# Feasibility Study of Renewable Hybrid System for Island Bhola (Char Fasson) A Case Study

by

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# Declaration

We hereby declare that the thesis titled **“Feasibility Study of Renewable Hybrid System for Island Bhola (Char Fasson): A Case Study”** submitted to the Department of Electrical and Electronics, in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering, is our original work and was not submitted elsewhere for the award of any other Degree or Diploma or any other Publication.

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# List of Acronyms

| | |
|---|---|
| **AWEC** | Alta Wind Energy Center |
| **AC** | Alternating Current |
| **AGM** | Absorbed Glass Mat |
| **AWEP** | Albany Wave Energy Project |
| **BIPV** | Building Integrated Photovoltaic |
| **CETO** | Cylindrical Energy Transfer Oscillating |
| **COE** | Cost of Energy |
| **CSP** | Concentrating Solar Power |
| **DC** | Direct Current |
| **DOD** | Depth of Discharge |
| **GHS** | Grid Hybrid System |
| **HWAT** | Horizontal Axis Wind Turbine |
| **HOMER** | Hybrid Optimization of Multiple Energy Resources |
| **NASA** | National Aeronautics and Space Administration |
| **OWC** | Oscillating Water Column |
| **PTO** | Power Take Off |
| **PV** | Photovoltaic |
| **PWEP** | Perth Wave Energy Project |
| **SMC** | Solar Heating and Cooling |
| **VWAT** | Vertical Axis Wind Turbine |
| **WEC** | Wave Energy Converter |

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# Abstract

The global demand of energy is increasing day by owing to population growth, economic prosperity and technical innovation, the planet is getting more complicated every day. On the other hand, the natural sources of energy like coal, gas, fossil fuel are diminishing exponentially. Local renewable energy sources can overcome this scarcity without massive investment. Countries like Bangladesh are as well trying to utilize renewable energy sources to satisfy their growing demand. People in the remote area like Bhola (Char Fasson) have been suffering from insufficient electricity for many years. Considering the availability of enough wave height and velocity of Bay of Bengal and wind power in the shoreline makes Bhola a suitable place for this hybrid power generation system. HOMER simulation software was used to conduct the study, design, and simulation of this Hybrid Renewable Power Generation System. The aim is to produce 16 MW power and to provide electricity to 91200 households and other non-residential loads. Cost per unit is $0.26 and initial cost is $142M and other post calculations are also done via HOMER software

# Chapter 1

# Introduction

Renewable energy is replacing fossil fuel due to the exhaustibility, environmental effects, ozone layer depletion and increasing price of fossil fuel. Worldwide 6% of total energy was supplied by this renewable energy in 2008 [1] [2]. That number reaches to 10.6 within 9 years [1]. But Bangladesh is using only 3% of the total energy ratio [2]. One-third of Bangladesh's electricity production relies on imported fossil fuel energy and 65 percent of the country's electricity production depends on natural gas, though someday the current gas reserve will be diminished [2].

Bangladesh is a land of natural beauty and has enormous potential for renewable energy resources. In Bangladesh, solar energy is a vital energy resource and solar photovoltaic (PV) cells are one of the most customary technologies used in Bangladesh, mainly in hilly areas, rural areas and coastal areas. Bangladesh, as a nation with rivers and oceans, has a lot of room for wave energy. Bangladesh also has wind as a green energy source. For energy generation, mini and micro wind generation sites are available along Bangladesh's coastline. As a result, green energy plays a critical role in Bangladesh's energy production.

The unreliability of production due to the unpredictability of these services at various times and site locations is one of the key challenges of using sustainable systems such as wind, wave, and solar as a single device. The integration of energy technologies to build a hybrid renewable energy system to improve efficiency is a viable solution to this problem. There are many advantages of using such systems, including reducing carbon emissions, increasing efficiency and increasing reliability. Besides, the construction of transmission lines intrudes huge capital costs on the state. The hybridization of renewable technologies is then an appropriate choice to increase the supply of electricity and the quality of life and to reduce the government's energy costs in these areas.

## 1.1 Objectives

- Design and simulate a “Hybrid Renewable Power Generation System” for Bhola (Char Fasson) using HOMER simulation software.
- The goal is to produce **16 MW** electricity and provide electricity to **91200 household** and other consumers.
- Estimate the cost per kWh and cost (initial cost and pet present cost) of the whole system.

## 1.2 Study Area

### *1.2.1 Geography and Demography*

Char Fasson is an upazila of Bhola District, Bangladesh. It occupies a total area of 1440.04 square kilometers. It lies between the latitudes of 21°54' and 22°16' north, and the longitudes of 90°34' and 90°50' east [3]. There are over 100 islands in Char Fasson. Char Fasson has a population of 456437 [4]. And almost 91200 families (Considering 5 people in each family).

Figure 1: Char Fasson

### *1.2.2 Current Scenario*

Total electricity demand of Bhola is 42 MW [5]. Where power production capacity of Bhola is almost 260 MW. Still Char Fasson is facing load shedding for 22 hours a day [6]. All the unions of the upazila have brought under the Rural Electrification Scheme. Yet, only a total of 18.7 percent of general households reported having electricity connection in the entire upazila [7].

## 1.3 Load Profile

Fans and lights are the loads considered to be supplied to the households, schools, colleges, madrasahs, hospitals etc. **Table 1** is created considering the types of loads and the demand [3] [4].

Here, the following have been taken into consideration,
Light = 15W
Fan = 45W
Street Light = 20W

**Table 1: Estimated Load**

| Consumer | Unit | Fan | Light | Total Fan | Total Light |
|---|---|---|---|---|---|
| Family (House) | 91200 | 2 | 4 | 182400 | 364800 |
| College | 21 | 15 | 4 | 315 | 84 |
| School | 454 | 8 | 2 | 3632 | 908 |
| Madrasa | 376 | 8 | 12 | 3008 | 4512 |
| Mosque/ Mandir | 606 | 6 | 6 | 3636 | 3636 |
| Hospital | 15 | 20 | 40 | 300 | 600 |
| Bazar | 58 | 30 | 30 | 1740 | 1740 |
| Street Light Pucca + semi pucca | 174 Km | - | 25/km | - | 3675 |

### 1.3.1 Daily Load Profile

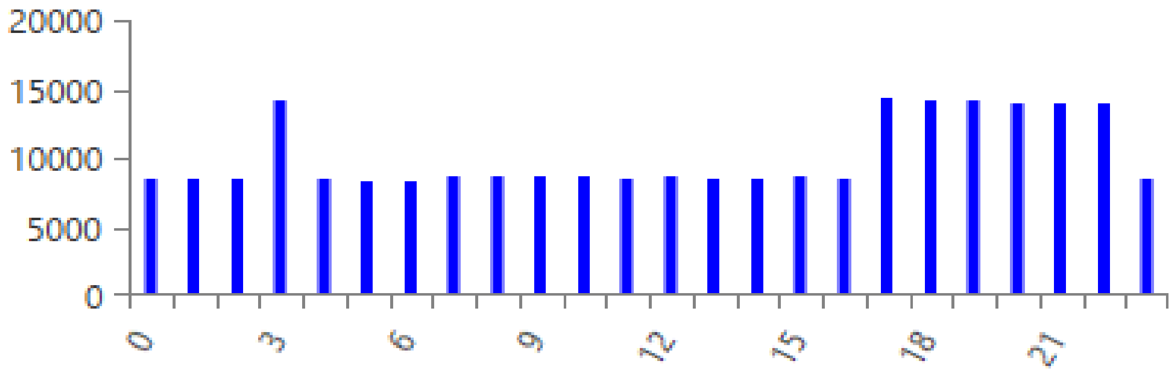


Figure 2: Daily Load Profile (HOMER)

The Figure 2 was generated in HOMER pro, and it describes the daily load usage in the specified area. Here we observe most of the load in between the hours 16 to 23, that is night time when most of the lights will be working. And the spike on the 3rd hour is due to the prayer time when everyone gets up to say their *Fazr* prayer.

### 1.3.2 Seasonal Load Profile

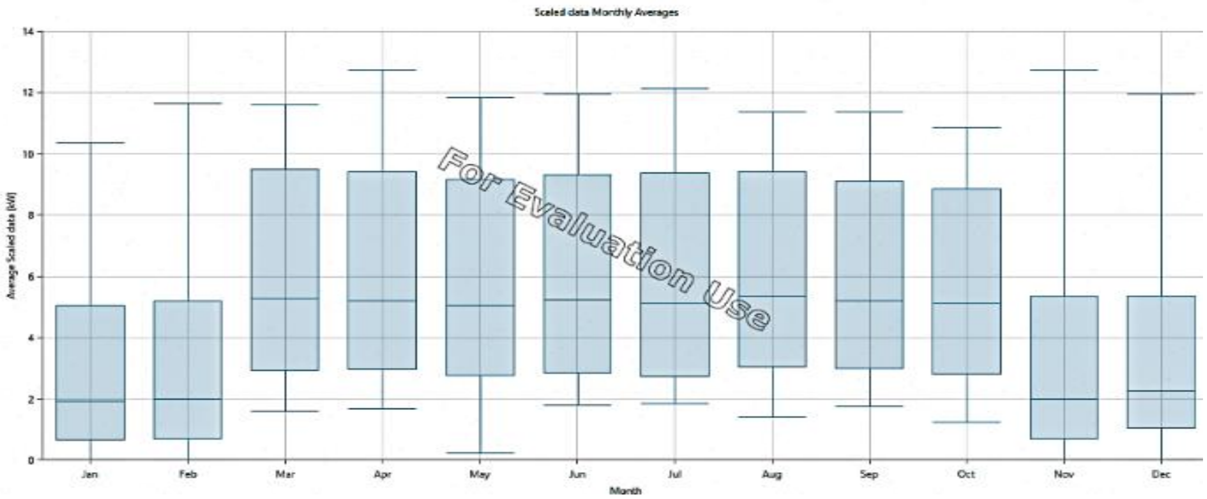


Figure 3: Annual Load Profile (HOMER)

In the Figure 3, the annual load profile has been shown. It is a graph of power vs month. If we observe carefully, we see that most of the power consumed is during the months of March to October. Since Bangladesh is situated in the northern hemisphere, these months indicate the summer season. During this time, it is natural that every household will have ceiling fans running almost 24 hours. As a result, the load will be more for a constant time.

## 1.4 System Configuration

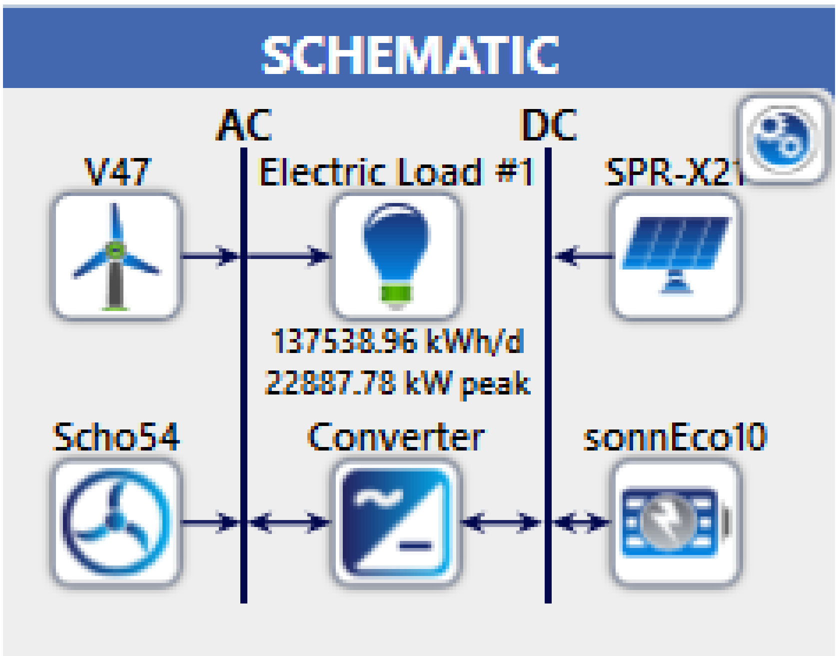


Figure 4: Schematic Diagram of the System (HOMER)

The proposed system consists of three sources of energy – wind turbine, solar panel and hydro turbine as equivalent to wave converter. Also, a converter to convert DC source to AC source. And battery for energy storage and to provide constant voltage to the consumers. The schematic diagram of the system is depicted in the Figure 4.

The Performance and contribution of each components of the system will be discussed separately in the following chapters.

# Chapter 2

# Solar Energy

## 2.1 History of Solar energy

One of the easiest renewable resource is the solar energy. Since ancient times man has used this form of energy for many day-to-day activities. Some of the which are still in practice today. For example, we dry our washed cloths in the sun, many types of food are dried in the sun to prepare different food products, hay is produced by drying paddy in the sun, and many for examples can be mentioned.

Solar power's early applications involved concentrating the energy of the sun into a magnifying glass to fuel cooking fires [8] [9]. By the third century B.C., for ceremonial rituals, Greeks and Romans reflected sunlight off "burning mirrors" to light holy torches [8] [9].

Figure 5: Focusing sunlight to start fire

Sun rooms were first used in ancient times to harness the sun's natural energy. These rooms have absorbed and filtered sunlight from Roman bathhouses to Native American adobes, and they are still popular in many modern homes.

One tradition of Greek solar culture is that Archimedes, a mathematician, set fire to the Roman Empire's besieged wooden ships. The myth goes that, before they made landfall, he used bronze shields to represent the sun's light energy, concentrating the beams and attacking the enemy [9]. Consider it a solar ray from the far east is unverified whether this really occurred in Archimedes' time or not [9]. But this solar power experiment was tested in the 1970s by the Greek navy [9]. They set a wooden test ship 50 meters out on fire using nothing but the mythical bronze shield and the energy of solar radiation [8] [9].

Unlike us humans, plants have used this solar energy far more effectively. One of the main physiological functions of the green plants, photosynthesis, occurs in the presence of sunlight. Here the solar energy of the sun is converted into chemical energy which is the food for the plants. This occurs in the leaves of the plant where there is a green pigment called Chlorophyll, which causes the reaction water and carbon dioxide to produce food and oxygen.

So just like plant, humans also wanted to use the sun to produce energy [8]. After many attempts, the French physicist Edmond Becquerel eventually discovered the photovoltaic effect in 1839 when working with a cell in a conducting solution consisting of metal electrodes [8]. He noticed that when he was exposed to light, the cell produced more electricity [8].

Willoughby Smith later discovered in 1873 that, selenium could act as a photoconductor. [8]

Just three years later, in 1876, William Grylls Adams and Richard Evans Day applied Becquerel's photovoltaic principle to selenium [8]. They said that when it was exposed to light, it could generate electricity [8].

In 1883, nearly 50 years after the discovery of the photovoltaic effect, American inventor Charles Fritz produced the first working selenium solar cell. Although we use silicon in modern solar panels, this solar cell was a major precursor to the technology used today.

The very first solar panel-powered satellite was launched by Hoffman Electronics in 1958. [8]

In a way, several scientists played a role in the development of solar cells **[8]**. The capacity of the photovoltaic effect is due to Becquerel, and Fritz is probably the father of all solar cells **[8]**.

## 2.2 Reasons for Solar Power Usage

Fossil fuels such as, gas, oil and coal along with nuclear power plants are the primary sources of world electricity production [10] [11]. Greenhouse gases such as, CFC, $CH_4$, $O_3$, but primarily $CO_2$ are released into the atmosphere because of the use of fossil fuels [10]. A small amount of carbon is emitted from the nuclear power plant (90 grams equivalent of carbon dioxide per kilowatt hour) [12] [10]. However, over thousands of years, nuclear waste stays intact, and is a possible cause of environmental contamination.

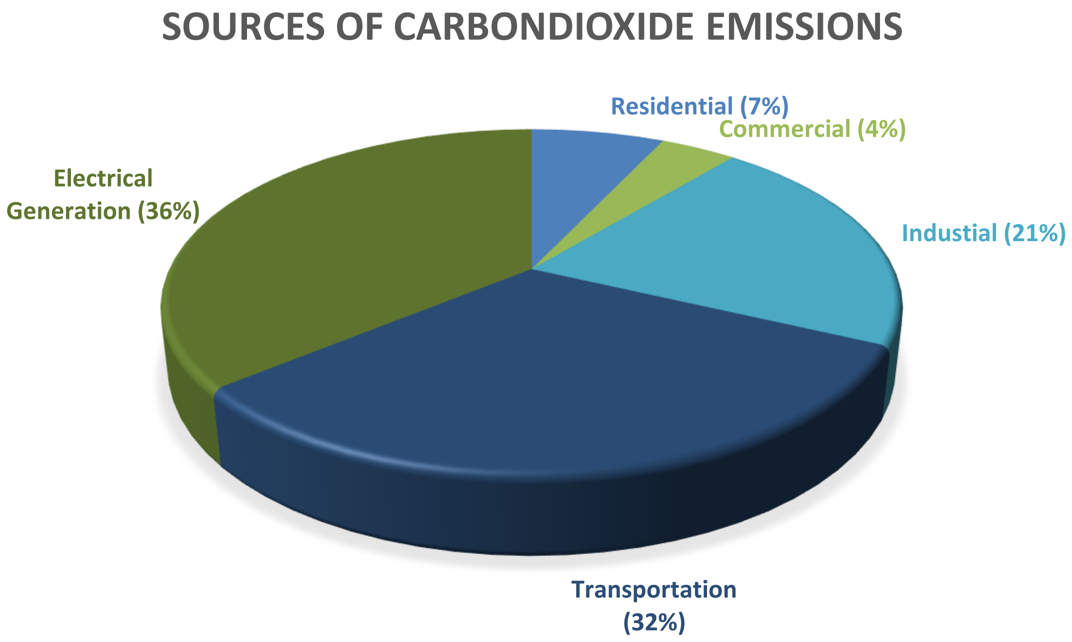


Figure 6: Sources of carbon dioxide emissions

Figure 6 [13] demonstrates that the production of energy is the cause of the highest carbon dioxide emissions. So, in practice, the output of this renewable energy contributes much to global warming. Extreme warming, as well as air degradation, is the biggest threat to human beings in our day.

In the other hand, as fossil fuel stocks diminish and aging power stations will shutter in the immediate future, there is an unprecedented energy shortage worldwide. Scientists and engineers are searching for safe, green energy in the face of global warming and the lack of natural gas. Solar energy can be considered as the best renewable because of the fact that the earth takes 3.8 YJ [1 YJ = $10^{24}$ J] of energy which is six thousand times greater than the worldwide consumption [14].

Bangladesh faces an acute electricity crisis. The major source of electricity production in Bangladesh is natural gas. However, limited gas supplies are insufficient to meet the needs of both homegrown necessities and mechanical and business requests, particularly long-haul power age prerequisites [10] [15].

Our current capacity for power generation is just about 4200 MW, while 6000 MW is the total power demand [16]. So, we can produce just 70 percent of our overall demand for electricity. Not only are we facing load shedding throughout the country due to this power crisis, but the manufacturing sector is also seriously impacted. This has resulted in decreased factory production and decreased export earnings.

There is a developing requirement for quickened urbanization, industrialization, quick populace development, expanding food creation, expanding day to day environments, and so on in the energy market [10] [15]. In Bangladesh, sun-oriented energy might be a major wellspring of force age [10] [15].

The public authority of Bangladesh intends to make it obligatory to mount sun-based boards on the roofs of both skyscraper and multi-storage facilities. Since sun-based energy is one of the cleanest and simplest wellsprings of energy, we ought to hope to discover it.

Anywhere on earth, solar energy is readily available. This can be used to produce power at the point of consumption. Solar-powered architecture is based on this theory **[11]**.

## 2.3 Current Solar Power Infrastructure on Earth

Huge work, analysis, thesis, application, consideration of design and improvement on solar technology are taking place around the world as well as in our region. So, that is why we have more than 35 company doing business, implementation and research on solar technologies [17].

University students from all around the world are experimenting with the solar system [17]. A group of students at Ahsanullah University of Science and Technology (AUST), for example, built a solar system for their school [17]. As part of their study, another group from Pennsylvania State University modeled and simulated a "Distributed Photovoltaic System" for their university [17]. Rajamangala University of Technology in Thanyaburi, Thailand, is building a photovoltaic facility for their university in order to support solar energy projects [17].

Scientists working profusely on solar panel production, such as scientists from California and Korea, have found a way to improve the performance of solar plastic panels [10] [15] [18]. They make them more competitive with conventional solar panels by doing this. Industrial buildings, homes, offices and businesses are implementing renewable energy solar systems. In Dezhou, Shangdong Province, for example, the largest solar powered building in northwest of China [15].

Figure 7: The largest solar power building situated in the northwest of china

The 4th World Solar City Congress will be held in the world's largest solar-powered building [10] [15] (Figure 7). We can also see buildings that are completely powered by solar energy, such as the stadium in Taiwan that was constructed for the 2009 World Games [10] [15].

Figure 8: Completely Solar Powered Stadium situated in Taiwan.

The Figure 8 shows the completely solar powered building located in Taiwan which does not require any power from the national grid [10] [15]. It is covered by eight thousand eight hundred and forty solar panels on the roof producing 1.14 million kWh per year [10] [15]. Due to this scheme, it is capable of preventing sic hundred and sixty tons of carbon dioxide to be released to the environment [10] [15] [19].

Many researches, improvements etc. on solar technologies are ongoing around the world and also in our country, huge strides have been taken to improve and implement solar power in the national grid [10] [15]. Solar energy is generally site based with some key factors.

Solar power is installed and supplied from a specific location to one or multiple consumers. Such as- an apartment complex or a house can use the rooftops, garden, lawn etc. to setup their solar panels to get the desired amount of power [10] [15]. Other than this, a single solar power plant can be planned for a specific amount of load, such as- Olmedilla Photovoltaic Park in Spain is capable of 60 MW of power [20], Sarnia Photovoltaic Power Plant in Canada is capable of delivering a power of 80 MW [21] [10] [15].

## 2.4 Impact of Solar Energy

The potential of solar energy is enormous. It is so significant that solar energy will meet the overall energy needs of the entire planet. In 2007-08, the world's gross energy consumption was 474 EJ (1 EJ= $10^{18}$ J) or roughly 15 TW (1 TW= $10^{13}$ W) [22]. Nearly 80%-90% of this energy comes from fossil fuels. These can be reduced significantly by the use of renewables like solar [23].

3,850,000 EJ of energy is received from the sun's earth [22]. That correlates to 174 PW (1 PW=$10^{15}$ W). Not all the energy is retained by the world, some parts of the light reflects back [10] [15]. Earth receives 89 PW of solar radiation following contemplation [10] [15]. In this immense number, just less than 0.02% is sufficient to replace the world's entire supply of fossil fuels and nuclear power [10] [15]. We can clearly grasp the tremendous promise of solar energy through this. Other environmental effects, costs, threats and abundance of solar energy have the greatest potential among all energy sources, given the greenhouse effect.

## 2.5 Solar energy technology

Solar energy, which is heat and radiant light, can be collected from the Sun using a wide range of ever-changing technologies such as solar heating, photovoltaics, solar thermal technology, molten salt power plants, solar architecture, and artificial photosynthesis.

It is an important source of renewable energy, and its systems, depending on how they absorb and transmit solar energy or transform it into solar electricity, are broadly defined as [24]

1. Active Solar
2. Passive Solar

The Active solar strategies include [25]

1. Photovoltaic (PV) devices
2. Concentrating Solar Power (CSP)
3. Solar Heating and Cooling (SHC).

Passive solar approaches include [24]

1. the angle at which a building faces the Sun
2. the choice of materials with suitable thermal mass or light-dispersive properties
3. the design of spaces that naturally distribute air

Through an electrical mechanism, photovoltaics (PV) generate electricity directly from sunlight and can be used to power anything from small electronics like calculators and road signs to large enterprises and homes. In the case of solar heating & cooling (SHC) and concentrated solar power (CSP) applications both use the heat generated by the sun to provide room or water heating.

## 2.6 Internal Structure of Solar Cell

A solar cell is a semiconductor P-N junction device where metal contacts are deposited at the front and rear side of a solar cell to collect the generated current. Metal contacts at the rear side is continuous while the metal contact at the front side is in the form of metal lines to allow sunlight in the cell. An anti-reflecting coating is put on the solar cell to ensure that incident light is not reflected back, rather enters the solar cell and gets absorbed [26].

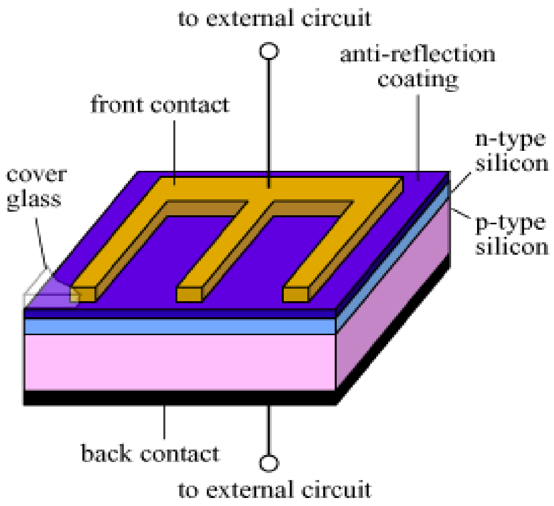


Figure 9: Internal Structure of a basic Solar Cell

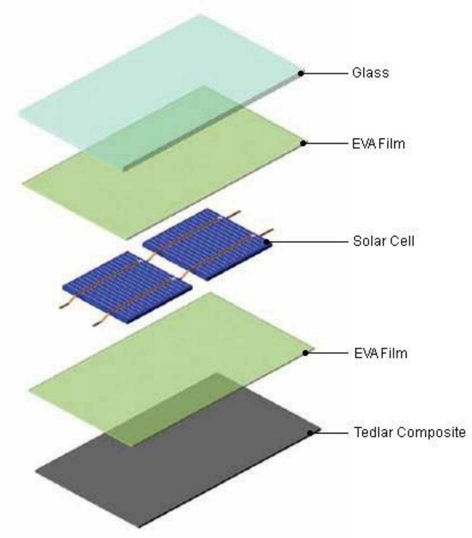


Figure 10: Layers of a Solar Cell

Solar panels consist of a cluster of photovoltaic (PV) solar cells which are connected in parallel and series. A number of solar cells make up a module. By combining a number of modules an array is formed. These arrays are what make a solar panel [26].

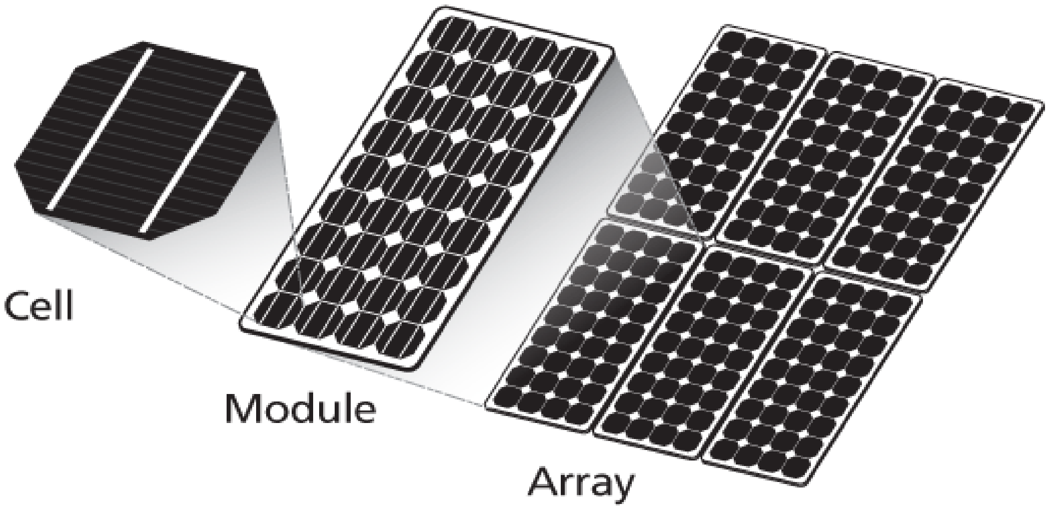


Figure 11: Cell-Module-Array (Panel)

A minimum of two layers of semiconductor material are used in the design of cells (generally pure silicon which is infused with boron and phosphorous) [10] [15]. One layer has a positive charge while the other layer will be negatively charged [10] [15]. As rays from the sun enter the solar plate, they are absorbed by the semiconductor atoms, and then emit electrons [10] [15]. Electrons flowing from the negative layer (n-type) of a semiconductor ultimately migrate to the positive layer (p-type), resulting in an electrical current [10] [15]. Here the point to be noted that the electric current flows in one direction, hence the electricity generated is DC [10] [15]. To use the electricity produced by the solar panel, the DC current has to converted to AC current using an inverter [26] [10] [15].

## 2.7 Photovoltaic Cell technologies

With the rising need for solar energy, innovative technologies are being applied and current technologies are being developed. There are four types of solar photovoltaic cells,

1. Mono-crystalline
2. Poly-crystalline
3. Thin film
4. Amorphous silicon

### 2.7.1 Mono-crystalline Cell

It is readily available and among the other types they are the most efficient materials for cells. They accumulate much of the module's power per square foot. From a single crystal, each cell is cut. To increase the number of cells in the solar panel, the wafers are then further sliced into the form of rectangular cells.

Figure 12: Monocrystalline Solar Panel

### 2.7.2 Polycrystalline cells

They are made of a silicon material, except that they are melted and poured into a mold. This produces a square block that can be cut into square wafers with less volume or material loss than cubic single-crystal wafers [10] [15].

Figure 13: Polycrystalline Solar Panel

### 2.7.3 Thin film panels:

It is the newest innovations integrated into the technology of solar cells. The thin film components are all copper indium dieseline, gallium arsenide and cadmium telluride. They are deposited directly on glass, stainless steel or other materials consistent with the substrate. Under low light conditions, some of them do marginally better than crystalline modules. A thin film, a few micrometers or less, is very thin.

Figure 14: Thin Film Solar Panel

### 2.7.4 Amorphous Silicon:

The current in thin film processing is amorphous silicon. On stainless steel rolls, Amorphous silicon vapor is dumped in this technology on a few micro-meter-thick amorphous films [10] [27]. Comparing with crystalline silicon, merely 1 percent of the element is used in this technology [10] [15].

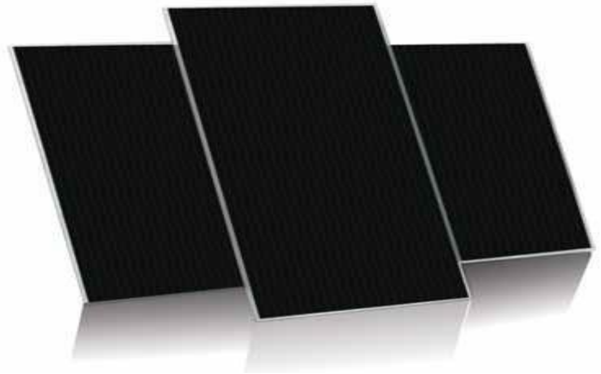


Figure 15: Amorphous Silicon Solar Panel

**Table 2** demonstrates the efficiency of different types of solar cells.

**Table 2: The Efficiency of Different Types of Solar Cells**

| **Solar Cell type** | **Efficiency (%)** |
|---|---|
| Mono-crystalline | 15 – 21 |
| Poly-crystalline | 12 – 18 |
| Thin film | 8 – 10 |
| Amorphous Silicon | 6 – 8 |

## 2.8 Different Kinds of Solar System Plan

There can be a number of solar system design and many more are being developed every now and then [10] [15]. But there are mainly 3 basic design that we will take into consideration [28], which are,

1. Grid tied system
2. Grid tied system with battery backup
3. Off grid system

### 2.8.1 Grid-tied system

A grid-tied system is a fundamental sunlight-based establishment that utilizes a standard lattice tied inverter and doesn't have any battery stockpiling [28]. This is ideal for clients who are as of now on the grid and want to add solar power to their home. These systems can pay the bill for state and government motivating forces which help to pay for the system [28]. Grid-tied system are easy to plan and are extremely financially savvy since they have generally couple of parts [28]. The principle objective of a grid-tied system is to bring down your energy bill and help from sun-based motivators [28].

One disadvantage of this kind of system is that once the facility goes out, thus will your system [28]. This is often for safety reasons as a result of linemen performing on the facility lines ought to grasp there's no supply feeding the grid [28]. Grid-tied inverters ought to mechanically disconnect once they don’t sense the grid [28]. This implies that you just cannot offer power throughout Associate in Nursing outage or Associate in Nursing emergency and you can’t store energy for later use [28]. You furthermore can’t manage the system once you use the facility from your system, like throughout peak demand time [28].

Be that as it may, there is positive in this framework as, if a client as of now has a fundamental matrix tied framework, they can add stockpiling later [28]. The arrangement is to do an air conditioner coupled framework [28]. Here the first lattice tied inverter will be combined with a battery back-up inverter [28]. This is a wonderful answer for buyers who will introduce sun based to exploit motivators, however can't put resources into the batteries presently [28].

A purchaser can profit by the net-metering on the grounds that at whatever point the sun based is creating more than the use, at that point force can be sent back to the matrix [28]. Once more, when the heaps are higher than the sun-oriented creation, the force can be purchased from the utility [28]. The client won't rely completely upon the sunlight-based force for the entirety of their heap [28]. Shockingly, when the framework goes down, the skies are overcast and there's no battery back-up in the framework, at that point will be no force [28].

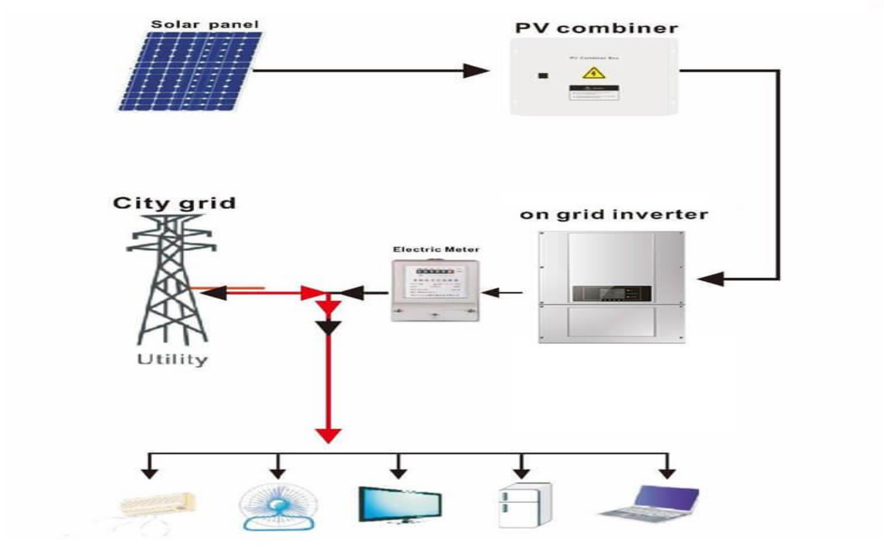


Figure 16: Grid-Tied System

The Figure 16 [28] shows the parts and exhibits how an essential network tie framework is arrangement [28]. A couple of primary segments joined to the current utility association [28]. The inverter is tied straightforwardly into the primary assistance board to change over the DC sun-oriented capacity to AC [28].

### 2.8.2 Grid-tied system with battery back-up:

The next system is a grid-tied system with battery back-up, also known as a Grid-Hybrid System (GHS) [28]. This type of system is perfect for those who are already connected to the grid and can afford to have battery back-up [28]. This framework will be recipient for the individuals who are inclined to blackouts in their general vicinity, or simply need to be prepared for blackouts [28].

This system brings best of both worlds as one can still be connected to the grid and will also be able to enjoy state and federal incentives, alongside lowering the utility bill [28]. Consequently, power outage won’t be of any threat [28]. Battery based grid-tied systems will provide power in case of power outage and energy can be saved up in case of an emergency [28]. One would be able to back up vital loads such as, lights and fans when there is no power from the grid [28]. Energy can also be used during peak demand times because the energy is stored in the battery banks [28].

But there are demerits. The expense will be essentially more than fundamental framework tied frameworks and are undeniably less effective [28]. There are additionally more segments due to the options of battery packs [28]. The expansion of the battery packs will likewise require a charge regulator to secure them [28]. A sub-board should likewise be introduced that will contain the significant burdens that should be sponsored up [28].

All the family stacks on the network can't be upheld up by the framework [28]. Some significant burdens which are required when the lattice power is down should be disconnected into a back-up sub-board [28].

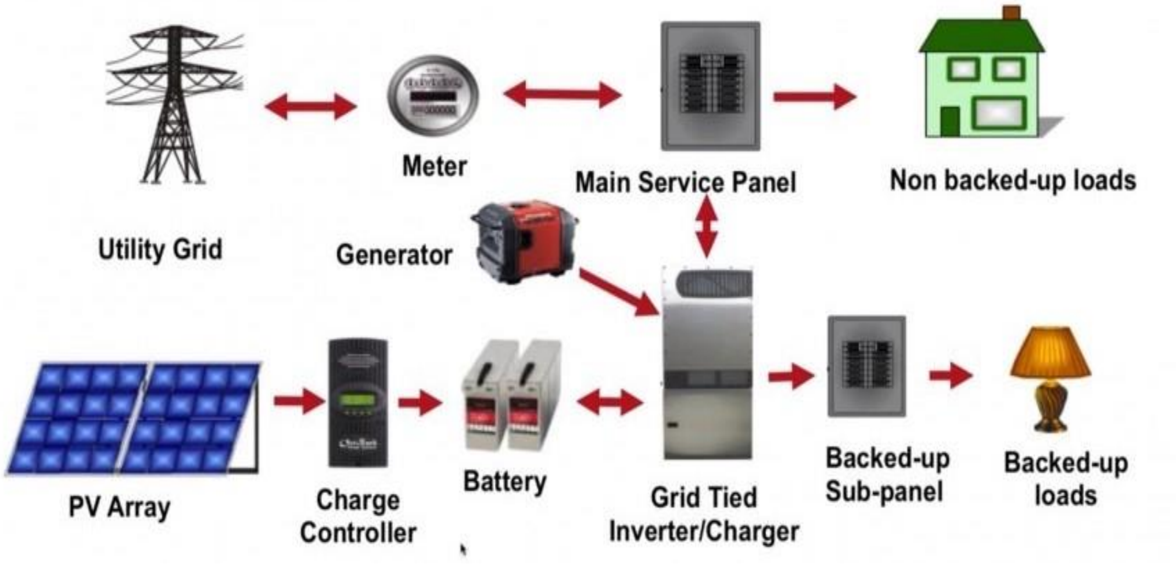


Figure 17: Grid-Tied System with Battery Backup

The Figure 17 [28] shows a flow diagram describing how each and every component in the system will have to be connected [28].

### 2.8.3 Off-grid system:

Off-grid systems are best for consumers who are unable to connect to the main grid [28]. The reasons may be because of geographical location or high installation cost of new connection [28]. In a sense, it impractical for a person connected to the grid to completely disconnect and install an off-grid system [28].

The one of benefits of an off-grid system is that a person will be able to become energy self-sufficient and can power remote places far away from the national grid [28]. There should be fixed energy costs and no utility bill can be charged [28]. Another aspect of off-grid systems is that the components are modular and the consumer can increase the capacity according to energy needs [28]. A person can start out with a small, budget-conscious system and add on as the time goes on [28].

Because the system is the only source of power, many off-grid systems will be equipped with multiple charging sources such as solar, wind and generator [28]. The weather and year-round conditions should be taken into consideration when designing the system [28]. If the solar panels are covered with dust, then cleaning should be down on a regular basis [28]. A back-up generator ought to be there simply on the off chance that the inexhaustible sources are insufficient now and again to keep the batteries charged [28].

One demerit is that off-grid systems may not qualify for some incentive programs [28]. The system will have to be designed to cover 100% of energy loads, and hopefully some excess amount [28]. Off-grid systems will have more components and will be more expensive than a standard grid-tied system [28].

Figure 18: Off-Grid System

The Figure 18 [28] describes the framework chart of a fundamental off network framework [28]. All the heaps are being provided by the batteries and there is no stockpile from the principle framework [28]. It isn't unexpected to have both AC and DC loads in an off-lattice framework as the DC loads are now and again more proficient in light of the fact that they are not experiencing the inverter [28].

## 2.9 PV Cell Mounting

There are different types of solar panel construction that can be performed. Several modes of mounting are carried out depending on the position and method. They are briefly described below:

### *2.9.1 Pole Mount*

There are mainly three types of pole mounts [29], which are:

1. Top of pole: The Solar Panels are mounted on the top of a metal rack and tilted to the sun. The base of the pole is generally concrete to have good foundation [10].

Figure 19: Top Pole Mounting

2. Side of pole mounting: Small solar panels are placed on side of telephone or electricity pole using a special type of ‘A’ shaped metal mount [10].

Figure 20: Side Pole Mounting

3. Tracking pole mounting: A special type of mount with a motor which tilts the solar panel according to the sun's path. It is the most advanced and efficient pole mount.

Figure 21: Tracking Pole Mounting

### 2.9.2 Ground Mount

It is also possible to install solar panels on the ground. Solar panels may be installed on the ground in the event of further power requirements or inadequate space on the roof.

Figure 22: Ground Mount

### 2.9.3 Building Integrated Photovoltaic (BIPV)

This is a special form of attachment system; the building floor, vertical walls and even atriums are mounted on the PV modules. There is huge advantage [30], which are,

- Mounting can be done in such a way that the architecture blends in with the rest of the building to make it more beautiful.
- Exclusive and multipurpose
- Fortification, preservation

### 2.9.4 Roof mounting

Roof mounting is generally of 2 types

1. Flat-Roof Mounting
2. Pitched-Roof Mounting

#### Pitched-Roof Mounting

Roof mounting is complicated, so careful mounting needs to be achieved based on the direction and angle. The tilt angle for the optimal performance needs to be fixed. We can't expect a roof to fit any of these categories. Hence there are three types of roof mount. They are-

**1. Flush mount**: The roof facing south is ideal for this assembly. Any slope is acceptable, but it is better to have a steep slope.

Figure 23: Flush Roof Mounting

**2. Angle mount:** This system is ideally suited for the roof with a lower pitch.

Figure 24: Angle Roof Mounting

**3. Fin Mount**: The solar panels are designed as fins and attached to the roof.

Figure 25: Fin Roof Mounting

### Flat-Roof Mounting

There are 3 types of flat roof mounting, which are

**1. Attached:** This category need infiltration and linking to the frame
**2. Ballasted:** There is no need for penetration, without this it can handle 90 mph of wind. [31]
**3. Hybrid:** It is a blend of ballasted and structural system. The concept of hybrid system is more ballast and less penetration or vice versa.

## 2.10 Parts of a Solar Photovoltaic system

A normal solar Photovoltaic system would be a collection of solar panels, batteries, controller, power converter (Inverter) and the load [10]. Figure 26 demonstrates the block diagram of PV system [10].

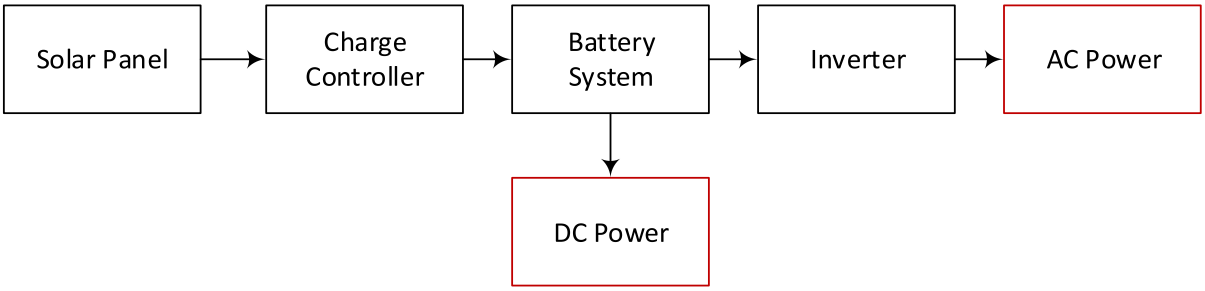


Figure 26: PV System's Block Diagram

### 2.10.1 Solar Panel

The output of a PV panels a function of potential different and of solar radiant energy. The power output of the panel can be found by the product of the Voltage (V) and the Current (I). But there are a lot of variables which influence the final output which is useable. Such as,

- high temperature reduces the efficiency of the panel
- dust and other particles can accumulate on the surface of the panel causing less radiation to reach the cells
- some of the cell maybe defective and produce less output

Many such factors have to take into consideration which calculating the final useable amount of power.

The power produced by the solar panel is calculated by the equation-1 [32] considering that the panels are fully clean and good amount of solar radiation is able to reach the cells,

$$P_{PVout} = P_{NPV} \times (G/G_{ref}) \times [1 + K_T(T_C - T_{ref})] \qquad (1)$$

Where,
$P_{PVout}$ is the PV cell output power
$P_{NPV}$ is the reference condition rated power
$G_{ref}$ is the reference condition Solar radiation ($G_{ref} = 1000W/m^2$)
G is the Solar radiation ($W/m^2$)
$T_{ref}$ is the reference condition Temperature ($T_{ref} = 25$ °C),
$K_T$ is the Temperature Coefficient of maximum power for poly-crystalline and mono-crystalline Silicon
$T_C$ is the temperature of the Cell

Considering a panel of $P_{NPV} = 10$ kW, rated power. Converting the value from the resources the avg solar radiation is $G = 235$ W/m$^2$. The reference temp. and radiations are respectively $T_{ref} = 25$ °C and $G_{ref} = 1000$ W/m$^2$. A cell can reach a temp of $T_C = 65$ °C in summer days. And finally, for monocrystalline cells $K_T = 8$
Therefore, from the above equation, $P_{PVout} = 7.5434$ kW

In other words, using the SunPower X21-335-BLK panel, with an efficiency of 21%, we would get 7.9 kW from a 10-kW rated panel. Due to reduced efficiency at high temp, we got 7.5 kW.

### 2.10.2 Charge controller

The need for a charging controller occurs where the battery is used in a system. The unknown voltage builds up is regulated by a charge controller. The solar cells generate more voltage on a bright sunny day, which can result in battery loss. When charging the battery, a charging controller helps preserve the equilibrium [33].

### 2.10.3 Batteries

Batteries are used for energy charges. There are several kinds of batteries that are present on the market. But for solar PV technologies, all of them are not appropriate. Nickel/cadmium batteries are the most commonly used batteries. Batteries with high energy density, such as bromine/zinc, Sulphur/Sodium flow batteries, are available [10]. But the nickel/metal hydride battery provides the highest cycling efficiency for medium-term batteries [10]. Chromium/Iron redox and manganese/zinc batteries are suitable for the long-term alternative [10]. Very few batteries are as good as the Batteries from Absorbed Glass Mat (AGM) for solar PV use available [34].

A battery bank can utilize as a support framework and it keeps up steady voltage over the entire electrical burden [35]. The battery bank is viewed as a regular method to manage the capacity of electrical force with high viability [35]. Its delivering level can't outperform a base limit described as the significance of delivery [35].

The storage capacity ($C_{Wh}$) is calculated by the equation-2 [32] [35].

$$C_{Wh} = (E_L \times AD)\eta_{inv} \times \eta_b \times DOD \quad \text{.............}(1)$$

where:

$E_L$ = The Demand of Total Energy
DOD = Depth of discharge of the Battery
AD = Daily autonomy
$\eta_{inv}$ = Efficiency of Inverter
$\eta_b$ = Efficiency of Battery

The capital cost is \$50 with substitution cost will be \$50 and battery lifetime are expected to be 10 years.

### 2.10.4 Power Converter (Inverter)

Power converter is considering a prime part in a hybrid energy system [35]. It is made of some power electronic devices [35]. Between the AC and DC parts, a power converter is supposed to hold power upstream [35]. Let’s consider for a hybrid system of 5 kW [35]. The capital expense of the converter will be \$300 and the substitution cost will be \$300 [35]. Lifetime of a single unit is expected to be 15 years having an efficiency of 95% [35].

The working process of power converter is shown in Figure 27.

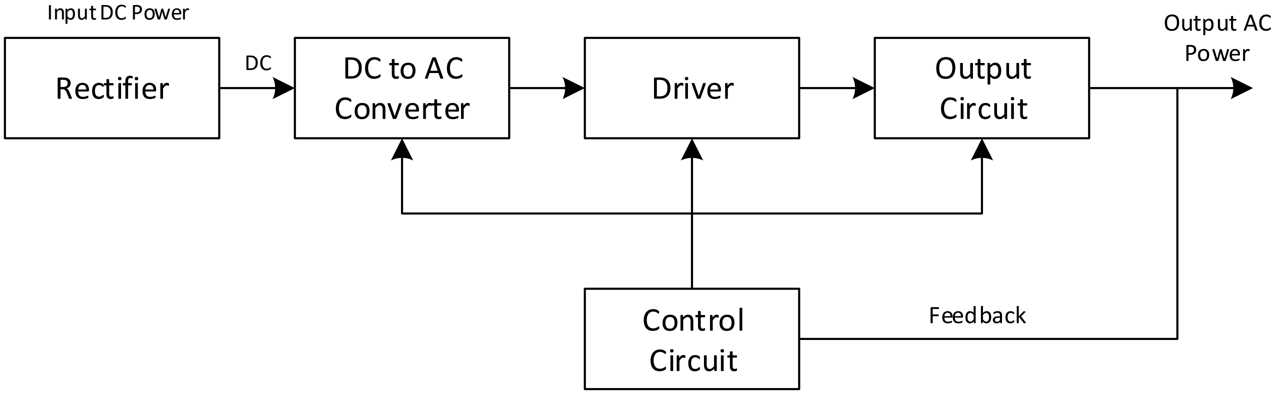


Figure 27: Block Diagram of Power Converter

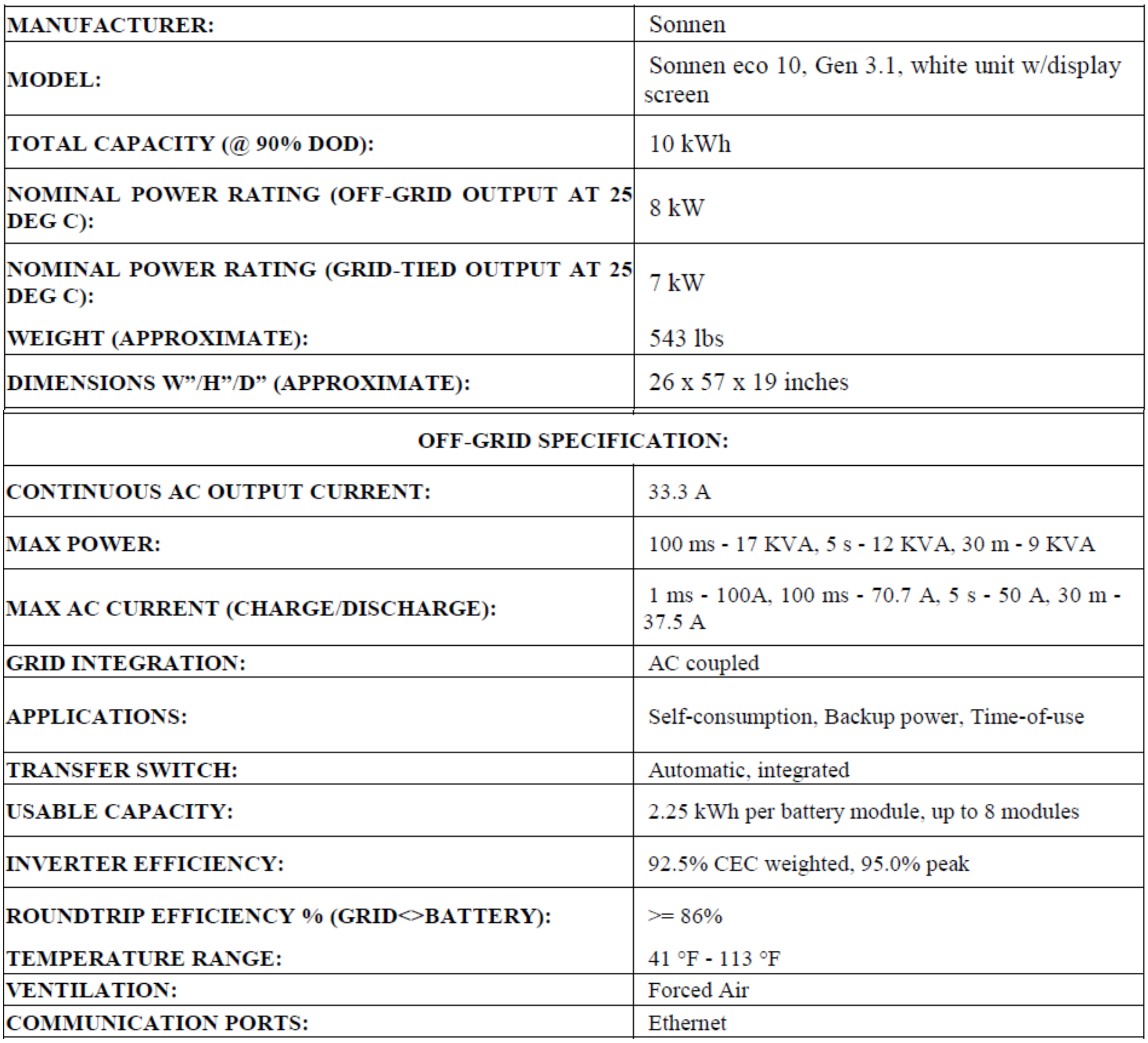
## 2.11 Component Configuration

The configurations of the Battery and the Solar Panels using for the scheme will be given along with some brief discussions

### 2.11.1 Battery Configuration

The battery used for the model is the 10kWh rated Sonnen eco 10. They are quite cheap and are available in the local market. They are mostly used in renewable energy production models because of their reliability. The specifications are given in the following **Table 3** [36]

Table 3: Battery Configuration

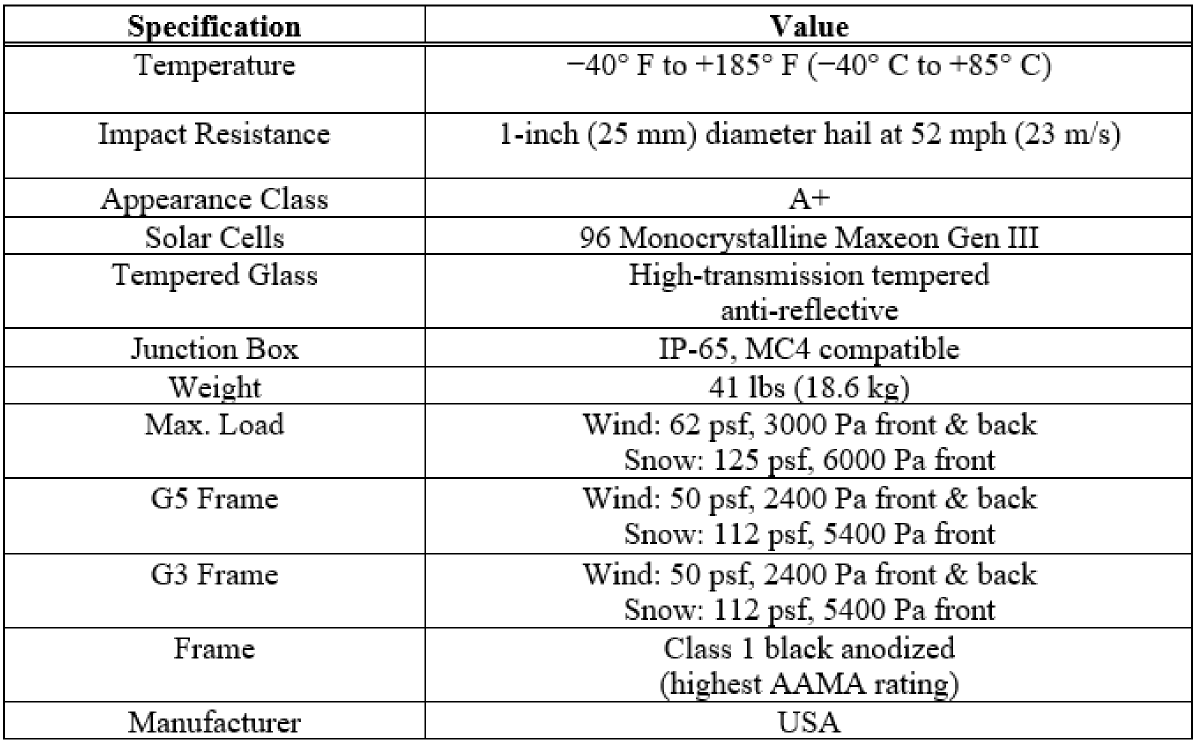


| | |
|---|---|
| **MANUFACTURER:** | Sonnen |
| **MODEL:** | Sonnen eco 10, Gen 3.1, white unit w/display screen |
| **TOTAL CAPACITY (@ 90% DOD):** | 10 kWh |
| **NOMINAL POWER RATING (OFF-GRID OUTPUT AT 25 DEG C):** | 8 kW |
| **NOMINAL POWER RATING (GRID-TIED OUTPUT AT 25 DEG C):** | 7 kW |
| **WEIGHT (APPROXIMATE):** | 543 lbs |
| **DIMENSIONS W"/H"/D" (APPROXIMATE):** | 26 x 57 x 19 inches |
| **OFF-GRID SPECIFICATION:** | |
| **CONTINUOUS AC OUTPUT CURRENT:** | 33.3 A |
| **MAX POWER:** | 100 ms - 17 KVA, 5 s - 12 KVA, 30 m - 9 KVA |
| **MAX AC CURRENT (CHARGE/DISCHARGE):** | 1 ms - 100A, 100 ms - 70.7 A, 5 s - 50 A, 30 m - 37.5 A |
| **GRID INTEGRATION:** | AC coupled |
| **APPLICATIONS:** | Self-consumption, Backup power, Time-of-use |
| **TRANSFER SWITCH:** | Automatic, integrated |
| **USABLE CAPACITY:** | 2.25 kWh per battery module, up to 8 modules |
| **INVERTER EFFICIENCY:** | 92.5% CEC weighted, 95.0% peak |
| **ROUNDTRIP EFFICIENCY % (GRID<>BATTERY):** | >= 86% |
| **TEMPERATURE RANGE:** | 41 °F - 113 °F |
| **VENTILATION:** | Forced Air |
| **COMMUNICATION PORTS:** | Ethernet |

### 2.11.2 Solar Panel Configuration

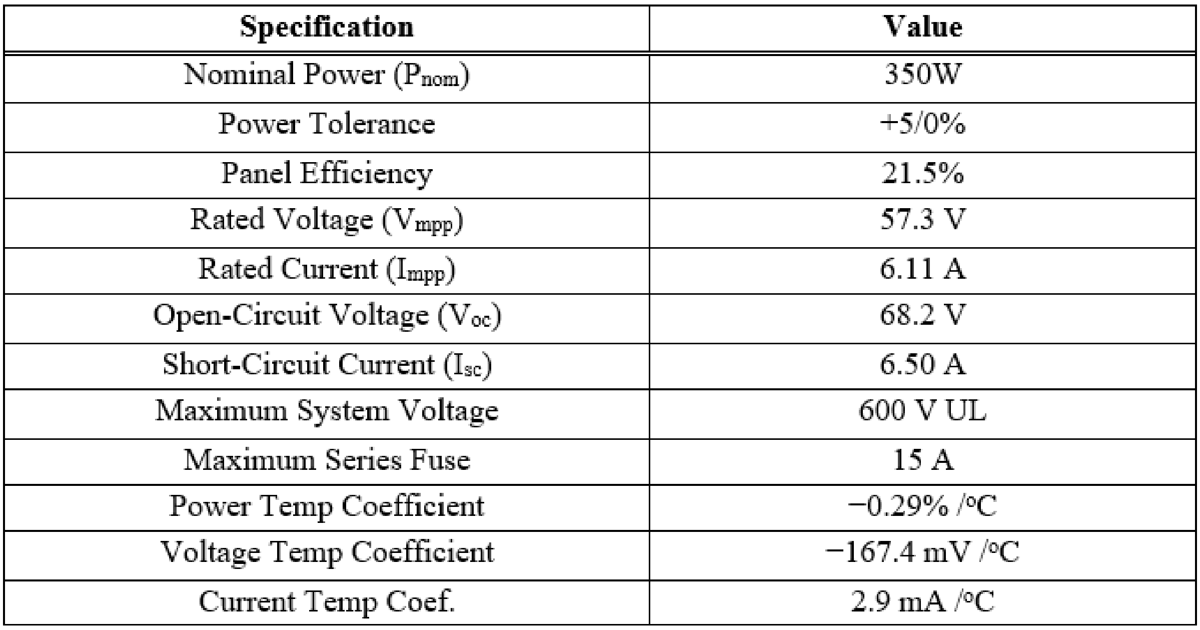
The panel used in the setup is the SunPower X21-335-BLK, which is a monocrystalline celled solar panel with high efficiency. The specifications of the panel are given in the following two tables. **Table 4** [37] shows the operating condition and mechanical data while **Table 5** [37] shows the electrical specifications.

Table 4: Operating Condition and Mechanical Data



| Specification | Value |
|---|---|
| Temperature | −40° F to +185° F (−40° C to +85° C) |
| Impact Resistance | 1-inch (25 mm) diameter hail at 52 mph (23 m/s) |
| Appearance Class | A+ |
| Solar Cells | 96 Monocrystalline Maxeon Gen III |
| Tempered Glass | High-transmission tempered anti-reflective |
| Junction Box | IP-65, MC4 compatible |
| Weight | 41 lbs (18.6 kg) |
| Max. Load | Wind: 62 psf, 3000 Pa front & back<br>Snow: 125 psf, 6000 Pa front |
| G5 Frame | Wind: 50 psf, 2400 Pa front & back<br>Snow: 112 psf, 5400 Pa front |
| G3 Frame | Wind: 50 psf, 2400 Pa front & back<br>Snow: 112 psf, 5400 Pa front |
| Frame | Class 1 black anodized (highest AAMA rating) |
| Manufacturer | USA |

Table 5: Electrical Data of Solar Panels



| Specification | Value |
|---|---|
| Nominal Power ($P_{nom}$) | 350W |
| Power Tolerance | +5/0% |
| Panel Efficiency | 21.5% |
| Rated Voltage ($V_{mpp}$) | 57.3 V |
| Rated Current ($I_{mpp}$) | 6.11 A |
| Open-Circuit Voltage ($V_{oc}$) | 68.2 V |
| Short-Circuit Current ($I_{sc}$) | 6.50 A |
| Maximum System Voltage | 600 V UL |
| Maximum Series Fuse | 15 A |
| Power Temp Coefficient | −0.29% /°C |
| Voltage Temp Coefficient | −167.4 mV /°C |
| Current Temp Coef. | 2.9 mA /°C |

# Chapter 3

# Wind Energy

Wind energy is considered to be one of the most usable renowned renewable energy. By using the wind speed energy is produced. Wind energy is becoming popular for its unlimited resources and low operation and maintenance cost. Wind farms are consisting of many wind turbines. It can be offshore or onshore type farms. Wind energy provides almost 5% worldwide generation of electricity. For this purpose, the coastal area of Char Fasson has potential to produce wind energy from there.

## 3.1 History

Wind power plant was first built in Iran. These windmills were used to grind grain or draw water, and were used in grist manufacturing and sugarcane enterprises [38]. They were constructed of six to twelve sails shrouded in reed tangling or cloth material [38]. Later wind energy is introduced in Europe in middle century. Fausto Veranzio, a Croatian scientist, first described advanced wind turbine technology. He introduced V shaped turbine first. The first wind turbine was a battery charging system invented by Scottish scholastic James Blyth in July 1887 to fuel his summer home in Marykirk, Scotland [38].

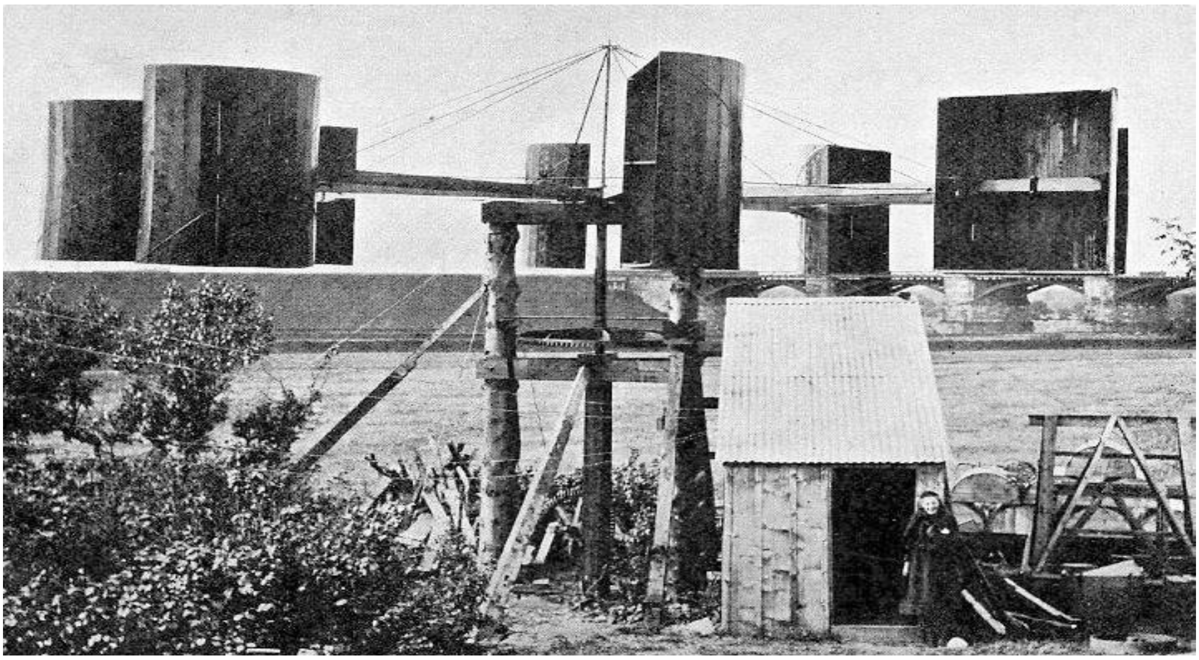


Figure 28: James Blyth's Windmill

Charles F. Brush fabricated the main consequently worked wind turbine in the wake of counseling neighborhood University teachers and partners Jacob S. Gibbs and Brinsley

Coleberd and effectively getting the outlines peer-inspected for power creation in Cleveland, Ohio [38]. Despite the fact that Blyth's turbine was viewed as uneconomical in the United Kingdom, power age by wind turbines was more practical in nations with broadly dispersed populaces [38].

By the 1930s, wind generators for power were regular on homesteads, for the most part in the United States where conveyance frameworks had not at this point been introduced [38]. In this period, high-tractable steel was modest, and the generators were set on pre-assembled open steel cross section towers [38]. In the pre-winter of 1941, the primary megawatt-class wind turbine was synchronized to a utility network in Vermont [38]. The Smith–Putnam wind turbine just a short time prior to enduring a basic disappointment [38]. The unit was not fixed, in view of a lack of materials during the war [38]. The primary utility network associated wind turbine to work in the UK was worked by John Brown and Company in 1951 in the Orkney Islands [38].

Improvements in petroleum frameworks essentially killed any wind turbine frameworks bigger than supermicro size [38]. In the mid-seventies, nonetheless, hostile to atomic fights in Denmark prodded mechanics to produce microturbines of twenty-two kW [38]. Organizing owners into affiliations and co-agents resulted in public authority and energy lobbying, as well as driving powers for greater turbines, in the 1980s and later [38]. Nearby activists in Germany, incipient turbine makers in Spain, and huge financial backers in the United States in the mid-1990s at that point campaigned for strategies that animated the business in those nations [38].

## 3.2 Worldwide Wind Energy Scenario

Many countries now a days are utilizing wind speed to create electricity. World’s largest wind power plant is situated at Gansu, China namely Gansu Wind farm. Its capacity is 7965MW.

Figure 29: Gansu Wind Farm, China

This project is one of the biggest projects of Chinese government. Wind speed is suitable for producing electricity at Gansu. Alta Wind Energy Center (AWEC), otherwise called Mojave Wind Farm, is the third biggest coastal breeze energy project on the planet. The Alta Wind Energy Center is a breeze ranch situated in Tehachapi Pass of the Tehachapi Mountains, located in Kern County of California, USA. Its capacity is 1548MW.It is the biggest wind power plant of USA.

Figure 30: Alta Wind Energy Centre

In Tamil Nadu, India there is a 1500MW wind power plant named Muppandal Wind Power plant.

Figure 31: Muppandal Wind Power Plant

Wind power plants are increasing day by day around the world. That’s why technology related to wind turbine is also becoming advance.

## 3.3 Wind Energy Scenario in Bangladesh

In our country wind plant capacity is 1.9MW. Our scientists are working hard to increase this rate. There are many places in our country where wind speed is suitable for producing energy. First wind power plant of our country is situated at Muhuridam, Feni. Its installed capacity is 0. 9MW.It has 4 turbines having 225kW each. Another wind power plant is situated at Kutubdia island where 50 turbines 50kW each is used. In future, Denmark has shown interest to build a 100MW wind power plant at Patuakhali.

Figure 32: Kutubdia Wind Power Plant

Figure 33: Muhuridam Wind Power Plant

Our government has planned to make digital Bangladesh. As a part of this program the number of wind power plants will be increased in near future.

## 3.4 Wind Turbine

Wind Turbines are mainly two types. One is horizontal axis wind turbine (HAWT) another is vertical axis wind turbine (VAWT).

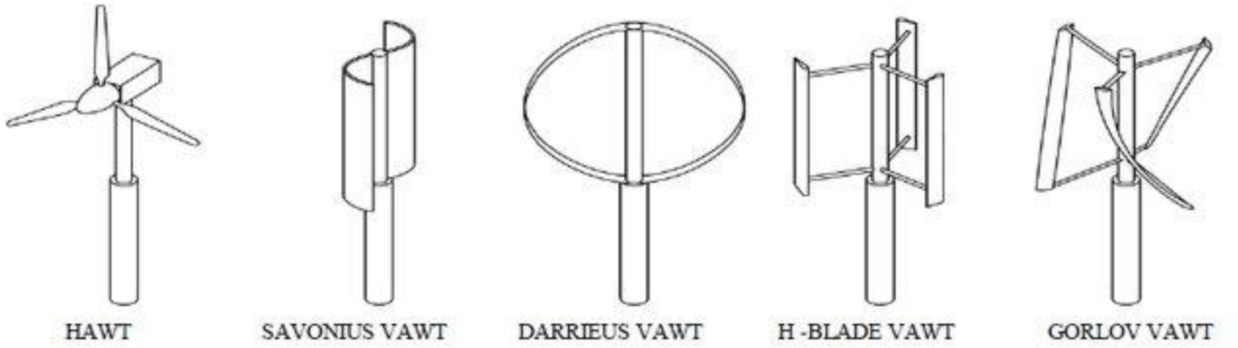


Figure 34: Different Types of Wind Turbines

### *3.4.1 HAWT*

The most well-known breeze system prototypes are HAWTs [39]. HAWTs use a rotor with streamlined edges (such as airfoils) that can be mounted upwind or downwind [39]. HAWTs are typically single-bladed and run at high edge tip speeds [39]. Upwind rotors require a yaw, or tail vane, to help them align towards the airflow, while downwind rotors have coned tips, allowing the turbine to position itself independently [39]. However, one downside of downwind rotors is that they have been observed to ‘stroll' around while trying to align with twists at low speeds, limiting low wind speed energy creation [39].

Modern HAWTs use sleek lift power to transform each rotor cutting edge in the same way as planes do [39]. For the most part, the lift capacity fills in as follows [39]. Wind streams through both the upper and lower segments of a sharp point as it is exposed to the elements [39]. However, due to the angle of the lip, air ignores the higher point of the edge much more easily (due to a longer carry length) than the lower divide, resulting in a low-pressure region on the outside [39]. The pressing factor difference between the cutting edge's top and bottom sides produces a push against the edge's highest point [39].

### *3.4.2 VAWT*

**Savonius VAWT:** Savonius wind turbines are a kind of vertical-hub wind turbine (VAWT), utilized for changing over the power of the breeze into force on a pivoting shaft [40]. The turbine comprises of various aero foils, for the most part—however not generally—vertically mounted on a turning shaft or structure, either ground positioned or fastened in airborne frameworks [40].

**Darrieus VAWT:** The Darrieus wind turbine is a kind of vertical hub wind turbine (VAWT) used to create power from wind energy [41]. Various bended aero foil cutting edges mounted on a pivoting shaft or framework make up the turbine [41]. At fast turning rates, the shape of the cutting edges helps the sharp edge to be centered on only in strain [41]. Straight cutting edges are seen in a couple of closely connected breeze turbines [41]. This turbine concept was covered by Georges Jean Marie Darrieus, a French aeronautical professional, who filed a patent application on October 1, 1926 [41]. There are major difficulties in defending the Darrieus turbine from heavy winds and in making it self-start [41].

**H-blade VAWT**: This type of wind turbines consists of H shaped of blade. Modern wind technologies are used this kind of turbines because of its efficiency. By using it we can generate decent amount of energy from wind.

**Gorlov VAWT:** Gorlov vertical axis wind turbines are used for low wind speed area. It is formed by using helical shaped turbine. Its turbine principle is almost as similar as Darrius vertical axis wind turbine.

## 3.5 Vestas V-47

For the simulation Vestas V-47[660kW] model is used as wind turbine which is a HAWT. It is used to convert mechanical energy to electrical energy. Its hub height is 50m and lifetime 20 years.

Figure 35: Vestas V47 Wind Turbine

Vestas V47 wind turbine model specification is given in **Table 6** [42]

Table 6: Vestas V47 Specifications

| Specification | Value |
|---|---|
| Rated Power | 660kW |
| Blade number | 3 |
| Rotor diameter | 47m |
| Hub height | 40-55m |
| Swept area | 1,735.0 m² |
| Highest Rotor Speed | 27.5rd/min |
| Cut-in speed | 4m/s |
| Cut-off speed | 25m/s |
| Generator Voltage | 690V |
| Lifetime | 25years |

## 3.6 Wind Turbine Working Principle

The uneven heating of the atmosphere allows the surface of the earth to have a temperature gradient, which results in wind movement. Planet rotation and earth irregularities have critical impacts on wind velocity. Wind turbine transforms the kinetic energy of wind to produce electric or mechanical energy. Wind hits the blades and produce force. A shaft inside the nacelle, which goes into a gearbox, turns the spinning blades. The gearbox increases the speed of rotation of the generator, which transforms rotational energy into electrical energy using a magnetic field. The power output is sent to a transformer that converts the generator's electricity to the proper voltage for the distribution system. The below Figure 36 shows the flow diagram of a wind turbine system.

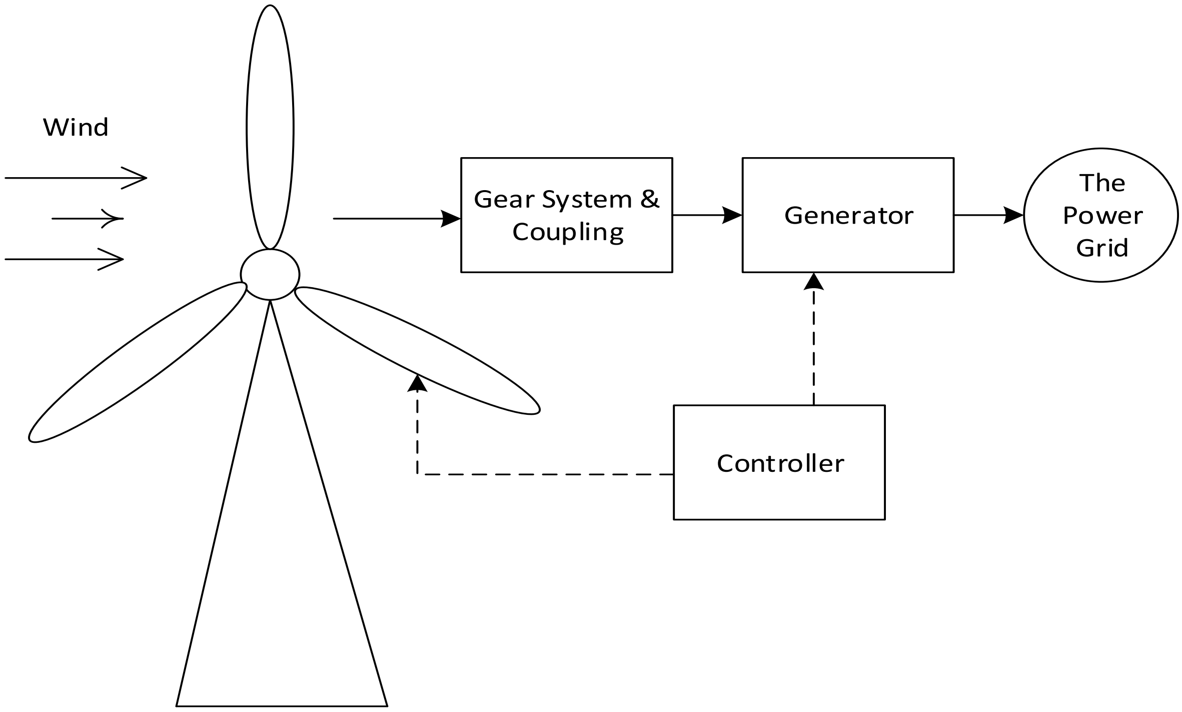


Figure 36: Block Diagram of Wind Energy Converter

The generator rotor receives the increased rate from the gear and coupling unit. Rotational energy is converted into electrical energy by a generator. In order to take control action, wind direction, wind speed, generator output, and temperature are all sensed by the controller, which then sends out the appropriate control signals.

To calculate power generated from wind turbine we use this equation below [43]

$$P_{WT} = \begin{cases} P_{Rated}\left(\frac{V^3 - V_{Cutin}^3}{V_{Rated}^3 - V_{Cutin}^3}\right) & V_{Cutin} < V \leq V_{Rated} \\ P_{Rated} & V_{Rated} < V \leq V_{Cutoff} \\ 0 & V > V_{Cutoff}\ or\ V < V_{Cutin} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

where

$P_{Rated}$ is the wind turbine's rated power (kW)
V is the speed of the wind (m/s)
$V_{Cutin}$ is the cut-in wind speed (m/s)
$V_{Cutoff}$is the cutoff wind speed (m/s)
$V_{Rated}$is the rated wind speed (m/s)

And for the effective electrical power output below equation is used [44]

$$P_{e,WT} = P_{WT}.A_{WT}.\eta_{WT}$$

Where
$P_{e,WT}$ is the effective electrical power
$A_{WT}$ is the swept area
$\eta_{WT}$ is the turbine efficiency

# Chapter 4

# Wave Energy

Wave energy generated from the oceans has an impressive capacity for electricity production, covering approximately 70 percent of the earth's surface [1]. It is possible to extract a significant amount of approximately 32 TW/year from the ocean waves [1]. While in nearshore areas it is possible to generate as much as 2 TW [1]. Considering this level of available energy and high-power density of water waves, interest in ocean wave energy is growing. Moreover, this power density is higher than wind and solar by one or two orders of magnitude.

The power flux of ocean waves is defined in kW/m, and denotes by the average power that passes through a cross section of unity width and infinite depth, perpendicular to the wavelength [45]. An analogy is the power exerted per meter by waves breaking on a shoreline [45]. Power flux is P and can be calculated from the significant wave height H and the period T by Equation 4 [45]. Where, ρ is the density of sea water and g is the gravitational acceleration constant [45].

$$P = \frac{\rho g^2 H^2 T}{64\pi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

## 4.1 Wave Energy Conversion Steps

Figure 37 shows the different stages of wave energy to electrical energy conversion.

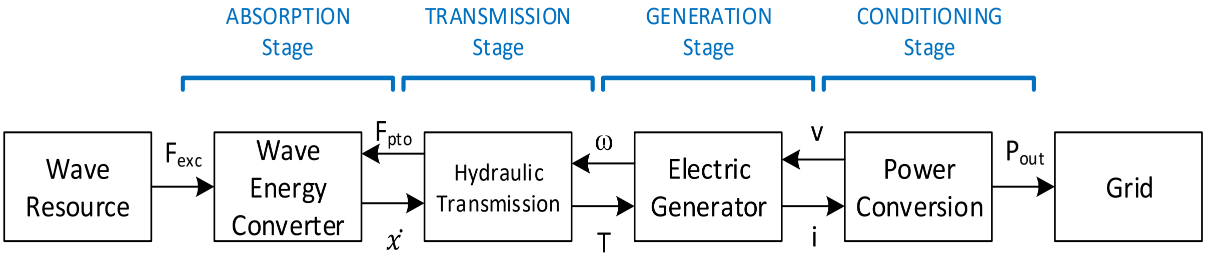


Figure 37: Wave Energy Conversion Steps

### 4.1.1 Absorption stage

In this stage, WEC body Converted waves energy to mechanical energy (Kinetic and potential energy) [46]. This body is known as the hydrodynamic subsystem [46]. The movements of the body are caused by wave force ($F_{exc}$). This velocity ($\dot{x}$) of the body is used for power generation [46].

### *4.1.2 Transmission stage*

In this stage, the motion energy of the body is transferred to energy in the transmission system. This stage's configuration is closely linked to the characteristics of the generator. Pressurized hydraulic fluid generated from hydraulic cylinders are used [46]. Pressurized gas, fluid(sea-water) or a direct shaft can be present in other forms of systems [46].

### *4.1.3 Generation stage*

In this stage, electric current is generated from the transmission energy [46]. This stage along with the transmission stage, is called the PTO system [46]. Hydraulic systems containing a hydraulic motor, used to produce electricity. Air turbines, low head water pressure turbines, linear generators or a direct drive mechanical PTO can be used in other systems [46].

### *4.1.4 Conditioning stage*

Generated electric charges are converted to the correct form of current and voltage to deliver to the power grid [46].

## 4.2 Challenges with Wave Energy Converters

**Seasonal variations**

The marine states are not consistent and they change throughout the year [47]. This results in unpredictable operating conditions and great difficulty in designing a Wave Energy Converter (WEC) that can cope with these variations and work efficiently [47] .

**Large wave periods**

Most of the types of WECs depend on resonance to capture efficient energy and high-energy locations such as the southern Australian shores appear to have a comparatively large wave period [47]. This involves large devices with very large masses to balance the natural frequency of the device with the frequency of ocean waves and achieve resonance with the incoming waves [47]. Because of the large volumes and masses, this results in design, development, transport, installation, mooring, and maintenance difficulties [47].

**Theoretical difficulties**

Wave energy harvesting is multidisciplinary [47]. This consists of boundary element methods of hydrodynamics, finite element methods of fluid mechanics, mechanical to electrical energy transfer, power electronics, and control theories [47]. For instance, hydrodynamics is technically intensive, containing complex theories of diffraction and radiation wave and often non-linear high order wave theories [47].

**PTO mechanisms**

In wave energy harvesters, there are several PTO mechanisms, the main ones are linear generators, power hydraulics, turbines, mechanisms for linear to rotary motion transmission, etc. For the PTOs, the seasonal variation presented previously poses a real challenge, as they are normally built to perform under constant conditions [47]. Conventional PTOs are designed to work under high velocities and low forces. But in ocean waves conditions, the velocities are low, and the forces are high, making the efficient operation of the PTOs difficult [47]. Finally, there is the problem of offshore management, as these devices are placed offshore (sometimes 40-50 kms from the landline) and maybe submerged underwater, making maintenance incredibly difficult and creating pollution problems for the natural ecosystem around them [47].

### Reliability and Operability

For wave energy harvesters, the transition from design to testing to commercial production has proved extremely difficult [47]. There are many explanations for this, including: no WEC stands out as the ultimate response to wave energy harvesting, particularly with a big portion of various models. Scaled testing of the real-sea WECs has proven to be extremely challenging and costly as well for commercialization [47].

### Cost of design iterations

Testing and designing WECs requires access, either by going offshore or by testing in a wave tank, to real ocean waves [45]. Both solutions are expensive and make variations of the design costly. Strict weather windows that restrict maintenance, repair and reconstruction are also restricted to the former alternative [45].

### Harsh environment

Harsh sea conditions, and particularly in storms or unconventional sea states, where the WEC is excited by extremely high waves of large heights and powers, raise a lot of structural and survival issues. This is why WEC needs to be built on the site for the worst-case weather scenario. The severe mooring loads are several times higher than the average loads and would be a big cost driver in the worst-case weather scenario [45].

### High power fluctuations

WECs have to extract power from the waves' reciprocal movement [45]. This varying speed directly causes the PTO's output power quality to be reduced, as the machinery cannot run at its optimal speed continuously [45]. This often transfers to the downstream power grid and needs built overcapacity, in addition to affecting the cost of the PTO [45].

### Limited power rating

The incoming waves have a limited wavelength, which restricts most WEC technologies to their full scale [45].

## 4.3 Environmental and Other Issues

The effect of WEC systems and their functioning on their immediate environment has to be examined [48]. Its activity emits little to no greenhouse gases, equivalent to all renewable energy systems, which makes WEC environmentally friendly in the first place. Analysis should be carried out to guarantee that the WEC facility has little or no adverse effect on aquatic plants and marine life at the site where the WEC will be installed [48]. It should be noted that, once energy has been removed from the waves, WECs on shoreline areas can limit shoreline erosion. There is risk that WEC structures can bring in new species into the immediate environment and even become artificial reefs, causing the local ecosystem to change its balance [48]. Precautionary measurements should be taken to avoid leakage or to make the hydraulic fluid biodegradable. Ocean environment can be polluted by Drilling, dredging and other construction activities and can cause imbalance in the natural habitat of the ocean plants and animals. Trapping, collisions, etc. could have other adverse effects on marine life. The effect of the biofouling and seaweeds on the WEC structure can lead to decrease in performance and also quicken structural degradation. [48]

## 4.4 Wave Converters

The kinetic energy present in the air-induced waves is transformed into electrical energy. The electrical energy conversion is achieved by using WEC (wave energy converter). There are different types of converters –

1. Point absorber [49]
2. Attenuator [49]
3. Oscillating water column [49]
4. Oscillating Wave Surge [49]
5. Over Topping Device [49]

### 4.4.1 Point Absorber

Through the relative motion between a body that moves in response to wave force and fixed or immobile structures, point absorbers extract energy. By using the vertical position floater, the electricity produced by this process. The position of the ‘moving body’ may be on the surface or submerged and the 'fixed body’ can fixed to the seabed [50]. Using a linear or rotary generator, electricity can be generated, or a fluid can be pumped directly using mechanical force and motion [50].

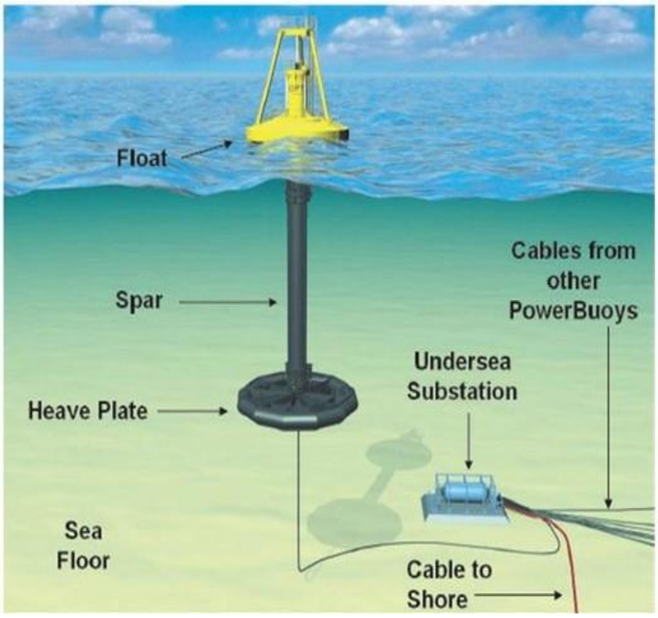


Figure 38: Point Absorber (Power Buoy)

### 4.4.2 Attenuator

Attenuator lies on the ocean surface. It is parallel to wave direction. Hydraulic pumps are used to produce electricity using flexing motion and then feed this energy to the grid. Swells produce this flexing motion. Usually, surface attenuators have several floating segments linked to each other. Instead of many parts, some attenuator designs consist of a single long, versatile surface phrase.

Figure 39: Attenuator (Pelamis)

### 4.4.3 Oscillating Water Column

Oscillating Water Columns (OWCs) are a type of Wave Energy Converter (WEC) that harnesses energy from the oscillation of water caused by wave inside a hollow chamber. It's one of the oldest wave energy harvesting processes. To pressurize air in a chamber, these devices use wave action, pushing it through an air turbine. The resulting vacuum draws air back through the turbine and into the chamber as water recedes from the chamber. The air column is pushed by waves to behave like a piston. Bidirectional turbines are used in this system. This implies that, irrespective of the direction of airflow, the turbine still rotates in the same direction, allowing continuous generation of energy. To generate electricity, the turbine can be coupled to a rotary generator.

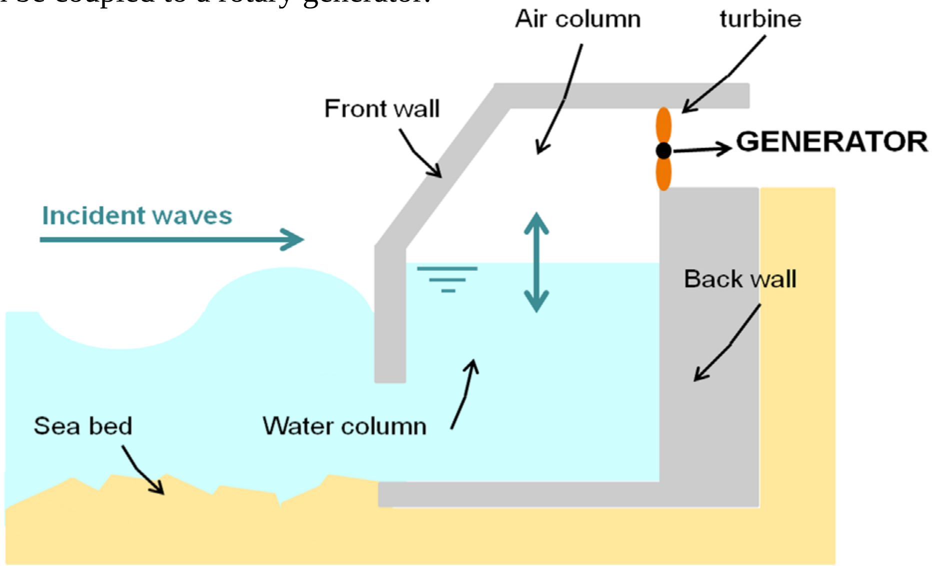


Figure 40: Oscillating Water Column

### 4.4.4 Oscillating Wave Surge

Oscillating wave surge is also called Oyster Wave Energy Converter. It is a type of hydro-electric wave energy device. It uses the ocean wave motion to produce electricity. Usually, such devices have one fixed end connected to a structure or the seabed, while the other end is free to travel [49]. Energy is gathered from the relative motion of the body to the fixed point, guided by the horizontal motion of waves (surge) [49]. As the wave hits the PCU and a back and front movement is produced, a hydraulic piston will be pushed. As a result, the hydroelectric turbine rotates and generates electricity.

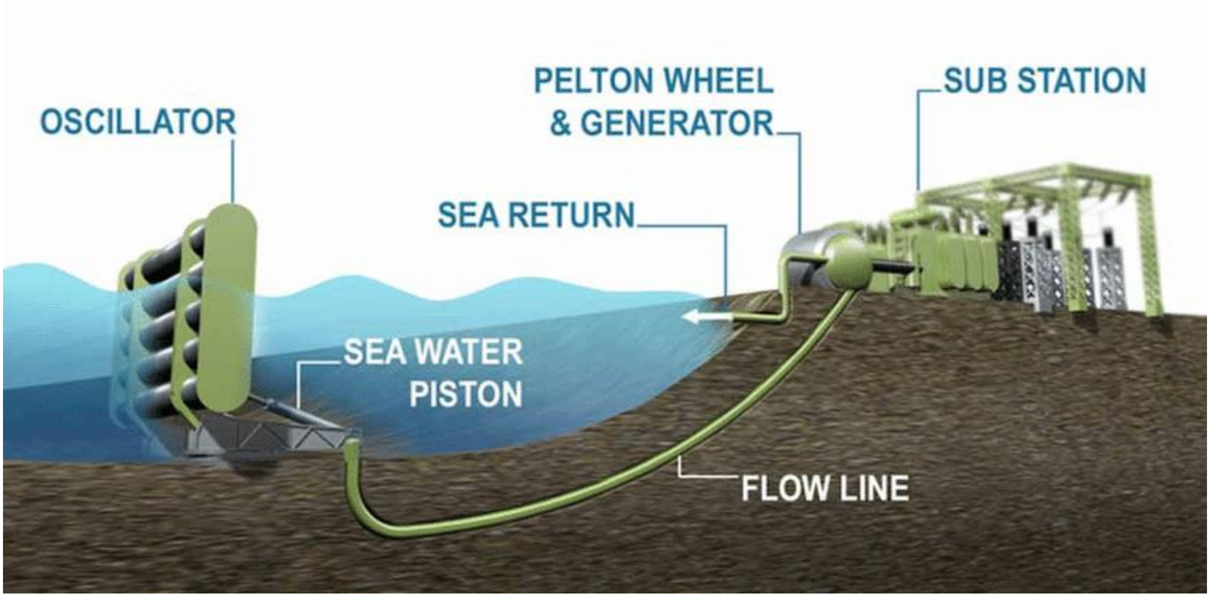


Figure 41: Oscillating Wave Surge

### 4.4.5 Over Topping Device

Over topping device are long structure that collects sea water in reservoir using the wave motion to a higher water level than the sea surface [50]. The pressure difference between reserved water and the surface water forces fluid through a low-head turbine attached to a generator, where electricity is generated similar to traditional hydropower [50]. This type of devices can be implemented onshore or offshore(floating) [50]. To concentrate the wave energy, 'collectors' can be used [50].

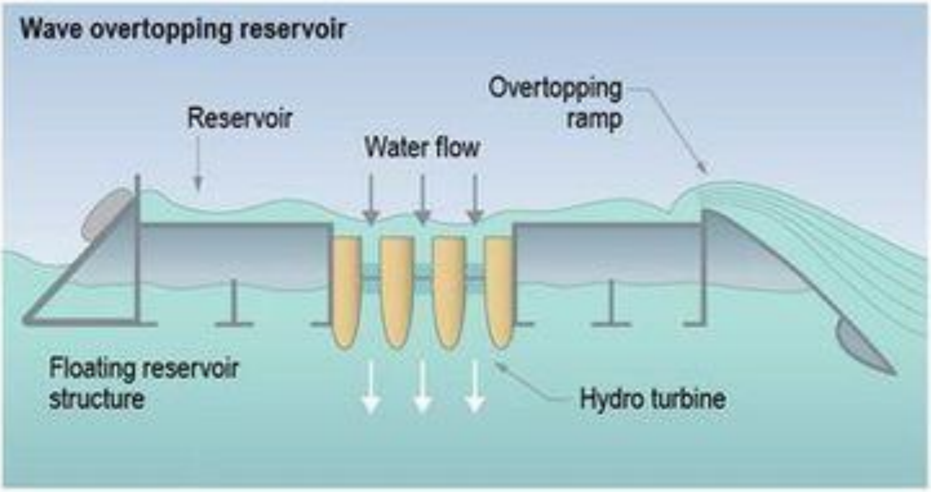


Figure 42 Over Topping Device

## 4.5 Wave Energy Technologies

Different types of WEC technologies are shown in the **Table 7** [51] and **Table 8** [52]. These tables also show the working principle and corresponding projects and their descriptions.

**Table 7: Different Wave Energy Technologies**

| Technology | System | Principle |
|---|---|---|
| Oscillating water column | Fixed | Isolated<br>In breakwater<br>Near shore |
|  | Floating | - |
| Oscillating bodies | Fixed-shoreline | - |
|  | Floating | Translation (heave)<br>Rotation |
|  | Submerged | Translation (heave)<br>Rotation |
| Overtopping | Fixed | Shoreline (with concentration)<br>Shoreline (without concentration) |
|  | Floating | - |

**Table 8: 10 of the Commercial WEC Systems**

| Category | Device Type | Dimensions | RP (kW) |
|---|---|---|---|
| Point absorber | Pontoon Power Converter | 80m | 3619 |
| | Ocean Energy Buoy | 50m | 2880 |
| | Wave Bob | 20m | 1000 |
| | Ceto | 7m | 260 |
| | Seabased AB | 3m | 15 |
| Attenuator | Sea Power | 16.75m | 3587 |
| | Wave Star | 70m | 2709 |
| | Pelamis | 150m | 750 |
| | Oceantec | 52m | 500 |
| Terminator | Wave Dragon | - | 5900 |

## 4.6 Why Point Absorber?

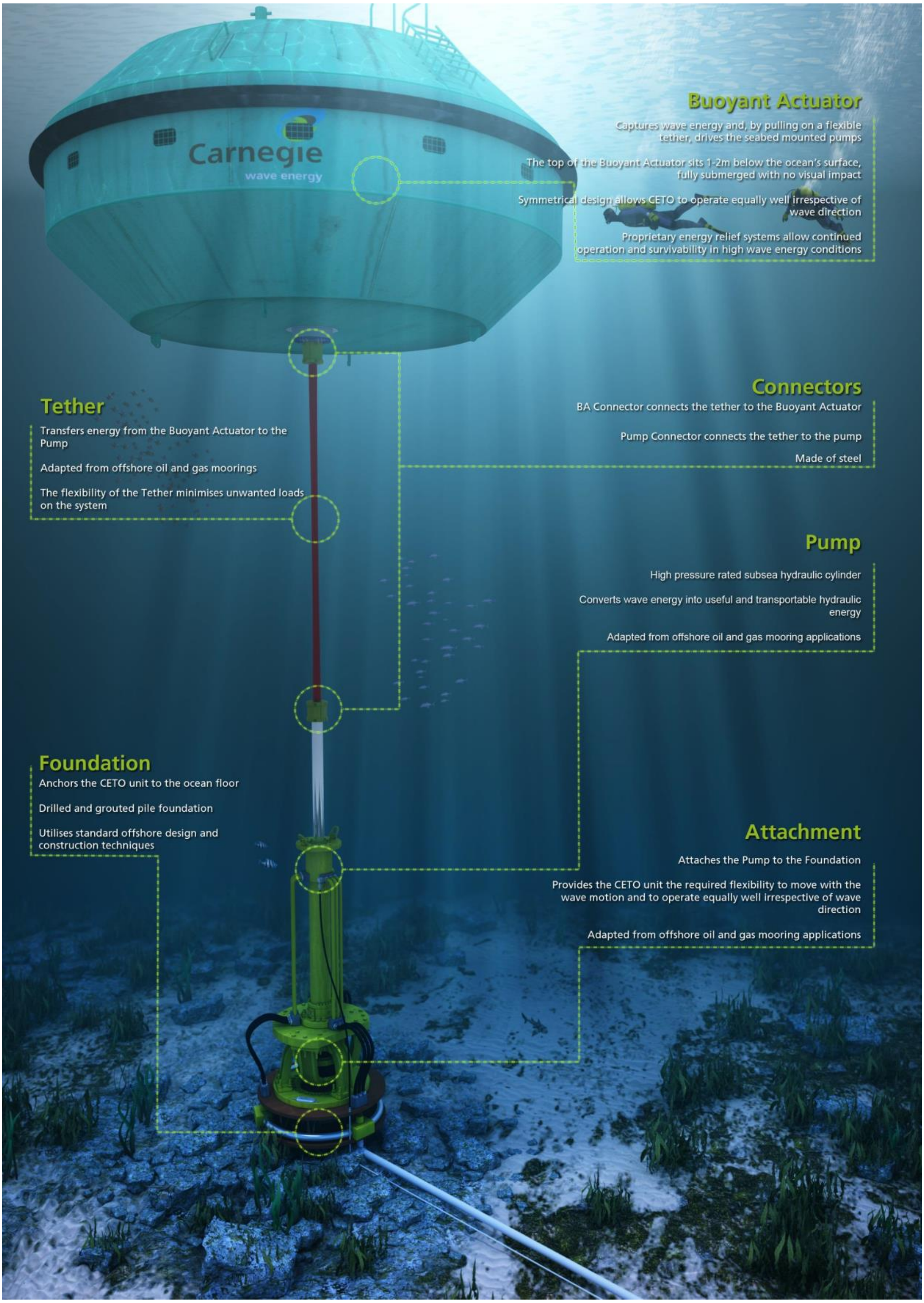
One of the most promising of all these different solutions is the point-absorber technology [53]. First of all, its small dimensions make it possible for the device to be independent of wave-direction and capable of absorbing power from all wave directions, which can differ greatly throughout the life of the device [53]. In addition, this technology has the benefits of fast manufacturing and installation [53]. Due to their relatively compact size, when compared to other forms of WECs, the amount of energy that traditional single point-absorber WECs can generate is relatively small [53]. However, by using several point-absorbers, which consist of many floaters, this restriction can be overcome [53].

## 4.7 Ceto

CETO (named after Greek sea goddess) is one of the most widely used point absorber technologies.

The schematic of CETO wave energy converter is shown in the Figure 43. The submerged buoys are connected to the pumps that are attached to the seabed by tether in a cluster [54]. As the wave turbulence passes overhead, the buoys are lifted upwards while impose tension on the tethers, enabling the pistons inside the pumps to move upward-expelling fluid at high pressure [54]. The high-pressure fluid, usually water, is pumped back to a manifold in which it travels to the coast [54]. The pressurized water then is used to drive a turbine directly for electricity generation or to desalinate water, or both [54].

CETO hence individuate itself from other WEC’s in that the output of the plant is not electricity but pressurized fluid [54]. With a typical off-the-shelf farm- Pelton, or similar high-head turbines connected to electric generators, energy conversion from hydraulic to electrical takes place onshore [54] [55].



**Buoyant Actuator**

Captures wave energy and, by pulling on a flexible tether, drives the seabed mounted pumps

The top of the Buoyant Actuator sits 1-2m below the ocean's surface, fully submerged with no visual impact

Symmetrical design allows CETO to operate equally well irrespective of wave direction

Proprietary energy relief systems allow continued operation and survivability in high wave energy conditions

**Tether**

Transfers energy from the Buoyant Actuator to the Pump

Adapted from offshore oil and gas moorings

The flexibility of the Tether minimises unwanted loads on the system

**Connectors**

BA Connector connects the tether to the Buoyant Actuator

Pump Connector connects the tether to the pump

Made of steel

**Pump**

High pressure rated subsea hydraulic cylinder

Converts wave energy into useful and transportable hydraulic energy

Adapted from offshore oil and gas mooring applications

**Foundation**

Anchors the CETO unit to the ocean floor

Drilled and grouted pile foundation

Utilises standard offshore design and construction techniques

**Attachment**

Attaches the Pump to the Foundation

Provides the CETO unit the required flexibility to move with the wave motion and to operate equally well irrespective of wave direction

Adapted from offshore oil and gas mooring applications

Figure 43: Ceto Device

The CETO units are equipped for function in shallow waters 20 to 50 m depth. Usually, not more than 2 kilometers from shore and sometimes much closer than that [54].

### 4.7.1 CETO Features

[56]

- Type: Totally submerged point absorber.
- Location: Near-shore or deep-water location.
- Power Generation: On-shore or off-shore (Figure 44, Figure 45).
- Power & water production with onshore production
- Design: Modular design largely using proven subsea components

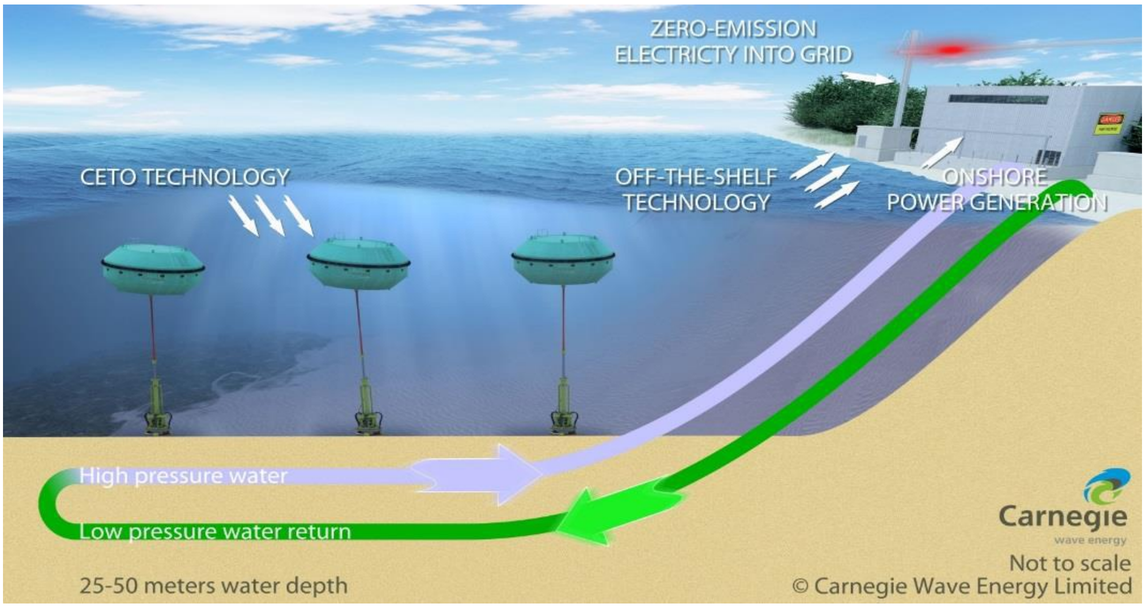


Figure 44: On-Shore Power Generation

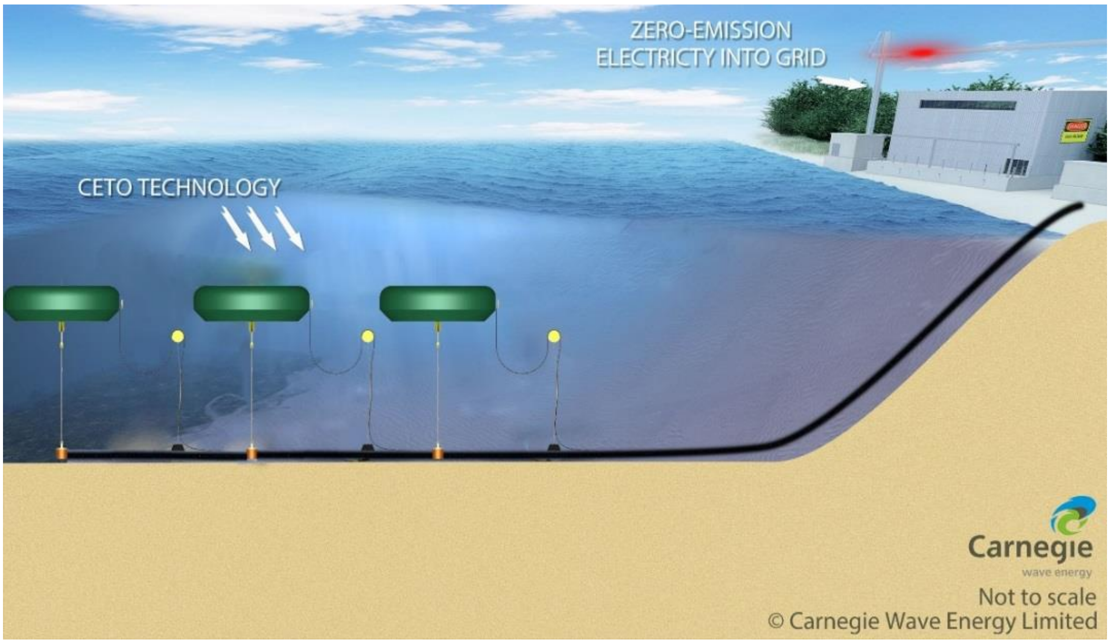


Figure 45: Off-shore Power Generation

### 4.7.2 Advantages of Ceto device

[57]

- It is fully submerged. So, no Visual Impact.
- It is well developed and has been tested for 10 years with onshore wave tank and thousands of hours of in ocean.
- It is very flexible. It can operate in various of water depths, wave directions and seabed conditions.
- It is fully submerged and an extreme wave mitigation system. So, it’s survivability to storm is unquestionable.
- It provides emission free energy and water security to countries and islands
- It is highly scalable for its modular array design.
- It is one of the Cleanest technologies. It has minimal environmental impact and can co-exists with marine life.

### 4.7.3 Ceto 5 Perth Wave Energy Project

All the details and specification of Perth Wave Energy Project (PWEP) are given in the **Table 9** [58].

**Table 9: PWEP specification**

| | |
|---|---|
| Country | Australia |
| Site | Garden Island, Perth |
| Year | 2014 |
| Device Installed | Ceto 5 |
| Wave Climate | 35 KW/m |
| Device Output | 3×240 KW |
| Device Characteristics | In construction |
| Status | propose Grid connected & desalination/ Expected to power 3500 homes |

### 4.7.4 Ceto 6

Compared with the CETO 5 units deployed in the Perth Wave Energy Project, Carnegie's 6th generation CETO wave energy unit (CETO 6) will be more powerful and deliver increased power generation [59]. Albany has one of the world's most consistent wave energy resources, experiencing a 100 percent swell of more than 1 m [59].

The Albany Wave Energy Project (AWEP) was a technology demonstration project involving the design, production and installation of a CETO 6 Unit in the current license area of Carnegie, offshore from Torbay and Sandpatch in Albany, Western Australia.

At a location approximately 1.5 kilometers offshore from the current Albany wind farm, Carnegie's wave buoy proposed to be installed [60]. The data buoy is deployed at a water depth of 30 meters. In December, a significant wave height, $H_{max}$ (maximum wave height) 6.8 m was recorded [60].

### *4.7.5 CETO 6 Design*

[56]

- **Capacity**: 1MW (1000kW) per unit
- **Diameter**: 50% increase in diameter than previous CETO 5 devices.
- **Rated capacity**: 4 times increase in rated capacity than CETO 5.
- **Buoy Actuator**: Electricity generates in BA
- **Commercialization**: First commercial generation unit

## 4.8 WAVE Energy Converter Specifications

As wave energy converters are not available in HOMER library. But hydrokinetic turbines are available which use the kinetic energy of water to produce electricity. Hence, we used "Schottel-54kW" hydrokinetic turbine to produce equivalent energy that we could have produced from a Ceto-6 (WEC) device. The specification of Schottel-54 is given in the **Table 10** [61] [54].

**Table 10: Schottel-54 specification**

| | |
|---|---|
| Blade diameter | 5 m |
| Rated power | 54 kW |
| Rated water velocity | 2.6 $ms^{-1}$ |
| Cut in velocity | 0.71 $ms^{-1}$ |
| Cut out velocity | 04.60 $ms^{-1}$ |
| Nacelle weight | 800 kg (approx.) |

# Chapter 5

# Resources and Production

For renewable energy converters to function properly, they have to be installed in locations with proper abundance of the necessary resources.

## 5.1 Renewable Resources in Bhola

Bhola is located to the south of Bangladesh and it is full of natural resources. It is blessed with proper amount of sunlight, wind speed and wave speed throughout the year. These resources will be discussed in this section.

### *5.1.1 Solar Resources*

The monthly average solar irradiation and clearness index has been collected from Surface meteorology and Solar Energy by NASA which was built in HOMER pro software and are shown in Figure 46.

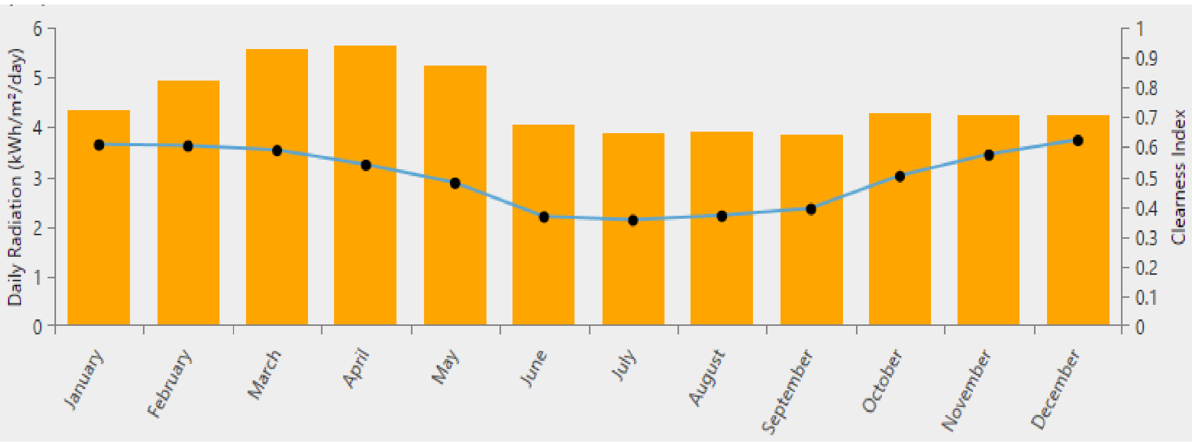


Figure 46: Daily Solar Radiation and Clearness Index

The yellow bars indicate the solar radiation in kWh/m$^2$/day over the months and the dotted line is the cleanliness index. Our main focus is on the solar radiation. Here we can observe the typical northern hemisphere radiation which is more during the summer season and then reduces during the monsoon when there is a considerable amount of cloud cover.

### *5.1.2 Wind Resources*

The average wind speed has been found from NASA Prediction of worldwide energy resources (power) database and it is being depicted in the Figure 47. Annual Average wind speed at Char Fasson is 5.07ms$^{-1}$ which is suitable for producing wind energy.

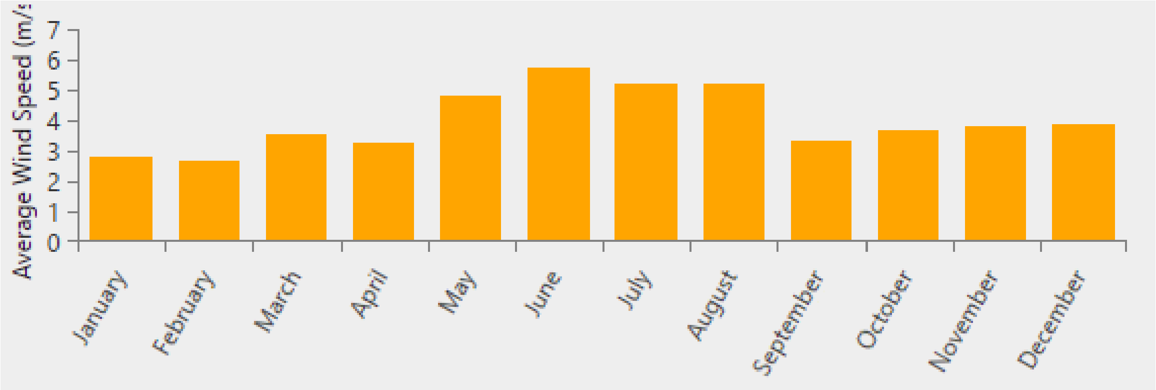


Figure 47: Average wind speed

The trend in the graph shows that the wind speed increases during the months of April to September above the average wind speed. These are the monsoon season. The wind speed can be seen the most during the monsoon season due to the geographical location of the coastal part of Bangladesh. Wind speed over 6 ms$^{-1}$ can be seen in the month of June and July. During these month, large storm attacks the coast of Bangladesh.

### *5.1.3 Wave Resources*

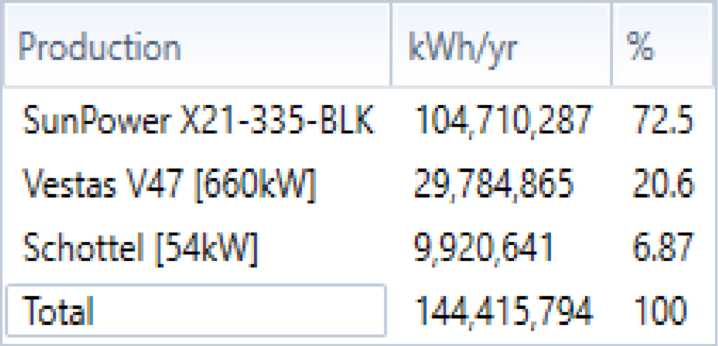
According to online marine weather forecast [62], Wave height is 2ft and period is 12s. Wave velocity 0.6 m/s - 1 m/s [63] [64].

Bay of Bengal has the average wave height, $H = 1$m and period, $T= 8$ second.
Density of water in Bay of Bengal, $\rho = 1029$ kg/m$^3$.
Gravitational acceleration, $g = 9.8$ m/s$^2$

From the equation 4 stated in chapter 4, we get,
Power flux for Bay of Bengal, $P = 3.93$ kW/m

## 5.2 Power Production

In order to produce 18MW of power, we input all the variables in HOMER pro, and it output the most optimized system. Figure 48 shows the production percentage table of solar, wind and wave. Here we can observe that solar will produce 77%, wind will produce 18.7% and wave will produce 4.32% of the total power.

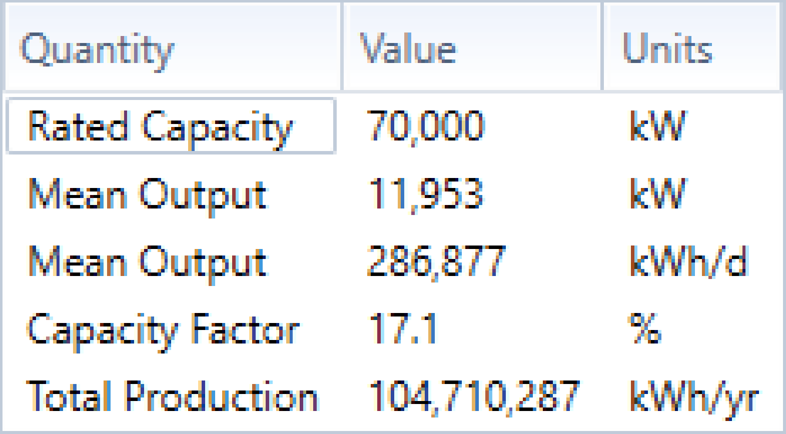


| Production | kWh/yr | % |
|---|---|---|
| SunPower X21-335-BLK | 104,710,287 | 72.5 |
| Vestas V47 [660kW] | 29,784,865 | 20.6 |
| Schottel [54kW] | 9,920,641 | 6.87 |
| Total | 144,415,794 | 100 |

Figure 48: Production Percentage of Different Sources

### 5.2.1 *Solar Power Production*

We can observe the solar power production in the following Figure 49.



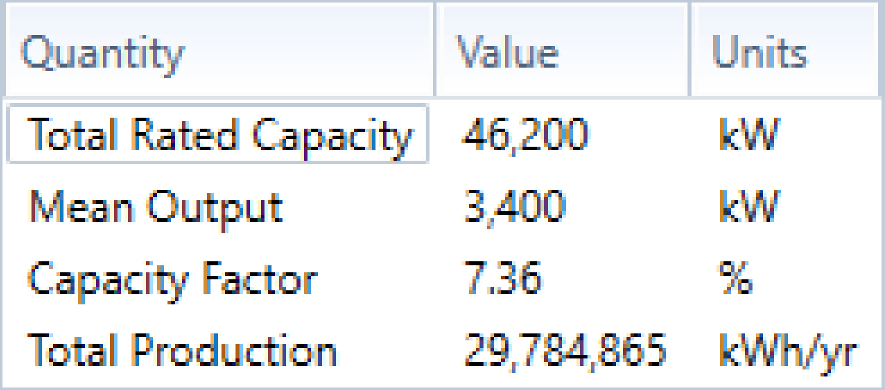
| Quantity | Value | Units |
|---|---|---|
| Rated Capacity | 70,000 | kW |
| Mean Output | 11,953 | kW |
| Mean Output | 286,877 | kWh/d |
| Capacity Factor | 17.1 | % |
| Total Production | 104,710,287 | kWh/yr |

Figure 49: Solar Production

From the rated capacity of 70 MW panels, due to the 21.5% efficiency, we are ending up with an average power output of 11.953 MW, which is, as told earlier, is 72.5% of the targeted total power.

### 5.2.2 *Wind Power Production*

Again, let us observe the power produced by wind turbines in the Figure 50



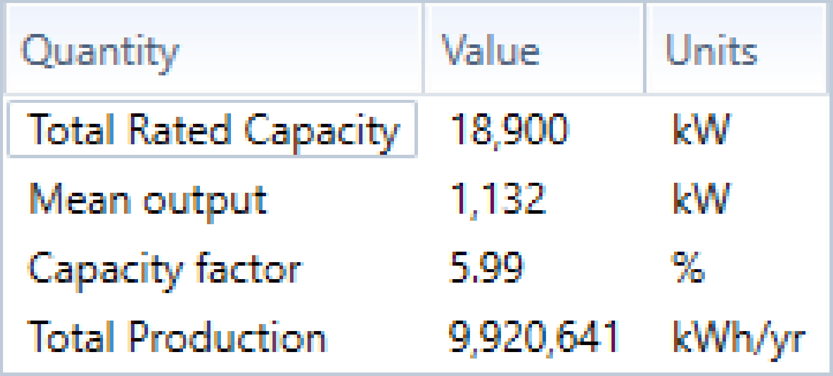
| Quantity | Value | Units |
|---|---|---|
| Total Rated Capacity | 46,200 | kW |
| Mean Output | 3,400 | kW |
| Capacity Factor | 7.36 | % |
| Total Production | 29,784,865 | kWh/yr |

Figure 50: Wind Production

The total rated capacity of all the wind turbines sums up to 46.2 MW and the final output of the turbines equals 3.4 MW which is 20.6% of the total targeted value.

### 5.2.3 *Wave Power Production*

Finally let’s see the power production of the wave absorbers in the Figure 51.



| Quantity | Value | Units |
|---|---|---|
| Total Rated Capacity | 18,900 | kW |
| Mean output | 1,132 | kW |
| Capacity factor | 5.99 | % |
| Total Production | 9,920,641 | kWh/yr |

Figure 51: Wave Production

The total rated capacity installed is 18.9 MW and due to losses, we are able to produce about 1.132 MW of electricity. As the technology advances, the efficiency will improve and we will be able to get more output. But for now, we are producing 6.87% of the targeted total power.

## 5.3 Monthly Power Production

The graph generated in HOMER pro, which is given in Figure 52 shows the production of power throughout the year. If we observe the graph carefully, we can see that the wave power production is almost constant as the wave velocity and height don’t vary that much during the year.

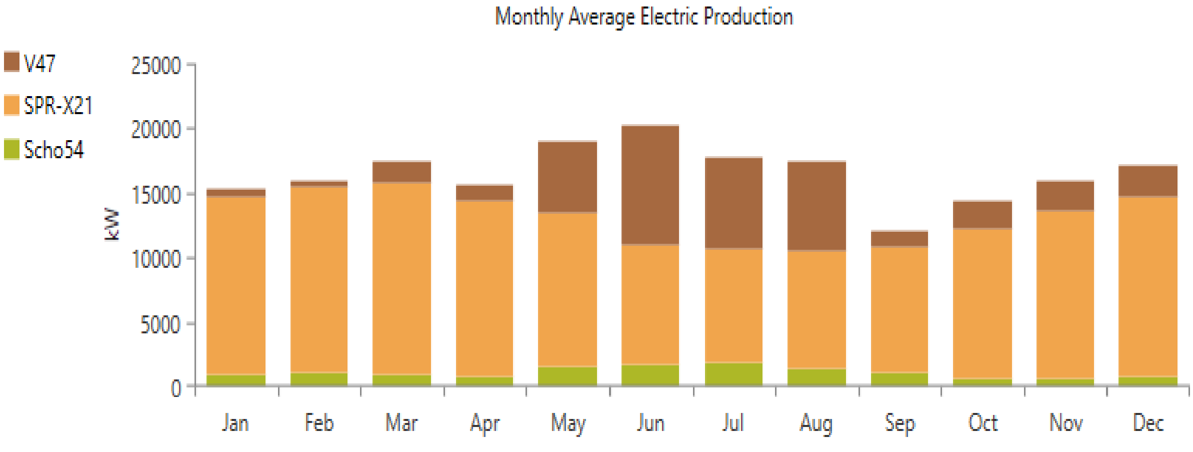
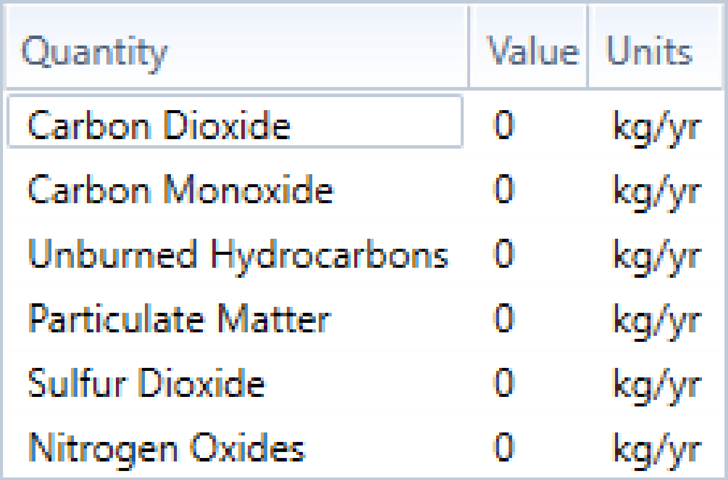


Figure 52: Monthly Production

But in case of wind, production increases during the middle of the year as the monsoon season comes and the wind speed increases. Also, during this time, the cloud coverage is more in compared to other months, so there is a slight reduction of solar power production. So, wind and solar almost makes up for each other to provide a constant supply of power. There is also another observation in the month of March. This is the summer season so solar power production is very good and also there is a good breeze to generate good electricity from wind. Hence during this month, the production is the highest.

## 5.4 Emission Analysis

Since the system is 100% renewable consisting of Solar, wind and wave energy, during the production of electricity, there is no emissions of any harmful gases. As generated by HOMER pro, we can see the percentage of any emission during the production in Figure 53 which is 0%.



| Quantity | Value | Units |
|---|---|---|
| Carbon Dioxide | 0 | kg/yr |
| Carbon Monoxide | 0 | kg/yr |
| Unburned Hydrocarbons | 0 | kg/yr |
| Particulate Matter | 0 | kg/yr |
| Sulfur Dioxide | 0 | kg/yr |
| Nitrogen Oxides | 0 | kg/yr |

Figure 53: Emission Analysis

# Chapter 6

# Cost Analysis

The system was configured in HOMER and all the necessary variables were inputted. Then the simulation was run and every possible outcome was shown. Some of the system had errors and some had good results. Here we are discussing the most optimized results giving the cost analysis.

## 6.1 Optimized System

All the data are from that optimized result. The system is 100% renewable consisting of solar, wind and wave energy. The results which HOMER output are shown in the **Table 11**

**Table 11: Optimized System**

| SPR-X21 (kW) | V47 | sonnEco10 | Scho54 | Converter (kW) | COE ($) | NPC ($) | Operating Cost ($) | Initial Cost ($) | Ren. Frac. (%) |
|---|---|---|---|---|---|---|---|---|---|
| 70,000 | 70 | 33,937 | 350 | 21,132 | $0.26 | $169 M | $2.06M | $142M | 100 |

From the **Table 11**, the first 4 data show the installed capacity of the system. Here the total rated power of the total array of solar panels is 70 MW. Then there will be 70 units of vestas V47 wind turbines, 33937 units of Batteries, 350 units of wave energy converters and the total rated power of the power converter will be 21132 kW. Here it is to be noted that the batteries are optional. If the scheme required battery backup, only then batteries will be used. If the total system is to be backup by the battery, then the amount in **Table 11** will be needed.

## 6.2 Cost of Each Components

The following two figures are the optimized output obtained from HOMER pro software, here in the graph we can observe that the cost of solar panels and wind turbines are the most. It is because of the fact that they will be producing the most amount of power and are the more consistent ones.

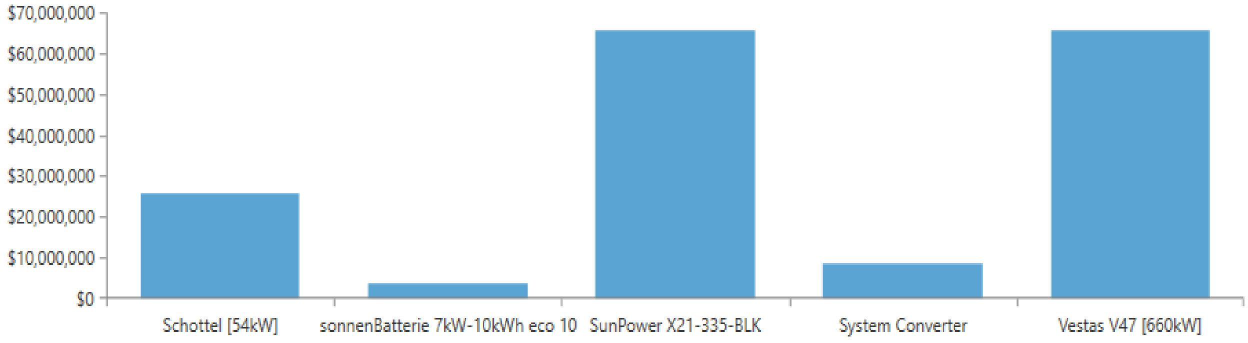
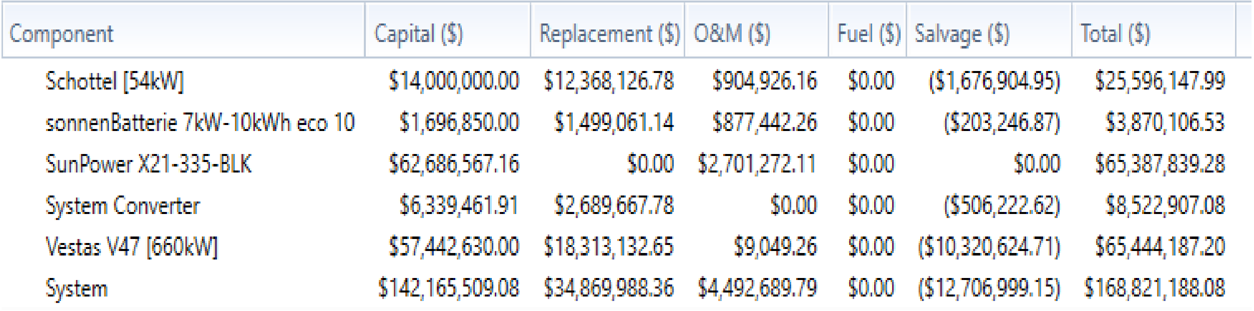


Figure 54: Cost of Individual Components



| Component | Capital ($) | Replacement ($) | O&M ($) | Fuel ($) | Salvage ($) | Total ($) |
|---|---|---|---|---|---|---|
| Schottel [54kW] | $14,000,000.00 | $12,368,126.78 | $904,926.16 | $0.00 | ($1,676,904.95) | $25,596,147.99 |
| sonnenBatterie 7kW-10kWh eco 10 | $1,696,850.00 | $1,499,061.14 | $877,442.26 | $0.00 | ($203,246.87) | $3,870,106.53 |
| SunPower X21-335-BLK | $62,686,567.16 | $0.00 | $2,701,272.11 | $0.00 | $0.00 | $65,387,839.28 |
| System Converter | $6,339,461.91 | $2,689,667.78 | $0.00 | $0.00 | ($506,222.62) | $8,522,907.08 |
| Vestas V47 [660kW] | $57,442,630.00 | $18,313,132.65 | $9,049.26 | $0.00 | ($10,320,624.71) | $65,444,187.20 |
| System | $142,165,509.08 | $34,869,988.36 | $4,492,689.79 | $0.00 | ($12,706,999.15) | $168,821,188.08 |

Figure 55: Total Cost analysis

### 6.2.1 Solar Power Cost

Cost of a ‘’SunPower X21-335W-BLK 335-Watt Solar Panel Module’’ is $395 [65]. The lifetime of the solar panels is taken to be twenty years. According to HOMER, the total cost of installation will be $62 million and operation and maintenance cost for its whole life time will be about $3 million.

### 6.2.2 Wind Power Cost

Each wind turbine’s capital cost will be $824825.62 and replacement cost are $824825.62. Here maintenance and operation cost are $100 [66]. Therefore, the total cost of wind energy will be $65 million.

### 6.2.3 Wave Power Cost

As Carnegie announced, a three-machine (Ceto-6, rated 1MW), 3MW demonstration plant costing about $25 million will now likely be installed in Australia [67]. According to the calculation of HOMER, the total cost of wave power will be $25 million

## 6.3 Cost of Electricity (COE)

The cost of energy (COE) is a calculation of how much it takes to produce power over the span of a lifespan, taking into account both costs and energy output (Figure 56). The COE is determined by multiplying the power output by the projected costs, yielding the cost of power in dollars per kWh.

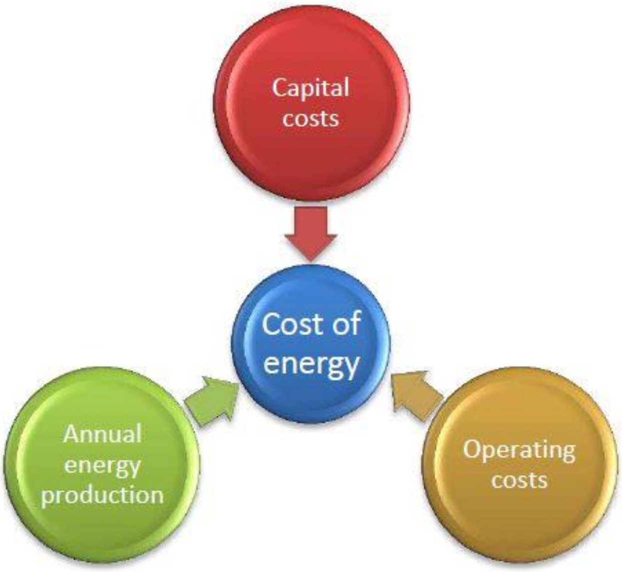


Figure 56: Cost of Electricity

On the assumption that the operation and maintenance (O&M) expense and power produced are constant per year, the cost of energy is specified as the amount of capital and lifetime operating and maintenance costs separated by lifetime electricity generation to the grid [58].

$$\text{Cost of energy} = \frac{\text{Capital cost} + \text{PV (O\&M costs)}}{\text{PV (Energy Production)}}$$

The current value over the service life is denoted by PV. A marine energy device's capital costs, operational costs, and efficiency are all linked; enhancing one can necessitate sacrificing another. This approach is used in the current study to measure energy costs. However, the cost of generation and repair is often used to compare the cost of an existing installation [46] [58]:

$$\text{Cost of O\&M generation} = \frac{\text{PV (O\&M costs)}}{\text{PV (Energy production)}}$$

From **Table 11**, cost of Energy (COE) is determined $0.26 per kWh for this hybrid system considering the cost of the converter and battery. Net present cost is $169M and the initial cost is $142M.

The Payback Period is calculated to be 4 years. Hence after 4 year, the capital cost will be retrieved. But there is a chance of increasing the payback period in order to reduce the COE and make the scheme more attractive to the local people.

# Chapter 7

# Conclusion

To summarize the total scheme, we are producing 16MW power using solar, wind and wave energy with a cost of electricity of $0.26 having 4-year Payback Period and 0 running cost. The power will be enough for about 91 thousand rural families.

Some of the advantages are power supply to areas outside the national grid, complete renewable energy, zero emissions, can be implemented in the other parts of southern region as well.

Again, we noticed that there can be some drawbacks such as, COE high for general/local people, initial cost is high, WECs are not locally manufactured

With growing power demand, Remote Island is in desperate need of uninterruptible electricity. However, it is not possible to connect to the national grid and it is costly and unsustainable to use fossil fuel like oils and coal to generate necessary amount of electricity. Renewable electricity is a solitary solution. The book explains the viability of a hybrid solar power plant to supply power to the local 91200 families of Char Fasson using HOMER pro. Here, for the optimum scenario, the cost of energy (COE) is 0.26$ with zero carbon emission.

Hence this paper provides the feasibility of using renewable hybrid system that will enable the local people to have the ability to use electricity as well as to reduce the carbon footprint altogether

Our future Plans are distribution and transmission study, improving the system to minimize the cost of energy, getting government approval, practical implementation, convincing local people about the benefit of using renewable energy

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