DEVELOPMENT OF SOLAR PHOTO VOLTAIC SYSTEM FOR THE PREMISES OF NEPAL OIL CORPORATION Ltd. KATHMANDU IN NEPAL

A DISSERTATION

Submitted in partial fulfillment of the Requirement for the award of the degree

of

MASTER IN TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEM

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is presented in this report, entitled, **"DEVELOPMENT OF SOLAR PHOTO VOLTAIC SYSTEM FOR THE PREMISES OF NEPAL OIL CORPORATION Ltd. KATHMANDU IN NEPAL",** submitted in partial fulfillment of the requirement for the award of the degree of Master of Technology in **"Alternate Hydro Energy Systems" in Department of Hydro and Renewable Energy, Indian Institute of Technology, Roorkee,** is an authentic record of my own work carried out during the period from July 2018 to June 2019 under the supervision and guidance of **Dr. R.P. Saini**, Professor, **Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee, Roorkee.**

I also declare that I have not submitted the matter embodied in this report for award of any degree.

Date: June 2019 **(TILA SUBEDI)**

Place: IIT, Roorkee

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

According to the annual report data record 2073/74 of Nepal oil Corporation Ltd., high budget expenditure is used for purchase the petroleum products from the third country to fulfill the daily energy needs and is increasing its demand by 20% per annum. Also, the trend of daily increasing price of petroleum products proportion to the money inflation/deflation rate plays vital role that directly affects the country economy. Together with the high potential of Hydroelectricity, Nepal has huge potential in solar energy. In the present scenario, Solar Photovoltaic (SPV) technology has been applied in standalone plants in Nepal, mostly in rural areas. Despite this, nation should launch such a clear directive in institutional policy for SPV technology comprising with the diversified techno economic and financial indicator that play vital role for energy management scheme in present and future as well. Now days its popularity has been utilized in industrial state and may cross the milestone for the present energy crunch in near future.

In this dissertation work, one of fuel storage depot of Nepal Oil Corporation Ltd. Kathmandu in Nepal was selected as study area. The proposed site is suitable for Development of Solar Photovoltaic Plant, allowing the optimum sun exposure of 300 days in year sunshine with average insolation intensity about 4.7 kWh/m ^{2}/day. The main objective of the dissertation work is to size a solar power generation plant utilizing the optimum available area in the fuel depot premises.

Under the present study, the rooftop area of the various buildings, fuel storage vertical tank including barren land, situated at the Nepal oil corporation premises is calculated as 33146.53m ^{2} to install the solar photovoltaic system for electricity generation. To size the solar photovoltaic plant typical meteorological year (TMY) data for hourly solar irradiance is collected from the National Renewable Energy Laboratory (NREL) website. Simulations were performed using solar industry's leading design tool, PVSYST for the system produced energy prediction which yields 3777MWh/year. Per unit generation cost is also calculated which come to be as NPR 5.28 for the grid-connected system. Though, per unit generation cost comparatively is high in designing the standalone system so that grid connected is preferred. After sizing the solar power plant, the total power plant capacity is recommended as 2 MW. Finally, power generated from the proposed solar plant is proposed to be evacuated through 11 KV pooling substation connected through a 11 kV transmission line to NEA owned Mathatritha Grid Substation at a distance of around 4 km from the proposed site. It is found that SPV could be a good alternative solution to fulfill current as well as future energy of the study area. However, there is a need to conduct further extensive studies on techno-economic viability.

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ABBREVIATIONS

SPV	Solar Photovoltaic
GoN	Government of Nepal
SWPS	Solar Water Pumping System
MPPT	Maximum Power Point Tracking
NPC	National Planning Commission
NEA	Nepal Electricity Authority
AEPC	Alternate Energy Promotion Centre
CBS	Central Bureau of Statistics
MoFN	Ministry of Finance
MoEN	Ministry of Energy
DoED	Department of Electricity Development
TMY	Typical Meteorological Year
NREL	National Renewable Energy Laboratory
NTPC	National Thermal Power Corporation
RET	Renewable Energy Technology
RPO	Renewable Purchase Obligation
GPS	Geographical Positioning System
NOC	Nepal Oil Corporation
TLF	Tank Lorry Filling
SKO	Superior Kerosene Oil
MS	Motor Spirit
HSD	High Speed Diesel
GIS	Geographical Information System
GCS	Geographic Coordinate System
WGS	World Geodetic System
LiDAR	Light Detection and Ranging
UTM	Universal Transverse Mercator
SCADA	Supervisory control and data acquisition
MATLAB	Matrix Laboratory
ANN	Artificial Neural Network
NSRDB	The National Solar Radiation Database
DG	Diesel Generator

IRR	Internal Rate of Return
IDC	Interest During Construction
EPC	Engineering, Procurement and Construction
CFAT	Cash Flow After Tax
PLF	Plant Load Factor
EOY	End of Year
O&M	Operation and Maintenance
DSCR	Debt Service Coverage Ratio
B/C	Benefit Cost Ratio
kW	Kilo Watt
MW	Mega watt
kWh	Kilo Watt hour
GWh	Giga Watt hour
MWh	Mega Watt hour
PLF	Plant Load Factor
NPV	Net Present Value
LCOE	Levelized Cost of Electricity
PPA	Power Purchase Agreement
PR	Performance Ratio
CUF	Capacity Utilization Factor
EYA	Energy Yield Assessment
STC	Standard Testing Condition
IAM	Incidence Angle Modifier
KVA	Kilo Volt Ampere
IPPs	Independent Power Producers
NPR	Nepalese Rupee
INR	Indian Rupee
PI	Profitability Index
CF	Cash Flow
PBP	Payback Period
SF	Solar Fraction

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The application of energy by the society has begun far from the development of human civilization. Solar energy, the ultimate source of energy, was used without conversion and mechanization in the ancient age. Solar radiation is becoming the best option and cost-effective energy resources of this world from 21st century onwards. Likewise, the abundant solar irradiation availability in Nepal shows encouraging atmosphere for solar development and farming venture in near future which can be a better solution for energy management in Nepal [1].

The average global solar radiation in Nepal varies from 3.6-6.2 kWh/m^2 /day, with sun shines of 300 days in a year, the number of sunshine hours almost amounts 2100 hours per year and average insolation intensity about 4.7 kWh/m^2/day (=16.92 MJ/m^2/day) it is greater than 4.38kWh/m^2/day (15.8 MJ/m^2day) measured by for Lao PDR. It was observed that the maximum value of seasonal solar radiation data, monthly solar radiation data and global solar radiation data is in Jumla whereas the minimum value was observed in Kathmandu for the same. The solar radiation data record trend is not systematic throughout the country. Though, Lao PDR based data from few years was reviewed at some site. Nepal lies in the favorable insolation zone with diversified geography. Thus, continuous observation throughout the country should be done in order to prove this statement [2-4].

Nepal is a landlocked country bordered by China and India with diversity in biosphere, climate (arctic/alpine to tropical) and diversified topography (lowland 72 m to highest peak 8848 m above the sea level). Due to insufficient technology and skilled manpower, Nepal does not extract its own coal and petroleum resources till date. On one hand, Nepal is dependent on import to fulfill its fuel demands from the third country and on the other hand, fossil fuels are non-renewable energy source. Moreover, it is clear that the dependency on fossil fuels are long-term threat to environmental sustainability.

In order to break this dependency, there should be clean energy revolution globally which can strengthen global energy security, insist long- term economic growth and handle environmental challenges such as anthropogenic climate change. Available literature shows that the rapid increasing rate of consumption trend in petroleum products is about 20 % per annum. This data is not a good sign of sustainability for country like Nepal [5&6].

Solar photovoltaic technology is old technology for Nepal looking back to the history, first solar PV was installed at Bhadrapur airport in 1963 in Nepal. During that time, due to higher investment and annual recurring cost compared to national grid electricity the use of solar photovoltaic system was not considered promising technology in government institutions, office as well as urban areas. Hence the SPV system is not developed satisfactorily in Nepal [7].

Now the declining trend of cost of solar photovoltaic component has aided from supplying quantitative and qualitative electricity in many office areas. Because of its flexibility in technology and advancement, installation of solar photovoltaic technology can be mounted on the ground, integrated with farming and grazing and also in water conducted channels, built as the roof and walls of the building as a building-integrated photovoltaic technique. The installation for the development of solar photovoltaic technology in case of office area feasible because the land availability is more, so the large scale as well as small scale of harnessing solar electricity from the rooftop in office building can be the best option to solve and manage energy demand in offices.

1.2 ELECTRICITY CONSUMPTION SCENARIO OF NEPAL

In Nepal, most of the people used traditional energy like fuel-wood, agriculture residues and animal dung. Expression of these energy in mathematical term is 91% percent and commercial energy like petroleum, hydropower and coal constitutes 9% as presented in Figure 1.1 [8].

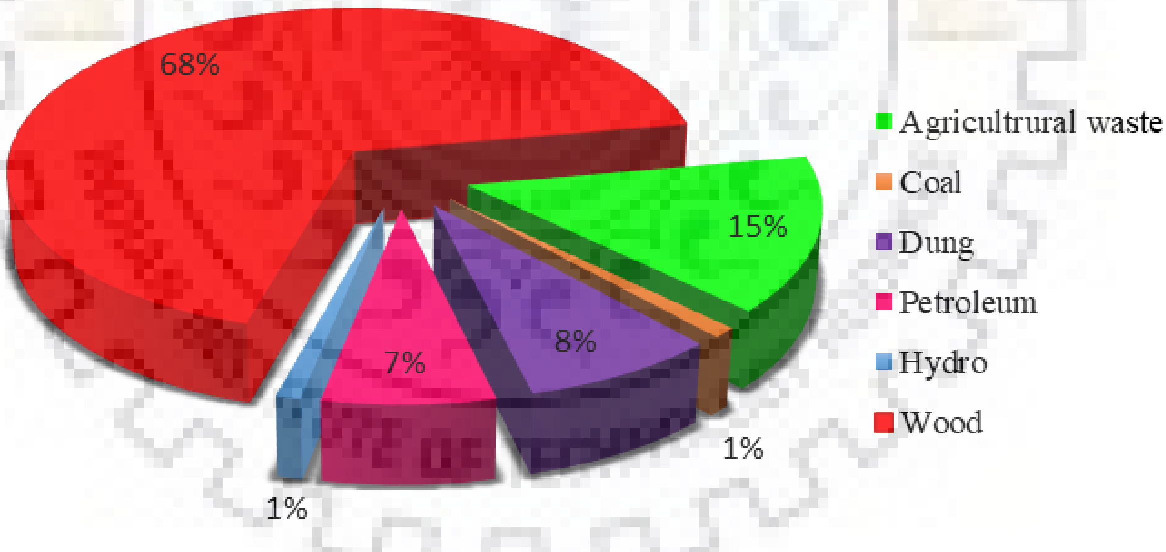


Figure 1.1 Energy Profile of Nepal [9].

Nepal relies heavily on traditional sources of energy. It has snowy mountains in the North acting as a perennial source for many rivers, streams and glaciers. The country has a capacity of producing 40 GW of hydropower from techno economically viability. But till date only 1.073 GW of generation capacity including that of the Independent Power Producers (IPPs) of capacity 511 MW is managed by the nation. Since generation capacity of nation is unable to fulfill the demand of energy the country, 479 MW of electricity is imports from India to fulfill the demand. Though country is rich in hydropower resources the development of large hydropower with respect to its potential is quite slow. thus, Nepal placed as unique case in term of rich in hydropower resources and poor in terms of hydropower generation considering its potential. Electricity, the only available utility energy, is mainly dependent on hydropower. The share of available electrical energy in the national electricity grid in Nepal is presented in Figure 1.2. Nepal does not have its own fossil fuel reserve. According to the annual report data record 2073/74 of Nepal oil Corporation Ltd., high budget fund is allotted in every fiscal year to purchase the petroleum products from the third country to fulfill the daily energy needs and is increasing its demand by 20% per annum[59]. Also, the trend of daily increasing price of petroleum products proportion to the money inflation/deflation rate plays vital role that directly affects the country economy. This is not only has resulted to huge trade loss, but has also made the country more dependent of energy [10-12].

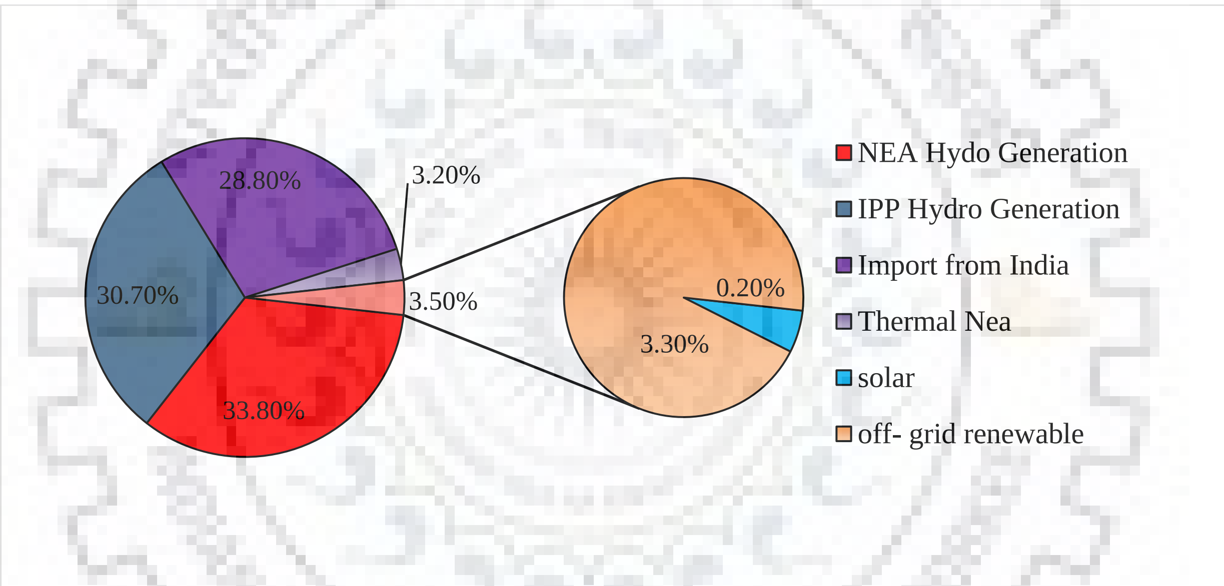


Figure 1.2 The Share of Available Electricity in the National Electricity Grid in Nepal [13].

It has been found that the among the commercial energy the contribution of solar energy is only 0.2 percent in national grid of Nepal which is about 2.68 MW.

1.3 PER CAPITA ENERGY CONSUMPTION

Per capita electricity consumption is one of the measurement tools for the economic growth of the nation. According to the World Energy Statistics chart of International Energy Agency (IEA), Nepal's electricity consumption is 140 kWh per capita and is slightly greater than some undeveloped African countries. The world's average energy consumption is 3030 kWh whereas Per capita energy consumption of Iceland is 53,816 kWh which is extremely high and lies in the top rank. [9].

Despite of huge hydropower potential, level of hydropower utilization is relatively low due primarily to financial resource constraints, institutional policy and inherent delays in project construction and implementation. Though, National Water Plan (NWP) 2005 set a goal to increase the electricity consumption for 2007 A.D. to 100 kWh per capita however; it slightly exceeds in 2014 A.D. Figure 1.3 shows the electricity consumption scenario of neighboring countries as well as that of Asian countries. It shows that Nepal has very low electricity consumption than the neighboring countries [3].

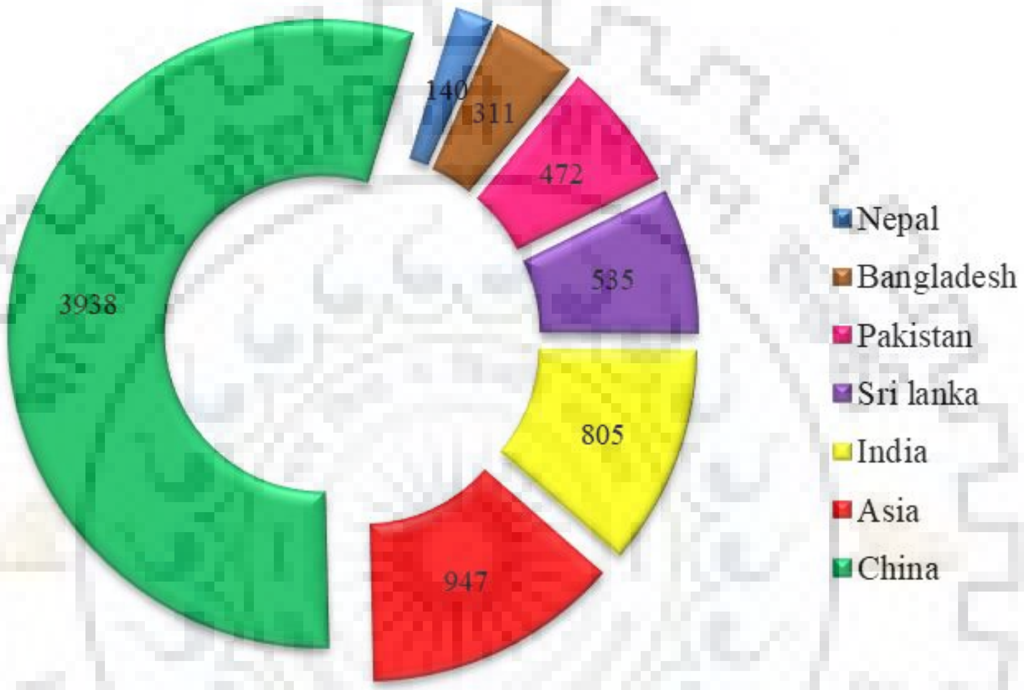


Figure 1.3 Per-Capita Annual Electricity Consumption Comparison [9].

1.4 SOLAR ENERGY

The primary and ultimate source of energy in the earth is the sun. The energy radiated by the sun is in the form of electro-magnetic waves, which includes heat & light. The forecasted age of the sun is approximately 5 billion years. About 720 million TWh/year insolation is received on earth's surface which far exceeds the annual energy need of the world by 6000 times. Technologically, solar energy can be harnessed by two routes;

a) Solar Thermal: The system that the solar energy is converted into heat energy for solar thermal application. Thermal energy from the sun is collected in appropriate solar collector. Solar collector is a device which is used to collect the solar radiation falling on it, convert this thermal energy and simultaneously transfer it to the load for application in solar thermal route.

b) Solar Photovoltaic (SPV): - It is the process of direct conversion of solar energy into electricity generation is called solar photovoltaic system. PV cell works on the principle of photovoltaic effect in which solar radiation are converted into electricity (DC). Mass production of PV cell and connect them to fulfill the energy requirement to form a module. Photovoltaic modules composed of solar cell are arranged in appropriate series and/or parallel combination to yield electricity in SPV. Cooking, lighting, water heating and other electric equipment are the energy end use of solar energy as an alternative source. Solar energy end uses devices used in Nepal are generally for lighting purpose at household level, buildings, colonies like: solar lamps mostly for street lamps and traffic lights in city area and solar Tuki in remote villages as household lamps. Solar based water pumping systems were proven as boon for the rural communities especially by uplifting the livelihood of rural women of Nepal by solving drinking water and irrigation problem. Solar water heaters are installed in the rooftop of urban areas to facilitate heating water. Mini-grid solar power within certain locality is also in operation in remote areas.

1.5 SOLAR ENERGY POTENTIAL IN NEPAL

According to German solar association BSW-Solar, the global solar industry has been seeing growth exponential in recent years, and which is expected to continue for next decade. After producing about 178 GW of solar PV power capacity by the end of 2014, global solar PV capacity is expected to hit 1.1 TW shortly by the end of 2022. It further expects the total global solar PV capacity will more than double, reaching at least 2.2 TW within the next 4 years. Figure1.4 shows the solar map of Nepal which excludes cities, national park, steep slopes (>45^o) of hills and mountains and water bodies that summarizes area under different annual direct normal radiation in Nepal [14].

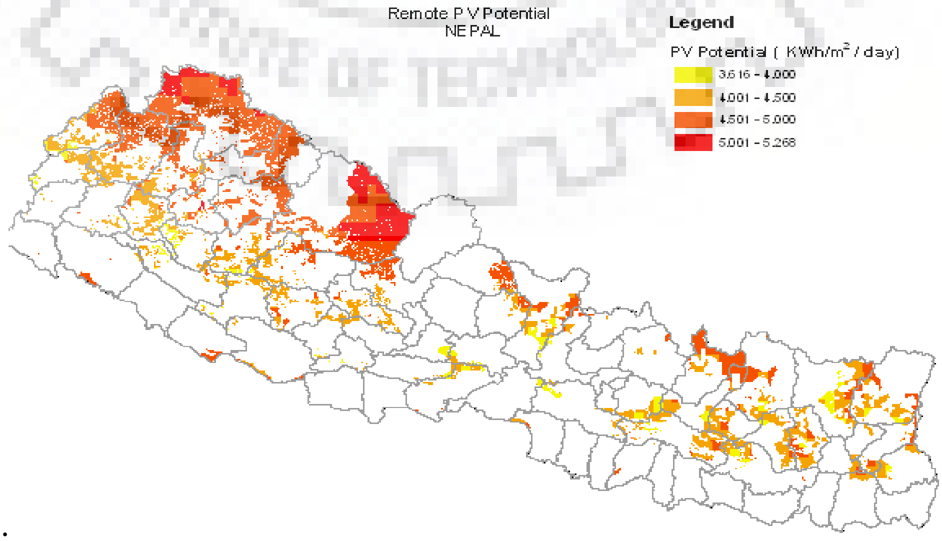


Figure1.4 Off Grid Solar Potential of Nepal [14].

Nepal has an area of 1,47,181 sq.km. Considering high concentrating solar radiation required for power generation from the CSP, area under average annual irradiance >5.5 kWh/m2/day is taken which is about 2729 sq.km. If only 2% of the best solar irradiance is taken for the power generation, it can yield 1829 MW.

In this estimation, non-electrified area seems lower than actual figure of remote area because protected areas having settlements and settlements within the buffer distance of 10 km which have no access to the national grid yet have not been included. Estimated population in the remote area extracted from the population density map based on Centre Bureau Statistics projected data of 2006 is about 2,411,177.The data of area under different annual direct normal radiation in Nepal is presented in Table 1.1 which shows that even a 1% of available potential with even 10% overall efficiency is harnessed; about 190 GWh of energy could be generated per day which is about 160 times the current annual generation [15].

Table 1.1 Area under Different Annual Direct Normal Radiation in Nepal[14] .

S.N.	Average radiation (kWh/m^2/day)	Area (km^2)	Total Potential (GWh/day)
1	4.16	2174	9044
2	5.22	32597	170156
3	5.56	2730	15179
Country Total			**194379**

Table 1.1 presents the grid connected solar power potential for which population density of 3500 per sq. km or greater was taken. The data shows that if 10% of the potential where the grid is available is harnessed with 10% overall efficiency, 116 GWh of energy can be added to the grid which is about 40 times the energy being contributed by NEA owned power plants. This shows a very good potential to integrate the roof top solar energy to the grid. On contrary to grid connected potential, the off-grid potential is also equally important to energize the remote villages. Studies reveal a very good potential of solar water heating systems as well in Nepal [14].

1.6 SOLAR PHOTOVOLTAIC SYSTEM

Nowadays, solar photovoltaic (SPV) is the mostly used alternative source of energy in the globe. There are many areas where plenty of reliable solar radiation is available but not the electricity. Therefore, utilization of solar photovoltaic is the good solution to provide electricity for such areas. Solar photovoltaic (SPV) systems are sustainable environmentally friendly distributed source of energy. Technically, SPV can be installed near load centers, providing benefits to the consumers that bulk power generation cannot be installed. In addition, SPV energy system is fuel free, low maintenance, and noiseless. Its gestation period is very short. It is highly mobile and portable because of its light weight. It also presents a high-power capability per unit of weight. The SPV power output matches very well with peak load demands. However, solar PV power is highly intermittent in nature due to variations in solar radiation and temperature levels. Due to this reason, where the solar power is directly connected to the load, the delivered power may not be reliable [16-18].

1.7 TYPES OF SOLAR PV SYSTEM

Based on the end use application, the solar photovoltaic systems are classified as: isolated and grid connected solar PV systems.

1.7.1 Stand-alone or Isolated Solar PV System

Stand-alone PV Systems and Off-grid Power Systems operate independently of the electric utility grid and are most often used in rural areas either there is no accessibility of grid extension or more expensive to construct the same rather than the cost of an alternative energy system. The DC power output by the solar array can be stored in the battery and the DC power fed to the inverter converts to AC power. The output power from the inverter is directly connected to the AC load appliances. Figure 1.5 shows the schematic diagram of Off-grid solar photo voltaic system.

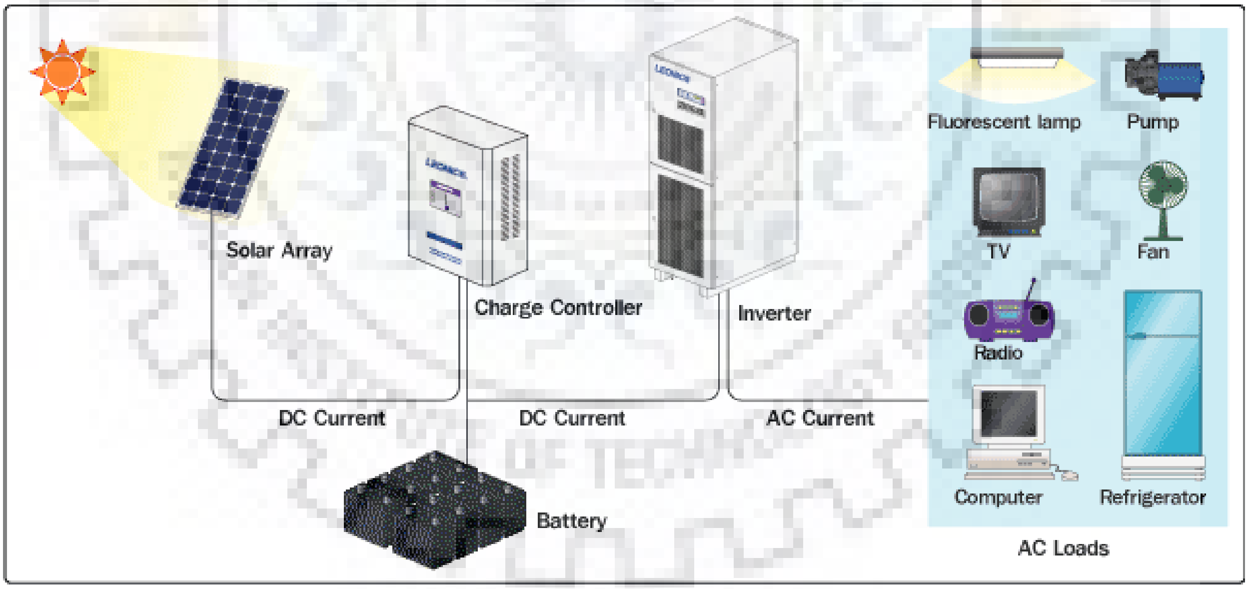


Figure 1.5 Schematic Diagram for off-grid Connected Solar Photovoltaic System [16].

In rare cases, stand-alone system are also install in urban area because of the inconvenience on tapping the utility grids. Most of the countries, this system has been installed to light the roads and streets. The system needs battery as a backup source for storing the electricity purpose during no sunshine hours and bad weather condition. Some of the secondary batteries like lead-acid, nickel-cadmium are used for the backup purpose [16].

1.7.2 Grid-Connected Solar PV System

In this system, the power generated by the PV array can be either used by the consumers or injected into the utility grid. Grid-connected solar photovoltaic (SPV) system reduces the dependency on the grid and gives financial benefits to the users by injecting the generated power into the grid. In a grid-connected PV system, the grid acts as an infinite energy storage capacity. This increases the overall reliability and efficiency of the system. This type of solar system gives benefit to the grid as well as users. During day-time when there is excess power generated from the solar system, the power can be delivered to the grid and when there is shortage of power generation electricity may be taken out from the grid through net metering system. A schematic diagram for Grid-connected solar system is shown in Figure. 1.6.

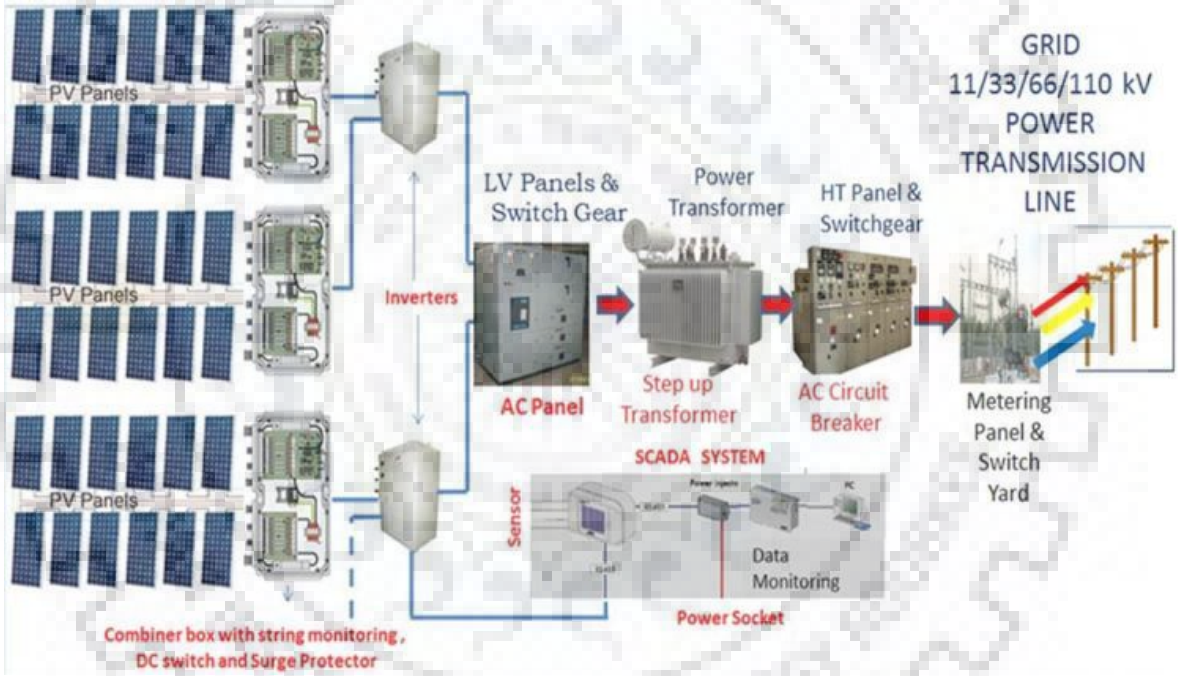


Figure 1.6 Schematic Diagram for Grid Connected Solar Photovoltaic System [16].

Grid connected solar PV system consists of components, mainly categorized into two categories as follows;

Major components

- Solar Panel
- Power Conditioning Unit/ inverter
- Utility Grid

Minor components

- DC array junction box set
- AC bus bar (LT and HT switch gear)

- Control room
- Cables and wires
- Mounting structures
- Earthing components and lightening arresters
- SCADA (Supervisory control and data acquisition)
- Water facilities/compound and fencing system and also roads inside the solar forms.

1.7.3 Photovoltaic Power Output

The output power generated from the solar photovoltaic system depends upon the active area of solar photovoltaic generator and the solar incident radiation on the solar PV array. The power output, P, for a solar PV module can be determined as below:

$$P = \eta_{pv} HA \text{ W/m}^2 \quad (1.1)$$

Where η_{pv} is the efficiency of the solar cell and H is the total solar radiation on PV array and A is the area of the solar module. Then, efficiency of solar module is given as:

$$efficienc(\eta_{pv}) = \frac{Out\ put}{Input}$$

$$= \frac{V \times I}{H \times A} \quad (1.2)$$

V and I are the voltage and current produced by the module respectively.

1.8 ORGANIZATION OF DISSERTATION WORK

This dissertation work has been managed in eight chapters. Each chapter is described as in the following order.

Chapter 1 addresses the overview of present energy consumption scenario of Nepal. The energy profile, percentage share of the available commercial energy, comparison of per capita energy consumption with neighboring countries was also mentioned in this chapter. This chapter also reveals the solar energy potential of Nepal and type of solar photovoltaic system.

Chapter 2 report the literature studies and work done under similar previous studies for the scope of development of rooftop solar photovoltaic system and development methodology for the study so that the objectives of this dissertation work can be specified. This chapter also includes the methodology adopted for the study in order to fulfill the objectives of the dissertation work and resource collected so far for processing the work smoothly so that better result was expected.

Chapter 3 is related to load estimation and overview of study area, apart from this, in this chapter the total area available for developing the SPV system is also calculated. Various connected load and their consumption pattern and capacity is also describing in this chapter.

Chapter 4 describes about power plant design and result presentation for grid connected as well as stand-alone system using PVSYST software.

Chapter 5 is related to economic analysis for grid connected system which is perform by using excel sheet.

Chapter 6 is the final chapter which is related to conclusions and recommendations.

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

This chapter discusses the literature studies and work done under previous studies for the scope and development of solar photovoltaic system and available in literature. An extensive literature review was conducted related to the assessment of solar irradiance potential, development methodology for sizing the accurate SPV system and financial analysis for some solar project as well.

2.2 REVIEW OF LITERATURE

2.2.1 Review on Renewable Energy Scenario

Chauhan and Saini [1] presented a review on many issues which are related to Integrated Renewable Energy System (IRES) based energy as well as power generation. There are different types of methodologies adopted and reported in literature for developing and sizing of the system components are also discussed.

Gupta et al. [80] proposed a mixed integer linear programming model for evaluating the techno-economic performance and optimization of an off-grid hybrid energy system that could incorporate micro/small hydro, biogas, biomass, solar photovoltaic, battery and diesel generator (DG). Combined dispatch strategy for the hybrid system and the use of the model and algorithm in a case study is also presented. It is concluded that the proposed methodology is capable of designing the village electrification system with least cost with flexibility.

Alex et al **[67]** presented about the different type of energy saving technology and devices which can be used in the present context. In this paper efficient use of energy, energy savings, new low power consuming energy technologies, energy storage for the humane engineer is also mention. Not only this the paper told about the Pico hydro systems, different kinds of solar PV systems, solar thermal technologies and project approaches presented in this paper, appropriate technical solutions to improve the livelihood of millions of disadvantaged people have been shown and discussed.

Khatod et.al.[68] discussed about the evolutionary programming-based method for the optimal placement of solar and wind-based DG in radial distribution system. The load model and DG model were implemented by probabilistic model. A sensitivity index method was applied to reduce the search space and quickly determine the location and size of DG. The fitness function was to minimize energy loss by considering different constraints to the system. In this method, it should be developed index method to generate population and this reduces the computational time. This method was tested on 69 bus, 12.66 kV test system and concluded with the significant amount of loss reduction with voltage improvement.

Neema et. al. [72] analyzed the combined utilization of various types of renewable energy sources. These various types of energy resources are therefore becoming increasingly attractive which are being widely used as alternative of oil-produced energy Research and development efforts in solar, wind, and other renewable energy technologies are required to continue for, improving their performance. these technology establishing techniques for accurately predicting their output and reliably integrating them with other conventional generating sources. The article highlights the future developments, which have the potential to increase the economic attractiveness of such system.

Gul et al. [76] reviewed the solar Photovoltaic technology in terms of photovoltaic materials efficiency and globally leading countries like China, Japan, USA, Germany and UK. Where it accounted for 80% of solar photovoltaic installation in 2014 and also discussed the driving policies, funding and research and development activities. In this study, it is concluded that the efficiency improvement is one of the key factors to establish PV technology in the market where multi-crystalline solar module has reached highest efficiency up to 20.4% rather than other PV materials and suggested that the solar photovoltaic will continue to increase its share of the energy mix concept under all scenarios around the world.

Subedi and Shakya [19] studied on the energy consumption and emission pattern in the commercial sector of rural tourism area up to 2030. In this article the case of Mount Annapurna Trekking Route of Mount Annapurna base camp at an altitude of 4130 m was selected as study area where the remote tourism and conservation area was also explored. For the analysis of three scenarios of energy system development, Long-Range Energy Alternatives Planning System (LEAP) modelling framework was used. Under this study, clean kitchen scenario and low carbon scenario will be reduced in energy consumption by 14% and 54.5% respectively in the year 2030 was significantly analyzed and proposed the necessity of policy shifting towards the promotion of utilizing clean energy resources in modern and efficient endues device. This article also recommended to the Government of Nepal for the same to formulate and revise different plan and policies focused on clean energy technology.

Dhital et.al [82] presented the importance of renewable energy in the remote area and to measure the sustainability of the rural Renewable Energy project, a framework was developed to access the RE projects of Nepal which are installed in the countryside. Under this study, it was concluded that for the technical criteria, environmental criteria, social criteria and institutional criteria, five sustainability metrics was developed separately to evaluate the reliability of the system and can be assessed. This article also highlights that the government of Nepal has been providing subsidies for renewable projects however the fund from international agencies was also invested and on comprising of all sorts of possible factors, the framework was developed that measures the sustainability of projects which has been either commissioned or on the phase of planning and installation also.

Dhital et.al. [20] presented multi-criteria decision making for sustainability of Renewable Energy system in Nepal based on Analytic Hierarchy Process in the context of Nepal. On the basis of selection criteria such as techno-economic, environmental and social aspects solar energy, biogas, micro hydropower and grid technology have been assessed however financial criteria is overall major priority as most of RE projects are one time funded either by GoN or donor agencies but may enhanced in course of time. In this journal, from the sensitivity analysis concluded that amongst alternative energy source there is the necessity to increase its technical and financial criteria to improve its ranking. Under this study sensitivity analysis curve was drawn for the final evaluation of sustainable energy system but the final decision is to be consistent and reliable.

2.2.2 Review on SPV Systems in Nepal

Bhandari and Stadler [21] presented a general overview of energy resources in Nepal. The status and perspectives of solar photovoltaic sector, benefit cost and breakeven analyses of solar photovoltaic systems in Nepalese urban areas have also been carried out. It is concluded from the study that although solar photovoltaic seemed to be expensive alternative, it should be considered with eco-friendly and sustainable alternative by the policy makers.

Shrestha [4] introduced the use of renewable energy i.e. solar photovoltaic based water pumping system in Nepal. Proper planning of resources, operation strategy and load forecasting & scheduling for the successful operation of the system is focused in the study. Solar photovoltaic based water pumping system is found to be more economic than diesel engine pump sets in context to Nepal.

Baral et al. [22] presented a review of status and policies of on-grid off-grid rural electrification and its status in Nepal. Several issues related to mini-grids and rural electrification in the nation are addressed. A structural change to ensure a private sector involvement, industrialization and synergy effect in the rural electrification is recommended.

Kafle [12] studied on hybrid energy system in order to focus on the off-grid electrification of one of the remote villages in Nepal. In most optimized manner. For the study purpose, Phungling town of Taplejung district is chosen as the site. All the renewable resources potential as well as the energy demand of the study area is individually assessed. The system is modeled to convert the renewable resources into electricity mathematically with generally achievable efficiencies.

Shrestha et al. [23] carried out the feasibility study and presented that there is a possibility of generating the huge amount of solar photovoltaic potential In Nepal and he also encouraged potential for development of solar PV grid-connected systems to be considered for Nepal. In his study he also mentions that there are no any difficulties for the development of SPV system which are identify previously. And that this technology could effectively participate in the improvement of the country's present crisis in the energy sector. The study also focusses on the point that solar PV grid-connected systems can be on of an important part of the country's long-term solution to address the present as well as future electricity shortage and high daily load shedding hours. This, as well helps in meeting the fast-growing electricity demand in reasonable short time periods. In addition, the stakeholder analysis has shown that the necessity of increasing the electricity production capacity in the country is generally recognized within the institutions, and the idea of implementing grid-connected solar photovoltaic systems/plants is in general welcomed and even supported by most of the decision makers.

Nepal [11] analyzed the potentials of renewable energy resources and their roles in developing countries. This article further highlights that Nepal have significant potential in renewable energy and can generate electricity by optimum use of available resources. This article also concludes that the accessibility of electricity in rural areas can be improved only by harnessing the renewable energy resources which further decrease in high dependency in fuelwood and other traditional energy and can minimize fuel imports from other countries.

Kayastha and Ale [24] suggested strategic options that the development of renewable energy can be enhanced by extending the capacity of energy units and recommend AEPC to provide supportive action for the same. The articles also criticize that the current policy for energy subsidy cannot address the needs of rural development and is not effective for the local people. Improvement, specifically in achieving coherency in subsidy for various technological options and a close interdisciplinary coordination among different organization should be maintained in the development of energy sector. Resource mapping and techno-economical assessment in cluster level can be one of the ideas to find out the potentiality of renewable energy in each cluster. Different types of RETs can be implemented in those clusters, so the district wise prioritization of renewable energy resources is necessary.

Shakya et al. [25] presented a brief about the present energy scenario of Nepal based on account study mention about the natural resources along with the present renewable energy technology (RET). By considering the various renewable energy and its applications consisting of biogas technology, biomass technology, micro and Pico It focuses on the trend of RET-hydro technology, wind technology, solar thermal technology, solar PV technology, geothermal energy observed until mid of 2003. It also highlights their manufacturing capability and commercialization, government energy policy and strategy, main barriers and suggestions for barrier removal. Finally, the paper contains some recommendations and action plan for promotion, development and commercialization of renewable energy technology in Nepal.

Dhami [26] analyzed that Integration of PV units in the buses reduce the current flowing through the branch of the network and loss is minimized. Similarly, voltage drop in the line is reduced and hence the profile of the voltage level increases. System loss is proportional to the size of PV unit. But greater the size increases the cost of the installation and maintenance. The system load ability has improved due to the integration of PV at the best location and of optimal size. In addition, that, voltage stability is improved and hence the quality of the power increases significantly

Jha et al. [27] presented the potential status of renewable energy-based DG in Kathmandu. He identified potential of the renewable energy-based DG like PV, wind, micro-hydro on hourly based potential for different seasons and succeeded to achieve the optimal location and size of DGs in the distribution network to minimize energy loss and DG cost. In this study, 12 bus distribution network is selected and obtained results were tested effectively using genetic algorithm tool.

Pokharel [28] introduced the main characteristics of alternative energy technologies that are used in Nepal and discussed so far about the barriers for the promotion of these technologies.

Adhikari et al. [2] used daily global solar radiation, sunshine hours and meteorological data for Jumla, Pokhara, Kathmandu, and Biratnagar to derive the regression constants for the estimation of global solar radiation for those selected sites. They found that high altitude location (Jumla) has high potential of global solar radiation and low altitude location (Biratnagar) has least value of solar radiation.

Gurung et al. [29] reviewed the renewable energy situation in Nepal and highlighted the policies and subsidies for the optimal utilization of the REs in rural and isolated communities.

Gurung et al. [30] highlighted the status and perspective of micro hydro plants in Nepal. The energy driven socio-economic development in a typical electrification project in Tangting, Nepal is also discussed. Existence of challenging situation of providing energy to the remote areas in Nepal and scope of systematic and comprehensive study supported by research for the remote poor communities in Nepal is concluded from the study. In a separate study, the current policies and subsidies for the optimal utilization of renewable energy resources in isolated and poor rural communities are highlighted and the promotional barriers of rural electrification are identified.

Regmi and Adhikari [31] studied the meteorological data such as solar radiation data (1975-1984, and 2002-2010), duration of sunshine hours (1968-2004), analyzed temporal characteristics of solar energy and investigate solar energy potential in Kathmandu valley as well.

DoED [32] performed a feasibility study to identified the different potential site for SPV projects in Nepal. In this report various site and location were listed with the possible installed capacity.

Bhandari and Stadler [33] studied that the solar photovoltaic development of Nepal. Nepal has rough and mountainous topography, high cost of grid extension, and low and scattered population density, especially those living in rural areas. Due to this fact, about 44% only of the total population has access to grid electricity. This study focused only on benefit cost and breakeven analysis of Nepalese urban areas not in rural areas and also prevails that tapping solar energy using PV technology might be viable, environment friendly and one of the reliable alternatives for both urban and rural electrification. This article presented the classification of solar PV on the basis of application in Nepal and also concludes that without considering many social aspects, the rural electrification should not be decided on the basis of mere monetary benefits.

Dhital et.al [34] surveyed that Nepal lag basic social infrastructure due to the geographical situation and for water provision the livelihood of women especially in the mountain regions was very difficult that spent more useful time to carry water. This article interrelates the subsidy policy and the technical design and performance of solar water pumping systems which were commenced in the hilly region of Nepal. In this study, the original field data from 38 wards from various regions of Nepal was collected and measured the technical efficiency of solar water pumping systems whether it may enhance the performance of SWPS according to relevant economic policies. Furthermore, the article concluded that on addressing the efficient and effective solar water pumping system installation methods might be the key point on the policy agenda. Despite this, due to roughed topography of the nation villagers at rural areas stick financial and resource constraints.

Dhital et.al [35] reported the various renewable energy technology scenario and sustainability of the government supporting solar PV drinking water projects at that particular time was observed. In this article, the assessment of the selected alternatives was carried out within criteria comprises technical, environmental, financial and institutional indicators. Thus, decision was made on optimum alternative. It was concluded that by promoting the hydropower and solar PV technology can enhance energy sustainability for the nation.

2.2.3 Review on Development of Solar Photovoltaic System

Ekren et al. [64] presented an optimum sizing procedure of sizing photovoltaic-wind-battery hybrid system using net present value method to compare the breakeven point in opting distribution line extension or the hybrid system for energizing a GSM BTS and concluded that the hybrid system is more economical when the distance to the electricity network is more than 4817 m.

Sonalki [36] illustrated the design methodology of photovoltaic system in page no 423 on chapter no.15 in the book of solar photovoltaic. PV system are sized to meet the given load requirement and also involves a decision on which configuration is to be adopted. Author also discussed about the precise sizing of the PV system. For designing the precise PV system, following points should be considered.

- Seasonal variation in load: Proper estimation should be done for load variation sothat photovoltaic system design does not fail at any worst time of year maintaining the system cost effective and reliable.
- Precise estimation of solar radiation data: System should be designed for the month of lowest radiation.
- Sun-tracking solar PV modules: About 30% of extra energy should be achieved by the same set when PV modules are tracked to follow the sun.
- Ambient temperature in which modules and batteries are working: As the ambient temperature increases, performance of the PV modules and battery degrades.
- Type of PV technology used in the system: Under the same operating condition, there should be the variation of the performance of the modules of different technology of same power and as the function of temperature is manufacturer dependent. Hence, before optimizing the PV system design, manufacturer’s data sheet should be collected.
- Types of batteries used: Before starting the system design, the notification about the Depth of discharge, rate of charge and discharge, available charge capacity under different operating temperatures and charge discharge rates, number of cycles battery can operate etc. shall be checked.
- Dust level in the environment: The dust level of the site should be checked and measured where the PV system should be installed because accumulation of dust on PV panels reduces the energy output. It is concluded that the energy output from the PV panels should be estimated based on the dust level and scheduled cleaning frequency of the module

A report has been presented on national level one day awareness workshop on comprehensive rooftop solar energy utilization at IIT Roorkee Campus, Roorkee in India and also mentioned that India is planning to install 40 GW of PV Rooftop Solar system by 2022. This report contained states policies on Grid connected solar rooftop. As per Uttarakhand electricity regulatory commission "Renewable Purchase Obligation" quotes that if energy from renewable and non-conventional sources of energy becomes available in state as specified RPO in this clause, the generator or the distribution company of the state can approach the commission for permitting procurement of such energy in excess of specified Renewable purchase obligation **[37]**.

Gautam et al. [38] presented solar power technologies which can help mitigate the present power shortage problem as Nepal receives good solar insolation. Despite having good solar photovoltaic potential, its adoption is limited to rural areas due to lack of government support and higher cost. This article analyzed the electricity shortage problem and assesses the feasibility of rooftop solar power in urban areas. The assessment analyzes problems and shortcomings of current system and recommends policy changes to increase use of rooftop solar power. The detailed study was conducted to investigate the potential of solar photovoltaic system development in Nepal and its possible contribution to solve Nepal's power crisis.

Tamrakar [39] presented rooftop solar power generated from 17 different housing sectors around Kathmandu valley which was estimated and extracted to fulfill about 40% of the electricity demand on the residential area of Kathmandu valley. This study analyzed the geographical potential using Hill shade algorithm depending upon the position of sun in the sky and recommend to government of Nepal for making policies and programs regarding opportunities to the public by motivating and encouraging them for solar energy generation.

Lupangu and Bansal [40] reviewed various sizing, modeling, maximum power point tracking (MPPT) methods for the efficient operation of grid-connected PV systems. This article also addressed some technical challenges on the current state of PV systems based on energy policies, various cell technologies, Maximum Power Point Tracking (MPPT) and converter/inverter technology, energy management and scheduling techniques, reliability, power quality and control systems issues.

Wang et al. [41] presented an overview of Chinese progress on the development of modern solar greenhouse, their attempts to mitigate the effect of heat loss, shadowing and poor light condition for applicable integration. This article also concluded that solar technology had been proven effective in order to promote solar energy utilization in modern solar greenhouses.

Gwamuri and Mhlanga [42] discussed about the components required for designing the stand- alone Photovoltaic system which will power all electric appliances at a medium energy consumption residence in Selbourne Brooks in Bulawayo. This article also studied the factors affecting the design and size of the system in order to get reliable and cost-effective system**.**

Carl [43] analyzed for the utilization of geographical information system (GIS) and light detection and ranging (LiDAR) data with statistical analysis to identify how much solar photovoltaic potential exist for residential rooftops. This study also carried out least square multiple linear regression analysis in order to identify the influence of slope, elevation, rooftop area and lot size on the modeled photovoltaic potential values.

Chiteka and Enweremadu [44] studied on the development of solar photovoltaic system sizing with the application of battery storage which is applicable for the entire major location in Zimbabwe. In this study, the database was integrated with a visual basic 6.0 program that needs information about average peak, sunshine hours values, latitude as well as the insolation values of each place in order to design the solar photovoltaic system sizing application. The article relates the calculation of the total load estimation followed by the sizing of the solar array, tilt angle, inverter size and charge controller. The article also concludes that optimal tilt angles could be selected effectively and reduce losses due to non-optimal tilt angles by 8.3%. Hence overdesigning cost of the system also eliminated.

Bergamasco and Asinari [45] analyzed the outstanding growth of the photovoltaic energy market and presented that as per new directives on renewable energies of the European Commission (2009/28/EC), the European Union should meet a target of 20% share of the total energy consumption from renewable sources by 2020. In this report the assessment of the photovoltaic energy potential passes through the evaluation of the roof surface area available for installation was studied by considering rooftop integrated photovoltaic system. Furthermore, this report reveals a methodology for estimating the PV solar energy potential with the application to Piedmont Region (North-Western Italy). From the analysis of available GIS data, the suitable roof area for installation of solar photovoltaic system is calculated. In this study, from the database of the Joint Research Centre of the European Commission, the solar radiation maps are studied and is concluded that the PV solar energy potential assessment is indeed reproducible for other regions or countries at different scale depending upon the computational resources available as the procedure requires easy and freely accessible data like solar radiation maps, statistical data on population and energy consumption as well as GIS data of that area object of study.

Aeron [46] studied about the renewable energy resources can play better role if forecasting of renewable energy is made in advance and analyzed that integrating renewable energy to the grid, power generation is intermittent. In this dissertation work, smart grid model was prepared by visiting live solar plant at Port Blair, the first renewable energy plant of National Thermal Power

Corporation (NTPC). Within this report it was mentioned that the ANN model includes the data having parameters like date, month, time, humidity, temperature and solar radiation for 11 months in which remaining 1 month is used for validation of this model. In this report it is concluded that forecasting the solar radiation by developing the model, solar power should be predicted simply by multiplying by number of panels used and their efficiency. This report also recommended that if parameters like humidity and temperature were recorded in the hardware model in MATLAB so that once the data get recorded for at least 8 months then similar model can be developed for such area like Roorkee. SCADA system was used for displaying the working of the prototype of hardware made in this dissertation work.

2.2.4 Review on Financial Analysis

Branker et al. [74] studied the economic feasibility of the project by using the levelized cost of electricity (LCOE) generation to compare with other generating technology. In PV technology LCOE results to insist policy mandates or make investment decisions over expanding geographical regions. This technology will be becoming more and more economically advantageous source. When the levelized cost of electricity (LCOE) of solar photovoltaic is considered with grid electrical prices of conventional technologies then grid parity is considered. In this article the review of methodology and key assumptions of LCOE for solar photovoltaic has been performed.

Dhital et.al. [47] overviewed the challenging aspects for rural electrification in Nepal and perceived whether the installed project on different places of country enhance the socio-economic growth of society. This article forecast the decreasing trend on PV panel cost and increasing the electricity tariff rate might increase the sustainable status of renewable system installed where the high investment may be due to the material cost, labor cost, transportation cost, high interest rate especially in the remote areas. Sustainability associated with value of invested money was also mentioned in this article.

Agrawal [48] presented on the compatibility with the geographic, climatic and socio-economic features with the solar photovoltaic system of India. In this dissertation work, based upon the average solar radiation data, the system was designed and sized according to the nature of load. From this study, it is concluded that fulfilling the energy needed of various end user of solar energy of different sectors such as lighting, heating, cooking, agriculture in an individual manner sounds cheaper than the decentralized power stations.

Rehber [49] highlighted that the formulating and evaluating investment projects, the nation economic change plays vital role in all developing countries scenario. The article mentioned that the nature of the investment varies country to country. The researcher also introduced that for the guidance of the development and restructuring of the country economy, the government can charge either domestic taxes or granting subsidies and can rationing of scarce resources or tariffs, sometimes to impose control on private investment otherwise the government can invest directly on the project on its part. The writer focused that for a sound investment, the project should comprise benefits and costs of investment and some aspects of the financial proposal like market analysis for export, import, location, capacity and technology adopted for the production unit.

Koganti et.al. [50] analyzed the importance of significant factors like green power, environment protection and emission reduction in electricity generation in the present scenario for reducing the capital investment and operational cost as well. This article presented the economic analysis of a solar power plant which was installed at BVRITH, Hyderabad India. The main objectives of the article is to recommend a better mode of operation of Solar photovoltaic on the economic point of view either on grid or off grid and hence calculating the most economic cost analysis of a solar project together with payback period seeking further improvement as well. The article summarizes that the utility grid connected system is better than off grid because of the large battery bank installation add extra expenses in investment on battery bank and its high maintenance cost in off grid system. Thus, grid connected system was preferred. The article also emphasized that for minimizing the financial risk of the project, the developer can share of loan, equity and subsidy as far as possible.

Based on the literature review, gaps are identified and discussed as follows:

2.3 GAPS IDENTIFIED

- In most of the urban area of developing country, the assessment for the feasibility of the rooftop solar potential faces some difficulties due to the non-availability of the size of housing/apartment and their orientation for installing solar PV system. Most of the study focused on economic analysis of solar photovoltaic system only in rural areas not in urban areas.
- No study is carried out for the extra cost to implement the sun tracking mechanism of solar PV modules which may produce 30% extra energy.
- There are very few and limited studies available for potential assessment of rooftop solar photovoltaic in Nepal. Due to the lack of integrated energy policy and competition among public institution in the energy sector to promote solar photovoltaic system for maximum utilization of rooftop solar power in urban as well as rural areas.

Based on the literature review carried out and research gaps identified as discussed above, keeping this in view, the work under this dissertation was proposed with the main objective to develop a reliable and cost effective solar photovoltaic system with the use of suitable technique in the premises of Nepal Oil Corporation, Kathmandu, Nepal in order to fulfill the requirement of the premises. Followings are the specific objectives proposed for the present study;

2.4 OBJECTIVES OF STUDY

- To estimate the area available for solar photovoltaic system installation in the premises of Nepal oil corporation Ltd. Kathmandu in Nepal.
- To estimate the load and the potential of solar energy.
- To size the SPV system for the available area.
- To conduct the techno-economic analysis of the proposed solar photovoltaic system.

2.5 PROPOSED METHODOLOGY

This section presents about the methodology adopted and the material collected with its processing for the research work. The research begins with the development of the methodology based on aiming the objective of the study. In order to fulfill the objective of the study, the flowchart for methodology adopted under the present study has been depicted in the Figure 2.1

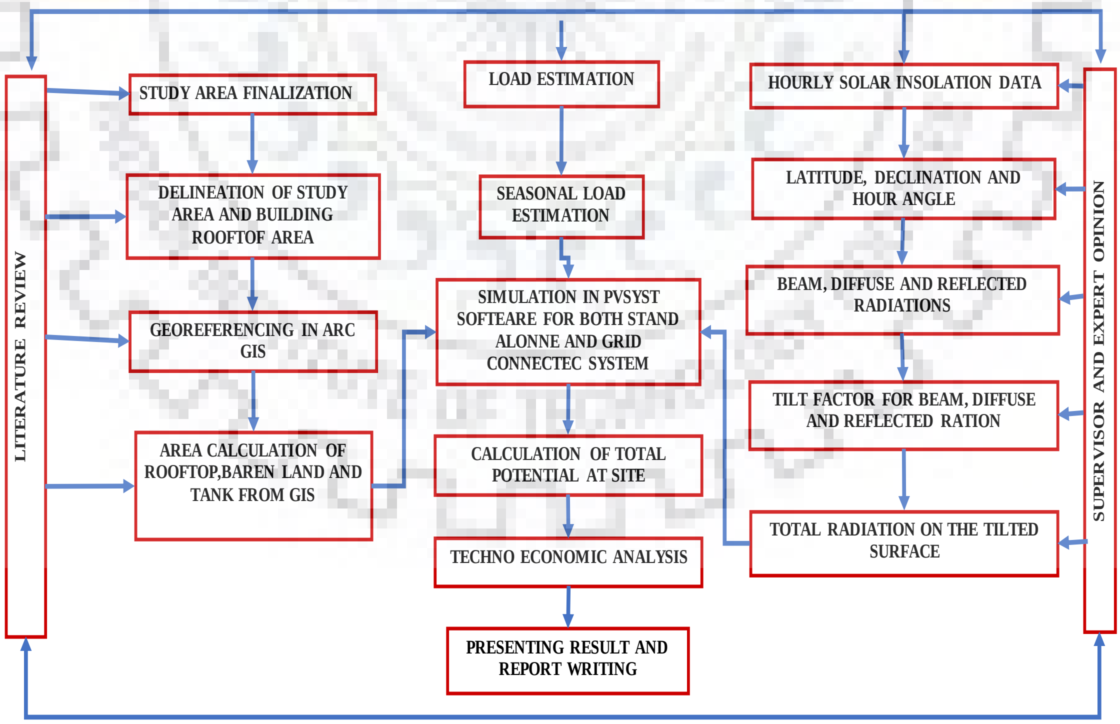


Figure 2.1 Flowchart for Methodology Adopted under Present Study.

CHAPTER 3

ABOUT STUDY AREA AND ESTIMATION OF SOLAR ENERGY & LOAD

3.1 GENERAL

For this study, Nepal oil corporation Ltd. Thankot depot is selected. Nepal Oil Corporation Ltd. is the government owned organization established in 2027 B.S. as per “Company Act 2021” with the aim to import, store and distribute petroleum products within the country. It consists of five regional offices, three branch offices, seven Aviation fuel stations/depots and two Aviation fuel Refueling stations. Nepal oil corporation Ltd. has a total petroleum product working storage capacity of 68,364 Kiloliters and around 600 employees are engaged on technical, financial and administrative sections [5].

3.2 DETAILS OF THE STUDY AREA

Nepal has growing market for alternative solar energy resources. Subsidies from Non-Governmental organizations and government of Nepal to the sales of solar panels are more than 750,000 homes in need. The trend of increasing rate of number of houses installed the solar energy is 10% every year. The interest and motivate is developed by the people in urban areas after the fuel crisis which results that the industry might grow in exponential form in near future. Nepalese people often used to make queues overnight at retail outlets routinely as government talks fail to resolve the crisis. The Public, who are suffering from load shedding are using inverter as a backup source are also directed to solar energy due to the fact that the electricity from the utility grid is not sufficient to charge their inverter battery [49]. According to the online data that was captured dated on 12.05.2019, Nepal import 10286 MWh amount of electricity from neighboring country India. Prior to this, there is the schedule of load shedding hours exist in commercial/Industrial Estate.

In the context of Nepal Oil Corporation, Ltd. Solar energy is indeed as a backup source. At present Nepal oil corporation Ltd. has installed diesel engine generator set (2x200kVA) as a backup source of the electrical energy for the purpose of storing the petroleum products, Loading/Unloading tank truck lorries, performing lab test, processing the paper works like computer billing system and other miscellaneous daily official works to fulfill the daily demand of petroleum products in Kathmandu valley including nine districts (Kathmandu, Bhaktapur, Lalitpur, Sindupalchowk, Kavrepalanchowk, Dolakha, Rasuwa and Dhading). As the solar energy is clean, environment friendly and green energy, it accesses to reliable and affordable energy[77].

It is indeed a viable option to the NOC providing a reliable energy access to some extent with the relatively recent realization of global warming, pollution and its resultant adverse effect on the health of the public the major area of concern is fuel quality and pollution control.

3.2.1 Site Topography

The proposed site has bedrock-soft sediment paleo topography under Kathmandu valley which is suitable for solar PV plant allowing optimum sun exposure.

3.2.2 Site Access

The prithvi highway that passes by the side of the proposed site and has better accessibility to the site is observed to be suitable for the transport of heavy equipment/ machinery at the time of installation.

3.2.3 Area Requirement

The total rooftop area to be available including spare land for the installation of solar power plant in the premises of Nepal Oil Corporation Ltd. is 33146.53 m^2 units were calculated from ARC GIS 10.4. Whereas the solar power generated is to be 2 MW.

3.2.4 Water Requirement

The water requirement for the proposed site during the construction period can be catered from the dip boring which is specially installed in the depot premises for firefighting purposes against petroleum products hazards.

3.2.5 Evacuation

The solar power generated from the solar can be evacuated for the case of Grid connected system. The solar power generated from the plant shall be stepped up to 11 kV through the pooling substation and then connected to the Mathatritha grid substation of NEA that lies at a distance of around 4 km from the proposed site. Table 4.1 shows the site details of the study area.

3.2.6 Weather station

No weather station has been installed at the site till date. The meteonorm data from available data source NREL-NSRDB can be gathered for the requirement of the project. According to the climatic conditions that has experienced in the previous time, site weather can be forecast in a useful way. The detailed information of the study area is given in the Table 3.1.

Table 3.1 Details information of the study area [54].

S.N	Descriptions	Value
1.	Country	Federal Democratic Republic Country, Nepal
2.	Province No.	3
3.	District	Kathmandu, Nepal
4.	Municipality	Chandragiri, Municipality
5.	Core study area	Nepal Oil Corporation Ltd. Fuel depot in Kathmandu Nepal
6.	Latitude, Longitude	27.7ºN 85.33ºE
8.	Total Area of the NOC premises	33146.53 m^2
9.	Total power requirements	400 kW
10.	Total number of fuel storage vertical tanks	9
11.	Types of fuel storage in the station	Motor Spirit (MS), High speed Diesel (HSD),and Superior Kerosene Oil (SKO).
12.	Fuel Storage capacity of the station	6000KL of motor spirit and 4100KL of Diesel
13.	Total No. of roof top buildings and available barren lands.	As per mentioned in the table 4.2,4.3& 4.4

Among the fuel depot offices of NOC, Fuel depot Thankot, Kathmandu is second largest fuel storage capacity station and located at former Thankot Village Development Committee, now becomes a part of Chandragiri Municipality in the Kathmandu district province No.3 of country, Nepal. Geographically, the proposed site lies in the bed of Chandragiri hill and contains the total area of 33146.53 m^2. The Geographical positioning system (GPS) coordinates of the proposed study area which is shown in Table 3.1 is 27º42'2.7684" N and 85º18'0.5040" E and is situated under Kathmandu valley[51&55].

The purpose of establishing the fuel depot is to store daily transport of fuel, stock transfer within other fuel depot, Loading /unloading the tank truck lorry, maintaining the quality control of the fuel to fulfill the petroleum products demand of Kathmandu valley including nine neighbour districts viz Kathmandu, Bhaktapur, Lalitpur, Sindupalchowk, Kavrepalanchowk, Dolakha, Rasuwa and Dhading. The geographical location of the study area in the map of Nepal is shown in the Figure 3.1 [51].

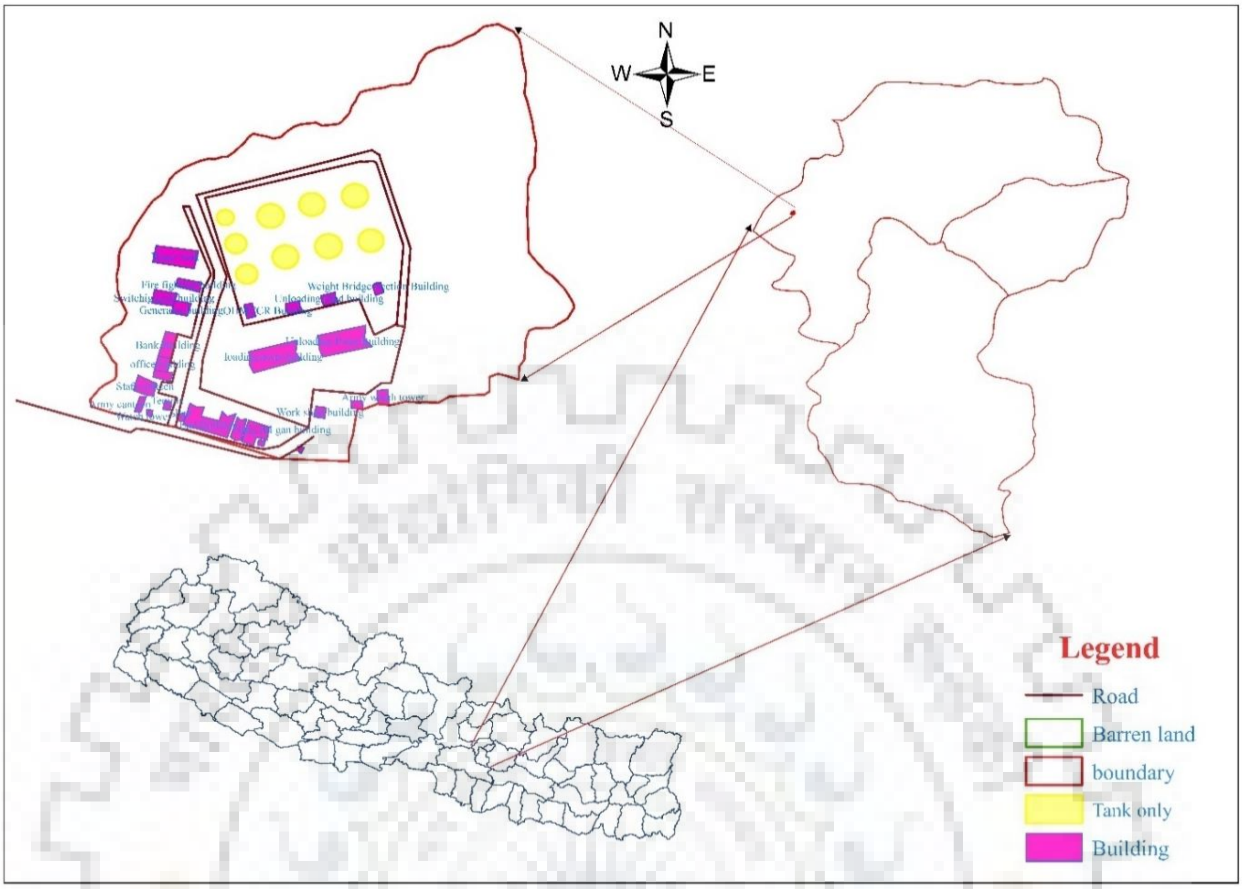


Figure 3.1 Location of study area in the map of Nepal.

Proposed site is located at capital city Kathmandu Nepal. The focused area which is proposed for the present study is Nepal oil corporation limited fuel depot. There are all together nine vertical fuel storage tanks. The total area of office premises is about 33146.53 m^2.

3.3 METHODOLOGY ADOPTED

In order to carry out this study following methodology has been adopted.

Step 1 Site selection: Under the present study, Fuel Depot, Thankot, Kathmandu of Nepal Oil Corporation Ltd. is to be selected. The rooftop area to be available in the study area is surplus including barren lands over its periphery where the solar panel can be installed easily and have good accessibility of resource. Because of this, NOC can establish the solar power plant in the proposed site and expected to develop a solar power plant in the premises by utilizing the optimum area and the solar insolation data available to fulfill the present energy demand as well as in future. The generated energy is expected to sale the Nepal Electricity Authority (NEA).

Step 2 Data collection: The present study is based on both, primary and secondary data. The secondary information was collected from Nepal oil corporation, Department of Electricity Development (DoED), Nepal Electricity Authority (NEA), Alternate Energy Promotion Center (AEPC) Central Bureau of Statistics (CBS), National Planning Commission (NPC), Ministry of

Finance (MoFN) and Ministry of Energy (MoEN). The books, reports, published and unpublished SPV development in Nepal. Attempt could be made to collect primary data, although it should not have significant role.

Step 3 Delineations of study area and rooftop area calculation: The satellite image utilized as a part of this study has been captured from Google Earth as Google Earth Incorporation has promptly made accessible its satellite imagery for researchers and educational activities under the legitimate utilization provision of Google Earth authorization guidelines [47].The image position has been georeferenced in Arc Map environment with the aid of latitude and longitude. For georeferencing at least 3 points with known geographical coordinates are required. The geographic coordinate system used in this study is World Geodetic System 1984 (GCS WGS 1984) and for calculation and analysis is projected system WGS 1984 UTM zone 45N for Nepal. The boundary is drawn as required using manual digitization in Arc Map to form a polygon which behaves as a shape file. After making the shape file of each rooftop of office building and barren land area of each polygon is calculated by using calculate geometry tool from Arc GIS 10.4.1.

Step 4 Load estimation: Load estimation is the process of find out the total load required, for this propose the primary source of data are collected form from the Nepal oil corporation Thankot depot. The number of electrical appliances used in the office premises, their operating hours and types of load data from the study area was collected. After collection of necessary data, the daily load curve and seasonal load curve are plot form the excel sheet. It is one of the major tasks for development of the solar photovoltaic system in the study area.

Step 5 Module selection: In order to estimate the total solar potential module output in manual design in practice different method for PV module selection can be adopted. For this study, peak hour method is used to estimate the module daily output. Photovoltaic (PV) module generates electrical power by converting solar radiation into direct current electricity using semiconductors or other materials that exhibits the photovoltaic effect. Solar PV modules are available in various wattages. For the simulation process, PV module is selected depend upon the availability of solar radiation and rooftop area to be available in the study area. Finally, PVSYST software should verify for the same.

Step 6: Peak hour" method of estimating module daily output: The module daily output can be estimated by using weather data. This method involves converting the actual measured insolation on a tilted surface into the equivalent number of hours of "peak hours" of standard full sun irradiance at 1000 W/m^2. Multiplying the number of "peak hours" times the module "peak output" (Imp measured at 1000 W/m^2) gives an estimate for the number of Ah/day from a module.

Module Output = Peak Hours × Peak Power (3.1)

If the insolation data on a tilted surface is in units of kWh/m^2, then the conversion to peak hours is easy. For example, if the average insolation for a month is 6.6 kWh/m^2, this can be rewritten as 6.6 hours ×1 kw/m^2. But recall that 1 kWh/m^2 is just 1000 Watts/m^2, and is just the standard irradiance used by manufacturers to rate module output. It is as if the module was exposed to the standard peak irradiance level of 1000 W/m^2 for 6.6 hours. This of course did not happen, but it makes for a simple calculation. The standard irradiance level of 1000 W/m^2 is important because module output at that condition is given in all manufacturer's literature, so manufacturer's literature values can be used [48].

Step 7: Calculation of Ah/day: To calculate the Ah/day from a module using peak hours, multiply the peak hours times the module Imp. For example, the average daily irradiance profile is shown for a surface tilted to 20° for a location. The total insolation falling on that surface in March is 6.6 kW/m^2. This can be rewritten as 6.6 hours × 1 kW/m^2. In Figure 3.2 the equivalent irradiance profile with the sun suddenly "turning on" to the peak irradiance level of 1000 W/m^2 and staying at that level for 6.6 hours were shown.

Module output is calculated by multiplying this peak hour value for equivalent peak hours times the module Imp. For example, for a typical 35 Watt module with Imp of 2.0 amps, this would be 6.6 × 2 amps = 13.2 Ah/day. For a typical 75 watt module with Imp of 4.4 amps, this would be 6 6 × 4 4 amps = 29 Ah/day. The average daily irradiance profile for the location in July, the total insolation that fell on a surface tilted to 20° would be only 4.5 kW/m^2. This would equate to 4.5 peak hours of irradiance. Calculate array size based on the month with the lowest insolation for a load profile that is constant throughout the year, or for each month and compare to the load required for that month and choose the largest number of modules needed in any month. Figure 3.1 shows the graphical representation of irradiance profile with the sun suddenly" turning on" to the peak irradiance level.

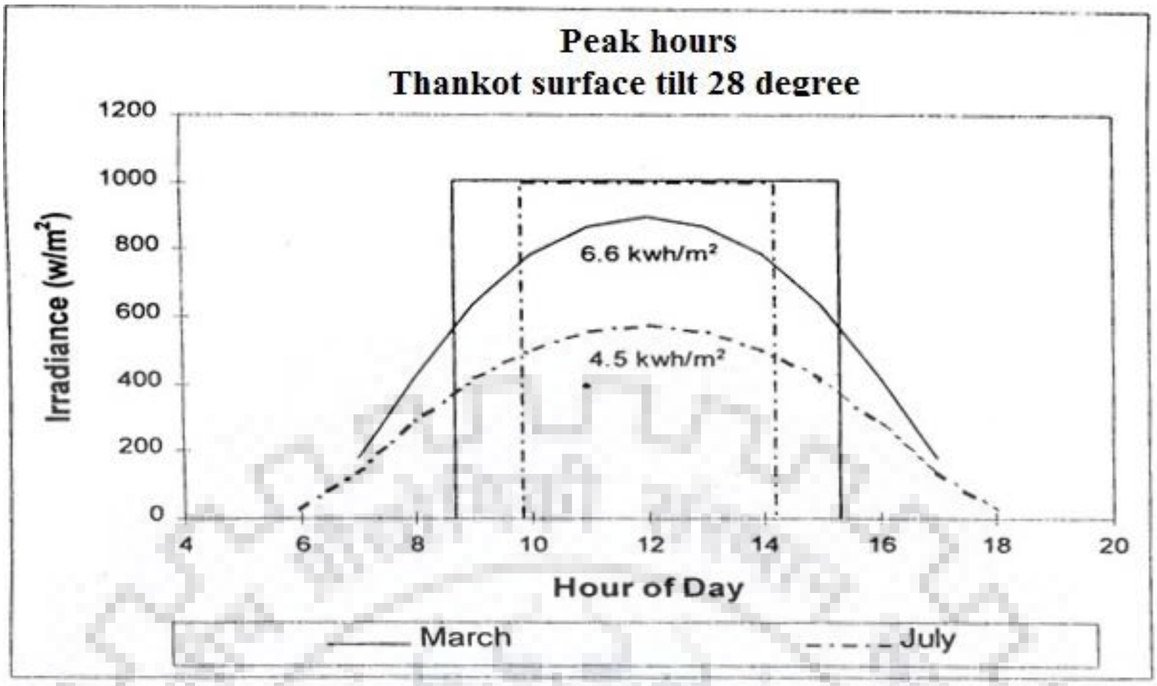


Figure 3.2 Equivalent Irradiance Profile with the Sun Suddenly "turning on" to the Peak Irradiance Level of 1000 W/m^2[52] .

If insolation data is reported in units other than kWh/much as Langleys (calorie/cm^2), Megajoules/m^2, or Btu/ft^2, then multiply by the conversion factor presented below to change into kWh/m^2 and therefore peak hours. Table 3.2 gives the conversion factors to convert the unit of insolation value to standard insolation value.

Table 3.2 Conversion Factors For Peak Hours[52].

Unit of Insolation	Multiply by this factor to convert to peak hours.
kwh /m^2/day	1.0
Langley / day	0.01162
MJ / m^2/ day	0.2777
Btu/ft^2 /day	0.003155

Step-8: Translating from Horizontal to Tilted Insolation: For many regions of the world, the only available solar radiation data is in the form of monthly averages for daily global horizontal insolation. Photovoltaic system designers require insolation data for tilted surfaces to properly size systems. For this reason, methods are needed to translate actual measured horizontal data to reasonably accurate values for tilted surfaces. Presented next are a number of empirical and geometric relationships required for this estimation. The total solar insolation or radiation intercepted on a tilted surface is made up of three contributors:

- direct beam radiation coming from the actual disk of the sun
- diffuse whole-sky radiation coming from the entire canopy of the sky; and
- reflected radiation bouncing from the ground or nearby surfaces.

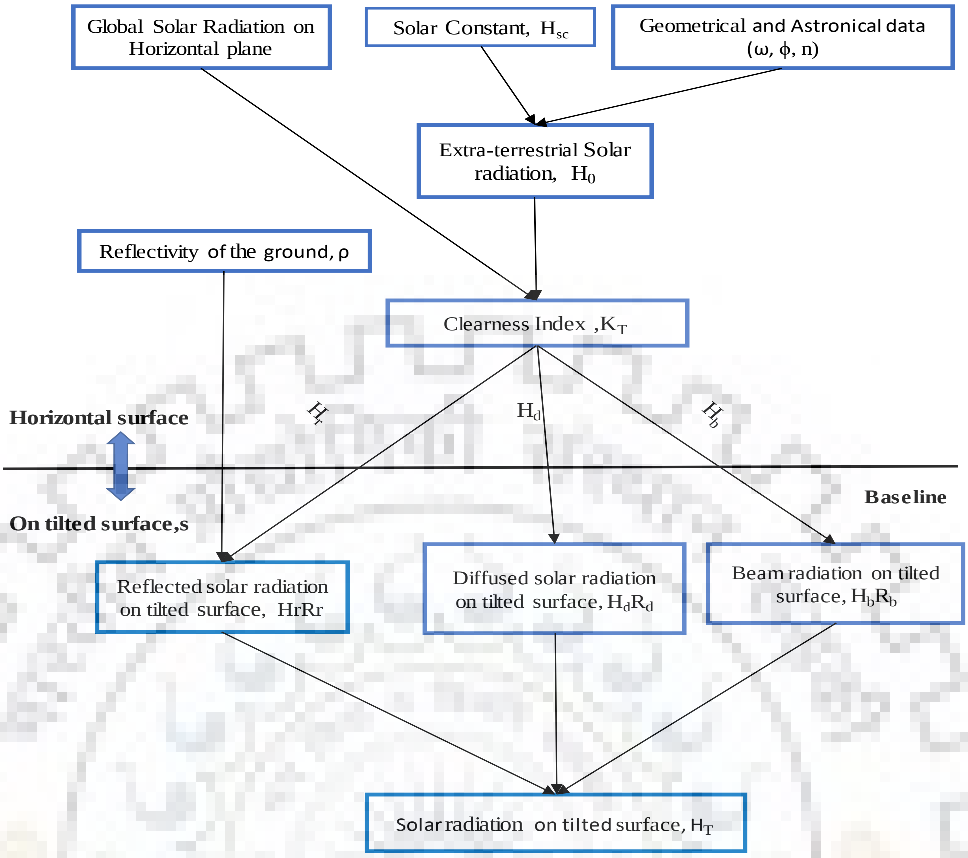
Total Insolation on a Tilted Surface is the sum of Direct (beam) Insolation, Diffuse (whole-sky) Insolation and Reflected Insolation.

When measurements of total (global) insolation on a horizontal surface are recorded, and then averaged, these components are lost, and all that remains is a total "bucket" of insolation with no information about how much was direct and how much was diffuse. Separate these two components from the total, because it contributes to the total insolation on a TILTED surface in different ways. The diffuse component is just a function of how much of the total canopy of the sky the tilted surface "sees". The direct component needs to be added up as the angle of the sun changes during the day, and is a function of the exact path of the sun on that day at that latitude. The reflected component just depends on the tilt angle of the surface, as it accumulates the same fraction of both the direct and diffuse. Summary of steps to calculate insolation on a fixed tilted surface using monthly average insolation data measured on a horizontal surface are given in Table 3.3 [**52**].

Table 3.3 Steps to Calculate Insolation on a Fixed Tilted Surface[52]**.**

Step	**Procedure**	**Variable**
1	Establish the desired tilt angle for the modules and the site latitude.	s, L
2	Read from literature the measured average terrestrial insolation on a horizontal surface for each month.	
3	Determine the declination and sunset hour angle for a representative day for each month. These are geometric variables that depend only on day of year and latitude.	δ, h_s
4	Determine the extraterrestrial horizontal insolation. This is the radiation outside the atmosphere, a variable due the non-circular orbit of the Earth around the Sun.	
5	Calculate the clearness index, the ratio of actual terrestrial to extraterrestrial insolation. This indicates how much of the theoretical radiation actually got through to the surface.	
6	Determine the ratio of the diffuse to total insolation. This comes from a model of the sky, and separates the diffuse or indirect radiation from the total. (The remainder would be the beam or direct radiation coming from the disk of the sun).	
7	Determine the sunset angle for a tilted surface (if different from the angle for a horizontal surface).	h'_s
8	Determine the beam radiation tilt factor. This is a geometric factor that adjusts for the surface area presented at a tilt angle compared to horizontal.	
9	Select the ground cover and the associated ground reflectivity factor.	
10	Calculate the final total insolation on a tilted surface by adding up the contribution for direct, diffuse, and reflected insolation.	

Figure 3.3 shows the pictorial view for transferring the horizontal irradiance data to tilted surface, above the base line is shows the horizontal irradiance data whereas below base line gives the process for converting the horizontal data to any tilted surface.



Where ρ_g = ground reflectivity, generally use 0.2 as default value. Table 3.4 gives ground reflectivity for various common surfaces.

Figure 3.3 Methodology Flow Chart for Transfering Horizontal Radiation to Tilt Surface.

Table 3.4 Ground reflectivity factor for various common surfaces[52].

Ground Condition	**Ground Reflectivity factor ρ_g**
Earth roads	0.04
Water surfaces from above	0.07
Coniferous forest (winter)	0.07
Weathered blacktop	0.10
Gravel, bituminous roof	0.13
Soils (clay, loam)	0.14
Dry grass	0.20
Crushed rock	0.20
Weathered concrete	0.22
Green grass	0.26
Forest in autumn, ripe field	0.26
Dark building surfaces	0.27
Dead leaves	0.30
Light building surfaces	0.60
Snow	0.75

Step 9: Battery Sizing: Battery sizing for development of stand-alone solar photovoltaic system is one of the challenging tasks, for this the day of Autonomy or reserve needed to estimate first [**52**].

Days of Autonomy or Reserve: The battery bank is sized to operate the loads during a long sequence of below average insolation days. The battery as being "full of charge" is considered. During a below average days, the array cannot supply all the amp-hours of charge needed to replace what the load draws from the battery. So the battery ends up being discharged at the end of the day. If the next day is again below average, then the battery again discharges some to operate the loads. This process can go on for only so long before the battery discharges to a point that is may become damaged. The system designer must build into the battery capacity enough equivalent days of charge to operate the loads autonomously, meaning without any input of energy from the solar array. These equivalent days of reserve are referred as "days of autonomy".

The usual rough values that are used in most system sizing calculations are about 4-7 days for non-critical applications, and 7-14 days or even more for more critical applications. Non-critical situations usually involve occupied systems, where the users can adjust their load demand a little to accommodate the bad weather. Critical situations might involve commercial or governmental systems for communications or navigation, or important health needs such as hospitals and clinic. And very remote systems must have a large capacity in their battery bank to allow for the time it would take a maintenance crew to arrive at the site [**52**].

Rough Guide to Days of Reserve or Autonomy	
Non-critical Applications 4-7 days	Average 5 days
Critical Applications 7-14 days	Average 10 days

Basic Battery Sizing Calculation: The basic formula for calculating battery size is presented in Equation 3.2. It involves multiplying the number of days of reserve time the amount needed daily for the load. This would give the first approximation to the size of the battery capacity. But all of the battery capacity to be discharged during the "days of autonomy" cannot be allowed. Manufacturers recommend that only 80% of even deep cycling batteries, be discharged. So, divide by the maximum percentage usable to give the amount of capacity to install.

Maximum Percentage Usable	
Deep Cycling Battery Type	Up to 80%
Shallow Cycling Battery Type	Up to 50%

The formula then is given below for calculating the battery capacity that must be installed.

$$\text{Battery Capacity} = \frac{\text{Number of Days of Reserve} \times \text{Daily Load}}{\text{Maximum \% Usable}} \tag{3.2}$$

Each battery has a nominal voltage, depending on how many single cells are connected by the manufacturer. Some large cells are only two volts, some smaller units are six or twelve volts. The formula for the number of batteries to connect in series to give the voltage for the loads is simply the nominal system voltage divided by the nominal battery voltage given in Equation 3.3.

$$\text{Number of Series Battery} = \frac{\text{Load Nominal Voltage}}{\text{Battery Nominal Voltage}} \tag{3.3}$$

Complete Battery Sizing Calculation: Putting all these correcting factors together, a final formula calculating the capacity of a photovoltaic battery bank was developed and is given in Equation 3.4 [**51**].

$$\text{Battery Capacity} = \frac{\text{Number of Days of Reserve} \times \text{Daily Load}}{\text{Maximum \% Usable} \times \text{Temp. Derate} \times \text{Rate Factor}} \tag{3.4}$$

Step 10 Inverter Selection: As far as application concern, the most important characteristics of the inverter are output power and surge power, output efficiency and power waveform. For the best inverter selection, the total load in the study area should be identified. The load that needs surge power eg. pumps, electric motors, compressors can take a much higher power at the time of starting should be estimated. This estimated surge power gives the better idea for selecting the required inverter and hence one can ask the manufacturer for the characteristic curve for such inverter. This is how the efficiency of the inverter can be determined from the characteristic curve. It depends upon the load i.e. part load, full load. If we oversize the inverter and operate the system at part load it affects the efficiency of the inverter. The capability of the inverter is how the heat can be dissipated by it and is dependent on ambient temperature. The voltage and frequency are the two parameters to obtain the best quality of output power from the inverter. High efficiency over the entire power range is very important for a god performance of the system. One of the important task for development of solar photovoltaic system is inverter selection after find out the total solar irradiance, PV module and load profile of study area the proper size of inverter was selected.

Step 11 Modeling in PVSYST software: PVSYST software is the one of the design tools for developing the solar photovoltaic system for both stand alone and grid connected system. From project setting menu in software, the location of study area is first fixed. After setting the study area lat/long in software the solar data were automatically fed to the system for simulation, there is provision for fed the input data manually also. Then system design is done in the software and simulation is done. all the process is same for stand-alone system except there need to be give the load data of the study area and time of operation. Based on the result of techno-economic analysis, the best system should be preferred.

Step 12 Economic analysis: The project analysis cost parameters like: Net present value, Internal rate of return, Benefit cost ratio, Per Unit Generation Cost, Payback period, Debt service Coverage Ratio and other financial terms are expected to be calculated for the techno-economic analysis in order to know the feasibility of any project. An approach to economic analysis that looks at the total life costs of these different systems is required. Similarly, there are different type of SPV component found in market which cater the need to perform the economic analysis to choose the optimal size of the system. In the present study economic analysis can be perform in both PVSYST and excel sheet. On the basis of per unit generation cost of the solar energy to be generated, decision should be made either stand alone or grid connected to be preferred.

Step 13 Validation and conclusions: Per unit generation cost should be reviewed and shall be comparable according to the present tariff rate of saleable energy rate in Nepal. The provision should be made for the excessive energy selling facility to NEA as per the Power purchase Agreement (PPA) clause quoted by the Government of Nepal.

3.4 DELINEATION OF STUDY AREA BOUNDARY AND ROOFTOP

The geographic coordinate system used in this study is World Geodetic System 1984 (GCS WGS 1984) and for calculation and analysis is projected system WGS 1984 UTM zone 45N for Nepal. The boundary is drawn as required using manual digitization in ArcMap to form a polygon which behaves as a shapefile. The required image for processing is then extracted by the tool known as extracted by the mask in ArcMap. Figure 3.4 shows the proposed study area in arc base map with boundary.

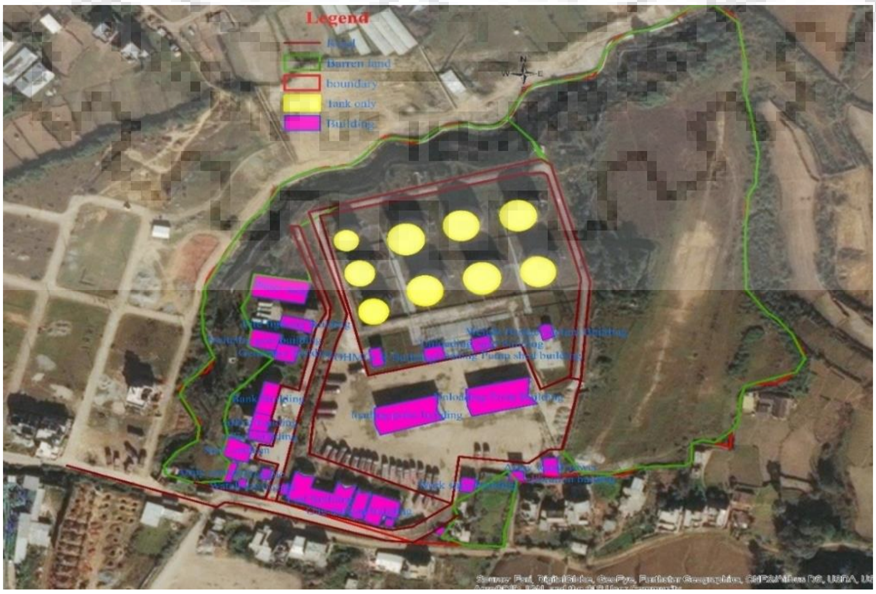


Figure 3.4 Proposed Study Area in Arc Base Map with Boundary.

3.5 CALCULATION OF AREA FOR SOLAR PANEL INSTALLATION

One of the essential tasks for developing the solar photovoltaic in premises of Nepal oil corporation limited, Thankot depot is to find out the total area available and rooftop of area of various building situated in area. To get the study area boundary and rooftop area delineation of boundary and roof top is done in ARC GIS 10.4.1 manually and make the shape file for each category i.e. shape file for building, tank etc. the digitization work in Arc GIS 10.4 is shown in Figure 3.5

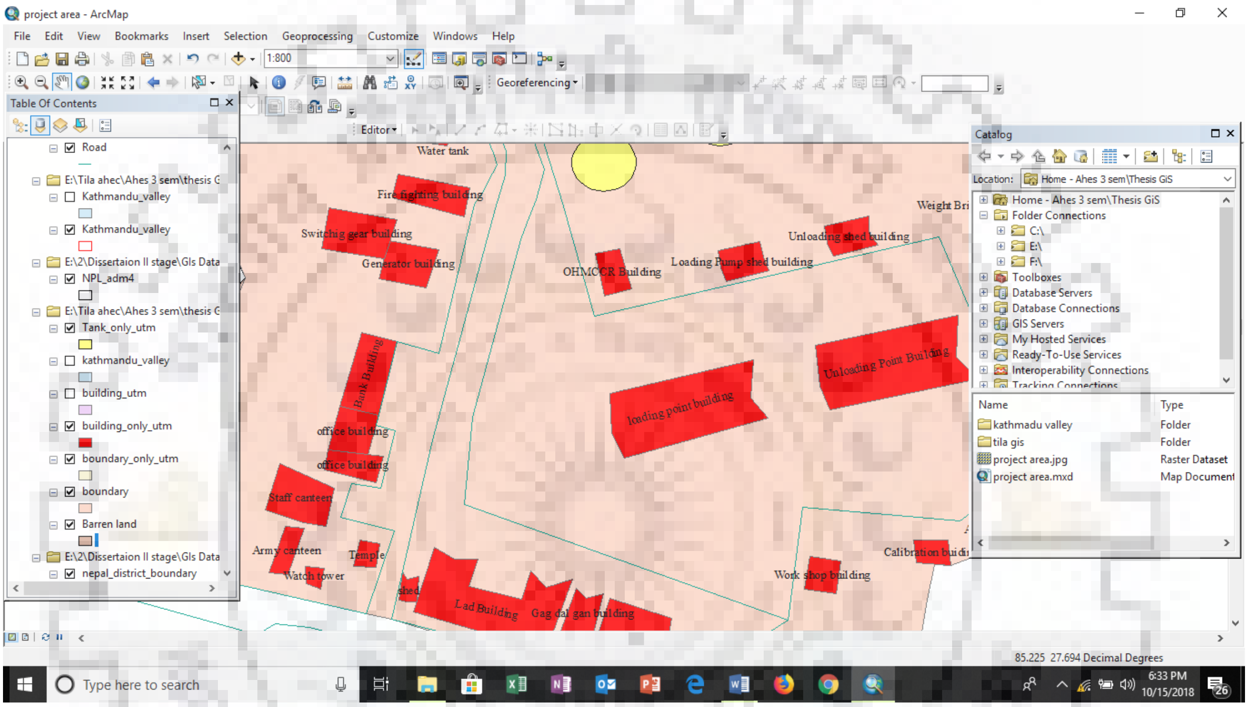


Figure 3.5 Digitization Work for Calculating the Area of Rooftop in ARC GIS Enviroment.

After making the shape file for each layer the area is calculated through ARC Gis by converting each file in WGS 1984 UTM 45 N coordination system. To calculate the area first the attribute table was opened from layers bar, them from table option we add field for calculation of area. Then from calculate geometry we can simply calculate all available area of the rooftop, barren land and fuel tank. The rooftop area available on the loading/unloading point of tank truck/lorry filling shed, laboratory rooftop area, Oil handling master control room rooftop area, loading/unloading pump shed rooftop area, rooftop area available in tank truck calibration tower, weight bridge section, workshop building, firefighting building, switchgear building Jagdal building for the Nepal army cadre to maintaining the security of petroleum products and hazards. This table also includes rooftop area of generator house building, office building, Branch office of Bank of Kathmandu, which is establish for the facilitating the monetary transaction to the consumers of Nepal oil corporation Ltd. and other miscellaneous buildings. Finally, the rooftop area to be available for solar photovoltaic system installation of each building has been calculated individually from Arc GIS 10.4 shown in Figure 3.6.

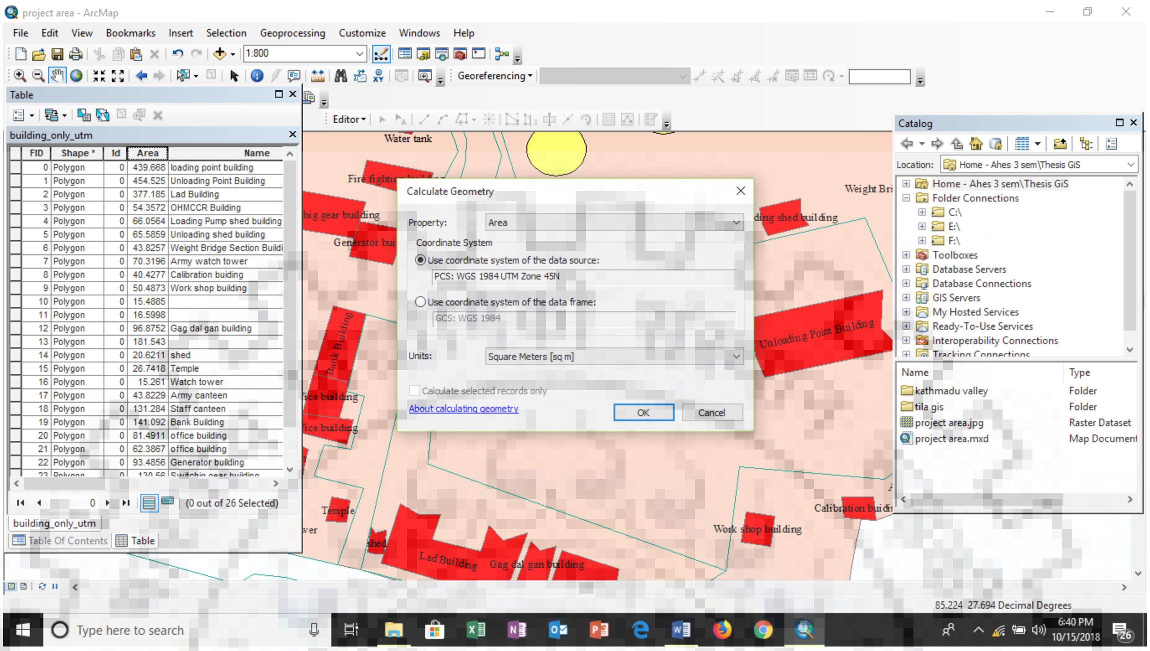


Figure 3.6 Calculation of Area of each Rooftop using ARC GIS 10.4 .

Figure 3.7 shows the all boundary and overall view of study area in shape file format.

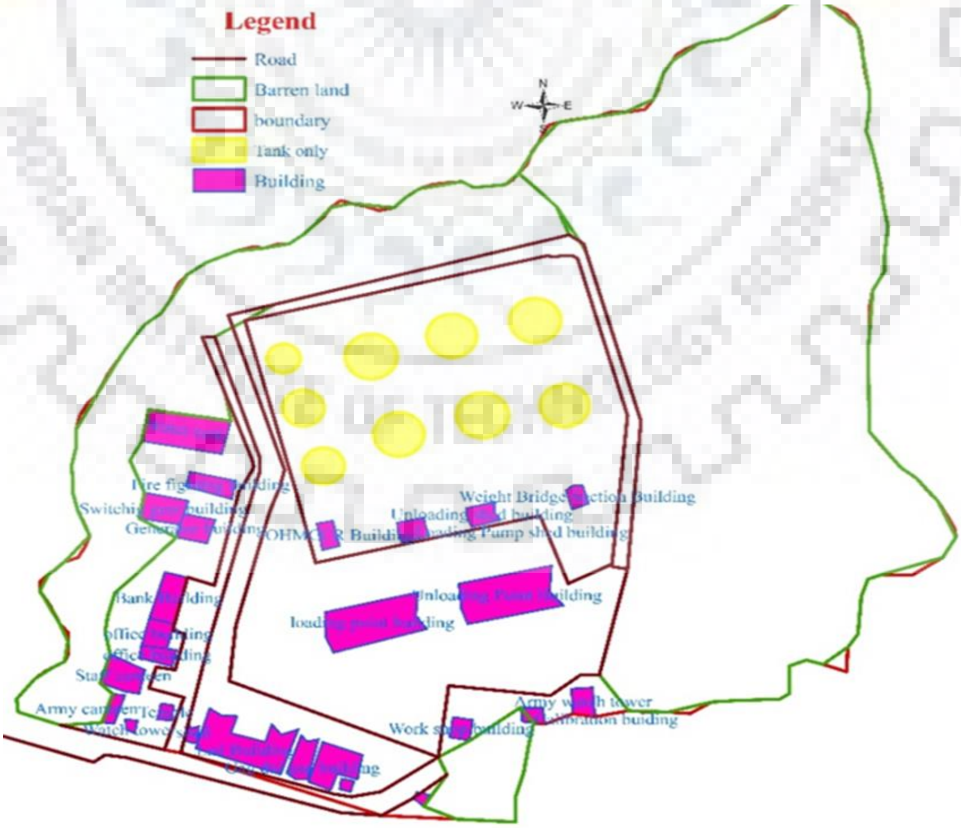


Figure 3.7 Proposed Study Area in ARC GIS Map with Boundary.

In order to size the reliable, efficient and cost effective solar photovoltaic system, the area to be available in the proposed site is calculated in square meter units. Table 3.5 gives the individual rooftop area to be available in the NOC premises. It was calculated from the table that the maximum rooftop area to be available is on Unloading point TLF shed whereas the minimum area available is on Nepal army watch tower. After accumulating all area to be available, the total area to be available for the proposed study area is 33146.53 m^2.

Table 3.5 Rooftop area of the individual building of the proposed site.

S.N	Name	Area (m^2)
1	loading point TLF shed building Rooftop	439.67
2	Unloading Point TLF shed building Rooftop	454.52
3	Lab Building rooftop	377.18
4	OHMCCR Building rooftop	54.36
5	Loading Pump shed building rooftop	66.06
6	Unloading Pump shed building rooftop	65.59
7	Weight Bridge Section Building	43.83
8	Army watch tower-1	70.32
9	Calibration Tower building	40.43
10	Work shop building	50.49
11	Watch tower-2	15.49
12	Watch tower -3	16.60
13	Jag dal Gan building-1	96.88
14	Jag dal Gan building-1	181.54
15	Visitors waiting room shed	20.62
16	Temple	26.74
17	Watch tower-4	15.26
18	Army canteen	43.82
19	Staff canteen	131.28
20	Bank Building	141.09
21	office building-1	81.49
22	office building-2	62.39
23	Generator house building	93.49
24	Switch gear building	130.56
25	Firefighting building	96.64
26	Water Tank	319.38
	Sub-total rooftop area (A)	**3135.72**

The area of tank was calculated also Table 3.6 describes the rooftop area of existing fuel storage vertical tank is calculated individually. Depending upon the size of the tank, proportionate content of petroleum products is stored for stock transfer and depot load purpose. Motor Spirit, High Speed Diesel and Superior Kerosene Oil are stored in the vertical tank. The total rooftop area available for the installation of the solar array is 1582.93 m^2

Table 3.6 Rooftop area of the vertical oil storage tank.

S.N.	Name of oil tank	Area (m^2)
1	Motor Spirit (MSTank-1)	87.38
2	Superior Kerosene Oil (SKOTank-3)	212.20
3	Motor Spirit (MS Tank-5)	197.39
4	Motor Spirit (MS Tank-2)	135.54
5	High Speed Diesel(HSD Tank-4)	137.94
6	Superior Kerosene Oil(SKO Tank-6)	199.86
7	High Speed Diesel(HSD Tank-8)	215.98
8	High Speed Diesel(HSD Tank-7)	206.80
	High Speed Diesel(HSD Tank-9)	189.84
		1582.93

One of the benefits for the study area is that there is large amount of barren land which is available at the premises of depot. The total area of Spare/barren land available for the installation of Solar Photovoltaic system in the premises of Nepal oil corporation ltd. has been calculated and is given in Table 3.7. Total available barren land area is 2827.88 m^2 calculate from ARC GIS. Nepal Oil Corporation Ltd. Kathmandu, Nepal purchased the barren land available for the purpose of depot extension to fulfill the market demand of petroleum products in future. In the present scenario this area is proposed to install the solar array in order to meet the energy demand for their captive use. Hence, the total available area of the study area is calculated as given in Table 3.7.

Table 3.7 Barren Land Available in the Premises of the Present Study Area.

S.N.	Barren land	Area (m^2)
1	Eastern side	20925.20
2	Western side	6631.63
3	Southern side	871.05
	Sub-total barren land area (C)	**28427.88**
Total available rooftop area including barren land of study area (A+B+C)		**33146.53**

After accumulating all sub-total rooftop area to be available including barren land, the total area to be available for the proposed site is 33146.53 m^2.

3.6 DATA COLLECTION OF THE STUDY AREA

The proposed site was visited and a physical inspection of fuel depot has been made. The bird eye view images were taken at the time of physical inspection of the present study area. The photograph of Nepal oil corporation limited with difference view was taken on dated 10 Aug 2018. The photograph includes rooftop area of available building, tank lorry filling shed, fuel storage vertical tank, tank farm area, loading unloading shed with available barren land of the present study area which can be used to installed solar photovoltaic system for electricity generation. Figure 3.8 shows the bird eye view image of the various existing rooftop building i.e. laboratory, store room and Jagdalgan house in the Nepal oil corporation Ltd. Thankot depot office premises.

Figure 3.8 Bird Eye View Image of Laboratory and Jagdalgan Building Rooftop.

Figure 3.9 shows the bird eye view image of the barren/spare land in the Nepal oil corporation Ltd.Thankot depot office premises. This plane land belongs to the organization itself and can be proposed to install the solar panel for the solar power generation.

Figure 3.9 Bird eye view image of available Barren land.

Figure 3.10 shows the bird eye view image of the rooftop buildings i.e. loading/unloading point of tank truck/lorry filling shed, Oil handling master control room loading/unloading pump shed, tank truck calibration tower, weight bridge section, in the Nepal oil corporation Ltd. Thankot depot office premises.

Figure 3.10 Bird’s Eye View of Available Rooftop Area of Fuel Tank Truck Loading/Unloading Shed.

Figure 3.11 shows the bird eye view image of the fuel storage vertical tank including tank farm area.

Figure 3.11 Bird's Eye View Image of Fuel Storage Verticle Tank/ Tank Farm Area.

3.7 LOAD ESTIMATION

To access the load estimation following procedure has been carried out. Electrical Load survey was carried out for calculating the daily energy demand of the proposed site. The electricity consumption for the storage of petroleum products (MS, HSD, SKO), loading/Unloading tank lorry, performing quality control test in laboratory, tank truck calibration, firefighting safety and other daily officials works and the daily load of the fuel depot of Nepal oil corporation premises was calculated and the power requirement per day is as shown in the excel sheet and shown in Annexure 1.

The energy demand of the study area has been calculated by knowing the hourly energy demand per day. From the above data, the load profile has drawn which is as shown in Figure 3.12. The line graph in the Figure 3.12 illustrates the hourly load demand of fuel depot at Nepal oil corporation Ltd, Kathmandu in Nepal.

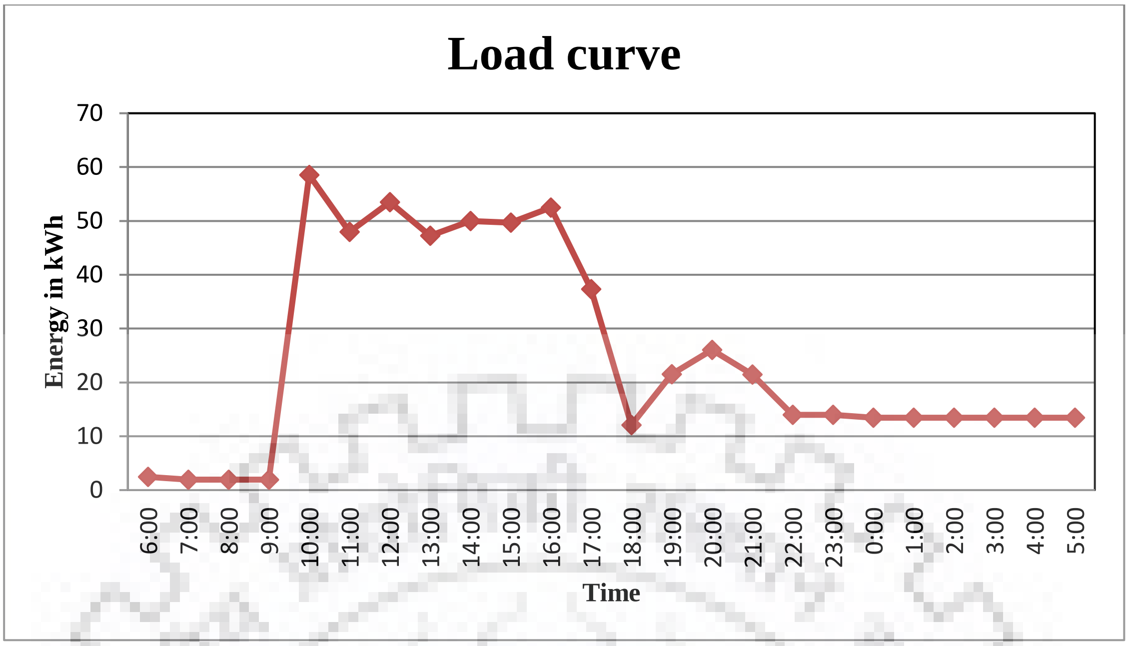


Figure 3.12 Load Profile of the Study Area of Nepal Oil Corporation in Kathmandu.

The load is estimated as the power consumed per hour to operate the fuel depot smoothly in a day time i.e. from 6:00 AM to 5:00 AM. The load variation showed a slightly steady from 6:00 AM to 9:00 AM in the morning but significant rise over 9:00 AM to 5:00 AM the power requirement is continued with the gradual increase due to which most of the centrifugal pump, motors in loading/unloading fuel and the electrical apparatus use to perform quality control test in the laboratory begins to operate at the same time.

From the graph one can forecast that 11:00 AM in the daytime is the peak load period of fuel Depot at Nepal oil corporation limited. The power consumption is likely to be steady from 12:00 noon to 5:00 PM. For an hour load variation dramatically reduced up to 6:00 PM. The graph projects the load is incredibly increased from 6:00 PM to 10:00 PM. It is because of the security team, Nepal army who were residing in Jagdal building use electrical power to pump water for firefighting purpose, domestic purposes like cooking, housekeeping, lighting overall the premises of fuel depot, heating and other accessories. It is seen that from 10:00 PM to 5:00 AM the power requirement is steady. Only for the lightning purpose of depot premises area power is consumed and hence a load curve is drawn.

3.7.1 Seasonal Load

On the basis of load survey given in Annex 1, some electrical appliances like room heaters and fans are operated seasonally on according to the weather condition of Kathmandu valley the seasonal load data for entire year. Table 3.8 illustrates the seasonal load demand in kWh for the operation of electrical appliances like fan, heater etc. which are operated only in seasonal basis.

Table 3.8 Seasonal Load Profile of Proposed study area.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	sept	Oct	Nov	Dec
Fan Load (KWh)	0	0	60	50	163	164	190	264	264	163	50	0
Heater Load (KWh)	625	500	300	18	18	18	18	18	18	18	300	500

It is evident from the table that the heaters are operated only in winter season in order to adjust with cold weather where the maximum power demand is recorded on the months of January while the fans are operated only in summer season so that one can feel easy to work within the sunny days where the maximum power demand is recorded on the month of august and September. Figure 3.13 shows the seasonal load curve which is in the form of inverted shape.

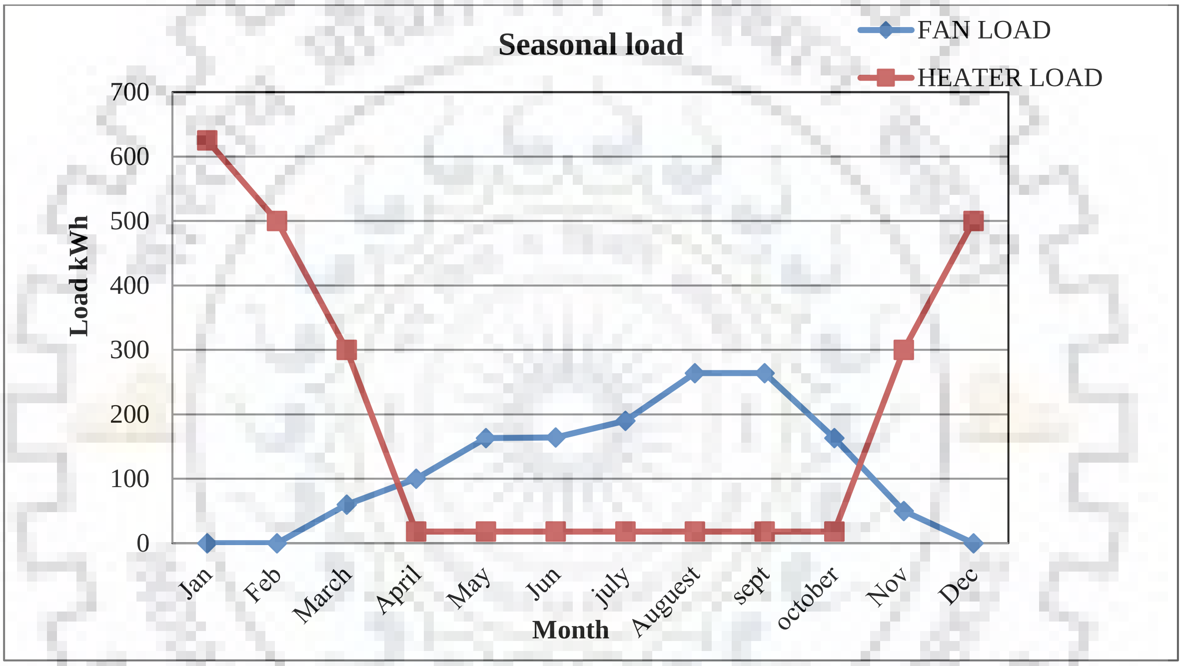


Figure 3.13 Seasonal Load Profile of Thankot.

The line graph represents the monthly seasonal load demand over the year of fuel depot at Nepal oil corporation Ltd. Due to the cold weather in winter at Kathmandu valley the load demand for the operation of electrical heater is maximum at the month of January. From January the load demand trend is continued with the gradual decrease and dropped significantly at the month of April.

3.8 HOURLY SOLAR RADIATION DATA COLLECTION OF THE STUDY AREA

To assess the solar radiation data for the present study area, the data was firstly tried to assess from the Department of Hydrology and Meteorology of Nepal. Unfortunately, the data thus obtained by the department was not maintained properly which was just used to generate a little idea and not useful as a whole. Due to this fact, the reliable data of the hourly solar radiation containing global horizontal solar radiation, direct normal irradiance, extra-terrestrial direct normal radiation, extra-terrestrial horizontal radiation, diffuse radiation from 2001 to 2015 are collected as Typical Meteorological Year (TMY) file from the National Renewable Energy Laboratory (NREL) datasets for the station 444540, TIF and solar map are also downloaded [56].

NREL NSRDB meteonorm solar radiation data has been used for the energy yield assessment at the time of simulation in PVSYST. No ground measured data on the proposed site was available for energy yield assessment. The data thus obtained from the sites indicates that an annual mean of 4.7 kWh/m^2/day global horizontal irradiation is received at the site which is among the average bracket of irradiation received in Nepal and hence, can be considered suitable for the solar power project. The hourly solar radiation containing global horizontal solar radiation, direct normal irradiance, extra-terrestrial direct normal radiation, extra-terrestrial horizontal radiation, diffuse radiation from 2001 to 2015 are collected as Typical Meteorological Year (TMY) are converted into tilted surface by direct input in the PVSYST as a simulation parameter. Meanwhile, all the formulas required for conversion of solar radiation in to tilted from horizontal irradiance are

Step 1: Set the slope and azimuth

Step 2: Find solar declination angles

$$\boldsymbol{\delta} = 23.45 \sin\left[\frac{360}{365}(284+n)\right] \quad \textbf{(3.5)}$$

Where, n= Day of the year

Step 3: Find the sunset hour angle hs

$$h_s = \cos^{-1}(-\tan\varphi \times \tan\partial) \quad \textbf{(3.6)}$$

Where, φ is the latitude angle of location

$$H_o = \frac{24}{\pi} \times H_{sc}\left[\left\{1 + 0.033\cos\left(\frac{360}{365}\right)\right\} \times \left\{\cos\varphi \times \cos\delta \times \sin h_s + \left(\frac{2\pi h_s}{360}\right) \times \sin\varphi \times \sin\delta\right\}\right] \quad \textbf{(3.7)}$$

Step 4: Extra-terrestrial solar radiation, H_o

Where, H_{sc} is the solar constant =1353 W/m^2

Step 5: Find the clearness index K_T

$$K_T = \frac{H}{H_0} \quad \textbf{(3.8)}$$

Step 6: Find the diffused solar radiation H_d

$$H_d = H[0.775 + 0.00653(h_s - 90) - \{0.505 + 0.00455(h_s - 90)\}\cos(115K_T - 103)] \quad \textbf{(3.9)}$$

Also, the diffuse solar radiation was calculated by using following empirical formula.

$$\frac{H_d}{H} = (1 - 1.13KT) \quad \textbf{(3.10)}$$

Step 7: Find beam radiation, H_b and reflected radiation, H_r

$$H_b = H - H_d \quad \textbf{(3.11)}$$

$$H_r = \rho_g \times H \quad \textbf{(3.12)}$$

Where ρ_g= The reflectance of the ground (≈0.2) also called albedo

Step 8: find the tilt factor for beam radiation (R_b)

$$Rb = \frac{\sin(\varphi - s)\sin\delta + \cos(\varphi - s)\cos\delta\cos\omega}{\sin\varphi\sin\delta + \cos\varphi\cos\delta\cos\omega} \quad \textbf{(3.13)}$$

Step 9: find the tilt factor for difuse radiation, R_d

$$R_d = \frac{1 + \cos s}{2} \quad \textbf{(3.14)}$$

Step 10: find the tilt factor for reflected radiations (R_r)

$$R_r = \frac{1 - \cos(s)}{2} \quad \textbf{(3.15)}$$

Where s is the tilt angle

Step 11: Find the total radiation on tilted surface, H_T

$$H_t = (H_bR_b + H_dR_d + H_rR_r) \quad \textbf{(3.16)}$$

Where, ρg= The reflectance of the ground (≈0.2) also called albedo.

The TMY insolation data obtained from the NREL are converted into the tilted surface by using above formulae. Hence, monthly average hourly global horizontal solar radiation data of the study area are calculated which is given in the Table 3.9 [56].

Since, we calculate solar radiation data by using the above formula in order to validate the same which are obtain from the PVSYST software. Hence the data are almost similar which are getting from the simulation result.

Table 3.9 Monthly Average Hourly Global Horizontal Solar Radiation (Wh/m²).

Month	6	7	8	9	10	11	12	13	14	15	16	17	18
JAN	0.00	0.00	48.71	195.81	391.00	523.94	607.65	614.29	569.58	457.45	290.23	115.55	9.29
FEB	0.00	3.11	91.89	279.46	477.79	639.11	698.93	717.07	684.29	554.07	374.54	176.43	34.89
MAR	0.00	27.35	167.45	377.87	558.71	707.06	783.29	769.77	714.23	581.87	409.10	232.52	67.74
APR	4.00	91.43	283.03	505.73	691.87	815.23	897.93	844.77	787.57	668.43	499.13	293.63	93.17
MAY	19.32	123.55	294.48	504.19	666.65	771.26	873.29	864.45	828.84	668.77	479.71	309.39	129.55
JUN	25.47	125.33	288.93	500.83	629.00	742.37	789.17	843.97	738.93	635.50	516.63	332.40	159.47
JUL	14.58	103.35	216.97	367.74	512.10	587.68	642.97	669.06	590.48	560.42	416.55	271.97	128.55
AUG	5.00	77.84	214.35	368.32	496.39	661.71	760.42	756.35	751.58	624.10	478.13	289.52	114.74
SEP	0.67	62.97	193.63	394.10	561.90	660.70	705.50	738.00	642.80	509.30	358.13	214.90	58.63
OCT	0.00	40.42	196.52	404.97	561.13	662.74	729.84	688.68	590.39	474.97	319.71	127.39	13.65
NOV	0.00	14.17	141.07	328.90	485.10	600.83	655.83	621.33	556.20	402.97	247.93	79.20	0.93
DEC	0.00	1.00	70.06	222.39	381.58	504.77	576.06	571.52	503.16	370.45	223.87	71.74	0.61

This chapter summarize the overall review of study area, methodology adopted and resource needed for the research needed for the study. During calculation of available area high-resolution satellite imagery has been utilized. The total rooftop area available is 33146.53 m^2 calculated by using ARC GIS 10.4 and presented. Solar insolation data for the study is also collected and load estimation is also performed are presented. in this Chapter are the system parameters which further helps in simulation in PVSYST software for Power plant design and results presentation as well.

CHAPTER 4
SIMULATION FOR SIZING THE PV SYSTEM

4.1 GENERAL

As far as the system parameters i.e. calculated area, estimated load, solar energy and other required data which helps further simulation procedure are calculated in the previous chapter, a model can be developed in the PVSYST software. This chapter discusses about the sizing of solar photovoltaic system. For sizing PV system, simulation is done by developing a system model in PVSYST software for both stand alone and grid connected system. Peak hour method is used to size the standalone system done for comparison the result with the software results. Hence, the result of both systems is analyzed and compared in order to prefer the optimum solar photovoltaic system. The PV system is sized considering with the main criteria given below;

- Solar Power (average insolation available).
- Availability of the grid in the vicinity of the proposed site in order to evacuate generated power on 24 Hours a day basis.
- Details about design process are presented in the following sections.

4.2 DESIGN OF STAND-ALONE SPV AND RESULT PRESENTATION

4.2.1 SPV System Sizing

The aim of photovoltaic system sizing is to calculate the number of solar PV modules and batteries required for the reliable operation of the load requirement of a study area on the annual basis. For a PV system, particularly in stand-alone mode needs sizing very carefully. On the one hand, oversizing the SPV plant has a very adverse effect on the price of the generated power, on the other hand under sizing a SPV plant reduces reliability of supply. Successfulness of such a system depends upon the balancing of maximum reliability and minimum cost. As proper system design and array size can reduce high energy cost of SPV to an extent without reducing the component price.

4.2.2 Load Estimation

Any electrical appliances that need electrical power to operate is called load. In standalone system design, it is necessary in order to determine how much amount of energy is required to operate the load. Load estimation parameters that are considered during the time of load estimation in study area are as following:

- Types of load AC (resistive, inductive) or DC load.
- Number of loads (e.g., Lamps, cooler, Air Conditioning, fans pumps, motors, heater, TV etc.)
- Ampere, voltage and wattage rating of each load.
- Hourly operation of individual load.
- Wh/day required by the load and
- Efficiency of the power conditioning unit.

The energy consumed by the load can be mathematically calculated by multiplying the power rating of load by the number of operation hours. The unit of energy is Wh. For the case of multiple load of the same unit, the total energy consumed by each load is calculated by the number of loads of same type. The energy consumed by each load is calculated in hourly basis. To simulate in PVSYST the connected load is categories as seven type and wattage of appliances is calculated by taking the mean of the total load.

The daily energy consumed by the load is 489 kWh/day. In the study area only, AC loads are considered because most of the appliances works on AC power. The daily energy demand should be estimated but it should be considered that also if there is a lot of variation in the daily energy requirement at specific season then the system should design for the worst-case scenario, i.e., for the highest energy consumption period. The daily load consumption and energy demand of the study area is given in the Table 4.1.

Table 4.1 The Daily Energy Demand(kWh) Usages of the Load.

S. N	Particular	Nos	Power (Watt)	Total Load (Watt)	Energy Demand (kWh)
1	Light Load (CFL, Tube light, Incandescent)	260	37.6	9777	32.465
2	Night lamp (SON-T & Halogen)	28	857.1	23998.8	168
3	Fan load	38	70.42	2676	17.92
4	AC	2	4000	8000	64
5	Pump Motor (Centrifugal pump load, Dewatering)	16	7292.81	116685	153.03
6	Miscellaneous (Computer, CC camera, Fire control)	32	73.06	2338	23.6
7	Heater	10	1000	10000	30
	Total			**173476**	**405.015**

4.2.3 Rating of Inverter

The DC power generated by the PV array is fed to the battery. Then, this power is supplied to the inverter through battery bank in order to convert DC to AC or simply through converter for the DC load respectively. Proper inverter and converter should be select in order to get better quality of voltage and frequency of the system. the ampere rating of converter and inverter should be specified in order to handle the current output from the battery. Generally, the input voltage ranges from 12 V, 24 V 72 V and the current from 1 A to about several 10 s of A while the output voltage inverter specification is 220 V AC, 50Hz. The power rating of inverter should be specified in according to PV system developed. In this design, total load connected in the system is 173476 W. therefore the inverter's power handling capacity should be 173476 W. In actual practice, the inverter rating should be selected close to the rating of total load connected in the study area

Daily energy supplied to inverter: In this design, daily energy consumed by load is estimated to be 489.015 kWh. The inverter can handle this much amount of energy is supplied by the battery as well as DC to AC with good efficiency at least 90%. the energy fed by the battery to the inverter input should be more than the energy input by the load. Good inverters provide efficiency as high as 97 percent. Assuming the inverter efficiency is 90 percent, then the energy supplied by the battery to inverter should be 543340 Wh.

$$\text{Energy Supplied from the battery to inverter} = \frac{489015}{0.90} = 543340 \text{ Wh}$$

4.2.4 Deciding the System Voltage

In PV system, the voltage and current from the PV module output are measure in DC whereas the inverter converts the voltage and current AC. The output voltage of the inverter is decided by the voltage at which the load operates. But the input voltage to the inverter is also called as a system voltage, terminal voltage of battery bank and PV array terminal voltage is decided by the other considerations. It depends on the factors like: battery voltage, line current, allowable voltage drop, power loss in the cable etc. In general, terminal voltage of battery used in a PV system is 12 V. and hence, the PV system voltage should be 12 V. If large power PV system is required then it should be in multiple of 12 V, i.e., 12 V, 24 V, 36 V, 48 V etc. By taking into account of voltage drop and power losses in cables, hence minimizing the current carried by the cable system voltage should be selected for higher PV system. For high system voltage can be acquired by connecting more battery and PV panel in series as well. To increase the system voltage, battery should be connected in series. Similarly, it would require two panels in series to generate enough voltage to charge series connected batteries of 24 V terminal voltages. It is concluded that for large PV system, number of batteries and PV panel are required in which the system becomes more expensive.

4.2.5 Sizing of Batteries

The energy required to be supplied by the battery is estimated that 543340 Wh. Similarly, we also estimated that the terminal voltage of the battery band could be 24 V. after sting this condition the number and size of battery required for developing the system is calculated by concerning following parameter

- Depth of discharge (DoD) of battery;
- Voltage and Ampere-hour (Ah) capacity of battery; and
- Number of days of reserve.

4.2.5.1 Determine the Battery Capacity for Given Load

Determination of the battery capacity for the given load is one of the important tasks for development of solar photo voltaic system for this the deep cycle discharge battery are taken. the batteries which are find in market has a depth of discharge (DoD) in the range of 60% to 80%. Here the batteries of 12 V, 100 Ah capacity which have DoD of 70% are taken into account. After this setting the usable capacity of 100 Ah battery is only 100×0.7 =70 Ah calculated. As we already calculate the energy that need to be supply by the battery is 543340 Wh and system voltage is 24 Volts. Dividing the energy to be supplied by the system voltage would give the required charge capacity (Ah) of the battery. Thus, required charge capacity 22639.2 Ah is calculated by using the following formula

$$\text{Required charge capacity} = \frac{543340}{24} = 22639.2 \text{ Ah}$$

After calculating the required charge capacity of battery, number of batteries of capacity 12V, 100Ah used for supplying the required for above charge capacity was found out. Taking into account that the DoD (70 % as we consider), all the charge capacity of the battery is not used. Therefore,

The number of batteries required = $\frac{22639.2}{100\times0.70}$ = 323.4 batteries of 100 Ah should be used. The calculated number of batteries required is in fraction, since the battery number is always whole number, we need to round of this number; thus, we need 324 batteries to supply the required charge capacity. As per the total number of batteries we required, some extra charge capacity (22680 Ah instead of 22639.2 Ah required) is available to the load. So, for the development of solar photo voltaic system these 324 batteries should be connected in parallel. Since we are going to developed the SPV system whose terminal voltage is 24 V and available batteries is 100 Ah of 12 V only. Therefore, in order to get 24 V, two 12 V battery should be connected in series to 24 V terminal voltage [36].

Thus, to fulfill the demand of study area 162 number of batteries of 100 Ah capacity in the battery bank, two of them connected in series and 162 such a series connected batteries are connected in parallel.

Battery Autonomy: While designing the PV system, a battery bank should be connected for storing the charge during no sunshine hours as well as the bad weather conditions. When there is no generation of power by the PV panel, the battery can withstand the energy needed by the load.for such purpose battery autonomy is required. Depending upon the day of reserve, the battery bank size should be increase and cost as well. The total charge that store in the battery and to be supplied for two days autonomy can be calculated as 22680 Ah + 2×22680 Ah =67917.5 Ah (equal three times greater required for no autonomy). Now instead of 324 number of 12 V, 100 Ah, 324×3=972 Nos can be required.

4.2.6 Sizing of PV Modules

While designing PV system it should be done in opposite direction of the energy flow in the system. To design the capacity and the number of PV module, the system sizing parameters under consideration are as followings;

- Voltage, ampere and power rating of the module;
- Insolation data at specified location and time;
- Battery efficiency
- Module temperature;
- Charge Controller and MPPT efficiency;
- Soiling losses.

4.2.7 Daily Energy Generated by PV Panel

The energy generated from the PV panel is fed to the battery to store the total energy in the battery bank and supply daily energy requirement to the load. For the case of autonomy, the battery bank should store more energy than the daily energy consumption by the load. In this design, the daily energy supplied by the battery bank to the inverter input is 543340 Wh. The energy generated from the PV panel should always higher than the energy supplied from the battery bank to the inverter input. This is because of the rating and derating factor of battery bank. The efficiency of battery depends upon type of battery used. Normally the battery efficiency will be between 80 and 90%. Assuming that battery efficiency is 85%. Therefore, the energy fed to the input terminal of battery should be estimated as 639223.5 Wh.

Energy fed to input terminal of battery = $\frac{543340}{0.85}$ = 639223.5 Wh.

The efficiency of the charge controller which is connected before the battery input terminal is also considered. In this design, assume controller efficiency is 90% then the total energy generated by the PV panel at the controller circuit input should be estimated as 710248.36 Wh.

Energy generated by the PV panel = $\frac{639223.5}{0.90}$ = 710248.36 Wh.

Thus, per day energy generated by the PV panel is estimated as 710248.36 Wh. The system should be designed such that the controller circuit can handle the current flowing from the PV module to its input and output from the controller circuit to the battery. For the case of voltage, it should be same as that of system voltage i.e., 24 V in this case.

4.2.8 Solar Radiation, Capacity and Number of Panels

Solar radiation is the main factor for charging the battery, for charging the battery it is necessary that, the PV panel need to supply the energy to the battery bank at 24 V. Therefore, the PV panel should generate 29593.68 Ah i.e.

Total Ah generated by the panel = $\frac{710248.36}{24}$ = 29593.68Ah.

When the total Ah generated by the panel is found to design, other factor which degrade the performance of solar cells can be taken into account. For this high module operating temperature, dust settlement on PV modules, etc., are consider, the ampere hour produced by the PV modules are depend on all these parameters. For the mitigation of this situation, derating factor 0.9 taking into account. therefore, total Ah generated by the PV panel should be 32881.8 Ah can be calculated as

Total Ah generated by the panel = $\frac{29593.68}{0.9}$ = 32881.8Ah.

Since the PV system is developed by using the peak hour method the, solar PV module's power the capacity is measured at an input solar radiation of 1000 W/m2. During the day from sunrise to sunset, the intensities of solar radiation varies significantly. Normally, the number of daily sunshine hours equivalent to 1000 W/m2 (equivalent peak sunshine hours) is estimated for the location at which PV system needs to be installed. From the ten years solar radiation data, the study area where the PV system is to be installed, the peak sunshine hour of the study area is 5.5 hour. So, by dividing the Ah capacity i.e., required to be produced by the PV panel, by the equivalent peak sunshine hours, total Ampere that should be produced by the PV module obtained is 5978.5A.

Total Ampere produced by PV panel = $\frac{32881.8}{5.5}$ = 5978.5A

After calculating the total Ah hour produced by the panel, it is time to decide the peak power capacity of PV module. In order to calculated the capacity of PV module, various power capacities PV module can be used. A typical Peak power rating, Wp (Maximum power the module will produce under 1000 W/m2 and at 25o C) of modules varies from 5 Wp to 300 Wp. Let us consider that we use 136 Wp module is used for this work. The manufacturer data sheet will provide the current and voltage of the module at maximum power point, the rated Wp of module. The typical value of voltage and current of 136 Wp module at maximum power point (Vm and Im) is 37.1V and 8.41 A respectively. To estimate number of modules required to produce 5978.5A current. Since one module can provide 8.41 A, therefore, number of modules $= \frac{5978.5}{8.41} =$ 710.8, approximately 771Nos.

These modules should be connected in parallel, but again two modules are needed to connected in series to get voltage higher than 24V (system voltage), required for charging the battery. Thus, overall number of modules is equal to 771×2 i.e., 1421 modules of 136 Wp, each row containing two modules in series and there should be 771 such rows in parallel.

4.3 MODELLING IN PVSYST SOFTWARE

The modeling in PVSYST needs various input parameters. The input parameters for PVSYST are stated in the previous sections of this chapter. The simulation results are presented below. Figure 4.1 describes the output result after the simulation, various color and their size indicate the various loss and their values. Where Lu stands for the unused energy after the battery became full charge which is found 1.22 kWh/kWp/day, lc is collection loss or PV array losses which found 1.51 kWh/kWp/day, Ls is the system losses and battery charging and equal to 0.47 kWh/kWp/day, and Y_f is the energy supplied to the user and 2.23 kWh/kWp/day.

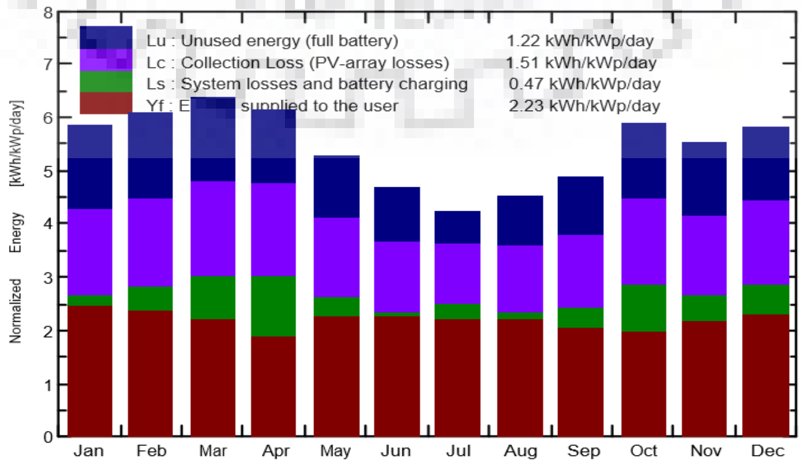


Figure 4.1 Normalize Production (per installed kWp): Norminal Power 405 kWp.

Figure 4.2 describes the performance with respect solar fraction for various month of the study area. From the Figure, it is found that the performance ratio and solar fraction is 0.40 and 0.510 respectively.

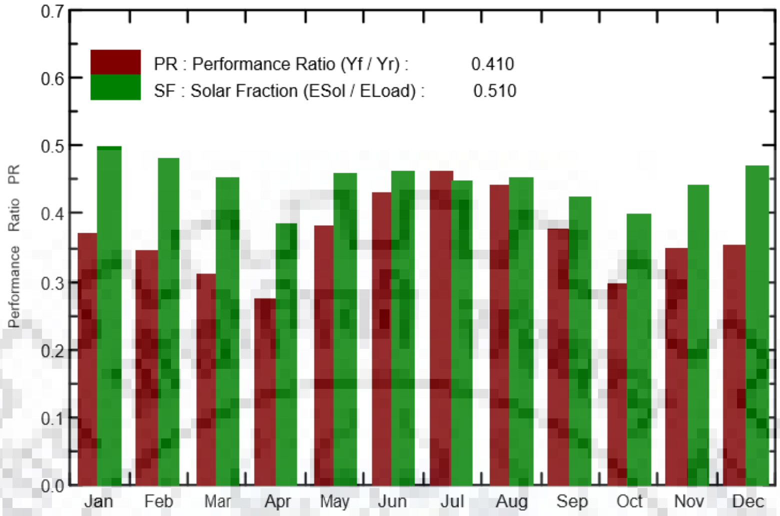


Figure 4.2 Performance Ratio and Solar Fraction SF.

Similarly, the balance and main results of the plant are given is Table 4.2.

Table 4.2 Balance and Main Result of new simulation variant Standalone on NOCL.

	GlobHor (kWh/m^2)	GlobEffV (kWh/m^2)	E Avail (MWh)	EUnused (MWh)	E Miss (MWh)	E User (MWh)	E Load (MWh)	SolFrac (MWh)
January	126.9	172.1	51.14	19.66	23.67	31.14	54.81	0.568
February	133.2	161.7	48	18	22.34	27.16	49.5	0.549
March	173.9	186.8	54.91	19.45	26.57	28.24	54.81	0.515
April	182	173.3	50.53	16.27	29.7	23.34	53.04	0.44
May	174	153.7	45.13	14.43	26.02	28.79	54.81	0.525
June	152.3	131.1	38.78	11.89	25.08	27.96	53.04	0.527
July	141.4	122.6	36.43	7.12	26.79	28.02	54.81	0.511
August	143.3	130.4	38.8	11.03	26.49	28.32	54.81	0.517
September	137.5	137.3	40.83	13.04	27.53	25.51	53.04	0.481
October	149.1	171.8	50.77	17.22	29.94	24.87	54.81	0.454
November	122.6	156.6	46.23	15.95	26.38	26.66	53.04	0.503
December	122.4	170.5	50.27	16.72	25.45	29.36	54.81	0.536
Year	1758.7	1867.9	551.83	180.77	315.96	329.37	645.33	0.51

Where,

GlobEff: Effective Global, corr. for 1AM and shadings   Euser: Energy supplied to the user

E Avail: Available Solar Energy   E User : Energy supplied to the user

SolFrac: Solar fraction (EUsed / ELoad)   GlobHor: Horizontal global irradiation

Eunused : Unused energy (full battery) loss   E miss: missing energy

Euser: energy supplied to load   E load: Energy need of the user (load)

4.4 SIMULATION FOR SIZING THE GRID CONNECTED PV SYSTEM

PVSYST is one of the design tools for the study, sizing, simulation and data analysis of complete PV systems. This tool has been used to generate realistic energy yield simulation results that are presented in this chapter. Main features of PVSYST are as:

- Detailed computation of the used components (modules, inverters, etc.)
- Simulation on hourly basis and detailed evaluation and consideration of different loss factors.
- Calculation of arbitrary orientated module planes (fixed)
- Most accepted and used tool to generate simulation results for big PV power plants, as the results are based on systematic and refined approach.
- Understood to give the most accurate simulation results

4.5 STEP FOR THE DEVELOPING OF A PROJECT IN PVSYST

Developing the project in PVSYST software is very important task for getting the correct and realistic result. In order to get the correct result, it is necessary that we should inter the correct value of data in software. The location of study area and availability of solar radiation and meteorological data plays the vital role for get the correct simulation result. One of the advantages of development and simulation of result in PVSYST 6.7.9 software is that it takes the all the solar and meteorological data automatically after fixing the location of study area while designing. There is also facility of give the any solar radiation as well as meteoritical data in PVSYST software manually also. that following step were adopted for studying this project.

- The geographical location and NSRB TMY data for the grid connected project was Specified first and project was created first.
- Basics system variant, including the orientation of the PV modules, Required Power or Available area, the type of PV modules, inverter was defined in the software. other variant provide in the software were set as default value. PVSYST will propose a basic configuration for this choice and set reasonable default values for all parameters that are required for a first calculation. Then simulation was performed by using this variant and save it. It will be the first rough approximation that will be refined in successive iterations.
- Successive variants were Defined by progressively adding perturbations to this first system, e.g., far shadings, near shadings, specific loss parameters, economic evaluation, etc. simulation were done and save each variant so that compare them and understand the impact of all the details that’s are adding to the simulation.

4.6 PV POWER PLANT ENERGY PRODUCTION

The annual energy yields for the selected site is predicted using the basic by considering the following factor:

- Sourced average monthly horizontal irradiation, wind speed and temperature data from on- site weather station and compared with the other sources which included satellite image derived data and data from land based meteorological stations.
- These data have been assessed and judiciously selected for use in the energy yield simulation software. Calculated the global incident radiation on the collector plane, taking into account shading.
- Calculation of losses, using the inverter specifications, PV module specifications, PV module characteristics in details, on-site conditions and plot layout. Applied system downtime losses, plant unavailability, ohmic losses, module degradation transformer losses and transmission line losses to obtain an energy yield over the life cycle of the project. The losses considered in simulation are given in Table 4.3.

Table 4.3 Description of Energy Yield Losses.

Losses	Description
Shading	Three types of shading losses are considered in the PV energy yield model: horizon shading, shading between modules rows and near shading due to trees and buildings height.
Incident angle	The incidence angle loss accounts for losses in radiation penetrating the front glass of the PV modules due to angles of incidence other than perpendicular
Low irradiance	The conversion efficiency of a PV module reduces at low light intensities.
Module temperature	The characteristics of a PV module are determined at standard temperature conditions of 25˚C. For every ˚C temperature rise above this, module efficiency reduces according to their temperature coefficient.
Soiling	Losses due to dust and bird droppings; soiling the module.
Module quality	Most PV modules do not match exactly the manufacturer's nominal specifications. Modules are sold with a nominal peak power and a given tolerance within which the actual power is guaranteed to lie.
Module mismatch	Losses due to "mismatch" are related to the fact that the real modules in an array do not all rigorously present the same current/voltage profiles: there is a statistical variation between them.
DC wiring Resistance	Electrical resistance in wires between the power available at the modules and at the terminals of the array gives rise to ohmic losses (I^2R).
Inverter performance	Inverters convert from DC into AC with a certain specified maximum efficiency. Depending on the inverter load, they will not always operate at maximum
MPP tracking	The inverters are constantly seeking the maximum power point (MPP) of the array by shifting inverter voltage to the maximum power point voltage. Different inverters do this with varying efficiency.
AC losses	This includes transformer performance (MV/HV) and ohmic losses in the cable leading to substation.

Downtime	Downtime is a period when the plant does not generate due to failure. The downtime periods will depend on the quality of the plant components, design, environmental conditions, diagnostic response time and the repair response time.
Grid availability and disruption	The ability of a PV power plant to export power is dependent on the availability of the distribution or transmission network. Unless detailed information is available, this loss is typically based on an assumption that the local grid will not be operational for a given number of hours/days in any one year, and that it will occur during periods of average production Power is required for electrical equipment within the plant. This includes the inverters, electrical switchboards, security systems, tracking motors, monitoring equipment and lighting.
Degradation	The performance of a PV module decreases with time.

4.7 ENERGY PREDICTION

Energy Yield Assessment (EYA) of solar projects forms the basis for project developers and financial institutes for financial modelling of the project. The predicted yield values from EYA exercise are expressed at P50, P75, and P90 confidence level. These values indicate that the predicted energy yield value will exceed with 50%, 75%, and 90% probability, respectively. Table 4.4 gives the summary of Solar PV power plant at P50.

Table 4.4 Summary of Solar PV Power Plant.

PV module (silicon Polycrystalline)	Trina Solar (TSM-T315PEG14RIAL
Module peak power (Wp)	315
Total number of modules (Nos)	7600
Tilt Angle	28°
Total Module Area (m^2)	14913
Installed Nominal power (kWp)	2394

After simulation, the results from the PVSYST software for the Energy Yield Prediction for 2 MW Solar PV power plant are given in the Table 4.5.

Table 4.5 Energy Yield Prediction for 2 MW Solar PV Power Plant.

Orientation	Fixed Tilt
Fixed Angles	28 ^{o}
Manufacturer	Trina TSM-315PD14
Max. output, $P_{max,}$ at STC (W)	315
Maximum power voltage, $V_{mpp,}$ (Volts)	37.1
Maximum power current, $I_{mpp,}$ (A)	8.51
Open-circuit voltage, $V_{oc,}$ (V)	45.6
Short-circuit current, $I_{sc,}$ (A)	9.00
Temperature co-efficient of Power (%/0c)	-0.4
Length (mm)	1984
Width (mm)	998
Thickness (mm)	7.6
Weight (kg)	22.5
Inverter (2 Nos)	ABB PVS800-57-1000kW-C

Module Efficiency	16.25%
Annual Effective global irradiation (kWh/m^2)	1871.1
Annual Global irradiation on collector plane (kWh/m^2)	1982.7
Plant DC capacity (kW)	2394
Plant AC capacity (kW)	2000
Horizontal Global irradiation (kWh/m^2)	1758.7
PV panel Area	14913
Global incident in collector plane	12.70%
Near shading loss	3.10%
IAM factor on global	2.70%
Soiling Loss	3.00%
Efficiency at STC	16.25%
Irradiance Level	0.40%
Temperature	8.3%
Module Quality	0.40%
Light induced Degradation	2.00%
Mismatch	1.10%
Ohmic Wiring	1.10%
Inverter loss during operation%	1.70%
Inverter loss over nominal inverter power	0.00%
Total loss factor post inverter %	1.7%
Annual energy Yield at invert output (MWh)	3777
AC Wiring %	0.50%
External Transformer loss %	1.10%
Total losses factor post transformer %	1.59%
Annual energy yield after AC losses (MWh)	3716.95
Annual AC Specific Yield (kWh/kWp)	1843
Performance Ratio (PR) %	79.6%

4.8 UNCERTAINTY

The uncertainty in energy yield predictions is difficult to quantify, as it is a function of many independent factors. The discussion below represents simplification of the estimated uncertainty, which is believed to be the best approach given the uncertainty in the resource data.

4.8.1 Uncertainty Resources and Modeling

Energy yield prediction is based on NREL NSRDB climatological database. The quality of ground- measured data is determined from the accuracy of instruments, operation and maintenance routines, calibration, quality and post processing. The monthly mean irradiation data has been obtained from the NREL NSRDB climatological database and synthetic weather generator. For Nepal this is given with an uncertainty of 4.1%. as shown in Figure 4.3.

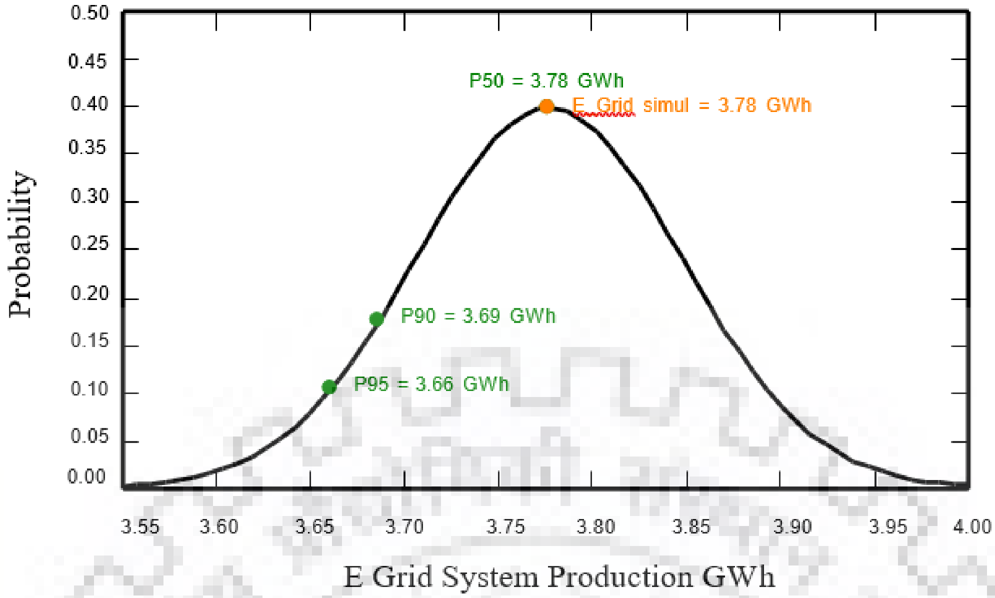


Figure 4.3 Probablity Distribution Curve for System Productuion.

The Probability distribution of the system production forecast for different years is mainly dependents on the mateo data used for the simulation, and depends on the following choices:

NREL NSRDB data sources : Meteo Type

Specified Deviation : Year deviation from average of 3 %

Year-to year variability : Variance of 0.5 %

The Probability distribution variance is also depending on some system parameters uncertainties.

Specified deviation: PV module modeling/Parameters: 1 %

Inverter efficiency uncertainties: 0.5%

Soiling and mismatch uncertainties: 1 %

Degradation uncertainties: 1 %

Global variability (mateo + system): Variance of 1.9 %

From these data total variability of 71 MWh is obtained. Whereas, the average power output is 3777 MWh, i.e. the system has 50% probability to get at least 3777 MWh power output. There is a 90% chance to get at least 3686 MWh power output and 95% chance to get at least 3661 MWh power output.

4.8.2 Inter-Annual Variation in the Solar Resources

Mean global daily irradiation on a horizontal plane varies on an annual basis. This means that the plant owner does not know what energy yield to expect in any given year, but can have a good idea of the expected yield in the long term. The likely variation can be quantified based on analysis of variation in long-term irradiation data in the vicinity of site.

This exercise gives the standard deviation of variation in irradiation. Where historical irradiation data for the site measured is not available, analysis of nearby meteorological stations and satellite-derived data must be used. For the solar site, low-resolution historical data is available from NASA's Surface Meteorology and Meteonorm Solar Energy data set. These datasets are analyzed and computed the coefficient of variation (standard deviation divided by the mean) as shown in table below.

4.9 TOTAL UNCERTAINTY

Combining the uncertainties in energy yield and inter-annual variation in the solar resource, the P50 value presented in Table 4.6 are obtained. These values represent the confidence interval on the energy yield estimate.

Table 4.6 Uncertainty Summary for 2 MW Solar PV Power Plant.

Uncertainty over 25 years, including inter-annual variation in resource	
Standard Error in NREL NSRDB Climatological data (%)	4.1%
Standard Error in Energy Yield Value (%)	1.86%
Uncertainty over 25 years, including inter-annual variation in resource	4.5%
Expected CUF @ P50 %	**21.55%**

4.10 CAPACITY UTILIZATION FACTOR

The performance of a PV power plant is often denominated by a metric called the capacity utilization factor. It is the ratio of the actual output from a solar plant over the year to the maximum possible output from it for a year under ideal conditions. Capacity utilization factor is usually expressed in percentage.

Capacity Utilization Factor (C.U.F) = (Actual energy from the plant (kWh)) / (Plant Capacity (kWp) × 24 × 365)

The energy generation of a plant primarily depends on two key parameters; solar radiation received and the number of clear sunny days experienced by the plant’s location.

4.11 PERFORMANCE RATIO

Performance Ratio is a measure for the performance of a PV system taking into account environmental factors (temperature, irradiation, etc.) Performance Ratio (PR) of a plant for a period of time = Energy measured (kWh)/ (Irradiance (kWh/m^2) on the panel × Active area of PV module (m^2) × (PV module efficiency) PR can be used as a tool to compare different solar PV systems with each other, even if they are located at different locations since all environmental factors will be taken into account. Therefore, only the design and the ability of the system to convert solar energy into electrical energy will be compared with each other.

4.12 SELECTION OF INVERTER AND COMPONENTS

For a complete reliable system and to ensure high energy yield from the plant, components with latest technology and credible manufacturers have been selected. The selected inverter ABB PVS800-57-1000kW-C is known to perform at very high efficiency over a wide range of load.

4.13 SELECTION OF MONITORING SYSTEM

Monitoring system for 2 MW Solar power plant would require state of the art technology to allow for regular real time monitoring and analysis. Some of these requirements are given below;

- Monitors the performance of the entire power plant (string wise monitoring, junction boxes, inverters, etc.)
- Evaluates (strings, power produced, inverter, nominal/actual value), quantity of DC Power & AC
- Measures instantaneous irradiation level and temperature at site along with module back surface temperature.
- Alerts in case of error (discrepancy in normal operation of components, like module string/ diodes/ inverter/ junction box / loose contacts/ etc.) to facilitate recognition and correction of the fault with minimum downtime.
- Visualizes nominal status of the connected components via Control Center PC Software (diagnosis on site or remote)
- Logs system data and error messages for further processing or storing
- Stores and visualizes energy yield data (for life of the plant) in the Portal from where the data can be accessed remotely.

4.14 BALANCE AND MAIN RESULTS

The balance and the main results of the PVSYST software are given in the Table 4.7. From the table it is seen that the minimum Global solar irradiance at collector plate which is tilt at a angle of 28 degree observe at month of July is 131.2 kWh/m^2 and maximum of 197.8 kWh/m^2 observe in the month of March.

Table 4.7 Balance and Main Results of New Simulation Variant Grid on NOCL.

Month	GlobHor kWh/m²	DiffHor kWh/m²	T Amb ºC	GlobINC kWh/m²	GlobEff kWh/m²	Earray kWh	E_Grid kWh	EApGrid kVAh	PR
Jan	126.9	39.85	10.69	181.9	172.4	372614	289172	340241	0.664
Feb	133.2	43.06	13.98	170.9	162.0	341726	335927	395253	0.821
March	173.9	67.77	18.94	197.8	187.2	385787	379216	446187	0.801
April	182.0	85.42	23.46	184.0	173.5	353075	347280	408611	0.788
May	174.0	99.64	24.71	163.8	153.9	319420	313892	369327	0.800
June	152.3	97.90	24.94	140.0	131.2	276752	271828	319834	0.811
July	141.4	94.03	22.85	131.2	122.8	264717	259767	305644	0.827
Aug	143.3	86.74	22.92	139.3	130.7	279086	274041	322438	0.822
Sept	137.5	72.39	21.71	146.1	137.6	292389	260496	306501	0.745
Oct	149.1	59.31	18.97	181.9	172.2	362754	356574	419547	0.819
Nov	122.6	45.46	15.56	165.6	156.9	333847	328052	385988	0.827
Dec	122.4	40.22	12.06	180.1	170.7	366949	360680	424378	0.837
Total Yearly	1758.7	831.49	19.24	1982.7	1871.1	3949116	3776925	4443949	0.796

This chapter explores the result of PVSYST software in both standalone and Grid connected system in order to size the most efficient PV system for the study area. For the stand-alone system peak hour method is also used to calculate the number of solar panel installed to meet the energy demand of study area. After analyzing the result of peak hour method to the result of simulation only 405 kWp nominal power is only used in study area. On the other hand, per unit used energy cost is NPR 38.88 which is expensive and not relevant to the present tariff quoted by the Government of Nepal. From the overall review, it can be decided to prefer grid connected system because the study area has more power potential and more power can be generated from the same. Again, simulation was performed for grid connected and hence the result are analyzed as per followings:

i. The total no. of modules is 7600 of Trina Solar.
ii. The total area occupied by the PV panel is 14913 m^2.
iii. Two inverter of capacity 1000 kW ac has been used to convert DC power to AC power.
iv. the optimum power generated from the grid connected system is 2 MW.
v. The system yields energy of 3777MWh/year

vi. Specific Production: 1578 kWh/kWp/year

vii. Performance Ratio PR: 79.57%.

Long term financial balance was also reported in the simulation results that further helps in performing the detail economic analysis of the project. All the results of the simulation in detail are reported in Annexure 2 and Annexure 3 respectively.

CHAPTER 5

ECONOMIC ANALYSIS

5.1 GENERAL

This chapter includes the detail economic analysis according to the data obtained from the simulation results of the grid connected system. Energy generation and other required data are extracted as per requirement for further calculation of financial parameters in order to analyze the financial viability of the project. Based on the total energy generation, investment, debt equity ratio, equity injection plan, tax and welfare policy and other financial terms, a financial model is developed in order to calculate the financial parameters over the life cycle of the project. The detailed information of the financial model is as given in the Table 5.1.

Table 5.1 Financial Model for the Project

Particular	Unit	Value
Capacity of project	MW	**2.00**
Per MW Cost in (NRS)	NRS	96,912,648
Project Cost in (NRS	NRS	193,825,296
Plant load Factor		21.56%
Weighted Rate	NRS	**7.30**
Annual Energy generation (kWh)	kWh	**3,776,916**
Equity (**30.00%)**	NRS	58,147,589
Debt (70.00%)	NRS	135,677,707
O&M as of Total Investment	Percent	1.03%
O&M Increment	Percent	2.00%
Welfare and Bonus	Percent	2.00%
O&M Cost	NRS	**2,000,000**
Equity Injection		
Year 1	NRS	58,147,589
Corporate Tax	Percent	20.00%
Interest Rate	Percent	**10.00%**
Increment	Percent	0.00%

5.2 COST ESTIMATION

On comparing the economic evaluation reported by the simulation result with the district dar rate revised by the District Development Committee, Kathmandu on the Fiscal year 2075/76, the per unit rate cost estimate chart is developed with breakdown of each component and total cost of the project is calculated. The cost is break down into two categories i.e. Engineering procurement construction (EPC) and Local cost respectively. The detailed information of cost estimation is as given in the Table 5.2. the estimated complication time for project is consider as 6 months.

Table 5.2 Detail Cost Estimation of the Project

S.N.	Description	Unit	Quantity	Rate/unit	Amount Nrs.
EPC cost					
1	Solar Modules	Nos	7600	13723.92	104301792
2	Support/ integration	LS	1	3447360	3447360
3	Inverter (1000kW ac)	Nos	2	3830400	7660800
4	Setting wiring	LS	1	6128640	6128640
5	End Bay at Grid Substation	LS	1	6511680	6511680
6	Mounting structure	LS	1	10725120	10725120
	Sub Total (A)				**138775392**
Local cost					
7	Civil Works and All Erection Works (Land Levelling, Fencing, Cable trench, Drainage, MMS Foundation, ICR, SCADA Room, Switching Station, TL Foundation)	LS	1	9192960	9192960
8	Transmission Line	LS	1	3600000	3600000
9	IDC	LS	1	1692000	1692000
10	Bank Fees	LS	1	286000	286000
11	Import Duty	LS	1	596000	596000
12	Miscellaneous	LS	1	39682944	39682944
	Sub Total (B)				**55049904**
	Total cost (A+B)				**193825296**
	Per MW (NPR Crore)				**9.69**

5.3 COST ANALYSIS

In order to determine the financial parameters for the total power generation in grid connected system, all the necessary formulas are generated and calculated in excel sheet. Annual energy generation, annual revenue, cash flow, cost benefit analysis, debt service coverage ratio, levelized cost of electricity generation and other required financial terms are calculated. The detail information of financial calculation is shown in excel sheet on Annexure 4.

5.4 SOURCE OF FINANCE

The source of finance for the project is managed as per debt equity ratio i.e. 70% debt and 30% equity of the total project cost. Debt of the project is managed by the financial institute or the consortium of banks which are especially established by the Government for the investment of energy development but as per limitation of bank for debt release, the fund may be managed by the consortium of banks also. For this case, there should be a lead bank among the bank that release high fund. Nepal oil corporation Ltd. Kathmandu, Nepal can inject its own fund for equity

5.4.1 Loan Financing

Of the total initial estimated project cost, NPR 13.57 crores (70%) shall be financed from bank loan and remaining NPR 5.81 crores (30%) shall be financed by shareholder's equity. The loan amount shall be withdrawn over the entire construction period in various installments as and when required. The interest rate on bank loan has been assumed to be 10.0% per annum. The interest accrued and due during the construction period (IDC) shall be treated as part of the project cost and be capitalized along with the loan drawdown amount.

5.4.2 Equity Capital

The total equity requirement for the Project is NPR 5.81 crores which is the 30 percent of total investment. It is proposed that the corporation shall raise required equity capital. since Nepal oil corporation is the profit orientated government commercial organization, equity shall be managed from organization easily.

5.5 POWER GENERATION

The Project has an installed capacity of 2 MW. This project shall generate 3.7 GWh energy each year. Of this total energy 4 percent loss is assumed and hence, net saleable energy shall be 2.617 GWh. The monthly energy generation is extracted from the Table 4.7 and which is also obtained from simulation result is shown in the Table 5.3; which gives the detail of energy generated per month.

Table 5.3 Energy Generated per Month.

Month	Energy kWh
January	289171
February	335926
March	379215
April	347279
May	313891
June	271827
July	259767
August	274041
September	260495
October	356574
November	328051
December	360679
Total	3776916

The graphical representation of monthly energy trend is shown in Figure 5.1 indicates that the maximum energy is generated at the month of March and minimum energy is generated is observed in month of July.

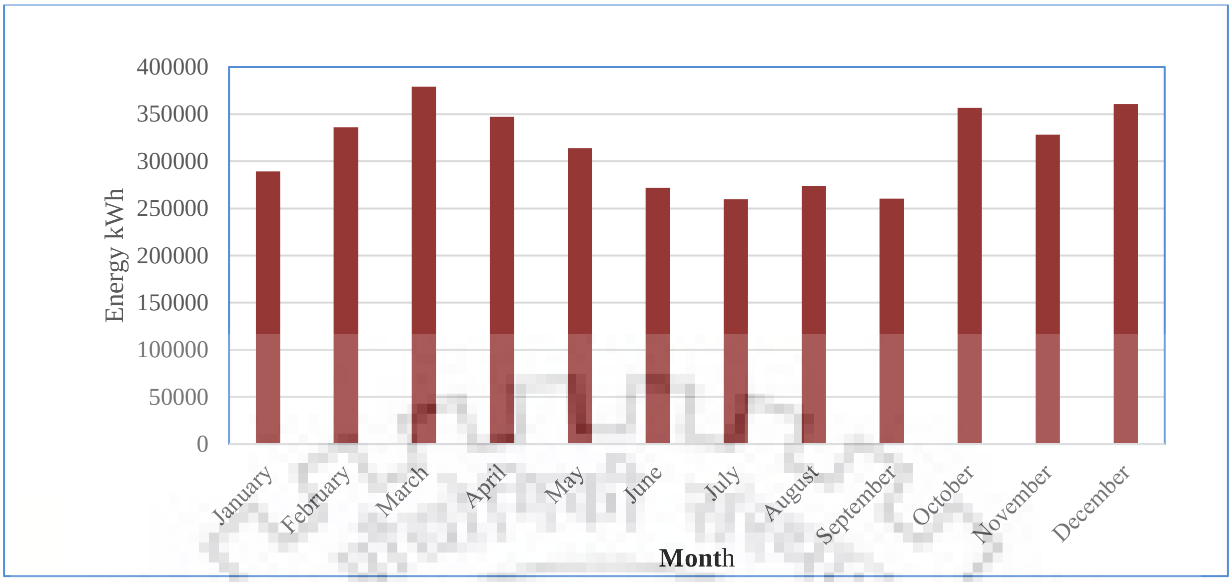


Figure 5.1 Monthly Energy Generation Trend.

5.6 REVENUE FROM THE PROJECT

The monthly energy generation obtained from the table 5.3 is responsible to generated the revenue for the project. The monthly energy generated shall be sold to the Nepal Electricity Authority at a fixed price as indicated in the Power Purchase Agreement. The energy price for this project is fixed at NPR 7.30 per kWh. The estimated revenue from the sale of energy from this project for the first year of operation is shown in Table 5.4.

Table 5.4 Monthly Revenue Generation Trend.

Month	Energy Generated	Rate (NRS)	Amount (NRs)
January	289171	7.3	2110948.3
February	335926	7.3	2452259.8
March	379215	7.3	2768269.5
April	347279	7.3	2535136.7
May	313891	7.3	2291404.3
June	271827	7.3	1984337.1
July	259767	7.3	1896299.1
August	274041	7.3	2000499.3
September	260495	7.3	1901613.5
October	356574	7.3	2602990.2
November	328051	7.3	2394772.3
December	360679	7.3	2632956.7
	3776916		27571486.8

The graphical representation of monthly revenue generated by the project trend is shown in Figure 5.2 which shows that the maximum revenue is generated at the month of March and minimum revenue is generated is observed in month of July.

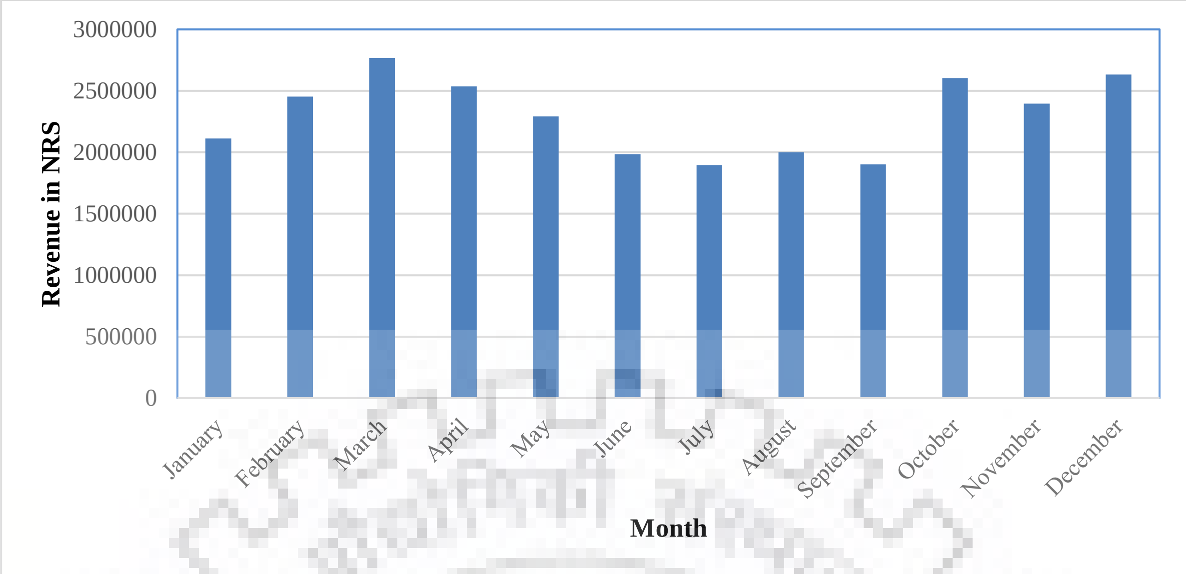


Figure 5.2 Monthly Revenue Bar Chart.

NOC shall operate the solar power plant with its staffs. Monthly energy generation shall be calculated from the energy meter placed on the substation control room. The monthly invoice shall be submitted to the NEA for payment. Payments of monthly bill are made after 45 days of the date of submission. The monthly payment cheque directly goes to the Lead bank and is deposited in an escrow account maintained with the lead bank. The bank with consultation with the developer makes the distribution of the payment amount. Plant operation and management expenses are provided the first priority in payment. Upon the successful commissioning and operation, the cash flow of this project is sufficient to meet all its payment obligations such as O&M cost, debt servicing and dividend to the shareholders.

5.7 CASH FLOW DIAGRAM

The graphical representation of the both cash inflows and cash outflows with respect to a time scale is known as cash flow diagram. The long-term economic balance cash flow which is obtain from simulation result is given in Table 5.5. sellable energy cost, running cost and interest for the project life ie 25 years is calculated. On the basis of this calculation yearly balance and cumulative balance is obtained.

Table 5.5 Long Term Economic Balance Cash Flow

Year	Loan 10.00%	Running costs (KRs)	Sold energy	Yearly Balance (KRs)	Cumulative Balance
0	19480	459	17223	-2717	(2717.00)
1	19480	459	17223	-2717	(5434.00)
2	19480	459	17223	-2717	(8151.00)
3	19480	459	17223	-2717	(10868.00)
4	19480	459	17223	-2717	(13585.00)

Year	Loan 10.00%	Running costs (KRs)	Sold energy	Yearly Balance (KRs)	Cumulative Balance
5	19480	459	17223	-2717	(16302.00)
6	19480	459	17223	-2717	(19019.00)
7	19480	459	17223	-2717	(21736.00)
8	19480	459	17223	-2717	(24453.00)
9	19480	459	17223	-2717	(27170.00)
10	0	459	17223	16764	(10406.00)
11	0	459	17223	16764	6358.00
12	0	459	17223	16764	23122.00
13	0	459	17223	16764	39886.00
14	0	459	17223	16764	56650.00
15	0	459	17223	16764	73414.00
16	0	459	17223	16764	90178.00
17	0	459	17223	16764	106942.00
18	0	459	17223	16764	123706.00
19	0	459	17223	16764	140470.00
20	0	459	17223	16764	157234.00
21	0	459	17223	16764	173998.00
22	0	459	17223	16764	190762.00
23	0	459	17223	16764	207526.00
24	0	459	17223	16764	224290.00
25	0	459	17223	16764	241054.00

The time scale represents the end of year (EOY). Generally, vertically downward arrows represent the cash out flow (i.e. costs or expense), where the vertically upward arrow represents the cash inflows (i.e. revenue or income). Figure 5.3 shows the cash flow diagram of the long term economic balance of the project. It represents that the total expenditure for loan repayment over 10 years is about 1.9 crores/year and total life cycle saving of the system in terms of cash is around 24 crores and yearly savings comes around 1.5 crores/year for 25 years.

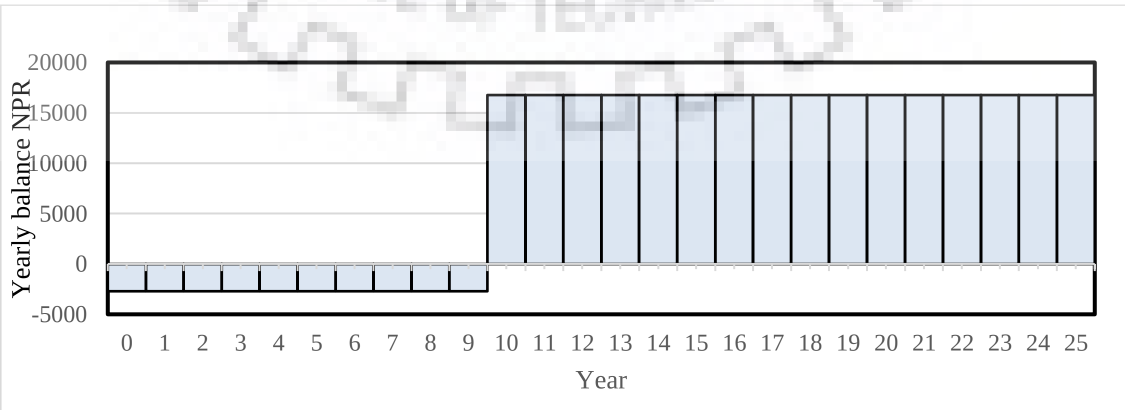


Figure 5.3 Yearly Balance Cash Flow Diagram.

Cumulative Yearly Cost Balance: The cumulative yearly cost balance is obtained on the basis of yearly balance saving cash flow trend as described previously. Figure 5.4 shows the cumulative balance cash flow diagram of the total investment made by Institute and gains by installing the system. It can be seen that the loan repayment expenditure 1.04 crore for 10 years and the total savings by the institute in the total life cycle of 25 years period is more than 24 crores, which can be seen from the long-term financial balance sheet.

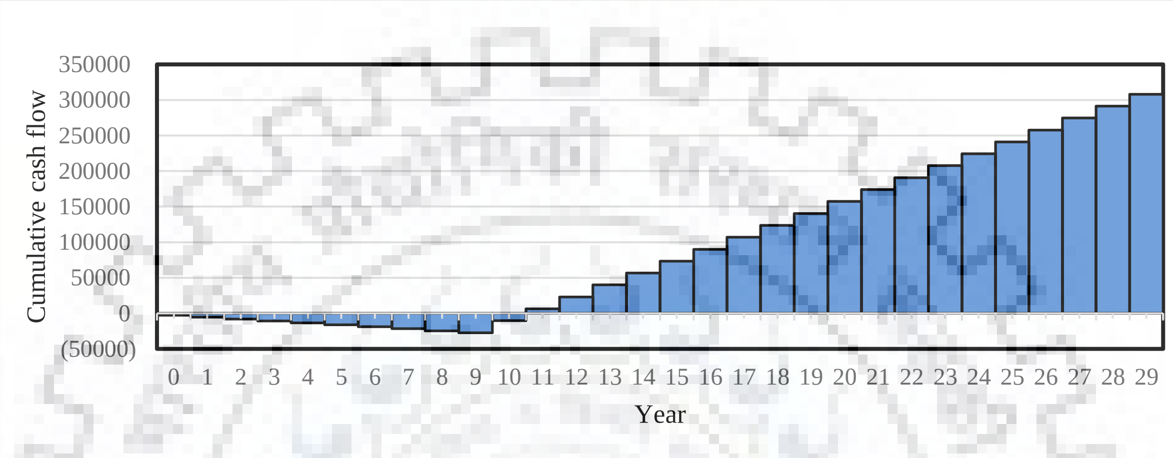


Figure 5.4 Cumulative Cash Flow Diagram for Project.

5.8 REPAYMENT OF BANK LOAN AND INTEREST

The Company shall receive total loan of NPR 13.57 crores (including IDC) to finance the project. The loan shall be repaid in 10 years in equal quarterly statements. The calculated loan repayment model of the project is summarized in Table 5.6

Table 5.6 Equal Quarterly Installment Model.

Loan (RS)				135,677,707
Quarters (Nos)				40
Interest Rate				10%
Quarterly Instalment (NRS)				5,404,889
Annual Loan Repayment Plan				
Year	**Principal**	**Interest**	**Total**	**Outstanding**
0				135,677,707
1	8,358,790	13,260,765	21,619,555	127,318,917
2	9,226,540	12,393,015	21,619,555	118,092,377
3	10,184,374	11,435,181	21,619,555	107,908,003
4	11,241,643	10,377,912	21,619,555	96,666,359
5	12,408,671	9,210,884	21,619,555	84,257,688
6	13,696,851	7,922,704	21,619,555	70,560,837
7	15,118,761	6,500,795	21,619,555	55,442,077
8	16,688,283	4,931,272	21,619,555	38,753,794
9	18,420,742	3,198,813	21,619,555	20,333,052
10	20,333,052	1,286,503	21,619,555	0
	135,677,707	80,517,844		

5.9 FINANCIAL ANALYSIS

5.9.1 Debt Service Coverage Ratio

The debt service coverage ratio (DSCR) is the ratio of net operating income to debt payment. It is a popular benchmark used in the measurement of an income-producing project's ability to produce enough revenue to cover its debt payments. The rule of thumb is, "A project is acceptable if the ratio is greater than one". Mathematically, it is calculated as:-

$$\text{Debt Service Coverage Ratio} = \frac{\text{Net income (before interest, Depreciation and tax)}}{\text{Debt Services (Principal Repayments + Interest Payments)}}$$

Since the loan repayment duration for this project is 10 years, DSCR is calculated for the first ten years. It shows that the project can service the bank loan easily. The average DSCR for the loan repayment period is computed to be 1.11 with highest value of 1.18 and minimum value of 1.06.

5.9.2 Plant Load Factor

The installed capacity of the project is 2.0 MW. The Plant Load Factor (PLF) has been computed as under:

PLF = Actual Generation (kWh) / (Installed Capacity * 1000 * 365 days * 24 hours) * 100 %

= 21.56 %

5.9.3 Net Present Value (NPV)

NPV may be described as the summation of the present values of cash proceeds (CFAT) in each year minus the summation of present values of the net cash outflows in each year. NPV can be calculated by using the following equation:

$$NPV = CF_0 + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \ldots\ldots\ldots\ldots\ldots + \frac{CF_n}{(1+i)^n}$$

Nominal NPV (without discounting cash flows)

NPV = 330,032,433

Discounted NPV (with discounted cash flows)

NPV = 12,225,2546

The investment decision rule for the project under NPV is to accept the project if the NPV is positive and reject if it is negative. Since, the NPV of this project is positive, the project appears viable.

5.10 INTERNAL RATE OF RETURN (IRR)

This technique is also known as yield on investment, marginal efficiency of capital, marginal productivity of capital, rate of return, time –adjusted rate of return and so on. Like the present value method, the IRR method also considers the time value of money by discounting the cash streams. The basis of the discount factor, however, is different in both cases. In the case of the net present value method, the discount rate is the required rate of return and being a predetermined rate, usually the cost of capital; its determinants are external to the proposal under consideration. The IRR is that discount rate which equates the present value of cash inflows with the present value of cash outflows. We can use the following equation to solve for the project IRR:

$$Cf_0 + \frac{Cf_1}{(1+IRR)^1} + \frac{Cf_2}{(1+IRR)^2} + \ldots\ldots\ldots\ldots + \frac{Cf_n}{(1+IRR)^n} = 0$$

$$\sum_{t=0}^{n} \frac{Cf_t}{(1+IRR)^t} = 0$$

NPV = 0

Thus, internal rate of return (IRR) is that discount rate at which the project NPV is zero. The Project IRR is computed to be 10.88% and the equity IRR is computed to be 11.97%.

5.11 BENEFIT COST RATIO (PROFITABILITY INDEX)

Another time-adjusted method for evaluating the investment proposals is the Benefit/Cost ratio or profitability index (PI). It is the ratio of the present value of future cash inflows (NPV + the Initial Investment), divided by the Initial Investment.

Rules of Profitability Index

If PI > 1, Good Investment

If PI < 1, Bad Investment

The formula to calculate benefit-cost ratio or profitability index is as follows:

$$\text{PI or B/C Ratio} = \frac{\text{NPV} + \text{Initial Investment}}{\text{Initial Cash Outlay}}$$

The benefit cost ratios of the Project at different discount rates are shown in Table 5.7.

Table 5.7 Benefit Cost Ratio at different Discount Rate.

Discount Rate	Profitability Index
0%	2.7
12%	1.06
10.88%	1.00

5.12 PAYBACK PERIOD

The period within which the invested money can be recovered or saved is known as payback period. The payback period is one of the most popular and widely recognized methods for evaluating investment proposals. This method identifies the required number of years to pay the original cost of the investment, normally disregarding salvage value. Cash flow here represents CFAT (Cash Flow After Tax). Thus, the payback method measures the number of years required for the Cash Flow to pay back the original outlay required in an investment. Payback period can be calculated in two different ways:

5.12.1 Simple Pay Back Period

Simple payback period may be defined as the number of years required to recover the initial cash invested in a project. If the project generates constant annual cash inflows, the payback period can be computed dividing initial cash outlay by the annual cash inflow. That is:

$$\text{Simple Payback Period} = \text{Year before full recovery} + \frac{\text{Unrecovered Amount}}{\text{Next Year's Cash Inflow}}$$

The simple payback period of the Project is calculated as follows:

= 7.94 years

5.12.2 Discounted Payback Period

The discounted payback period is the length of time required for a project to recover its initial capital outlay from the discounted cash inflows. The discounted payback period can be computed by using the following formula:

$$\text{Discounted PBP} = \text{Year before full recovery} + \frac{\text{Unrecovered Amount}}{\text{Next Year's Disounted Cash Inflow}}$$

The discounted payback period of the Project is calculated as follows:

= 13.81 Years

5.13 LEVELIZED COST OF ELECTRICITY

It is the cost of generating per unit of solar energy considering all the construction cost as well as interest payments and the O&M cost. The calculated average LCOE over 25 years for this project is NRs 5.41 per kwh.

5.14 RISK, UNCERTAINTY AND SENSITIVITY ANALYSIS

The information based on some techno-economic and financial proposal of a solar power project, some predictions and lump sum estimation shall be made about the energy yield, per unit energy generation cost etc. wherever the cause may involve some risks and uncertainty. The possible outcomes like climatic condition, weather, earthquake, natural disaster, demonetization, blockade which can be categorized by numerical probabilities is said to be risk. The probability distribution of the various outcomes which are unpredicted at the present is known to be uncertainty. The simple approaches which are used to deliver some figures that shows how a project can respond practically for such changing condition and the procedure of receiving the expected probable changes in to consideration is termed as sensitivity analysis. For the method of evaluating sensitivity analysis, the formal life is more than the project life should be considered.

Table 5.8 Calculated Value for the Financial Analysis of the Project.

S.N	Description	Value
1.	Plant load factor (PLF)	21.56%
2.	Internal Rate of Return, Project IRR	10.88%
3.	Internal Rate of Return, Equity IRR	11.97%
4.	Benefit Cost Ratio at 0% Discount Rate, (B/C) Ratio	2.7
5.	Benefit Cost Ratio at 12% Discount Rate, (B/C) Ratio	1.06
6.	Benefit Cost Ratio at 10.880% Discount Rate, (B/C) Ratio	1.00
7.	Simple Payback Period	7.94
8.	Discounted Payback Period	13.81
9.	Levelized Cost of Energy/kWh	5.41
10.	Average Debt Service Coverage Ratio (DSCR) in 10 years	1.11

This chapter summarizes the overall calculation of the cost analysis of the financial terms in order to check the financial viability of the project. The calculated value of some decision parameters of the project discussed in this chapter is given in the Table 5.8 and other financial term lies in the range that indicates that the project is financially viable. Hence, the project is economically feasible.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 GENERAL

SPV is the fastest growing power generation technology to tap renewable energy. It has the advantage of more effective utilization of generated power which is accomplished through the inverter, which converts DC power generated from PV modules to AC power used for ordinary power supply to electric equipment. Taping solar energy through SPV technology in case of official area is feasible due to sufficient availability of spare land on office premises and rooftop buildings to some extent. This study focused on the development of SPV potential on second largest fuel storage depot of Nepal Oil Corporation Ltd. Kathmandu in Nepal. The proposed site is located on Chandragiri Municipality under Kathmandu valley. All the available rooftop area including barren/spare land area under the fuel depot premises was calculated on ARC GIS 10.4 version and presented in this report. The site was visited for the data collection of energy requirement per hour, electrical load survey was carried out according to the energy consumption trend of past year on the depot and by the method of interacting verbal questionnaire to the officials. At the mean time some eye bird view image of the study area was captured. For sizing SPV system, the solar insolation data were collected as Typical Meteorological Year (TMY) file from the National Renewable Energy Laboratory (NREL) datasets. Furthermore, simulations were performed using solar industry's leading design tool, PVSYST for the energy yield prediction and Financial analysis is done in order to analyse the economic viability of the solar power project.

6.2 CONCLUSIONS

From the present study following conclusions are drawn;

i. Based on the site data collected for availability of land, the total area of 33146 m^2 is estimated and proposed to install PV array accordingly.

ii. In order to estimate the solar energy available at the site, typical meteorological year (TMY) file from NREL NSRDB meteonorm solar radiation data has been used and solar energy has estimated for the study area. Further, a daily load of 489 kWh was estimated.

iii. Simulations were performed using PVSYT for the system produced energy Prediction which yields of 3777 MWh/year for grid connected system. The total power plant capacity is found as 2 MW. The total solar power generated in the proposed site is proposed to be evacuated through available 11 KV pooling substation that is connected through a 11 KV transmission line to NEA owned Matatritha Grid substation located at a distance of around 4 KM from the proposed site.

iv. Trina “TSM-PD14 315” modules of power rating of each module as 315Wp and ABB PVS800-57-1000kW-C or equivalent inverters are proposed for the present study.

v. The project site is well suited for setting up the capacity of 2 MW Solar Power Plant for grid connected using Solar Fixed tilt Technology with Trina “TSM-PD14 315” modules with a power rating of 315Wp and ABB PVS800-57-1000kW-C AC or equivalent inverters. The site has high solar radiation and using the above configuration, the annual energy yield is predicted to be 21.5 % at (P50).

vi. In order to check the economic viability of the project, the financial decision parameters i.e. Internal Rate of Return (IRR), Benefit to Cost ratio (B/C) ratio, Payback Period, Plant Load Factor (PLF), Levelized cost of electricity, Debt Service Coverage ratio and other financial terms are calculated and Presented. Moreover, the loan repayment model is also developed for 10 years plan on quarterly payment basis and presented.

vii. Based on the cost estimation, the Project cost is found to be NPR 19,38,25,296 and NPR 5.18 is estimated for per unit generation cost of the system. NEA is proposed to purchase the generated electricity throughout the life of the project and hence the project may be low counterparty risks.

6.3 RECOMMENDATIONS

Government of Nepal is supporting the development of solar photovoltaic technology regarding policies and opportunity in the rural areas but not addressed in the urban area so far. There should be the necessity with clear vision to roll over the development of SPV system and policy shifting ahead.

The promotion for the use of clean energy technology, the nation should formulate and review various plan and policies concerning on clean energy technology.

As the proposed system of Photovoltaic is found economically feasible, it is recommended to install grid connected Solar Plant in the present study area. Further, the individual area of available rooftop buildings on the study area premises can be calculated. In order to minimize the losses in wires, cable connections and other losses, the power generated from the individual rooftop buildings can be utilized for the same to fulfill the power requirement of individual building simultaneously.

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ANNEXURE 1

LOAD PROFILE OF STUDY AREA

S.N	Particular	Nos	Power (Watt)	Total Load (watt)	Energy Demand (kWhr)	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00
A	**Main Office building**													
1	CFL	2	11	22	0.22	0	0.01	0.01	0.011	0.022	0.022	0.022	0.022	0.022
2	Tube light (Double Rod)	55	40	2200	10.8	0.5	0.5	0.5	0.5	1.1	1.1	1.1	1.1	1.1
3	Tube light (Single Rod)	5	20	100	0.56	0	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
4	Room Heater	13	1000	13000	52					6.5	6.5	6.5	6.5	6.5
5	Mobile charger	15	1	15	0.12					0.015	0.015	0.015	0.015	0.015
6	TV	1	150	150	0.06					0.015	0.015		0.015	0.015
7	Desktop computer	21	78	1638	12.8					1.6	1.6	1.6	1.6	1.6
8	Power socket	15	1000	15000	0									
9	Incandescent lamp	40	26	1040	4.2	0.1	0.05	0.05	0.05	0.5	0.5	0.5	0.5	0.5
13	Photocopy machine	1	594	594	0.3						0.05	0.05	0.05	0.05
14	Printer	15	100	1500	0.35					0.05	0.05	0.05	0.05	0.05
15	Scanner	2	100	200	0.24					0.03	0.03	0.03	0.03	0.03
16	Fan	15	78	1170	8.8					1.1	1.1	1.1	1.1	1.1
17	LED Lamp	3	9	27	0.268	0	0.01	0.01	0.013	0.027	0.027	0.027	0.027	0.027
19	AC	2	4000	8000	64					8	8	8	8	8
	Total(A)			**44656**	**154.718**	**0.6**	**0.61**	**0.61**	**0.614**	**19.01**	**19.06**	**19.044**	**19.059**	**19.059**
B	**Out door System**													
1	Obstruction light	40	5	200	2.2									
2	Discharge lamp(SON-T)	18	500	9000	0									
3	CC Camera Security	10	20	200	4.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	NOC LED Display Board	1	100	100	2.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	Halogen lamp	10	1500	15000	105									
	Total(B)			**24500**	**114.4**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
C	**Generator Building**													
1	Tube light (Double Rod)	6	40	240	0.096					0.012	0.012	0.012	0.012	0.012
2	Incandescent lamp	5	40	200	0									
3	Pump	1	735	735	0.08					0.02	0.02	0.02	0.02	
	Total©			**1175**	**0.176**	**0**	**0**	**0**	**0**	**0.032**	**0.032**	**0.032**	**0.032**	**0.012**
D	**Switch Gear Building**													
1	Tube light (Double Rod)	11	40	440	0.96	0.1	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

S.N	Particular	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00
A	**Main Office b**															
1	CFL	0.022	0.022	0.02												
2	Tube light (Double Rod)	1.1	1.1	1.1												
3	Tube light (Single Rod)	0.05	0.05	0.05												
4	Room Heater	6.5	6.5	6.5												
5	Mobile charger	0.015	0.015	0.02												
6	TV															
7	Desktop computer	1.6	1.6	1.6												
8	Power socket															
9	Incandescent lamp	0.5	0.5	0.5												
13	Photocopy machine	0.05	0.05													
14	Printer	0.05	0.05													
15	Scanner	0.03	0.03	0.03												
16	Fan	1.1	1.1	1.1												
17	LED Lamp	0.027	0.027	0.03												
19	AC	8	8	8												
	Total(A)	**19.04**	**19.04**	**18.9**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
B	**Out door Syst**															
1	Obstruction light					0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	Discharge lamp(SON-T)				9	4.5	9	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
3	CC Camera Security	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
4	NOC LED Display Board	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	Halogen lamp					15	15	15	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	Total(B)	**0.3**	**0.3**	**0.3**	**9.3**	**20**	**24.5**	**20**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**
C	**Generator Bu**															
1	Tube light (Double Rod)	0.012	0.012	0.01												
2	Incandescent lamp															
3	Pump															
	Total©	**0.012**	**0.012**	**0.01**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
D	**Switch Gear Building**															
1	Tube light (Double Rod)	0.08	0.08	0.08												

S.N	Particular	Nos	Power (Watt)	Total Load (watt)	Energy Demand (kWhr)	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00
2	Incandescent lamp	8	40	320	0.192	0	0.02	0.02	0.016	0.016	0.016	0.016	0.016	0.016
3	deep boring Pump	2	2200	4400	3.3						2.2	0		
4	Out door Lamp(SON-T)			0	0									
	Toal (D)			**5160**	4.452	**0.1**	**0.1**	**0.1**	**0.096**	**0.096**	**2.296**	**0.096**	**0.096**	**0.096**
E	**Fire fighting Building**													
1	Tube light (Double Rod)	10	40	400	0.144	0	0.01	0.01	0.012	0.012	0.012	0.012	0.012	0.012
2	Incandescent lamp	6	40	240	0.12	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	Pump	1	90000	90000	0									
4	Compressor	1	2200	2200	2.2					1.1	1.1			
5	Fire control system	500	1	500	6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Total(E)			**93340**	**8.464**	**0.5**	**0.52**	**0.52**	**0.522**	**1.622**	**1.622**	**0.522**	**0.522**	**0.522**
F	**Unloading point Building**													
1	light (SON-T)	18	500	9000										
	Total(F)			**9000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G	**Loading point Building**													
1	light (SON-T)	18	500	9000										
	Total (G)			**9000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
H	**Jagdal Gan Building**													
1	Tube light (Double Rod)	17	40	680	1.8	0.3								
2	Incandescent lamp	11	40	440	1.2	0.2								
3	CFL	5	9	45	0.15	0								
4	light (SON-T)	9	500	4500	4.95									
	Total (H)			**5665**	**8.1**	**0.5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
I	**Work shop Building**													
1	Welding machine	1	750	750	0									
2	Grinder	1	250	250	0									

S.N	Particular	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00
2	Incandescent lamp	0.016	0.016	0.02												
3	deep boring Pump			1.1	2.2											
4	Out door Lamp(SON-T)															
	Toal (D)	**0.096**	**0.096**	**1.2**	**2.2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
E	**Fire fighting Building**															
1	Tube light (Double Rod)	0.012	0.012	0.01												
2	Incandescent lamp	0.01	0.01	0.01												
3	Pump															
4	Compressor															
5	Fire control system	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Total(E)	**0.522**	**0.522**	**0.52**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
F	**Unloading point Building**															
1	light (SON-T)															
	Total(F)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G	**Loading point Building**															
1	light (SON-T)															
	Total (G)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
H	**Jagdal Gan Building**															
1	Tube light (Double Rod)					0.3	0.3	0.3	0.3	0.3						
2	Incandescent lamp					0.2	0.2	0.2	0.2	0.2						
3	CFL					0.025	0.03	0.025	0.025	0.025						
4	light (SON-T)					0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Total (H)	**0**	**0**	**0**	**0**	**0.975**	**0.98**	**0.975**	**0.975**	**0.975**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**
I	**Work shop Building**															
1	Welding machine															
2	Grinder															

S.N	Particular	Nos	Power (Watt)	Total Load (watt)	Energy Demand (kWhr)	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00
3	Drill Machine	1	250	250	0.25							0.25		
4	Tube linght (Double rod)	17	40	680	0.24	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5	Incandescent lamp	8	40	320	0.18	0	0.02	0.02	0.015	0.015	0.015	0.015	0.015	0.015
	Total (I)			**2250**	**0.67**	**0**	**0.04**	**0.04**	**0.035**	**0.035**	**0.035**	**0.285**	**0.035**	**0.035**
J	**Lab Building**													
1	Tube light (Double rod)	17	40	680	5.44					0.68	0.68	0.68	0.68	0.68
2	Incandescent lamp	8	40	320	1.2					0.15	0.15	0.15	0.15	0.15
3	CFL	2	9	18	0.72					0.09	0.09	0.09	0.09	0.09
4	Fan	4	78	312	1.2					0.15	0.15	0.15	0.15	0.15
5	Lab Heater	6	1000	6000	48					6	6	6	6	6
5	Adjust fan	15	60	900	7.2					0.9	0.9	0.9	0.9	0.9
	Total(J)			**8230**	**63.76**	**0**	**0**	**0**	**0**	**7.97**	**7.97**	**7.97**	**7.97**	**7.97**
K	**Canteen Building**													
1	Tube light (Double rod)	3	40	120	1.44	0.1	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
2	Incandescent lamp	1	40	40	0.48	0	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
3	CFL	2	9	18	0.216	0	0.02	0.02	0.018	0.018	0.018	0.018	0.018	0.018
4	Fan	2	78	156	0									
5	Adjust fan	1	60	60	0.72	0.1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
6	Water pump	2	375	750	0.75						0.75			
	Total (K)			**1144**	**3.606**	**0.2**	**0.24**	**0.24**	**0.238**	**0.238**	**0.988**	**0.238**	**0.238**	**0.238**
L	**OHMCCR Building**													
1	Tube light (Double rod)	5	40	200										
2	Incandescent lamp	3	40	120										
3	CFL	1	9	9										
4	Fan	1	78	78										
5	Dewatering Water pump	2	375	750						0.75		0.75		
	Total(L)			**1157**	**0**	**0**	**0**	**0**	**0**	**0.75**	**0**	**0.75**	**0**	**0**
M	**Loading Pump shed Building**													
1	Tube light (Double rod)	3	40	120										
2	Pump motor	1	2200	2200	13.2					2.2	2.2	1.1	2.2	2.2
3	Pump motor	3	9300	27900	39.6					9.9	4.95	4.95	4.95	4.95
	Total(M)			**30220**	**52.8**	**0**	**0**	**0**	**0**	**5.5**	**2.75**	**5.5**	**2.75**	**5.5**

S.N	Particular	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00
3	Drill Machine															
4	Tube linght (Double rod)	0.02	0.02	0.02												
5	Incandescent lamp	0.015	0.015	0.02												
	Total (I)	**0.035**	**0.035**	**0.04**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
J	**Lab Building**															
1	Tube light (Double rod)	0.68	0.68	0.68												
2	Incandescent lamp	0.15	0.15	0.15												
3	CFL	0.09	0.09	0.09												
4	Fan	0.15	0.15	0.15												
5	Lab Heater	6	6	6												
5	Adjust fan	0.9	0.9	0.9												
	Total(J)	**7.97**	**7.97**	**7.97**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
K	**Canteen Building**															
1	Tube light (Double rod)	0.12	0.12	0.12												
2	Incandescent lamp	0.04	0.04	0.04												
3	CFL	0.018	0.018	0.02												
4	Fan															
5	Adjust fan	0.06	0.06	0.06												
6	Water pump															
	Total (K)	**0.238**	**0.238**	**0.24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
L	**OHMCCR Building**															
1	Tube light (Double rod)															
2	Incandescent lamp															
3	CFL															
4	Fan															
5	Dewatering Water pump															
	Total(L)	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0	0	**0**
M	**Loading Pump shed Building**															
1	Tube light (Double rod)															
2	Pump motor	1.1	2.2													
3	Pump motor	4.95	4.95													
	Total(M)	**2.75**	**5.5**	**5.5**												

S.N	Particular	Nos	Power (Watt)	Total Load (watt)	Energy Demand (kWhr)	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00
N	**Un-Loading Pump shed Building**									6.6	3.3	6.6	6.6	3.3
1	Tube light (Double rod)	5	40	200						1.5				
2	Pump motor	1	5500	5500	22					5.5	2.75	2.75	2.75	2.75
3	Pump motor	3	22000	66000	42.9					6.6	3.3	6.6	6.6	6.6
	Total(N)			**71700**	**64.9**	**0**	**0**	**0**	**0**	**13.6**	**6.05**	**9.35**	**9.35**	**9.35**
O	**Calibration Building**													
2	Pump motor	1	1500	1500	10.5					1.5	1.5	1.5	1.5	1.5
	Total(O)			**1500**	**10.5**	**0**	**0**	**0**	**0**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
P	**Weight Bridge Building**													
1	Weight Bridge	1	1000	1000										
2	Pump motor	1	5500	5500	19.25					2.75	2.75	2.75	2.75	2.75
3	Tube light (Double rod)	3	40	120										
4	Incandescent lamp	2	40	80										
5	lamp (SON-T)	3	500	1500										
	Total(P)			**8200**	**19.25**	**0**	**0**	**0**	**0**	**2.75**	**2.75**	**2.75**	**2.75**	**2.75**
Q	**Toilet Building**													
1	Tube light (Double rod)	2	40	80	0.48	0	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2	Incandescent lamp	2	40	80										
3	Out door Lamp(SON-T)	2	500	1000										
	Total(Q)			**1160**	**0.48**	**0**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**
R	**Army Canteen Building**													
1	Tube light (Double rod)	2	40	80	0.6	0	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2	Incandescent lamp	2	40	80	0.48	0	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
3	CFL	2	9	18	0.27	0	0.02	0.02	0.018	0.018	0.018	0.018	0.018	0.018
4	Heater	10	1000	10000	30					5	2.5	5	2.5	2.5
	Total ®			**10178**	**31.35**	**0.1**	**0.1**	**0.1**	**0.098**	**5.098**	**2.598**	**5.098**	**2.598**	**2.598**
	Total			**3E+05**	**537.626**	**2.5**	**1.9**	**1.9**	**1.94**	**58.54**	**47.99**	**53.48**	**47.24**	**49.97**

S.N	Particular	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00
N	**Un-Loading Pump shed Building**	3.3	6.6	2.2												
1	Tube light (Double rod)															
2	Pump motor	2.75	2.75													
3	Pump motor	6.6	6.6													
	Total(N)	**9.35**	**9.35**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
O	**Calibration Building**															
2	Pump motor	1.5	1.5													
	Total(O)	**1.5**	**1.5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
P	**Weight Bridge Building**															
1	Weight Bridge															
2	Pump motor	2.75	2.75													
3	Tube light (Double rod)															
4	Incandescent lamp															
5	lamp (SON-T)															
	Total(P)	**2.75**	**2.75**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Q	**Toilet Building**															
1	Tube light (Double rod)	0.04	0.04	0.04												
2	Incandescent lamp															
3	Out door Lamp(SON-T)															
	Total(Q)	**0.04**	**0.04**	**0.04**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
R	**Army Canteen Building**															
1	Tube light (Double rod)	0.04	0.04	0.04	0.04	0.04	0.04									
2	Incandescent lamp	0.04	0.04	0.04												
3	CFL	0.018	0.018	0.02	0.018	0.018	0.02									
4	Heater	5	5	2.5												
	Total ®	**5.098**	**5.098**	**2.6**	**0.058**	**0.058**	**0.06**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Total	**49.7**	**52.5**	**37.4**	**12.1**	**21.53**	**26**	**21.5**	**13.98**	**13.98**	**13.5**	**13.5**	**13**	**13**	**13**	**13**

ANNEXURE 2

SIMULATION RESULTS OF STAND-ALONE SYSTEM

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Stand Alone System: Simulation parameters

Project : **Development of solar SPV for premeses of NOC in Nepal**

Geographical Site		**Thankot depot**		Country	**Nepal**
Situation		Latitude	27.69° N	Longitude	85.23° E
Time defined as		Legal Time	Time zone UT+5.8	Altitude	1396 m
		Albedo	0.20		
Meteo data:		**Thankot depot**	NREL NSRDB Typ. Met. Year Suny_2000 to 2014 - TMY		

Simulation variant : **New simulation variant1 new modified1**

	Simulation date	06/04/19 13h08
	Simulation for the	**25th year of operation**

Simulation parameters		System type	**Stand-alone system**		
Collector Plane Orientation		Tilt	28°	Azimuth	0°
Models used		Transposition	Perez	Diffuse	Imported

PV Array Characteristics

PV module	a-Si:H tripple	Model	**a-Si:H, tripple junction**		
Custom parameters definition		Manufacturer	Generic		
Number of PV modules		In series	20 modules	In parallel	149 strings
Total number of PV modules		Nb. modules	2980	Unit Nom. Power	136 Wp
Array global power		Nominal (STC)	**405 kWp**	At operating cond.	384 kWp (50°C)
Array operating characteristics (50°C)		U mpp	627 V	I mpp	612 A
Total area		Module area	**6441 m²**	Cell area	5579 m²

PV Array loss factors

Array Soiling Losses			Loss Fraction	3.0 %
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	17 mOhm	Loss Fraction	1.5 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.1 % at STC
Module Quality Loss			Loss Fraction	2.5 %
Module Mismatch Losses			Loss Fraction	0.8 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %
Module average degradation	Year no	25	Loss factor	0.4 %/year
Mismatch due to degradation	Imp RMS dispersion	0.4 %/year	Vmp RMS dispersion	0.4 %/year

Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

System Parameter		System type	**Stand Alone System**		
Battery		Model	**Open 12V / 100 Ah**		
		Manufacturer	Generic		
Battery Pack Characteristics		Voltage	24 V	Nominal Capacity	5500 Ah
		Nb. of units	2 in series x 55 in parallel		
		Temperature	Fixed (20°C)		
Controller		Model	Universal controller with MPPT converter		
		Technology	MPPT converter	Temp coeff.	-5.0 mV/°C/elem.
Converter		Maxi and EURO efficiencies	97.0 / 95.0 %		
Battery Management control		Threshold commands as	SOC calculation		
		Charging	SOC = 0.90 / 0.75	i.e. approx.	30.7 / 24.8 V
		Discharging	SOC = 0.20 / 0.45	i.e. approx.	22.3 / 24.1 V

Stand Alone System: Detailed User's needs

Project : **Development of solar SPV for premeses of NOC in Nepal**

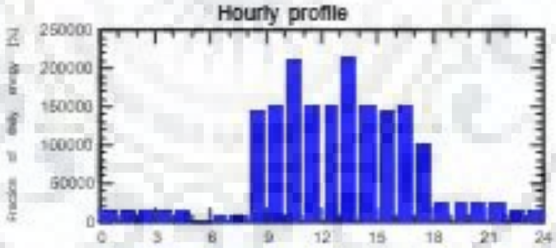
Simulation variant : **New simulation variant1 new modified1**
Simulation for the 25th year of operation

Main system parameters	System type	**Stand alone**			
PV Field Orientation	tilt	28°	azimuth	0°	
PV modules	Model	a-Si:H, tripple junction	Pnom	136 Wp	
PV Array	Nb. of modules	2980	Pnom total	**405 kWp**	
Battery	Model	Open 12V / 100 Ah	Technology	Lead-acid, vented, plates	
Battery Pack	Nb. of units	110	Voltage / Capacity	**24 V / 5500 Ah**	
User's needs	Daily household consumers	Constant over the year	Global	645 MWh/year	

Daily household consumers, Constant over the year, average = 1768 kWh/day

Annual values

	Number	Power	Use	Energy
Lamps (CFL, incadecentTube lingt)	100	80 W/lamp	8 h/day	64000 Wh/day
Night light(SONT, Halogen)	28	857 W/app	9 h/day	215964 Wh/day
Room Heater	10	1000 W/app	5 h/day	50000 Wh/day
Fridge / Deep-freeze	4		5 Wh/day	780000 Wh/day
Fan load(Adust fan, ceiling fan,wall fan)	38		4 Wh/day	10640 Wh/day
pump motor(pump,dewatering pump, fule pump)	16	7293 W tot	6 h/day	641766 Wh/day
Miscelleneous (computer, CC camera, fire control)	32	32 W tot	6 h/day	5632 Wh/day
Stand-by consumers			24 h/day	24 Wh/day
Total daily energy				1768026 Wh/day



Stand Alone System: Main results

Project : **Development of solar SPV for premeses of NOC in Nepal**

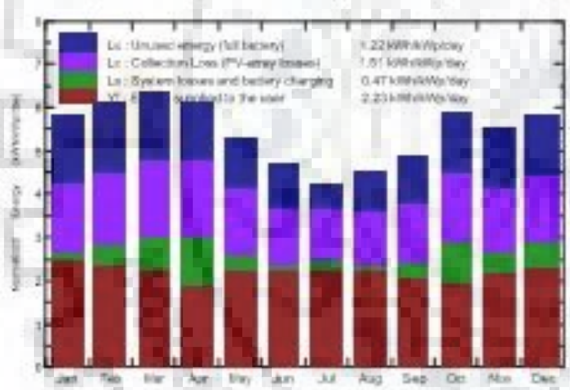
Simulation variant : **New simulation variant1 new modified1**
Simulation for the 25th year of operation

Main system parameters

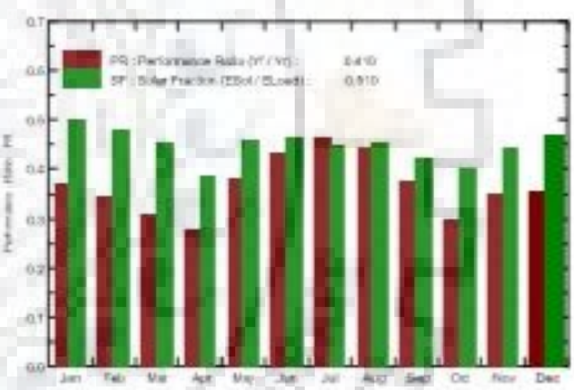
Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	a-Si:H, tripple junction	Pnom	136 Wp
PV Array	Nb. of modules	2980	Pnom total	**405 kWp**
Battery	Model	Open 12V / 100 Ah	Technology	Lead-acid, vented, plates
Battery Pack	Nb. of units	110	Voltage / Capacity	**24 V / 5500 Ah**
User's needs	Daily household consumers	Constant over the year	Global	645 MWh/year

Main simulation results				
System Production	**Available Energy**	**551.8 MWh/year**	Specific prod.	1362 kWh/kWp/year
	Used Energy	329.4 MWh/year	Excess (unused)	180.8 MWh/year
	Performance Ratio PR	41.00 %	Solar Fraction SF	51.04 %
Loss of Load	Time Fraction	65.5 %	Missing Energy	316.0 MWh/year
Investment	Global incl. taxes	47542587 India	Specific	117 India/Wp
Yearly cost	Annuities (Loan 10.0%, 10 years)	7737337 India/yr	Running Costs	262903 India/yr
Energy cost		**24.3 India/kWh**		

Normalized productions (per installed kWp): Nominal power 405 kWp



Performance Ratio PR and Solar Fraction SF



New simulation variant1 new modified1

Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E Avail MWh	EUnused MWh	E Miss MWh	E User MWh	E Load MWh	SolFrac
January	126.9	172.1	51.14	19.66	23.67	31.14	54.81	0.568
February	138.2	161.7	48.00	18.09	22.34	27.16	48.50	0.549
March	173.9	186.8	54.97	19.46	28.57	26.25	54.81	0.515
April	102.0	173.3	50.53	16.27	29.70	23.34	53.04	0.440
May	174.0	153.7	46.13	14.43	26.02	26.79	54.81	0.525
June	152.3	131.1	30.70	11.08	25.80	27.96	53.04	0.527
July	141.4	122.6	36.43	7.12	26.79	26.02	54.81	0.511
August	143.3	130.4	38.80	11.05	28.49	26.32	54.81	0.517
September	137.5	137.3	40.83	13.04	27.53	25.51	53.04	0.481
October	149.1	171.6	50.77	17.22	29.84	24.97	54.81	0.454
November	122.6	166.8	46.23	15.96	26.36	26.68	53.04	0.503
December	122.4	170.4	50.27	16.72	25.45	29.36	54.81	0.536
Year	1758.7	1867.9	551.88	180.77	315.96	329.37	645.33	0.510

Legends:

GlobHor	Horizontal global irradiation	E Miss	Missing energy
GlobEff	Effective Global, corr. for IAM and shadings	E User	Energy supplied to the user
E Avail	Available Solar Energy	E Load	Energy need of the user (Load)
EUnused	Unused energy (full battery) loss	SolFrac	Solar fraction (EUsed / ELoad)

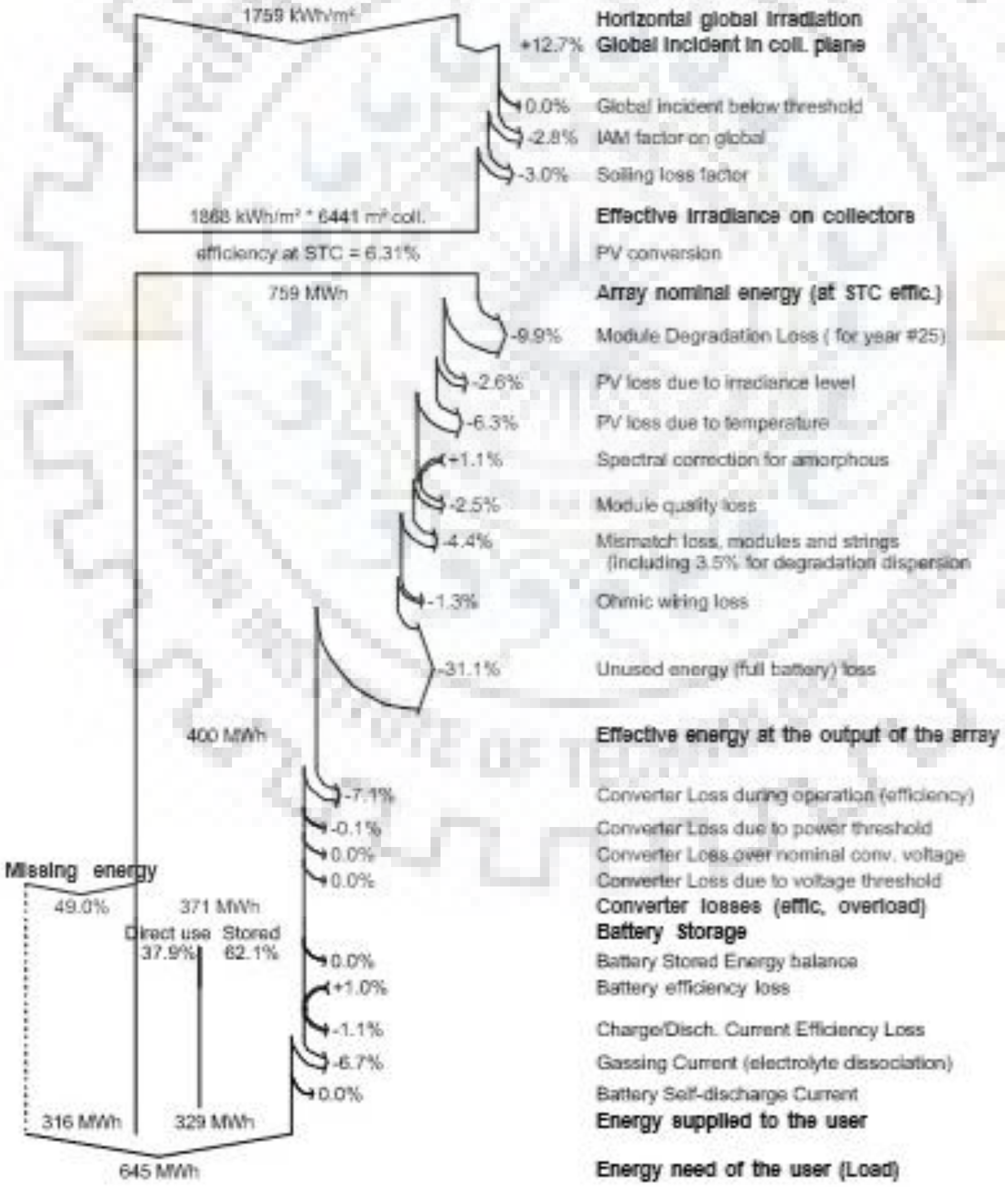
Stand Alone System: Loss diagram

Project : **Development of solar SPV for premeses of NOC in Nepal**

Simulation variant : **New simulation variant1 new modified1**
Simulation for the 25th year of operation

Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	a-Si:H, tripple junction	Pnom	136 Wp
PV Array	Nb. of modules	2980	Pnom total	**405 kWp**
Battery	Model	Open 12V / 100 Ah	Technology	Lead-acid, vented, plates
Battery Pack	Nb. of units	110	Voltage / Capacity	**24 V / 5500 Ah**
User's needs	Daily household consumers	Constant over the year	Global	645 MWh/year

Loss diagram over the whole year



Stand Alone System: Economic evaluation

Project : **Development of solar SPV for premeses of NOC in Nepal**

Simulation variant : **New simulation variant1 new modified1**
Simulation for the 25th year of operation

Main system parameters	System type	**Stand alone**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	a-Si:H, tripple junction	Pnom	136 Wp
PV Array	Nb. of modules	2980	Pnom total	**405 kWp**
Battery	Model	Open 12V / 100 Ah	Technology	Lead-acid, vented, plates
Battery Pack	Nb. of units	110	Voltage / Capacity	**24 V / 5500 Ah**
User's needs	Daily household consumers	Constant over the year	Global	645 MWh/year

Investment

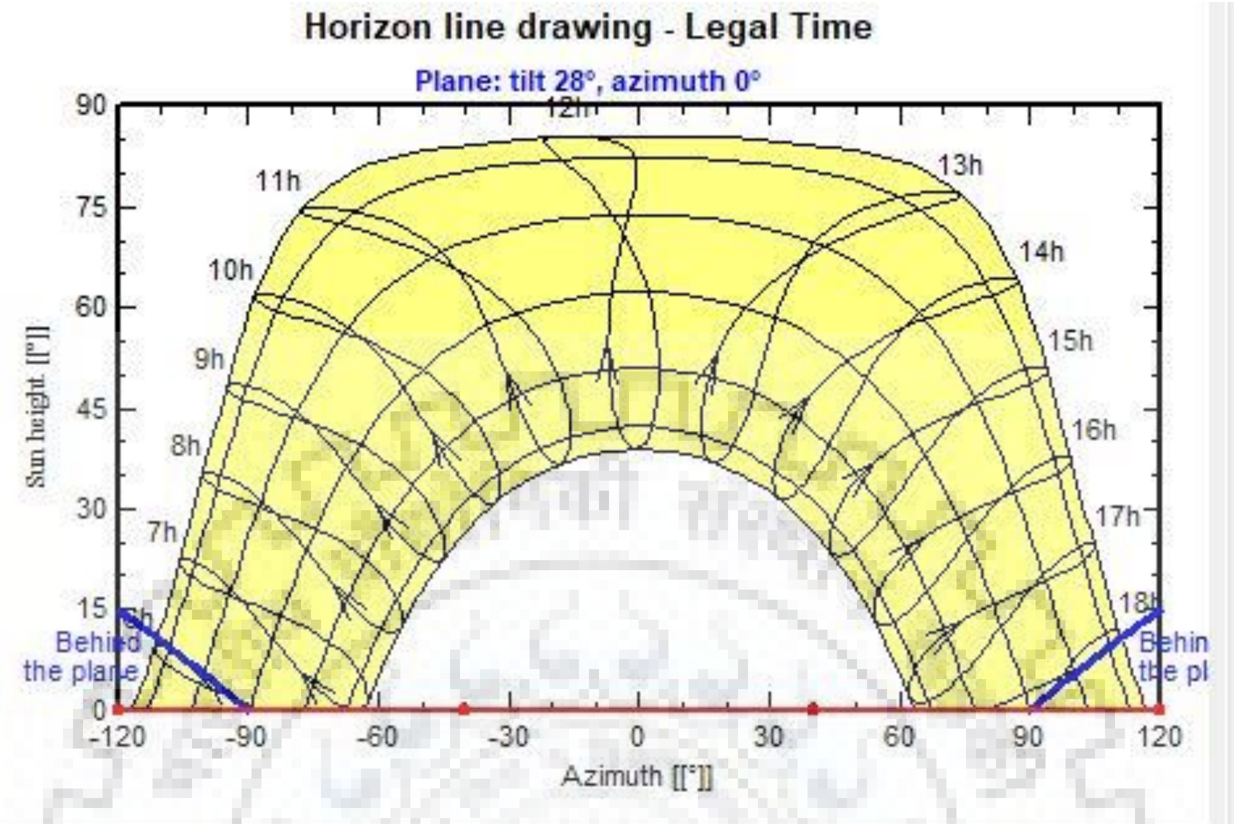
PV modules (Pnom = 136 Wp)	2980 units	7785 India / unit	23199300 India
Supports / Integration		284 India / module	846320 India
Batteries (12 V / 100 Ah)	110 units	7096 India / unit	780560 India
controller			230000 India
Settings, wiring, ...			6700000 India
Mounting structure			6703200 India
Ht/ILt Pannel			2415546 India
Transport and assembly			1000000 India
Engineering			1000000 India
Substitution underworth			-801840 India
Gross investment (without taxes)			**42073086 India**

Financing

Gross investment (without taxes)		42073086 India
Taxes on investment (VAT)	Rate 13.0 %	5469501 India
Gross investment (including VAT)		47542587 India
Subsidies		0 India
Net investment (all taxes included)		**47542587 India**
Annuities	(Loan 10.0 % over 10 years)	7737337 India/year
Maintenance		0 India/year
insurance, annual taxes		0 India/year
Provision for battery replacement	(lifetime 2.0 years)	262903 India/year
Total yearly cost		**8000240 India/year**

Energy cost

Used solar energy	329 MWh / year
Excess energy (battery full)	181 MWh / year
Used energy cost	24.3 India / kWh


Horizon line drawing - Legal Time
Plane: tilt 28°, azimuth 0°
Sun height [[°]]
Azimuth [[°]]
90
75
60
45
30
15
0
-120
-90
-60
-30
0
30
60
90
120
12h
11h
13h
10h
14h
9h
15h
8h
16h
7h
17h
18h
Behind the plane

ANNEXURE 3

SIMULATION RESULT OF GRID-CONNECTED SYSTEM

PVSYST V6.70		07/04/19	Page 1/8

Grid-Connected System: Simulation parameters

Project : **Dessertation for grid connection also**

Geographical Site	**Thankot depot**		Country	**Nepal**
Situation	Latitude	27.69° N	Longitude	85.23° E
Time defined as	Legal Time	Time zone UT+5.8	Altitude	1396 m
	Albedo	0.20		
Meteo data:	**Thankot depot**	NREL NSRDB Typ. Met. Year Suny_2000 to 2014 - TMY		

Simulation variant : **New simulation variant grid NOC 2075.11.26**

Simulation date 11/03/19 21h51

Simulation parameters	System type	**No 3D scene defined**		
Collector Plane Orientation	Tilt	28°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Arrays Characteristics (2 kinds of array defined)

PV module	Si-poly	Model	**TSM-315PEG14**		
Custom parameters definition		Manufacturer	Trina Solar		
Sub-array "Sub-array #2"					
Number of PV modules		In series	20 modules	In parallel	190 strings
Total number of PV modules		Nb. modules	3800	Unit Nom. Power	315 Wp
Array global power		Nominal (STC)	**1197 kWp**	At operating cond.	1074 kWp (50°C)
Array operating characteristics (50°C)		U mpp	663 V	I mpp	1618 A
Sub-array "Sub-array #2"					
Number of PV modules		In series	20 modules	In parallel	190 strings
Total number of PV modules		Nb. modules	3800	Unit Nom. Power	315 Wp
Array global power		Nominal (STC)	**1197 kWp**	At operating cond.	1074 kWp (50°C)
Array operating characteristics (50°C)		U mpp	663 V	I mpp	1618 A
Total	Arrays global power	Nominal (STC)	**2394 kWp**	Total	7600 modules
		Module area	**14913 m²**	Cell area	13319 m²

Inverter	Model	**PVS800-57-1000kW-C**		
Original PVsyst database	Manufacturer	ABB		
Characteristics	Operating Voltage	600-850 V	Unit Nom. Power	1000 kWac
			Max. power (=>25°C)	1200 kWac
Sub-array "Sub-array #2"	Nb. of inverters	1 units	Total Power	1000 kWac
			Pnom ratio	1.20
Sub-array "Sub-array #2"	Nb. of inverters	1 units	Total Power	1000 kWac
			Pnom ratio	1.20
Total	Nb. of inverters	2	Total Power	2000 kWac

PV Array loss factors

Array Soiling Losses			Loss Fraction	3.0 %
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Array#1	6.9 mOhm	Loss Fraction	1.5 % at STC
	Array#2	6.9 mOhm	Loss Fraction	1.5 % at STC
	Global		Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

PVSYST V6.70		07/04/19	Page 3/8

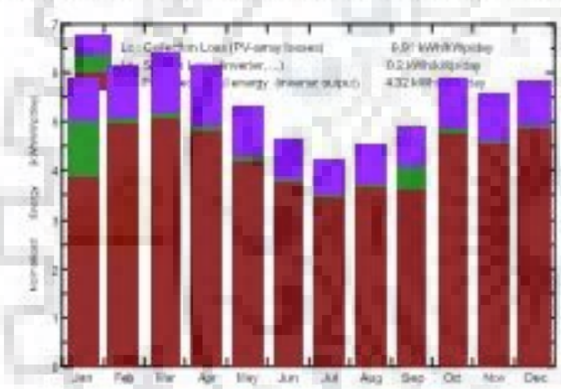
Grid-Connected System: Main results

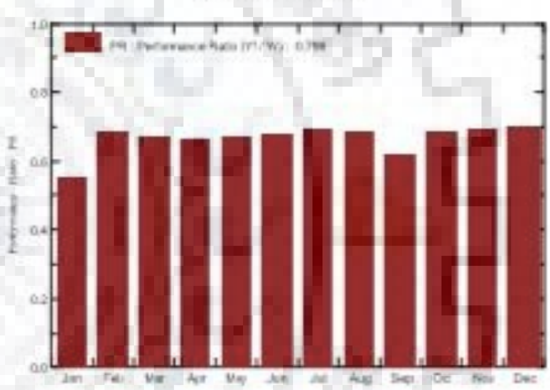
Project : **Dessertation for grid connection also**

Simulation variant : **New simulation variant grid NOC 2075.11.26**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	TSM-315PEG14	Pnom	315 Wp
PV Array	Nb. of modules	7600	Pnom total	**2394 kWp**
Inverter	Model	PVS800-57-1000kW-C	Pnom	1000 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)		Cos(Phi)	0.850 lagging

Main simulation results				
System Production	**Produced Energy**	**3777 MWh/year**	Specific prod.	1578 kWh/kWp/year
	Apparent energy	4444 MVAh	Perf. Ratio PR	79.57 %
Investment	Global incl. taxes	135258295 India	Specific	56.5 India/Wp
Yearly cost	Annuities (Loan 10.0%, 10 years)	22012665 India/yr	Running Costs	459285 India/yr
Energy cost		**5.95 India/kWh**		





New simulation variant grid NOC 2075.11.26

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EApGrid MVAh	PR
January	126.9	39.85	10.69	181.9	172.4	372.6	289.2	340.2	0.664
February	133.2	43.06	13.98	170.9	162.0	341.7	335.9	395.3	0.821
March	173.9	67.77	18.94	197.8	187.2	385.6	379.2	446.2	0.801
April	182.0	86.42	23.46	184.0	173.5	353.1	347.8	408.6	0.788
May	174.0	99.64	24.71	163.8	153.9	319.4	313.9	369.3	0.800
June	152.3	97.90	24.94	140.0	131.2	276.8	271.8	319.8	0.811
July	141.4	94.03	22.85	131.2	122.8	264.7	259.8	305.6	0.827
August	143.3	56.74	22.92	139.3	130.7	279.1	274.0	322.4	0.822
September	137.5	72.39	21.71	146.1	137.6	292.4	260.5	306.5	0.745
October	149.1	59.31	18.97	181.9	172.2	362.8	356.6	419.5	0.819
November	122.6	45.46	15.46	165.6	156.9	333.6	328.1	386.0	0.827
December	122.4	40.22	12.06	180.1	170.7	366.9	360.7	424.4	0.837
Year	1758.7	831.79	19.24	1982.7	1871.1	3849.1	3776.9	4443.9	0.796

Legends:

GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EApGrid	Apparent energy to the grid
		PR	Performance Ratio

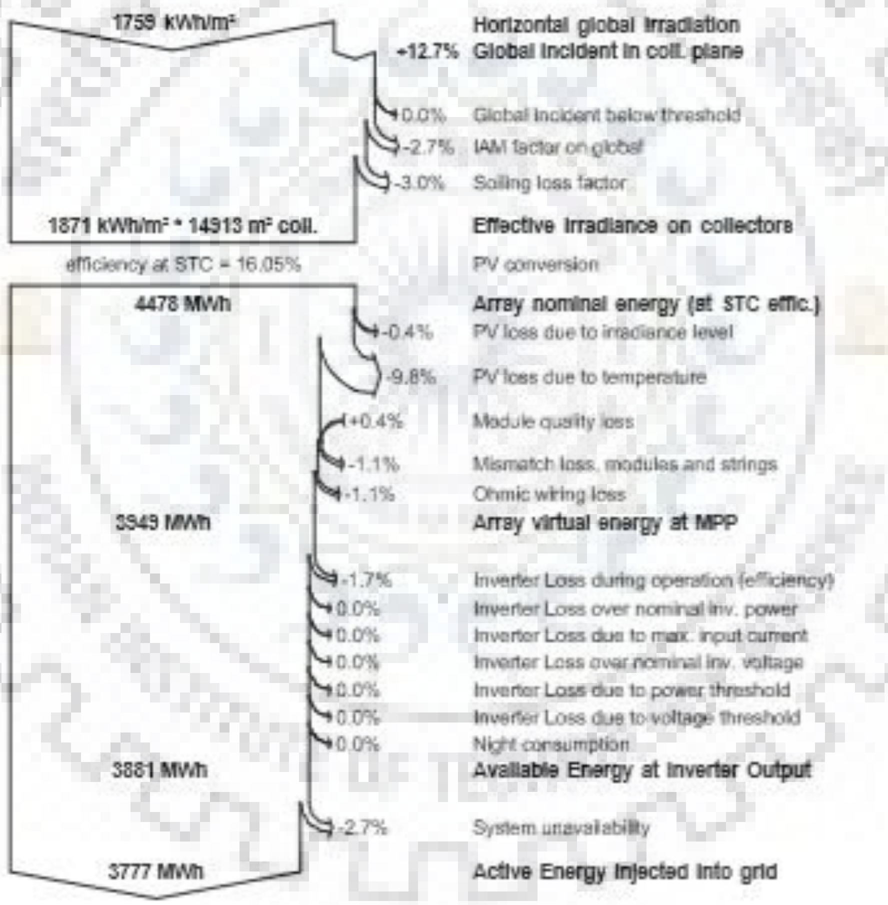
Grid-Connected System: Loss diagram

Project : **Dessertation for grid connection also**

Simulation variant : **New simulation variant grid NOC 2075.11.26**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	TSM-315PEG14	Pnom	315 Wp
PV Array	Nb. of modules	7600	Pnom total	**2394 kWp**
Inverter	Model	PVS800-57-1000kW-C	Pnom	1000 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)		Cos(Phi)	0.850 lagging

Loss diagram over the whole year



2342 MVAR — Reactive energy from the grid: Cos(Phi) = 0.850

4444 MVA — **Apparent energy to the grid**

Grid-Connected System: P50 - P90 evaluation

Project : **Dessertation for grid connection also**

Simulation variant : **New simulation variant grid NOC 2075.11.26**

Main system parameters	System type	**Grid-Connected**			
PV Field Orientation	tilt	28°		azimuth	0°
PV modules	Model	TSM-315PEG14		Pnom	315 Wp
PV Array	Nb. of modules	7600		Pnom total	**2394 kWp**
Inverter	Model	PVS800-57-1000kW-C		Pnom	1000 kW ac
Inverter pack	Nb. of units	2.0		Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			Cos(Phi)	0.850 lagging

Evaluation of the Production probability forecast

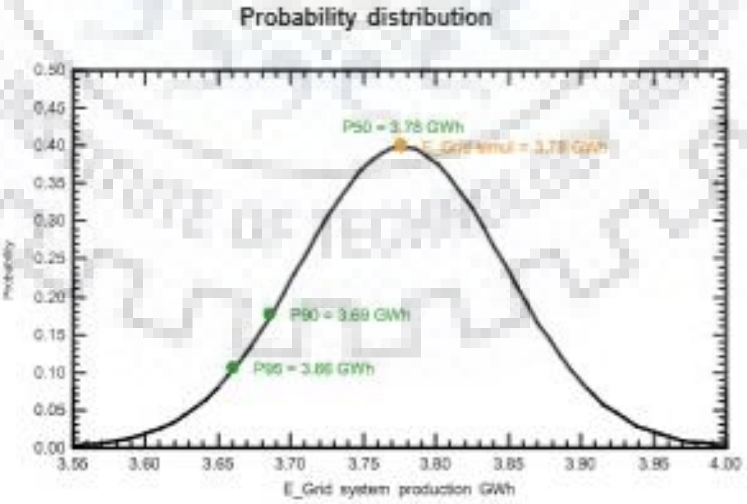
The probability distribution of the system production forecast for different years is mainly dependent on the meteo data used for the simulation, and depends on the following choices:

Meteo data source		NREL NSRDB Typ. Met. Year Suny_2000 to 2014	
Meteo data	Kind	TMY, multi-year	
Specified Deviation	Climate change	0.0 %	
Year-to-year variability	Variance	0.5 %	

The probability distribution variance is also depending on some system parameters uncertainties

Specified Deviation	PV module modelling/parameters	1.0 %	
	Inverter efficiency uncertainty	0.5 %	
	Soiling and mismatch uncertainties	1.0 %	
	Degradation uncertainty	1.0 %	
Global variability (meteo + system)	Variance	1.9 %	(quadratic sum)

Annual production probability	**Variability**	**71 MWh**
	P50	**3777 MWh**
	P90	**3686 MWh**
	P95	**3661 MWh**



Grid-Connected System: Long Term Financial Balance

Project : **Dessertation for grid connection also**

Simulation variant : **New simulation variant grid NOC 2075.11.26**

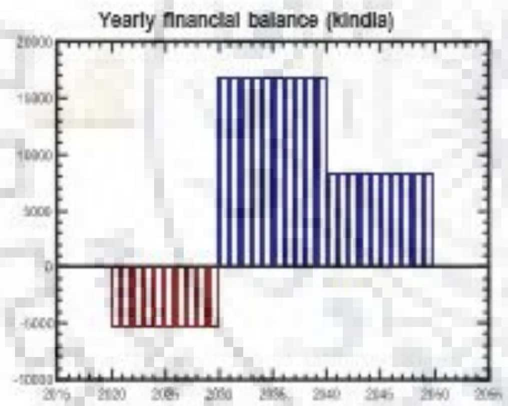
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	TSM-315PEG14	Pnom	315 Wp
PV Array	Nb. of modules	7600	Pnom total	**2394 kWp**
Inverter	Model	PVS800-57-1000kW-C	Pnom	1000 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)		Cos(Phi)	0.850 lagging

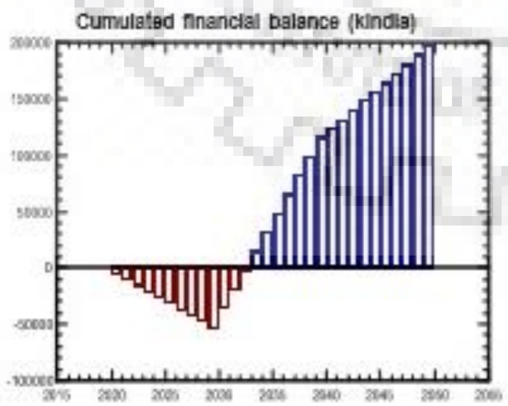
Electricity sale

Feed-in Tariff	**4.56 India/kWh**	Warranty over	**20 years**
Annual connexion tax	0 India		

Long term balance and Running conditions

Annual sale tariff depreciation	0.0 % / year
Annual production reduction	0.0 % / year
Feed-in tariff Warranty over	20 years
Tariff reduction after contractual warranty	-50 %
Loan duration (payment of annuities)	10 years





Long term economic balance

Year	Loan 50.0 %	Running costs	Sold energy	Yearly Balance	Cumul. Balance
2020	22013	458	17223	-5249	-5249
2021	22013	458	17223	-5249	-10498
2022	22013	458	17223	-5249	-15747
2023	22013	458	17223	-5249	-20996
2024	22013	458	17223	-5249	-26245
2025	22013	458	17223	-5249	-31495
2026	22013	458	17223	-5249	-36744
2027	22013	458	17223	-5249	-41993
2028	22013	458	17223	-5249	-47242
2029	22013	458	17223	-5249	-52491
2030	0	458	17223	16764	-35728
2031	0	458	17223	16764	-18964
2032	0	458	17223	16764	-2200
2033	0	458	17223	16764	14563
2034	0	458	17223	16764	31327
2035	0	458	17223	16764	48090
2036	0	458	17223	16764	64854
2037	0	458	17223	16764	81617
2038	0	458	17223	16764	98381
2039	0	458	17223	16764	115144
2040	0	458	8611	8152	123297
2041	0	458	8611	8152	131449
2042	0	458	8611	8152	139601
2043	0	458	8611	8152	147753
2044	0	458	8611	8152	155905
2045	0	458	8611	8152	164057
2046	0	458	8611	8152	172209
2047	0	458	8611	8152	180362
2048	0	458	8611	8152	188514
2049	0	458	8611	8152	196666

ANNEXURE 4

FINANCIAL ANALYSIS

Cost-Benefit Analysis

Nominal

Year	O&M	Royalty	Bonus & Welfare	Tax	Capital Expenditure	Total Cost	Benefit	Cash Flow	Cumulative
0					193,825,296	193,825,296		(193,825,296)	(193,825,296)
1	2,000,000		91,154			2,091,154	27,571,487	25,480,333	(168,344,963)
2	2,040,000		96,681			2,136,681	27,020,052	24,883,372	(143,461,592)
3	2,080,800		111,239			2,192,039	26,830,924	24,638,885	(118,822,707)
4	2,122,416		127,795			2,250,211	26,643,102	24,392,891	(94,429,816)
5	2,164,864		146,557			2,311,421	26,456,602	24,145,180	(70,284,636)
6	2,208,162		167,750			2,375,912	26,271,401	23,895,489	(46,389,147)
7	2,252,325		191,627			2,443,952	26,087,499	23,643,547	(22,745,600)
8	2,297,371		218,465			2,515,836	25,904,890	23,389,053	643,453
9	2,343,319		248,568			2,591,887	25,723,565	23,131,678	23,775,131
10	2,390,185		282,276			2,672,461	5,543,496	22,871,035	46,646,166
11	2,437,989		303,474	1,487,022		4,228,485	25,364,697	21,136,212	67,782,377
12	2,486,749		298,948	1,464,844		4,250,540	25,187,146	20,936,606	88,718,983
13	2,536,484		294,427	1,442,692		4,273,603	25,010,844	20,737,241	109,456,225
14	2,587,213		289,911	1,420,565		4,297,689	24,835,783	20,538,094	129,994,318
15	2,638,958		285,399	1,398,457		4,322,814	24,661,940	20,339,126	150,333,444
16	2,691,737		280,891	2,752,735		5,725,364	24,489,317	18,763,954	169,097,398
17	2,745,571		276,386	2,708,582		5,730,539	24,317,877	18,587,338	187,684,736
18	2,800,483		271,883	2,664,457		5,736,823	24,147,663	18,410,840	206,095,576
19	2,856,492		267,383	2,620,350		5,744,225	23,978,639	18,234,413	224,329,989
20	2,913,622		262,883	2,576,254		5,752,760	23,810,790	18,058,030	242,388,019
21	2,971,895		258,384	2,532,165		5,762,444	23,644,116	17,881,672	260,269,691
22	3,031,333		253,885	2,488,076		5,773,294	23,478,610	17,705,316	277,975,007
23	3,091,959		249,386	2,443,982		5,785,327	23,314,266	17,528,939	295,503,945
24	3,153,799		244,885	2,399,871		,798,555	23,151,052	17,352,497	312,856,443
25	3,216,874		240,382	2,355,745		5,813,001	22,988,992	17,175,991	330,032,433

IRR of the Project	**10.88%**	
NPV (Nominal)	**330,032,433**	**329,595,316**
NPV (Discounted)	**12,225,546**	**17,294,223**
Normal Payback Period (yrs)	**7.94**	
Discounted Payback Period (yrs)	**13.81**	
B/C Ratio (Nominal)	**2.7**	
B/C Ratio (Discounted)	**1.06**	
Equity IRR	**11.97%**	

B/C Ratio or PI = (NPV + Initial Cash Outlay)/Initial Cash Outlay

Debt Service Coverage Ratio

Particulars/Year	1	2	3	4	5
Net Profit after Tax	4,466,556	4,737,345	5,450,692	6,261,967	7,181,284
Add:					
Interest on Debt	13,260,765	12,393,015	11,435,181	10,377,912	9,210,884
Depreciation	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012
Total	**25,480,333**	**24,883,372**	**24,638,885**	**24,392,891**	**24,145,180**
(P+I)	21,619,555	21,619,555	21,619,555	21,619,555	21,619,555
DSCR	**1.18**	**1.15**	**1.14**	**1.13**	**1.12**
Particulars/Year	**6**	**7**	**8**	**9**	**10**
Net Profit after Tax	8,219,773	9,389,740	10,704,769	12,179,852	13,831,520
Add:					
Interest on Debt	7,922,704	6,500,795	4,931,272	3,198,813	1,286,503
Depreciation	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012
Total	23,895,489	23,643,547	23,389,053	23,131,678	22,871,035
(P+I)	21,619,555	21,619,555	21,619,555	21,619,555	21,619,555
DSCR	1.11	1.09	1.08	1.07	1.06

Levelized Cost of Electricity

Project Life	25	years		
Loan Term	10	years		
Rate of interest	10%			
Anuity Factor	0.162745395			
Initial Cost	193825296	Equity (30%)	58147589	Loan (70%) 135677707

Year	1	2	3	4	5	6	7	8	9	10	11	12
Energy Generation	3776916	3701377	3675469	3649740	3624192	3598822	3573630	3548615	3523776	3499109	3474616	3450294
ONM Cost	2000000	2040000	2080800	2122416	2164864.3	2208161.6	2252324.8	2297371.3	2343318.8	2390185.1	2437988.8	2486748.6
Debt Payments	13260764.99	12393014.82	11435181	10377911.69	9210884.2	7922704.2	6500794.5	4931272.3	3198813.4	1286502.9		
Land Lease	0	0	0	0	0	0	0	0	0	0	0	0
Depreciation	7753011.84	7753011.84	7753011.8	7753011.84	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8
Tax	0	0	0	0	0	0	0	0	0	0	1487022.2	1464843.8
Equity Ambursement	9463252.301	9463252.301	9463252.3	9463252.301	9463252.3	9463252.3	9463252.3	9463252.3	9463252.3	9463252.3		
Bonus and Welfare	0	96680.50875	111238.62	127795.2494	146556.83	167750.46	191627.36	218464.68	248568.42	282275.92	303473.92	298947.71
Total Annual Cost	32477029.13	31745959.47	30843484	29844387.08	28738569	27514880	26161011	24663372	23006965	21175228	11981497	12003552
LCOE (Rs/kwhr)	8.60	8.58	8.39	8.18	7.93	7.65	7.32	6.95	6.53	6.05	3.45	3.48
Av. LCOE (NRs)	5.41											

13	14	15	16	17	18	19	20	21	22	23	24	25
3426143	3402162	3378348	3354701	3331216	3307899	3284745	3261752	3238920	3216248	3193735	3171377	3149177
2536483.6	2587213.3	2638957.5	2691736.7	2745571.4	2800482.8	2856492.5	2913622.3	2971894.8	3031332.7	3091959.3	3153798.5	3216874.5
0	0	0	0	0	0	0	0	0	0	0	0	0
7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8	7753011.8
1442692.2	1420564.6	1398457.2	2752735.5	2708581.5	2664456.9	2620350.3	2576254.5	2532165	2488076.1	2443981.7	2399871.4	2355744.7
294426.97	289911.15	285399.42	280891.38	276385.87	271883.36	267382.68	262883.11	258384.19	253885.32	249385.89	244884.83	240382.12
12026615	12050701	12075826	13478375	13483551	13489835	13497237	13505772	13515456	13526306	13538339	13551567	13566013
3.51	3.54	3.57	4.02	4.05	4.08	4.11	4.14	4.17	4.21	4.24	4.27	4.31

Projected Loan Repayment Model

	Quarter	Loan Outstanding	Rate	Interest	Principal	Quarterly Payment
YR 1	1	135,677,707	10%	3,391,943	2,012,946	5,404,889
	2	133,664,761	10%	3,341,619	2,063,270	5,404,889
	3	131,601,491	10%	3,290,037	2,114,851	5,404,889
	4	129,486,640	10%	3,237,166	2,167,723	5,404,889
YR 2	5	127,318,917	10%	3,182,973	2,221,916	5,404,889
	6	125,097,001	10%	3,127,425	2,277,464	5,404,889
	7	122,819,537	10%	3,070,488	2,334,400	5,404,889
	8	120,485,137	10%	3,012,128	2,392,760	5,404,889
YR 3	9	118,092,377	10%	2,952,309	2,452,579	5,404,889
	10	115,639,797	10%	2,890,995	2,513,894	5,404,889
	11	113,125,904	10%	2,828,148	2,576,741	5,404,889
	12	110,549,162	10%	2,763,729	2,641,160	5,404,889
YR 4	13	107,908,003	10%	2,697,700	2,707,189	5,404,889
	14	105,200,814	10%	2,630,020	2,774,868	5,404,889
	15	102,425,946	10%	2,560,649	2,844,240	5,404,889
	16	99,581,705	10%	2,489,543	2,915,346	5,404,889
YR 5	17	96,666,359	10%	2,416,659	2,988,230	5,404,889
	18	93,678,129	10%	2,341,953	3,062,936	5,404,889
	19	90,615,194	10%	2,265,380	3,139,509	5,404,889
	20	87,475,685	10%	2,186,892	3,217,997	5,404,889
YR 6	21	84,257,688	10%	2,106,442	3,298,447	5,404,889
	22	80,959,242	10%	2,023,981	3,380,908	5,404,889
	23	77,578,334	10%	1,939,458	3,465,430	5,404,889
	24	74,112,904	10%	1,852,823	3,552,066	5,404,889
YR 7	25	70,560,837	10%	1,764,021	3,640,868	5,404,889
	26	66,919,970	10%	1,672,999	3,731,890	5,404,889
	27	63,188,080	10%	1,579,702	3,825,187	5,404,889
	28	59,362,893	10%	1,484,072	3,920,816	5,404,889
YR 8	29	55,442,077	10%	1,386,052	4,018,837	5,404,889
	30	51,423,240	10%	1,285,581	4,119,308	5,404,889
	31	47,303,932	10%	1,182,598	4,222,290	5,404,889
	32	43,081,642	10%	1,077,041	4,327,848	5,404,889
YR 9	33	38,753,794	10%	968,845	4,436,044	5,404,889
	34	34,317,750	10%	857,944	4,546,945	5,404,889
	35	29,770,805	10%	744,270	4,660,619	5,404,889
	36	25,110,186	10%	627,755	4,777,134	5,404,889
YR 10	37	20,333,052	10%	508,326	4,896,562	5,404,889
	38	15,436,490	10%	385,912	5,018,977	5,404,889
	39	10,417,513	10%	260,438	5,144,451	5,404,889
	40	5,273,062	10%	131,827	5,273,062	5,404,889

Projected Balance Sheet

Details/Year	1	2	3	4	5	6	7	8	9	10
Source of Fund										
Shareholder Equity										
Paid-up Capital	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589
Reserve and Surplus	4,466,556	9,203,901	14,654,593	20,916,560	28,097,845	36,317,617	45,707,358	56,412,127	68,591,979	82,423,499
Total	**62,614,145**	**67,351,490**	**72,802,182**	**79,064,149**	**86,245,433**	**94,465,206**	**103,854,946**	**114,559,716**	**126,739,568**	**140,571,088**
Long Term Debt										
Bank Loan	127,318,917	118,092,377	107,908,003	96,666,359	84,257,688	70,560,837	55,442,077	38,753,794	20,333,052	-
Other Loan	-	-	-	-	-	-	-	-	-	-
Total	**127,318,917**	**118,092,377**	**107,908,003**	**96,666,359**	**84,257,688**	**70,560,837**	**55,442,077**	**38,753,794**	**20,333,052**	**-**
Total Liabilities	**189,933,062**	**185,443,866**	**180,710,184**	**175,730,508**	**170,503,122**	**165,026,043**	**159,297,023**	**153,313,510**	**147,072,620**	**140,571,088**
Application of Funds										
Fixed Assets	193,825,296	186,072,284	178,319,272	170,566,260	162,813,249	155,060,237	147,307,225	139,554,213	131,801,201	124,048,189
Less										
Depreciation	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012
Net Fixed Assets	**186,072,284**	**178,319,272**	**170,566,260**	**162,813,249**	**155,060,237**	**147,307,225**	**139,554,213**	**131,801,201**	**124,048,189**	**116,295,178**
Current Assets										
Receivable	5,220,529	5,627,730	5,588,340	5,549,222	5,510,379	5,471,807	5,433,503	5,395,466	5,357,700	5,320,193
Cash and Bank Balance	6,140,248	9,146,864	12,205,584	15,018,038	17,582,506	19,897,011	21,959,307	23,766,842	25,316,731	26,605,717
Loan and Advances	-	-	-	-	-	-	-	-	-	-
Total Current Assets	**11,360,777**	**14,774,594**	**17,793,924**	**20,567,260**	**23,092,885**	**25,368,818**	**27,392,810**	**29,162,308**	**30,674,431**	**31,925,910**
Less Current Liabilities										
Provision for Dividend	-	-	-	-	-	-	-	-	-	-
Other Current Liabilities	7,500,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000
Net Working Capital (CA-CL)	**3,860,777**	**7,124,594**	**10,143,924**	**12,917,260**	**15,442,885**	**17,718,818**	**19,742,810**	**21,512,308**	**23,024,431**	**24,275,910**
Total Assets	**189,933,062**	**185,443,866**	**180,710,184**	**175,730,508**	**170,503,122**	**165,026,043**	**159,297,023**	**153,313,510**	**147,072,620**	**140,571,088**

Details/Year	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Source of Fund															
Shareholder Equity															
Paid-up Capital	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589	58,147,589
Reserve and Surplus	95,806,699	108,990,293	121,974,523	134,759,604	147,345,719	158,356,661	169,190,987	179,848,815	190,330,216	200,635,234	210,763,894	220,716,198	230,492,125	240,091,611	249,514,590
Total	**153,954,288**	**167,137,882**	**180,122,112**	**192,907,193**	**205,493,308**	**216,504,250**	**227,338,576**	**237,996,404**	**248,477,805**	**258,782,823**	**268,911,483**	**278,863,787**	**288,639,714**	**298,239,199**	**307,662,178**
Long Term Debt															
Bank Loan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Loan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total Liabilities	**153,954,288**	**167,137,882**	**180,122,112**	**192,907,193**	**205,493,308**	**216,504,250**	**227,338,576**	**237,996,404**	**248,477,805**	**258,782,823**	**268,911,483**	**278,863,787**	**288,639,714**	**298,239,199**	**307,662,178**
Application of Funds															
Fixed Assets	116,295,178	108,542,166	100,789,154	93,036,142	85,283,130	77,530,118	69,777,107	62,024,095	54,271,083	46,518,071	38,765,059	31,012,047	23,259,036	15,506,024	7,753,012
Less															
Depreciation	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012	7,753,012
Net Fixed Assets	**108,542,166**	**100,789,154**	**93,036,142**	**85,283,130**	**77,530,118**	**69,777,107**	**62,024,095**	**54,271,083**	**46,518,071**	**38,765,059**	**31,012,047**	**23,259,036**	**15,506,024**	**7,753,012**	**(0)**
Current Assets															
Receivable	5,282,951	5,245,974	5,209,251	5,172,784	5,136,576	5,100,623	5,064,919	5,029,462	4,994,259	4,959,298	4,924,583	4,890,109	4,855,880	4,821,887	4,788,136
Cash and Bank Balance	47,779,171	68,752,754	89,526,718	110,101,279	130,476,613	149,276,520	167,899,562	186,345,859	204,615,475	222,708,465	240,624,852	258,364,643	275,927,810	293,314,301	310,524,042
Loan and Advances	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Current Assets	**53,062,122**	**73,998,728**	**94,735,969**	**115,274,063**	**135,613,189**	**154,377,143**	**172,964,481**	**191,375,321**	**209,609,734**	**227,667,763**	**245,549,435**	**263,254,752**	**280,783,690**	**298,136,188**	**315,312,178**
Less Current Liabilities															
Provision for Dividend	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Current Liabilities	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000	7,650,000
Net Working Capital (CA-CL)	**45,412,122**	**66,348,728**	**87,085,969**	**107,624,063**	**127,963,189**	**146,727,143**	**165,314,481**	**183,725,321**	**201,959,734**	**220,017,763**	**237,899,435**	**255,604,752**	**273,133,690**	**290,486,188**	**307,662,178**
Total Assets	**153,954,288**	**167,137,882**	**180,122,112**	**192,907,193**	**205,493,308**	**216,504,250**	**227,338,576**	**237,996,404**	**248,477,805**	**258,782,823**	**268,911,483**	**278,863,787**	**288,639,714**	**298,239,199**	**307,662,178**