

Study on the Economic Feasibility of a 100 kW Solar Mini Grid at Sandwip Island by Using RETScreen

**A Report Submitted in the fulfillment of the requirements for the Degree of
B.Sc. in EEE.**



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PREFACE

The thesis titled:

Study on the Economic Feasibility of a 100 kW Solar Mini Grid at Sandwip Island by Using RETScreen

Done under my supervision, meets acceptable presentation standard and can be submitted by Md. obydul Islam (112-33-577) and Md. Habibur Rahman (113-33-764) has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering on November,2014.

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Declaration

We hereby declare that, this internship report has been done by us under the supervision of **Professor Dr. M. Shamsul Alam, Dean**, Department of EEE Daffodil International University. We also declare that neither this internship report nor any part of this internship report has been submitted elsewhere for award of any degree or diploma.

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Dedication

To our venerable parents

ACKNOWLEDGEMENT

First we express our heartiest thanks and gratefulness to the Almighty ALLAH for his divine blessing make us possible to complete this project successfully.

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Finally we have special acknowledgement for our group members for their understanding each other and hard working from beginning up to the end. In order to bring this project to be operative the hard working and understanding of all the members was very important.

ABSTRACT

In this work the 100kW solar mini – grid installed at Sandwip has been studied thoroughly to analyze the investment. The mini-grid power generation plants include product model numbers are Grid tie inverter SMC11000TL, Bidirectional Inverter SI5048, Multi – cluster Box MC-Box 12.3, Sunny Island Charger SIC40, Bat fuse, Sunny Web Box, Solar modules: Kyocera, Deep cycle solar battery: Hoppecke-Germany, OPzS3000, 2V, 3000Ah, Generator 40KW. The electrical load is considered based on the local needs and the electrical load demand is 93.8 kW. The system supplies 230V ac. The major share of the energy comes from solar while the contribution of diesel generation is very small. Economic feasibility has been analyzed with RETScreen version 4, developed by Minister of Natural Resources Canada was used to evaluate benefits from clean energy production from power generation projects and savings through energy efficiency projects, accounting for project costs, emission reductions, and financial risk. Result shows that the project payback period of 7.4 years, the internal rate of return on equity (19.6%) and internal rate of return on asset (14.2%) (Life time of 20 years with low maintenance) in comparison with the local generating electricity, which predicts that the 100 kW solar mini grid at Sandwip, Chittagong is feasible for Bangladesh. The outcome of this project adverts that the solar mini grid can be a much better solution to protect our ambience and ameliorate the life style of the people in far villages who are underprivileged up until now.

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Chapter 1

Introduction

1.1 Introduction

Energy is one of the basic ingredients required to alleviate poverty and socio-economic development. The energy prospect is generally assessed on the basis of available commercial sources of energy i.e. fossil fuel like gas, coal, oil etc. Worldwide, there is a major transition underway in the energy sector.

It is happening due to the following three major reasons:

- (i) A decline in fossil fuel availability, their predicted gradual extinction in the next few decades and the resultant price volatility due to demand-supply gap.
- (ii) The need to drastically cut global emissions for mitigating climate change (80% reduction by 2050).
- (iii) The need for energy security.

In Bangladesh efficient utilization of renewable energy resources is yet to assume commercial dimensions and hence rational policy dissemination on renewable energy usage is essential. The renewable energy includes solar, wind, biomass, hydro, geothermal, tidal wave etc.

The use of renewable energy is attractive for solar energy application in many developing countries. This technology, referred to as photovoltaic(PV),converts the sun energy into electricity through electromagnetic means when PV module is exposed to sunlight.The solar radiation energy is converted into DC power and requires an inverter it into AC power.

1.2 Literature review

Shafiqur Rehman, Luai M. Al-Hadhrami [4] has presented a PV – diesel hybrid power system with battery backup for a village being fed with diesel generated electricity to displace part of the diesel by solar. The sensitivity analysis done in this paper showed that at a diesel price of 0.6\$/l the COE from hybrid system become almost the same that of the diesel only system and above it, the hybrid system become more economical than the diesel only system.

BK Bala, SaifulAzam Siddique [2] has presented Optimal design of a PV-diesel hybrid system for electrification of an isolated island—Sandwip in Bangladesh using genetic algorithm. This study reveals that the major shares of the cost are for solar panels and batteries. Technological development in solar photovoltaic technology and economic production of batteries would make rural electrification in the isolated islands more promising and demanding. Finally, the sustainability of solar-diesel hybrid mini-grid for an isolated island—Sandwip is discussed.

Ahmad AgusSetiawan, Yu Zhao, Chem. V. Nayar [3] has done Design, economic analysis and environmental considerations of mini-grid hybrid power system with reverse osmosis desalination plant for remote areas. This paper discusses the design process of a mini-grid hybrid power system with reverse osmosis desalination plant for remote areas, together with an economic analysis and environmental considerations for the project life cycle. Simulations based on an actual set of conditions in a remote area in the Maldives were performed using HOMER for two conditions: before and after the Tsunami of 26th December 2004. Experimental results on the prototype 5 kVA mini-grid inverter and reverse osmosis desalination plant, rated at 5.5 kWh/day, are also presented here to verify the idea of providing power and water supplies to remote areas.

In this paper Md. Alam Hossain Mondal, A. K. M. Sadrul Islam [5] has done a techno- economic feasibility analysis for 500 kW grid connected solar photovoltaic (PV) system at a northern location of Bangladesh. HOMER and RETScreen computer tools and monthly average solar radiation data from NASA is used for study. The detailed cost analysis of this project is demonstrated here. The environmental effects and benefits are also renounced for PV system.

MohanlalKolhea, SunitaKolhea, J.C. Joshib [1] has done Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India. The economic viability of a stand-alone solar photovoltaic (PV) system with the most likely conventional alternative system, i.e. a diesel-powered system, has been analysed for energy demand through sensitivity analysis using a life-cycle cost computation. The sensitivity analysis allows estimation of the comparative viability of PV against a conventional alternative system based on particular country-specific parameters. The overall PV best and worst case viability, as compared to a conventional diesel-powered system, have been obtained from sensitivity analysis of the energy demand.

1.3 Purpose of the project

The main objective of this project is to analyze a 100 kw Solar mini – grid system consisting of Photovoltaic Arrays and as backup, a Diesel Generator in a remote area.

To complete the system and store the store the produced electricity, batteries and converters are appended. Choosing an optimized to provide electricity at a competitive price to the people and subside the emission of pollutants. Promote Solar Energy Production and uses in Urban, Sub Urban, Rural and Agriculture & Industrial Sector.

1.4 Power Crisis in Bangladesh

Bangladesh has been facing electricity shortage for many years. But in last few years this problem has exceeded the common people's patient. Bangladesh is located in tropical region. So except for few months in winter most of the part of a year is summer. In summer the temperature rises up to 40 degree Celsius, when it is nearly

impossible to stay without electricity. In this modern world electricity is the main and fundamental demand for common people.

Bangladesh is an over populated country, where on an average more than 1617 people live in per square mile. But we cannot ensure 24 hours electricity supply to our people. Every summer Bangladesh faces huge load shedding problem. According to the official statistics, our electricity shortage has gone up 500 MW to 600 MW in 2014, whereas the electricity demand was up to 7500 MW. Every summer we face an uncertain condition due to power.

Power Development Board (PDB) sources informed that the officially estimated power demand is now up to 7500 MW. Only the capital Dhaka needs around 2000 MW of power to run. Problems in the Bangladesh's power sector include high system losses, delays in completion of new plants, low plant efficiencies, erratic power supply, electricity theft, blackouts, and shortages of funds for power plant maintenance. Overall, the country's generation plants have been unable to meet system demand over the past decade.

1.5 Scope of Renewable Energy

Renewable energy is the energy that comes from natural resources such as sunlight, wind, tides, rain and geothermal heat, which are all renewable. These energies are derived from natural processes that are restored constantly. Electrical energy is derived from solar, wind, ocean, hydropower, biomass, geothermal resources, biofuels and hydrogen. If we can use renewable energy to produce power, we can certainly reduce the power shortage to some extends. Bangladesh government and engineers are also concentrating on using renewable energy. Bangladesh has planned to produce 5% of total power generation by 2015 and 10% by 2020 from renewable energy sources like air, waste and solar energy

1.6 Organization of this project

Chapter 1: The project has been introduced.

Chapter 2: Photovoltaic Technology and its prospects are briefly discussed.

Chapter 3: The 100 KW PV mini grid installed at Sandwip has been discussed.

Chapter 4: A brief discussion about RETScreen Software is given.

Chapter 5: Analysis, Result & discussion on the project are presented here.

Chapter 6: The research work has been summarized and recommendation as an engineer for future work has been discussed.

Chapter 2

Photovoltaic Technology

2.1 Introduction

There is a good prospect of harnessing solar power in Bangladesh. Solar energy is derived from the sun through the form of solar radiation. Power generation with solar energy depends on Photovoltaic and heat engines. In our case as we are finding a solution for urban power shortage problem. Here in urban area wind, ocean, hydropower etc. are not possible to be used as a form of renewable energy to generate power. And among the rest we are going to work with Solar, as it is already being popular in our country but in a very narrow span.

2.2 Solar energy attractive in Bangladesh

1. Bangladesh is situated between 20.30 – 26.38 degrees north latitude and 88.04 – 92.44 degrees east longitude.
2. Daily average solar insolation rate is 4 to 6.5 KWh per square meter.
3. Maximum amount of radiation is available on the month of March- April (6.5h) and minimum on December- January (4h)[18].

2.3 Solar panel

Solar panels produce electricity from sunlight. The first solar panel-powered satellite was launched in 1958 by Hoffman Electronics[8].

A solar panel consists of number of photovoltaic (PV) solar cells connected in series and parallel. These cells are made up of at least two layers of semiconductor material

(usually pure silicon infused with boron and phosphorous). One layer has a positive charge; the other has a negative charge. When sunlight strikes the solar panel, photons from the light are absorbed by the semiconductor atoms, which then release electrons. The electrons, flowing from the negative layer (n-type) of semiconductor, flow to the positive layer (ptype), producing an electrical current. Since the electric current flows in one direction (like a battery), the electricity generated is DC.

2.4 Solar Cells and how it works

A single PV cell is a thin semiconductor wafer made of two layers generally made of highly purified silicon. The layers have been doped with boron on one side and phosphorous on the other side, producing surplus of electrons on one side and a deficit of electrons on the other side. When the wafer is bombarded by sunlight, photons in the sunlight knock off some of excess electrons, this makes a voltage difference between the two sides as the excess electrons try to move to the deficit side. In silicon this voltage is .5 volt. Metallic contacts are made to both sides of the semiconductor. With an external circuit attached to the contacts, the electrons can get back to where they came from and a current flow through the circuit. This PV cell has no storage capacity; it simply acts as an electron pump. The amount of current is determined by the number of electrons that the solar photons knock off. Bigger cells, more efficient cells, or cells exposed to more intense sunlight will deliver more electrons

2.5 Solar PV technology

With the growing demand of solar power new technologies are being introduced and existing technologies are developing. (See the fig. 2.1) There are four types of solar PV cells:

- Single crystalline or mono crystalline
- Poly-crystalline
- Thin film

- Amorphous silicon

2.5.1 Single – crystalline or mono crystalline

It is widely available and the most efficient cells materials among all. They produce the most power per square foot of module. Each cell is cut from a single crystal. The wafers then further cut into the shape of rectangular cells to maximize the number of cells in the solar panel.

2.5.2 Polycrystalline cells

They are made from similar silicon material except that instead of being grown into a single crystal, they are melted and poured into a mold. This forms a square block that can be cut into square wafers with less waste of space or material than round single-crystal wafers.

2.5.3 Thin film panels

It is the newest technology introduced to solar cell technology. Copper indium diselenide, cadmium telluride, and gallium arsenide are all thin film materials. They are directly deposited on glass, stainless steel, or other compatible substrate materials. Some of them perform slightly better than crystalline modules under low light conditions. A thin film is very thin-a few micrometer or less.

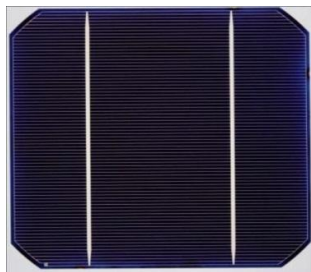
2.5.4 Amorphous Silicon

Amorphous silicon is newest in the thin film technology. In this technology amorphous silicon vapor is deposited on a couple of micro meter thick amorphous films on stainless steel rolls. Compared to the crystalline silicon, this technology uses

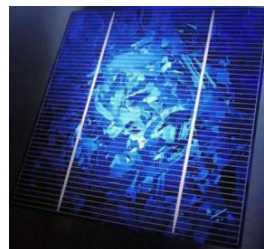
only 1% of the material. Table 2.1 below shows the efficiency of different types of solar cells.

Table 2.1 Efficiency of different types of solar cells

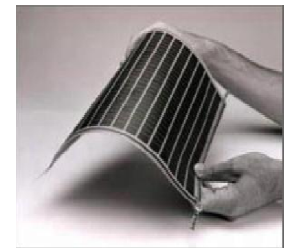
Cell type	Efficiency, %
Mono crystalline	12-18
Polycrystalline	12-18
Thin film	8-10
Amorphous	6-8



*Monocrystalline Silicon
Thin Film Silicon*



Polycrystalline Silicon



Amorphous

Fig 2.1 Three types of solar PV cells

2.6 Type of the system design

There can be various types of solar system design. But there are three basic design consideration, they are-

1. Grid tied
2. Off-grid

2.6.1 Grid tied

The main application of solar PV in Singapore is grid-connected, as Singapore's main island is well covered by the national power grid. Most solar PV systems are installed on buildings or mounted on the ground if land is not a constraint. For buildings, they are either mounted on the roof or integrated into the building. The latter is also known as Building Integrated Photovoltaics ("BIPV"). With BIPV, the PV module usually displaces another building component, e.g. window glass or roof/wall cladding, thereby serving a dual purpose and offsetting some costs (See the fig 2.2).

2.6.2 Off – grid

Off-grid solar PV systems are applicable for areas without power grid. Currently, such solar PV systems are usually installed at isolated sites where the power grid is far away, such as rural areas or off-shore islands. But they may also be installed within the city in situations where it is inconvenient or too costly to tap electricity from the power grid. For example, in Singapore, several URA parking sign lights are powered by off-grid solar PV systems. An off-grid solar PV system needs deep cycle rechargeable batteries such as lead-acid, nickel-cadmium or lithium-ion batteries to store electricity for use under conditions where there is little or no output from the solar PV system, such as during the night(See the fig2.3).

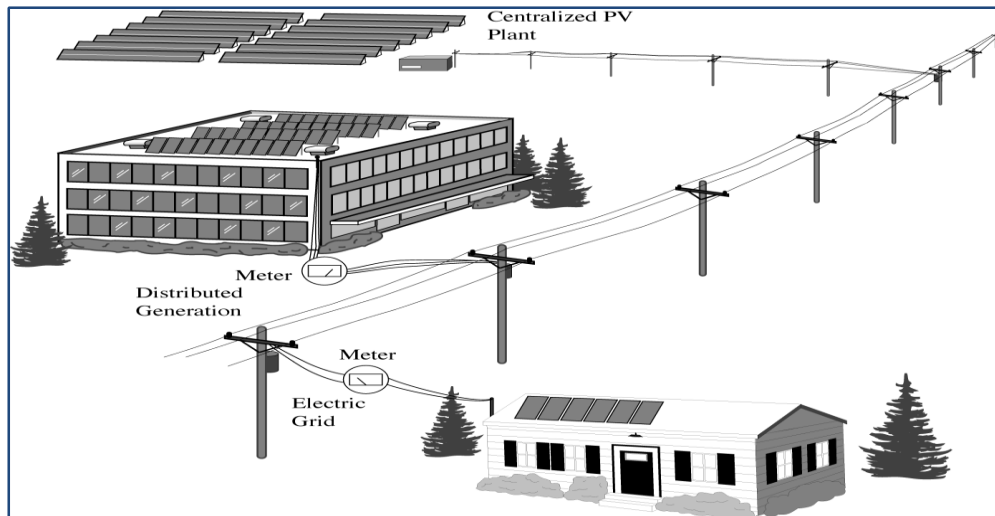


Fig 2.2 Grid tied[16]

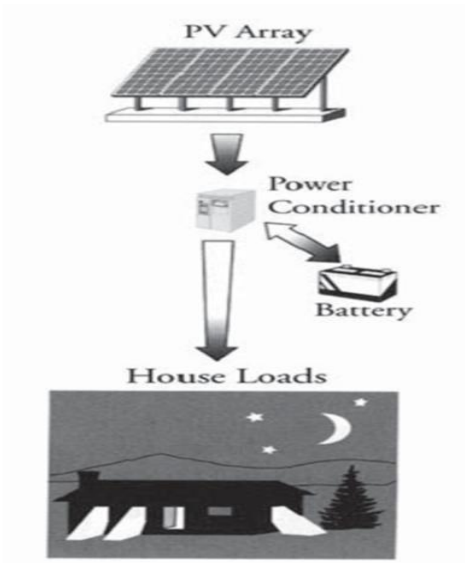


Fig 2.3 Off – grid[16]

2.7 Component of solar PV system

A typical solar PV system consists of solar panel, charge controller, batteries, inverter and the load. Figure 2.3 shows the block diagram of such a system.

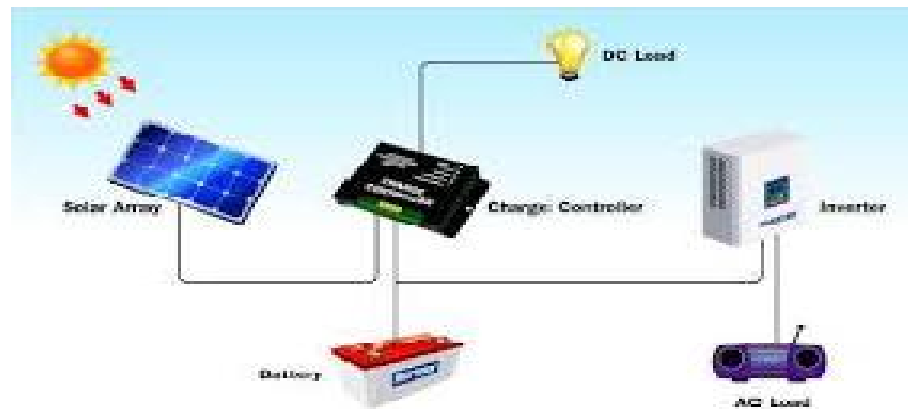


Fig 2.4 Component of solar system[21]

2.7.1 Charge controller

When battery is included in a system, the necessity of charge controller comes forward. A charge controller controls the uncertain voltage build up. In a bright sunny day the solar cells produce more voltage that can lead to battery damage. A charge controller helps to maintain the balance in charging the battery [7].

2.7.2 Batteries

To store charges batteries are used. There are many types of batteries available in the market. But all of them are not suitable for solar PV technologies. Mostly used batteries are nickel/cadmium batteries. There are some other types of high energy density batteries such as- sodium/sulphur, zinc/bromine flow batteries. But for the medium term batteries nickel/metal hydride battery has the best cycling performance. For the long term option iron/chromium red ox and zinc or manganese batteries are best. Absorbed Glass Mat (AGM) batteries are also one of the best available options for solar PV use.

2.7.3 Inverter

Solar panel generates dc electricity but most of the household and industrial appliances need ac current. Inverter converts the dc current of panel or battery to the ac current. We can divide the inverter into two categories. They are-

- Stand alone and
- Line-tied or utility-interactive

2.8 solar energy system site considerations

One of the first things most home owners ask when considering a solar system is “Yeah, but will that work at my house?” This is soon followed by a litany of concerns

such as to which way their house faces towards the sun, overhanging trees, too cold a climate and other factors. The good news is that both passive and active solar systems can work under a wide variety of conditions. Photovoltaic systems in particular tend to be much more site tolerant than most people suspect. Nonetheless, there are a number of site factors I should consider before deciding if solar is right for you, and if so what kind of solar system you should go with[9]. Here are a few things to consider:

2.8.1 Shade

Shade is always a factor in the use of photovoltaic systems. If you live in a heavily wooded area you may need to determine if the trees blocking the potential site for our PV panels can be removed or cut back. In denser neighborhoods trees may not reside within our property line and this might not be an option. In such cases, consider alternative locations for our panels. Sometimes a set of panels mounted on a tracking system in the back yard can accomplish as much as a roof mounted system.

2.8.2 Roof Direction and Pitch

While it is true that south facing roofs are better for locating solar panels, most systems still can produce strong output even if they do not face south.

For example, if a roof is 45 degrees off of due south it will output only 4% less electricity than if it were facing perfectly south. Roof angles are also fairly robust when it comes to placing panels. Generally a 30% angle is recommended. However a south facing roof with a strong 45% pitch will produce only 3% less electricity than one facing a perfect 30 degrees.

2.8.3 Snow and Leaves

The impact of snow and leaves, in contrast, is often an underrated factor in the performance of PV systems. PV panels work best when they are kept clear of debris or snow. Even a small amount of obstruction can significantly impair their performance. This is why regular maintenance is always recommended to keep the panels clean.

2.8.4 Proximity to the Power Grid

If our home or home site is more than half a mile from the nearest power line you may want to consider going with an off-the-grid solar system using some combination of passive and active PV systems with batteries. Electric utilities can charge \$50,000 or more to run a line to our home and battery systems with generators typically run far less than that.

2.8.5 Cost of Electricity

PV systems make particular sense in locations which have high electric rates. In the U.S. states such as California have very high electric rates (20 to 30 cents per kilowatt hour).

2.8.6 Financial Incentives

Many states have become very aggressive in providing financial incentives to homeowners who wish to install PV systems. California, New York, Colorado, Florida and Illinois are among the leaders in providing incentives.

2.9 Grid – Tied vs Off – Grid System

Photovoltaic systems for the home can generally be classified into those that are designed to make use of an existing electric grid(grid-tied system) or those that are designed for rural use where no electric grid is available(off-the-grid system). In a grid-tied system there is no need for a battery system to store the energy that the solar panels generate. Instead the power grid itself acts in a sense as a giant battery that uses any excess electricity that your solar panels may generate, and which you can draw from on cloudy days when there is insufficient sunlight to fully power your home.

We believe that grid-tied systems offer a number of advantages over off-the-grid PV systems. Overall they are less expensive than off-the-grid systems because they do not require either batteries or battery charging controllers. Because they require less equipment they are also much simpler systems to set up and use. They take less time to install and require very little maintenance. We also think they are far more efficient and environmentally friendly than off-the-grid systems. With a grid-tied system none of the energy your PV panels generate is wasted. On sunny days when your panels are producing more electricity than you are using the energy is transferred to the grid where it can immediately be used by others. In an off-the-grid system, once your batteries are fully charged, any excess electricity being generated by your panels has to be dumped to prevent the batteries from being overcharged. This results in wasted electricity.

However, in some situations, particularly in rural areas which have no grid, there may be no option other than to go with an off-the-grid system. For a home owner to pay the utility company to bring power lines into their property can cost upwards of \$10,000 per quarter mile. For many owners of rural properties this makes hooking to the grid economically non-viable. Off-the-grid systems require more care and maintenance but can give a homeowner a strong sense of independence.

2.10 Tracking Systems

Tracking systems are hardware devices usually used on pole mounted solar arrays to allow the positioning of the solar panels to follow the movement of the sun. This helps ensure that there is maximum exposure for the solar cells. A tracking system can increase the output of your PV system by up to 30% in the summer and 15% in the winter over non-tracked systems.

Tracking systems are usually classified as being either passive or active. In a passive system the tracker follows the sun from east to west without using any type of electric motor to power the movement. Instead the system rotates from a combination of heat and gravity. Because no external source of electricity is needed such systems are ideal for remote off-the-grid scenarios or use with water pumping systems where peak the peak demand is in the summer.

Tracking systems are also sometimes classified as to the number of axis they track against. Simple one axis systems rotate only left to right rather than in an arch. A two axis tracking system will track both left to right and up and down. This allows it more accurately to follow the true arch of the sun throughout the day.

Passive tracking systems have some limitations. First, they are somewhat susceptible to high winds which can throw the tracker off the proper direction. They can also be somewhat sluggish in getting moving in cold temperatures because they are mechanically rather than electronically driven. Active tracking systems are powered by small electric motors and require some type of control module to direct them. They are similar in approach to the systems supporting giant TV dishes. Active systems require some electric power which can come from an external source or from the solar panels themselves depending upon the model.

The big question with trackers is whether or not the additional cost, of a tracking system, both initial cost and maintenance cost, is justified by the additional electric power they generate. Tracking systems require maintenance and add a good bit of complexity to the system simply because they have moving parts.

CHAPTER 3

Sandwip 100 kW Solar Mini Grid Island

3.1 Site of the Mini grid

Sandwip is an historical island & upazila of chittagong district. It is located on the estuary of the Meghna River on the Bay of Bengal and separated from the Chittagong coast by Sandwip Channel. It has a population of nearly 350,000 & the total area of 7624 sq km. The population density of sandwip approximately 439 sq km. There are fifteen unions on Sandwip Island. The whole island is 50 kilometers long and 5-15 kilometers wide. It is nearby the main port city of Chittagong and It is located at the north-eastern side of The Bay of Bengal. It is bounded by Bay of Bengal on the south, Companiganj on the north, NoakhaliSadar, Hatiya and Meghna estuary on the west, Sitakunda and Mirsharai, and Sandwip Channel on the east(See the fig 3.1 Sandip Upuazila map)[10].

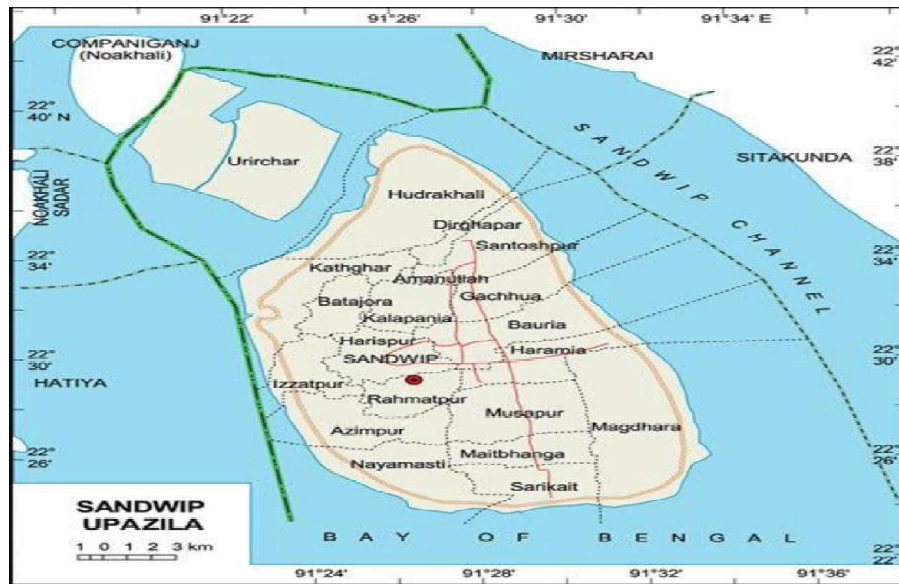


Fig 3.1: SandwipUpuazila, Chittagong, Bangladesh

3.2 100 kW Solar Mini Grid at Sandwip Island

ProkaushaliSangsad Limited (PSL) has provided technical assistance in power generation from nation's first solar mini grid of 100 kW in the remote island of Sandwip, Chittagong. Part of the world that makes headlines with natural disasters is now the proud owner of the largest single solar installation in the country. Energy Systems of Bangladesh in association with Asantys Systems of Germany, has completed the turnkey installation of this power plant. IDCOL has financed the power plant with grant and loan from KfW of Germany. With its formidable location in the mouth of Bay of Bengal, national power grid is beyond the reach of Sandwip. The island is difficult to access and devoid of any modern infrastructure.

Purobi Green Energy Limited, a private company is distributing solar power through a mini-grid to meet the daily demand of a rural market of Sandwip. About 400 consumers are expected to get electrification service on a daily basis by paying monthly bills through electric meters. Using state of the art hardware for power generation and control, this plant will be totally self-operated with direct power from the solar modules for daytime use, and reliable energy storage for the night. On September 29, 2010 the power plant came into operation and the first consumer is a local cooperative bank followed by the local police station, hotels and commercial shops. High quality and reliable grid power supply is being used for computers, lights, fans and other appliances instead of polluting Diesel generators. Engr. AsmaHuque, Managing Director of PSL and Chairperson of Purobi Green Energy Limited handing over the meter to the first mini grid consumer, manager of Rupali With a total lack of communication infrastructure, transport of hardware to Sandwip was a challenge to the team. It has taken approximately 6 months to complete installation of the project. Today the solar park has power supply from the field, and on the roof top of the PGEL office building.

The largest solar park in Bangladesh of 100kW is located in the southern coastal island Sandwip island of Chittagong district. The most interesting part of this solar power plant is that 60 percent of the total 100 kW can be directly fed into the three phase line through grid tied inverters during daytime. This will serve local offices, schools and households and other user during daytime. Excess energy from this power supply will go to the battery bank. In addition, remaining 40 percent of the energy

will be stored in high quality battery bank for the night, when the market is in peak demand. The battery bank is storage of energy for the evening hours. Special device called recombinants minimize 80 percent of battery maintenance. Sophisticated grid tie inverters are used to convert power from solar modules for feeding into the local mini-grid. The Sunny Island inverters are bidirectional inverters connected to the Batteries and the modules. They also control overall system performance. Grid tied inverters are dedicated solar inverters that produces 220 V and supply directly to the 3 phase grid line. Although preliminary feeding is through a local mini grid, the plan is to distribute power through the dormant grid line of PDB that was never energized in the past 20 years.

Asantys Systems of Germany gave technical training to the local engineers on the operational features of the inverters being used in this power plant. Some demand side management has helped in improving the power consumption pattern for the consumers, who will pay through electric meter readings. The users are pleased with the energy efficient appliances and stable power supply that is available on demand. The power supply has direct impact on the financial performance of the small enterprises of EnamNahar market that had no grid power supply before. Once the existing grid line is used, local households can also get service from this solar power plant [6].

Similar units of this capacity and features could be installed in other remote inland and islands of Bangladesh. Such power supply can augment the national grid power at through independent off-grid generation at local level. Through an effective financial planning, the solar technology can contribute to the economic and social benefit of the people in remote locations. An inauguration ceremony to mark commercial operation of 100kW Solar based power plant of purobi green Energy Ltd was held on Saturday, 22 January 2011 at Sandwip, Chittagong. Now July 2014 no. of the connection 268. In 2013 total consumption 95,885 KW please see the Table 3.1 No. of connections as of July 2014, Table 3.2 Energy consumption category, Fig 3.2 Total Nos. of connection, Fig 3.3 Energy Consumption (KWH), Table 3.3 Monthly Consumption 100 KW Solar mini grid at Sandwip Island below:

Table 3.1 No. of connections as of July 2014[20]

Consumer Type	Nos.
Commercial Shops	189
Financial institutions/ Bank/ Govt. office	15
School	2
Mosques	5
Hospital/Pathological Lab	8
Households	49
TOTAL	268

Table 3.2 Energy consumption category [20]

Type of consumer	Nos.	Avg. consumption (kwh)/month	Avg. Bill Tk./month
Large Consumer (Consumption more than 100 kWh)	15	183	6,269
Medium Consumer (Consumption 41 to 100 kWh)	38	62	2,203
Small Consumer (Consumption 1 to 40 kWh)	215	15	624

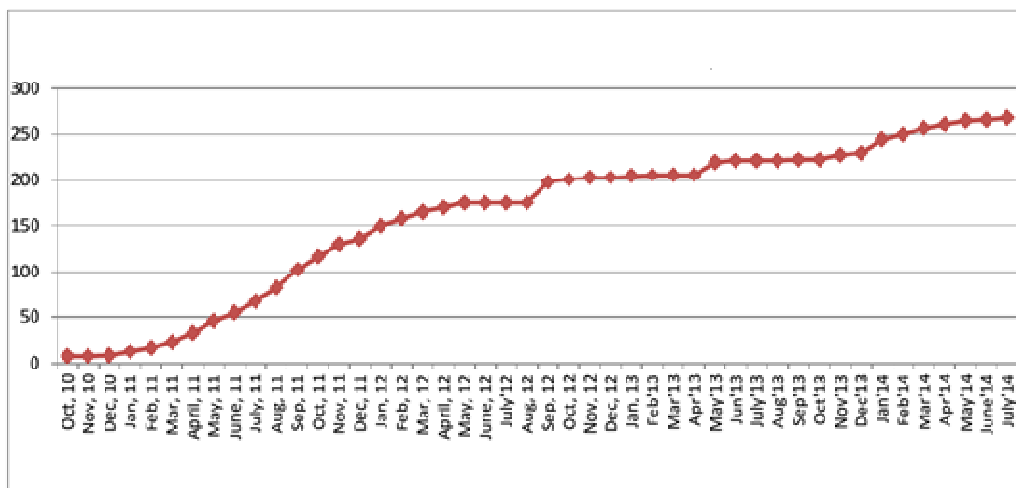


Fig 3.2 Total Nos. of connection[14]

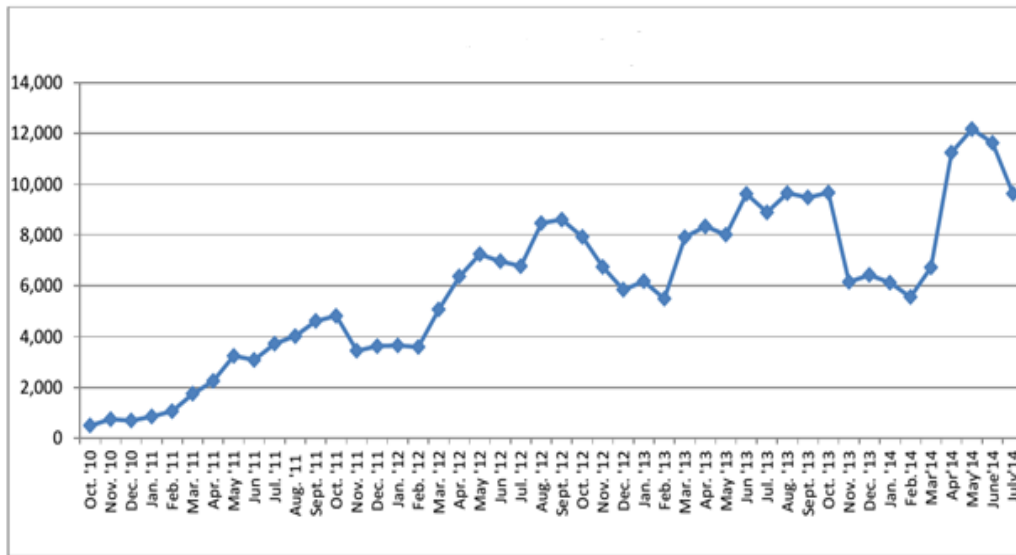


Fig 3.3 Energy Consumption (KWH) [14]

Table 3.3 Monthly Consumption 100 KW Solar mini grid at Sandwip Island [19]

Used Energy	Energy from Solar PV	Energy from Diesel Genset	Total
January ,2013	6,150	33	6,183
February	5,494	0	5,494
March	7,814	107	7,921
April	7,872	470	8,342
May	7,066	950	8,016
June	8,059	1,566	9,625
July	7,219	1,679	8,898
August	6,571	3,083	9,654
September	7,090	2,393	9,482
October	7155	2,499	9,654

November	5,583	575	6,158
December	5,832	596	6,428

3.3 Information about 100 KW solar mini grid project

Name of the Project : 100 kW Solar Mini Grid, Enamnahar, Sandwip, Chittagong

Project Area : 0.6 Acre

Project Cost : BDT 57.71 Million

Financed By : IDCOL, kfW-Germany and World Bank

Loan 30% : Tk 17.31 Million

Grant 50% : Tk 28.86 Million

Equity 20% : Tk 11.54 Million

Proposed Electricity Supplied Area : Enamnahar Bazar, Malek MunsirBazar,
Khontar Hat & Ponditar Hat.

Proposed Length of Distribution Line : 4 kilometer

Proposed Number of Consumers : Commercial Shop- 390, Health Center-
5 & School- 5

Technical Assistance : ProkaushaliSangsad Limited (PSL), Dhaka, Bangladesh

Technology Supplied : Energy Systems (BD) Ltd, Asantys Systems (Germany)

Hardware Details : Solar Module- Kyocera , Inverter- SMA Solar Technology

AG, Germany Battery- Hoppecke, Germany

Introducing PGEL Management :

AsmaHuque, Chairman

JohirulAlam, Managing Director

Bimal Kumar Chandra, Director

Alauddin Ahmed, Director

DidarulAlam, Director

3.4 Technology of the Solar Mini grid

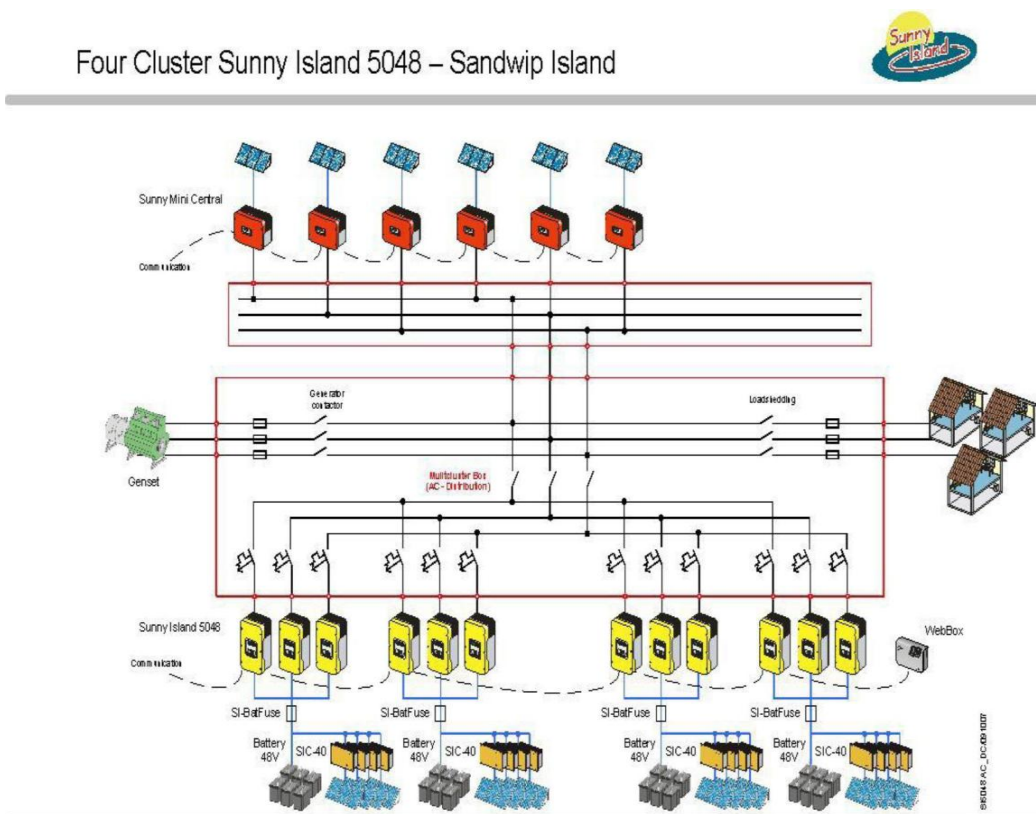


Figure 3.4 Solar Micro Grid Layout using Four Cluster Sunny Island[19]

The system design is based on AC-coupled bus concept. The main idea is to provide direct solar energy to the consumer via an AC bus through converters, when the converter energy (radiation) meets with the energy demand. Surplus will be charged via a so called “sunny island” charger into the batteries.

The size of the solar micro-grid project under consideration is 100 kW accompanied by 40 kW Diesel. The solar micro-grid is given in Figure 3.4, which is a combined operation of several subsystems.

3.5 List of major Equipments

Table 3.4: major Equipments list [20]

Equipment	Supplier	Country of Origin
Photovoltaic Module	Kyocera	Japan (Assembled in China)
Grid tie inverter SMC11000TL	SMA Solar Technology AG	Germany
Battery OPzS3000, 2V, 3000Ah	Hoppecke	Germany
Bidirectional Inverter SI5048	SMA Solar Technology AG	Germany
Sunny Web box & Battery Fuse	SMA Solar Technology AG	Germany
Multi – cluster Box MC- Box 12.3	SMA Solar Technology AG	Germany
Sunny Island Charger SIC40	SMA Solar Technology AG	Germany
Battery Main Switch	SMA Solar Technology AG	Germany

3.6 Supplier Details

SMA solar Technology AG.SMA is one of the world's largest producers in this segment and has a product range with the matching inverter type for any module type and any power class. This applies for grid tied applications as well as island and backup operation. The Sunny Mini Central produced by SMA already has an efficiency of over 98%, allows for increased electricity production. SMA's business model is driven by technological progress. Due to its flexible and scalable production, SMA is in a position to quickly respond to customer demands and promptly implement product innovations. This allows the Company to easily keep pace with the dynamic market trends of the photovoltaic industry[12].

Kyocera is one of the leading PV module suppliers of the world. In IDCOL Solar Home System Program more than 80% modules are supplied by Kyocera and the performance of these modules is quite satisfactory [18].

Hoppecke is one of the leading battery manufacturers in Germany. This company has been developing and producing batteries since 1927.HOPPECKE is now the specialist for industrial battery systems, and at the same time the largest manufacturer in European ownership[13].

3.7 Description of Major Equipments

3.7.1 Photovoltaic (PV) Module:

The PV Module is polycrystalline and highly efficient. There will be 324 nos. of 200Wp and 240 nos. of 135Wp PV Modules. The PV Module is expected to be procured from Kyocera[23].

The major features of the proposed PV module model KC200GH-2P are as follows:

Particulars	Model KC200GH-2P
-------------	------------------

Maximum Power (P _{max})	200Wp (+10%/-5%)
-----------------------------------	------------------

Maximum Power Voltage (V _{mp})	26.3V
--	-------

Maximum Power Current (Imp)7.61A

Open Circuit Voltage (Voc)32.9V

Short Circuit Current (Isc)8.21A

3.7.2 Multi – clusterBox MC-Box 12:

There will be 1 no. of multi cluster box. The model used is SMA MC Box-12.3 Option Code 30001 (include: 3: 4 Multi – clusterPiggy- Back RS485 and CAN Bus).

Major Features:

1. 3-phase Multi – clusterBox for the easy installation of stand-alone and hybrid systems with Sunny island 5048 up to a power range of 110 kW.
2. Completely wired and equipped with a main connector for PV and wind turbine systems.
3. Connection for a maximum of 4 clusters consisting of three Sunny Island 5048 devices each.
4. Integrated generator and load-shedding contactor.
5. The communication cables necessary for the installation are included [22].

3.7.3 Bidirectional Inverter SI5048:

There will be **12 nos. of bidirectional inverter. The model used is SMA SI 5048** Option Code 0031.

Major Feature:

1. Bi-directional battery inverter for setting 3 -phase stand-alone systems
2. Modularly extendable
3. Multi – cluster operation

4. High flexibility
5. Maximum efficiency of more than 95%
6. Optimize for partial load operation
7. Intelligent battery management for maximum battery lifetime
8. Charge level calculation
9. Excellent overload capability
10. Integrated display and control panel
11. Integrated protective functions, DC fuse
12. Output: short-circuit proof
13. Operating temperature range: -25 °C ... +50 °C
14. Continuous charging current of the battery at 25 °C for 100 A battery type: lead NiCd, battery capacity 100 - 10,000 [22].

3.7.4 Grid tie inverter SMC11000TL:

There will be **6 nos. of inverter. The model is SMA SMC 11000TL-11** Option Code 8000x1.

Main Features:

1. Inverter for the feeding-in of solar electricity into the low-voltage grid in grid-parallel operation
2. Transformer-less with all current sensitive failure current monitoring unit
3. Opti-Cool cooling concept - maximum output up to 40°C ambient temperature
4. Integrated display; suitable for indoor/outdoor mounting
5. SMA Grid Guard grid monitoring
6. Electronic Solar Switch (ESS) circuit-breaker: integrated protective functions

7. Input: thermally monitored varistors, ground fault monitoring, reverse polarity prevention via short-circuit diode
8. Output: short-circuit proof (current regulation) [22].

3.7.5 Sunny Island Charger SIC40:

There will be 16 nos. of chargers of Model: SMA SIC 40-MPT. Main features of the charger are as follows:

1. MPP solar charge controller, weight: 10kg.
2. Automatic regulation and single point of operation from Sunny Island
3. Up to four devices can be connected in parallel, modularly extendable, active MPPtracking, efficiency > 98 %, suitable for indoor and outdoor installation due to IP65, fanless. Integrated protective functions: short-circuit / reverse polarity / overload / excessive or insufficient voltage / overheating and under cooling; operating temperature range: - 25°C ...+60 °C;
4. Battery type:flooded and sealed lead acid batteries ;charge control IuoU process
5. Input: 48v/30a, output: 48v/40a [22].

3.7.6 Sunny Web box &Battery Fuse (Communication Kit)

There will be one communication kit of model SMA Sunny WebBox Option Code 2001. The main features are as follows:

1. Multi-functional data logger and communication center for setting parameters
2. System monitoring, remote diagnostics, archiving data and visualization of up to 50 inverters
3. The data is automatically transferred to Sunny Portal if desired

4. The Sunny WebBox is easily operated using a web interface
5. The data is accessed using a SD card or the integrated FTP server [22].

3.7.7 Deep Cycle Industrial Battery

These batteries are used mainly for solar/off grid applications, telecommunication, and traffic systems. System requirements of 48V and 12000 Ah total will be met with series and parallel connections of 2V units of 96 industrial batteries. Battery banks with tubular plate industrial batteries of 48 Volt (made up of 2V units) 12000 Ah total are proposed for a 100 kW PV system. Due to the tubular configuration of the positive plate, these batteries are designed to withstand deep discharge and have a longer life. The proposed batteries are manufactured in Germany, with a service warranty of 10 years [13].

Technical Specifications of the batteries are given below.

Rated Voltage	: 2V
Battery Capacity	: 3000Ah@10hr
Plate Type	: Positive Plate Tubular
Brand	: HOPPECKE

Main Features:

1. Highest Cycle stability during PSoC operation – due to the tubular plate design with efficient charge current acceptance
2. Maximum efficiency with reduced charging factor – ready for use of optional electrolyte recirculation
3. Maximum compatibility – dimensions according to DIN 40736 -1
4. Higher short – circuit safety even during the installation – based on HOPPECKE system connectors

5. Extremely extended water refill intervals up to maintenance – free – optional use AquaGen® recombination system minimizes emission of gas and aerosol [13].

3.7.8 Battery Main Switch:

There will be 4 nos of battery main switch and the model used is SMA BATFUSE-B.03 Option Code 30. The main features are as follows:

1. 1-pole NH 1 battery fuse as a load disconnecting switch for up to 3 SunnyIslands
2. 6 DC input ports (2 x Battery an 4 x Sunny Island Charger)
3. 1 x auxiliary voltage output with 8.6 x 250
4. A fuse plug with 6 additional replacement fuses for SunnyIsland 5048 [22].

3.7.9 Diesel Generator

40 kW Diesel generator has used.

Power capacity	:40Kw, 50KW
Voltage	: 400/230V, Current:727A
R.P.M	: 1500, Power Factor: .8
Frequency	: 50Hz
Engine Brand	: YANMAR
Type	: 4TNV106-GGEA
Alternator Brand	: MECCALTE
Type	: EC032 –1L/4
Controller Brand	: ELECTRO
Type	: EMP – 705

3.8 Tariff Comparison

Table 3.5 the average tariff rate being charged by these existing operators are as given below:

Table 3.5 the average tariff rate being charged by these existing operators [19]

Diesel generator operators	Average tariff rate (BDT per kWh)	Average tariff of the diesel generator operators (BDT per kWh)	Effective tariff of the Proposed Project (BDT per kWh)
Operator-1 Brothers Computer	52.60	64.91	30.52
Operator-2 Ripon	66.21		
Operator-3 Bazar Committee	72.83		
Operator-4 Laik	72.83		
Operator-5 Afsar	60.09		

Table 3.6 Project Debt Facilities [19]

Facility	Amount (BDT million)	Interest Rate	Tenor	Grace	Repayment
Term loan	17.31	6% p.a.	10 years	2 years	Annuity; In 16 (sixteen) semi-annual installments

3.9 Operating Expenses Assumption

Expenses of the Project include the following:

1. Utility
2. Salary and allowances
3. General and administrative expenses
4. Insurance cost

3.10 Utility expenses:

Diesel and lubricating oil will be required to run the diesel generator. Pricing and requirement of these are as follows:

A general 5% cost escalation has been considered in each of these cost items.

3.11 Salary and Allowances:

5% yearly increment has been considered for each of the employees

Table 3.7 Depreciation and Amortization [19]

Depreciation	No of years	Rate
Plant, Machinery & Equipment	20	5%
Building and Civil Construction	20	5%
Battery	7	14%
Amortization	No of years	Rate
Technical assistance	5	20%

3.12 Total Cost of 100 KW Solar Mini Grid at Sandwip:

Table 3.8 Total cost of 100KW solar mini grid at sandwip Island [19]

Installation cost	Rating	Price TK
PV panel	100kw	19,500,000
Battery	96 nos. (Each : 3000Ah, 2V)	10,124,334
Inverter	66 KW (11KW 6Nos.)KW Grid tie+ 60 KW (5KW 12Nos.) Bi- directional	7,725,000
Other Accessories related to hardware		1,808,500
Diesel Generator	40KW	750,000
Distribution line		3,434,102
Land & Land Development		1,667,521
Civil construction		4,364,720
Frame for Solar Panel		731,900
DC Cable		404,397
AC Household Meters & Earthing kit		626,000
Transportation		619,322
Import Duty + Clearing Cost		754,895
Total Capital Cost		52,510,691
Technical Assistance, Insurance cost, Plant establishment, Contingency cost (3%), Project Management (1 year) etc.		3,843,986

Total Project Cost		56,354,677
Running Cost (Site + Head office) 2013		334,836
Cost for Battery	Free	
Cost for Diesel per year	2013	245,307
Employee Salary	2013	542,000

Chapter 4

Overview of RETScreen Software

4.1 Introduction

The RETScreen International Clean Energy Project Analysis Software can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of proposed energy efficient and renewable energy technologies (RETs). The RETScreen Software has been developed to overcome the barriers to clean energy technology implementation at the preliminary feasibility stage. It provides a proven methodology for comparing conventional and clean energy technologies. The analyst can therefore focus on the pre-feasibility study, rather than developing the methodology; combined with the tool's minimal data input requirements and built-in weather and product databases, this results in fast, accurate analyses that cost roughly one-tenth the amount of pre-feasibility studies with custom-developed methodologies. This permits the screening of multiple potential projects, such that the most promising ones can be identified and implemented [11].

4.2 Overview of RETScreen Software

Fundamental to the RETScreen Software is a comparison between a “base case”—typically the conventional technology or measure—and a “proposed case”—the clean energy technology. This has very important implications for how the user specifies costs: RETScreen is ultimately not concerned with the absolute costs, but rather the incremental costs—the costs of the proposed case that are in excess of those for the base case. The user can either enter incremental costs directly or enter both the full cost associated with the proposed case and any credits stemming from base case costs made unnecessary by the proposed technology.

RETScreen's greenhouse gas emission reduction analysis adheres to this same analysis approach: it reports the reduction in GHG emission associated with changing from the base case to the proposed case technology.

4.3 Five step standard project analysis

While a different RETScreen Clean Energy Technology Model is used for each of the technologies covered by RETScreen, the same five step standard analysis procedure is common to all of them. As a result, the user who has learned how to use RETScreen with one technology should have no problem using it for another. Since the RETScreen Software is developed in Microsoft®Excel, each of the five steps in the standardised analysis procedure is associated with one or more Excel worksheets. Figuresen 4.1 presents the RETScreen Software Model Flow Chart's Five Step Standard Project Analysis, which are further described below:

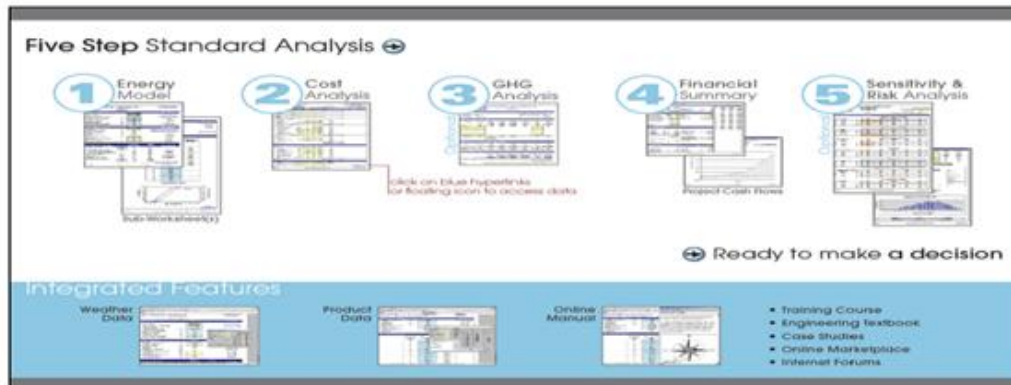


Fig 4.1 RETScreen Software Model Flow Chart: A Five Step Standard Analysis [17]

STEP 1 - Energy Model (and sub-worksheet(s)): In this worksheet, the user specifies parameters describing the location of the energy project, the type of system used in the base case, the technology for the proposed case, the loads (where applicable), and the renewable energy resource (for RETs). In turn, the RETScreen Software calculates the annual energy production or energy savings

STEP 2 - Cost Analysis: In this worksheet, the user enters the initial, annual, and periodic costs for the proposed case system as well as credits for any base case costs that are avoided in the proposed case (alternatively, the user can enter the incremental costs directly). The user has the choice between performing a pre-feasibility or a feasibility study. For a “Pre-feasibility analysis,” less detailed and less accurate information is typically required while for a “Feasibility analysis,” more detailed and more accurate information is usually required.

STEP 3– Greenhouse Gas (GHG) Analysis (optional): This optional worksheet helps determine the annual reduction in the emission of greenhouse gases stemming from using the proposed technology in place of the base case technology.

STEP 4 - Financial Summary:In this worksheet, the user specifies financial parameters related to the avoided cost of energy, production credits, GHG emission reduction credits, incentives, inflation, discount rate, debt, and taxes. From this, RETScreen calculates a variety of financial indicators (e.g. net present value, etc.) to evaluate the viability of the project. A cumulative cash flow graph is also included in the financial summary worksheet.

STEP 5 - Sensitivity & Risk Analysis (optional):This optional worksheet assists the user in determining how uncertainty in the estimates of various key parameters may affect the financial viability of the project. The user can perform either a sensitivity analysis or a risk analysis, or both.

4.4 Photovoltaic Project Model

The RETScreen® International Photovoltaic Project Model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for three basic PV applications: on-grid; off-grid; and water pumping. For on-grid applications the model can be used to evaluate both central-grid and isolated-grid PV systems. For off-grid applications the model can be used to evaluate both stand-alone (PV-battery) and hybrid (PV-battery-genset) systems. For water pumping applications the model can be used to evaluate PV-pump systems.

Six worksheets (Energy Model, Solar Resource & System Calculation (Solar Resource & System Load), Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis), Financial Summary and Sensitivity and Risk Analysis (Sensitivity)) are provided in the Photovoltaic Project Workbook file.

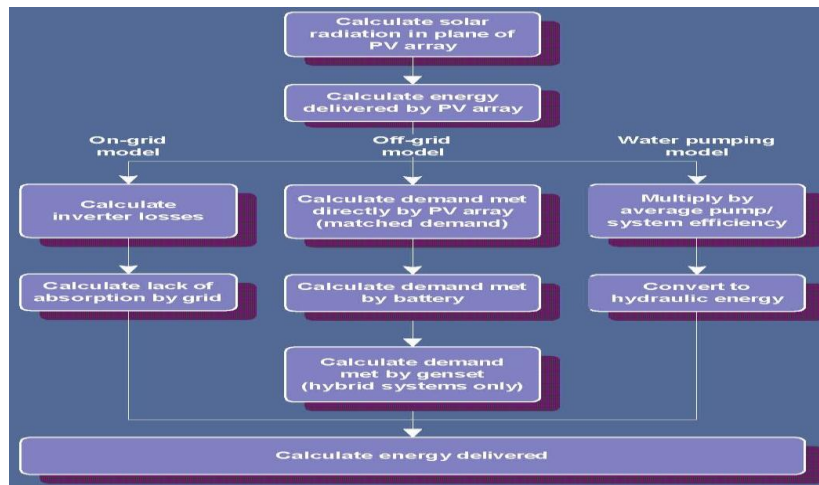


Fig 4.2 Photovoltaic project model [17]

4.5 Energy Model

As part of the RETScreen Clean Energy Project Analysis Software, the Energy Model and Solar Resource and System Load Calculation worksheets are used to help the user calculate the annual energy production for a photovoltaic project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies.

Project name

The user-defined project name is given for reference purposes only. For more information on how to use the RETScreen Online User Manual, Product Database and Weather Database, see Data & Help Access.

Site Conditions

The site conditions associated with estimating the annual energy production of a photovoltaic project are detailed below.

Project location

The user-defined project location is given for reference purposes only.

Nearest location for weather data

The user enters the weather station location in the Solar Resource & System Load worksheet and it is copied automatically to the Energy Model worksheet.

Currency Options

To perform a RETScreen project analysis, the user may select a currency of their choice from the "Currency" cell in the Cost Analysis worksheet.

Units, Symbols & Prefixes

Table 4.1 presents a list of units, symbols and prefixes that are used in the RETScreenmodel.

Note: 1. The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon.

2. The tonne (t) unit used in RETScreen refers to metric tonnes

Latitude of project location

The user enters the latitude of the project location in the Solar Resource & System Load (SR&SL) worksheet and it is copied automatically to the Energy Model worksheet.

Table 4.1 List of Units, Symbols and prefixes [17]

Name of unit	Symbol for unit
ampere	A
calorie	cal
cubic feet per minute	cfm
day	d
degree Celsius	°C
degree Fahrenheit	°F
dollar	\$
feet	ft
gallon ⁴	gal
hectare	ha
hertz	Hz
horse-power	hp
hour	h
joules	J
kilogram	kg
kilometre	km
kilowatt	kW
litre	L
megawatt	MW
metre	m
mile	mi
mile per hour	mph
million Btu	mmBtu
pascal	Pa
percentage	%
person day	p-d
person hour	p-h
person trip	p-trip
person year	p-yr
pound	lb
pound-force/square inch	psi
second	s
tonne ²	t
volt	V
watt	W
week	w
yard	yrd
year	

Name of Prefix	Symbol for Prefix
kilo	k
mega	M
giga	G

Annual solar radiation (tilted surface)

The model calculates the total annual solar radiation incident on the PV array, in MWh/m², from monthly data entered by the user in the Solar Resource & System Load (SR&SL) worksheet.

Annual average temperature

The annual average temperature typically ranges from -20 to 30°C, depending upon the location.

The temperature at standard conditions is 15°C.

DC energy demand for months analysed

The model calculates the DC energy demand, in MWh, for the season of use. This is calculated from data entered in the Load Characteristics section of the Solar Resource & System Load (SR&SL) worksheet.

AC energy demand for months analysed

The model calculates the AC energy demand, in MWh, for the season of use. This is calculated from data entered in the Load Characteristics section of the Solar Resource & System Load (SR&SL) worksheet.

System Characteristics

The system characteristics associated with estimating the seasonal energy production of a photovoltaic system are detailed below. Some other system characteristics (particularly those used to calculate the system load) can be found in the Load Characteristics section of the Solar Resource & System Load (SR&SL) worksheet.

Application type

The user enters the type of PV application in the Solar Resource & System Load (SR&SL) worksheet and it is copied automatically to the Energy Model worksheet. There are three basic applications: On-Grid, off-grid & Water Pumping.

Grid type

The user selects the type of grid from the two options in the drop-down list: "Central-grid" and "Isolated-grid." Central-grid is recommended for systems where the size of the grid (and the load it satisfies) is so large that the utility will always be able to use all the energy produced by the PV system

PV energy absorption rate

The user enters the PV energy absorption rate (%). This is the amount of energy produced by the PV system that will actually be delivered to the utility. The remaining energy is available for other potential uses, or possibly "wasted" because of mismatches between PV output and utility energy demand.

PV system configuration

The user selects from the drop-down list the type of off-grid system under consideration: "PV/battery" or "PV/battery/genset." PV/battery should be used if the system does not include a back-up generator. Use PV/battery/genset if the system includes a generator (genset). Genset, as defined here, also includes thermoelectric generators (TEGs). The user will need to decide whether or not to include a genset in the PV system.

Base Case Power System

This sub-section deals with the definition of the base case scenario. For water pumping applications, the base case power system includes the pump system. The base case is used for financial calculations and does not have any bearing on the energy calculations for the energy system.

Source

The user selects, from the drop-down list, the source of power/energy being displaced. The options available address the replacement of conventional electrical sources (genset, thermoelectric generator, grid extension or non-rechargeable batteries), light source (non-electric lantern) and mechanical sources (engine driven pump or other mechanical pumps, such as hand pump or animal driven pumps) with a photovoltaic system. A final option, "Other," can be selected for cases not falling in one of the above categories.

Fuel type

The user selects the type of fuel displaced by the PV system. A list of common fuel types are provided in the drop-down list. The fuel options address the replacement of conventional fossil-fuel generators and engine driven pumps (Natural gas, Propane, Diesel (#2 oil), Gasoline, Kerosene) or fossil fuel lanterns (Kerosene, Propane) with a photovoltaic system.

For water pumping applications, if the source of power/energy being displaced is set to "Grid extension" then the fuel type is automatically set to "Grid mix."

Specific fuel consumption

Depending on the "Application type" being evaluated, the user enters the amount of fuel consumed by the base case system to either provide a given amount of electrical energy (kWh) or provide a given amount of water (L - litres of water pumped) or to produce a given amount of light over a certain period (year).

Inverter capacity

The user enters the inverter capacity, in kW AC (that is, the nominal output of the inverter). By default the user will likely enter the Suggested inverter (DC to AC) capacity calculated above. If the detailed load calculator in the Solar Resource & System Load (SR&SL) worksheet is used, the AC peak load may be overestimated, because the load calculator assumes that all AC loads can occur simultaneously.

Average inverter efficiency

The user enters the combined efficiency, expressed in %, of the electronic devices (maximum power point tracker and inverter) used to control the PV array and transform its DC output to AC. Values between 80 and 95% are typical. A value of 90% is suggested as a starting point. Zero should be entered if the PV system has no AC load.

Miscellaneous power conditioning losses

The user enters power conditioning losses (%), if any, not taken into account elsewhere. For example, this could include losses incurred in DC-DC converters or in step-up transformers. In most cases this value will be zero.

Battery

This sub-section deals with the characteristics of the battery bank.

Days of autonomy required

The user enters the size of the battery, expressed in days of autonomy (d). In other words this is the number of days that the system, starting from a state of full charge, would be able to meet the load using the batteries only.

Nominal battery voltage

The user enters the nominal voltage of the batteries to be used, in V.

Usual battery voltages are 6, 12, 18, 24, 36, 48, or 72 Volts. The nominal battery voltage has no influence on the energy predictions of the model; it is simply used to convert battery capacity from Ah to Wh, according to the relationship: $Wh = V \times Ah$

Battery efficiency

The user enters the average efficiency (%) of the battery, as specified at the nominal temperature of 25°C. In the absence of information from the battery supplier, an efficiency of 85% may be used.

Maximum depth of discharge

The user enters the percentage of the rated battery capacity that can be withdrawn repeatedly without abnormal loss of battery life. The maximum depth of discharge depends on the size and type of the battery. In the absence of additional information (for example from manufacturer's data) the user can refer to the values in the table below.

Table 4.2 Maximum depth of discharge for rechargeable batteries

Battery type	Default maximum depth of discharge
Lead-acid (car)	20%
Lead-acid (gel)	20%
Lead-acid (PV, vented)	60%
Nickel-Cadmium	85%

Charge controller (DC to DC) efficiency

The user enters the average efficiency of the charge controller, in %. A default value of 95% is suggested

Battery temperature control

The user enters the type of temperature control applied to the battery. The options from the dropdown list are: "Ambient," "Constant" and "Minimum." This item is used to derate the battery capacity according to the temperature conditions it experiences.

Constant battery temperature

The user enters the constant temperature at which the battery is kept, in °C. For example if the battery is located in a basement a value of 18°C is appropriate.

Minimum battery temperature

The user enters the minimum temperature at which the battery is kept, in °C. For example if the battery temperature is kept above the freezing point of water, enter 0°C.

If lead-acid batteries are chosen, this value should be higher than -15°C to prevent the batteries from freezing.

Average battery temperature derating

The model calculates the loss of nominal (25°C) battery capacity resulting from temperature conditions experienced by the battery, in °C. This value is averaged over the season of use.

Battery derating depends mainly on the temperature at which the battery operates. Lower temperatures result in a larger temperature derating. If the battery is kept at a constant temperature of 25°C year round, the battery temperature derating is zero. It can reach as high as 30% or more if the battery operates part of the year at very low temperatures.

Nominal battery capacity

The user enters the actual nominal capacity of the battery bank, in Ah.

By default the user will likely enter the value calculated in the model under "Suggested nominal battery capacity"

Note: The RETScreen PV model is not designed to analyse "PV-battery" or "PV-battery-genset" systems that have less than one day of storage or more than 15 days of storage.

PV Array

This sub-section deals with the characteristics of the photovoltaic array.

PV module type

The user selects the type of PV module considered for the application. The seven options from the drop-down list are: "mono-Si," "poly-Si," "a-Si," "CdTe," "CIS,"

"spherical-Si" and "User defined." The Nominal Efficiencies of PV Modules table presents a comparative summary of the different types of modules.

The PV module type selected will depend on a number of factors, including: price from suppliers, product availability, warranties, efficiencies, etc. Without further information either "mono-Si" or "poly-Si" may be used as a first selection as each have similar prices on a \$/W_p basis and are the most common PV modules used today.

PV module manufacturer / model

The user enters the name of the PV module manufacturer or model number. This is for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

Nominal PV module efficiency

The user enters the nominal efficiency (%) of the PV module under consideration. The user can consult the RETScreen Online Product Database for more information. Module efficiency depends primarily on the type of cell used (mono-Si, poly-Si, a-Si, CdTe, CIS, spherical-Si

Keeping this in mind, in the absence of other data the following values may be used.

Table 4.3 Nominal efficiency of PV modules

Cell type	Default efficiency (%)	Default temperature coefficient (1/°C)
mono-Si	13	0.004
poly-Si	11	0.004
a-Si	5	0.0011
CdTe	7	0.0024
CIS	7.5	0.0046

NOCT (Nominal Operating Cell Temperature)

The model calculates the Nominal Operating Cell Temperature (NOCT), in °C. NOCT is defined as the module temperature that is reached when the PV module is exposed to a solar radiation level of 800 W/m², a wind speed of 1 m/s, an ambient temperature of 20°C, and no load.

PV temperature coefficient

The model calculates the PV temperature coefficient.

In the case where the user selects "User-defined" under "PV module type," the user enters the temperature coefficient of the PV module. The efficiency of photovoltaic cells varies with their operating temperature. Most cell types exhibit a decrease in efficiency as their temperature increases. The PV temperature coefficient, μ (expressed in % / °C), is defined in the RETScreen

PV model as:

$$\eta(T) = \eta(T_{ref})(1 - \mu(T - T_{ref}))$$

where

$\eta(T)$ = the efficiency of the solar cell at temperature T,

$\eta(T_{ref})$ = the efficiency of the cell at temperature Tref,

T = the operating temperature of the module, and Tref = the reference temperature (usually 25°C). The value of μ depends primarily on the type of cell used. It is often fairly difficult to find this value on manufacturer datasheets; therefore in the absence of this information the default values found in the Nominal Efficiencies of PV Modules table may be used.

PV array controller

The user selects from the drop-down list the type of PV array controller that is used to interface the PV array to the rest of the system: "MPPT" and "Clamped." A Maximum Power Point

Tracker (MPPT) is an electronic device used to maintain the operating voltage of the array at a value that maximises array output, regardless of changes in load impedance or changes in array operating conditions due to variations in temperature or insolation. If the user selects "MPPT," the efficiency of the array will be optimal. A "Clamped" PV array controller is a direct connection between the array and the batteries; in this configuration the array operates at the voltage set by the battery.

Miscellaneous PV array losses

The user enters array losses (%) from miscellaneous sources not taken into account elsewhere in the model. This includes, for example, losses due to the presence of dirt or snow on the modules. Typical values range from zero to a few percent. In some exceptional circumstances (e.g. very harsh environment) this value could be as high as 20%.

Nominal PV array power

The user enters the nominal power of the PV array, in kWp. For "Off-grid" or "Water pumping" applications, as a first guess the user will likely enter the "Suggested nominal PV array power" then enter lower or higher values to perform a sensitivity analysis of the system.

PV array area

The model calculates the area that will be covered by the PV array, in m². This is simply the nominal PV array power divided by the nominal module efficiency. The user should verify the value calculated by the model

Charger (AC to DC) efficiency

The user enters the efficiency (%) of the battery charger/rectifier. Values usually range between 80 and 95%. If data from the manufacturer is not available a value of 80% will likely be a reasonable estimate.

Suggested genset capacity

The model calculates the suggested capacity of the genset, in kW. The genset is sized so that:

- i) it can always meet the AC load, and
- ii) it can nominally recharge the batteries in 8 h.

Suggested genset capacities usually range from very small values (which should be considered as impractical) to a few kW.

Genset capacity

The user enters the genset capacity, in rated kW for continuous operation.

The genset capacity will likely be within $\pm 25\%$ of the suggested genset capacity; significant deviations from the suggested value may affect battery operation and life expectancy.

Fuel type

The user selects the type of fuel used by the genset.

Specific fuel consumption

The user enters an estimate of the fuel consumption of the genset, per unit kWh of electricity delivered.

Table 4.4 Average Genset specific fuel consumption

Fuel type	Units	Suggested value
Natural gas	m ³ /kWh	0.55 – 0.60
Propane ¹	L/kWh	0.90 – 1.10
Diesel (#2 oil)	L/kWh	0.40 – 0.50
Kerosene	L/kWh	0.80 – 1.00
Gasoline	L/kWh	0.60 – 0.75

Power Conditioning

This sub-section deals with the characteristics of the power conditioning hardware.

Average inverter efficiency

The user enters the combined efficiency, expressed in %, of the electronic devices (maximum power point tracker and inverter) used to control the PV array and transform its DC output to AC. Values between 80 and 95% are typical. A value of 90% is suggested as a starting point.

Suggested inverter (DC to AC) capacity

The model calculates the suggested capacity of the inverter, in kW AC (that is, the nominal output of the inverter). This value is calculated based on "Nominal PV array power" and "Average inverter efficiency" entered by the user.

Inverter capacity

The user enters the inverter capacity, in kW AC (that is, the nominal output of the inverter).

By default the user will likely enter the Suggested inverter (DC to AC) capacity provided above.

Miscellaneous power conditioning losses

The user enters power conditioning losses (%), if any, not taken into account elsewhere. For example, this could include losses incurred in DC-DC converters or in step-up transformers. In most cases this value will be zero.

Annual Energy Production (for months analysed)

This section summarises the annual energy production of the photovoltaic project.

Equivalent DC energy demand

The model calculates the equivalent DC energy demand, in MWh. This is the sum of the DC demand and the AC demand divided by inverter efficiency, over the season of use.

Equivalent DC demand not met

The model calculates the electrical demand that is not met by the system over the season of use, in MWh. This quantity is expressed as an equivalent DC demand, that

is, it is the amount of energy that the photovoltaic system is unable to provide to meet both DC and AC loads.

Overall PV system efficiency

The model calculates the overall efficiency of the PV system, in %. This value is the amount of renewable energy delivered divided by the amount of solar radiation incident on the photovoltaic array. Typical values range from 3% to 13%, depending on module type, power conditioning efficiencies and solar radiation distribution.

PV system capacity factor

The model calculates PV system capacity factor (%) which represents the ratio of the average power produced by the system over a year to its nominal rated PV array power. It is calculated as the ratio of the renewable energy delivered over the nominal PV array power multiplied by the total hours in a year.

Renewable energy collected

The model calculates the amount of electrical energy produced by the photovoltaic array during the season of use, in MWh. Depending on latitude and system size this value may range from a fraction of one MWh to several hundred MWh or more.

Renewable energy delivered

The model calculates the annual renewable energy delivered (MWh), which is the amount of equivalent DC electrical energy actually delivered by the PV system to the load, or the utility in the case of an on-grid system. This value is transferred to the Financial Summary worksheet as an input to conduct the financial analysis.

Units switch: The user can choose to express the energy in different units by selecting among the proposed set of units: "GWh," "Gcal," "million Btu," "GJ," "therm," "kWh," "hp-h," and "MJ."

Excess RE (Renewable Energy) available

The model calculates the excess renewable energy available (MWh), which is the amount of renewable energy produced by the system, that could not be used by the

grid because of mismatches between PV output and utility energy demand (see "PV Energy absorption rate").

Solar Resource & System Load Calculation

As part of the RETScreen Clean Energy Project Analysis Software, the Solar Resource & System Load Calculation worksheet is used in conjunction with the Energy Model worksheet to calculate the energy load and energy savings of a photovoltaic system.

Site Latitude and PV Array Orientation

Site conditions and system characteristics associated with estimating the annual solar energy resource are detailed in the RETScreen manual.

Nearest location for weather data

The user enters the weather station location with the most representative weather conditions for the project. This is used for reference purposes only. The user can consult the RETScreen Online Weather Database for more information.

Latitude of project location

The user enters the geographical latitude of the project site location in degrees measured from the equator. Latitudes north of the equator are entered as positive values and latitudes south of the equator are entered as negative values. The user can consult the RETScreen Online Weather Database for this information.

PV array tracking mode

The user selects the type of sun tracking device upon which the PV system is mounted. The options from the drop-down list are: "Fixed," "One-axis," "Two-axis" and "Azimuth." If the PV array is mounted on a fixed structure the user may select "Fixed." The remaining choices may be selected if the PV array is mounted on a tracker. See the fig. 4.3.

A tracker is a device supporting the photovoltaic array which moves the array in a prescribed way to minimize the angle of incidence of beam radiation on the array's surface

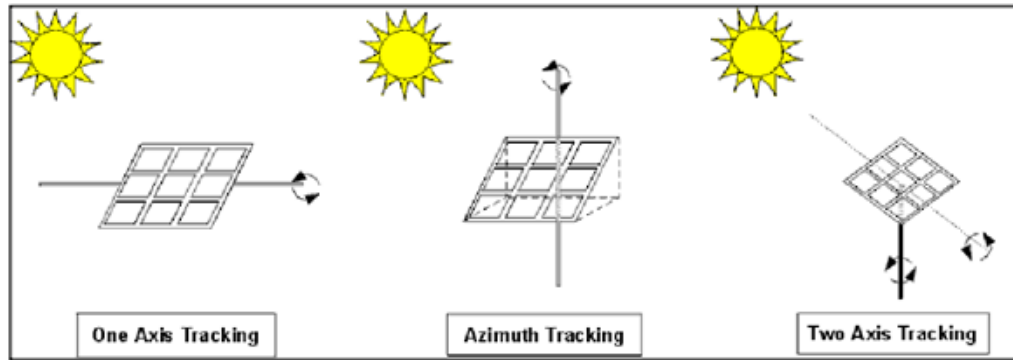


Fig 4.3 Sun tracking device

Depending on whether or not a tracking device is used, the following parameters also need to be entered in the PV model (See the table 4.5):

Table 4.5 PV array tracking mode

Tracking Mode	Parameters required
No tracking	Slope and azimuth of PV array
1-axis tracking	Slope and azimuth of tracking axis
2-axis tracking	None
Azimuth tracking	Slope of tracking axis

Slope of PV array

The user enters the angle between the photovoltaic array and the horizontal, in degrees.

Azimuth of PV array

The user enters the angle between the projection, on a horizontal plane, of the normal to the surface and the local meridian, with zero due south (for the purpose of this model, the sign has no importance).

The preferred orientation should be facing the equator, in which case the azimuth angle is 0° in the Northern Hemisphere and 180° in the Southern Hemisphere. In the case of a PV array mounted directly on the roof of a building, the azimuth is equal to

that of the roof, which should be chosen to be as close to equator facing as possible. For example, a solar collector in the

Northern Hemisphere facing south-west would have an azimuth angle of 45° (see figure 4.4).

If two walls are being used, the average of the absolute values for the orientation should be calculated. For example, if one wall is 30 degrees west of south ($+30^\circ$) and the other wall is 60 degrees east of south (-60°), enter 45 degrees. Alternatively, if one wall were due east (-90°), and the other due west ($+90^\circ$) the average of the absolute values would be 90° .

Note that the azimuth must be entered with respect to true south and not magnetic south.

Compasses point to magnetic north (the complement of magnetic south) and azimuth directions based on this measure must be adjusted for the magnetic declination (for more information, refer to "Magnetic declination"). If the azimuth direction is being determined from site drawings, it should be determined what reference the site north is using. Site north does not always correspond to true north, as it is sometimes adjusted for convenience in the site and building drawings.

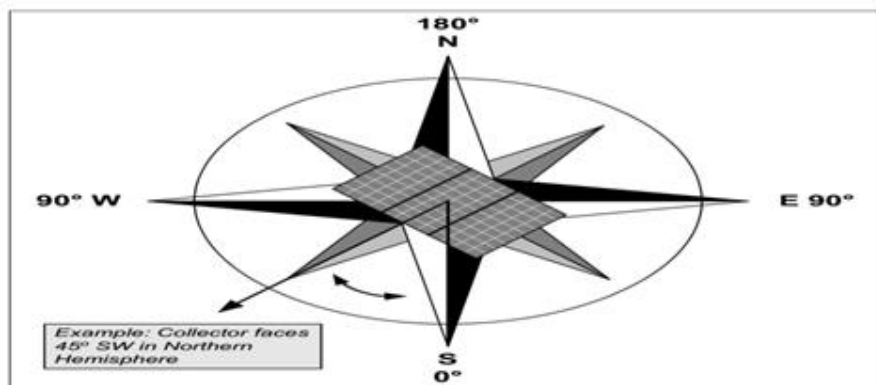


Fig 4.4 Azimuth of PV array [16]

Monthly average daily radiation on horizontal surface

The user enters the amount of solar radiation received on average during one day on a horizontal surface at the site, in (kWh/m²)/d. Data in (MJ/m²)/d should be divided by 3.6 to be converted to (kWh/m²)/d. Data in (BTU/ft²)/d should be divided by 317 and data in (cal/cm²)/d or Langleys should be divided by 86 to be converted to (kWh/m²)/d. The user can consult the RETScreen Online Weather Database for more information.

The values range from 0 during polar night months in the polar regions, to values around 8.5 (kWh/m²)/d in temperate climates during summer months.

Monthly average temperature

The user enters the average temperature for the month, in °C. This temperature is used to estimate the performance of the photovoltaic array as well as the efficiency of the battery. The user can consult the RETScreen Online Weather Database for more information.

Monthly average daily radiation in plane of PV array

The model calculates the amount of solar radiation received on average during one day on a tilted surface at the site, in kWh/m²/d. Typical values calculated by the model range from 0 to 10 kWh/m²/d.

Monthly solar fraction

The model calculates the monthly fraction (%) of the load met by the photovoltaic system (off grid and water pumping systems only)

Solar radiation (horizontal)

The model calculates the amount of solar radiation incident on a horizontal surface, in MWh/m², for the entire year and for the period (season) of use.

Solar radiation (tilted surface)

The model calculates the amount of solar radiation incident on the solar collector, in MWh/m², for the entire year and for the period (season) of use.

Average temperature

The model calculates the average ambient temperature, in °C, for the entire year and for the period (season) of use.

Load Characteristics

The load characteristics of the PV system are entered by the user in this section. The user specifies the type of application (on-grid, off-grid, or water pumping) as well as load details that will enable the model to estimate the energy requirements.

Detailed load calculator (off-grid system)

The user enters a detailed description of the various loads that the system will have to meet.

Description

The user enters a description of the load. This is for reference purposes only. For example if the load in question is an electric vacuum cleaner the user may enter "Vacuum cleaner."

AC/DC

The user selects whether the load is direct current (DC) or alternating current (AC). For example if the load is a standard electric vacuum cleaner the user would select AC.

Solar-load correlation

The user selects the solar-load correlation. The three options from the drop-down list are: "Negative," "Zero" and "Positive." "Negative" (i.e. negative correlation) corresponds to cases where the load is very irregular or occurs mostly at night. "Zero" (i.e. zero correlation) corresponds to steady loads. "Positive" (i.e. positive correlation) corresponds to loads that are turned on only when there is enough solar energy to power them directly.

Load

The user enters an estimate of the load, in kW. The following table 4.6 provides an estimate of typical loads encountered in an household. In the vacuum cleaning example the user would enter 0.8 (800 W converted to kW: $800/1,000 = 0.8$).

Table 4.6 Typical load in a Household [17]

Appliance	Estimated Power Rating (W)
AC appliances	
Block heater	500
Coffee maker	1,000
Clothes washer (excl. hot water)	450
Computer (desktop)	200
Dishwasher (excl. hot water)	1,200
Hair dryer, iron	1,000
Light, 25 W incandescent	25
Light, 10 W fluorescent	10
Light, 40 W fluorescent	40
Microwave oven	800
Power tools	250-1,000
Radio	30
Refrigerator	330
Television (B/W)	200
Television (color)	330
Toaster	1,000
Vacuum cleaner	800
Video cassette recorder	30
Water heater (electric)	5,000
DC appliances	
Computer, laptop	25
Fan, ceiling	25
Fan, 8"	15
Refrigerator	65
Security system	6
Telephone, cellular (standby)	0.02
Telephone, radio (standby)	25
Television (B&W)	10-20
Television (color)	45-60

Hours of use per day

The user enters an estimate of the number of hours that the load is used during a typical day (h/d).

For example if it takes one half-hour to vacuum the house the user would enter 0.5.

Days of use per week

The user enters an estimate of the number of days during which the load is used per week (d/wk).

In the vacuum-cleaning example, if vacuuming is done on Mondays, Wednesdays and Fridays the user should enter 3.

DC energy demand

The DC energy demand is the weekly averaged daily amount of DC energy required by all the individual loads. This value is automatically calculated in the model if the detailed load calculator is used. It must be entered manually by the user if the detailed load calculator is not used. Values can range from zero (if the entire load is AC) to a few tens of kWh or more.

AC energy demand

The AC energy demand is the weekly averaged daily amount of AC energy required by the load.

This value is automatically calculated by the model if the detailed load calculator is used. It must be entered manually by the user if the calculator is not used. Values can range from zero (if the entire load is DC) to a few tens of kWh or more.

AC peak load

The AC peak load is the maximum power drawn at any time during one day by the load. This value is automatically calculated by the model if the detailed load calculator is used. It must be entered manually by the user if the calculator is not used. Values can range from zero (if the entire load is DC) to a few kW or more. The AC peak load is required to estimate the size the inverter.

Note: The RETScreen Software for this step are described in detail in the software manual.

4.5 Cost Analysis

As part of the RETScreen Clean Energy Project Analysis Software, the Cost Analysis worksheet is used to help the user estimate costs associated with a PV project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

Type of analysis

The user selects the type of analysis by clicking on the appropriate radio button. For a "Prefeasibility analysis," less detailed and lower accuracy information is typically required while for a "Feasibility analysis," more detailed and higher accuracy information is usually required.

1. Keep the project development costs low in case funding cannot be secured, or in case the project proves to be uneconomic when compared with other energy options.
2. Spend additional money and time on engineering to more clearly delineate potential project costs and to more precisely estimate the amount of energy produced or energy saved.
3. To overcome, to some extent, such conflicts, the usual procedure is to advance the project through the following four stages:
 4. Pre-feasibility analysis
 5. Feasibility analysis
 6. Development (including financing) and engineering
 7. Construction and commissioning

Each stage could represent an increase of a magnitude or so in expenditure and a halving of the uncertainty in the project cost-estimate. This process is illustrated, for hydro projects, in the Accuracy of Project Cost Estimates figure 4.5.

At the completion of each step, a "go or no go" decision is usually made by the project proponent as to whether to proceed to the next step of the development process. High quality, but low-cost, pre-feasibility and feasibility studies are critical to helping the project proponent "screen out" projects that do not make financial sense, as well as to help focus development and engineering efforts prior to construction. The RETScreen Clean Energy Project Analysis Software can be used to prepare both the initial pre-feasibility analysis and the more detailed feasibility analysis.

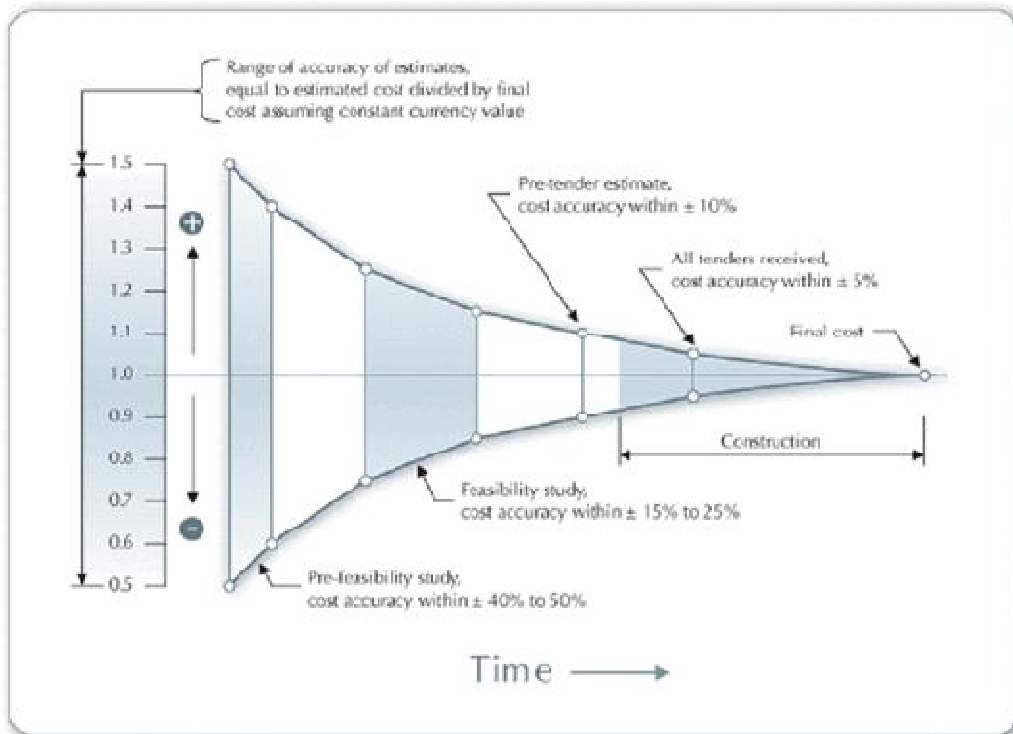


Fig 4.5 Accuracy of project cost Estimates [17]

Initial Costs (Credits)

The initial costs associated with the implementation of a PV project are detailed below. The major categories include costs for preparing a feasibility study, performing the project development functions, completing the necessary engineering, purchasing and installing the energy equipment, construction of the balance of equipment and costs for any other miscellaneous items.

Feasibility Study

Feasibility studies typically include such items as site investigations, a preliminary project design and a final report with detailed cost estimates.

Feasibility study project management and travel costs are also normally incurred. These costs are detailed in the RETScreen manual.

Note: The RETScreen Software for this step are described in detail in the software manual.

4.6 Financial Analysis

As part of the RETScreen Clean Energy Project Analysis Software, a Financial Analysis worksheet is provided for each project evaluated. This common financial analysis worksheet contains six sections: Annual Energy Balance, Financial Parameters, Project Costs and Savings, Financial Feasibility, Yearly Cash Flows and Cumulative Cash Flows Graph

One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers.

Annual Energy Balance

The summary items here are calculated and/or entered in the Energy Model and GHG Analysis worksheets and transferred to the Financial Summary worksheet.

Energy from genset

The energy delivered by the genset (MWh) over the season of use is calculated in the Energy Model worksheet and it is copied automatically to the Financial Summary worksheet.

Renewable energy delivered

The Energy Model calculates the annual renewable energy production (MWh) of the project.

This renewable energy delivered by the project also equates to the annual energy savings as compared with the base case electricity or pumping system.

Genset capacity

For "Off-grid" applications, the genset capacity (kW) of the project is entered in the Energy Model worksheet and it is copied automatically to the Financial Summary worksheet.

Nominal PV array power

For "Off-grid" applications, the nominal PV array power (kW) of the project is entered in the Energy Model worksheet and it is copied automatically to the Financial Summary worksheet.

Equivalent energy demand

For "Off-grid" applications, the equivalent DC energy demand is calculated in the Energy Model worksheet and it is copied automatically to the Financial Summary worksheet. For water pumping applications, the equivalent pumping energy demand is calculated in the Energy Model worksheet and it is copied automatically to the Financial Summary worksheet.

Financial Parameters

The items entered here are used to perform calculations in this Financial Analysis worksheet. Values for each parameter will depend on the perspective of the user (e.g. utility vs. independent power producer or service provider).

Energy cost escalation rate

The user enters the energy cost escalation rate (%), which is the projected annual average rate of increase for the cost of energy over the life of the project. This permits the user to apply rates of inflation to electricity or fuel costs which are different from general inflation for other costs

Inflation

The user enters the inflation rate(%), which is the projected annual average rate of inflation over the life of the project.

Discount rate

The user enters the discount rate (%), which is the rate used to discount future cash flows in order to obtain their present value. The rate generally viewed as being most appropriate is an organisation's weighted average cost of capital.

Project life

The user enters the project life (year), which is the duration over which the financial feasibility of the project is evaluated.

Debt ratio

The user enters the debt ratio (%), which is the ratio of debt over the sum of the debt and the equity of a project. The debt ratio reflects the financial leverage created for a project; the higher the debt ratio, the larger the financial leverage

Debt interest rate

The user enters the debt interest rate (%), which is the annual rate of interest paid to the debt holder at the end of each year of the term of the debt. The model uses the debt interest rate to calculate the debt payments.

Debt term

The user enters the debt term (year), which is the number of years over which the debt is repaid. The debt term is either equal to, or shorter than the project life.

Depreciation method

The user selects the depreciation method from three options in the drop-down list: "None," "Declining balance" and "Straight-line." This selection of the yearly depreciation of assets is used in the model in the calculation of income taxes and after-tax financial indicators.

Depreciation rate

The user enters the depreciation rate (%), which is the rate at which the un depreciated capital cost of the project is depreciated each year. The depreciation rate can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

Depreciation period

The user enters the depreciation period (year), which is the period over which the project capital costs are depreciated using a constant rate. The depreciation period can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

Tax holiday available

The user indicates by selecting from the drop-down list whether or not the project can benefit from a tax holiday. If the user selects "Yes," the tax holiday applies starting in the first year of operation, year 1, up to the tax holiday duration. The income tax calculation for the development/construction year, year 0, is not affected.

Tax holiday duration

The user enters the tax holiday duration (year), which is the number of years over which the tax holiday applies, starting in the first year of operation, year 1. For example, in India, certain renewable energy projects are given a five-year tax holiday.

Project Costs and Savings

Most of the summary items here are calculated and/or entered in the Cost Analysis worksheet and transferred to the Financial Summary worksheet. Some calculations are made in the Financial Summary worksheet.

Initial Costs

The total initial costs represent the total investment that must be made to bring a project on line, before it begins to generate savings (or income). The total initial costs are the sum of the estimated feasibility study, development, engineering, energy equipment, balance of equipment and miscellaneous costs and are inputs in the

calculation of the simple payback, the net present value and the project equity and debt.

Feasibility study

The feasibility study item represents the sum of the costs incurred to assess the feasibility of a project. It is net of any "credits" for not having to develop the base case project.

Development

The development item typically represents the sum of the costs incurred to bring a project to the detailed design and construction stage, once its feasibility has been proven. It is net of any "credits" for not having to develop the base case project.

Engineering

The engineering item typically represents the sum of the costs of the design activities required to go from the development stage to the construction stage of a project. It also includes costs for construction supervision. It is net of any "credits" for not having to develop the base case project.

Energy equipment

The energy equipment item typically represents the sum of the purchasing and installation costs of the energy equipment, less any "credits" for not having to purchase or install base case equipment.

Balance of equipment

The balance of equipment item represents the sum of the purchasing, construction and installation costs of all the elements of the energy system other than the equipment costs less any "credits" for not having to purchase or install base case equipment.

Miscellaneous

The miscellaneous item includes all the costs not considered in any of the other initial costs categories that are required to bring a project to the operational stage.

Incentives/Grants

The user enters the financial incentive; this is any contribution, grant, subsidy, etc. that is paid for the initial cost (excluding credits) of the project. The incentive is deemed not to be refundable and is treated as income during the development/construction year, year 0, for income tax purposes.

Annual Costs and Debt

The total annual costs are calculated by the model and represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M costs, fuel/electricity costs and debt payments. Note that the total annual costs include the reimbursement of the "principal" portion of the debt which is not, strictly speaking, a cost but rather an outflow of cash. These costs are described briefly below.

O&M

The operation and maintenance (O&M) costs are the sum of the annual costs that must be incurred to operate and maintain the energy system, in excess of the O&M cost required by the base case electricity system. The model uses the O&M cost to calculate the total annual costs and the yearly cash flows.

Fuel

For "Off-grid" applications with PV/battery/genset system configuration, the annual cost of fuel to run the system is transferred from the Cost Analysis worksheet. This value represents the cost of fuel to run the genset.

Debt payments - debt term

The model calculates the debt payments, which is the sum of the principal and interest paid yearly to service the debt. Whereas debt payments are constant over the debt term, the principal portion increases and the interest portion decreases with time. In that respect, it is similar to the yearly annuity paid to reimburse the mortgage of a house. Debt payments are calculated using the debt interest rate, the debt term and the project debt.

Annual Savings or Income

The total annual savings represent the yearly savings realised due to the implementation of the project. From the perspective of an independent power producer or service provider, these "savings" will be viewed as "income." It is directly related to the avoided cost of energy derived from implementing the project. It is an input in the calculation of the simple payback and the debt service coverage.

Energy savings/income

For "On-grid" applications, the annual energy savings are equal to the sum of the product of the "Renewable energy delivered" and "Avoided cost of energy" and the product of the "Excess RE available" and the "Avoided cost of excess energy."

For "Off-grid" applications, the annual energy savings are equal to the product of the "Renewable energy delivered," "Specific fuel consumption" and "Avoided cost of energy."

Capacity savings/income

The annual capacity savings are equal to the product of the "Firm RE capacity" and the "Avoided cost of capacity." The yearly value of capacity savings is escalated at the inflation rate.

RE production credit income – duration

The model calculates the RE production credit income, which represent the income (or savings) generated by the sale or exchange of the RE production credits during the

RE production credit duration. It is calculated from the renewable energy delivered and the RE production income value. The yearly value of RE production credit income is escalated at the RE credit escalation rate.

Periodic Costs (Credits)

The periodic costs and periodic credits entered by the user in the Cost Analysis worksheet are transferred here.

The model escalates the periodic costs and credits yearly according to the inflation rate starting from year 1 and throughout the project life.

End of project life - Cost/Credit

The value of the energy project at the end of its life entered by the user in the Cost Analysis worksheet is transferred here. This amount is also commonly referred to as the salvage value (or disposal value).

The salvage value entered is assumed to be representative of year 0, i.e. the development/construction year prior to the first year of operation (year 1).

Financial Feasibility

The results provide the decision-maker with various financial indicators for the proposed project.

Simple Payback

The model calculates the simple payback (year), which represents the length of time that it takes for an investment project to recoup its own initial cost, out of the cash receipts it generates. The basic premise of the payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment.

Year-to-positive cash flow

The model calculates the number of years to positive (cumulative) cash flow, which represents the length of time that it takes for the owner of a project to recoup its own initial investment out of the project cash flows generated.

Net Present Value - NPV

The model calculates the net present value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. NPV is thus calculated at a time 0 corresponding to the junction of the end of year 0 and the beginning of year 1.

Annual Life Cycle Savings

The model calculates the annual life cycle savings (ALCS) which is the levelized nominal yearly savings having exactly the same life and net present value as the project. The annual life cycle savings are calculated using the net present value, the discount rate and the project life.

Energy production cost

The model calculates the energy production cost per kWh. The energy production cost could be used to either calculate the avoided cost of energy for the project to break even or the economic energy production cost.

Project equity

The model calculates the project equity, which is the portion of the total investment required to finance the project that is funded directly by the project owner(s). The project equity is deemed to be disbursed at the end of year 0, i.e. the development/construction year. It is calculated using the total initial costs, the initial cost incentives and the debt ratio.

Project debt

The model calculates the project debt, which is the portion of the total investment required to implement the project and that is financed by a loan. The project debt leads to the calculation of the debt payments and the net present value. It is calculated using the total initial costs and the project equity.

Debt payments

The model calculates the debt payments, which is the sum of the principal and interest paid yearly to service the debt. Whereas debt payments are constant over the debt term, the principal portion increases and the interest portion decreases with time. In that respect, it is similar to the yearly annuity paid to reimburse the mortgage of a house. Debt payments are calculated using the debt interest rate, the debt term and the project debt.

Yearly Cash Flows Pre-tax

The model calculates the net pre-tax cash flows, which are the yearly net flows of cash for the project before income tax. It represents the estimated sum of cash that will be paid or received each year during the entire life of the project. Note that the initial costs are assumed to occur at the end of year 0 and that year 1 is the first year of operation of the project. Annual costs and savings given in the Financial Summary worksheet, which reflect amounts valid for year zero, are thus escalated one year in order to determine the actual costs and savings incurred during the first year of operation (i.e. year 1).

After-tax

The model calculates the net after-tax cash flows, which are the yearly net flows of cash for the project after income tax. It represents the estimated sum of cash that will be paid or received each year during the entire life of the project.

Cumulative

The model calculates the cumulative cash flows, which represent the net after-tax flows accumulated from year 0. It uses the net flows to calculate the cumulative flows.

Cumulative Cash Flows Graph

The cumulative cash flows are plotted versus time in the cumulative cash flows graph. These cash flows over the project life are calculated in the model and reported in the Yearly Cash Flows table.

Blank Worksheets (3)

These worksheets are provided to allow the user to prepare a customized RETScreen project analysis. For example, the worksheets can be used to enter more details about the project, to prepare graphs, to perform a more detailed sensitivity analysis and to create a custom database.

Note: The RETScreen Software for this step are described in detail in the software manual.

4.7 Greenhouse Gas (GHG) Emission Reduction

Analysis

As part of the RETScreen Clean Energy Project Analysis Software, a GHG Analysis worksheet is provided to help the user estimate the greenhouse gas emission reduction (mitigation) potential of the proposed project. This GHG emission reduction analysis worksheet contains four main sections: Background Information, Base Case System (Baseline), Proposed Case System (Project) and GHG Emission Reduction Summary. The Background Information section provides project reference information as well as GHG global warming potential factors. The Base Case Electricity System and the Base Case Heating System sections provide a description of the emission profile of the baseline system, representing the baseline for the analysis. The Proposed Case Heating System section provides a description of the emission profile of the proposed project, i.e. the PV project. The GHG Emission Reduction Summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections and from values entered or calculated in the other RETScreen worksheets (e.g. annual energy delivered). Results are calculated as equivalent tonnes of CO₂ avoided per annum. This is an optional analysis.

Type of analysis

The user selects the type of analysis from the two options in the drop-down list: "Standard" and "Custom." "Standard" analysis uses many pre-defined parameters in the calculations whereas "Custom" analysis requires that these parameters be entered by the user.

Global Warming Potential of GHG

The model indicates the global warming potential of methane (CH₄) and nitrous oxide (N₂O). If the user selects the "Custom" type of analysis, different values from the default values provided may be entered by the user. Researchers have assigned Global Warming Potentials (GWPs) to greenhouse gases to allow for comparisons of their relative heat-trapping effect. The higher the global warming potential of a gas the greater the contribution to the greenhouse effect. For example nitrous oxide is 310 times more effective than carbon dioxide at trapping heat in the atmosphere.

GWPs of gases are defined as a unit multiple of that given to carbon dioxide (CO₂), which is assigned a reference value of 1 (i.e., the GWP of CO₂ is 1 and the GWP of N₂O is 310). The default values are those defined by the Revised Intergovernmental Panel on Climate Change (IPCC) Guidelines for Greenhouse Gas Inventories, 1996[15].

GHG emission factor

The model calculates the GHG emission factor for each reference fuel type. Values are calculated based on the individual emission factors, the fuel conversion efficiency and the T & D losses, if any. For "On-grid" projects and for applications where the base case power/energy source is "Grid extension," the weighted GHG emission factor for the total electricity mix is calculated on the bottom row of the table. Units are given in tonnes equivalent of CO₂ emission per megawatt-hour of end-use electricity delivered (tCO₂ / MWh).

GHG Emission Reduction Summary

Based on the GHG emission data entered, the model calculates the annual reduction in GHG emissions when the base case system is displaced with the proposed case.

Base case GHG emission factor

The model transfers the base case GHG emission factor calculated in the base case heating system (baseline) section. This value represents the amount of GHG emitted per unit of end-use energy delivered for the base case system. Units are given in tonnes equivalent of CO₂ emission per megawatt-hour of end-use energy delivered (tCO₂ / MWh).

Proposed case GHG emission factor

The model transfers the PV project GHG emission factor calculated in the proposed case electricity system section. This value represents the amount of GHG emitted per unit of end-use energy delivered if the PV project is installed. Units are given in tonnes equivalent of CO₂ emission per megawatt-hour of end-use energy delivered (tCO₂ / MWh).

Annual GHG emission reduction

The model calculates the annual reduction in GHG emissions estimated to occur if the proposed project is implemented. The calculation is based on emission factors of both the base case and the proposed case system and on the end-use energy delivered by the PV project on an annual basis. Units are given in equivalent tonnes of CO₂ emission per year (tCO₂/yr).

Note: The RETScreen Software for this step are described in detail in the software manual.

4.8 Product Data

Some of the product data requirements for the model are provided in the RETScreen Online Product Database. To access the product database, the user may refer to "Data & Help Access."

The product database provides information on the equipment associated with the project. From the online product database dialogue box the user may obtain product specification and performance data, as well as company contact information[17].

Product manufacturers interested in having their products listed in the product database can reach at:

RETScreen@International

CANMET Energy Technology Centre - Varennes

Natural Resources Canada

1615 Lionel-Boulet, P.O. Box 4800

Varenes, Quebec, CANADA J3X 1S6

Tel: +1-450-652-4621

Fax: +1-450-652-5177

E-mail: rets@nrca.gc.ca

Note: The RETScreen Software for this step are described in detail in the software manual.

4.9 Weather Data

This database includes some of the weather data required in the model. To access the weather database the user may refer to "Data & Help Access." While running the software the user may obtain weather data from ground monitoring stations and/or from NASA's satellite data.

Ground Monitoring Stations Data

From the dialogue box, the user selects a region, then a country, then a sub-region (provinces in Canada, states in the United States and N/A in the rest of the countries), and finally a weather station location. The weather station usually corresponds to the name of a city/town within the selected country. From the dialogue box the data can be pasted to the spreadsheets by clicking on the "Paste Data" button. Only data that are in bold are pasted to the spreadsheets; all other data are provided for reference purposes only.

NASA Global Satellite Data

A link to the NASA Surface meteorology and Solar Energy Data Set Website is provided in the online weather database dialogue box. The user is able to select the data required for the model by clicking on a region on the world map illustrated on the NASA Website. The location is narrowed down to a "cell" within a specified latitude and longitude. The user may simply copy and paste this data to the RETScreen spreadsheets or manually enter these values [17].

Note: The RETScreen Software for this step are described in detail in the software manual.

Chapter 5

Analysis, Result & discussion

5.1 Introduction

Our target here is to estimate the cost and investment over a long period of time by using the software, RETscreen International. This is Renewable Energy Project analysis software. Also the financial viability of renewable energy will be evaluated for our useful reference. The project area is considered to be in Sandwip,Chittagong. Below provide the summary of the project:

Project Name: 100 KW solar mini grid at Sandwip Island

Project Location: Sandwip,Chittagong

Nearest location for weather data: Chittagong

Estimated local power requirement: Daily average- 474.10 kWh, Annual-173.046 MWh

Daily Average: 474.10 kWh (AC)

Annual average: 173.046 MWh (AC)

Project Duration analysis for: 20 years

The total investment is calculated considering the Feasibility study, Structural development cost, Engineering and the purchase of Equipments and maintenance cost. Project plan is designed for 20 year of duration.

5.2 Start

The RETScreen® International project information include the project name, location, project type ,analysis type, type of language used , currency, units , symbol & prefixes.

Fig 5.1 shows the project information.The data inputs for the RETScreen Project Information are shown in Figure 5.1.

Project information [See project database](#)

Project name: 100 kW Solar mini-grid at Sandwip Islan
 Project location: Chittagong, Bangladesh
 Prepared for: Daffodil International University
 Prepared by: Md.Obydul Islam & Md.Habibur Rahman
 Project type: Power
 Technology: Photovoltaic
 Grid type: Off-grid
 Analysis type: Method 2
 Heating value reference: Higher heating value (HHV)
 Show settings:
 Language - Langue: English - Anglais
 User manual: English - Anglais
 Currency: Bangladesh
 Units: Metric units

Site reference conditions [Select climate data location](#)

Climate data location: Châttagâm
 Show data:

Unit	Climate data	
	location	Project location
Latitude	°N	22.3
Longitude	°E	91.8
Elevation	m	13
Heating design temperature	°C	16.5
Cooling design temperature	°C	29.9
Earth temperature amplitude	°C	9.0

Month	Air temperature		Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heatingdegree-days	Coolingdegree-days
	°C	%							
January	20.4	54.7%	4.42	100.1	2.0	21.6	0	322	
February	22.7	55.3%	4.98	100.0	2.2	23.9	0	354	
March	25.2	61.7%	5.44	99.7	2.3	27.0	0	472	
April	26.3	73.1%	5.51	99.5	2.4	28.1	0	489	
May	27.1	79.1%	5.11	99.2	2.4	28.8	0	531	
June	27.5	84.7%	4.16	98.9	2.7	28.4	0	525	
July	27.3	85.9%	4.04	98.9	2.6	27.9	0	535	
August	27.1	85.5%	4.18	99.0	2.3	27.8	0	531	
September	26.7	84.1%	4.02	99.3	1.9	27.6	0	502	
October	26.0	77.9%	4.28	99.7	1.6	26.8	0	496	
November	23.8	69.4%	4.25	100.0	1.8	24.4	0	413	
December	21.3	60.1%	4.28	100.2	1.8	22.1	0	351	
Annual	25.1	72.7%	4.55	99.5	2.2	26.2	0	5523	
Measured at	m				10.0	0.0			

Complete Energy Model sheet

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Fig 5.1 Project Information

5.3 Energy model

In the base case system we assume that 100 KW diesel generator and base case load 93800W. The data inputs for the RETScreen Energy model power project base case system and the results are shown in Figure 5.2.

RETScreen Energy Model - Power project

Power project

Base case power system

Grid type	Off-grid	
Technology	Reciprocating engine	
Fuel type	Diesel (#2 oil) - L	
Fuel rate	BDT/L	70,000
Capacity	kW	100.00
Heat rate	kJ/kWh	12,000
Annual O&M cost	BDT	30,000
Electricity rate - base case	BDT/kWh	22.060
Total electricity cost	BDT	3,817,473

Load characteristics

Method 1 Method 2

Description	AC/DC	Intermittent resource-load correlation	Base case load W	Hours of use per day h/d	Days of use per week d/w	Proposed case load reduction %	Proposed case usage time reduction %
CFL LIGHT	AC	Negative	32,000.00	5.00	7		
FAN	AC	Zero	27,000.00	7.00	7		
TV	AC	Zero	8,000.00	4.00	7		
FREEZE	AC	Zero	5,000.00	10.00	7		
AC	AC	Negative	2,000.00	4.00	7		
PRINTER	AC	Positive	6,000.00	0.75	7		
COMPUTER	AC	Zero	5,000.00	4.00	7		
PHOTOCOPIY	AC	Positive	1,800.00	2.00	7		
OTHERS LOAD	AC	Negative	7,000.00	1.00	7		

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh	0.00	0.00
Electricity - daily - AC	kWh	474.10	474.10

Percent of month used

		Base case	Proposed case	Energy saved
Electricity - annual - DC	MWh	0.000	0.000	
Electricity - annual - AC	MWh	173.047	173.047	0%
Peak load - annual	kW		70.00	

Fig 5.2 Base case system

The data inputs for the RETScreen power project Propose case system and the results are shown in Figure 5.3

Proposed case power system			
Inverter			
Capacity	kW	98.0	Peak load - annual - AC
Efficiency	%	90%	
Miscellaneous losses	%	2%	
Battery			
Days of autonomy	d	1.0	
Voltage	V	48.0	
Efficiency	%	90%	
Maximum depth of discharge	%	60%	
Charge controller efficiency	%	90%	
Temperature control method		Ambient	
Average battery temperature derating	%	0.3%	
Capacity	Ah	12,000	19,071
Battery	kWh	576	
Technology			
Photovoltaic			
Resource assessment			
Solar tracking mode		Fixed	
Slope	°	23.2	
Azimuth	°	0.0	
<input checked="" type="checkbox"/> Show data			
		Daily solar radiation - horizontal	Daily solar radiation - tilted
		kWh/m²/d	kWh/m²/d
Month			Electricity delivered to load
			MWh
January	4.42	5.56	13.32
February	4.98	5.79	12.43
March	5.44	5.78	13.71
April	5.51	5.41	12.54
May	5.11	4.77	11.63
June	4.16	3.84	9.29
July	4.04	3.77	9.42
August	4.18	4.02	9.93
September	4.02	4.08	9.66
October	4.28	4.73	11.35
November	4.25	5.12	11.81
December	4.28	5.53	13.18
Annual	4.55	4.86	138.29
Annual solar radiation - horizontal	MWh/m ²	1.66	
Annual solar radiation - tilted	MWh/m ²	1.77	
Photovoltaic			
Type		poly-Si	
Power capacity	kW	100.00	142.9%
Manufacturer	Kyocera		
Model	poly-Si - KC200GT		
Efficiency	%	14.2%	500 unit(s)
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m ²	704.2	
Control method	Maximum power point tracker		
Miscellaneous losses	%	2.0%	
Summary			
Capacity factor	%	18.3%	
Electricity delivered to load	MWh	138.29	79.9%
Peak load power system			
Technology			
Reciprocating engine			
Fuel type	Diesel (#2 oil) - L		
Fuel rate	BDT/L	70.000	
Charger efficiency	%	90.0%	
Suggested capacity	kW	70.0	
Capacity	kW	41	58.6%
Electricity delivered to load	MWh	34.8	20.1%
Manufacturer	Yanmar Diesel Engine		
Model	4TNV84T		
Heat rate	kJ/kWh	12,000	1 unit(s)

Fig 5.3 Propose case system

5.4 Cost analysis

The cost components are divided into initial cost and annual (operation and maintenance) cost. The initial cost is further broken into: feasibility study, development, engineering, power system, and balance of system & miscellaneous. The cost categories are further broken down as shown in Fig 5.4. The data inputs for the RETScreen CostAnalysis Power project Method 2 is shown in Figure 5.4, and Annual cost, Annual savings & Periodic cost as calculated by RETScreen and the detailed cost evaluation for the project is presented in Figure 5.5.

RETScreen Cost Analysis - Power project

Settings						
<input type="radio"/> Method 1	<input checked="" type="radio"/> Notes/Range	Notes/Range				
<input checked="" type="radio"/> Method 2	<input type="radio"/> Second currency	None				
	<input type="radio"/> Cost allocation					
Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs	
Feasibility study						
Site investigation	p-d	1	BDT 404,397	BDT 404,397		
Resource assessment	project			BDT -		
Environmental assessment	p-d	1	BDT 731,900	BDT 731,900		
Preliminary design	p-d			BDT -		
Detailed cost estimate	p-d			BDT -		
GHG baseline study & MP	project			BDT -		
Report preparation	p-d			BDT -		
Project management	p-d			BDT -		
Travel & accommodation	p-trip			BDT -		
User-defined	cost			BDT -		
Subtotal:				BDT 1,136,297		2.0%
Development						
Contract negotiations	p-d	1	BDT 754,895	BDT 754,895		
Permits & approvals	p-d			BDT -		
Site survey & land rights	p-d	1	BDT 619,322	BDT 619,322		
GHG validation & registration	project			BDT -		
Project financing	p-d			BDT -		
Legal & accounting	p-d	1	BDT 626,000	BDT 626,000		
Project management	p-d	1	BDT 1,667,521	BDT 1,667,521		
Travel & accommodation	p-trip			BDT -		
User-defined	cost	1	BDT 4,364,720	BDT 4,364,720		
Subtotal:				BDT 8,032,458		14.3%
Engineering						
Site & building design	p-d			BDT -		
Mechanical design	p-d			BDT -		
Electrical design	p-d	1	BDT 1,808,500	BDT 1,808,500		
Civil design	p-d			BDT -		
Tenders & contracting	p-d			BDT -		
Construction supervision	p-d			BDT -		
User-defined	cost			BDT -		
Subtotal:				BDT 1,808,500		3.2%
Power system						
Base load - Photovoltaic	kW	100.00	BDT 195,000	BDT 19,500,000		
Peak load - Reciprocating engine	kW	41.00	BDT 18,300	BDT 750,300		
Road construction	km			BDT -		
Transmission line	km	1	BDT 3,434,102	BDT 3,434,102		
Substation	project			BDT -		
Energy efficiency measures	project			BDT -		
User-defined	cost	1	BDT 10,124,334	BDT 10,124,334		
Subtotal:				BDT 7,225,000		73.7%
Balance of system & miscellaneous						
Specific project costs						
Delivery equipment	project			BDT -		
Preparation equipment	project			BDT -		
Storage equipment	project			BDT -		
Distribution equipment	project			BDT -		
Building & yard construction	m ²			BDT -		
Spare parts	%			BDT -		
Transportation	project			BDT -		
Training & commissioning	p-d			BDT -		
User-defined	cost	1	BDT 3,843,986	BDT 3,843,986		
Contingencies	%			BDT 56,354,977		
Interest during construction				BDT 56,354,977		
Subtotal:				BDT 3,843,986		6.8%
Total initial costs				BDT 56,354,977		100.0%

Fig 5.4 Total cost

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Land lease & resource rental	project			BDT -
Property taxes	project			BDT -
Insurance premium	project			BDT -
Parts & labour	project	1	BDT 542,000	BDT 542,000
GHG monitoring & verification	project			BDT -
Community benefits	project			BDT -
General & administrative	%		BDT 542,000	BDT -
User-defined	cost	1	BDT 334,836	BDT 334,836
Contingencies	%		BDT 876,836	BDT -
Subtotal:				BDT 876,836
Fuel cost - proposed case				
Diesel (#2 oil)	L	12,076	BDT 70,000	BDT 845,327
Subtotal:				BDT 845,327
Annual savings				
Fuel cost - base case				
Diesel (#2 oil)	L	54,107	BDT 70,554	BDT 3,817,473
Subtotal:				BDT 3,817,473
Periodic costs (credits)				
User-defined	cost			BDT -
battery replacement		10	BDT 16,368,705	BDT 16,368,705
End of project life	cost			BDT -

Fig 5.5 Annual cost, Annual savings & Periodic cost

5.5 Emission analysis

In this project the optimized system utilizes 100 KW generator and about 54107 L of diesel per year. The total amount of carbon dioxide emission is about 113 kg/ year. fig 5.6 clearly depicts about the emitted environment pollutants and their amount of emission per year. From this figure we can ensure and recount this Solar mini grid is quite environment friendly.

RETScreen Emission Reduction Analysis - Power project

Emission Analysis							
<input type="radio"/> Method 1 <input checked="" type="radio"/> Method 2 <input type="radio"/> Method 3		Global warming potential of GHG 25 tonnes CO2 = 1 tonne CH4 (IPCC 2007) 298 tonnes CO2 = 1 tonne N2O (IPCC 2007)					
Base case system GHG summary (Baseline)							
Fuel type	Fuel mix %	CO2		N2O	GHG		GHG emission tCO2
		emissionfactor kg/GJ	CH4 emissionfactor kg/GJ	emissionfactor kg/GJ	Fuelconsumption MWh	emissionfactor tCO2/MWh	
Diesel (#2 oil)	100.0%	69.3	0.0019	0.0019	577	0.252	145.3
Total	100.0%	69.3	0.0019	0.0019	577	0.252	145.3
Proposed case system GHG summary (Power project)							
Fuel type	Fuel mix %	CO2		N2O	GHG		GHG emission tCO2
		emissionfactor kg/GJ	CH4 emissionfactor kg/GJ	emissionfactor kg/GJ	Fuelconsumption MWh	emissionfactor tCO2/MWh	
Diesel (#2 oil)	48.2%	69.3	0.0019	0.0019	129	0.252	32.4
Solar	51.8%	0.0	0.0000	0.0000	138	0.000	0.0
Total	100.0%	33.4	0.0009	0.0009	267	0.121	32.4
GHG emission reduction summary							
Power project	Base caseGHG emission		Proposed caseGHG emission		Gross annualGHG emissionreductio	GHG creditstransactio	Net annualGHG emissionreductio
	tCO2		tCO2		n tCO2	n fee %	n tCO2
	145.3		32.4		112.8		112.8
Net annual GHG emission reduction		113	tCO2	is equivalent to	20.7	Cars & light trucks not used	

Fig 5.6 Emission analysis

5.6 Financial analysis

The data inputs for the RETScreen Power project Financial parameters and the results are shown in Figure 5.7. Here we assume that Fuel cost escalation rate 10%, Inflation rate 5%, Discount rate 2%, Project life 20 years, Debt ratio 30%, Debt interest rate 6%, Debt term 10 years, Effective income tax rate 35%, Depreciation rate 15%, Tax holiday duration 15 years.

RETScreen Financial Analysis - Power project		
Financial parameters		
General		
Fuel cost escalation rate	%	10.0%
Inflation rate	%	5.0%
Discount rate	%	2.0%
Project life	yr	20
Finance		
Incentives and grants	BDT	28,856,639
Debt ratio	%	30.0%
Debt	BDT	16,906,493
Equity	BDT	39,448,484
Debt interest rate	%	6.00%
Debt term	yr	10
Debt payments	BDT/yr	2,297,051
Income tax analysis <input checked="" type="checkbox"/>		
Effective income tax rate	%	35.0%
Loss carryforward?		No
Depreciation method		Straight-line
Depreciation tax basis	%	73.7%
Depreciation period	yr	15
Tax holiday available?	yes/no	Yes
Tax holiday duration	yr	15

Fig 5.7 Financial parameters

The detailed cost evaluation for the real project is presented in Figure 5.8, Fig 5.9 Annual income, Fig 5.10 Financial viability, Fig 5.11 Yearly cash flows & Fig 5.12 Cumulative Cash flows graph.

Project costs and savings/income summary			
Initial costs			
Feasibility study	2.0%	BDT	1,136,297
Development	14.3%	BDT	8,032,458
Engineering	3.2%	BDT	1,808,500
Power system	73.7%	BDT	41,533,736
Balance of system & misc.	6.8%	BDT	3,843,986
Total initial costs	100.0%	BDT	56,354,977
Incentives and grants		BDT	28,177,339
Annual costs and debt payments			
O&M		BDT	876,836
Fuel cost - proposed case		BDT	845,327
Debt payments - 10 yrs		BDT	6,125,469
Total annual costs		BDT	7,847,632
Periodic costs (credits)			
battery replacement - 10 yrs		BDT	16,368,705
Annual savings and income			
Fuel cost - base case		BDT	3,817,473
Other income (cost) - 20 yrs		BDT	1,600,000
Total annual savings and income		BDT	5,417,473

Fig 5.8 Project costs and savings/income summary

Annual income			
Electricity export income			
<hr/>			
GHG reduction income			<input checked="" type="checkbox"/>
Net GHG reduction	tCO2/yr		113
Net GHG reduction - 20 yrs	tCO2		2,269
GHG reduction credit rate	BDT/tCO2		
<hr/>			
Customer premium income (rebate)			<input checked="" type="checkbox"/>
Electricity premium (rebate)	%		
<hr/>			
Customer premium income (rebate)	BDT		0
<hr/>			
Other income (cost)			<input checked="" type="checkbox"/>
Energy	MWh		50
Rate	BDT/MWh		32,000.000
Other income (cost)	BDT		1,600,000
Duration	yr		20
Escalation rate	%		4.0%
<hr/>			
Clean Energy (CE) production income			<input type="checkbox"/>

Fig 5.9 Annual income

Financial viability		
Pre-tax IRR - equity	%	27.2%
Pre-tax IRR - assets	%	13.1%
<hr/>		
After-tax IRR - equity	%	19.6%
After-tax IRR - assets	%	14.2%
<hr/>		
Simple payback	yr	7.4
Equity payback	yr	5.8
<hr/>		
Net Present Value (NPV)	BDT	56,222,882
Annual life cycle savings	BDT/yr	3,438,407
<hr/>		
Benefit-Cost (B-C) ratio		2.43
Debt service coverage		1.75
<hr/>		
GHG reduction cost	BDT/tCO2	(30,307)

Fig 5.10 Financial viability

Yearly cash flows			
Year #	Pre-tax BDT	After-tax BDT	Cumulative BDT
0	-10,591,845	-15,504,193	-15,504,193
1	1,733,264	1,733,264	-13,770,928
2	2,082,490	2,082,490	-11,688,439
3	2,464,946	2,464,946	-9,223,493
4	2,883,911	2,883,911	-6,339,583
5	3,342,990	3,342,990	-2,996,592
6	3,846,150	3,846,150	849,558
7	4,397,752	4,397,752	5,247,310
8	5,002,593	5,002,593	10,249,902
9	5,665,949	5,665,949	15,915,851
10	-20,269,272	-20,269,272	-4,353,421
11	9,489,052	9,489,052	5,135,631
12	10,365,154	10,365,154	15,500,785
13	11,326,704	11,326,704	26,827,488
14	12,382,197	12,382,197	39,209,686
15	13,540,980	13,540,980	52,750,666
16	14,813,331	9,628,665	62,379,331
17	16,210,559	10,536,864	72,916,195
18	17,745,103	11,534,317	84,450,511
19	19,430,645	12,629,920	97,080,431
20	-22,148,809	-22,148,809	74,931,622

Fig 5.11 Yearly cash flows

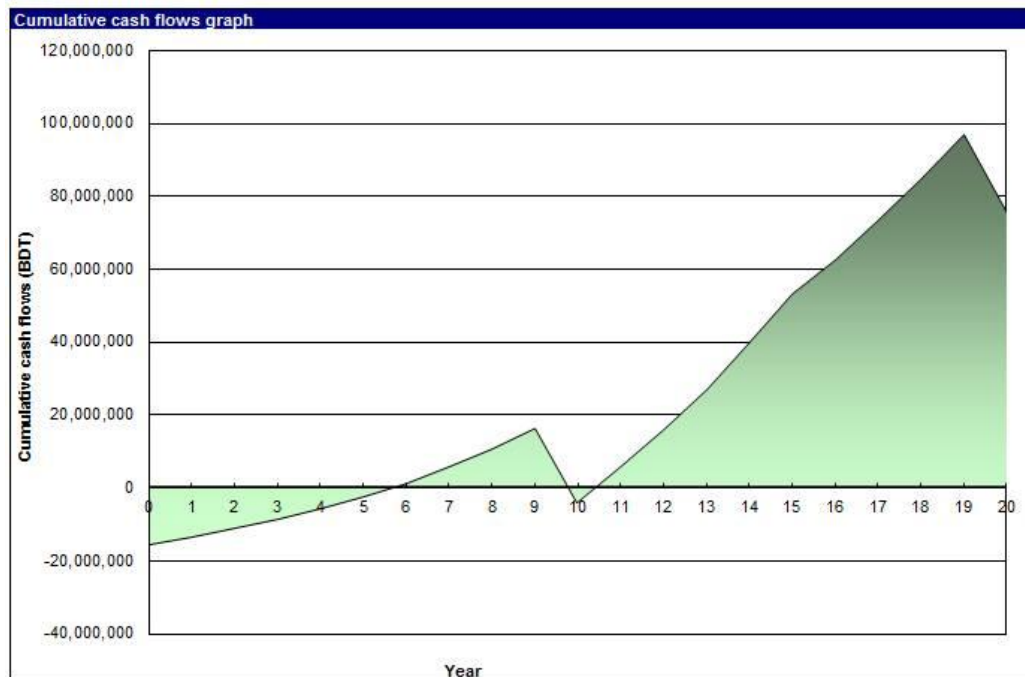


Fig 5.12 Cumulative Cash flows graph

5.7 Result

Cost analysis of the system has been performed excluding the cost of the 100 kW solar mini grid and it is predicted from fig. 5.12 that the investment money will be pay backed after 7.4 years. The result shows that the 100 kW solar mini grid financially viable at the prevailing market condition. This can clearly be seen in the cumulative cash flow graph (Fig 5.12), where right from year one, the profit begins to increase to about TK 7,49,31,622 by end of the entire project life of 20 years.

5.8 Discussion

1. In this project battery must be replaced every 10 years. So there is extra cost after every 10 years other than the initial install cost. Load may vary during any part of the day. GHG analysis sheet is used. The nearest location in this software was used Chittagong. Weather data of the project location would give much realistic result.
2. Studies have shown that the sustainability of off-grid electrification in rural areas depends on the level use of the electricity for productive purposes. Thus, other programmes that help in the development of micro-scale enterprises should be considered alongside the off-grid electrification programme to increase the income available to the rural dwellers to encourage payment for the electricity services.
3. There may also be some technical risks involved in building the mini-grid for the project, metering, installation of new modules if load exceeds the capacity. The investor must possess requisite technical skills to manage the technical challenges that may arise. In addition, as the educational level of rural dwellers is usually low, getting people with requisite knowledge to carry out basic or emergency maintenance on such facilities should need arise may be difficult, thus in planning for such projects, there is need to train few people in the community on maintenance.
4. Solar radiation data is available from several sources including satellite simulations. The data collection and simulation is a complex procedure and

can have inaccuracies varying from 3 to 20%. The most reliable data is ground measured with accurate instruments.

5. The performance (Capacity utilization factor) CUF depends on several factors including the solar radiation, temperature, air velocity apart from the module type and quality, angle of tilt(or tracking), design parameters to avoid cable losses and efficiencies of inverters and transformers. There are some inherent losses which can be reduced through proper designing but not completely avoided.
6. Rural consumers are by nature conservative customers, they earn low incomes and are thus sensitive on how they spend their hard earned money. And although they may understand the advantages electrification has to offer, they will trade cautiously on the cost of the service, and will look out for the best way to save money. Therefore, in the event of electrification, innovativeness is necessary in ensuring that the electricity tariff is low enough to entice rural consumers to initially take up the energy service. But also, community participation is important in ensuring the success of the project, as their input offers a more solid foundation on the needs and views of the people. All these factors need to be considered in the prefeasibility phase of the project before any decision to implement is made.

Chapter 6

Conclusion

6.1 Conclusion

This paper could be summarized from the analysis that the project life time has been considered to be 20 years. The internal rate of return on positive and internal rate of return on equity(19.6%) & internal rate of return on asset (14.2%) the simple payback is time (7.4 years) capacity factor of 18.3%, with a positive NPV. The result shows an excellent electrical, economic and environmental profile. The unmet load is about zero and the cost of energy per unit is competitive with the conventional system. Again the emission of pollutants is pretty much low. Initial establishment cost and total NPC over total lifespan is reasonable. The increase in load in future can be met with a small tuning in the system as there exists some excess electricity. So the system is feasible for Bangladesh. Any government or non – government organization interested in PV mini grid system can utilize this model for implementing their project.

6.2 Recommendation as an Engineer

1. There is a vast scope of solarizing existing Solar – Diesel Mini Grids/ establishing stand – alone Solar Mini Grids in Bangladesh [5 MW and above] This photovoltaic system can be installed in those rural, hilly and island region where the people are deprived from the power source of main grid [24].
2. The government should subsidized the procurement and installation cost considering Solar Energy as a primary Green Electricity source to overcome present energy crisis.
3. Intelligent devices like microprocessors, PLC (programmable logic controller) may be added to the system to keep the operating point (maximum power point) for maximum efficiency. To taken care of the uncertainty in the insolation level, use of fuzzy control can be done. Use of feedback path for automatic control- position control servo for changing the transformation ratio

4. For successful implementation of renewable energy projects and initiatives lending procedure will be simplified and strengthened.
5. Existing renewable energy financing facility shall be expanded that is capable of accessing public, private, donor, carbon emission trading (CDM) and carbon funds and providing financing for renewable energy investments.
6. In addition to commercial lending, a network of micro-credit support system will be established especially in rural and remote areas to provide financial support for purchases of renewable energy equipment.
7. Power Division of Ministry of Power, Energy and Mineral Resources will facilitate investment in renewable energy and energy efficiency projects. Sustainable Energy Development Agency, in co-operation with local government offices, will set up an outreach program to develop renewable energy programs.
8. Sustainable Energy Development Agency will consider providing subsidies to utilities for installation of solar, wind, biomass or any other renewable/clean energy projects.
9. Private sector participation including joint venture initiatives in renewable energy development will be encouraged and promoted. Power Division of Ministry of Power, Energy and Mineral Resources / Sustainable Energy Development Agency may assist in locating the project(s) and also assist in acquiring land for renewable energy project(s).
10. Renewable energy project investors both in public and private sectors shall be exempted from corporate income tax for a period of 10 years from the date of notification of this policy in the official gazette and it will be extended periodically following impact assessment of tax exemption on renewable energy.
11. There is limited potential of small hydro power plants in the hilly regions and existing irrigation project locations. BPDB and Bangladesh Water Development Board (BWDB) should work together to implement a pilot project at any of the prospective regulating structures of Tista Canal system.
12. Given that renewable energy technologies are still initially more expensive in comparison to the alternatives. The corresponding energy costs are high. With current research trends, this should change in the nearby future. Locally designed and fabricated renewable energy technologies, displace the cost and need for importing system components.

13. There are also still plenty of research opportunities in more efficient and reliable power conditioning devices, also energy storage technologies are still progressing towards better energy densities and conversion efficiencies, and lower maintenance needs, as demonstrated by technologies such as fly wheels, ultra-capacitors and advanced batteries of lithium, sodium, and flow batteries. Energy storage has an important role in renewable energy applications, and better storage technologies will lead to more reliable hybrid mini-grid system operation.
14. Also hybrid mini-grids require trained personnel for operation. Through community participation, implementers should be in a position to organize and train a few community members on the day-to-day technical aspects of operating the system. This will ensure system operational stability even in the absence of the regulators.
15. Most importantly, a viable financial model needs to be developed to ensure economic sustainability of rural electrification projects. Many of these systems struggle to survive without donor participation or government subsidies. A sustainable economic structure can be structured around mechanisms such as renewable energy funding schemes, enabling the commercial viability of rural renewable energy electrification programs.

Future work Plan

1. Incorporate other energy sources, such as wind or hydro turbines, into the hybrid system analysis.
2. Incorporate the ability to model and compare both DC and AC coupled system architectures
3. Make more use of the open-source approach to software development. Making proprietary models and tools more open would allow further development by a broader community and reduce the risk that valuable work is lost because the original developers no longer have the time or resources to continue maintenance and further development.
4. Develop an <intermediate> tool for experienced designers that is more flexible than the basic dimensioning tools but is oriented towards system design rather

than to research and simulation. The tool should incorporate the improvements listed above.

5. To promote solar water heaters, use of electricity and gas for water heating will be discouraged. In this regard necessary steps will be considered accordingly.
6. It would be desirable to monitor the solar plant installations and build up database for future work. It is also recommended to carry out a detailed study for several locations with active involvement of IMD database.
7. Research should be conducted to establish the financial viability of using other sources of clean energy fuels such as biomass and biogas as a substitute to bio-oil.
8. A comprehensive study should be carried out to assess the biomass potential of the country for modern applications like gasifiers. Waste-to-energy project should be given serious contemplation which will not only provide electricity, but also reduce the unpleasant waste disposal problems of metropolitan cities of the country.
9. Where possible, links should be made with energy efficiency considerations. For example, solar water heaters are perfect to promote in the tourist sector in these sunny islands, but the message may come around more convincing when solar water heaters are promoted as part of a range of energy saving options that result from energy audits in hotel buildings.
10. The solar data that has been analyzed in this thesis were obtained from satellite observations that are readily available online, however these data are not as accurate as ground measurements. Therefore, in future work, ground measurements could be utilized for more reliable results.
11. Using different types of renewable energy in hybrid systems, in order to utilize all available renewable energy resources, may offer an option for higher reliability. Therefore, this thesis may be a starting point for further work on future projects for e.g. use of PV/wind turbine systems.
12. Studying the impact of high penetration level of PV systems on the utility grid could be good subject for future work.
13. In addition, as future technology becomes smarter, studying the option of using smart grid functionality with PV-grid connected system could be also good subject for future work.

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