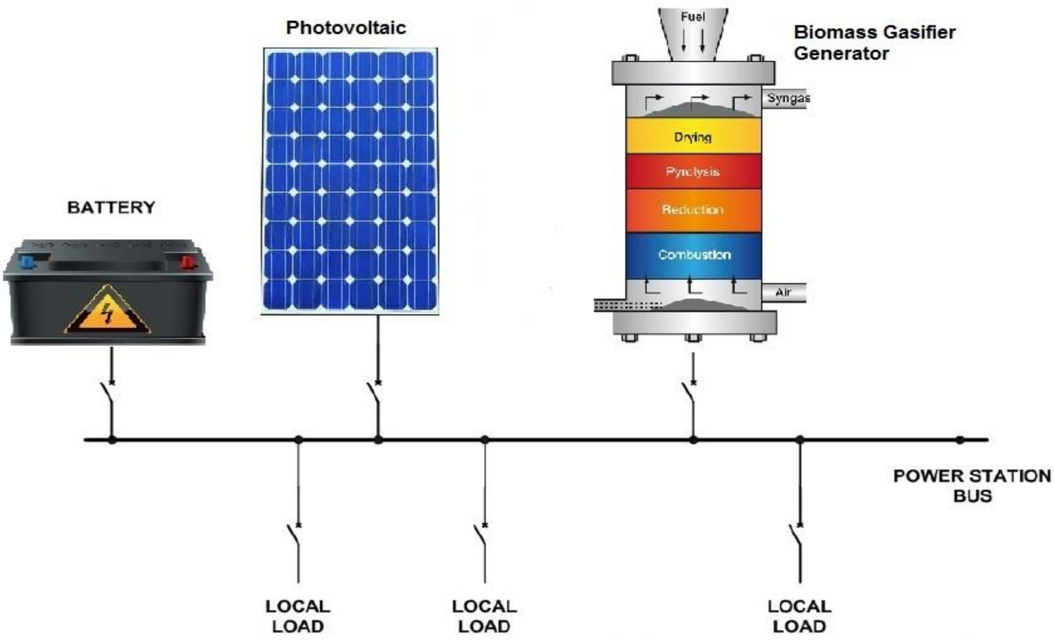


Figure 3.7 Complete Hybrid System

Combining Bio gasification plant and generator with-PV-Battery hybrid system will improve the green energy percentage in the total energy production. Bio gasification plants can operates on all green waste which can be found from agriculture and forest by products. Groote Eylandt characterised by extensive lateritic plains with savanna woodland which has many diversity of plants such as dune shrub, monsoon vine forests, riparian woodlands and paperbark swamps and coconuts. Carbon and Hydrogen are the main fuel elements for gasification plant and it also can be found from variety of bio products such as council solid waste, wood waste, industrial and council sludge, plastic, and tires. Figure 3.6 shows detail of complete system where bio gasification plant can save enough diesel consumption to produce power and convert maximum demand to green energy. Adding backup generator gives flexibility to power plant for their maintenance work and also in emergency backup power if any of the plant suffer any damage. Energy produced with this system can minimize the land fill and it is 100% renewable

Chapter 4: Result and Discussion

Based on demand, proposed three different method as a part of solution to minimise fossil fuel and maximize renewable source for power generation. In present situation GEMCO is supplying the power to community. If 1027 kW PV system is added to main grid connection, it can produce 4763 kWh/d energy which is equivalent to 40% of total community demand and same amount of reduction in diesel consumption. As 40% reduction in load will not effect on generator efficiency. This suggested power system was found to have a capital cost of 2,054,813 $ with an operating annual cost 10,274 $, total net present cost (NPC) of 11,072,090 $ and levelized cost of energy (LCOE) is 0.217 $/kWh which is cost of energy over 25 years of life. This cost is cheaper then grid connection charges 0.27$/kWh. Table 4.1 provides all detail of PV system. Figure 4.1 clearly shows significant reduction in Grid power which provide by diesel generators.

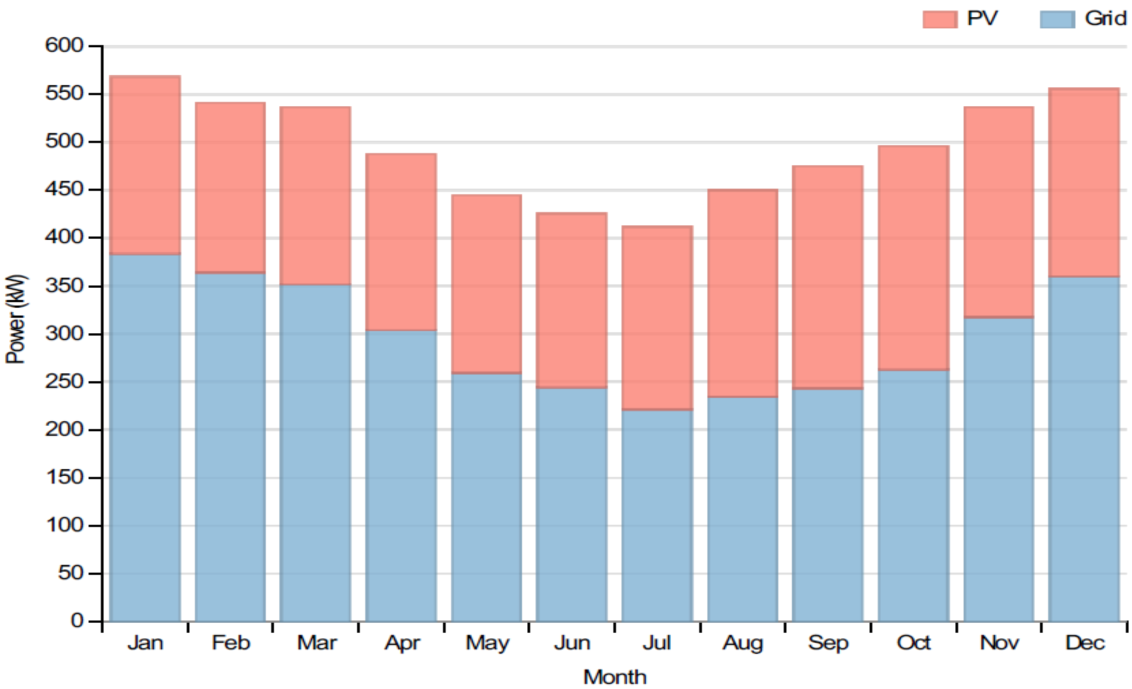


Figure 4.1 Monthly mean power contribution by solar PV and diesel power systems.

Table 4.1 Technical data and study assumption of Grid Connected PV system only

Description	Data
Grid Connected PV system	1027 kW
Capital cost	1946A$/kW
Life time	25 years
Operation and maintenance cost (O&M)	812 A$/year
Grid O&M cost	695,118 A$/year
PV output	40%
Energy Demand	4GWh/year
PV penetration	43.46%
Levelized cost ((LCOE)	0.217 $kWh
Total Production	1738492 kWh/year

Main objective of this project is to provide an energy solution to community in case of mining operation ceased. As a solution two hybrid system was proposed. Both comprise with PV system and Battery bank. Main different between this two hybrid system is diesel power generator and Biomass generator. The suggested optimal hybrid power system with diesel generator was found to have a capital cost of 12,099,289$ and system with Biomass generator`s capital cost of 8,858,937$. An annual operating cost of diesel system 180,867 while biomass generators' is 509,140$. The total net present cost (NPC) for diesel hybrid system is 18,826,620$ and for Biomass hybrid system is 14,496,257 $. In long runs biomass hybrid system is cheaper and provides 100% renewable energy with free fuel. The energy output and the economic analysis of the biomass hybrid system and diesel hybrid system related sensitivity analysis is provided in the forthcoming paragraphs.

4.1 Energy yield analysis

Table 4.2 Power production of Hybrid systems

Hybrid Systems	PV-Diesel Generator-Battery bank	PV-Biomass Generator-Battery bank
PV Production	88%, 4660MWh/yr	42%, 1877 MWh/yr
Generator Production	12%, 614 MWh/yr	58%, 2570 MWh/yr
Renewable Fraction	88%	100%

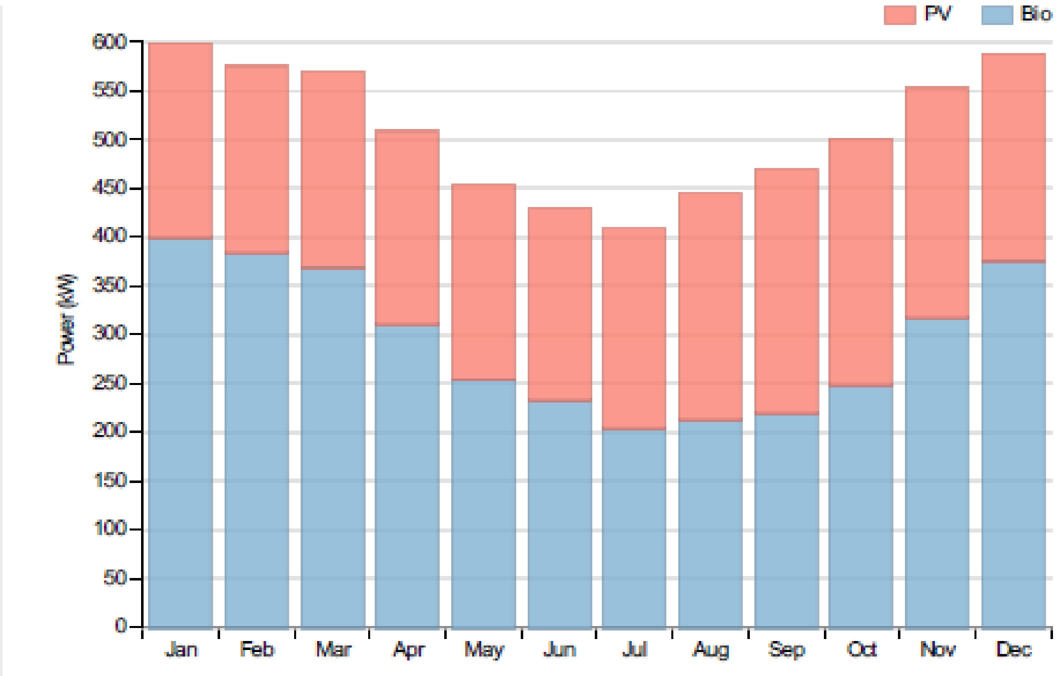


Figure 4.2 PV-Biomass Power distribution

Table 4.2 summarizes the energy contribution by two different hybrid systems. Biomass Generator system will operate only 9 hours of the day, which means less hours of operations and plants will have longer life and will required lesser maintenance. Demand of energy is higher in months for January, February and March as being tropical weather and wet season will reduce the PV production. Load demand and supply difference can be seen in Figure 4.2.

4.2 Greenhouse gas (GHG) emissions

The proposed PV-Biomass-Battery hybrid power system could avoid addition of 2724 tonnes of GHG equivalent of CO_2 annually in to the local atmosphere of the Groote Eylandt. Biomass generator can use variety of different fuel sources which includes human waste which can be received from council waste water treatment plant and rubbish collection depot. This material also produce environmental effect to surrounding area when it's not discard appropriately. There is not exact figure for waste produced by local community but according to ABS, in 2006-07, 2100 kg/year waste was produced by an Australian. Part of the waste can be utilise as fuel of the biomass for further reduction in emissions. Table 4.3 provides detail comparisons between three systems in regards to carbon emissions. Biomass generators has lowest emission among all system.

Table 4.3 Annual GHG emissions for hybrid power system

Pollutant	PV+Diesel (t/yr)	PV+Generator+ Battery (t/yr)	PV+Biomass+ Battery (t/yr)	Diesel Generator only (t/yr)
Carbon dioxide	1634	491	1.4	3853
Carbon monoxide	-	1.2	0.016	9.5
Sulphur dioxide	7	1	0	7.7
Nitrogen oxides	3.3	11	0.010	85

4.3 Economical analysis

The total costs of each component of the hybrid power systems, including the PV panels, generator, battery bank and power converters, and the breakup of capital cost, O&M, replacements, fuel and salvage costs is given in Table 4.4.

Table 4.4 Net present Costs breakup

Components	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)
System 1: PV-Biomass Generator-Battery bank					
Flat plate PV	2,107,115	0	86,981	0	0
Biogas Generator(1.5MW)	4,500,000	1,557,391	3,670,589	0	-11,029
Li-Ion Battery	1,803,000	27,450	235,686	0	-2,946
System Converter	448,823	81,998	0	0	-8,800
All Total	8,858,937	1,666,839	3,993,256	0	-22,776
System 2: PV-Diesel Generator-Battery bank					
Flat plate PV	5,508,583	0	352,091	0	0
Diesel Generator(1.8MW)	900,000	432,045	822,149	2,384,707	-3,145
Li-Ion Battery	5,340,600	1,798,120	1,137,84	0	-315,378
System Converter	350,107	146,087	0	0	-27,191
All Total	12,099,289	2,376,252	2,312,086	2,384,707	-345,715
System 3: Diesel Generator					
Diesel Generator(1.8MW)	900,000	6,455,830	6,047,039	18,704,525	-83,880
All Three	System 1	System 2	System 3		
NPC	14,496,257	18,826,620	32,023,515		

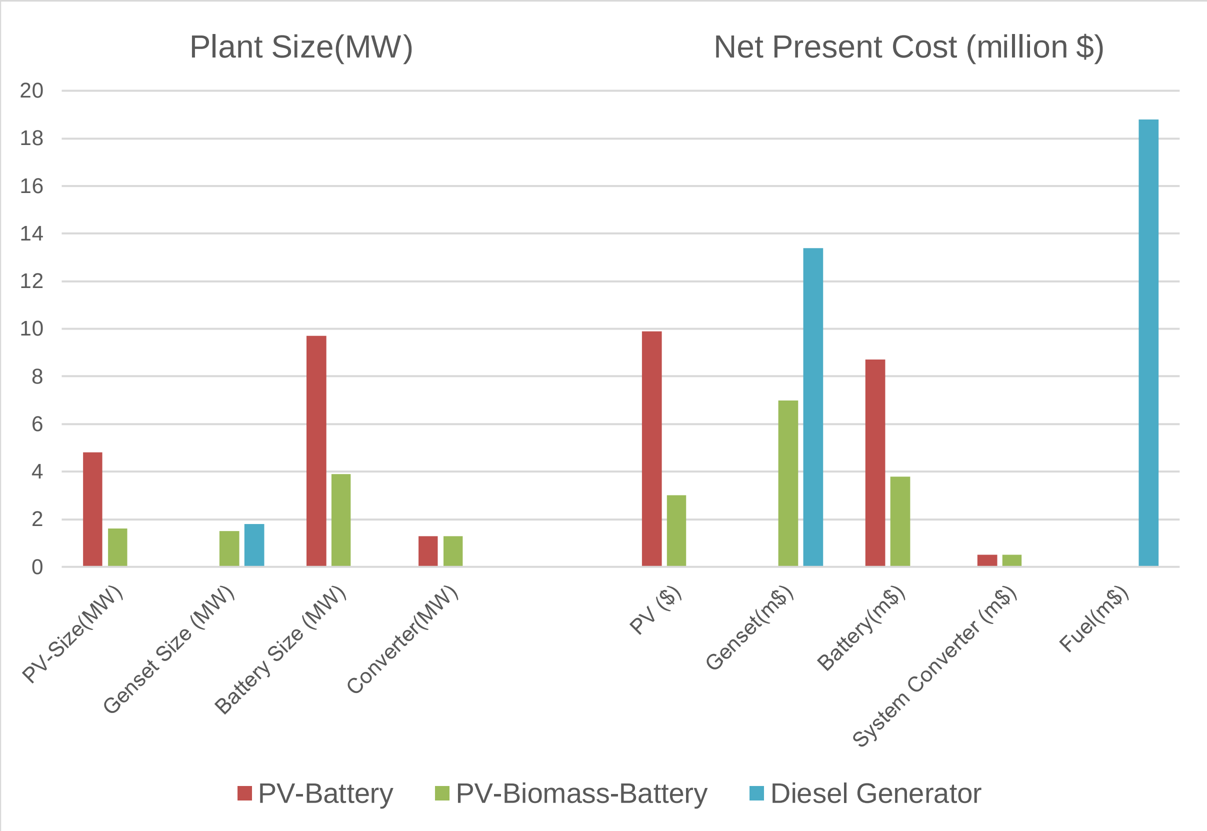


Figure 4.3 Cost comparison between systems

Table 4.5 Levelized cost of energy

Levelized Cost of Energy (LCE)			
Diesel Generator	PV-Biomass-Battery	PV-Generator-Battery	PV-Battery
0.626 $/kWh	0.462 $/kWh	0.368 $/kWh	0.389 $/kWh

It is evident, that bulk of the total net present cost (NPC) is accounted for PV and Battery bank. Figure 4.3 shows the comparison between proposed two hybrid power systems and diesel only power system to meet the power demand. Figure 4.3 also conclude that the cost of PV and battery bank both close to same price. Biomass generator has higher O&M cost compare to diesel generators due to number of different components and number of employee required to operate the plant. Furthermore, in system 2 and system 3, annual fossil fuel cost for diesel generator was 2,384,707$ and 1,463,194$. There is no fuel cost for Biomass as fuel source is free. The cost of energy can increase if international price for diesel increase. So diesel only plant, hybrid system with diesel generators becomes un-economical compared to PV-Biomass-Battery hybrid power system. Table 4.5 provides LCE (Levelized cost of energy) comparisons between all different power generation sources to meet the demand.

PV-Biomass-Battery hybrid system has higher LCE compare to other two and lower then diesel generator. But biomass plant operates with 100% renewable resources which gives many more benefits compare to diesel power system. Each MWh of electricity produced from renewable sources reduces about 1.7 barrels of fuels which means saving of 6800 barrels of Diesel annually ,reduction in fossil fuel investment worth of 108,000 $ and reduction of 1644 t/yr of GHG entering in to the atmosphere annually. In 25 years' of life of hybrid system with Biomass generators reduces fossil fuel significantly, and creating more jobs for local community by creating opportunity to harvesting biomass, O&M, and reduction of land fill which reduces the land contamination.

Additionally, the utilization of renewable energy source will also result in earning of carbon credit which is applicable under Section 162, Carbon Credits (Carbon Farming Initiative) Act 2011. The major accounting firms estimate that worldwide the carbon industry will become the largest capital market on international exchanges and exceed the value of all oil and coal markets combined. The carbon industry today is where the computer industry was in the 1960's and it will grow to exceed the IT industry in size. Even at the relatively low introductory price of $23 per tonne, the Australian Government estimates an industry revenue flow of $14 billion per annum derived from the payment and purchase of carbon offsets.

There is a funding from ARENA (Australian government Renewable energy agency) on renewable energy projects for remote communities. ARENA is providing more than 50% of capital cost as renewable energy investment by federal government. This funding can reduce the capital cost of this project and save big amount for community and NT government. The opportunity of investment in renewable energy is really high with maximum return in short term. This is the reason for many organisations are investing in large renewable projects around the Australia.

Chapter 5: Recommendation and further work

Price of components such as PV and Battery banks are used from local suppliers and compared with price provided by HOMER, where rest of the components price were provided by HOMER. Homer Analysis does not have Ni-Fe battery components to test so all analysis done on Li-ion battery banks. For future reference and project implementation Ni-Fe battery banks is more suitable for Groote Eylandt. Price of both battery bank are same. Ni-Fe battery banks gives significant benefits in total life of project, and when it has to salvage it gives good return too.

There are 358 residential house in Groote Eylandt. If their peak demand can be reduced by implementing passive cooling system and changing their lights to LED. There is more can be done to reduce their peak demand and hours of operation of Biomass generator. Section 2.5 Peak demand limiting provides brief overview of how this can achieve. Future student can do a project of how the community can reduce their peak demand with innovative ideas and cost to implement it.

Further work also can be done on social and economic side of the project if mine close its operation. There are many opportunity in tourism and fishing industry and this can be another project for economic students to consider. Other area of work can be done on biomass fuel resources and sustainability of this resources. Groote Eylandt has large forest area and some of the part of forest can be use as harvesting field and this can be a new industry for them to export this fuel sources. This industry can make significant effect on future of island community.

Chapter 6: Conclusion

The main objective of this project is to provide 100% renewable energy to community of Groote Eylandt. This objective is achievable with PV- Battery bank and hybrid system which includes PV-Battery bank and Biomass gasifier. There are other option to provide energy to this community with use of fossil fuel but in long run this option is expensive compare to renewable power sources.

Power system with PV-Battery bank only has to consideration of the losses with power storage. Most of battery banks works around 80% of its capacity. This system required larger solar farm and larger storage capacity which will increase its initial cost of installation. Where, combining the two different power source system such as PV+ Battery bank with Biomass gasifier will gives opportunity and flexibility to work with both in case of any emergency and one of the power system is damaged.

If there is a sudden closure of GEMCO mine and there is not much time to provide energy to community then, it required 1.8 to 2 MW diesel generator to operate 24hr to meet the demand. This generator will consume around 1500 kL/yr diesel with two years of operation life. In other hand renewable power source does not have any fuel cost. Groote Eylandt is being an island, when any things goes there it stays there. It means all rubbish which produce by island, it will stay there. Biomass gasifier will use this rubbish as its fuel source to minimize its land field and soil pollution. Power generation will create employment opportunity for locals to keep the community alive.

Warnindilyakwan aboriginal people living on Groote Eylandt from thousands of years. There is no option to remove this community from their native land, other than create an environment for this community to thrive. There is an opportunity to create large scale renewable project on this island and also big portion of funding is available from ARENA which make this project achievable in near future. Government of NT and power and water corporation (PWC) of northern territory has to act now to fulfil the community need.

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Appendix A:

A.1: Project Proposal

ENG4111/4112 Research Project
Project Specification

For: Jayesh Patel

Title: STATCOMs for load balancing

Major : Electrical and Electronic engineering

Supervisor: Dr. Leslie Bowtell

Enrolment : ENG4111 – EXT S1, 2016
ENG4112 – EXT S2, 2016

Project Aim: Investigate application of STATCOM in Micro Grid with renewable energy(PV solar) to work as Power factor corrector, Voltage controller and Peak demand limiting with the use of Smart Energy meter and PLC (Programmable Logic Controller).

Programme : Issue A, 15th March 2016

1. Feasible study of Load profile where system can be purpose to install, possible detail energy audit to get clear picture of Load profile to get accurate result of Load.
2. Cost effective ness of the system modal to the area under which system can be used.
3. Create experimental modal of the micro grid with fix load and analysis.
4. Set up experimental system with Smart meter, PLC and PC
5. Establish communication between all components
6. Programme PLC to communicate smart meter and renewable power source with STATCOM to read power factor, Voltage control to balance load and demand limiting.

If time permits:

7. Setup system with real PV Solar as renewable power source and compare both result.

AGREED:

Student
Jayesh Patel
Digitally signed by Jayesh Patel
DN: cn=Jayesh Patel, o=USQ, ou=USQ, email=u1056583@umail.usq.edu.au, c=AU
Date: 2016.03.14 13:55:41 +10'00'

Supervisor
Dr. Leslie Alan Bowtell

ENG4111/4112 Research Project

Project Specification

For: Jayesh Patel

Title: Analysis of the Potential for 100% renewable energy supply to Groot Eylandt

Major : Electrical and Electronic engineering

Supervisor: Dr. Leslie Bowtell

Enrolment : ENG4111 – EXT S1, 2016
ENG4112 – EXT S2, 2016

Project Aim: Investigate Transiting from grid connection to 100% renewable and economical case study of Groot Eylandt if mining business gets closed.

Programme: Issue B, 7th August 2016

1. Research and analysis effect of mine closure in remote community.
2. Based on research and analysis propose a power system model which can be sustainable and close to 100% renewable with minimum expenditures and efficient.
3. Feasible study of Load profile where system can be purpose to install, possible detail energy audit to get clear picture of Load profile to get accurate result of Load.
4. Create experimental model of the micro grid, Battery bank, Generator and wind turbine with fix load and analysis.
5. Cost effective ness and sustainable of the system model to the area under which system can be used in off grid situation in case of grid power is not available.

AGREED:

Student

Jayesh Patel

Digitally signed by Jayesh Patel
DN: cn=Jayesh Patel, o=USQ, ou=USQ, email=u1050583@umail.usq.edu.au, c=AU
Date: 2016.03.14 13:55:41 +10'00'

Supervisor

Dr. Leslie Alan Bowtell

A.2: Risk Assessment

Description Of hazard:	People at Risk	Number of People at risk	Part of the body at risk	Risk Level	Part of Project associated with this	Short term controls	Long term controls	Completion details
Eye strain	Myself	1	Eyes	High	• Constant use of computers	• Use a room with appropriate lighting • Take regular breaks	• Appropriate lighting • Regular breaks	Employer: USQ Prepared by: Jayesh Patel Date:25/09/16
Body and back strain	Myself	1	Body and Back	High	• Constantly sitting for long hours	•	•	Employer: USQ Prepared by: Jayesh Patel

Scale:

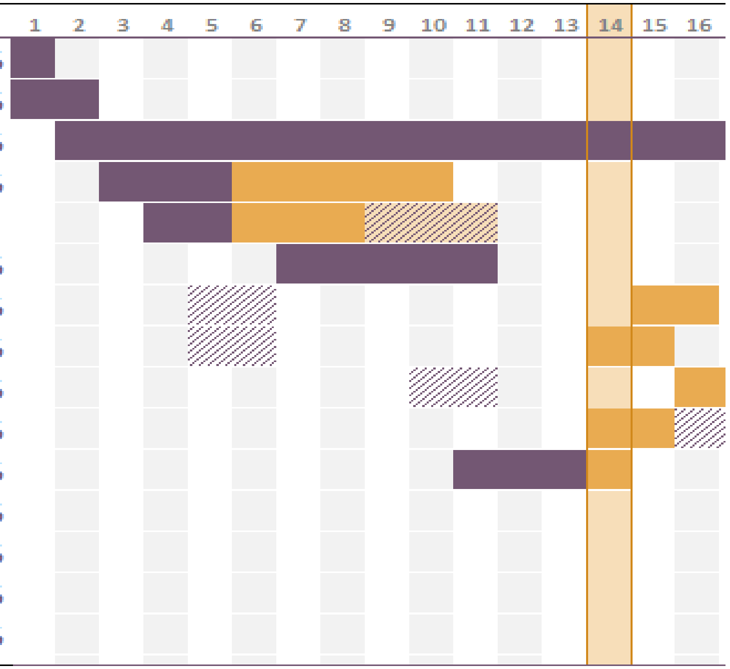
Low	Moderate	High

A.3: Project Timeline 1st Semester

Project Planner

Period Highlight: # ▲▼ Plan Actual

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Topic Allocation	1	1	1	1	100%
Projcect Specification	1	2	1	2	100%
Literature Review	2	16	2	18	100%
Load Data Analysis	3	3	3	8	100%
Cost Effectiveness of system	4	2	4	8	70%
Interim Project Preliminary Report	7	5	7	5	100%
Setup Experimental Model of Micro grid	5	2	15	2	100%
Homer Analysis	5	2	14	2	100%
Compare Analysis Result	10	2	16	3	100%
Gets Result for Report	16	2	14	2	100%
Final Project Preliminary Report	11	3	11	4	100%
Prepare First draft and Submit	19	8	19	8	100%
In cooperate supervisor for final dissertation	25	4	25	4	100%
Prepare Final Dissertation	25	5	25	5	100%
Proof read and Submit	30	3	30	32	100%



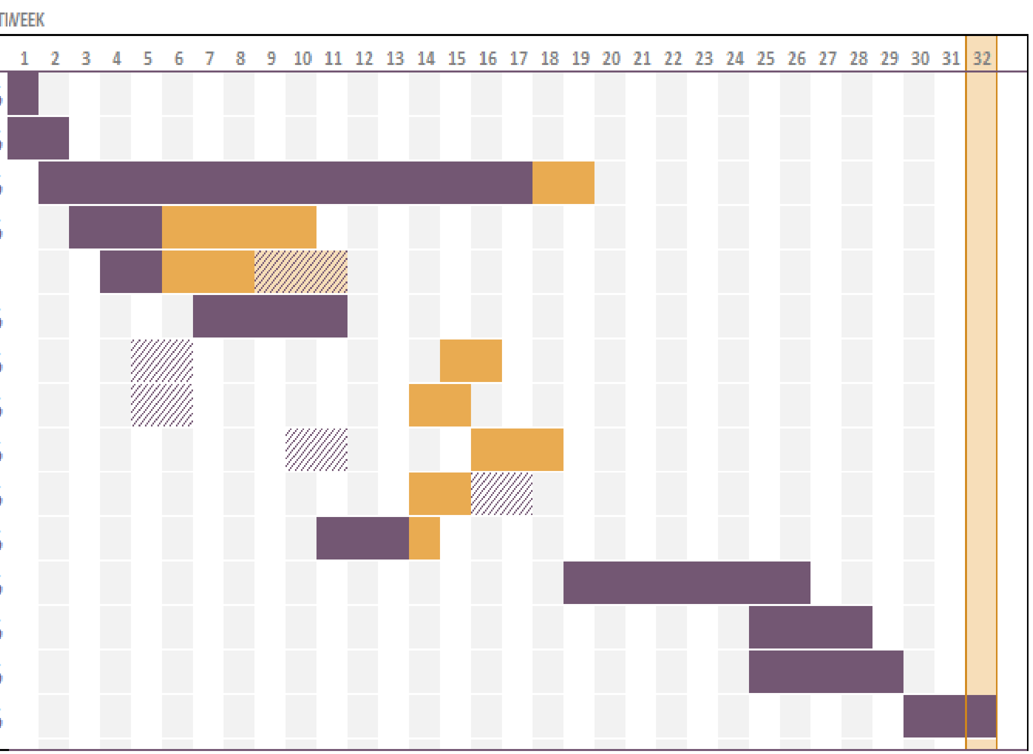
A.4: Project Timeline 2nd Semester

Project Planner

Period Highlight: #

Plan | Actual | % Complete | Actual (beyond plan) | % Complete (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Topic Allocation	1	1	1	1	100%
Projcect Specification	1	2	1	2	100%
Literature Review	2	16	2	18	100%
Load Data Analysis	3	3	3	8	100%
Cost Effectiveness of system	4	2	4	8	70%
Interim Project Preliminary Report	7	5	7	5	100%
Setup Experimental Model of Micro grid	5	2	15	2	100%
Homer Analysis	5	2	14	2	100%
Compare Analysis Result	10	2	16	3	100%
Gets Result for Report	16	2	14	2	100%
Final Project Preliminary Report	11	3	11	4	100%
Prepare First draft and Submit	19	8	19	8	100%
In cooperate supervisor for final dissertation	25	4	25	4	100%
Prepare Final Dissertation	25	5	25	5	100%
Proof read and Submit	30	3	30	32	100%



A.5: Residential Energy Audi Report

	Fan 65W	Electric Cook Top(1,1,1.	40W Fluorescent	Fridge 240 L	Cooling kW(total)	Hotwater System (2.4kW)	Washing Machine		
Efficiency %	90		90			85			
Number	4	1	5	1	5	1	1		
Demand KW	0.288	7.5	0.22	0.044	5	2.82	0.033		
				250L	1 to 6.5				
Load Factor	0.5	0.2	1	1/0.5	0.25	0.25	1		
When/long	All day	Any Time	Night	0.015	Some time	24hr	Some Time		
Hour	On/Off								
HOUR	65W	7.5KW	40W	Column!	5KW	2.4KW	250W	LOAD PROFILE KWh	
1	0.144	0	0	0.015	0	0.705	0	0.864	
2	0.144	0	0	0.015	0	0.705	0	0.864	
3	0.144	0	0	0.015	0	0	0	0.159	
4	0.144	0	0	0.015	0	0	0	0.159	
5	0.144	0	0	0.015	0	0	0	0.159	
6	0.144	0	0	0.015	0	0	0	0.159	
7	0.144	1	0.22	0.015	0	0	0	1.379	
8	0.144	1	0.22	0.044	0	0	0	1.408	
9	0.144	0	0.22	0.044	0	0	0	0.408	
10	0.144	0	0	0.044	0	0	0.033	0.221	
11	0.144	0	0	0.044	0	0	0.033	0.221	
12	0.144	1	0	0.044	0	0	0	1.188	
13	0.144	1	0	0.044	0	0	0	1.188	
14	0.144	0	0	0.044	1	0	0	1.188	
15	0.144	0	0	0.044	1	0	0	1.188	
16	0.144	0	0	0.044	1	0	0	1.188	
17	0.144	1.5	0	0.044	0	0	0	1.688	
18	0.144	1.5	0.11	0.044	0	0	0	1.798	
19	0.144	0	0.22	0.044	0	0	0	0.408	
20	0.144	0	0.22	0.015	0	0	0	0.379	
21	0.144	0	0.22	0.015	0	0	0	0.379	
22	0.144	0	0.11	0.015	0	0	0	0.269	
23	0.144	0	0	0.015	0	0.705	0	0.864	
24	0.144	0	0	0.015	0	0.705	0	0.864	
Total(kW)	3.456	7	1.54	0.708	3	2.82	0.066	18.59	
From Load Data	(ABS Data) ly Use(KWh)		19.18	Hourly	799.4 W			Miscellaneous power usage(kW)	0.59
								Microwave	
								TV	
								Phone Chargers	
Domestic Charge (cents/kWh) – standard tariff 26.88								Total Demand	19.18

A.6: Software

Invoice of Purchased Homer Energy software

HOMER ENERGY

Thank you for your purchase!

Jayesh Patel

[illegible]

Order Information

Order Number: 21062

Quantity	Item	Item Price	Subtotal
1	HOMER Pro: Student monthly single user license with modules: Biomass, Run Of River Hydro, Combined Heat and Power, Advanced Load, Hydrogen, Advanced Grid, Advanced Storage, Multi-Year, MATLAB Link	$30.00	$30.00
		Total:	**$30.00**

Payment Information

Payment Date: 10-07-2016
Payment Total: $30.00
Payment Status: Paid

Transaction ID: 8688898499

HOMER Energy
1790 30th St., Suite 100
Boulder, CO 80301
+1 720-565-4046

A.7: Homer Energy Analysis Report

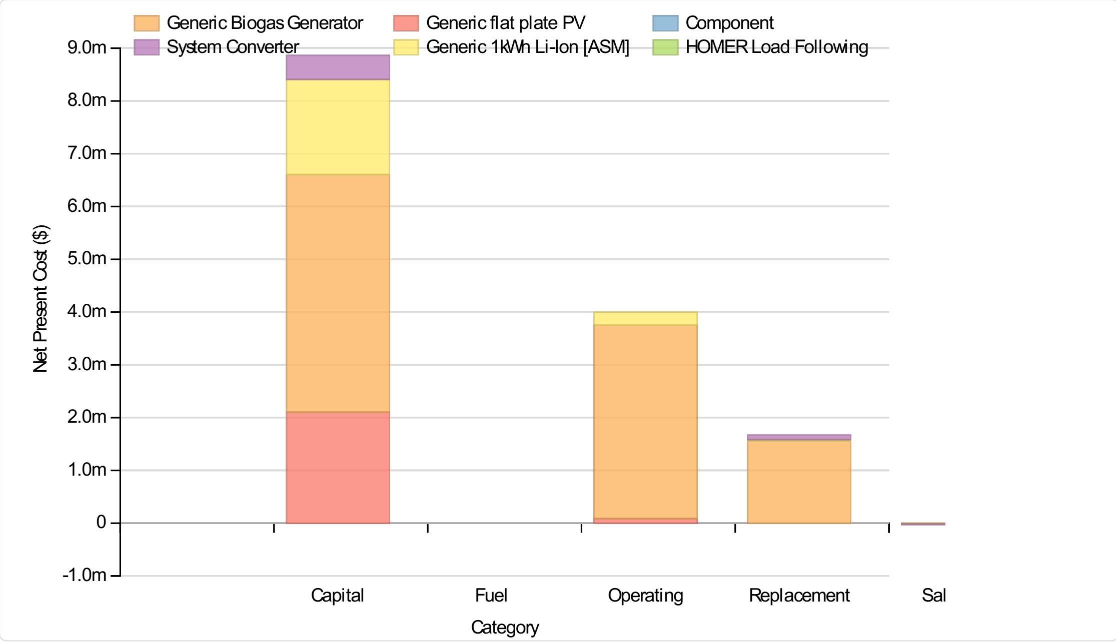
System generated analysis report of biomass gasifier hybrid system is attached next page.

System Report

System architecture

PV	Generic flat plate PV	1,109	kW
Generator	Generic Biogas Generator	1,500	kW
Storage	Generic 1kWh Li-Ion [ASM]	3,005	strings
Converter	System Converter	1,496	kW
Dispatch Strategy	HOMER Load Following		

Cost summary



Cost Summary

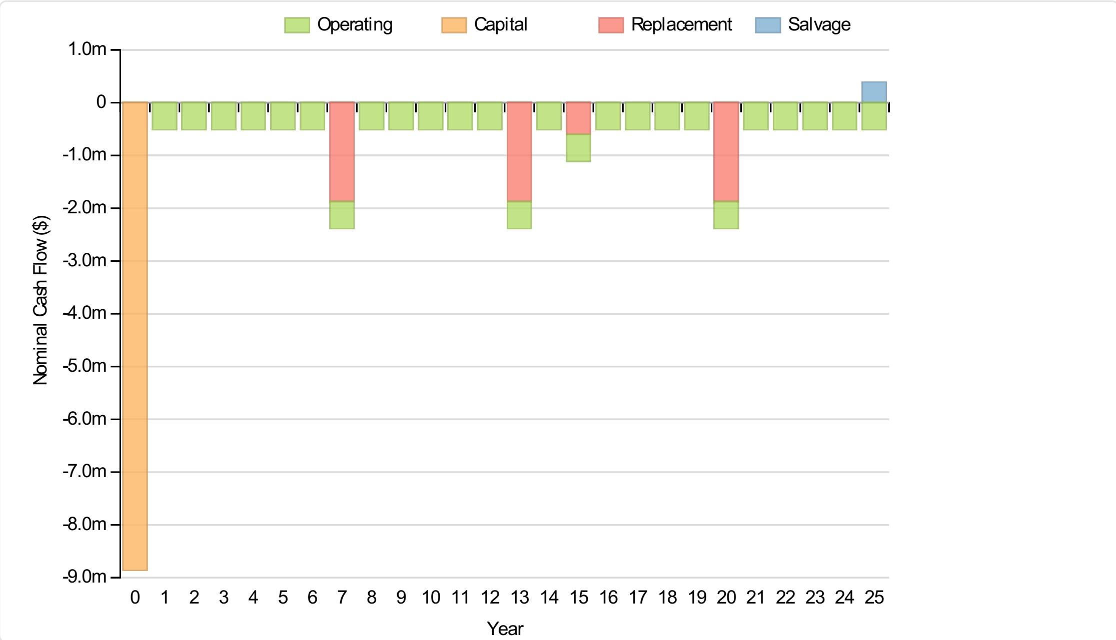
Total net present cost	14496257	$
Levelized cost of energy	0.462	$/kWh

Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Generic flat plate PV	2,107,115	0	86,981	0	0	2,194,096
Generic Biogas Generator	4,500,000	1,557,391	3,670,589	0	-11,029	9,716,950
HOMER Load Following	0	0	0	0	0	0
Generic 1kWh Li-Ion [ASM]	1,803,000	27,450	235,686	0	-2,946	2,063,190
Generic 1kWh Li-Ion [ASM]	0	0	0	0	0	0
System Converter	448,823	81,998	0	0	-8,800	522,020
System	8,858,937	1,666,839	3,993,256	0	-22,776	14,496,257

Annualized Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Generic flat plate PV	268,657	0	11,090	0	0	279,747
Generic Biogas Generator	573,750	198,567	468,000	0	-1,406	1,238,911
HOMER Load Following	0	0	0	0	0	0
Generic 1kWh Li-Ion [ASM]	229,882	3,500	30,050	0	-376	263,057
Generic 1kWh Li-Ion [ASM]	0	0	0	0	0	0
System Converter	57,225	10,455	0	0	-1,122	66,558
System	1,129,514	212,522	509,140	0	-2,904	1,848,272



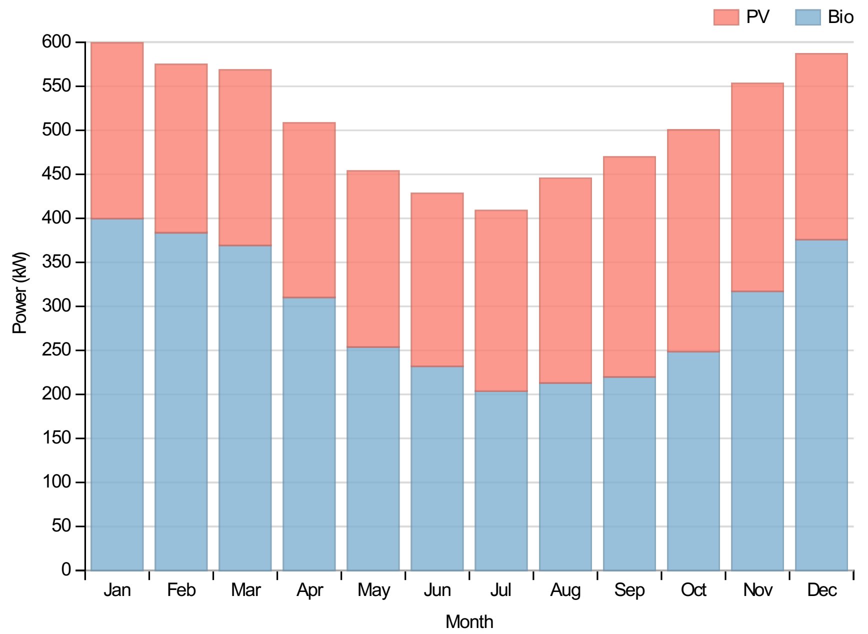
Electrical

Quantity	Value	Units
Excess electricity	17455	kWh/yr
Unmet load	133	kWh/yr
Capacity shortage	610	kWh/yr
Renewable fraction	1	

Component	Production(kWh/yr)	Fraction (%)
PV	1,876,571	42
Generator	2,570,326	58
Total	4,446,897	100

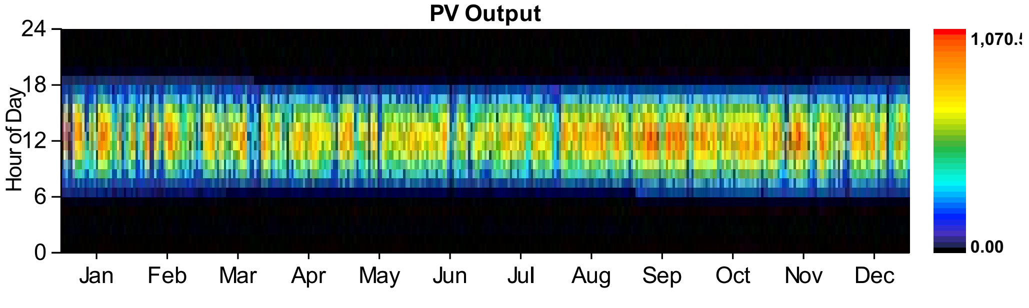
Load	Consumption(kWh/yr)	Fraction (%)
AC primary load	3,999,537	100
DC primary load	0	0

Load	Consumption(kWh/yr)	Fraction (%)
Total	3,999,537	100



PV:Generic flat plate PV

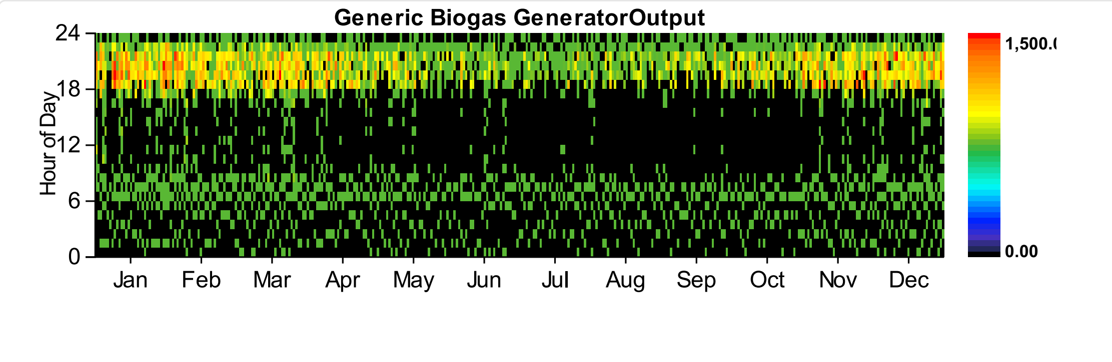
Quantity	Value	Units
Rated capacity	1109	kW
Mean output	214	kW
Mean output	5141.29	kWh/d
Capacity factor	19.32	%
Total production	1876571	kWh/yr
Minimum output	0.00	kW
Maximum output	1070.59	kW
PV penetration	46.92	%
Hours of operation	4329	hrs/yr
Levelized cost	0.149	$/kWh



Generator:Generic Biogas Generator

Quantity	Value	Units

Quantity	Value	Units
Hours of operation	3120	hrs/yr
Number of starts	1570	starts/yr
Operational life	6	yr
Fixed generation cost	243.75	$/hr
Marginal generation cost	0.00	$/kWh
Electrical production	2570326	kWh/yr
Mean electrical output	824	kW
Min. electrical output	750	kW
Max. electrical output	1500	kW
Fuel consumption	8012	L/yr
Specific fuel consumption	2.18	L/kWh
Fuel energy input	8568773	kWh/yr
Mean electrical efficiency	30	%



Battery:Generic 1kWh Li-Ion [ASM]

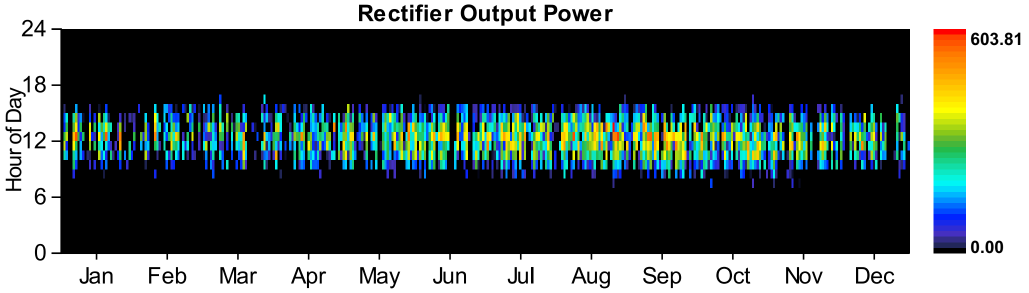
Quantity	Value
String size	1
Strings in parallel	3,005
Batteries	3,005
Bus voltage	4

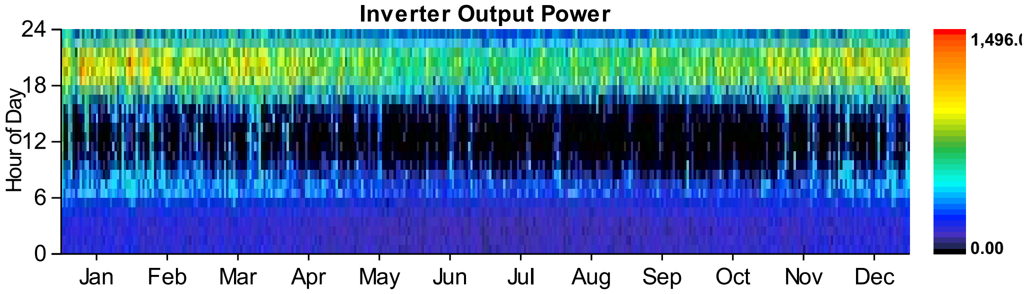
Quantity	Value	Units
Nominal capacity	3069	kWh
Usable nominal capacity	2455	kWh
Autonomy	5	hr
Battery wear cost	0.000	$/kWh
Average energy cost	0.000	$/kWh

Quantity	Value	Units
Energy in	1049937	kWh/yr
Energy out	960960	kWh/yr
Storage depletion	1797	kWh/yr
Losses	87180	kWh/yr
Annual throughput	1005419	kWh/yr

Converter

Quantity	Inverter	Rectifier	Units
Capacity	1,496	1,346	kW
Mean output	289	38	kW
Minimum output	0	0	kW
Maximum output	1,496	604	kW
Capacity factor	19	3	%
Hours of operation	7,019	1,688	hrs/yr
Energy in	2,816,983	394,864	kWh/yr
Energy out	2,535,285	335,634	kWh/yr
Losses	281,698	59,230	kWh/yr





Emissions

Pollutant	Emissions	Units
Carbon dioxide	1444	kg/yr

Pollutant	Emissions	Units
Carbon monoxide	16	kg/yr
Unburned hydrocarbons	0	kg/yr
Particulate matter	0	kg/yr
Sulfur dioxide	0	kg/yr
Nitrogen oxides	10	kg/yr