The Government of Nepal:
Ministry of Energy, Water Resources and Irrigation
Alternative Energy Promotion Centre
Making Renewble Energy Mainstream Supply in Nepal

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Message from Executive Director

Alternative Energy Promotion Centre (AEPC) under the Ministry of Energy, Water Resources and Irrigation has been promoting renewable energy technologies to increase access to clean lighting and cooking solutions in rural Nepal since its establishment in 1996. Mini grid systems, usually utilizing local indigenous resources such as solar, solar/wind hybrid or mini/micro hydropower are the most sought out electrification solutions in rural Nepal. More recently, solar mini grid systems have become cleaner, cheaper and a quicker viable alternative to large hydropower based central grid expansion in the country. With more than 25 years of experience in developing micro-hydropower systems and ten years of experience in promoting solar mini grids, the technical expertise required to plan, develop and promote such systems are now easily available within the country.

Till date, AEPC has supported 30 solar and solar/wind hybrid mini grid systems with a total capacity of 1262 kW powering more than 7500 households. These mini grids are providing improved electricity access of at least tier 3 level (more than 200W per household as per Multitier Framework, World Bank). They are not only lighting homes but are also creating income-generation activities through electricity-based enterprises. These enterprises have drastically improved the livelihood of rural people by creating employment opportunities, increasing income, and reducing women's drudgery in agro-processing. In a nutshell, electricity generation through mini grids has resulted in multi- faceted positive impacts on the rural livelihood and economy of Nepal.

Rapid technological advancements have exponentially reduced the shortcomings of solar technology. The state- of-the-art inverter and battery technologies provide reliable electricity while

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ensuring longevity of the mini grid system. Furthermore, solar and solar/wind hybrid mini grids allow for flexibility in expansion to meet the increase in energy demand in the future.

Moreover, mini grid systems use advanced inverter technologies that enable them to safely Interconnect to the national grid in case of grid extension in the mini grid areas. Grid-interconnected mini grid systems, also known as distributed generation sources, increases the energy security of the mini grid area, minimizes power losses compared to the central grid's long distance transmission lines, enhances the power quality of the grid, and enables sustainable utilization of the local renewable resources while having minimal environment impacts.

The mini grid systems in Nepal are generally built, owned and operated by the mini grid beneficiaries/end-users under different business models with financial and technical assistance from AEPC. During the operation phase, these systems can meet the operation and maintenance costs through monthly tariff collection from end-users, making them financially sustainable as well as technically sound in the long term. However, the initial investment required in these mini grid systems is high and thus the projects are heavily dependent on AEPC's financial subsidy. Moreover, the lack of direct involvement of the private sector has resulted in lengthy down-time and low service delivery. Hence, AEPC is committed to finding the right mix between the investment by project owners and the subsidy by AEPC, as well as to determine the adequate business model for the private sector to sustainably provide energy access as well as after sale services, while minimizing the Government's economic costs.

Recently, the Government of Nepal has launched the "Mini Grid Special Programme" which aims to support the fulfillment of the Government's energy access targets indicated in the Ministry's White Paper, 15th Periodic Plan, Nationally Determined Contributions, and other commitments. Moreover, AEPC has also envisioned to promote large number of mini grid projects in the coming years; therefore, the Guidelines for the Feasibility Study of Solar Mini Grid Projects has been prepared to ensure high technical quality of these systems, as well as good engineering practices among all AEPC-led donor programmes. This document will help guide the efforts of mini grid designers and practitioners, as well as provide further knowledge for academia and renewable

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energy enthusiasts. The authorities will regularly update and review this guideline in the future to reflect the latest developments in knowledge and technology.

I would like to take this opportunity to thank my colleagues at AEPC for preparing and finalizing the guidelines. I would also like to acknowledge the efforts of the Renewable Energy for Rural Livelihood (RERL) project under AEPC for preparing and publishing this document. We are also grateful for the support provided by the Asian Development Bank, UNDP and the World Bank in solar mini grid. I hope that this document will be a beneficial resource for the development of further mini grid systems in the country.

....

Dr. Madhusudhan Adhikari
Executive Director
Alternative Energy Promotion Centre

3 June 2022

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List of Abbreviations

°C	Degree Centigrade
AC	Alternating Current
AEPC	Alternative Energy Promotion Center
ADB	Asian Development Bank
AM	Air Mass
Amp	Ampere
a-Si	Amorphous Silicon
BoS	Balance of System
c-Si	Crystalline Silicon
CAPEX	Capital Expenditure
CB	Circuit Breaker
CUF	Capacity Utilization Factor
DC	Direct Current
DNI	Direct Normal Irradiation
DSCR	Debt Service Coverage Ratio
DHI	Diffuse Horizontal Irradiation
DoED	Department of Electricity Development
EIA	Environmental Impact Assessment
IEC	International Electro technical Commission
IFC	International Finance Corporation
IEE	Initial Environment Examination
EPC	Engineering, Procurement, Construction
EMI	Electromagnetic Interference
GCR	Ground Coverage Ratio
GESI	Gender Equality and Social Inclusion
GHI	Global Horizontal Irradiation
GTI	Global Tilted Irradiation
HV	High Voltage
IEE	Initial Environmental Examination
IPP	Independent Power Producer
IPPAN	Independent Power Producer Association of Nepal
IGBT	Insulated Gate Bipolar Transistor
IRR	Internal Rate of Return
Isc	Short Circuit Current
kV	Kilo Volt
kW	Kilo Watt
kWh	Kilowatt Hour
LCOE	Levelised Cost of Energy
LV	Low Voltage
LPS	Lightning Protection System
LVRT	Low Voltage Ride Through
MCB	Miniature Circuit Breaker
MV	Medium Voltage
MCCB	Molded Case Circuit Breaker
MPPT	Maximum Power Point Tracking

MW	Mega Watt
MVA	Mega-Volt Ampere
MWp	Mega Watt Peak
MoPE	Ministry of Population and Environment
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
NEA	Nepal Electricity Authority
NOCT	Normal Operating Cell Temperature
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
OPEX	Operational Expenditure
Pmp	Maximum Power Point Power
PPA	Power Purchase Agreement
PR	Performance Ratio
PV	Photovoltaic
RERL	Renewable Energy for Rural Livelihood
RAP	Resettlement Action Plan
ROI	Return on Investment
SCADA	Supervisory Control and Data Acquisition
SPV	Special Purpose Vehicle
STC	Standard Test Conditions
TL	Transmission Line
ToR	Terms of Refernce
ToC	Table of Contents
TCO	Total Cost of Ownership
THD	Total Harmonic Distortion
UL	Underwriters Laboratories
Voc	Open Circuit Voltage
Vmp	Maximum Power Point Voltage
WACC	Weighted Average Cost of Capital
Wp	Watt Peak
WB	World Bank

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Executive Summary

In the context of Nepal, solar and solar-wind hybrid mini grids are one of the most innovative technologies deployed to provide energy access to rural and isolated communities, and meet their development needs. In 2011, the first solar-wind hybrid mini grid of 12 kW installed capacity (10 kW wind + 2 kW solar PV) was implemented in Dhaubadi village of Nawalparasi district. By 2021, 65 solar and solar-wind hybrid mini grids with a cumulative installed capacity of 2697 kW were in operation serving more than 8,600 rural households and powering around 6050 rural enterprises. Subsequently, to further maximize the positive socio-economic impact of installed solar mini grids, the Government of Nepal has launched the "Mini Grid Special Programme" in 2019 with ambitious targets that will ultimately contribute to the Government's target of Electricity for All by 2023.

Further, solar and solar-wind hybrid mini grids are of strategic importance to Nepal in meeting the challenges of energy security. Solar mini grids are complementary energy producers that can deliver electricity at the household, business/commercial, community, or industrial/utility levels. Thus, the application of solar mini grids in adequately meeting the local energy demand is flexible and far reaching.

This Guideline for the Feasibility Study of Solar Mini Grid Project provides information and guidance on the planning, design and implementation framework to consultants, developers, investors, and renewable energy enthusiasts of solar mini grid projects. Furthermore, this Guideline will serve as a reference to authorities while reviewing feasibility study reports from consulting firms in the process of implementing solar mini grid projects. This Guideline provides a detailed explanation of the procedures required during project planning, study and implementation of solar mini grid projects in Nepal.

This Guideline also identifies the key planning and strategic aspects of solar energy development in Nepal. It provides guidelines for site selection, demand assessment, renewable resource assessment, design considerations, uses of simulation software, environment and social impact assessment, cost estimation, and financial analysis used by the Alternative Energy Promotion Centre (AEPC) while designing solar mini grid systems. Nonetheless, the document is not intended to address every circumstance and consideration such that it may not be relevant to every project. Rather, this Guideline endeavors to be a blueprint document for development of solar mini grid projects in Nepal with consideration of the major design principles and the country context.

GUIDELINES FOR FEASIBILITY STUDY OF SOLAR MINI GRID PROJECTS

I. BACKGROUND

Solar energy technology is an emerging field with high potential for significant technological advances in the future. Nepal has committed to the SDG-7 target of providing affordable, reliable, sustainable and modern energy for all by 2030. Consequently, Nepal has set a target to provide access to electricity for 99% of the households by 2030. Moreover, the White Paper 2018 has also set several targets related to energy access. It has set ambitious projections and targets such as: (i) the per capita energy consumption shall be 700 units and 1,500 units in next five and ten years respectively, (ii) "Harek Basti Urja Basti" shall be implemented under which 100 – 500 kW of renewable distributed generation will be made available in each of the 753 local units, (iii) 5-10% of generation will be sourced from RE to ensure diversity in the power generation, and (iv) 200 MW SPV projects will be implemented in Province 2. Although the Constitution has envisioned education and health services as basic rights, the lack of electricity access is a major hurdle in promotion of these rights. Further, the Government will accelerate the promotion of mini grid programmes to fulfill the targets set by White Paper 2018 and other international commitments. In line with these targets, AEPC has planned to implement a large number of solar mini grid projects in areas that are distant from the central grid. In 2019, AEPC launched "Mini Grid Special Programme" which further simplified the implementation process of solar mini grid systems. Further, to provide adequate support and capacity building of the stakeholders, there is a necessity of quality guidelines to carry out the feasibility study of solar mini grid projects.

II. PURPOSE AND OBJECTIVES OF THE GUIDELINE

The objectives of this Guideline are to provide detailed guidance on the preparation of Pre-Feasibility, Detailed Feasibility, and Environmental and Social Safeguards studies. Specifically, this Guideline will help with:

- Suitable site selection for mini grid
- Demand and resource assessment
- Defining minimal design standards and/or design considerations for major components of solar mini grid
- Design and the design tool for system configurations of the solar mini grid
- Cost estimation and preparation of bill of quantity
- Defining the financial model considerations during project development
- Facilitation for better outcomes by early identification of impacts

III. SCOPE OF GUIDELINE

Primarily, this Guideline provides information on major design considerations of solar mini grid projects in Nepal. However, this Guideline also covers feasibility study guides for solar-wind hybrid mini grid projects. The technical aspects defined in this Guideline are equally applicable for both solar and solar-wind hybrid mini grid projects.

The basic principles along with the standards and criteria for technical design and illustration of the connection process are provided for Nepal-specific conditions. Thus, this Guideline shall serve as a basis for the designers in the planning and decision-making process.

This Guideline also provides information on specific aspects to clarify certain provisions of the standards, in particular the environmental and social safeguard aspects that should be considered while developing the solar mini grid projects.

The site selection, environmental assessment, and design considerations outlined in this guideline are primarily related to the development of ground-mounted solar mini grid systems. They are not intended to apply to rooftop mounted systems; nonetheless, the assessment principles and outcomes of the solar energy elements may be applicable to some degree.

Although the focus of this Guideline is on solar mini grid, it can also be used for solar-wind hybrid mini grid projects.

IV. LIMITATION OF THE GUIDELINE

The Guidelines' scope is limited to Pre-Construction and it does not provide guidance for construction supervision of solar mini grid systems. It focuses mainly on the Feasibility and Environmental Study, Technical Design Considerations and Financial Analysis. Hence, the Guideline does not include the standards or requirements related to:

- Installation
- Engineering, Procurement, and Construction (EPC) works
- Post-construction considerations such as Testing and Commissioning requirements
- Post-commissioning stages such as Operations and Maintenance (O&M) aspects of the solar PV system
- Structural analysis of mounting structure of wind turbine

V. DOCUMENT STRUCTURE

The document is structured as follows:
Chapter 1 presents the solar mini grid related policy and the scenario of the solar mini grid sector in Nepal.

Chapter 2 presents the site selection criteria and the demand assessment of the solar mini grid system.

Chapter 3 presents the solar resource parameters, sources of solar resource data, and the major available satellite-based meteorological databases.

Chapter 4 presents the description of methodology for conducting pre-feasibility and feasibility study including energy assessment, productive uses of electricity, consideration of gender equality and social inclusion, land acquisition, etc.

Chapter 5 presents design considerations for the solar mini grid components including PV module/array, array mounting structure & foundations, battery, inverter, safety and system protection, DC and AC cable, civil engineering works, and monitoring system. It also includes design consideration of wind generation components as well as the transmission and distribution line.

Chapter 6 presents the basis for project cost estimation and preparation of the bill of quantities (BoQ).

Chapter 7 presents the estimation of energy yield, loss types & loss calculation, PV plant performance parameters, degradation, and life cycle energy yield estimation.

Chapter 8 presents the financial and economic analysis parameters such as CAPEX, OPEX, LCOE, NPV, IRR, Payback period, revenue analysis, financing parameters, financing output, and sensitivity analysis.

Chapter 9 presents the format for environment and social safeguards.

Chapter 10 elaborates the risk assessment related to solar mini grid project development.

Chapter 11 presents the detailed feasibility study report format and the table of content to be included by consultant

This document also includes a sample bill of quantity, glossary, wind glossary, useful information and conductor current ratings as ANNEXES to the Guideline.

CHAPTER 1: SOLAR MINI GRID SECTOR IN NEPAL

1.1. ALTERNATIVE ENERGY PROMOTION CENTRE (AEPC)

Alternative Energy Promotion Centre (AEPC) is the apex government body established in 1996 under the Ministry of Energy, Water Resources and Irrigation (MoEWRI) with the objective of promoting Renewable Energy Technologies (RETs) for the socio-economic development of the rural people suffering from energy scarcity.

The development objective of AEPC is to increase access to renewable and clean energy, improve the living standard, increase employment and productivity, reduce dependency on traditional energy sources, and promote sustainable socio-economic development of women and men in rural communities.

The mission of AEPC is to increase access to renewable energy (RE) and promote it as the major source of energy to improve people's living conditions. Over the last two decades, it has been actively promoting the use of RETs through implementation of a number of programs and projects to meet the rural energy needs.
AEPC provides direct financial and technical assistance through subsidy provision and capacity development support for establishment and management of RE projects (10 kW to 1000 kW) in the country. It has been implementing programs jointly with the local government while partnering with the Civil Society Organizations (CSOs) such as Non-Government Organizations (NGOs), Community Based Organizations (CBOs) and User Groups along with the private sector and financial institutions.
It also works with research/academic institutions focused on technological innovation. AEPC has been working on standardization, affordable maintenance, capacity development, and integration in planning, monitoring and networking activities to ensure optimal use of RETs in livelihood enhancement. Further, AEPC's activities include formulating and implementing policies which are directed towards coordinating, integrating, promoting and facilitating RE development in Nepal.

1.2. POLICIES AND OTHER PROGRAMS INCORPORATING SOLAR ENERGY TECHNOLOGIES

1.2.1. Rural Energy Policy, 2006

The Government of Nepal formulated the 'Rural Energy Policy' in 2006 which mandated a sector-wide approach in the delivery of energy services targeted at rural poverty reduction and environmental conservation by ensuring access to clean, reliable and adequate level of energy in the rural areas.

This policy incorporated small- and institutional-scale Solar Photovoltaic (SPV) systems and emphasized its study and research for cost reduction and efficient use. Specifically, the policy tied-up Solar Energy Technologies (SETs) with irrigation, health, education and drinking water as targeted services.

1.2.2. Renewable Energy Subsidy Policy, 2022

The provision of subsidy for small-scale Solar Home Systems (SHSs) began with formulation of the first RE Subsidy Policy in 2006/07. However, the Renewable Energy Subsidy Policy, 2016 was the first instance when a subsidy was allocated for solar and solar-wind hybrid mini grid projects. It has provisioned for subsidies amounting up to 60% of total system cost. The recent Subsidy Policy, 2022 has provisioned for subsidies amounting up to 90% for the local government owned up to 250kW solar mini projects and 60% for private, PPP, cooperative and community based solar mini grid projects upto 100kW.

1.2.3. Nepal Photovoltaic Quality Assurance (NEPQA), 2015

Nepal Photovoltaic Quality Assurance (NEPQA) is the technical standard for components of a Solar Photovoltaic (PV) System used in Nepal. The Renewable Energy Test Station (RETS) is responsible for conducting tests based on NEPQA and certifying the quality of the PV systems and components used in PV applications. The NEPQA is a collaborative effort of AEPC, RETS and other SPV stakeholders. Currently, NEPQA 2015.rev1 is in effect and AEPC has initiated its revision to accommodate the latest technologies available in the market.

1.2.4. Mini Grid Special Programme Implementation Modality, 2076

Mini Grid Special Programme Implementation Modality 2076 has been approved by MoEWRI for implementation of solar mini grid projects under Himali Solar Mini Grid Programme and Ujjyalo Nepal Programme.

1.2.5. Guidelines for Developing Utility-Scale Solar PV Project in Nepal

AEPC has prepared Guidelines for Developing Utility-Scale Solar PV Projects in Nepal in close coordination and consultation with the Ministry of Energy Water Resources and Irrigation (MoEWRI), Department of Electricity Development (DoED) and Nepal Electricity Authority (NEA). The main objective of this Guideline is to provide information to the Developers, Investors, Promoter of Solar PV projects who are in the process of development or intending to develop and invest in Utility-Scale Solar PV projects in Nepal. This guideline also provides a basis for consultants to undertake detailed feasibility studies including site identification, resource assessment, technical design, financial analysis, social and environmental considerations, and power evacuation of utility-scale SPV projects.

1.2.6. The Government's Other Rural Electrification Programs

The Government of Nepal's current policy divides rural electrification into two sub-sectors, largely defined as grid-based (on-grid) and isolated (off-grid). On-grid rural electrification is administered under MoEWRI through the Department of Electricity Development (DoED) as the regulator and promoter, and the Nepal Electricity Authority (NEA) as the vertically integrated agency responsible for national implementation. Off-grid electrification in rural areas is administered under MoEWRI through promotion and implementation by AEPC.

In 2003/04, NEA launched Community Rural Electrification Program (CREP) to provide grid access to communities in rural areas who are deprived of national grid electrical services. The model is set up in such a way that communities can buy power in bulk from NEA and manage/ operate the local distribution system through village organizations called Community Rural Electrification Entities (CREE). The tariff paid by CREEs for purchasing bulk power from NEA is less than the tariff paid by CREE's customers. Thus, CREE organisations utilise the profits for the operation and maintenance of the overall enterprise. Further, CREEs are required to contribute only 10% (previously 20%) of the project cost for connection to the grid and the remaining 90% (previously 80%) is provided by the Government through NEA.

1.3. PAST EXPERIENCES IN SOLAR PV AND WIND

Though Nepal had a few solar PV systems mainly powering telecommunication systems, it was only after the establishment of AEPC in 1996 A.D. that the country witnessed a surge in the application of SPV systems for electrifying rural households. By mid of 2021, AEPC has supported more than a million solar home systems (SHS) from 10 Wp to 100 Wp capacities all over the country. Similarly, around 3,000 Institutional Solar Power Systems (ISPS) in schools and health posts, around 2,300 PV Pumping System (PVPS) for small-scale irrigation and around 200 for drinking water supply have been installed through AEPC. This massive effort resulted not only in rapid rural electrification but also helped develop national capacity to deploy SPV systems.

The history of solar mini grid in Nepal started in 1984 with the collaboration of the Government with the French Government for financing of three SPV mini grids for electrification of Tatopani, Simikot and Gamgadi villages. In 2011, with the support from Asian Development Bank (ADB), AEPC implemented a 12 kWp Solar-Wind hybrid mini grid project in Dhaubadi of Nawalparasi district. Soon, AEPC accelerated the deployment of solar mini grid programmes in Nepal realizing the benefits of shorter project implementation cycles, availability of solar resources, generation of grid-quality electricity for both household and enterprise use, and feasibility of installation in almost all geographical locations of Nepal. By mid of 2021, AEPC has promoted 30 off-grid solar and solar-wind hybrid mini grids to cumulative capacity of 1,262 kW all across Nepal. These mini grids are providing improved electricity access to rural households at power level of 200W per household, as well as powering higher wattage micro, small & medium enterprises at 1500W per connection for fixed durations.

CHAPTER 2: DEMAND ASSESSMENT

2.1. LOAD ASSESSMENT

Accurate load assessment is a challenging endeavor but is one of the most important factors in correct power and storage sizing and estimation of the system's electricity generation and losses. Load profiles must be broken down seasonally (summer, autumn, winter and spring) to properly reflect the fluctuations in available energy, temperature, consumer patterns, etc. The "estimated daily load curve" should be plotted for a full 24-hour period in one hourly interval. It is also essential to consider the peak load and any important surges during this process. These considerations should be presented and discussed at length with all stakeholders before agreement and approval.

2.2. POWER AND ENERGY DEMAND FORECAST

The load demand in general will be guided by two main factors namely demand per household and the number of households to be connected to the mini grid. The power and energy demand will most likely fluctuate over the day; thus, a proper energy demand forecast has to be carried out for individual households on the basis of their likely electricity use pattern. Further, both the power as well as energy demand of households may vary on a seasonal basis, thus the load curve of the multiple seasons may have to be considered. Socio-economic factors like migration, population growth, etc. are other important factors to consider. An illustrative demand assessment of 50 household based communities is given in the table below.

TABLE 1: SAMPLE DEMAND ANALYSIS TABLE

SN	Electricity Uses	Quantity	Watts/ Unit	Total Watts	Uses Hours / Day	Coincidence Load Factor	Watt-hour /Day
1	**Households**	**50**					
1.1	Main Room Light per households	3	5	15	5	85%	64
1.2	Other Lights per households	2	3	6	5	85%	26
1.3	Mobile Charging per households	2	3	6	1	100%	6
1.4	Radio per households	1	5	5	2	5%	1
1.5	Cooling Fans per households	2	30	60	8	95%	456
1.6	TV 21" per households	1	40	40	4	40%	64
1.7	Direct to Home (DTH) Receiver	1	40	40	4	40%	64
1.8	Refrigerator	1	90	90	11	5%	50
1.9	Desktop/Laptop Computer	1	120	120	4	2%	10
	Per Household Uses			382			739
	Total Household Uses			**19,100**			**36,943**

TABLE 1: SAMPLE DEMAND ANALYSIS TABLE

SN	Electricity Uses	Quantity	Watts/ Unit	Total Watts	Uses Hours / Day	Coincidence Load Factor	Watt-hour /Day
2	**PEU Demand**						
2.1	PEU Demand-Poultry Farm	1	250	250	12	1.00	3,000
2.2	PEU Demand-Hotel and Restaurant	1	500	500	5	1.00	2,500
	Total PEU Uses			**64,000**			**5,500**
3	**Other Public Uses**						
3.1	Temple/Mosque/Church etc.	1	200	200	5	1	1,000
3.2	Health post	1	500	500	5	1	2,500
3.3	Police Office	1	200	200	5	1	1,000
3.4	APF	1	500	500	5	1	2,500
3.5	School	1	1000	1,000	4	1	4,000
3.6	LED Street Lights	20	15	300	8	1	2,400
	Total for Other Public Uses			**2,700**			**13,400**
4	**Control-Power House**						
4.1	Lights	5	5	25	6	1.00	150
	Total for Control-Power House			25			150
	Grand Total			**85,825**			**55,993**

Coincidence load factor is usability or availability of devices. For example, S.N. 1.1 in the table above has a coincidence load factor of 85% for main room lights, which means only 85% of installed main room lights for 50 households shall be used on an average on any particular day. Similarly, S.N. 1.4 has a coincidence load factor of 5% for radio, which means 5% of total households shall be using radio in the community at an instant. Such demand analysis tools should be used to accurately estimate the power, energy and safety requirements of not only the households but also productive energy uses (PEUs) and community energy uses (CEUs). The daily load curves of these three types of energy usage shall be graphed and the "Combined Load Curve" will help accurately determine the peak power sizing (kWp), storage (kWh) and energy demand and generation matching (kWh) for a 24-hour cycle.

2.3. PRODUCTIVE END USE POSSIBILITIES

To ensure financial attractiveness of RE projects for investors, the installed system must maximize utilization of renewable resources. Though the primary purpose of solar mini grid is to meet the basic household electricity needs, PEUs and CEUs should be encouraged to ensure sustainable revenue generation and employment creation. As both solar and wind resources are intermittent in their energy producing capability, diversity in types of end uses can also help balance this intermittency and optimize the investment cost. The most common end use possibility may be information and communication centers, agro-grinding mills, small-scale furniture/wood workshops, poultry farms, metal and grill workshops, photo studios, tailoring businesses, private health clinics, electronic repair shops, restaurants, bakeries and other small enterprises which require the use of appliances like refrigerators, rice cookers, televisions, printers, photocopiers, etc. The productive energy demands also known as enterprise loads are generally day time loads; thus, the SPV or wind power can be directly supplied to these loads without using up costly storage resources and thus leading to savings.

2.4. COMMUNITY BENEFIT ASSESSMENT

It is important to quantify direct and indirect socio-economic benefits that the new system will usher into the life of the rural community before any serious attempt is made to implement the new initiative. Baseline study should be conducted to properly understand the current socio-economic condition of the client community. Specifically, the prevailing health, education, communication and entertainment aspects of their life should be studied in detail to properly quantify the benefits that will result directly as well as indirectly due to the installation of the new system.

2.5. FEASIBILITY STUDY SURVEY

Site survey is one of the most important aspects for feasibility study as it directly relates to design quality. Thus, this Guideline has suggested the use of the format presented in Appendix 1 while conducting feasibility studies for solar mini grid projects. The questionnaires are developed for both individual household and focused group discussions. In case of individual household demand surveys, the consultant has to take an appropriate sample of atleast 10% of the total potential beneficiaries.

CHAPTER 3:
SOLAR RESOURCE ASSESSMENT

3.1. SOLAR RESOURCE ASSESSMENT

Solar Resource Assessment (SRA) refers to the analysis of a prospective solar energy production site with the end goal being an accurate estimate of that facility's Annual Energy Production (AEP). The main goal of Solar Resource Assessment in reference to site-specific measurement is to collect "ground truth" meteorological data for the purpose of lowering the uncertainty of the Annual Energy Production. The site-specific Solar Resource Assessment provides an accurate context from which long-term satellite derived irradiance data can be corrected. Before assessment of solar resources on the site it is crucial to know the basics of the solar parameters and different factors affecting the solar resource assessment.

3.2. IRRADIATION AND PEAK SUN HOURS (PSH)

Irradiation is the total quantity of radiation solar energy per unit area received over a given period, e.g. daily, monthly or annually. The Systeme International (SI) unit for energy is called joule (J). Since this unit is a relatively small quantity, larger quantities of energy, such as solar radiation, are often expressed in terms of MegaJoule (MJ).

The conversation factor from solar energy (MJ: megajoules) to irradiation (kWh: kilowatt-hours) is:

1kWh = 3.6MJ or 1MJ = 1/3.6 kWh

Daily irradiance is commonly referred to in daily peak sun hours (PSH).

Note: To convert MJ/m² to kWh/m² (or PSH), divide the number of MJ/m² by 3.6

3.3. SOLAR RESOURCE PARAMETERS

Site selection and planning of PV power plants require reliable solar resource data. The solar resource of a location is usually defined by the following parameters and are shown in the Figure below.

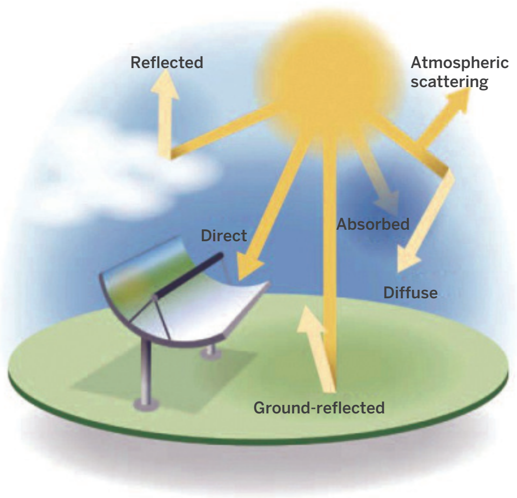

Figure 1: Solar radiation components resulting from interactions with the atmosphere (Source: NREL)

3.3.1. Direct Normal Irradiation (DNI)

Direct Normal Irradiation is the total energy received on a unit area of surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the Sun at its current position in the sky. This represents the maximum possible beam radiation that is measurable.

3.3.2. Diffuse Horizontal Irradiation (DHI)

Diffuse Horizontal Irradiation is the total energy received on a unit area of horizontal surface from all directions when radiation is scattered off the atmosphere (aerosols, dust, particles) or surrounding area.

3.3.3. Global Horizontal Irradiation (GHI)

GHI is the total solar energy received on a unit area of horizontal surface. It includes energy from the sun that is received in a direct beam (DNI) and DHI. So, GHI is measured by the total amount of direct and scattered radiation being received on a horizontal surface.

GHI is a reference radiation for the comparison of climatic zones and also an essential parameter for calculation of radiation on a tilted plane.

For all solar mini grid projects to be implemented through AEPC should have a GHI value more than 4kWh/m^2 per day.

3.3.4. Global Tilted Irradiation (GTI)

GTI is the total energy received on a unit are of surface with defined tilt and azimuth, fixed or sun-tracking. Unlike the horizontal surface, the tilted surface also receives a small amount of ground reflected radiation. This is the sum of the scattered radiation, direct and reflected. GTI is derived from GHI and DNI.

3.4. SOURCES OF SOLAR RESOURCE DATA

There are many sources where these data can be extracted. Solar radiation tables are often developed based on the measurement of direct and diffuse radiation each hour, recorded as hourly irradiance (W/m^2), giving the total daily irradiation (kWh/m^2 or MJ/m^2). The sum of direct and diffuse irradiation gives global irradiation, which is then used to calculate peak sun hours (PSH) as detailed above. The annual irradiation generally increases closer to the equator. However, note that the irradiation variations do not strictly correlate to latitude, as other factors affecting this can be altitude, local precipitation etc.

Long term annual average values of GHI and DNI can be obtained for a site by interpolating measurements taken from ground-based measurement stations or by solar models that utilize satellite, atmospheric and meteorological data. Ideally, historical values of hourly GHI values are used for PV project development. At least 10 years of continuous data are required in order to account for climate variability as the changes in pattern occur from year to year. However, such extensive historical data is not available from ground-based measurement stations. There are two main sources of Solar Resource Data.

3.4.1. Satellite Derived Data

Satellite-derived data can offer a wide geographical coverage and can often be obtained retrospectively for historical periods in which no ground-based measurements were taken. This is especially useful for assessing long term averages. A combination of analytical, numerical and empirical methods can offer 15 minutes data with a nominal spatial resolution down to 250m, depending on the location and field of view of the satellite.

For locations that have a low density of meteorological stations and rely on satellite data, on-site resource monitoring may be considered during the feasibility stage of the project. On-site solar radiation data collected from solar resource monitoring stations may be used to calibrate satellite-derived estimates, thereby reducing bias and improving accuracy. The best results are obtained by monitoring for a full twelve months or longer to capture seasonal variations.

3.4.2. Ground Based Measurement

Solar radiation resources assessment (SRRA) stations are set up for long term measurement of solar data at ground level. A typical SRRA station consists of two towers of 1.5 m and 6 m tall each for measuring solar and meteorological parameters such as wind velocity, temperature, precipitation, and humidity. The 1.5 m tall tower houses a solar tracker equipped with Pyranometer, Pyranometer with shading disc and Pyrheliometer to measure global, diffuse and direct irradiance respectively. The 6 m tall tower houses instruments for measuring ambient temperature, relative humidity, atmospheric pressure, wind speed, and direction, rainfall and a state of-the-art data acquisition system. The solar sensors are traceable to the World Radiometric Reference (WRR) and the meteorological sensors are traceable to the World Meteorological Organization (WMO). Each SRRA station is totally powered by solar PV modules. A trigger switch is also installed at each SRRA station to track the cleaning status of the SRRA stations on a daily basis. Data is sampled every second and averaged over a minute and transmitted to the Central Receiving Station (CRS) through GPRS mode. Advance Measurement Stations (AMS) can be set up for quantification of attenuation of solar radiation due to the presence of aerosols in the atmosphere and for the measurement of the reflectivity of the earth (Albedo), incoming long wave radiation and atmospheric visibility for research and developmental activities.

Well maintained land-based sensors can measure the solar resource with a relative accuracy of 3-5%. Long term data from such stations may be used to calibrate satellite – derived data. However, maintenance is very important since soiled or ill-calibrated sensors can easily yield unreliable data.

3.5. ACQUIRING SOLAR RESOURCE DATA

There are a variety of different solar resource datasets that are available with varying accuracy, geographical coverage, time resolution, spatial resolution and historical time period. Table below summarizes the major available satellite-based meteorological databases globally and suitable for Nepal.

TABLE 2: ACQUIRING SOLAR RESOURCE DATA

Database (satellite Based)	Area	Coverage	Time Period	Time Resolution	Spatial Resolution	Values (Time series)	Parameters	Type	Website
SolarGIS	Globally	Latitude 60°N and 50°S	From 1994	15 min	0.25Km x 0.25Km	hourly	GHI, DNI	Commercial	https://solargis.com/
Meteonorm	Globally		1991-2010/ 1996-2015	1-hourly		monthly	GHI, DNI	Commercial	http://www.meteonorm.com/
Solar Energy Mining (SOLEMI)	Europe, Africa, Asia		1991-today (Europe), 1999-2006 (Asia)	1-hourly	2.5Km x 2.5Km	hourly	GHI, DNI	Commercial	https://wdc.dlr.de/data_products/SERVICES/SOLARENERGY/description.php
3Tier	Europe, Africa, Asia	48°N and 60°S	1999-present	1-hourly	3Km x 3Km	hourly	GHI, DNI	Commercial	https://www.3tier.com/
Surface meteorology and Solar Energy (SSE)-NASA	Globally		1983-2005	3-hourly	100Km x 100Km	monthly	GHI, DNI	Free	https://eosweb.larc.nasa.gov/sse/

CHAPTER 4: SURVEY AND INVESTIGATION

4.1. INTRODUCTION

The design guide is a prescriptive guidance for system designers who will develop solar power based mini grid systems in Nepal whether it be government, non-government, and commercial or not for profit.

This guidance focuses on the holistic objectives which are required by the various project stakeholders throughout the lifecycle of the project, this typically includes socioeconomic, financial, environmental and technical aspects. In general, all solar power systems (from commencement of the project to completion) proceed through several phases, each requiring specific effort. The following are various phases of solar PV system lifecycle:

- Site identification
- Site assessment
- Feasibility study
- Complete proposal
- Tenders and Contract award negotiations
- Project integration
- System integration and Installation
- Construction supervision and monitoring
- Final test, performance verification and acceptance
- Operation and maintenance

4.2. SITE SELECTION FOR SOLAR MINI GRID

Site selection is a critical issue due to its direct impact on the technical, economic, environmental and social aspects. While considering the site selection, the following major parameters should be considered.

TABLE 3: SITE SELECTION PARAMETERS

SN	Parameters	Description
1	Availability of Solar Resource	• Global Horizontal Irradiance (GHI) with more than 4kWh/m² should be considered to have higher energy yield. GHI value should be validated from freely available or commercially available meteorological data sources for different chosen sites.
2	Shading	• Far Shading: shading due to hills or mountains or building on the far horizon should be avoided • Near Shading: shading due to nearby trees, building, structures, overhead cabling should be avoided Both far shading and near shading should be assessed with the help of sun path diagram or any other shadow analysis tool.
3	Availability of Land Area	• Should have sufficient space to accommodate the required capacity to be installed. • Typically require about 7 to 10 m² per kWp for relatively flat land and depends on two factors: • 1) Type of solar PV technology chosen (PolyCrystalline or MonoCrystalline or HIT or Thin Film). 2) Land shape & slope, tilt angle and shading.

SN	Parameters	Description
4	Topography and Orientation	• Land should have a good southern exposure without significant shading. Sites that are flat or slope towards the south are ideal.
	Accessibility	• Shortest possible distance should be chosen from project site to access road and highway • Quality of existing roads or new proposed construction roads should be carefully considered for the transportation of equipment (by vehicle or by porter)
5	Geotechnical	The ground should be substantially stable
6	Climatic Characteristics	The weather factors that should be considered are: • Flooding: Flood risk assessment mainly to the powerhouse, erosion of mounting structure and foundations • Wind Speed: Sites with high wind speed should be avoided • Snow: 1) Sites prone to regular covering of snow areas should be avoided 2) For less snow areas, the design of array mounting structures should consider the extra weight of snow
7	Right of Way	Proper right of way for transmission and distribution lines should be carefully considered in order to avoid the unnecessary delay in project implementation schedule, land acquisition and land agreement procedures
8	Permits and Clearances	• Local land use zoning regulations • Possibility to acquire land lease Construction permit

4.3. PRE-FEASIBILITY PLANNING

Pre-feasibility study is an early stage analysis of a potential project. The study is conducted by a group of small teams and is designed in order to decide whether or not the project will be worth proceeding with or not and commitment of additional financial resources. The following are fundamental tasks involved in conducting Pre-Feasibility Study.

- Site Assessment
- Roof-top and ground mount planning;
- Solar Resource Assessment
- Demand Assessment
- Cost estimate
- Estimation of Energy Yield
- Financial and Economic Analysis
- Environmental and Social Safeguards Screening
- Preliminary Risk assessment

4.4. FEASIBILITY PLANNING

Solar mini grid feasibility study is the most fundamental engineering effort required for assessing and planning any type of solar mini grid design. Feasibility study is the cornerstone of solar mini grid design because it provides an in-depth, meaningful assessment of the energy potential and the relationship to consumers and productive end use.

Solar feasibility study is also of paramount importance in securing investment in solar mini grids, since it provides detailed assessments of solar energy production potential as well as sets up a bankable engineering platform for future project execution.

The following are fundamental tasks involved in conducting Feasibility Study:

- Site assessment
- Roof-top and ground mount planning;
- Solar resource assessment
- Demand assessment and projection
- Shading analysis
- System design
- Design layout

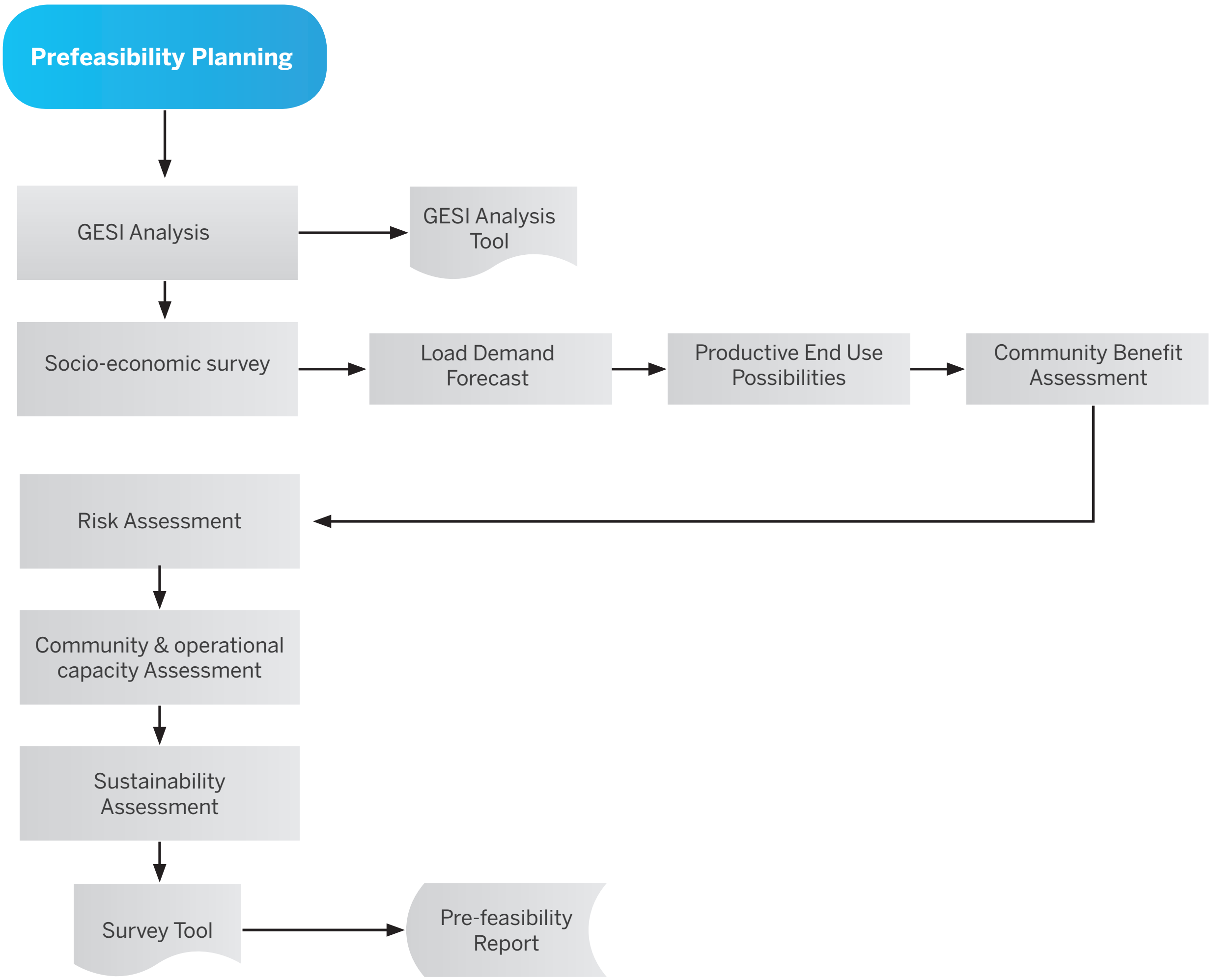

Figure 2: Pre-feasibility Process

- BoQ and Cost Estimate
- Estimation of Energy Yield
- Financial and Economic Analysis
- Environmental and Social Safeguards
- Risk assessment

The engineer or designer will need the following documentation in order to provide a comprehensive analysis. Solar system feasibility studies usually involve several site visits and a close collaborative effort with the organization or community at that location.

It is key to understand the linkage between services delivery via the mini grid and how it will be accepted by the end-user. This is essential in determining the long term success and sustainability of a project as well as securing investment and investor confidence in the viability of a project. Therefore the design guidance focuses primarily on socioeconomic and financial assessment in pre-feasibility planning, as these are the key drivers for the mini grid project.

4.5. GENDER EQUALITY AND SOCIAL INCLUSION

Gender Equality and Social Inclusion (GESI) established the socially constructed power relations between women and men's roles, responsibilities, opportunities and decision-making authority. The approach has created a space of new realities and relationships as girls, boys, women and men of any age, class, caste, ethnicity, religious identity or different ability are enabled to live with dignity, justice and respect, asserting their rights and responsibilities.

The conceptual framework acknowledged in this guideline is taken from Gender Equality and Social Inclusion Mainstream Plan of AEPC, 2013 and GESI Policy 2018 of AEPC which are mentioned below as it is:

4.5.1. Social inclusion/exclusion

Social inclusion is defined as, the premeditated and systematic removal of institutional and social barriers, with the enhancement of incentives to increase the access of diverse individuals and groups to naturally access opportunities.

Social Exclusion is defined as, the practice of excluding a group of people and/or individuals from social relations and institutions and preventing them from full participation in the normal, normatively prescribed activities of the society in which they live.

4.5.2. Gender

"Gender" refers to the socially constructed roles, behaviors, activities, and attributes that a given society appropriates for women and men. "Male" and "female" are sex categories, while "masculine" and "feminine" are gender categories.

4.5.3. Equality

Focuses on ensuring that all members of society have equal opportunities, equal satisfaction of basic needs, legal equality, socio-cultural equality, economic equality and political equality. It is the result/outcome expected from the nation, organization and the development program.

4.5.4. Gender Equality

The absence of discrimination on the basis of gender in exercising rights, undertaking responsibilities and seizing opportunities, in the allocation of resources or benefits. It is the full and equal exercise by women and men of their human rights.

Energy is a basic need of human beings. Improved energy sources improve levels of welfare, increase standards of living, and provide opportunity for income generation. However, differences in energy access have remained a challenge for a majority of the population with respect to gender and the socially marginalized groups.

The social issues caused by gender inequality and social exclusion can be overcome by innovative GESI measures. The purpose of the GESI approach is to address key issues such as access and articulation of women and equal participation of poor and socially excluded groups in benefit sharing. It plays a vital role to narrow down the existing gaps between women and men belonging to various social groups (vertically in social hierarchy and horizontally in gender hierarchy). Therefore, the GESI approach is an indispensable intervention widely applied for equal access and control on development inputs for the nation and for development projects. The DFS survey team should collect information from the field visit as mentioned below;

- What is the current access to various energy sources and services (e.g., electricity, kerosene, diesel, fuel wood) by people (men, women and socially excluded groups) in the project area?
- Women and children suffering from energy-related environment and health problems, such as smoke emissions and indoor air pollution?
- How are energy sources for households collected? Can the proposed project include a specific intervention to reduce women's time and drudgery related to collecting energy sources (time spent or distance travel to access to fuelwood, kerosene etc)?
- Is the proposed energy services and sources affordable, particularly to poor, socially excluded groups and households headed by women? What will be the viable options (such as financing schemes to upset cost of connection fees or adoption of efficient appliances) to improve

affordability for the socially excluded, single women, poor and households headed by women?

- What are the possibilities of powering social services, such as clinics and public lighting to improve maternal health, and women's mobility and safety (e.g., unavailability of streetlights due to lack of reliable energy source) to participate in activities outside the home after dark?
- What are the opportunities of access to electricity that facilitates provision of drinking water, agricultural uses and can reduce the time spent fetching water?
- What is the financial status and ability of the female-headed households and single women, earthquake hit groups, conflict victims, and disaster-prone, socially disadvantaged / marginalized household's sources of collateral to pay upfront costs to acquire electricity?
- Status of micro and small enterprises in project areas and women's involvement. How does the proposed project encourage women & men as well as excluded groups in establishing micro and small enterprises?
- Is there Income Generation opportunities for men/women of all social groups through the electrification projects?

Proper assessment of socio economic aspects of any candidate site/locality is a prerequisite for any new intervention in the area which may disturb the way things were being done hitherto. Current energy use patterns, management of energy needs for different purposes, position of energy in priority ladder, economic condition of the people, willingness to accept newer technology, ability to pay and willingness to pay etc. are vital information that shall be obtained at the outset.

In Nepal, many of the alternative energy technologies are being implemented under community owned and community managed modality. Government role is mainly limited to policy formulation, subsidy channelizing and providing technical assistance to the community to be involved from the very beginning through commissioning till operating of the plant. Based on the past experience, it makes sense to follow the same models.

Community participation is widely acknowledged as an essential ingredient for ensuring equity and the sustainability of any decentralized electrification. Local participation in the form of village community organization or cooperatives generally contributes to better project management, though to varying degrees. The level of engagement of communities in the operation and management of projects differ significantly. Very often rural communities get involved in the project development from the very inception of the project planning until the commissioning and operation of projects. In some other cases, participation seems to be less active and limited to the upkeep of the project operation and management. Capacity building of community representatives on various aspects of Mini Grid has been acknowledged as an important ingredient in the successful operation of mini grid projects.

Sustainability is the ultimate key for any investment to be meaningful. A lot of time, money and sweat will be wasted if the installation cannot operate sustainably for the desired period of time. There are various aspects of sustainability including ecological, social, financial and technical and all aspects shall be thoroughly analyzed before any conclusion could be reached for go/no go.

CHAPTER 5: SYSTEM DESIGN

5.1. SYSTEM DESIGN CONSIDERATIONS

When designing solar mini grid systems, the engineer or the designer must consider numerous parameters which include but are not limited to the following:

- Site assessment considerations;
  - site location and land area requirement;
  - meteorological data;
  - electrical system;
- Load profile assessment considerations;
  - Seasonal load profile, daily load profile, daily energy requirement and annual energy requirements;
  - Surge power requirements;
  - Peak power requirements;
- PV system configuration;
  - Selection of PV module
  - Selection of charge controller
  - Array layouts with shading analysis;
  - Selection of grid connected inverter
  - Inverter and/or MPPT Controller configuration
  - Energy Matching PV array and charge controller
  - Matching PV array and grid connected inverter;
- Storage system configuration;
  - Selection of battery storage
  - Battery configurations
  - Battery Selection of battery inverter
  - Inverter configurations
  - Matching battery storage and battery inverter
- Diesel Generator Configuration (if case of diesel hybrid);
  - DG set dimensioning;
  - DG set control;
- Wind Turbine Configuration;
  - Selection of wind turbine
  - Selection of wind controller
  - Turbine and tower dimensioning;
  - Power synchronization (in case of hybrid technologies)
  - Wind system control;
- Powerhouse and Power Plant Fence dimensioning
- Power transmission and distribution system components dimensioning
- Protection System Dimensioning for Generation and Distribution system
- Cabling schedule;
- Control and monitoring system;
  Reporting.

5.1.1. Peak sunshine hour (PSH)

The term "peak sun hours" refers to solar insolation which a particular location would receive if the sun is shining at its maximum value for a certain number of hours. It is equivalent to Global Horizontal Irradiance (GHI) in particular place. If GHI per day is 4kWh/m² that means PSH will be 4 hours. AEPC supported mini grid shall have to design for an average of 4hrs of PHS.

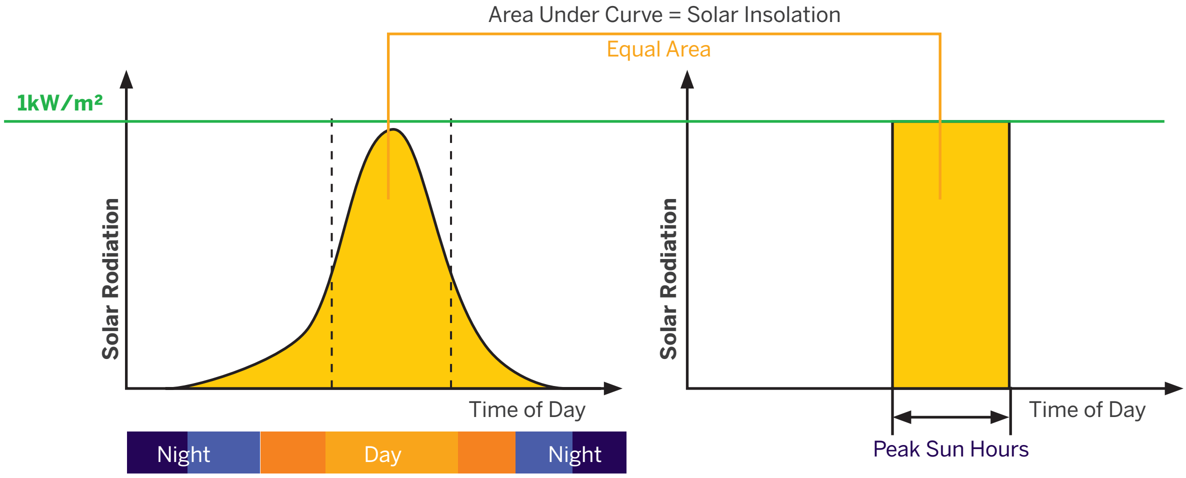

Figure 3: Peak Sunshine Hour (Source: PVeducation)

5.2. MINI GRID ARCHITECTURES

Mini grids vary considerably in terms of scale, complexity and loads. They can incorporate many different types and combinations of power generation and energy storage technologies, including fossil fuel generators, micro-turbines, photovoltaics, batteries and energy management systems.

The designer will have the choice to organize solar mini grids into four basic configurations or architectures: ac coupled, dc coupled and DC and AC Coupled and DC-AC coupled with distributed generation systems. There are pros and cons associated with each design approach.

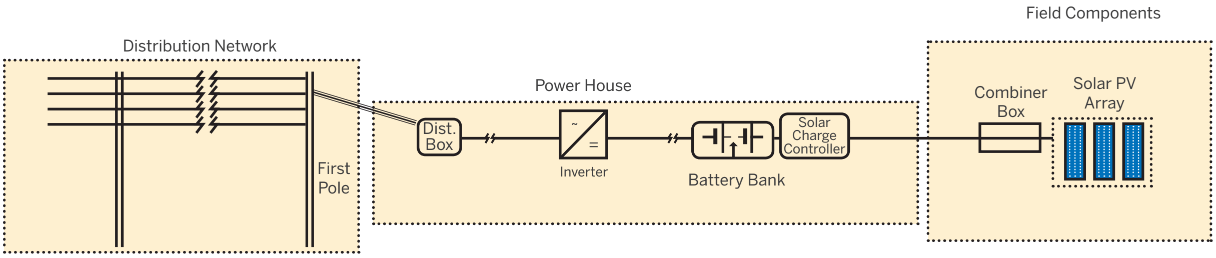

Figure 4: General Architecture of Solar Mini Grid

5.2.1. AC Coupled

In an AC-coupled configuration, there are separate PV inverters and battery inverters. These separate inverters connect to one another on the ac side of the system, typically through a dedicated subpanel containing backup loads. The PV inverter is typically a standard utility-interactive inverter, albeit one capable of receiving external controls. The storage inverter controls battery charging and discharging.

An AC-coupled configuration typically offers improved conversion efficiencies and equipment availability, as well as simplified system monitoring and serviceability. Conversion efficiencies are improved because the PV system connects to standard utility-interactive inverters, which are often 97% or 98% efficient. While power converter options are more limited than PV inverter options, several vendors serving the solar market also offer commercial-scale energy storage converters. Further, you can deploy any power converter suitable for dc coupling as a dedicated storage converter in an AC-coupled mini grid system. Having all of these options to choose from makes it relatively easy for the designers to identify a storage converter with the desired capacity rating and product features.

An additional benefit to using utility-interactive PV inverters is that you can use standard Original Equipment Manufacturer (OEM) or third-party PV monitoring solutions. While this may sound trivial, it is an important consideration for some applications. For example, off-the-shelf monitoring options are valuable for design flexibly for the many and varied monitoring requirements now demanded by project stakeholders. Meanwhile, having two separate inverters makes it easier for technicians to isolate the storage system from the PV system for maintenance and troubleshooting. It is recommended that both the inverters are compatible, shall communicate well with each other and designed by the same manufacturer.

The drawbacks of ac coupling relate to costs, space requirements and system control. Because ac-coupled systems require two separate inverters, they are typically more expensive than a comparable system deployed using a single multi-interface converter. Systems deployed using a dedicated energy storage converter face difficulties with RETS and import procedures. Two inverters also take up more physical space than a single converter. Lastly, system control and interoperability may be more limited or complicated in systems deployed using two inverters, especially if the inverter manufacturers differ. Mismatched inverters may also make it more difficult to monitor both the PV and the energy storage systems effectively.

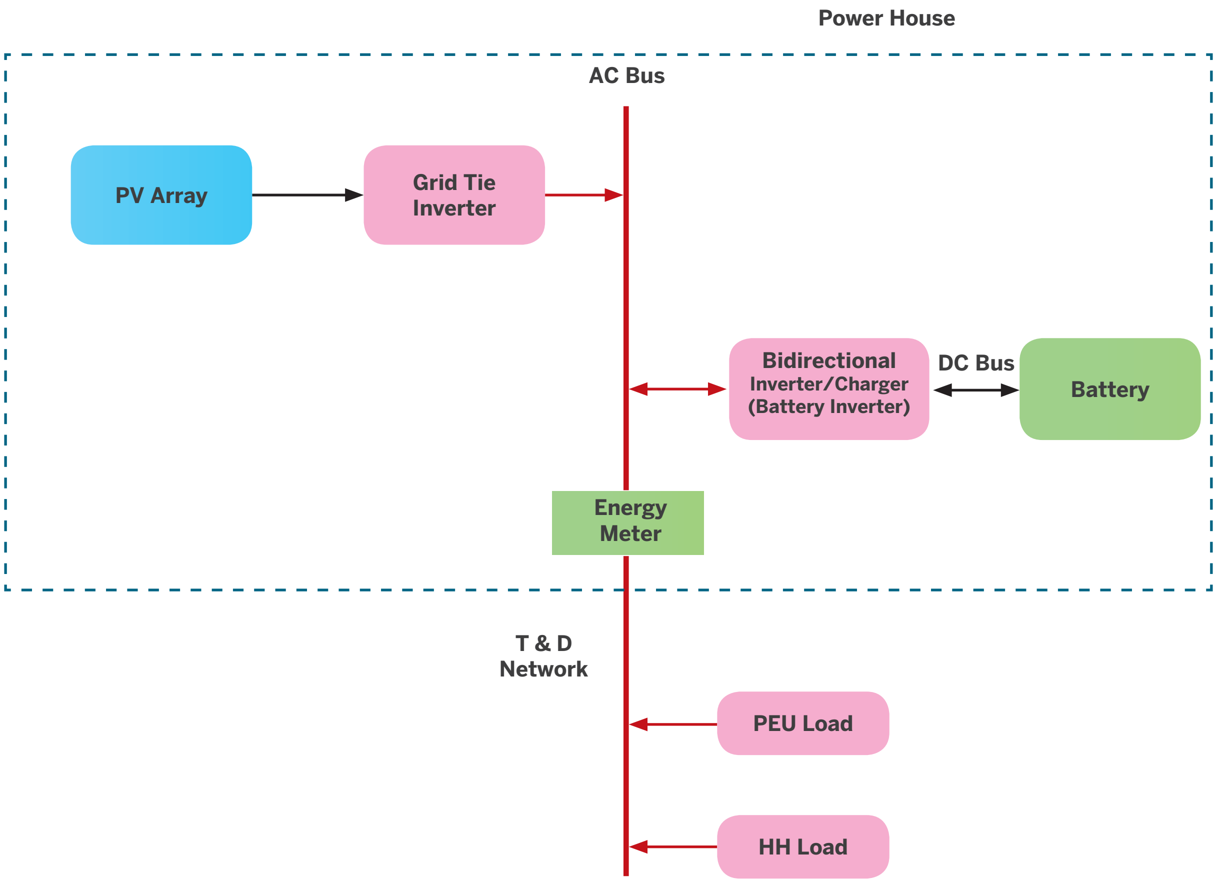

Figure 5: AC Coupled System

The AC coupled design topology is flexible in terms of battery bank size optimization at present as well as future interconnection to the mains grid system if required. Some of advantages and disadvantages are elaborated below;

Advantages:

- Supply day time load with relative high "PV to day-load" efficiency (high efficiency conversion of PV inverters and assuming that load<PV production);
    - *"PV to day-load" efficiency = PV inverter efficiency = 95%*
- Flexibility for future system extensions (addition of PV Array/PV inverter blocks connected on the same AC bus, or connection to other AC sources, such as the future grid);
- Use of different AC generation sources working in parallel as a hybrid system;
- PV inverters being massively deployed on the international market, monitoring solutions of PV inverters and PV Array are mature and commercially available.

Disadvantages:

- Charge battery with low "PV to battery" efficiency (due to several consecutive DC-AC conversions):
    - *"PV to battery" efficiency = PV inverter efficiency (95%) x charger efficiency (90%) = 86%*
- Supply nighttime load with lower "PV to night-load" efficiency;
    - *PV to night-load" efficiency = PV inverter efficiency (95%) x charger efficiency (90%) x battery efficiency (80%) x battery inverter mean efficiency (87.5%)= 60%*
- Requires potentially more physical space due to separate PV inverter and battery inverter, as well as control system;
- Higher system cost per Wp (specific cost) due to additional components (PV inverter), additional functions required for the battery inverter (control system, charger) and additional installation time;
- Required compatibility between PV inverter, control system and battery inverter;

Configuration typically designed for hybrid systems using different generation sources leading to a more complex operation of the system.

5.2.2. DC coupled

In a dc-coupled configuration, the PV and energy storage systems share a common inverter with three or more interfaces. Two interfaces on the dc side of the converter are dedicated to the PV and battery inputs, and a third interface on the ac side of the converter provides an input for the utility grid. While power from the PV array flows in one direction only, power flow on both the battery and utility interfaces is bidirectional.

DC coupling can reduce material and labor costs compared to an AC-coupled system since it can rely on a single power converter. DC-coupled systems are generally more compact in terms of physical space. Not only do you have to install fewer pieces of equipment, but also this approach eliminates redundant subcomponents and controls. Meanwhile, the process of qualifying the energy storage components with RETS is simplified when the solar and storage share the same converter.

In specific scenarios, dc coupling may provide unique performance benefits. For example, battery charging from the PV array could be more efficient in a dc-coupled system if the loads are outside peak sun hours.

The potential drawbacks of dc coupling include limitations related to product availability, weighted efficiency, shared converter capacity and energy metering. Relatively few equipment vendors offer multi-interface converters for solar mini grids. As compared to a standard utility-interactive inverter, these specialty converters have a lower rated efficiency, typically in the 92% to 96% range.

DC coupled systems using traditional inverters are more difficult at scale. For example, stacking charge controllers with small voltage windows results in a lot more devices, cables, connectors and combiner panels, it is also not always possible to synchronize all the charge controllers to a single point of control which limits the ability to effectively manage battery charging and system control. The designer should consider whether there is a compromise in system services and functionality by having two dc sources share converter capacity. Obtaining investor/stakeholder agreement may also present a problem, since there are losses associated with energy storage system charge and discharge cycles.

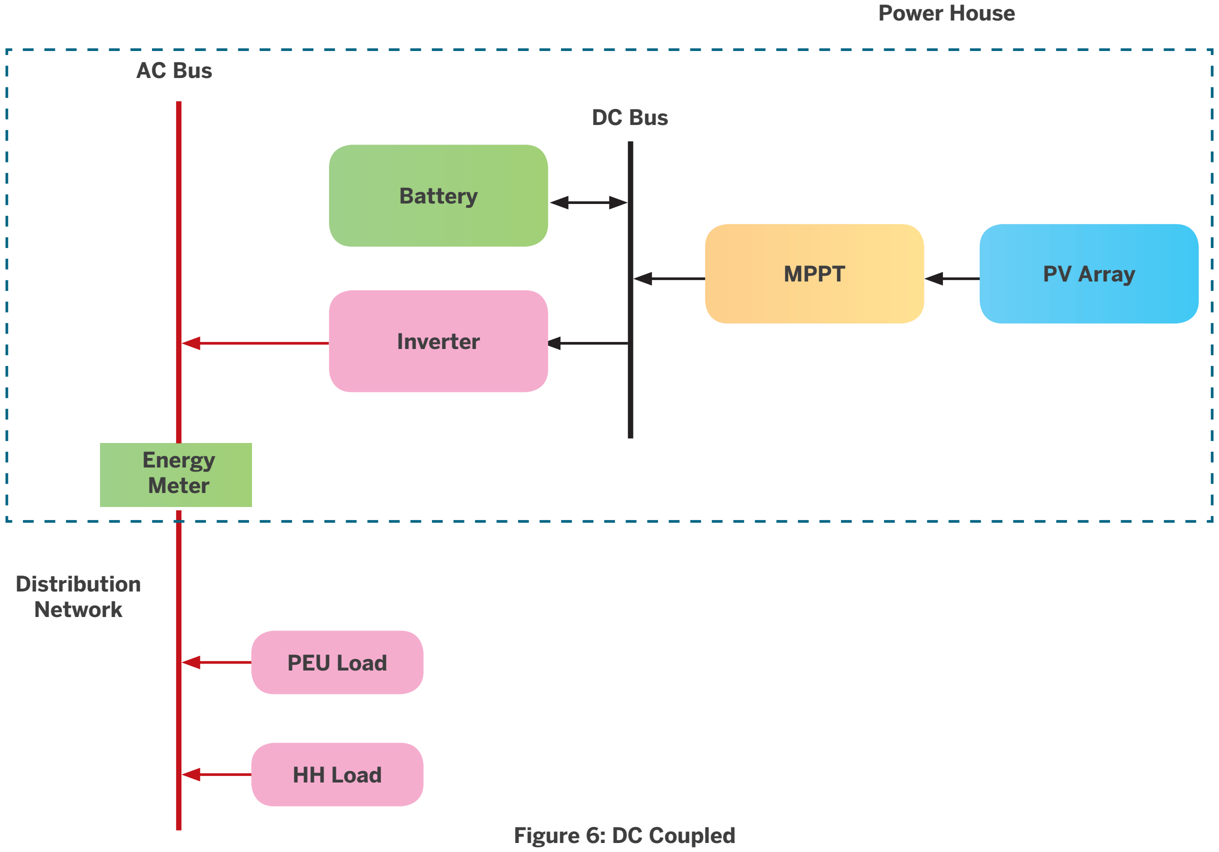

Figure 6: DC Coupled

The advantages and disadvantages of a DC coupled system are listed as below.

Advantages:

- Charge battery with relative high "PV to battery" efficiency:
  - *"PV to battery" efficiency = MPPT SCC efficiency = 95%*
- Supply nighttime load with relative high "PV to night-load" efficiency:
  - *"PV to night-load" efficiency = MPPT SCC efficiency (95%) x battery efficiency (80%) x battery inverter mean efficiency (87.5%)= 67%,*
- More compact in terms of physical space;
- Low system cost for relatively small off-grid PV systems.

Disadvantages:

- Supply day time load with relative low "PV to day-load" efficiency (assuming that load<PV production):
  - *"PV to day-load" efficiency = MPPT SCC efficiency (95%) x battery inverter mean efficiency (87.5%)= 83%*
- High system cost for relatively large off-grid systems, as multiple solar charge controllers (and potentially inverters) are required as well as the associated balance of system components (cable, combiner boxes, etc.).

5.2.3. DC and AC coupled system

A hybrid system configuration integrates additional generator(s) into the dc- or ac-coupled mini grid. This architecture is mainly beneficial where there are chances of full drainage of battery caused by faulty low voltage discharge protection of battery or improper O&M. This architecture overcomes the shortcomings of AC coupled systems.

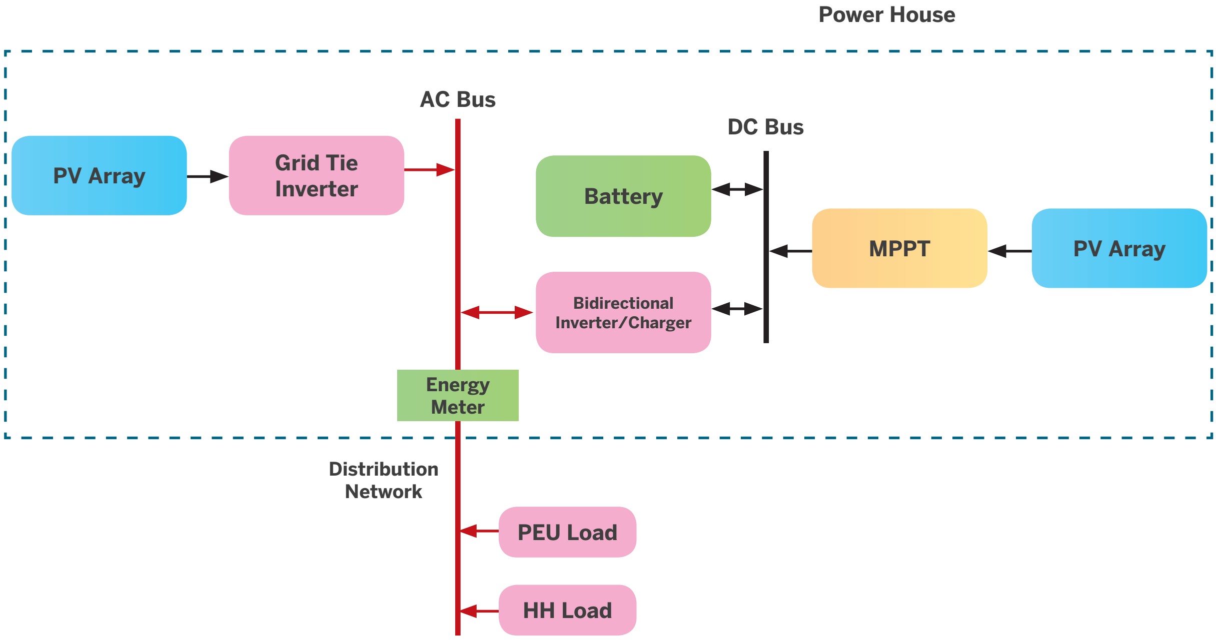

Figure 7: DC and AC Hybrid Coupled System

5.2.4. DC-AC coupled with distributed generation

This system shall be adopted where there is a long transmission line (say >5km) and availability of land at one place is not possible. In that case, the portion of PV array and grid tie inverter can be synchronized in the T&D line at the far end from the power house. The biggest advantage of this architecture is I2R loss minimization. Further, the quality and reliability of electricity is also enhanced.

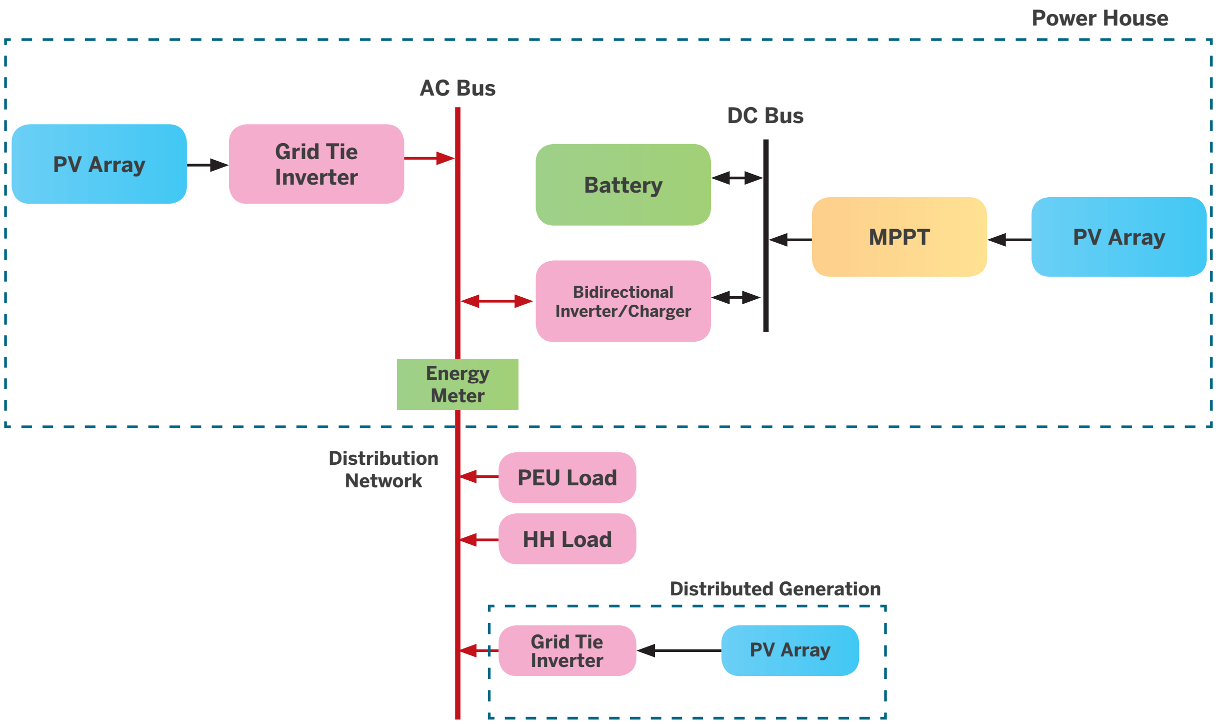

Figure 8: DC-AC coupled with distributed generation

5.3. MODELING AND SIMULATION

Accurately predicting PV system performance is one of the most important tasks in the design of a solar mini grid. Expected performance informs design decisions, serves as the basis of financial models, tariff determination, informs the bill of materials and can make or break a potential project.

It is very important to have consistent and reproducible energy performance estimates to satisfy investors and independent reviews. Even a couple percentage difference among predicted energy production results can have a significant impact on project financing and investor confidence. Generally speaking there are no rules or standards for using performance modeling tools even in the mature International solar markets. As a result, performance estimates from different design firms for the same project can show large discrepancies and variations.

The most important factors in PV system performance prediction are all to do with the meteorological conditions that are used by the simulation software, the weather dataset determines these values and are therefore the most significant factor in the design. Key factors but not limited to:

- Global Horizontal Irradiance (GHI)
- Plane-of-array Irradiance (POA)
- Incidence Angle (IAM)
- Soiling
- Temperature
- AC wiring
- Model Mismatch
- Light-Induced Degradation (LID)
- Inverter efficiency
- Near Shading
- DC wiring
- Power Tolerance
- Inverter clipping

5.4. METEOROLOGICAL MODELING DATA

Weather data selection is one of the most challenging aspects of the modeling process. In effect, we are using historical weather data to predict future performance of the solar mini grid system, another way of saying this is we are trying to predict at some level the weather and the future, both of which are of course extremely difficult.

All the designer can do in this case is use the best weather data possible, evaluating and selecting weather data based on criteria such as record duration, source and quality, representativeness and alignment with other sources is advantageous.

a) Record duration
Meteonorm 7.3 allows access to historical time series of irradiation and temperature data which accurately representing the average long-term climate for a given location requires many years' worth of weather data, the longer the better, up to 30 years.

b) Source and quality
Direct measurement data or ground based logged data taken from the site is optimal over modeled data based on records such as observed cloud coverage and satellite-derived irradiance, however direct measurement data will probably not be available and may not be complete. In this case, satellite data would be preferred.

c) Representativeness
You can also evaluate meteorological data based on how well the location where the station recorded data represents the project site, you might be able to find weather data for a site that is in a similar region that has similar site conditions. In this case, site elevation is very important as elevation has a considerable impact on PV performance.

d) Alignment with other sources
After locating sources of weather data, you should compare the annual and monthly values for GHI, DNI and ambient temperature across all files. This comparison should expose any mismatches in the available datasets.

In summary, typically you can achieve the lowest uncertainty in weather data by cross-checking multiple sources of data and then using short-duration ground measurements to improve the quality of a long-term satellite dataset.

5.5. SIMULATION SOFTWARE

Many software tools of various scopes are available either as free of cost tools or commercially licensed products. In the context of solar mini grid design the more appropriate software packages that are commonly used in the design of solar mini grid are included here.

a) PVSyst

http://www.pvsyst.com/
Comprehensive vendor neutral PV simulation with storage and hybrid simulation. Including bill of materials, performance simulation, financial simulation, cabling dimensioning and diagramming. PV*Syst focuses more on technical configuration and economic analysis and has been extremely popular in Europe and the USA for many large solar plants and mini grids in the past. PVSyst is a stand-alone tool.

Main Features of the PVSyst:

- Complete database of PV modules, grid connected inverters, meteorological data
- Useful 3D application to simulate near shadings
- Import of irradiation data from NASA, Meteonorm, PVGIS databases
- Import of PV modules and inverters data from PHOTON INTERNATIONAL Database
- Economic evaluation and payback
- Able to import Meteo Data from many different sources, as well as personal data
- Provide results in the form of full report, graphs and tables, as well as data export for use in other software

b) Helioscope

https://helioscope.folsomlabs.com/
Comprehensive vendor neutral PV simulation including bill of materials, performance simulation, financial simulation, cable dimensioning and diagramming. Does not include storage or hybrid simulation. It is a web-based tool.

Main Features of HelioScope:

- Import of irradiation data
- Import of PV modules and inverters data
- Useful 3D application for site plan and array layout design
- Single line diagrams, electrical layout
- Detailed presentation of the simulation results, including shading report and charts

c) PVGIS

PVGIS is a data platform hosted by the EU Joint Research Commission. PVGIS offers data on solar irradiation for Europe, Africa and Asia. Geographic information on monthly or daily global irradiation data can be presented on a Google-based map. A quick PV yield estimation can also be calculated, both on- and off-grid.

d) Homer Pro

http://www.homerenergy.com/HOMER_pro.html
Extremely comprehensive vendor neutral PV simulation with storage and hybrid simulation. Including bill of materials, performance simulation, financial simulation, and cable dimensioning. Homer focuses more on energy efficiency and economic analysis.

e) PV*sol

http://www.valentin-software.com/en/products/photovoltaics
Extremely comprehensive vendor neutral PV simulation with storage and hybrid simulation. Including bill of materials, performance simulation, financial simulation, cabling dimensioning and diagramming. PV*Sol focuses more on technical configuration and economic analysis. PV*sol includes the meteonorm database which contains data for Nepal. PV*SOL is also a stand-alone tool.

Main Features of PV*SOL Premium:

- Import of irradiation data from Meteonorm database
- Import of PV modules and inverters data
- Import of satellite maps to quickly and easily create buildings

- Shading analysis
- Detailed presentation of the simulation results, including charts and cash flow table

f) PVWatts

http://www.pvwatts.com
PVWatts is a free tool developed by the US government, it includes basic vendor neutral PV simulation including performance simulation and financial simulation. Does not include storage or hybrid simulation. PVWatts is primarily focused on basic energy production and financial analysis.

g) SketchUp

http://sketchup.com/en
Sketchup is a 3D modeling tool that is available in a free or commercially licensed version. Sketchup has excellent shade and sun path modelling capabilities by geolocation with google maps. It can be used for holistic site layout of PV arrays, cabling planning, shading analysis and provide comprehensive drawings for EPC's and stakeholders.

5.6. GENERATION SYSTEM DESIGN

5.6.1. Solar PV Module

While deciding on the PV module, following factors should be taken into considerations:

a) Sizing PV Array

The PV array size has to be chosen based on the daily energy demand of the community.

$$\text{PV Array Size (Watt-peak)} = \frac{\textit{Daily Energy Demand (Watt-Hour)}}{\textit{Total Loss Factor*Peak Sunshine Hour (Hour)}}$$

- Daily energy demand shall be obtained from the demand analysis.
- Total loss factor should be between 0.6 to 0.7
- Peak Sunshine Hour of a particular place will be equivalent to Global Horizontal Irradiation of a particular place. It should be between 4 to 6 kWhr/m² per day which is equivalent to 4 to 6 hours of PSH. In an average, PHS of 4 hrs can be considered.

b) Standard Test Conditions (STC)

The standard test condition refers to following condition

- Solar Irradiance of 1000 W/m²
- Solar cell surface temperature of 25°C and
- Air Mass of 1.5

STC refers to laboratory conditions. Usually, solar modules are rated at STC thus there is always a W_p (Watt-peak) unit used for solar modules capacity.

The Air Mass is the path length which light takes through the atmosphere normalized to the shortest possible path length (i.e. when the sun is directly overhead). Air mass quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust. Air Mass = $1/\cos\theta$, where θ is angle from the vertical (zenith angle), when the sun is directly overhead, the air mass is 1. Air Mass 1.5 refers to the 48.2° inclination of the sun from the vertical.

c) Nominal Operating Cell Temperature (NOCT)

NoCT refers to following condition
Irradiance 800W/m²
Solar Cell Surface temperature of 45°C
Ambient Temperature of 20°C
Wind speed of 1m/s,

NOCT refers to more idealized conditions as it takes ambient temperature rather cell temperature in the STC condition.

EXAMPLE:

A 327Wp solar panel at STC can deliver maximum of 243W at NOCT i.e. at NOCT, it delivers 74% of its maximum power at STC

d) PV Array Row Spacing

Consideration must be given so that one row of modules does not cast a shadow on the row behind. The PV modules will be on tilted frames facing true South to optimize energy production. Calculations need to be done to find the minimum distance between PV array rows to avoid winter mid-day shading. Basic trigonometry will provide the calculations needed. Here is trigonometry calculation;

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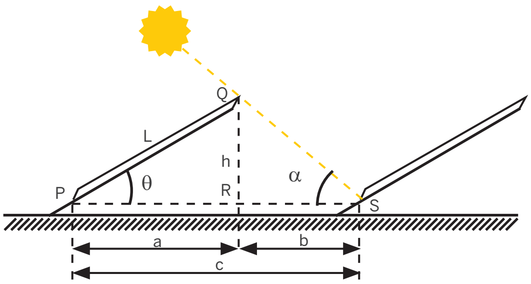


Figure 9: Row Spacing Calculation

Θ is tilt angle which is equal to latitude of the place
α is altitude or elevation angle which can be find from sun-path diagram
L is length of module
c is pitch

In triangle PQR, $h = L \times \sin\theta$ and $a = L \times \cos\theta$
In triangle QRS, $b = h / \tan\alpha = L \times \sin\theta / \tan\alpha$
$pitch = a+b = (L \times \cos\theta) + (L \times \sin\theta / \tan\alpha)$
for perfectly south facing
$pitch = a+b = (L \times \cos\theta) + [(L \times \sin\theta / \tan\alpha) \times \cos\beta]$ for azimuth angle of β

e) Environmental Considerations

To choose the right PV module for an installation, it is important to consider the following aspects of the installation site:

- Local temperature range, Minimum and Maximum temperature
- Temperature effect on the power output
- Suitability of the roof structure for the proposed installation
- If ground-mounted, the suitability of the ground type for the proposed installation
- Exposure to salt spray – this may impact on warranty of module
- Snow loading – this may affect the mounting structure suitability
- Temperature considerations

For a given installation in a hot climate, a thin film solar module might be selected because its output losses in high temperatures are less than for silicon modules.

Thin film solar technology has a lower operating efficiency compared to conventional mono-crystalline and polycrystalline silicon. This means that for the same installed capacity, the surface area required for thin film technology could be up to twice as much as other silicon technology.

As an Example, let us consider two systems operating with a cell temperature of 75°C.

Amorphous (thin film) system of 1kWp using Thin Film CIGS modules (power temperature coefficient of 0.31%/°C) has a temperature loss of 16%. Surface area required for this 1kWp array: ~ $9m^2$

Polycrystalline system of 1kWp using Crystalline Solar modules (power temperature coefficient 0.41%/°C) has a temperature loss of 22%. Surface area required for this 1kWp array: ~ $7m^2$

Nevertheless, while selecting PV modules the system designer needs to consider other important factors such as overall module efficiency, space requirement for PV array, power degradation, module power warranty, guarantee and expected life etc. The amorphous (Thin Film) array requires more space to accommodate the installation, more framing product and longer installation time than polycrystalline solar PV modules.

f) Available Land Area Considerations

In case of limited land area availability and the possibility of shading, high efficiency modules with larger capacity shall be considered to accommodate maximum capacity and generate maximum possible output from the limited space. Hence, selection of modules (type, dimensions, etc.) also depends on the available land area for installation.

g) Maximum System Voltage

The PV modules should be selected considering that the designed system will operate below the maximum system voltage of the module. Typically, modules are rated to a maximum system voltage of 600V DC or 1000V DC or 1500VDC.

h) Heavy Snow Considerations

For the project sites with high snow areas, the PV modules should be able to withstand the increased downwards pressure caused by the potential accumulated snow loads on the surface of the PV module.

i) Temperature dependency of Solar Cell

Solar cells are temperature dependent, higher the temperature lower the open circuit voltage and vice versa. Increase in temperature also increases short circuit current and versa. However the change in current is negligible compared to changes in voltage. Typical temperature curve is given below;

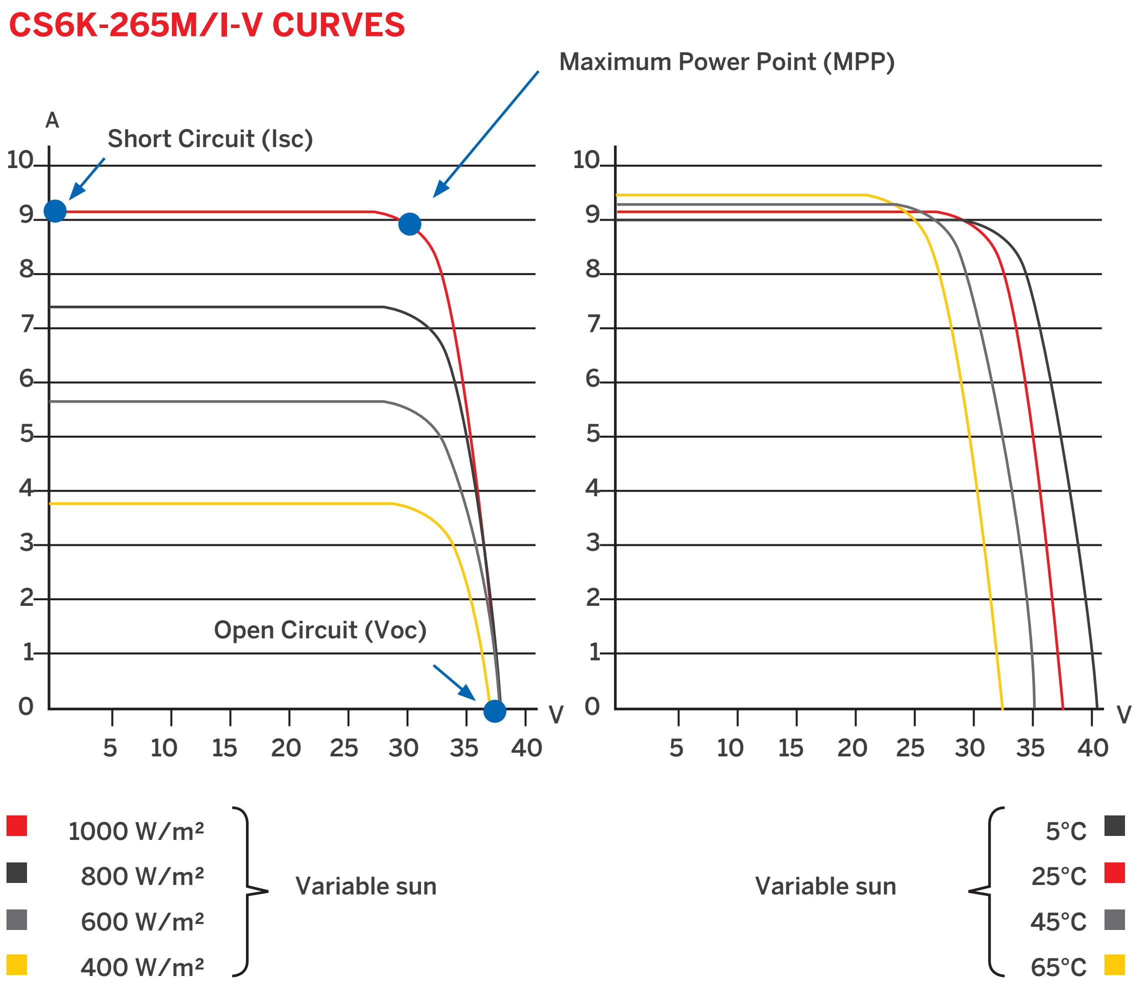


Figure 10: Temperature dependency of solar cell, Credit Canadian solar (source: Canadian solar)

j) Matching Array and PV Inverter Voltage

While designing a solar PV system, it is very important to match arrays based on PV inverter voltage. Mismatch may lead to lowering the energy yield of a system. For most of the 1500V DC input inverter, MPPT ranges fall in between 800-1300V. Minimum number of modules in series is based on

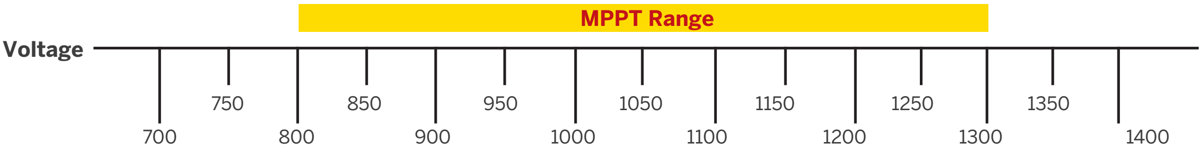


Figure 11: Array and PV Inverter Voltage Matching

the highest temperature of that place and vice-versa.

The voltage dependency can be found from formula listed below.

$V_{OC\ CELL\ EFF} = V_{OC\text{-}STC} + [\gamma V * (T_{CELL} - T_{STC})]$

Where,

$V_{OC\ CELL\ EFF} = V_{OC}$ at effective cell temperature, volts

$V_{OC\text{-}STC} = V_{OC}$ at STC, Volts

γV = Voc temperature coefficient, V/ ˚C

T_{CELL} = minimum expected cell temperature at specified temperature, in °C

An example below showing maximum number of modules in series

Annual minimum temperature at project site= 5°C
Temperature Coef V_{oc} of module = −0.35%/°C
V_{oc} of module= 44 V
Inverter Max input voltage = 1250V

Solution

Temp adjustment factor = -0.35% *(5-25)*44 = 3.08V **[formula used is 'γ_V * (T_{CELL} - T_{STC})']**
(Temp coef. is given in percentage thus have to multiply it by V_{oc})
$V_{oc\ cell\ eff}$ = 44+3.08 = 47.08 V
Maximum no. of modules in series = inverter max input voltage/ $V_{oc\ cell\ eff}$
= 1250/47.08 = 26.56
= 26
(always round down for maximum no. of modules)

An example below showing minimum number of modules in series

Annual maximum temperature of project site =55°C
Temperature Coef Vmp = −0.4%/°C
V_{mp} = 40 V
MPPT mini input voltage= 700V

Solution

Temp adjustment factor = -0.4% *(55-25)*40 = -4.08V **[formula used is 'γ_V * (T_{CELL} - T_{STC})']**
(Temp coef. is given in percentage thus have to multiply it by V_{mp})
$V_{mp\ cell\ eff}$ = 40+ (-4.08) = 35.92 V
Minimum no. of modules in series = MPPT mini input voltage/ $V_{mp\ cell\ eff}$
= 700/35.92 = 19.48
= 20
(always round up for minimum no. of modules)

5.6.2. Mounting System

Ground Mounted PV systems allow the construction, installation and commissioning to be carried out at ground level, and therefore to avoid working heights. Working at ground level without having to use ladders and lifts can serve time and expense for some installations. Ground mounted systems will also involve civil works, trenching and water management. These additional aspects involving location topography (soil composition and run-off etc) are not as commonly considered by installers familiar with rooftop systems and therefore may require advice from a civil and/or structural engineer. For the above reasons, not many small or medium-sized grid connected systems use ground mounted arrays, preferring to install roof mounted arrays.

Ground mounted systems are usually installed in rows of PV modules, and so the incident shading caused by one row of modules onto the row behind as the sun moves across the sky must be factored in when considering the layout. To avoid this as much as possible, and to work within a defined space, an installer must choose a distance between rows to keep shading losses to the minimum.

The ground mounted system might have to consider any maintenance requirements e.g. if installed on a grassed area, that any grass-cutting is shown as an ongoing maintenance cost and/or to suggest that the modules be installed a certain height off ground level to allow for vegetation growth between maintenance.

Example:

A 10,000 PV module system could comprise of:
100 single rows of 100 modules.
50 double rows of 100 modules long by 2 modules high.
25 quadruple rows of 100 modules long by 4 modules high.

These systems will all have the same area footprint if worked out with the same tilt angle and shading losses, but the increasing module array height increases the complexity and installed cost per module (as well as difficult to clean PV modules during operational phase). Based on the requirement that a given installed PV capacity fits within a finite physical area, if a ride-on lawn mower had to fit between the module rows, for the installation to take up as little as possible, a double row configuration might be the most economical option. Whereas if a utility truck is required to drive between rows, a quadruple row installation may be required.

If the cheapest single row installation option is chosen, there may only be enough room between each row for installers to carry modules to their installation point by hand or on a trolley. This could take longer, and hence cost more, than if wider rows allowed for a utility truck to hold and transport modules as they are installed.

Depending upon the local codes, a fence may be required to prevent unauthorized people from accessing the array and its surrounds, which can also be used for the system's security. As a ground mounted array is highly visible; it makes accessibility to thieves easier than a roof mounted system. Large scale systems may include security cameras, motion sensors and even security patrols, but these security expenses are unlikely to be justified for small scale systems.

Mounting systems carry general descriptions:

Fixed meaning that the PV array has a fixed orientation to the sun; or

Tracking meaning that the PV array is installed so that it moves either on a single or dual axis to optimize solar access.

- Rack mounts
- Pole Mounts
- Sun-Tracking mounts

a) Small Fixed Modular Systems

Fixed modular mounting systems might be a pre-engineered array frame designed to suit upto a 10kW of PV modules per frame. Larger installations may use multiples of these frames to mount large arrays, with the steel and aluminum structure fixed to a concrete foundation. Modules may be clamped or bolted to the frame, and some frames have a U-channel frame design which allows the modules to 'slide in' and allows for a faster installation to save on labour costs.

Where the soil is suitable and wind conditions low enough, earth screws may be suitable replacements for a concrete foundation. A front-end loader with an attachment could be used to install a small number of earth screws for a smaller installation, and this could be cheaper than hiring a pile-driver to sink anchors into the ground.

Figure 12: Small fixed modular system with four layers with concrete foundation (Source: Italy Grid System)

b) Fixed, Pile-Driven

For large ground mount installation, some companies have a faster installation method that uses a pile-driver to hammer a galvanized steel post, steel pipe, I-bar or concrete pier into the ground to which, a linear mounting system is attached, saving time and money over preparing a site with excavations and concrete foundations. With a pile drive system, a geotechnical engineer is required to survey the ground and check for soil compactness, soil type and rock or rubble size. Looser soils will require posts to be driven in deeper; for Example, upto 2.5 meter may be required. The site survey will also give engineer structural information about spacing required between posts.

Pile-driven installations do not need curing time to allow for concrete to set, and hence can save time in colder and wetter areas where concrete would take longer to cure.

Once the posts are driven into a suitable depth, a cross member is attached and rails are then secured to this, with modules then clamped onto the rails in the same way as roof mounted rail system. The linear installation method, with aluminum rails that are able to have a degree of curvature in their long spans, enables uneven ground to be used without expensive leveling using earth moving equipment.

With the cost of hiring a pile driver for installation and the geotechnical survey required, pile-driven mounting systems are not likely to be economical for systems smaller than around 100kWp.

If the geotechnical appraisal for a site shows that a pile driven system is not suitable or is too expensive, precast concrete 'blocks' or piers can be used as the individual mounting points for the ground mounted array framing. The logistics of bringing these blocks to site and distributing them would have to be assessed and priced as part of the installation proposal.

Figure 13: Pile driven pier system (Source: Conergy SAS)

c) **Tracking Systems**

Where system yields are important or space requirements limit the installation area, trackers can offer an increased output with a peak power lasting for a longer period of time each day.

Tracking systems usually have a higher equipment cost and require more maintenance than a fixed system, but these can be offset by a higher yield in the morning and afternoon than a traditional fixed system.

There are two main types of trackers; single axis trackers and dual axis trackers. A single axis tracker will move solar modules in one axis to follow the sun's path over the course of dawn to dusk (i.e. east to west), where as a dual-axis tracker will follow the sun's path dawn to dusk, and the seasonal movement of the sun from summer solstice to winter solstice (i.e. the modules are at a lower tilt angle in summer, and a higher tilt angle in winter).

d) **Single-Axis Trackers**

Single axis trackers have only one axis of movement, usually aligned with North and South. This allows the panels to arc from east to west, tracking the sun as it rises, travels across the sky, and sets. Single axis trackers cost less than dual axis trackers, and potentially offer more reliability and a longer life span as they have fewer moving parts. However, they have lower energy capture efficiency than their dual counterparts.

e) **Dual-Axis Trackers**

Dual Axis trackers have two axes of movements, aligned with North-South and with East-West, giving them a wide range of position options. As seasons change and the sun's path goes from low in the sky in winter to high in sky in summer, dual axis trackers can optimize the amount of solar energy captured.

Selecting a solar tracker depends upon system size, electric rates, land constraints, latitude and weather. The use of solar trackers increases electricity production by around a third, and some claim by as much as 40% in some regions, compared with modules at a fixed angle. Utility scale and large projects usually use horizontal single-axis solar trackers, while dual axis trackers are mostly used in smaller residential applications and locations with high government feed-in-tariffs. Vertical-axis trackers are suitable for high latitudes because of their fixed angle or adjustable angles. According to research conducted by Brac University in 2017 following is the difference in energy yield with respect to fixed axis found on dual and single axis trackers.

Yearly Total output Energy Difference with respect to fixed Axis	Percentage
Dual Axis	27.64%
Single Axis	23.28%

Figure 14: Solar tracking system in a field in La Calahorra, Granada, Spain (Source: Encyclopedia)

5.6.3. Solar Battery

One of the most significant components of the solar mini grid consists of battery storage systems that are frequently used to store electric energy harvested from solar PV systems for use during the absence of sunlight (such as at night and during cloudy conditions). Because of the significance of storage battery systems, it is important for design engineers to have a full understanding of the technology since this system component represents a considerable portion of the overall installation cost. More importantly, the designer must be mindful of the realities in handling, installation, and maintenance.

a) Determining battery size

The battery size can be determined based on following formula

$$\text{Battery Size (Watt-hour)} = \frac{\textit{Energy Required to Store (Watt-hour)*Days of Autonomy)}}{\textit{Charge-Discharge Efficiency*Depth of Discharge (DoD)}}$$

$$\text{Battery Size (Watt-hour)} = \frac{\textit{Energy Required to Store (Watt-hour)*Days of Autonomy)}}{\textit{Charge-Discharge Efficiency*Depth of Discharge (DoD)*DC system Voltage (Volt)}}$$

Energy required to store can be calculated for the night time uses of appliances as well as backup for day time high priority loads when there may not be clear sunny days. Productive End Uses load and public service loads usually run in the day time and will require minimum battery energy storage for unforeseen non-sunshine hours. Hence, designers can increase the battery size by 20-25% for day time load regulation based on demand assessment. The typical value of charge-discharge efficiency is 85%.

b) Depth of Discharge (DOD) (%)

The percentage of battery capacity that has been discharged is expressed as a percentage of maximum capacity. The depth of discharge for lead acid batteries shouldn't exceed 80 %, whereas lithium ion and flow batteries can go even up to 100%.

c) **Days of Autonomy**
The term days of autonomy means the number of days a battery bank can provide electricity supply without a recharged by the solar array. This guideline recommend a maximum of 2 days of autonomy for determining the battery capacity.

d) **Major Battery Types**
Solar mini grid backup lead acid batteries are divided into two categories based on what they are used for and how they are constructed. The major applications of batteries used for solar mini grids are deep-cycle discharge systems. The major manufactured processes include flooded or wet construction, gelled electrolyte, and absorbed glass mat (AGM) types.

Other battery types are becoming more mainstream, different types of lithium chemistry batteries and flow batteries. These types of batteries come in pre-packages units and careful consultation needs to be done with the battery vendor in order to have an effective battery management system (BMS).

Figure 15: Flooded Lead Acid Batteries (Sacred Sun)

Figure 16: Lithium Ion Phosphate Batteries, Credit Iron Edison.

Figure 17: Zinc Bromide Flow Battery, Credit Redflow

e) **Comparison of battery types used in solar mini grid**
Solar Mini Grid commissioned in Nepal has mainly used Valve Regulated Lead Acid Battery (VRLA) because of several advantages over other technologies. In the recent past, lithium-ion batteries are also getting popular due to the declining cost and ease of transportation to remote locations. Based on experiences and market availability, this guideline suggests the use of lead acid batteries, lithium ferrous phosphate and vanadium redox batteries. The comparison of these batteries is presented in Table 4 below.

TABLE 4: COMPARISON OF BATTERY TECHNOLOGIES (SOURCE: ELECTRICITY STORAGE VALUATION FRAMEWORK 2020 AND AEPC ANALYSIS)

Parameters	Battery Types		
Technical	Valve Regulated Lead Acid Battery (VRLA)	Lithium Ferrophosphate (LFP)	Vanadium Redox Battery (VRB)
Efficiency			
AC-to-AC (%)	81%	86%	72%
C-Rate (min)	C/10	C/4	C/8
C-Rate (max)	2C	2C	C/4
DOD (%)	80%	90%	100%
Max. Operating Temperature (°C)	0	65	50
Safety	High	High	High
Commercial			
Storage CAPEX ($/kWh)	226	466	268
Development & Construction (years)	0.25	0.5	1
Operating Cost ($/kWh)	3	8	11
Energy Density (Wh/L)	75	410	42.5
Power Density (W/L)	355	5050	2
Life (full equivalent cycles)	500	3500	10000
Maturity of Technology	Mature	Commercialization	Early Commercialization

f) Battery charge and discharge rate (C rate)

A C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. In the US battery capacity is typically specified as C20 however in Asia the capacity is given as C10. In Nepal it is typically C10 or C/10 however it could be different depending on where the batteries came from. For a battery with a capacity of 100 Amp-hrs, this equates to a discharge current of 10 Amps at C10 rate.

g) Battery Configuration

Batteries, like solar modules, need to be configured in strings and connected in series and parallel to establish the desired voltage and AH capacity. As a general rule of thumb, it is optimum to keep the whole battery bank design to the minimum number of cells, strings and minimum connections. In large battery banks over 500AH, it is recommended to always use industrial deep cycle 2v, 4v or 6 volt batteries.

Battery and Inverter manufactures will also have recommendations and limits which designers should pay strict attention to. For example, many inverter and battery manufacturers will recommend no more than a maximum of 3-5 strings. **This guideline recommends a maximum of 3 strings.**

It is always optimum to use less physical batteries, the installation site may prohibit the use of such large and heavy batteries, and for remote sites with difficult or limited access (helicopter) it might be necessary to use smaller batteries to ease logistics. For example if the requirement is 2000AH at 48V, it would be optimal to deploy a single string of twenty four 2v 2000AH industrial deep-cycle batteries instead of forty eight 2v 1000AH deep-cycle industrial batteries configured as 2 strings. If the requirement is for 6000AH at 48v, two strings of 3000AH batteries could be used rather than 3 strings of 2000AH or 4 strings of 1500AH.

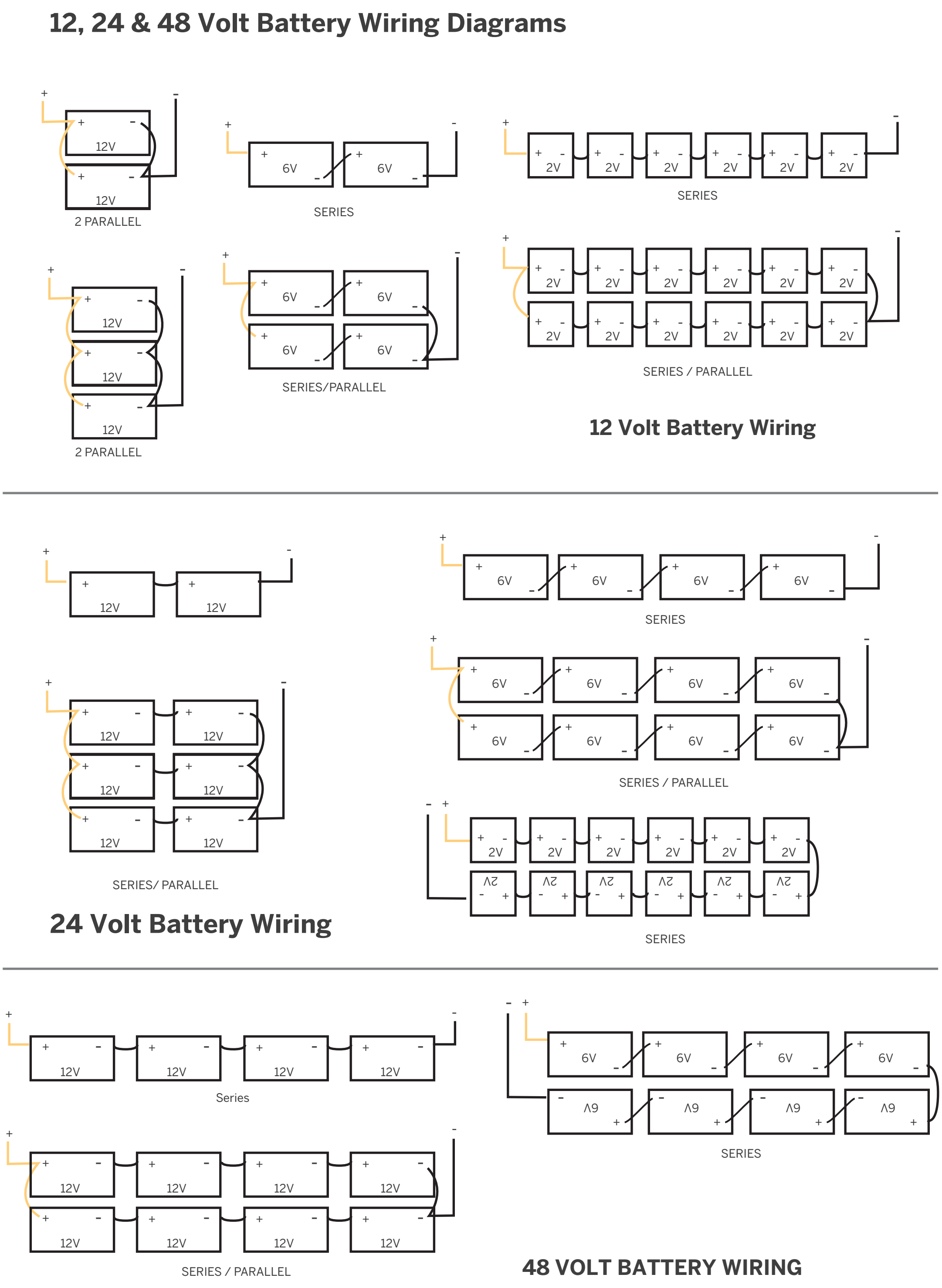


Figure 18: Battery Series-Parallel (credit Torjan Battery)

h) Storage Energy Management and Its Effect on Battery Life.

Different technology vendors approach the management of energy flows into and out of the batteries in many different ways, this is changing somewhat as we see newer battery technologies become available which include their own integrated battery management systems such as lithium or flow batteries. However it is necessary for the system designer to understand the different approaches and select the correct technology for the Mini grid application, especially when it comes to the traditional use of flooded, AGM and GEL batteries. Cycling is the determining factor in battery longevity, battery discharging and recharging is referred to as a cycle, battery manufacturers including cycling data with their battery product to allow designers to predict battery life based on how the mini grid system will cycle the batteries, this is actually determined by the mini grid architecture, technology vendor and system energy flows.

Traditional approach (DC coupled). In this type of system, all DC energy flows go in and out of the batteries. The AC loads are supplied via the battery charger/inverter. In this system topology, the batteries are typically discharged daily and recharged daily resulting in a complete cycle every day. Sometimes these systems might cycle a few times a day, which result in more cycles of the battery bank.

Managed approach (AC coupled). In this type of system, energy flows out of the battery when the AC coupled solar is not producing. When the AC coupled solar is online during the day, the system floats the battery bank to maintain the battery SOC, as the solar energy feed declines, the batteries begin to discharge again. This pattern repeats until the batteries are discharged to a programmed SOC level, once this level is reached, the system will again begin the recharge of the batteries to full capacity. In this way, the batteries are discharged to a low level over a programmable period and then recharged only when necessary. This approach has many advantages:

- Battery capacity in terms of usable energy over the life of the system is actually higher because the battery energy is being removed and utilized by the loads efficiently.
- Battery cycling is kept to minimum which increases the life of the batteries, increasing ROI.
- Battery charging is more efficient
- Overall energy management is smoother
- Maintenance and operations are reduced, less cycling means less charging which uses less water, less balancing issues, less energy wastage.

Another key feature of mini grid energy management is the tight integration of automatic generator set remote control for either peak power demand or battery charging applications.

Automatic generator control is essential for stability of the mini grid, tightly integrated generator control and energy management is a key feature of a properly designed mini grid. The energy management system must support automatic generator operation for two scenarios:

a. Automatic response to peak power demand, in this situation inverter must be able to fulfil the energy demand from internal surge capacity and storage for 15-30 minutes, in this time the system can automatically bring online generator support.
b. If battery SOC is critically low, the energy storage system can automatically call for generator support and connect the generator for charging batteries up to a pre-programmed safety level.

i) Battery Charging

Battery balancing and charging is of utmost concern to the system designer, it impacts the financial viability and operational capacity of the system and will cause critical system failure if not properly accounted for. It is the single most important factor in determining the long operational life of the battery bank/s.

Poor charging and management of batteries because of technology limitations or incorrect configuration will quickly ensure destruction of expensive batteries. Also poor battery management systems (BMS) will cause massive operational overheads due to balancing problems between batteries and battery strings. When we consider that large mini grid systems employ thousands of AH in battery storage and multiple strings, and these key issues become design imperatives.

Inverter and charging devices perform battery charging and management functions differently, some vendors offer superior technology and it is critical that the system designer choose the best technology for the application. The system designer should assess the overall battery management approach from the technology vendor carefully. Many of today's technology vendors are still using battery management technology designed and built in the late 80's and early 1990's. These technologies despite being marketed as superior technologies and features of their systems are actually insufficient to properly charge and manage a large mini grid system.

In mini grid applications, the battery charging and management must be as automatic as possible due to the sheer size and scale of the battery storage systems. The system must allow the installer to customize the battery charging and battery management setup to suit the battery application down to minute detail. Charging routines must be automatic and include scheduled automatic equalization (EQ) of the battery banks. Battery balancing and SOC management must be automatic using sophisticated algorithms based on system energy flows, battery charge levels, temperature, and battery bus resistance.

Battery balancing is a common requirement of flooded batteries as well as some particular AGM and GEL batteries. Balancing is performed by a controlled overcharging referred to as equalizing (EQ). Equalizing is actually a destructive process that shortens the battery life. However when used correctly, it can significantly improve battery performance and battery life. Equalization should be used in two situations, first is maintenance EQ and second in corrective EQ.

Maintenance EQ is the timely use of EQ charging to balance batteries that are starting to experience slight variations in specific gravity (SG) of the electrolyte between cells; this is a normal phenomenon that occurs when batteries are cycled overtime. This function must be performed by the BMS function of the system. Maintenance EQ can also be used to mix electrolyte or stir batteries after a cold period or during battery watering. In this case, the EQ charging would be initiated by the system operator manually for a short period of time, such as 1 hour. Therefore the system design should reflect the need to have automatic and manual EQ control.

Corrective EQ is employed when maintenance EQ has not been performed and the batteries have degraded to a state that causes system instability due to battery failure. Corrective EQ can be used to recover highly sulfated or stratified batteries before it is too late and they need to be replaced. However this situation should never occur due to automatic and correct maintenance EQ.

A suitable BMS and charging system will allow extensive customization and will include these features:

1. Battery inverter or inverter/charging will have power factor correcting (PFC) chargers. Charge controllers will use sophisticated MPPT algorithms.
2. All charging devices will tightly integrate with a single system manager for central and coordinated charging control, configuration and measurement across the technology platform.
3. The charging system will have prescribed approaches for integration of 3rd party chargers in the BMS, examples are DC coupled wind turbines.
4. Programmable values for bulk or boost charging, absorb or normal charging as prescribed by the battery manufacturer.
5. Customized values for equalizing charging as prescribed by the battery manufacturer.
6. Automatic SOC calculation based on highly sophisticated algorithms applied by the charging devices or battery inverters.
7. Programmable values for battery conductor length, conductor cross section and battery fuse or aggregator box resistance values.
8. Detailed prescriptive guidance on how to calculate the battery connection resistance and how to program the system.

9. Detailed system controller or management interface that provide clear access to all battery behaviors and functions.
10. Programmable and automatic deep discharge response with automatic load shedding in case of critical battery SOC.
11. Programmable and automatic generator set control via remote start and stop, with advanced generator control logic for either battery charging application or peak load demand response.

j) Battery Life Span

The life span of a battery will vary considerably depending on how it is used, how it is maintained and charged, the temperature, and other factors such as water quality used to refill cells. In extreme cases, it can be damaged within 10 to 12 months of use when overcharged. On the other hand, if the battery is maintained properly, the life span could be extended over 25 years. Another factor that can shorten the life expectancy by a significant amount is when the batteries are stored uncharged in a hot storage area. True Deep-cycle batteries are designed to be discharged down time after time and are designed with thicker plates. The major difference between a true deep-cycle battery and regular batteries is that the plates in a deep-cycle battery are made from solid lead plates and are not impregnated with lead oxide paste.

k) Battery Cabling

Battery cables provide the vital link between the battery, load and charging system. Faulty connections can lead to poor system performance, affect battery life, damage battery components and start fires. The majority of issues with battery cabling or battery connections comes from problems associated with the cable/connector or the battery terminal.

Battery system interconnects and cabling selection must consider:

- Careful conductor cross-section selection so that voltage drop shouldn't exceed 1%
- Minimum number of connections to reduce resistance.
- Properly insulated conductors.
- Quality connections, hydraulic crimped lugs with soldering.

Battery manufacturers will typically include pre-fabricated high quality bus bars or interconnect cables for joining cells together in the battery bank, it is preferable to always use these over and above anything else.

Battery cable should be sized to properly handle the expected load, cable ampacity is the ultimate safe current carrying capacity of the wire before damage occurs to the insulation. Undersized cables can lead to an unacceptable voltage drop and/or increased cable temperature. Refer to the table in the appendix for the suggested maximum ampacity for copper wire.

Many manufacturers highly recommend that connectors not only be mechanically crimped but also soldered to the cable's end. A properly crimped and soldered connector will provide a low resistance connection and reduce the amount of heat buildup at the connecting junction.

Battery manufacture will provide torque values for tightening interconnects to the battery terminals to ensure proper connection without risk of over tightening and damaging battery terminals. Installers should "finger tight" bolts and then employ torque wrench with prescribed setting to finish off.

l) Battery Electrolyte

A critical concern in the Nepalese context is the preparation of battery electrolyte. Batteries are typically shipped dry from factories outside of Nepal, the electrolyte is prepared locally and the batteries are filled, this is commonly known as "first filling". Batteries require very exact electrolyte mixtures and quality ingredients, this has a direct impact on the performance and life of the battery.

The electrolyte for lead-acid accumulators is diluted sulfuric acid with density values related to type of construction of the accumulator or as specified by the battery manufacturer. Diluted sulfuric acid is used as filling acid for unfilled dry charged cells or batteries with purified water used for the preparation of diluted sulfuric acid and for refilling of cells or batteries.

The purity of refilling water has to meet higher requirements than for filling electrolyte, because the impurities of the operating electrolyte will be increased by regular refilling of water. Electrolyte and water, not according to the manufactures requirements result in damage to the battery.

The electrolyte for lead-acid accumulators is diluted sulfuric acid (H2SO4) with density values as specified by the battery manufacturer. Diluted sulfuric acid is prepared by mixing concentrated sulfuric acid or sulfuric acid with high density of d > 1.30 kg/l and purified water. Sulfuric acid in concentrated form is colorless, high etching liquid with a density d= 1.84 kg/l.

Filling electrolyte. Diluted sulfuric acid used for first filling of accumulators or for replacement of electrolyte in the case of contamination of the operating electrolyte is called filling electrolyte. Filling electrolyte is best obtained from the factory with the batteries, if this is not possible then a suitable local technician should prepare the filling electrolyte adhering strictly to the battery manufacturer's instruction. Test certifications should be issued demonstrating the correct mixture of the electrolyte, only then should the acid consignment be accepted and used to fill the batteries.

Water use for topping up and preparation of electrolyte. The water should meet the physical requirements as shown in the table below and the chemical requirements as given in Table 2, in most cases the battery manufacturer would provide this information, this is provided here as a reference. Purified water in compliance with the requirements can be prepared from tap water by distillation or by ion exchange.

TABLE 5: CORRECTION OF DENSITY FROM MEASURING TEMPERATURE TO NOMINAL TEMPERATURE

specific gravity (kg/l)	correction factor* (kg/l per K)
1.10	0.00050
1.15	0.00060
1.20	0.00070
1.30	0.00050

*** The correction factor refers to the temperature range from 0°C to 55°C**

When the sulfuric acid is mixed with the water the mixture can be calibrated by measuring the density, this is known as specific gravity. The battery manufacturer will provide the necessary values for first filling, and this should be strictly adhered to and test certifications from calibrated equipment should demonstrate this. Specific gravity is relational to the ambient temperature of the conditions, therefore it is necessary to apply a correction factor to the specific gravity measurements according to the temperature at the time of filling. This is given here as reference.

Water and refilling water. Water (H2O) is an ingredient of the electrolyte for accumulators. Purified water is used for the preparation of electrolyte for accumulators and for refilling of water loss caused by overcharging and evaporation in the operating electrolyte.

TABLE 6: PHYSICAL REQUIREMENTS OF PURIFIED WATER FOR ELECTROLYTE

Appearance	
pH value	5 -7
Electric conductivity at 20°c	< 10 μS/cm

5.6.4 Maximum Power Point Tracking (MPPT)

An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes energy output from solar arrays. MPPT keeps tracking maximum power point from the STC (Standard Test Conditions) rating under almost all situations. MPPT controller is usually used in AC coupled systems.

MPPT Size(Watt)=Array Size (Watt)

MPPT is mostly inbuilt in the PV inverter. The PV array side voltage can go upto 250V whereas the output side voltage depends upon the DC input voltage (12V or 24V or 48V) of PV inverter.

5.6.5. Solar Charge Controller

A solar charge controller is usually used in DC coupling systems, also sometimes refered to as MPPT charge controller. It also gathers energy from solar arrays, and stores it in batteries. Along with the MPPT function, all the battery protection systems are in-built features of the Solar Charge Controller.

Usually, the voltage at PV array side and Battery connection side are the same. The Solar Charge Controller can be rated in Watt or Ampere.

$$\text{Solar Charge Controller (Watt)} = \frac{\textit{PV array capacity (Watt-peak)}}{F_{SM} * F_{CTD}}$$

Where,
F_{SM} = Safety margin factor
F_{CTD} = Charge controller temperature derating factor

$$\text{Solar Charge Controller (Ampere)} = \frac{\textit{PV array capacity (Watt-peak)}}{\textit{DC system voltage (volt)}}$$

In smaller DC coupled systems, solar charge controllers are mostly available without MPPT function. This kind of small scale solar charge controller comes with pulse width modulation (PWM) for battery protection functions.

5.6.6. Battery Inverter

a) Sizing

Battery inverters can be sized based on the peak load of the system. It can be further optimized by only assuming peak load to be supplied through battery energy.

$$\text{Battery Inverter Size (Volt-Ampere)} = \frac{\textit{System Peak Load (Watt)}}{\textit{Battery Inv.Efficiency*Power Factor}}$$

Battery Inverter efficiency ranges between 0.85 to 0.95

Power factor can be taken as 0.8 (lag)

b) Battery Inverter Configuration

When designing any multi-inverter systems such as stacked, multi-cluster and multi-phase system, the designer must be careful to understand the manufacturer's requirements for connection of the battery storage

For example, a single inverter system from any manufacturer will have the inverter connected to a type of fuse box which connects to all of the battery strings in the system. A stacked or 3 phase system will have all the inverters connecting to the fuse box and all of the battery strings, the inverters all sharing the fuse box and the battery strings.

In a multi-cluster system, each cluster must have its own fuse box and battery string. For example, if you have a 2000AH storage requirement and 2 inverter clusters, you would have 1000AH connected to one cluster and 1000AH connected to another cluster. The battery strings should be identical in terms of battery type, capacity, and cabling cross section, cabling length and connection types and battery fuse boxes.

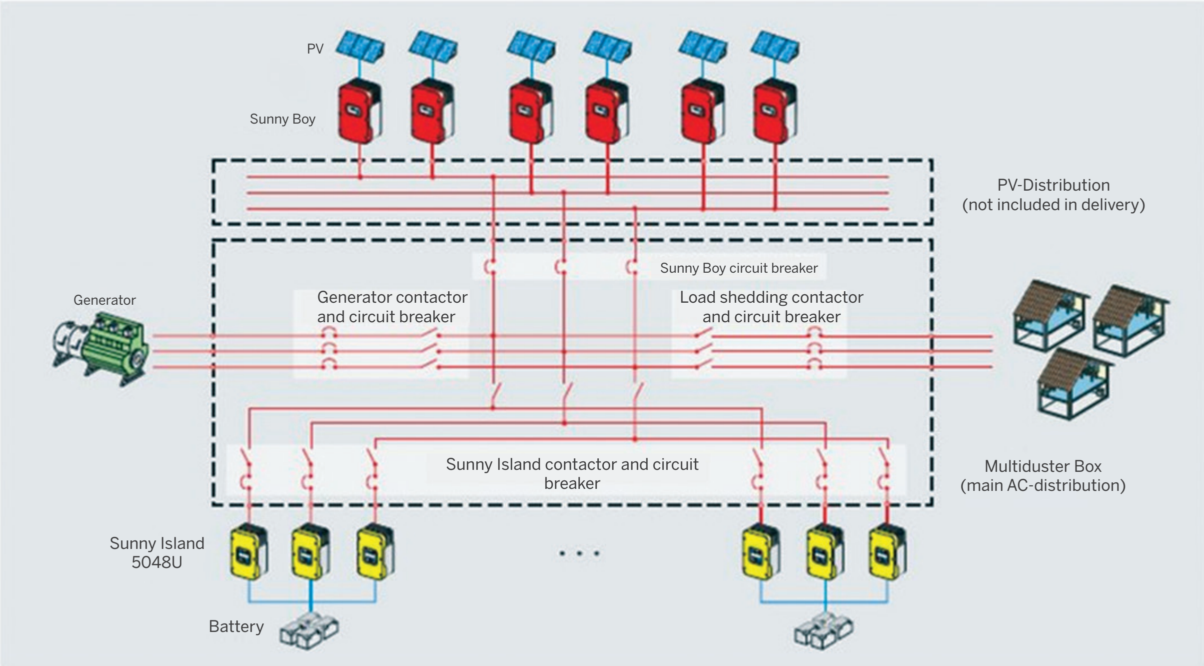


Figure 19: Battery and Battery Inverter Connection in an AC coupled system (credit SMA)

5.6.7. PV Inverter

a) Sizing

$$\text{PV Inverter Size (Watt)} = \frac{\textit{Array Capacity (Watt-peak)}}{P_{DC} \text{ to } P_{AC} \text{ ratio}}$$

P_{dc} to P_{ac} ratio can be taken from 1.2 to 1.4 because theoretical peak power of the modules is often not achieved in reality. Higher the ratio, better the advantage of inverter clipping.

b) Optimizing Array-to-Inverter Power Ratio

Solar arrays to PV inverters have been designed with much higher dc-to-ac ratios, up to and exceeding 1.4. The energy yield can be optimized with inverter clipping. The ratio 1 or less will make inverter size higher than the PV Array and inverters are typically less efficient at low power levels. In cold, sunny weather, the dc system is capable of generating more power than both the inverters and the ac system designed to handle. In this case the inverter restricts dc power output by simply moving the array off its maximum power point. Inverter power limiting results in a clipped, flat-topped power curve rather than the traditional bell curve, a phenomenon often referred to as clipping. What results is the inverter spends more time at maximum production output early and later in the day, the net result is a more predictable overall energy output.

In the morning and post afternoon, the solar irradiance is relatively lower resulting in lower power level which. If the DC to AC ratio is higher, the inverter can operate in higher loading conditions owing to higher efficiency. For lower DC to AC ratio, the DC power level would be lower resulting in lower efficiency due to lower loading of inverter. Consequently, there are some losses during the afternoon due to higher power generation and insufficiency of inverter size. Therefore, the total gain in the morning and post afternoon is higher than the loss in the afternoon. A typical inverter clipping is shown in figure below.

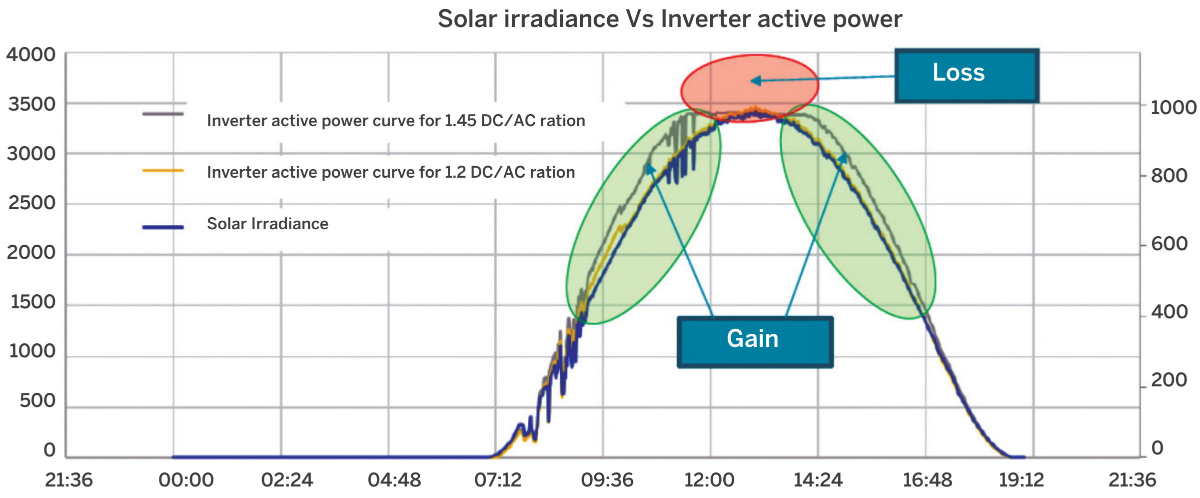


Figure 20: PV Inverter clipping effect

c) Types of PV inverter: Distributed Inverters vs. Centralized Inverters.

Internationally designers have been opting for distributed string inverter designs as opposed to large central inverter designs. Choosing between these two solar inverter designs comes down to a number of factors, but the primary considerations for most developers are total cost and energy production. Centralized designs are most common for larger commercial and utility-scale projects because of first-cost efficiencies and increasing requirements for utility interactive controls more widely available in central inverters. For small and medium size commercial projects involving carports, rooftops and multiple-angled applications, distributed architectures are generally preferred due to the ability of string inverters to optimize energy production in PV systems with variable array design parameters.

Distributed designs typically suit solar mini grids due to scale and variable array design parameters, however there are many other benefits inherent in the distributed approach:

- Optimized inverter-to-array ratio;
- Decreased dc BOS costs;
- Reduced space and infrastructure requirements;
- Maximizing uptime;
- Easy replacement;
- Improved redundancy and uptime;
- Design flexibility.

d) 1000V or 1500V DC PV circuits

There are many advantages in using 1000V or 1500 DC in higher string voltage designs over 600V DC or smaller DC voltages used in traditional DC coupled charge controller applications.

- Smaller diameter conductors due to higher voltage and lower current;
- Longer runs with less voltage drop;
- Reduced and simpler PV source circuits and DC source circuits;
- Greater predictability with cabling and voltage drop;
- Lower BOS costs;
- Higher reliability due to simpler configurations.

All equipment specified in the PV system design should be rated for 1000VDC irrespective of the nominal voltage of the PV system.

e) Inverter Cooling Concept and Environmental Conditions

Inverters de-rate when the internal temperature rises above a certain threshold, these thresholds will be documented in the equipment datasheet, resulting in lower energy output as well as possible increased wear on the internal electronic components. It is important to understand the cooling concept and design application of the inverter for the chosen installation environment.

For example some distributed string inverters are designed to be installed on roof top arrays, right next to the modules at no more than 15 degrees. These inverters have a different internal design which allows longer service life in the harsher outdoor environment, the warranty allows for this type of installation so it is a very acceptable design. However it is essential to understand the operating temperatures of the inverters and the impact it will have on the power output.

Typically it is optimum to locate inverters in a shady position with good airflow but there may be strong drivers for other options. Designers should consult the inverter documentation to understand the necessary clearance's required for good airflow and to understand the derating factor.

5.6.8. Protection System

Ensure sufficient protection system in accordance with the requirements to prevent or limit damage to its generation and auxiliary equipment. The different protection system are described in detail below;

a) Sizing the Battery Fuse

Based on largest current that could be drawn:

- If Inverter, obtain inverter manufacturers data
    - Continuous power rating (Watts)
    - 3 to 10 second surge rating (Watts)
    - Average inverter efficiency
- For each power rating determine the current drawn from the battery bank using I = Inverter Power Rating (W). (Inverter efficiency x nominal battery voltage)
- Consult HRC fuse curves

b) Location of Battery Fuses

Battery fusing preferably should not be in the same enclosure as the battery bank but if they are then they should be either a minimum of 500mm away from the batteries or 100mm below the top of the batteries.

Another method to keep the fuse separate from the battery bank is to place a vertical partition between the batteries and the fuse, thereby keeping the fuse as close to the batteries as possible but isolated from any hydrogen build up.

c) PV Array DC Isolator/Disconnect

- A load break PV array DC isolator (switch) shall be mounted near the inverter.
- In some countries this isolator is typically a double pole DC rated circuit breaker.

NOTE: A breaker not rated for the open circuit DC voltage of the array and the DC short circuit current of the array shall not be used as the PV Array Isolator.

- If the double pole DC circuit breaker is polarized then the installer shall ensure that it is wired correctly. Failure to wire correctly could lead to a fire when this isolator is operated in full sun.
- Where an inverter allows more than one input from the array an isolator shall be installed on each input.

d) AC Isolator/Disconnect at Inverter

- Where the inverter is not adjacent to the electrical panel to which it is connected, an isolator shall be provided at the inverter so that a person operating the switch has a clear view of any person working on the inverter.

e) Maximum series fuse ratings

- As per solar PV module manufacturer listed on datasheet and rear of module.
- Fuses must be fitted in both positive and negative string cables for all strings
- These fuses or DC circuit breakers (non-polarized) shall have the following current rating:
    - 1.25 x Isc of module < Fuse Rating < 2.0 x Isc of module
- If the array consists of sub-arrays then each sub array shall be protected by a fuse or circuit breaker (non-polarized) with the following rating:
    - 1.25 x Isc of sub-array < Fuse Rating < 2.0 x Isc of sub-array

f) Solar Supply Disconnect in AC Panel

- It is recommended that the interconnection of the grid connected PV system and the building's electrical system is undertaken at an electrical panel or distribution board.
- This connection shall be at an AC solar supply isolator located on the electrical panel (or distribution board) where the solar system is connected.

- This will be referred to as the main switch inverter supply.
- This isolator shall be lockable.
- A switch or isolator being lockable does not mean it needs a padlock or similar attached. It means that it is able to have a tag or small plastic locking device inserted to allow a person to work on the system safely. The intention is that the isolator locking device should include the installation of a tag/sign saying "DO NOT SWITCH ON-PERSON WORKING ON SYSTEM" or similar.
- The cable between the electrical panel and inverter requires protection so it is recommended that the isolator is a suitably rated circuit breaker.

g) Ground Fault

Ground fault monitoring and protection can be implemented in a variety of ways either as additional BOS components built into DC combiners or as automatic functions of the inverters. The current range of technologies are current sense monitors, which measure current flow through the ground bond of dc-grounded systems; isolation monitors, which measure array resistance to earth in temporarily or permanently ungrounded PV systems; and residual current detectors, which measure differential current between the positive and negative conductors. Designers should consult with the inverter manufacturer to facilitate adequate ground fault monitoring and protection.

h) Arc Flash

In large mini grid or commercial PV systems, hundreds or thousands of PV modules are connected in series and parallel. The combined dc output power potential at aggregation points, including combiner boxes, recombiner boxes or inverter-input combiner compartments is massive. In addition, dc voltages may approach 1,000 V and current levels may exceed 1 kA. While a system is energized, failures or human error during commissioning, testing and troubleshooting can cause arc-flash events that severely injure or even kill technicians and destroy critical equipment.

Arc flash events need to be dealt with in terms of operational procedures such as appropriate working clearances, safety equipment and clothing for technicians. However in terms of design inputs it is essential that the system designer calculate incident energy and specify correct HRC for the equipment.

i) DC Fuses or DC Circuit Breakers

All fuses that are used as overcurrent devices that provide a point of connection between PV arrays, collector boxes and batteries must be DC-rated. Circuit breakers must have a suitable AIC rating for the application, many multi-purpose AC/DC MCB's have an AIC rating that is too low for solar PV systems, it is generally better to use dedicated DC rating OCPD's which have higher AIC ratings.

5.6.9. Earthing and Lightning Protection

Earthing is a means of connecting the exposed conductive parts or neutral current conducting line or any equipment that can develop voltage potential in case of fault occurrence or lightning discharge, to the main earthing terminal as a way of discharging current to the earth or providing a way back to the source.

In system earthing, the neutral point of the current-carrying conductor is connected to the ground so that any imbalanced current in the neutral is disposed of to the earth and thus returned to the source.

In equipment earthing, the exposed non-current conducting parts which can develop potential in presence of current are connected to the earth. Such earthing is done to prevent shocks when there is insulation failure in the equipment and live wire touches to the equipment.

In the mini grid system or in any electrical system, both system earthing and equipment earthing are as important as the system itself. A proper earthing system protects equipment from fault currents as well as the person working in the vicinity. In addition to the system earthing and equipment earthing, earthing of a lightning protection should also be done which is known as Lightning protection system (LPS). LPS captures nearby, potential lightning strikes and discharges the high current and transient voltage to the earth.

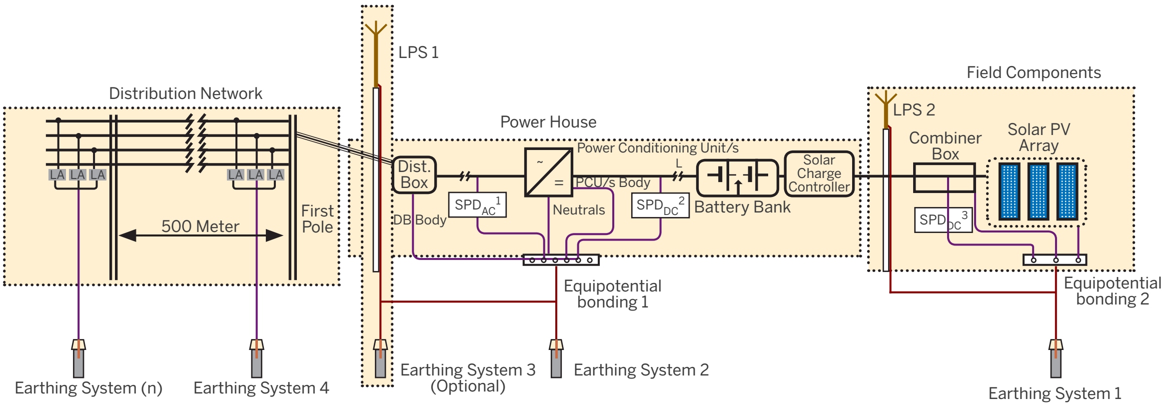


Figure 21: Earthing and Lighting Protection System of Mini Grid Systems

a) Lightning Protection

In geographic locations such as hill areas, where lightning is a common occurrence, the entire mini grid system and outdoor-mounted equipment must be protected with appropriate lightning-arrester devices and grounding systems. This will provide a practical mitigation and a measure of protection from equipment damage and burnout.

The LPS will safely divert the lightning discharge (high voltage and current) to the earth without affecting the critical equipment. An LPS consists of a lightning arrester to capture the nearby lightning, a down conductor to conduct current to the earth and an earthing system to discharge the current to the earth.

b) Surge protection measures

In addition to lightning discharge, the equipment also needs to be protected from transient overvoltage. In order to protect equipment from lightning and transient overvoltage surge protectors and arrestors are deployed.

The main function of a surge arrestor is to provide a direct conduction path for lightning charges to divert them from the exposed equipment chassis to the ground. A good surge arrestor, also called lightning arrestor, must be able to conduct a sufficient current charge from the stricken location and lower the surge voltage to a safe level quickly enough to prevent insulation breakdown or damage.

Surge protector, also known as Surge Protection Device (SPD), protects the equipment and circuits from transient overvoltage. An SPD is connected across the device or equipment to be protected as close as is practical. It is available for both AC and DC systems. There are 3 types of SPDs available (Type I, Type II and Type III) based on the 3 types of current wave. For applications in the mini grid system, it is highly recommended to use Type I+II SPD.

In the solar mini grid, to protect the AC system, SPDs may be fitted at the main incoming point of AC supply (at the consumer's cut-out) and to protect the DC system, surge suppression devices can be fitted at the inverter end of the DC cabling and at the array side. All DC cables should be installed to provide as short runs as possible. For cables longer than 10 meters, additional SPDs are required.

c) Equipotential bonding

Equipotential bonding is a measure applied to parts of the electrical installation to have a same potential under fault conditions. By applying this measure risk of electric shock is limited as there will be little or no difference in voltages (potential difference) between the parts that may otherwise become live.

Designer must have to consider following important point while designing lighting and protection system;

- If cable length between battery and inverter or between any equipment inside the power house is more than 10m, it has to use Surge Protection Devices (SPD) at both ends of the cable.

- All the DC and AC SPD should be type 2 (8/20 μs waveform) class
- Lighting arrester should be atleast class 2 (LPS 2) protection level and installed at minimum of 10m height to cover maximum area of power house and its surroundings. If coverage of assets is not sufficient, use another lighting arrestor.
- Use additional earthing systems if the earth resistance is too high in rock and dry areas.
- The separation of the earthing system should be atleast 10m.
- There should be exothermic bonding between copper trip (from lighting arrestor to earthing rod) and copper rod of earhing system.
- Lighting arrester for the distribution line should be of 0.5kV for 400/230V and 9kV for 11kV.
- The separation distance for the lighting arrester in distribution line should be 500m for 400/230V line and 1000m for 11kV lines.

5.6.10. Monitoring and Control

The traditional power sector has been using SCADA systems since the late 1980s, long before high-speed Internet connectivity became ubiquitous, and they provide active plant control and endless extensibility at a significant cost. Nowadays, web-based monitoring systems are relatively common from inverter manufactures and 3rd parties, they generally focus more on data acquisition than on plant control and operation, however various levels of control and operation are becoming more widespread.

Monitoring, control and operations are all critical activities in successful and sustainable mini grid options. The ability to measure energy productions, detect faults and control load are necessary factors in the economic viability of the power system. The key stakeholders will drive the requirements, but it is the role of the designer to translate this into a technology platform and manage the execution. Gathering this information during the planning stage of the project is crucial as monitoring, control and operations are design inputs that have strong dependencies to the equipment manufacturers, mini grid architecture etc.

Essential monitored data from the management system as a minimum should include:

- Weather-monitoring data:
  - Temperature;
  - Wind velocity and direction;
  - Solar irradiance;
  - Solar power output (DC voltage and DC current);
- PV Inverter:
  - Voltage and frequency;
  - Power output;
  - MPPT status;
  - Device status, temperature, error conditions;
- Battery Inverter:
  - Device status, temperature, error conditions;
  - Battery SOC;
  - Battery voltage and current;
  - Battery Temperature;
- Total system performance and malfunction.
- DC power production, accumulated daily, monthly, and annually.
- AC power production, accumulated daily, monthly, and annually.
- Alert triggers for remote signaling (display, email, sms).
  - Informational, Warnings and Error filtering;
  - Device failure or offline;
  - PV yield deviation
  - Battery SOC conditions;

The addition of a monitoring system inserts another layer of electrical equipment to the design, including power supply circuits, communication circuits, meters and IT equipment that must be located, sized and considered in advance to be fully incorporated into the PV plan set. The pre design process for determining the monitoring system should be considered just as important as sizing the correct inverter or choosing a racking system.

a) Design Considerations of Monitoring System

The monitoring and control design will be driven by the size and operational requirements of the project and the stakeholders. It is important to understand who will manage the system and what level of data granularity they will require. Utility connected solar and mini grid systems that sell or transfer power to the utility grid will normally have control requirements mandated by the utility; this could mean a SCADA system. For simpler stand-alone systems, a web-based monitoring platform is good for individual projects of smaller capacity or that do not have strict control mandates, web based is also a strong option for sites with distributed generation because of the ease and cost of linking sites via inexpensive Ethernet network or internet.

Typically web-based systems are available from the inverter vendor as an integrated component in their overall product offering. These monitoring systems will likely meet or exceed typical mini grid management requirements, but may lack control capabilities. Control capabilities could be added by integrating a 3rd party product or alternatively integrating a SCADA system. However SCADA might be cost prohibitive for smaller systems.

5.6.11. Powerhouse

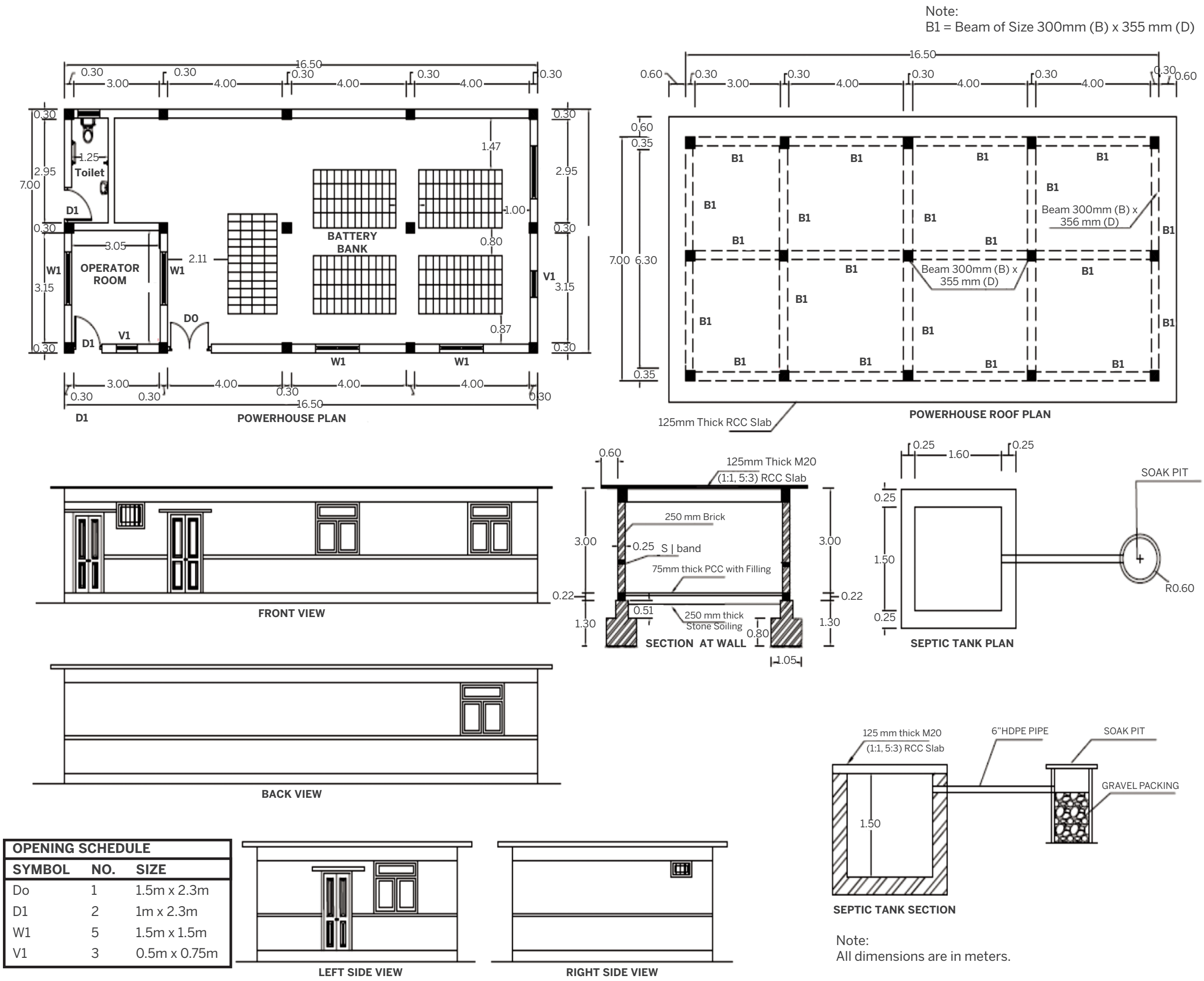
The powerhouse supports and houses the battery, solar charge controller, inverter, control and protection system and their accessories. The powerhouse design and layout should satisfy good performance of the equipment, economic construction and easy inspection and maintenance. The design and construction of the powerhouse should be made on the basis of data provided by the equipment manufacturer. There should be adequate space to place solar equipment (except solar array and T&D line accessories). The battery racks should be constructed and maintained in a level position and secured to the floor (seismic shock proof) and must have a minimum of 1 meter of walking space between racks for egress and maintenance. While dimensioning the power house, a segment for the operator room has to be considered. The structural design can be carried after the general layout and dimensions have been defined.

In solar mini grid projects, single floor type of powerhouse is recommended due to easiness in operation and maintenance. Layout of a project should consist of battery or battery racks, inverter, control panels, main distribution box, monitoring system, other safety equipment like fire fighting extinguishers, and service bay.

Requirements for Powerhouse Design is outlined below:

- Location of the powerhouse should be safe from flood, minimum voltage drop in the T&D line, availability of land for solar PV installation and powerhouse. The preferred location is village center.
- Powerhouses must also be easily accessible at all times to ensure proper operation.
- Geological condition of powerhouse site should be satisfactory
- The wall should be brick or stone masonry with load bearing or RCC frame structure and roof could be either RCC or CGI sheet depending upon site condition, availability of local resources like sand aggregate etc and ease of transportation material.
- The powerhouse building must follow the Nepal National Building Code prepared by the Department of Urban Development and Building Construction (DUDBC), Ministry of Urban Development.
- Adequate window and ventilation to exhaust battery fumes
- Properly bonded in the system earthing for lightning safety for personal and equipment.

Construction of toilets should be decided based upon community suggestions taken during focused group discussion while conducting site surveys. A typical layout of powerhouse is shown below;



OPENING SCHEDULE		
SYMBOL	NO.	SIZE
Do	1	1.5m x 2.3m
D1	2	1m x 2.3m
W1	5	1.5m x 1.5m
V1	3	0.5m x 0.75m

Figure 22: Typical powerhouse plan

5.6.12. Fencing

A fence is required to prevent unauthorized people from accessing the array, powerhouse and its surrounds, which can also be used for the system's security. As a ground mounted array is highly visible; it makes accessibility to thieves easier. A metallic entrance door and lock shall be included in the fencing premises.

The set-back (free space between fence and front of PV array) should be provided in the east, south and west side of the fence to avoid the shading in the solar array due to the fencing structure. Usually, the set-back length is equal to the height of the fence. Generally, two types of fencing can be used in solar mini grid; barbed wire fencing and chain mesh link.

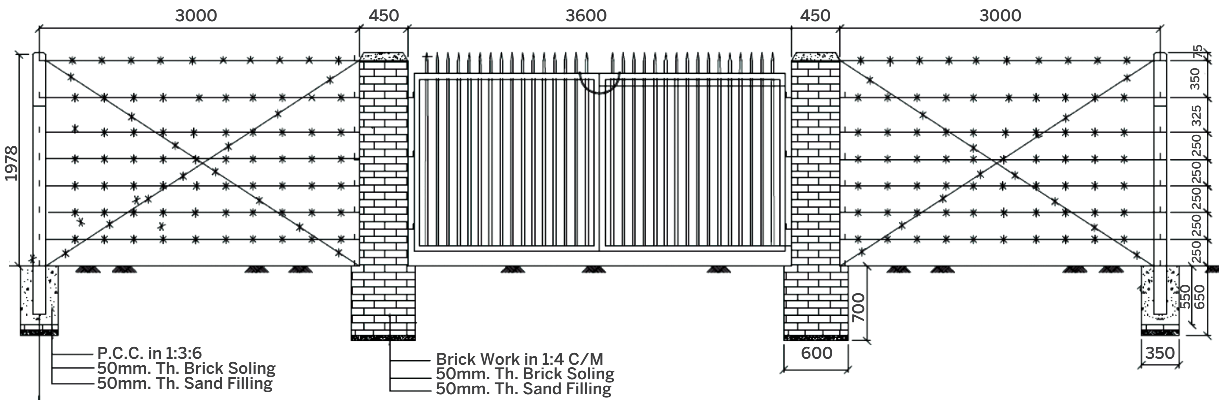


Figure 23: Fence and entrance gate

a) Barbed Fencing

Barbed wire fencing is a type of steel fencing wire constructed with sharp edges or points arranged in intervals along the strands. The fencing should have a minimum of five rows and two diagonal barbed wires. The diagonals of barbed wire shall be continuous & stretched between adjacent posts from the top horizontal row of barbed wire of one post to the bottom horizontal row of the second post. For fixing diagonals of barbed wire, separate nails of hook shall be provided in the posts.

Figure 24: Barbed Fencing

b) Chain link mesh

A chain-link fence is a type of woven fence usually made from galvanized steel wire. The wires run vertically and are bent into a zig-zag pattern so that each "zig" hooks with the wire immediately on one side and each "zag" with the wire immediately on the other. The chain link mesh size must be at least 2" x 2" of 10 guage. Chain link mesh is preferred in solar mini grid applications.

Figure 25: Chain link mesh fencing

5.7. WIND GENERATOR CONFIGURATION FOR HYBRID SYSTEM

5.7.1. Role of Wind Energy

Wind generator integration with the solar mini grid depends upon the variability of the wind resource and its obvious effect on the power delivery. In a situation where the wind generator/s output can carry most of the sites proposed base load, the solar component of the Mini grid is used to provide supplementary power in times when the wind energy falters and the storage component is used to provide a buffer between wind and solar as well as enabling several days' autonomy.

In a situation where the wind resource is not suitable to carry the base load due to intermittency, the wind resources will be there as a supplementary producer, the solar PV must be designed to carry the loads with the storage performing a similar role as mentioned previously. Understanding the role of the wind energy in the overall system design will largely be driven by the wind resource and estimated energy output.

5.7.2. Site Identification and Preparation for Pre-feasibility

Wind energy potential site identification is the 'first step' while planning for the promotion of wind power projects. Installation of Wind Meteorological Tower for the site specific ground based data collection thereby monitoring of wind data for at least one complete year is the 'second step' before putting large investment into the wind power project. AEPC has been continuously putting efforts so far long to identify sites and erect wind met mast systems for ground based data logging. The 'third step' will be estimation of daily, monthly and annual energy yield with the various possible sizes of market available wind turbines and relate to the financial viability during its feasibility study phase.

In order to analyze viability of wind or solar/ wind hybrid projects promotion, AEPC has been supporting the implementation of wind met masts of 10 meters, 20 meters and 30 meters high wind masts in the past. In addition to AEPC's continuous engagement through Nepal Government's own resources, AEPC has been engaged with multilateral development partners such as the World Bank and Asian Development Bank in developing Wind Atlas and wind energy feasibility study for the utility scale wind farm development in Nepal. Through both the external development partners AEPC implemented 10 numbers of each 80 meter high met tower systems and 5 numbers of each 40 - 60 meter high met towers, in various potential sites.

Ground based wind data collection experience of AEPC shows that the wind velocity and environmental factors are site specific and most of the identified potential sites of Nepal are observed to be wind speed varying between day-to-night as well as season-to-season of a year. The high variations of wind speed of most of the sites indicate risk of unstable power production through intermittent wind resources, which is unlike the wind energy generation in the other coastal countries. Therefore, rather than wind power plants alone, wind turbines along with solar PV or other generation sources seems to be viable to some of the wind potential sites of Nepal.

5.7.3. Design Considerations for Wind

Wind energy systems are complimentary with solar PV generators when the location has good wind energy resources. In this scenario a wind turbine or multiple turbines should be considered as another energy generation source for the mini grid. Conducting a site assessment for a wind power system is time consuming and requires good planning and capital investment. This is a situation where the maximum effort spent in "design time" will pay enormous dividends when the system is producing electricity. It will directly affect the reliability, stability and user acceptance of the overall solution to the community. Wind power systems are tricky to get right, poor planning will lead to an ineffective, costly and underperforming wind generator.

If quality wind data is available for the site, half of the problem is solved, however it is still highly recommended to get exact location specific measurements from your own equipment to do the best design possible. If no data is available, or the quality of the data you have is questionable it is absolutely necessary to acquire your own location specific data, overall a proper site assessment for wind entails four key steps:

- Make an initial site shortlist by identifying areas which are candidates for wind energy potentials.
- Choose location on the site for a tower, or multiple towers.
- Install anemometer data logger device/s to measure and capture history of wind patterns in the area.
- Review, correct and make an analysis of the wind data.

Talking to your preferred wind turbine manufacturer is an excellent way of getting a jump on this process. They will have design and simulation tools for sizing and understanding how the wind turbine will potentially perform. It is a good idea to talk to these experts about what metrics they need and want for their design tools. This will include things like average wind speeds, site altitude, wind speed probability, wind shear factor, tower height, anemometer height etc. The wind turbine will also have minimum speeds, sometimes called start-up speed as well as maximum speeds. These values need to be understood so that early analysis of the anemometer data demonstrates that the site is suitable. It will also help you to select a suitable anemometer for your requirements.

The overall objective is to collect a full 12 months of accurate site specific data. The data logger should be capable of recording metrics from the sensor every 1 minute, everyday day for 1 complete year. The data logger should also ship with software for sorting and analyzing the data. This will illuminate daily, monthly and seasonal variations in wind energy and will provide the best possible information for determining the wind energy potential and subsequent electrical energy production of the proposed system.

In case AEPC promoted small wind energy or solar/wind hybrid systems, the annual averaged wind power density should be more than 35W/m² at turbine hub height.

5.7.4. Information and Resources

The International renewable energy agency (IRENA) has prepared a comprehensive planning guide for the systematic measurement and collection of wind data. This document is an extraordinary resource for wind system designers and details every aspect of the planning, implementation and data collection activities. It is highly recommended that this document be downloaded and used to plan any wind measurement campaign. The guide can be downloaded from the IRENA website named WIND RESOURCE MEASUREMENT: GUIDELINES FOR ISLANDS (© IRENA 2015).

5.7.5. Analysis of the wind data

In the early days, the anemometer data should be collected regularly and analyzed to see if the site is producing worthwhile wind energy within the range that you need for your wind turbine. At this early stage you will be looking out for issues such as, overall poor wind energy metrics, wind energy out of range for the wind turbine, or problems with the anemometer or data logging.

If poor wind energy measurements are being recorded it is possible the tower is poorly sighted or the location itself is not suitable. It is often the case that a site that seemingly has good wind energy suffers from turbulent wind which lowers the actual usable wind energy. In this case, alternative tower locations should be tried.

Any issues with the anemometers should be rectified as soon as possible, smooth consistent data coming in from the anemometers is the goal and will provide the best possible information in which to make decisions with. Do not rely on these devices to operate on their own for months at a time. They may not be recording the data, if you are new to the anemometer you are using it is best to become familiar with their idiosyncrasies and operational behavior.

Talking to the wind turbine manufacturer as you go will provide you with some confidence regarding what wind metrics are going to work well with their particular product. They will be able to indicate what speeds in m/s are desirable and based on the emerging patterns from your data they will provide guidance and advice. Your objective is to collect 12 months of granular data and eventually provide this to the turbine manufacturer for simulation and design.

The ultimate goal is to realistically understand the relationship of seasonal wind energy and how this will equate to electrical output from the wind system. The wind system will be a complementary electrical generator, therefore proper design of the wind system is critical in the overall reliability and stability of any wind-solar-hybrid energy system.

5.7.6. Wind Generator Architectures and Integration Considerations

Wind generators are available in multiple capacities, configurations and electrical topologies (single phase, 3 phase, AC or DC). Selection of topology will be driven by the role of the wind turbine and the preferred technology vendor.

AC coupled Wind turbines can be easier to integrate into the mini grid, supplying direct AC power to loads, however it is essential that the wind system be controlled by the mini grid battery inverters, for example through phase shift power control mode. Wind turbines on the AC bus typically act in the same way as solar PV inverters do, therefore the requirements for control and integration are identical to that of a PV inverter. Collaboration between the wind technology vendor and the inverter vendor should be pursued with diligence to understand how the integration will work in reality.

DC coupled wind turbines require some additional planning, typically DC coupled turbines connect directly to the storage via a dedicated battery charger. In this case, the wind turbine charges the batteries directly whilst the energy management of the mini grid is performed by the battery inverters. Most inverter manufacturers will require some type of interface between the wind turbine charger and the batteries, typically this will be in the form of a current sensor and shunt combination to provide measurements of battery energy flows external to the inverters BMS. These “external” energy flows are calculated with the internal energy flows to understand the overall energy mix, and this is how the SOC is calculated. Battery inverters utilize the SOC to make critical decisions such as protection modes, load shedding and automatic generator control, so it is extremely important the SOC is accurately calculated.

5.7.7. Wind Turbine Sizing

The annual wind energy data shall be used for estimating energy yield (in kilowatt-hours per year) from the selected wind turbines. For the particular wind turbine, the wind turbine manufacturer may also help to estimate the energy production referring to the wind resource data of the particular site. The factors used to estimate wind turbine size are:

- Wind Turbine Power Curve
- Average annual wind speed of the site to related with the energy yield
- Height of the selected tower under plan (also the manufacturers recommendation)
- Frequency distribution of the wind (an estimate of the number of hours that the wind will blow at each speed during an average year)

5.7.8. Wind generator control considerations

Generally wind turbine generators include integrated control systems. These control systems should provide a means of preventing overvoltage and over speed of the wind turbine generator in high wind or no load operation.

Poor quality turbines and turbines with exaggerated performance claims are readily available in many markets, particularly from Chinese manufacturers. Turbines should be robust and operate to the specified power curve that is well documented and tested by multiple sources. For example, the midnight solar classic charge controller is pre-programmed with several power curves of well-known turbines, these turbine manufacturers have published the power curves and other independent equipment vendors have tested and validated these power curves in their commercial offerings, this gives the designer confidence that the power curves and integration of the product is mature and reliable.

The theoretical maximum power of a turbine at a given wind speed is 59% of the available power of the wind over the area of the blades. Care should be taken to ensure that the power and voltage input limits of the wind turbine inverter are not exceeded, especially under no load conditions. For example when the inverter is disconnected from the mini grid due to a grid failure. Overvoltage input into the inverter can cause damage and may void the warranty.

A dump load may be required to dissipate excess energy in the case of disconnection from the grid or to shed excess power if the batteries are full. Some wind turbine generators include this functionality in the turbine controller. Generally a tightly integrated system is the best way to ensure excellent performance and longevity of the wind turbine system.

5.7.9. Site Shortlisting

Finding and choosing the right site for a wind energy system is critical. Environmental factors will often point out high wind areas, for example trees that are bent over and forced to grow a particular way, or areas of vegetation which are stunted because of high wind or cold wind. Wind corridors will often impact vegetation in this way and can be a good indicator of wind energy potential.

Another approach is to discuss with the human inhabitants of the area, they will often understand and be familiar with the weather patterns of that place and they can provide valuable insight into locations that could have potential for wind energy. A third alternative is to study wind maps of the area if they exist. A wind map will give you wind speeds and wind density metrics for a particular region averaged down to a general area, but maps generally will not give you location specific data.

A site that is worth investigating has either a continual blow that varies in intensity daily and seasonally or it will have a daily recurring blow at a particular time, for example every day at around 12 noon till 8pm evening. The best candidates are the sites that have a continual blow. The 2nd best candidates are the sites that have a reoccurring blow that happen at predictable times. Other types of sites will generally be very poor in wind energy and are not worth investigating.

The best type of wind energy is continuous linear wind that is not disturbed by terrain features such as what is found out at sea. A large moving mass of energy translates into smooth consistent electrical output from the wind turbine, better efficiency and improved longevity.

Dynamic wind or turbulent wind such as what is experienced during a storm or wind that is stirred up by hills, buildings and vegetation contains less energy as well as making the wind turbine work harder. The net result is less power and more wear and tear on the turbine.

5.7.10. Tower sighting and configuration

Tower sighting is critical to find, assess and harvest the maximum energy potential. Mistakes made at this investigation stage can be rectified and will be less costly than changing the wind turbine later, it is highly recommended to do as much planning and investigation now to identify the best location possible.

If you have some idea of the size of the wind turbine you will use, check with the manufacturer for recommended minimum and maximum installation heights, all wind turbines have different rotor diameters that have min. and max. Heights, you should be putting the anemometer in this range or within the min. and max. Height range of all the turbines you are considering. The tower must be engineered to support these devices at these heights and must have a suitable foundation for the specific environment.

Introductory rule 1, the wind turbine should be a minimum of 10 meters above the nearest object, that means if there are trees at 15 meters height, the turbine should be at 15 meters + 10 meters = 25 meter height, therefore the tower must be able to secure the wind turbine at this height.

Introductory rule 2, the wind turbine should be a minimum of 250 meters clear of protruding masses that means the turbine should be in clear open air and away from hills, buildings, vegetation etc. which disrupt the linear flow of wind energy and cause turbulent wind conditions.

As with the wind turbine, the anemometer should follow the same design considerations.

a) Anemometer

The anemometer manufacturer will have guidance for how to install and site the device. However as a rule of thumb you should locate the anemometer with the same considerations as explained previously.

If possible, it is best to install more than a single anemometer on the tower at different heights to capture the different wind measurements at these different heights, this will translate into different energy outputs.

Some anemometers have multiple sensors that can be installed at varying heights which communicate back to a central data logger. If this is not possible, install a single anemometer/data logger at 10, 20, 30, 40, 50 meters as an example. By doing this you can compare the energy potential of the different heights and make a cost benefit assessment of the increased tower height vs. additional energy production.

5.8. TRANSMISSION AND DISTRIBUTION LINE DESIGN

5.8.1. Design of T&D line Components

1. Transmission lines can either be buried or suspended overhead on poles. Overhead lines are more common as they are less expensive and easier to install. Overhead lines are also easy to repair and maintain. Neutral lines should be placed on top of overhead low-tension lines preferably in lightning prone areas. When the settlements are densely populated or heavy snowfall is expected during winters, underground transmission lines may be preferred. Underground systems require less maintenance, however the cost of maintenance is much higher compared to overhead lines.
2. The design of transmission and distribution lines should be such that voltage drop at any distribution line end is limited to 10% of nominal value (11 kV or 33 kV line-5%, distribution transformer plus LT line -5%.)
3. The maximum transmission line-to-line voltage level permitted in an isolated system is 11 kV. Distribution Transformers sizes should be carefully determined (keeping in mind diversity factor into account and in a way that under no condition shall the power plant be overloaded). Oversizing the transformer on the basis of future load growth in clusters makes sense only if the plant size is such as to cater future load growth.This is to be noted that there are only few standard sizes of transformers available in the market and one has to sometime choose next higher rating just because exact size transformer is not available. For service connection, following voltage system should be used:
   i) Low Tension supply
      -230 V, single phase for loads upto 30 A
      -400/230 V, three phase for loads more than 30A
   ii) High Tension supply
      11 kV and 33 kV three phase systems for load more than 100 kVA
4. ACSR conductors are generally used for overhead transmission lines.

Standard Conductor sizes to be used in 33 kV line is 100 sq. mm ACSR(DOG)and conductor size to be used in 11 kV line is 100 sq mm(DOG) or 50 sq. mm ACSR(RABBIT). Aerial bundled cables (ABC) may also be used for overhead lines if poles are expensive. ACSR conductors are available in various sizes and designations. Their properties are presented in the Table below.

This guideline suggests to use Weasel or higher cross-section area ACSR conductors though there is a permissible voltage drop limit of lower cross-section area conductors.

TABLE 7: SIZES AND DESIGNATIONS OF ACSR CONDUCTORS USED IN MINI GRID SCHEMES

Name	Current rating in still air(A)	Resistance (Ω/km)	Inductive reactance at 50 Hz ad 50 cm spacing (Ω/km)	Approximate weight (Kg/km)
Squirrel	76	1.374	0.355	85
Gopher	85	1.098	0.349	106
Weasel	95	0.9116	0.345	128
Rabbit	135	0.5449	0.335	214
Otter	185	0.3434	0.328	339
Dog	205	0.2745	0.315	394

5. Armoured cables should be used for underground systems. PVC-insulated armoured cables may also be used but should be limited to short distribution lines, service lines, overhead distribution box (DB) connections and around the powerhouse. The provision of cable in the mini grid scheme is highly discouraged unless there is possibility of ice loading in the transmission/distribution line, safety is a critical measure and aesthetics is essential in tourism. The comparison between cable and overhead line is given in the table below.

The specifications of armoured and unarmoured cable are presented in annex E.

TABLE 8: COMPARISON BETWEEN OVERHEAD LINE AND CABLE

Property	Overhead Line	Cable
Ease of installation	Simple	Difficult
T&D over long distances	Good	Poor
Use indoors and highly populated areas	Difficult	Very good
Visual impact	High	None
Reliability	Good	Very good
Complexity of repair	Good	Very good
Cost of material	Low	Very high
Cost of installation	Low	Very high

6. The clearances of overhead conductors with ground, trees and other structures should maintained in accordance with the values presented in tables below

TABLE 9: MINIMUM GROUND CLEARANCES

S.N.	Voltage Level	Across Road (m)	Along Road (m)	Other places(m)
1.	above 230/400 V and below 11 kV	5.8	5.5	4.6
2.	11 kV to 33 kV	6.1	5.8	5.2

TABLE 10: MINIMUM CLEARANCES BETWEEN LIVE WIRES AND STRUCTURES OR TREES.

S.N.	Voltage Level	Minimum Clearance (m)
1.	230/400 to 11 kV	1.25
2.	above 11 kV and upto 33 kV	2

Note: Maximum deflection of wire due to wind pressure should be considered while fixing the minimum clearances.

7. The minimum sag for cables up to 11 kV can be calculated by:

$$d = (L/172.8)^2$$

where, d= sag in m

L= length of span in m

TABLE 11: SAG FOR SPANS OF OVERHEAD CABLES

Span (m)	20	30	40	50	60	80
Minimum sag (mm)	13	30	54	84	121	210

The value of sag should be included when determining the ground clearance of a transmission line.

8. Transmission poles should be made of reinforced concrete, or galvanized steel. All poles carrying 11 kV and 33 kV circuits shall be 11 meters high. Pre-stressed reinforced concrete poles are economical for the plain terrain. Steel telescopic poles are used at difficult hilly terrain. In the case of wooden poles, only treated poles should be used. The basic span shall be maintained within the following limits:

   33 kV line: 50m to 55 m

   11 kV line: 50m to 55 m

   Suitable dimensions for the wooden poles which can be used for three-phase transmission are given in the following table.

TABLE 12: POLE SPECIFICATIONS

IS Designation	410 SP-52	410 SP-43	410 SP-13
Recommended voltage	11kV	400V	230
Overall Length	11m	10m	8m
Planting depth	1.8m	1.6m	1.5m
Section Length, m			
Top section (h1)	2.7m	2.4m	1.75m
Middle section (h2)	2.7m	2.4m	1.75m
Bottom section (h3)	5.6m	5.2m	4.50m
Outside Diameter, mm			
Outside diameter, Top (h1)	114.3mm	114.3mm	88.9mm
Outside diameter, Middle (h2)	139.7mm	139.7mm	114.3mm
Outside diameter, Bottom (h3)	165.1mm	165.1mm	139.7mm
Thickness, mm			
Thickness, Top (h1)	3.65mm	3.65mm	3.25mm
Thickness, Middle (h2)	4.5mm	4.5mm	3.65mm
Thickness, Bottom (h3)	4.5mm	4.5mm	4.5mm
Approximate weight	175Kg	160Kg	101Kg
Base Plate	300mm x 300mm x 6mm	300mm x 300mm x 6mm	300mm x 300mm x 6mm
Cripling load, kgf	307Kg	348Kg	301Kg
Application of load from top of pole, m	0.6	0.6	0.3

9. Shackle insulators of appropriate voltage should be used in overall lines with voltages up to 1000 V. Stay insulators shall be provided on all stays sets along overhead lines of more than 1000 V. Insulator dimensions and appropriate conductors are listed in the table below.

TABLE 13: INSULATOR SPECIFICATIONS

S.N.	Size	Dimensions	Weight	Corresponding conductor
1	Small	55 mm × 55 mm	200 gm	Squirrel, service wire
2	Medium	75 mm × 90 mm	600 gm	Gopher, weasel and rabbit
3	Large	100 mm × 110 mm	1300 gm	Dog

10. Pin, Disc, Strain are used for high-voltage transmission.

11. The operating voltage and span determine the minimum spacing of the conductors. Generally conductor spacing on the poles should be at least 300 mm in case of up to 400 V, 400 mm in case of 1000 V and 600 mm in case of 11 kV lines. For aluminium conductors in horizontal or triangular alignment, spacing is given by the formula:
Spacing= $\sqrt{d+(V/150)}$
where, Spacing is in meters
V= voltage in kV
d = sag in meters
In general, 70% should be added as a safety factor on the value calculated above.

TABLE 14: MINIMUM ELECTRICAL CLEARANCE BETWEEN CONDUCTORS

S.N.	Voltage Level	Minimum Clearance between Phase to Phase (mm)
1	230/400	290
2	11 kV	670

12. A stay set should be provided at the first pole, at all poles set at an angle and at line ends. For safety and protection from storms, every fifth pole is generally stayed on both sides even if the poles are in a straight line.
13. Distribution lines and branches with more than 100 households or 10 kW should have a back-up breaker in a distribution box in order to be able to identify faults.
14. For easy maintenance and fault finding, the distribution system should be divided into different areas separated by switches and fuses.
15. Drop-out fuses and gang-operated switches of suitable ratings shall be provided at high voltage points.
16. Distribution transformers should be oil-immersed, natural-cooled single and/or three-phase, suitable for outdoors installation on 11 kV and 33 kV, 50 Hz distribution systems. The design of transformers should conform to the latest edition of the appropriate IEC specifications and/or other recognised international standards.

TABLE 15: FEATURES FOR DISTRIBUTION TRANSFORMERS

Type	Three-phase, 11/0.4 kV	Single-phase, 11/0.23 kV
Rated capacity		
Rated system voltage - Primary - Secondary	11 kV 400/230 V	11 kV 230 V
Highest system voltage - Primary - Secondary	12 kV 440 V	12 kV 250 V
Rated Frequency	50 Hz	50 Hz
Connection - Primary - Secondary	Delta Gnd. Wye	NA
Cooling System	ONAN	ONAN
Vector group	Dyn 11	NA
BIL for windings and bushings for primary side	75 kV	75 kV
Withstand voltage, 50 Hz, 60S - Primary - Secondary	28 kV 3 kV	28 kV 3 kV
Maximum allowable noise level at 3 metre hemispherical radius	<44 dB	<44 dB
Applicable standard	IEC	IEC

5.8.2. Service wire

Guidelines for service wire are discussed below.

1. The service wires should be doubly insulated: they should be PVC cable (concentric or multi-core) and additional voltage drops should not exceed 2%. Underground service connections should be either armoured cable or PVC cable in a protective circuit.
2. Service wire should be of the same material as the line conductor (aluminium) to avoid the galvanic corrosion.
3. For spans exceeding 20 m, in consideration of the mechanical strength required, service wire of minimum 4-6 mm² (depending on the span) should be used for all lighting loads regardless of the actual power supply. However, if the distance (span) between a pole and a house is very short (i. e. less than 20 m), then a twin flat cable of 2.5 mm² can also be used.
4. A switch fuse unit (main unit) should be installed in each house.
5. The fuse of the main switch should be rated to protect against exceeding the maximum current ratings of the service connection.
6. To avoid overloading transformers and/ or plants, a load-limiting device (ECC, MCB or PTC) should be installed in each household.
7. Service wires should be clamped to poles to avoid creating tension in connections.

5.8.3. Metering

The metering of energy consumption must be included in the mini grid design, however the scope or function of the metering solution depends on many factors. These factors vary widely but are typically linked to the socio-economic status of the community and the subsequent PPA or financial models implemented at the community level.

As a baseline, each consumer drawing power from the mini grid system should be connected via a meter that captures the consumer's energy consumption. The meter could be a simple analog or digital device that counts kWhr and can be read off by a person, it should be of good quality, calibrated and tamper proof.

Pre-paid meters enable energy to be pre-purchased as credits with consumers redeeming these credits for energy, the pre-paid meter is a gating mechanism, activating and deactivating according to the consumers credit validity. Pre-paid meters have seen widespread adoption, however a critical consideration in their use is the community's willingness to pay and acceptance of "pre-paying". Pre-paid meters are substantially more expensive than simple meters, the advantages and disadvantages must be weighed carefully. This guideline suggest to use accuracy class 1 for the meters.

Internationally, smart meters have become the cornerstone in the new conception of the electrical network or smart grid (SG), providing detailed information about users' energy consumption and allowing the suppliers to remotely collect data for billing. Nevertheless, their features are not only useful for the energy suppliers, but they can also play a big role in the control of the Mini grid since the recorded power and energy profiles can be integrated in energy management systems (EMS). In addition, basic power quality (PQ) disturbance can be detected and reported by some advanced metering and control systems. These metering systems can often include all functions of simple and pre-paid meters, obviously at a higher cost.

The cost of the meter is typically billed to the consumer via a connection fee, the community's ability to afford this connection cost is critical in the selection of the metering system. Pre-paid and Smart Meters are substantially more expensive, this cost cannot always be passed onto the consumer, therefore if the more expensive meter infrastructure is required, the mini grid operation will have to subsidize the cost to the consumer.

5.8.4. Voltage Drop calculation in distribution line/feeder

The increasing use of LEDs, which are replacing traditional incandescent lamps in rural areas, as also use of many other electronic gadgets and appliances has resulted in loads with lagging power factors. In such cases while calculating the voltage drop along the line, inductive reactance of the line needs to be considered apart from resistance.

Figure below shows three load currents having magnitude I1, I2, I3 and having power factors CosØ1, CosØ2 and CosØ3 tapped of a distributor. L1, L2 and L3 are the lengths of the three sections and r and x are the resistance and inductive reactance per unit length.

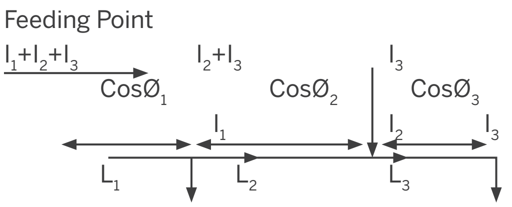


Figure: Distributor supplying loads at different power factors

Simplified Phase Voltage drop in case of a single phase system

$=2*[I_1L_1(r\cos Ø_1+x\sin Ø_1)+I_2(L_1+L_2)(r\cos Ø_2+x\sin Ø_2)+I_3(L_1+L_2+L_3)(r\cos Ø_3+x\sin Ø_3)]$

Simplified Line to Line Voltage drop in case of a balanced three phase system

$=1.732*[I_1L_1(r\cos Ø_1+x\sin Ø_1)+I_2(L_1+L_2)(r\cos Ø_2+x\sin Ø_2)+I_3(L_1+L_2+L_3)(r\cos Ø_3+x\sin Ø_3)]$

Above formulae may be suitably extended to cover the actual number of load tapings.

This guideline suggest not to exceed more than 10% of voltage drop in any section of line.

5.8.5. Cable Sizing and Installation Considerations

The following are some of the simplified procedures for cable selection. The four main electrical criteria for cable selection are:

1. Current rating.
2. Voltage drop.
3. Short-circuit capacity.
4. Earth loop impedance

Generally speaking, for:

- Short route length, current-carrying capacity requirement will dictate the cable size selection.
- Long route length, voltage drop or earth loop impedance requirement will dictate the cable size selection.
- The short-circuit capacity of a cable shall be such that all short-circuit current occurring at any point of a circuit shall not cause the cable conductor temperature to exceed the maximum permissible limit.

5.8.6. Current Rating

Current rating of a cable depends on:

1. Installation method, e.g., in air or ground, enclosed or unenclosed, etc.
2. Installation environment, e.g., ambient temperature, depth of laying, presence of other cables or circuits nearby, etc.
3. Limiting temperatures of the cables for normal use, e.g., PVC and XLPE insulated cables are 75°C and 90°C respectively.

Type of overcurrent protective device used appropriates the derating factor:

- 0.9 for fuses, with I2 = 1.6 x In.
    - Where: I2 = conventional overcurrent fusing or tripping current.
    - In = nominal current of the fuse or circuit breaker.
    - Current in neutral conductor

"4 core" shall mean 3 phase cores plus one neutral core. 4 core cables can have the same current rating as 3 core cables only if the neutral core is lightly loaded, i.e. less than 35% of the rated current of the phase conductor, and the harmonic content in the current is not significant, e.g. less than 15% for 3rd and 10% for 9th, 12th, etc., higher harmonics.

For other situations, de-rating may be required in order to take the additional heating effect due to the neutral current into consideration.

Current ratings in this technical guide are based on International standards with the following typical installation conditions. If other installation conditions are necessary, refer to derating/rating factors provided by the cable manufacturer for appropriate derating/rating factors.

- Not exposed to direct sunlight unless otherwise specified
- Single circuit
- Solar radiation (for cables exposed to sun only) = 1000W/m²
- Ambient air temperature = 40°C
- Ambient soil temperature = 25°C
- Depth of laying* = 0.5m

- Soil thermal resistivity = 1.2°C.m/W
- Supply frequency = 50Hz

*Measured to (a) center of cable or trefoil group of cables or (b) center of enclosure or trefoil group of enclosures

5.8.7. Short-circuit Capacity

During a short-circuit, the conductor temperature will increase due to the heat energy produced. To satisfy this requirement, the short-circuit permissible temperature limit of the conductor of cable must not be exceeded. This may require the time current curves of the short-circuit protective device to be checked against the cable damage curves.

5.8.8. Aerial Bundled Conductors (ABC) Cable

a) General

The cable shall be suitable for use within Nepal: altitude range 0-4000 meters, typical temperature range -5 deg. C to 45 deg. C, relative humidity 80-90%. The conductor shall consist of compact round stranded aluminum wires. They shall be of H2 or H4 grade (complying with IEC: 60228) and per the following:

- Upto and including 50 sq. mm. conductors = H2 grade.
- All sizes above 50 sq. mm. conductors = H4 grade.

The conductor shall be insulated by PVC material. The PVC insulating shall be black in colour and to be stabilized against deterioration caused by exposure to direct sunlight and ultraviolet radiation conforming to requirement specified IEC 60502.

The complete cable shall consist of four equal-size insulated conductors stranded together, and the direction of lay shall be right-hand. The type of construction shall cause the tensile load to be shared equally between four conductors. The core identification and the assembly (laying up) of cores be as per IEC 60502. Ridges shall be provided over phase core and neutral core also.

b) Electrical Properties

TABLE 16: ELECTRICAL PROPERTIES OF ABC CABLE

Cable Size mm²	Current Rating* (A)	Short Circuit Rating ** (kA)	Conductor Resistance @20˚C (Ω/km)	Conductor Resistance (ac) @ 80˚C (Ω/km)	Induction Reactance @50Hz (Ω/km)	Impedance (z) @50Hz at 80˚C (Ω/km)	Supporting Core Size mm²	Induction Reactance @50Hz (Ω/km)	Impedance (z) @50Hz at 80˚C (Ω/km)
25	105	2.3	1.2	1.49	0.096	1.493	54.6	0.101	1.493
35	144	3.2	0.868	1.078	0.096	1.082	54.6	0.097	1.082
50	183	4.6	0.641	0.796	0.09	0.801	54.6	0.089	0.801
70	228	6.4	0.443	0.55	0.089	0.557	54.6	0.086	0.557
95	227	8.5	0.32	0.397	0.086	0.406	54.6	0.081	0.405
120	322	11	0.253	0.314	0.084	0.325	70	0.079	0.324
150	350	13.8	0.206	0.256	0.082	0.269	95	0.079	0.268

*@ambient temp of 35˚C and conductor temp of 80˚C
**for 1 sec duration for final temp of conductor of 130˚C

c) Phase Identification

The identification of the conductors shall be provided by means of ribbing on the external surface of the insulation. The neutral conductor shall preferably be marked with a minimum of 12 for 25 mm², 16 for 50 mm² and 20 for 95 mm² ribs spaced evenly around the circumference of the core.

d) Size and Quantity

The sizes of cable shall be:

- 95 mm², 4 Core ABC
- 50 mm², 4 Core ABC
- 35 mm², 4 Core ABC
- 25 mm², 4 Core ABC

Additional phase conductors for street light may be required for centralized switching on/off.

e) Anchor Clamps

The anchor clamps shall be bolted type. The wedge of clamp shall be made of age and weather resistant insulating material with high mechanical strength. The tightening straps shall be made of hot dip galvanized steel. The clamp shall be loaded with the spring. The clamp shall have at least two bolts for tightening. The hooking end of the clamp shall be provided with a hot dip galvanized nuts and bolts with a safety lock.

- The clamp shall be suitable for following ABC.

ABC size/type	Min. Breaking load (kN)
95 sq. mm, 4-core ABC	43
50 sq. mm, 4-core ABC	37
25 sq.mm, 4-core ABC	37

f) Support Hooks or Suspension Clamp (Pigtail Type)

The support hooks shall be made of hot dip galvanized steel of sufficient sizes. The support hook shall be suitable for mounting in steel tubular (ST)poles. Support hooks suitable for Steel Tubular Poles: The support hooks shall be mounted on circular two-way clamps. The hook (pig tail) shall be mounted on one of the ways of the clamp. The clamp shall be suitable for following sizes of poles.

- Type TC6: Two-way clamp suitable for pole diameter ranging between 190 mm to 230 mm.
- Type TC8: Two-way clamp suitable for pole diameter ranging between 140 mm to 180 mm.

The remaining way of clamps shall be suitable for accommodating two numbers of double eye fitting, to be used along with anchor clamps. The width and thickness of clamp shall be not less than 50 mm. and 6 mm. respectively. Nuts and bolts of the clamp shall have a diameter not less than 16 mm.

g) Insulated Cable End Caps

The insulated cable end caps shall be made of weather and age resistant insulating material and shall have wet flashover voltage not less than 6 kV. The cap shall be heat shrinkable type and shall be coated internally with a suitable sealant. The caps shall be suitable for following sizes of ABC.

i. 95 sq. mm., 4-core ABC
ii. 50 sq. mm., 4-core ABC
iii. 25 sq. mm., 4-core ABC

h) Insulated Insulation Piercing Connectors

The insulated insulation piercing connectors shall be suitable for using with aluminum ABC and concentric cables. It shall be made of high quality, weather, heat and age resistant insulating material having wet flashover voltage not less than 6 kV. It shall be watertight and suitable for making connections to the live lines. The piercing of the main line and the tapping shall be done simultaneously. The design of the connectors shall be such that its removal is possible even after breaking of the shear head. The connector shall be provided with an end cap for tapping end. The connector shall be suitable for following cables.

Type	Main	Tapping
Type A	25-95 sq. mm, ABC	25-95 sq. mm, ABC
Type B	25-95 sq. mm, ABC	6-25 sq. mm, Concentric Cable

CHAPTER 6: PROJECT COST ESTIMATE

6.1. INTRODUCTION

The costing of the project shall be carried out based on the project component quantities and unit rates derived from the corresponding district rates for the fiscal year. Wherever possible, the current costs of equipment and material also need to be obtained from manufacturers. Where these are not available, costs shall be calculated based on the similar projects carried out or current ongoing projects within AEPC or outside AEPC.

TABLE 17: SUMMARY OF PROJECT COST

S. N.	Particulars
1	Pre-Operating Expenses
2	Power Generation Components; PV, Battery, Inverter
3	Protection System
4	Monitoring System
5	T&D line
6	Land Lease & Purchase if any
7	Office Equipment
8	Environmental & Social Costs
9	Project Engineering, Management & Supervision
10	Insurance & Miscellaneous

a) Assumptions

The following criteria and assumptions are the basis of the cost estimate:

The cost estimate and financial analysis shall be carried out in Nepalese currency.

The US $ to NRs exchange rate shall be used for cost.

b) Price level

The cost estimate shall be made at the price level of the current fiscal year. All costs shall be first estimated on a per unit basis for each of the components and then amount arrived after multiplying with number. These shall be added to obtain the entire project cost. Lump sum costs shall be allocated for components where a detailed breakdown of costs is not available or worthwhile using judicious judgement.

c) Material price and labor cost

Material costs reflect real costs incurred at other projects of similar size or having similar scope of works. The prices shall be calculated based on the district rate for the current fiscal year. It shall be stated whether the bulk of the construction material, the steel items for headrace pipe and penstock work and all of the electromechanical equipment need to be imported or available in the local market.

It shall also be stated whether skilled, semi-skilled and unskilled human resources can be obtained locally.

d) Indirect cost

The unit costs shall include profit, and overhead, which the contractor would charge. Along with that, Value Added Tax (VAT) will be applicable to mini grid material. The VAT of some solar equipment is waived off which can be obtained from AEPC.

6.2. GENERAL METHODOLOGY

The project shall be divided into a number of major components for the estimating process as follows:

- Pre-operating cost
  - Institutional set-up
  - Community mobilization
- Main Generation System
  - Solar PV Array
  - Mounting structure
  - Solar Charge Controller/MPPT Controller
  - Battery and Battery Management System
  - Battery Inverter and PV Inverter
  - Protection System
  - Monitoring System
  - Powerhouse
- Transmission Line system(including transformers, LT lines, service cable etc)
- Land and support: The cost components include land acquisition and lease, compensation to Forest Users' Committee, camp and other physical facilities, local development, access roads, if any, and environmental mitigation. This cost also shall include the cost of relocation of existing infrastructure facilities that lie in the project construction site.
- Annual operation and maintenance (for financial analyses)

6.2.1. Unit Rates/ Unit Prices

Unit rates should be derived for the major work items. Standard norms of practice and desingers' in-house experience shall be utilized in derivation of the unit rates. Wherever applicable, norms published by the District Coordination Committee (DCC) of the district in which the project lies can be used. The prices of material and other equipment can be obtained from the local market and also from projects under construction. A provision of 15~25% of the unit cost shall be adopted for overhead and profit. The following four sub-heads shall be estimated and the summation of these will be the rate of an item of work.

6.2.2. Contingencies

The estimated costs should include physical contingencies which allow for unforeseen cost increases that may become necessary as more information is obtained and evaluated. In view of the extent of investigations and study, the following contingencies shall be considered:

- Solar equipment 5%
- Civil Works - Surface & Infrastructure & General Items 10%

6.2.3. Annual operation and Maintenance Cost

The annual operation and maintenance (O & M) cost of a mini grid project is generally 1.5% to 3% of the total capital cost. It is less for larger plants and high for smaller plants. Alternatively this cost can be calculated with the breakdown of cost items. The cost items are:

- salary and benefits to the operators/managers
- cost of spare parts
- regular repair and maintenance cost
- insurance cost (if any)
- other costs

CHAPTER 7: ESTIMATION OF ENERGY YIELD

7.1. ESTIMATION OF ENERGY YIELD

The energy yield prediction is done to calculate the estimated energy generation from a PV system and it provides the basis for calculating project revenue. To accurately estimate the energy yield, information on solar resource data, temperature of the site are necessary. This chapter provides the description on type of losses, loss estimation, PV system performance (Specific Yield, CUF).

7.2. LOSS CALCULATION (TYPES OF LOSSES, METHODS OF LOSS ESTIMATIONS)

The factors that directly affect the energy generation are the losses due to temperature, soiling, mismatch, shading, low irradiance, voltage drop, inverter efficiency, transformer etc. The total efficiency of the system after considering all the losses is expressed as total de-rating factor or total loss factor. A summary of typical losses is provided in the following table.

TABLE 18: TYPE OF LOSSES AND LOSS ESTIMATION:

Loss Type	Description	*Estimated Loss (%)	Derating Factor
Module Temperature	This represents the losses due to rise in cell temperature of the module above the standard temperature conditions of 25oC. For every degree rise in temperature above the standard value, the efficiency can be reduced by around 0.5%.	7%	0.93
Module Soiling	This represents the losses due to dust, bird droppings and other foreign matter on the surfaces of PV modules that reduces the amount of solar radiation received. It is usually less than 4% but PV arrays located in arid, dusty areas with infrequent rain and regular covering of snow areas can experience soiling losses of 20 percent a year or higher.	3%	0.97
Mismatch	This represents the losses due to "mismatch" related to the fact that modules connected in series do not rigorously present the same I-V (Current-Voltage) curve characteristics. A de-rating factor of 0.99 represents a loss of 1 percent due to mismatch and is a reasonable assumption.	1%	0.99
Module Quality	Module quality losses refers to the deviation between actual module power and nominal power specified in the manufacturer specification. In case of positive tolerance on peak power, module quality loss can be considered as zero.	0%	0.00
Near Shading	Near shading losses affect only a part of the PV array. This partial shading could be caused by closer row to row alignment, external shading objects in the surroundings such as trees, buildings, poles, overhead cabling etc.	1%	0.99
Light and Temperature Induced Degradation (LeTID)	This represents the losses occurring at module temperature above 50oC under illumination. LeTID may occur regularly during summer and at peak times in hot climates.	1%	0.99

Loss Type	Description	*Estimated Loss (%)	Derating Factor
Low Irradiance	This represents the losses due to irradiance level (to consider the lower performance behavior of PV modules at low light).	2%	0.98
Reflection	This represents the losses due to the reflection of the sun rays on the PV module surface.	1%	0.99
DC Cable	This represents the losses between PV modules and inverter input and should be less than 3%. It includes voltage drops in wiring, connections, fuses, switches, or any other components, as applicable. These losses can be determined in the field by measurements of the current and voltage drops through the entire DC circuit. Total DC wiring and connection losses usually will be on the order of 3 percent for most PV systems, resulting in a derating factor of 0.97.	3%	0.97
Inverter	This represents the losses due to efficiency of the inverter. Almost all the good inverter manufacturers claim the maximum efficiency greater than 95%.	5%	0.95
AC Cable	This represents the losses from inverter to first pole. It includes voltage drops in wiring, fuses, and disconnects and usually is on the order of 1 percent or less for most PV systems, resulting in a derating factor of 0.99. These losses are smaller than DC cable losses.	1%	0.99
Transformer & Others	This represents the losses in terms of iron and resistive/inductive losses.	2%	0.98
Transmission & Distribution	This represents the losses in the transmission and distribution line, mainly the power loss.	5%	0.95
Total De-rating Factor (Multiplying all the De-rating Factors)			**0.714**

Note: * indicates the actual loss will be as per site conditions.

7.3. PV SYSTEM PERFORMANCE

The PV system performance can be determined by the following parameters.

- Performance Ratio
- Specific Yield
- Capacity Utilization Factor (CUF)

7.3.1. Performance Ratio (PR)

Performance Ratio (PR) is the ratio between actual energy yield and theoretical yield. The quality of a PV power plant is described by its Performance Ratio (PR). The PR, usually expressed as a percentage, can be used to compare PV systems independent of size and solar resource.

$$(PR) = \frac{\text{AC Yield (kWhr)} \times 1\,(1\text{kW/m}^2)}{\text{DC Installed Capacity (kWp)} \times \text{Plane of Array of Irradiance(kWhr/m}^2\text{)}} \times 100\%$$

PR is usually between 75% to 85%

7.3.2. Specific Yield:

Specific Yield refers to how much energy (kWh) is produced for every kWp over the period of a year. It is measured in kWh/kWp. The produced energy in MWh or GWh is simply the specific yield times the installed nominal power of the solar PV system and accounts for the annual production delivered at the site. Range from 1,000 kWh/kWp to over 2,000 kWh/kWp

The specific yield of a PV system depends on

- Amount of solar irradiation falling on the module plane
- Total System Losses or Total De-rating Factor

7.3.3. Capacity Utilization Factor (CUF)

The capacity utilization factor, usually expressed as a percentage, is defined as the ratio of total AC energy over a period of a year to the theoretically available AC nominal power operated for the entire year.
The CUF is defined as:

$$CF = \frac{\text{Energy generated (kWh/year)}}{\text{(8760 hours/year) x DC Installed Capacity (kWp)}} \times 100\%$$

Typical values of CUF for a modern PV plant will be in the range of 12–25 percent, depending primarily on location.

7.4. DEGRADATION AND LIFE CYCLE ENERGY YIELD ESTIMATION

The performance of a PV module will decrease over time. The degradation rate is typically higher in the first year upon initial exposure to light and then stabilizes. Factors affecting the degree of degradation include the quality of materials used in production, a manufacturing process, the quality of assembly and packaging of the cells into the module, as well as maintenance levels employed at the site.

Generally degradation of a good quality module is considered to be about 20% during the module life of 25 years @ about 0.7% per year. The Degradation Rate (DR) is calculated by using this formula.

$DR = [1- (PO_a/PO_n)] \times 100\%$

Where,

PO_n = original manufactured nameplate specification of the Module, expressed in Watts, excluding any specified positive tolerance

PO_a = power output of the Module, expressed in Watts, that a Module generates at a given point in time in a year after the Warranty Start Date in its 'Maximum Power Point' under STC

Module manufacturers may provide degradation warranties in stepped degradation and linear as shown in the figure below.

From the above figure, the power guarantee is provided as 2 step power warranty, 91.2% rated power output till 10 years and 80.7% till 25 years. The power degradation is 2.5% for the first year and 0.7% linearly each year thereafter until that date which is 25 years, following the warranty start date, at which time the Actual Power Output shall be not less than 80.7% of the Nominal Power Output. The estimation of energy yield (generation) is calculated by using this formula:

Energy Yield = Array Rated Power x Peak Sun (PSH) x Total De-rating Factor

It is measured in kWh or MWh or GWh.

Where,

Array Rated Power: This is the rated nameplate capacity of the system at STC, derived from total rated power of the modules. It is important to note that a PV array never works in those standard test conditions in the field and therefore array power will always be less than the rated power at STC.

Peak Sun: This is the amount of solar irradiation falling on the modules. Solar energy available in a given location is expressed as kWh/m²/day. This is commonly referred to as Peak Sun Hours (PSH). For example, if solar irradiation for a particular location is 4.5kWh/m²/day then PSH for that location will be 4.5 hours.

Total De-rating Factor: The total efficiency of the system after considering all the losses is expressed as total de-rating factor, which is explained in Loss Estimation above.

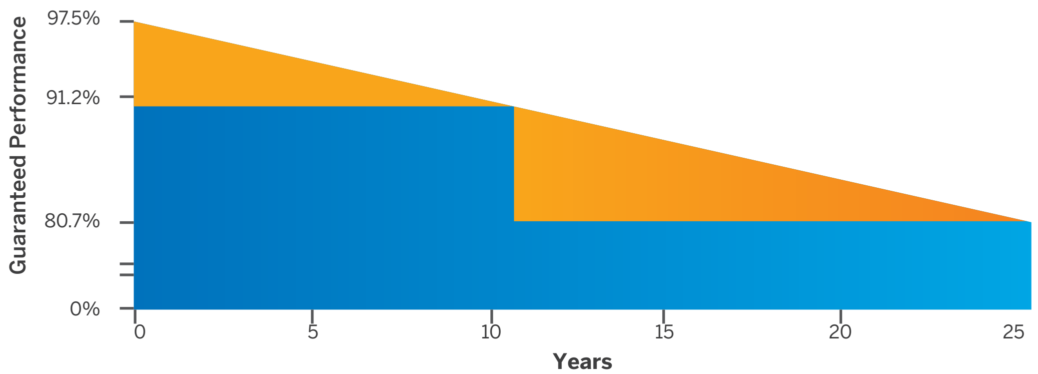


Figure 26: Example of PV Module Degradation

CHAPTER 8: FINANCIAL ANALYSES

8.1. GENERAL

The solar mini grid project must be technically feasible as well as financially viable. Apart from the technical, environmental and socio-economic aspects of the project, the financial analysis provides the most important indicators for the acceptability of the project for investment. The financial evaluation is aimed at giving potential investors an overview of the risks and benefits associated with financing the project. The analysis is based on the use of real time monetary values of the cost and benefit and makes use of market prices and, therefore, includes any taxes which will be levied on the factors of production and any subsidies, capital or operating costs, which may be received as part of the development. All costs are charged and all revenues credited to the analysis in the actual amounts expended or received at the time of expenditure. For this analysis the financial rate of return and cash flow is assessed from the perspective of a mini grid owner/operator. Financial analysis should be carried out in such a way to develop a mini grid into a business model.

The financial analysis is carried out by the usual discounted cash flow technique. The financial indicators are: the Internal Rate of Returns on Total Investment and Equity Investment, Net Present Value and Benefit Cost Ratio. The analysis is carried out in Nepalese Rupees (NPR) as the price for the energy that will be sold from this project will be in NPR. The relevant specific parameters applied for the financial analysis in this study are the following:

8.1.1. Subsidy

The amount of applicable subsidies for implementing new solar mini grid projects are as per Renewable Energy Subsidy Policy, 2078.

8.2. GENERAL ASSUMPTIONS

Analysis Period:
The analysis period starts with cash flow investment for project construction works which is distributed for each year of construction period generally 6 month to 1 year. Then the cost and revenue are spread over the economic life of the plant from the date of commercial generation. Generally, 15 years can be adopted as the economic life of a solar mini grid. One time of battery replacement has to be considered in the cash flow.

Reference Date:
A reference date for costs, exchange rate and discounting is established on the date of project evaluation.

Investment Cost:
The financial cost of project investment is made up of total project cost with contingencies, price escalation, taxes, duties, value added tax.

Operation & Maintenance (O&M) Costs:
Annual operation and maintenance cost of the plant is made up of salary of staff, repair & maintenance cost, taxes and duties, overhead of the company. The annual increment of O&M should atleast 1%.

Financing Mix:
The project is assumed to be developed with long term loan and equity investment of the Developer with financing mix of loan and equity as appropriate. After deducting subsidies and incentives, the remaining amount has to be divided into a loan equity ratio of 70:30.

Discount Rate:
A discount rate has to be chosen and used to calculate the Net Present Value and the Benefit Cost Ratio of the project as well as to compare with the calculated IRR on Equity Investment. Financial Discount Rate can be assumed to be 10%. This can be calculated by averaging the Weighted Average Lending Rate (Commercial Banks) over a period of 4 years (16 data points) as published by Nepal Rastriya Bank.

Energy Benefits:
Energy benefits of a project are based on the energy consumption in the supply area multiplied by the electricity tariff. The price of energy is generally based on prevailing tariff in similar projects or the electricity tariff of NEA.

The mini grid tariff rate should be fixed by the community for lighting and end use purposes. However financial parameters should be met. Community mobilizer can facilitate community for determining tariff.

8.3. FINANCIAL ANALYSIS AND PLANNING

An analysis is required to determine the financial feasibility of any project. The financial analysis includes the revenue from the collection of the electricity charges to the system users, the analysis of the Life Cycle Cost of the entire system, Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PB) and Levelized Cost of Electricity (LCOE). The NPV, IRR, PB and the LCOE are evaluated for 15 years as this is the assumed lifetime of the PV system including replacement costs of inverter or battery equipment according to their operational life.

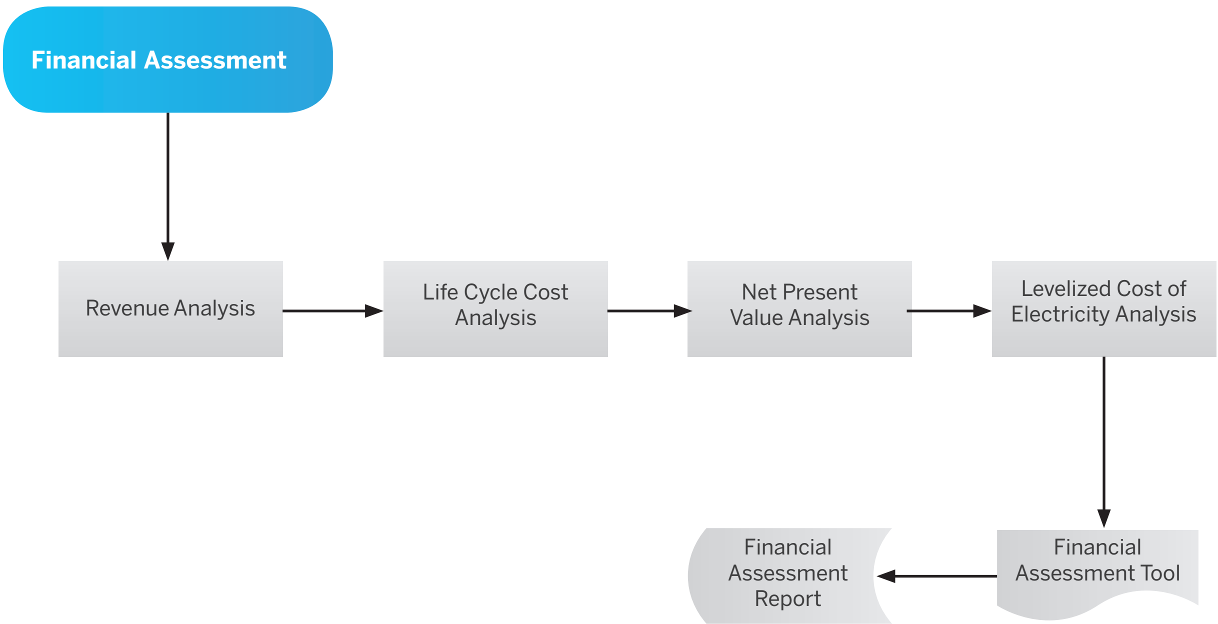


Figure 27: Financial Assessment Process

8.3.1. Revenue Analysis

Applicable tariff (for connected load and for energy) for different categories of consumers forms the basis for revenue analysis. Factors like time value of money, inflation etc. shall be considered to define a mechanism for tariff adjustment/escalation.

8.3.2. Life Cycle Cost Analysis

The LCC considers the investment cost, O&M and the replacement costs. The investment cost of this project comprises the costs of the PV array, the battery bank, inverter/battery charges, and wiring/BOS components. The costs of the wiring/BOS components may be assumed to be 10% of the cost of other components (PV array, battery bank, inverter/battery charger). The investment cost generally includes the cost of the equipment plus the installation cost and any modification required in the equipment. The cost of the system installation and other modifications required may also be assumed to be 10% of the sum of the main components. The annual cost of an energy system includes operational costs (including salary and benefits of the staff), mortgage payments, and maintenance and parasitic energy costs etc.

8.3.3. Sensitivity analysis

Sensitivity Analysis is the process of recalculating outcomes under alternative assumptions to determine the impact of variable parameters. Sensitivity analysis is one such method that is implemented to analyze the various risks to the project on uncertain conditions. Sensitivity analysis involves changing the inputs in the financial model to analyze how the cash flow of the project is impacted. Sensitivity analysis gives lenders and investors a greater understanding of the effects of changes in inputs on the project's profitability and bankability. It helps lenders and investors understand the key risks associated with the project. Consultant has to provide outcome of below mentioned financial parameter for following scenarios;

a) Without any financial incentive i.e. no subsidy
b) Subsidy with 60% of total project cost, 20% loan and 20% equity
c) Subsidy with 90% of total project cost, 10% equity

8.3.4. Net Present Value

The NPV is one of the most comprehensive approaches for the financial evaluation of a project. The NPV method evaluates the future cash flows of the system in a real value basis. This is done by discounting the cash flows at a specific interest rate. In addition, the recurrent costs of the project can be assumed to inflate or deflate at a fixed inflation rate.

8.3.5. Internal Rate of Return (IRR)

The internal rate of return is a discount rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis. IRR calculations rely on the same formula as NPV does. The formula and calculation used to determine this figure is as follows.

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0$$

Where:
C_t = Net Cash Inflow during the period t
C_0 = Total initial investment costs
IRR = the internal rate of return
t = the number of time periods

To calculate IRR using the formula, one would set NPV equal to zero and solve for the discount rate, which is the IRR. However, because of the nature of the formula, IRR cannot be easily calculated analytically and therefore must instead be calculated either through trial-and-error or by using software programmed to calculate IRR. This can be done in Excel easily with inbuilt IRR function.

8.3.6. Payback Period.

The payback period refers to the amount of time it takes to recover the cost of an investment or how long it takes for a developer to reach break-even. The desirability of an investment is directly related to its payback period. Shorter paybacks mean more attractive projects. This is a non – discounted cash flow method of capital budgeting which is its limitation.

8.3.7. Levelized Cost of Electricity (LCOE)

The LCOE is an abstract from reality and issued as a benchmark or ranking tool to assess the The LCOE is an abstract from reality and issued as a benchmark or ranking tool to assess the cost-effectiveness of different generation technologies. The method considers the lifetime generated electricity cost to estimate a price per unit of electricity generated. The method does not usually include risk and different actual financing methods available for the different technologies.

For the purpose of this guideline, the electricity consumed is used in the LCOE assessment instead of the electricity generated. Since this is a stand-alone system, part of the energy produced that is not stored in the battery bank or supplied to the load is dumped.

$$\text{LCOE} = \frac{\text{Sum of all costs over lifetime i.e. NPV value of all costs}}{\text{Sum of electricity consumed over lifetime i.e. NPV value of consumed electricity}}$$

$$= \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^n}}{\frac{E_t}{(1+r)^n}}$$

Where

I_t = investment expenditure

M_t = O&M expenditure

E_t = Energy Consumed

r = discount rate

n = expected life time of mini grid (can be assumed 15 years)

CHAPTER 9: ENVIRONMENTAL AND SOCIAL SAFEGUARDS

9.1. ENVIRONMENTAL AND SOCIAL ASSESSMENT

Environmental and Social Safeguard requirements of the projects shall be governed by the Environment Protection Act (EPA) 2076 and Environment Protection Rule (EPR) 2077 of the Government of Nepal and Environmental and Social Safeguard (ESS) Policy 2018 of AEPC. According to the EPA 2076, an environmental study report shall be prepared for any proposal as prescribed in the EPR 2077. A brief environmental study shall be carried out for solar and wind projects which will use up to 1 hectare forest land (Schedule-1, Ka.6). Initial Environmental Examination (IEE) shall be carried out for solar and wind projects with generation capacity of 1 to 10 MW (Schedule-2, Cha.7) and projects which will use 1 to 5 hectares of forest land (Schedule -2, Ka.12). However, Environmental Impact Assessment (EIA) shall be carried out for solar and wind projects with generation capacity more than 10 MW (Schedule-3, Cha.6), projects which will use more than 5 hectares forest land (Shedule-3, Ka.9) and projects in national parks, hunting reserve and wildlife reserve (Schedule -3, Ka.10). In terms of projects supported by Development Agencies such as the World Bank and Asian Development Bank, Environmental and Social Safeguard requirements as per the safeguard policy of respective agencies shall be fulfilled.

Solar mini grid systems are mainly for community electrification powering lighting in the households, school, hospital, office building etc. The adverse environmental impacts of these systems is generally not very significant. Mini grid systems could be located in a remote rural community, a group of villages or districts interconnected by transmission lines. The aggregate effects of several such projects could be of magnitude to cause adverse impact to the environment. Therefore, environmental and social impact due to implementation of such projects shall be considered in the detailed feasibility study. Environmental and Social Study for a mini grid project should identify key impact, predict magnitude, extent and duration of impact as well as suggest strategies for minimization/mitigation of impacts.

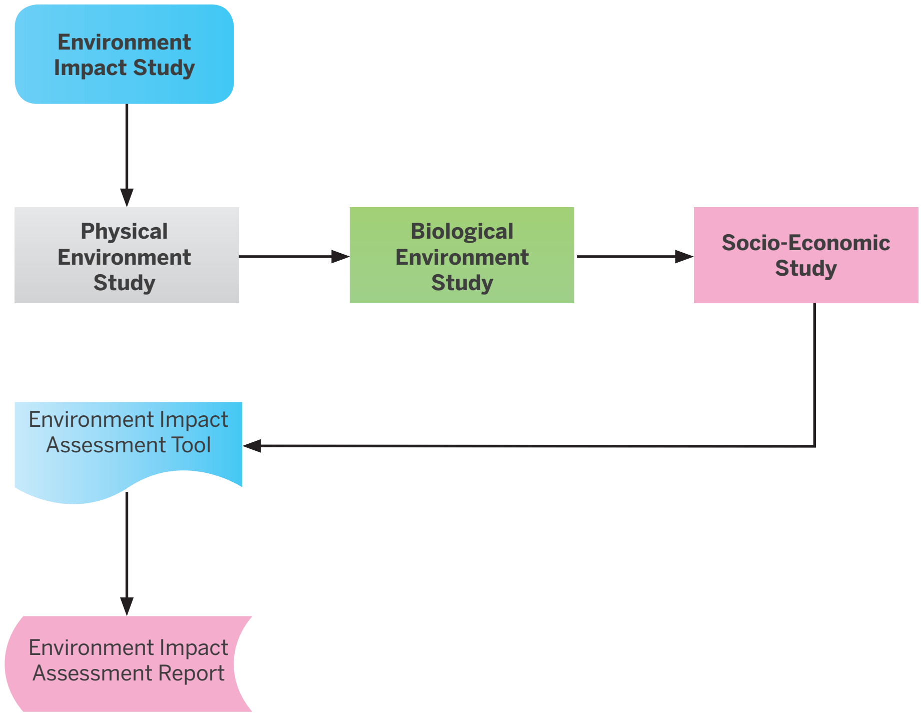


Figure 28: Environment Impact Assessment Process

9.2. PROCESS FOR ENVIRONMENTAL AND SOCIAL ASSESSMENT

9.2.1. Environmental and Social Screening and Categorization

Screening will determine whether the projects are likely to have potential adverse environmental and social impacts, establish the level of environmental/ social assessment required, help proponents to understand environmental and social issues related to the projects before they are considered for implementation, and assist in the decision-making process. Screening will be conducted based on criteria mentioned in Schedule 1, 2 and 3 of Environment Protection Rules 2077 (EPR, 2077) and Environmental and Social Safeguard (ESS) Policy of AEPC 2018.

Based on the environmental and social screening, projects will be categorized as High, Medium Low risk. AEPC will be responsible for the categorization decision of the project.

9.2.2. Baseline Data Collection of Existing Environmental and Social Conditions

Baseline data collection is a record of the situation and status of the project site before project implementation. It is a description of existing conditions against which subsequent change can be examined, predicted and confirmed.

Baseline study refers to the collection of existing physical, biological, socio-economic and cultural information of the proposed project area including changes that are expected in future.

For environmental assessment of the proposed project, the baseline conditions for the physical, biological, socio-economic, and cultural environment of the project area should be found out and documented for future records. The major categories of the environment likely to be included in the environmental report of Large Scale Solar PV and Wind are detailed below.

d) Physical Environment

Topography: general gradient and slope of the project location, general terrain condition of the project area, availability of land area, surrounding shadow objects, nearby settlements,

Geology: geological setting, status of geological stability or instability, characteristics of surface deposit, landslide and soil erosion, soil type

Seismicity

Meteorology:
- different climatic regimes, irradiance, temperature, rainfall, snowfall, annual Sun shine days, average daily sun-hours, wind speed

Climate change and natural disasters
- Explain in detail about how the project will be affected by the climate change impact
- Explain how the project is vulnerable to various natural calamities including flood, earthquake, drought, cyclone and so on

Project location from flood level

Air quality, water sources and its quality, noise level and drainage pattern

e) Biological environment

Forest management practice, flora, fauna (mammalian and avian), vegetation and forest type and composition.

9.2.3. Socio-economic and cultural environment

b. Demography: estimated population, population characteristic;
c. Social setting: Social structure of community (cast, ethnicity, religion), social practice, housing pattern, settlement pattern in core and immediate area;
d. Gender issue: role of women in society, their responsibility;
e. Infrastructure: access road, track, bridge, water supply system etc.;
f. Education: literacy rate, education facility;
g. Community resource: resource commonly used by community;
h. Economic characteristic: income, expenditure, skill level, occupation, employment, market;
i. Health and sanitation: health facility, institution, common diseases, sanitation condition;
j. Water use right: existing and proposed consumptive and non-consumptive uses of river water;
k. Land Ownership and availability
l. Land use: existing land use pattern (farmland, barren land, settlement, forest);
m. Historical and Cultural heritage sites

9.2.4. Methodology of Data Collection

Baseline information can be collected through maps and reports study, field visit and by detailed site survey such as household questionnaire form, focus group discussion (FGD) checklist, inventory and sampling depending upon the nature of the project. Primary data/information related to the environmental attributes like air, noise level, water quality, irradiance, and wind speed and geomorphology data directly collected from field studies. In the field study, a structural as well as semi structured questionnaire, focus group discussion and key informant interview tools are used to collect primary socio-economic information. Ecological information is collected from both primary data sources as well as from the secondary data sources. The following methodology can be adopted for the data collection:

f) Desk Study

Collect information and data from municipality/ rural municipality/ward profile, published and unpublished literatures related to project, report of similar project elsewhere, related papers, internet etc.

g) Field Work

The Study Team should visit the project area to observe, collect and analyze data/information for studying Physical, Biological, Social, Economic and Cultural Environment of the project area. The works should be carried out using the following methods:
- Walkover survey/Direct Observation
- Sampling
- Interviews/group discussion
- Stakeholder Consultation
- Checklist/questionnaire

h) Public Consultation
Public consultation refers to the process by which project directly affected persons and those who have plausible stake in the environmental and social impacts due to project activities are ascertained with a view to take into account all the material concerns or activity design as appropriate.

A stakeholder is any individual, group, agency or organization affected by a project and/or concerned or like-minded institutions in project outcomes, or in common resources impacted by a development project. A stakeholder should be treated as a "partner in development" and not as an opponent of the project.

The list of prospective stakeholders includes some or all of the following. In every category, gender issues must be given proper consideration; both women and men should be represented in activities.

- Affected local individuals, communities or households;
- Elected officials of concerned municipality/rural municipality;
- Concerned business people and entrepreneurs;
- Local NGOs, CBOs, Women Groups, Youth Groups, Clubs;
- Local influential individuals from affected area, such as informal or traditional community heads, school teachers, healers, social and religious leaders and other notable men and women;
- Health workers;
- Social workers;
- Project developer/proponent themselves.

Those stakeholders who are directly affected by the project activities are identified as the key stakeholder. They will be at the greatest risk and feel the impacts most intensely, so they are the prime stakeholder for the benefit and opportunities from the project. Therefore, their involvement and participation in the project activites is crucial from the beginning for the success of projects. Hence, at least one public consultation meeting should be conducted throughout the project cycle in the project area.

9.2.5. Data Analysis

The information and data collection from the fieldwork should be compiled in excel sheet and analyzed to establish the relation between the environmental and social impacts due to construction and operation of the proposed project and list their likely mitigation measures. Based on the data analysis, conclusions shall be drawn on environmental and social issues, resolutions and practical action to protect the environment of the project area.

9.3. ENVIRONMENTAL AND SOCIAL IMPACTS

Magnitude of environmental impacts of solar mini grid project implementation depends upon the selected site configuration and the scale of the project. A mini grid project covers a relatively small area and has a low impact on the existing environment (beneficial or favorable and adverse or unfavorable) than bigger scale projects. The environmental and social impact due to implementation of solar mini grid project construction activities are summarized below(Table 19).

The environmental and social implications may be beneficial or adverse, but the main objective of impact identification is to specify the issues that are likely to be affected by the implementation of the project. Environmental work related to the large scale solar PV and Wind project starts from the identification of the project. Synonymously the same time potential environmental impact should also be analyzed and predicted from analysis of the field situation as well as from secondary data of existing environment against proposed development activities. Environmental Management Plan (EMP) should be developed showing environmental issues, impact, impact prediction, mitigation measures and mitigation cost.

TABLE 19: ENVIRONMENTAL IMPACTS OF LARGE SCALE SOLAR PV AND WIND PROJECT

Activities	Impact
Construction Phase Solar PV mounting concrete pillars, wind turbine support foundation structure, Armor cable ground layout, powerhouse, earthing or grounding, project accessories, access road	Physical environment • Soil erosion and chances of landslide due to removal of tree, shadow obstacles and cutting existing slope and filling of loose excavated materials • Surface erosion from excavated material filling site • Change in land use pattern • Deterioration of surface water due to surface runoff from excavated site • Air pollution • Noise level • Water quality • Solid waste and muck disposal • Stockpiling of construction materials • Visual impact Biological Environment • Loss of forest and vegetation • Exploitation of none timber forest product • Hunting and Poaching • Stress on natural resources Socioeconomic Environment • Land Acquisition: Acquisition of private as well as governmental land • Visual intrusion caused by construction activities • Production of sound and noise due to wind turbine rotation • Shadow and shadow motion due to wind turbine rotation • Local birds strike on the wind turbine • Destruction and destroyed recreational spot and activities • Labor influx and management: Raised social issues from the migrated work force • Change in demographic profile • Impact on livelihood of Project Affectd Peoples (PAPs) • Occupational health and safety • Community health and safety • Health, hygiene and sanitation • Gender and vulnerable group • Employment opportunity • Impact on sites of cultural importance • Stress on infrastructure
Operation Phase	Physical Environment • Soil erosion and landslide triggering from instability site • Air quality • Noise level • Water quality • Visual impact • Flicker effect Biological Environment • Barrier on wildlife movement • Birds and bats mortality • Forest and vegetation • Socio-economic and cultural environment • Issue on electrical and electronic waste • Battery Management: Issue on lead acid disposal and battery recycling • Issue on mercury due to florescent bulb disposal • Issue on public health • Impact on livelihood of Project Affectd Peoples (PAPs) • Occupational health and safety • Community health and safety: Issue on public health • Stress on infrastructure • Employment opportunity

9.4. SOCIO-ECONOMIC BASELINE SURVEY

9.4.1. Introduction

The socio-economic data required for a mini grid development includes the collection of village profile data, identification of potential beneficiaries, load centres, economic and financial conditions of the beneficiaries and other relevant data.

9.4.2. Data/Information Requirement

For initiation of a mini grid power project data/ information specific to the project site needs to be collected. The required data/information shall be acquired through collection of information from the potential beneficiaries. In order to collect municipality/rural munilcipality level or ward level (if available) data secondary source shall be used. Whereas 10% of the total household from beneficiaries' communities shall be taken as sample for primary socio-economic data collection.

9.4.3. General socio-economic information

General socio-economic information shall be collected for preparing baseline information of the project so that the indicators can be compared before and after the installation of the mini grid project. Following information shall be included in the baseline surveying:

i) Identification
Identification of the location of the project and the beneficiary areas – specifically the load center (Focus Group Discussion FGD will be conducted in location of project).

j) Site Information
Information regarding the distance from the nearest road head and an airport to the project site and load centres.

k) Income and Expenditure Pattern
The income and expenditure habitude of the households of the load centers has been categorized into High, Medium and Low levels as perceived by the participants of the focused group discussion (FGD) in the respective load center. This should be taken as the baseline information for comparison in subsequent periodic FGDs.

l) Economic Activities (Livelihood)
Activities related to agriculture, livestock, cottage industry, remittance, agriculture production, industry and craft, business entities and more should be recorded.

m) Infrastructure
The public infrastructure including school, health post, road streets, services of information & communication (phone, internet, TV and postal), irrigations system, sources of drinking water, clubs, temples, gumbas, madrasa, church etc. available at the time of the FGD should be recorded under the Public Services heading.

n) Local Level Capacity
Local level capacity implies the available trained workforce within the beneficiary communities.

o) Education
Access to education and the annual dropout of students should be filled in.

p) Sources of Electricity and Consumption of Energy
Current use of elctricity sources such as solar home systems, Kerosene, diesel etc shall be recorded. Current use of electrical appliances/equipment as well as potential consumption of electricity after implementation of the project shall be filled in.

Consumption of different kinds of energy should be filled in.

q) Development activities
The development activities expected in the immediate future.

r) Willingness to Pay
The willingness to pay for electricity use as reported by the potential beneficiary during the FGD.

CHAPTER 10: RISK ASSESSMENT

There could be various types of risk profiles associated with any new project and in general such risk profiles vary from project to project. Risk profiles that need careful scrutiny in case of solar mini grid projects. The foremost risk may be associated with proper resource assessment as incorrect assessment will lead to premature failure of the project. Some of the risks may have tremendous negative effects whereas some others may be alleviated with proper back up planning. Similarly the risk of error in existing demand assessment and future demand projection needs to be minimized. Other risks may include geological risk, seismic risk, risk of large migration, technological risk, risk of alternative options (e.g. of grid electricity).

Some of the risks are site specific and they should be assessed during the field investigation and design period. The feasibility study shall collect and analyze adequate data/information associated with the risks as stated above. This will prevent harming the project implementation as well as operation. Appropriate measures should be suggested in descriptive form by the consultant on risk management.

10.1. UNCERTAINTY IN METEO DATA

The solar irradiance could have yearly variability. The climate evolution made solar irradiance more unpredictable. However, the uncertainty can be minimized by quality of the data recording, care of the operators, positioning, calibration and drift of the sensors, perturbations like shadings, dirt or snow on the sensors, etc. The quality of data depends upon the location difference (distance of measuring station) for terrestrial measurements.

The quality of the models used for interpreting the satellite data, which is in continuous improvement since 20 years. Usually the probability index p(xx) represents yield levels, for which the probability that the production of a particular year is over this value is xx%. The energy yield are derived at p(90), p(70) and p(50) data whenever possible/ required. For the bankable project P(70) is required.

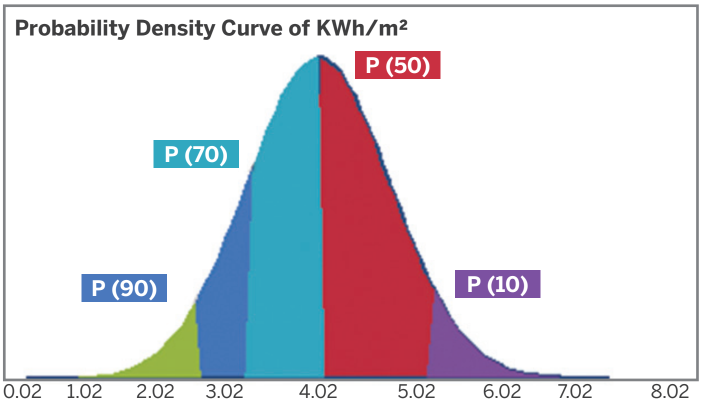


Figure 29: Uncertainty in Meteo Data

10.2. FINANCIAL RISK

The financial risks include change in interest, change in item rates, change in project cost, change in legislation, change in exchange rate, change in construction period, etc. These risks shall be analyzed during negotiations with lenders and community.

10.3. OTHER RISKS

Other risks in mini grid development can be:

10.3.1. Environmental risk

Environmental risks are related to water rights, relocation of existing structures (road, bridge, canal etc.), use of forest area etc. Information shall be collected by interacting with community people/relevant stakeholders of the project area and available secondary information. These data shall be analyzed and suitable mitigation measures shall be recommended in the detailed feasibility study. Timely negotiation and receiving permissions shall be made to avoid delay and interruption in construction and operation phase.

10.3.2. Political risk

Disturbances due to political instability lead uncertainty in a project implementation may result in delays and cost overrun. Assessment of such risk shall be carried out by qualitative methods.

10.3.3. Social risk

Social risks are associated with acquisition of land for the project and the implementation of the project without proper consultation and consent of the people residing in the project areas. Timely stakeholders engagement is recommended for minimizing such a risk. Social risk may arise due to excessive use of local resources (water, land, forest, construction materials, etc.) by the developer, intervention in the living style or tradition of the locals, etc. These risks shall be identified and adequate mitigation measures shall be recommended during the socio- economic and environmental studies of a solar mini grid project.

CHAPTER 11: FEASIBILITY STUDY REPORT FORMAT

Contents
List of Acronyms
List of Drawings
List of Figures
List of Tables
Executive Summary (Summary of the Detailed Feasibility Study Report)
Salient Features

THE FORMAT OF THE SALIENT FEATURES SHALL BE AS FOLLOWS.

S.N.	Heading	Particulars	Description
1	User Community	Name of the User Community	
2	Category	Sub project Category	
3	Subproject	Name of the Subproject Capacity	 ....kWp
4	Power House Location	GPS Coordinates	Latitude Longitude
		Altitude Province & District Municipality/Rural Municipality Village Approximate Distance from Nearest Highway to Subproject Site Approximate Distance from Nearest Road Head to Subproject Site	.........m ....Km ....Km
5	Households	Total Number of Households Total Number of Households/Businesses Total Number of Businesses Total Number of Anchors	.........Nos. ....Nos. ....Nos. ....Nos.
6	Land Profile	Type of Land Ownership of Land Current Land Use Pattern Topography and Orientation	
7	Land Acquisition	Willing Buyer/Willing Sale Leased Land Voluntary	
8	Solar Resource Potential, Technology and Subproject Capacity	Solar Insolation Type of PV Module Capacity of Each Module Module Efficiency Total No. of Modules	.......kWh/m²/day ....Wp ....% ....Nos.

S.N.	Heading	Particulars	Description
		Total PV Array Capacity	………kWp
		Type of Inverter1	
		Capacity of Each Inverter	………kW
		Inverter Peak Efficiency	………%
		No. of Inverters	………Nos.
		Total Inverter Capacity	………kW
		Type of Inverter2	
		Capacity of Each Inverter	………kW
		Inverter Peak Efficiency	………%
		No. of Inverters	………Nos.
		Total Inverter Capacity	………kW
		Type of Charge Controller	
		Capacity of Each Controller	………kW
		Charge Controller Peak Efficiency	………%
		No. of Charge Controllers	………Nos.
		Total Charge Controller Capacity	………kW
		Type of Battery	
		Capacity of Each Battery Set	………Ah
		No. of Battery Set	………Nos.
		Total Battery Capacity	………kWh
		Type of Wind Turbine	
		Capacity of Each Turbine	………kW
		No. of Wind Turbines	………Nos.
		Total Wind Turbine Capacity	………kW
		Type of Wind Controller	
		Capacity of Each Controller	………kW
		No. of Wind Controllers	………Nos.
		Total Wind Controller Capacity	………kW
9	Transmission and Distribution	Transformer Power Rating	………kVA
		Transformer Voltage	
		Primary	………kV
		Secondary	………kV
		Type of Transformer	
		Length of T&D Line	
		11kV Three Phase	………Km
		400V Three Phase	………Km
		230V Single Phase	………Km
		ABC Twisted Cables	
		4 Core 150mm² for 3-Phase	………Km
		4 Core 95mm² for 3-Phase	………Km
		4 Core 70mm² for 3-Phase	………Km
		4 Core 50mm² for 3-Phase	………Km
		4 Core 35mm² for 3-Phase	………Km
		2 Core 95mm² for 1-Phase	………Km
		2 Core 50mm² for 1-Phase	………Km
		2 Core 35mm² for 1-Phase	………Km
		2 Core 25mm² for 1-Phase	………Km
		ACSR Conductor	
		Rabbit (50mm²)	………Km
		Weasel (30mm²)	………Km
		Squirrel (20mm²)	………Km
		Pole Type & Number	
		410 SP-67 to 410 SP-72 (13 meter)	………Nos.
		410 SP-52 (11 meter)	………Nos.
		410 SP-29 (9 meter)	………Nos.
		410 SP-13 (8 meter)	………Nos.
10	Electricity Generation	Estimated Annual Energy Generation	………kWh/year
11	Cost Estimate	Estimated Subproject Cost	NRs.
12	Financial Overview	Project IRR	………%
		Payback Period	
		Break Even Point (BEP)	
		B/C Ratio	
		Levelized Cost of Energy	

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8. Design Layout
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       11.4.3. LCOE
    11.5. Financial Output
       11.5.1. Project Internal Rate of Return
       11.5.2. Net Present Value

11.5.3. Break Even Point
11.5.4. Payback Period
11.5.5. B/C Ratio
11.6. Other Banking Ratios
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12.1. Detailed Work Schedule of Subproject

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Annexes

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ANNEXES

ANNEX 1- DEMAND ASSESSMENT SURVEY FORM

TABLE 20: QUESTIONNAIRE FOR DEMAND SURVEY IN INDIVIDUAL HOUSEHOLD

Questionnaire			
Individual			
District			
Rural/Municipality			
Ward no/Tole			
Respondent Name			
Age			
Social			NOTE
Family Size			
Income Source			
Service			Please Tick
Agriculture			Please Tick
Business (mention type)			
Monthly Income			Total Income in Cash in NPR
Education			
Highest Education Level			Separate with comma for different classes. Eg: Input as
	Number	Classes Enrolled	1,2&3 for 3 Male Students in class 1, 2 & 3
Male Students			
Female Students			
Name of Nearest School			
Proximity to Nearest School			meters
Present Source of Lighting and monthly associated Cost			
Candle			Yes/No & NPR
Kerosene			Yes/No & NPR
Dry Cell			Yes/No & NPR
Solar Home System			Yes/No & NPR
Diesel Generator			Yes/No & NPR
Others			Please mention
Present Method of Cooking and monthly associate cost			
Fuelwood			Yes/No, kG/Lit & NPR
Biogas			Yes/No, kG/Lit & NPR
Others			Yes/No, kG/Lit & NPR
Average Monthly spending for Energy application			in NPR
Solar Home System (if any)			
Size of Solar Home System in Wp			
Year of Installation			
Financial Support			Self / AEPC / Other Donors
Cost of installed Solar Home System			
Drinking Water			

Questionnaire				
Water supply connection				Yes/No
Proximity to nearest water source				meters
Type of water Source				Tick whichever is applicable
River				
Spring				
Tap				
Reservoir				
Pond				
Health				
Name of the nearest Health Post				
Proximity to nearest Health Post				meters
Average Monthly spending on health related activates				
Record on existing health condition, if any				
Sanitation				
Availability of Toilet				Mention Yes/No
Awareness of sanitation				High/Medium/Low or No
Use of soap				Mention Yes/No
Solar Light				
Awareness of Solar lighting system				High/Medium/Low or No
Awareness of Solar Water Heating System				High/Medium/Low or No
Awareness of Solar Space Heating System				High/Medium/Low or No
Awareness of Solar Dryer				High/Medium/Low or No
Land				
Land Availability for Solar Panel, Battery and other accessories				Mention in sqm or No for unavailability
Available land for				Mention in sqm or No for unavailability
Agriculture				
Livestock				
Other Activities				
Interest in permitting land for Solar Mini Grid System				Mention Yes/No
Owner of the land/relationship to the owner				
Land Location GPS coordinates				
Technical				
Approximate distance for distribution network				meters
Proximity to nearest NEA GRID				meters
Demand of number of lights				Mention numbers and take reference of 4 watts for each room
Sun Period				
Sun Rise				Mention time in xx:xx am
Sun Set				Mention time in xx:xx pm
Load Calculation				
Proposed Load Type	Quantity	Load in Watts	Operating Hours	
Light				Ref: 3W LED
Radio				

Questionnaire	
TV	Ref: LCD/LED TV
Mobile Charger	Default 5 Watts
Other 1	
Other 2	
Other 3	
Other 4	
Other 5	
Financial	
Type of Work	
Government Job	
Agriculture	
Business	
Others	
Number of employed members	
Average Monthly HH Cash income	NPR
Average Monthly HH Cash expense	NPR
Average Monthly HH Case spend on	
Kerosene	NPR
Dry Cell	NPR
Firewood	NPR
Others	NPR
Business Type (If applicable)	
Shop	Please also specify the distance of these location to
Hotel	their HH & Grid, if any
Cottage Industry	
Others	
Potential Tariff structure & Tariff Rate	
Meter Reading	
Flat Base System	Yes/No & NPR
Others	Yes/No & NPR

TABLE 21: QUESTIONNAIRE FOR FOCUSED GROUP DISCUSSION

Questionnaire 2			
Focus Group Discussion			
Need Assessment			Note
Level of electricity need for the community			High/Medium/Low or No
Existing number of Solar Home System (SHS) users			
Current issue with existing SHS			Please specify issue
Current demand for additional electricity			High/Medium/Low or No
Community contribution			
Likelihood for community contribution			High/Medium/Low or No
Cash			Please specify the average expected cash contribution
KIND			Please specify the average expected kind contribution such as transportation from nearest road head to project site, unskilled labor and fencing.
Unskilled Human Resource			High/Medium/Low or No
Local Resource Availability			High/Medium/Low or No
Sand			
Water			
Stone			
Wood			
Aggregates			
Others			
Proposed site for Solar Mini Grid System or accessories			Please take photo and coordinate for GPS
Name of Location	Pros	Cons	
Location 1			
Location 2			
Location 3			
Location 4			
Existing source of electricity (except NEA Grid)			Mention Yes/No and Approximate Number of Installed Capacity & Units
Micro Hydro			
Institutional Solar			
Solar Home System			
Bio Mass			
Biogas			
Wind			
Expected time of use of electricity			Mention total hours
Day			
Night			
Expected demand of electricity for			Mention expected demand in kW & units demanded
Industrial application			
Agricultural application			
Service/Commercial			

Questionnaire 2			
Telecommunication			
Additional Demand of electricity			Mention expected number of units
Street Lighting			
Toilet Lighting			
Others			Mention type
Details on School Ownership			
Public			
Private			
Type of School			
Pre primary			
Primary			
Lower Secondary			
Secondary			
SLC			
Higher Secondary			
Higher Education			
Demand of Electricity for School end uses			
Computers			Mention expected number
Space heating			Mention expected size to cover space heating
Access to Internet			Mention potential users
Demand on evening study			Mention Yes/No
Income Generating Activity			
Type of IGA			
IGA 1	Potential Number of individual		
IGA 2			
IGA 3			
IGA 4			
IGA 5			
IGA 6			
Existing Market Condition			
Size of market			High/Medium/Low or No
Level of Business Skill			High/Medium/Low or No
Use of Technology & Business Application			High/Medium/Low or No
Estimated business transaction monthly			Reference from Local Cooperative
Employment			
Number of Youths			
Age Group	Male	Female	
13-19			
20-24			
Education Level			
Skill Level			
Employment Status			

Questionnaire 2	
% Indigenous (mention type)	
Development Organization	
Existing Finance Institution	
Past Activities by Finance Institution	
Existing Donor	
Past Activities by Donor	
Existing AEPC Activities	
Transportation	
Access to Road	Mention Yes/No
Type of Road Access	Black Topped/ Graveled/ Earthen/ Pedestrian
Number of Villages connected	
Availability of local transport vehicle	Mention Yes/No
Note Issues related to existing transport system/facility	
Focal Person	
Name	
Address	
Contact No.	
Email Id (if any)	

ANNEX 2- BILL OF QUANTITY- SAMPLE

PRICE SCHEDULE FOR GOODS TO BE OFFERED

Item No	Item Description	Unit of Measurement	Quantity	Unit Price (NPR)	Total Price (NPR)
	A- Power Generation Components:				
1	Solar Photovoltaic Array	kWp			
2	Three Phase Grid Tie PV Inverter with MPPT controller having in-built AC and DC surge protector	kW			
3	Off-grid Battery Inverter having feature of stackable as Master and Slave for 3-Phase Supply	kW			
4	MPPT Solar Charge Controller	kW			
5	Lithium Iron Phosphate (LiFePo4) with BMS, enclosure cabinet, cables and accessories	kWhr			
6	Solar PV Module support structure, hot dipped galvanized metal frame complete set	LS			
7	PV String Combiner Boxes with DC Fuses, DC MCBs, DC SPDs and Accessories	Set			
8	DC Combiner Boxes with DC Fuses, DC MCBs, DC SPDs and Accessories	Set			
9	DC and AC Copper Cables and Accessories	Set			
10	Grid Connected AC Combiner Box with AC MCB, AC MCCB, AC SPD & Accessories	Set			
11	Off-grid AC Combiner Box with AC MCB, AC MCCB, AC SPD & Accessories	Set			
12	DC Panel Board with DC Fuses and Accessories (Between battery bank and battery inverter)	Set			
13	AC Distribution Center with AC MCCB, ELCB, AC SPD & Accessories	Set			
14	Earthing System (Copper rod earth electrode of 2 meter length, 25mm diameter, backfill chemical compound of 25Kg and 16mm² earth cable)	Set			
15	Lightning Protection System (Air terminal, down conductor of minimum 25x3mm copper strip of 20m length, metal galvanized iron pole of 8 m, 4 inch diameter and 3 mm thickness)	Set			
16	Equipotential Bonding BusBar (Copper Earth Bus Bar with 10 connection point)	Set			
17	Control & Monitoring System with Accessories including communication router	Set			
18	Fire Extinguisher	Set			
19	Wall Fans for Powerhouse	Set			
20	Exhaust Fans for Powerhouse	Set			
21	PVC Water Tank 500Liter for Powerhouse Use	Set			
22	Office Equipments (Table, Chair, Shelf, Laptop, Printer)	Set			
	B- Power Transmission & Distribution Components				
1	PVC Insulated Copper Armoured AC Cable, 3.5 Core 120mm² (Power House to Transformer)	Meter			
2	Earthing System Complete Set for 11kV Line	Set			
3	Earthing System Complete Set for 400V and 230V Line	Set			
4	4-Pole MS Pole Tubular 16 meter 410SP-80 full galvanized for 11kV Line across the river	Nos			
5	Power Transmission 3-phase, MS Pole Tubular 11 meter 410SP-52 full galvanized	Nos			

Item No	Item Description	Unit of Measurement	Quantity	Unit Price (NPR)	Total Price (NPR)
6	Power Distribution 3-Phase, MS Pole Tubular 9 meter 410SP-29 full galvanized	Nos			
7	ACSR Conductor, Weasel for 11KV Line	Km			
8	Disc Insulators	Nos			
9	Pin Insulators	Nos			
10	Aluminum Conductor Insulated ABC Twisted Cable 4 core 95mm² for 3-Phase	Km			
11	Aluminum Conductor Insulated ABC Twisted Cable 4 core 50mm² for 3-Phase	Km			
12	Aluminum Conductor Insulated ABC Twisted Cable 2 core 35mm² for 1-Phase	Km			
13	Support Hooks (Pig Tail with Hexagonal Clamp of ABC, Pole Clamp) all complete	Set			
14	Anchor Clamp for ABC Cable	Set			
15	Piercing Connector for interconnection of service wire and Insulated ABC cable	Nos			
16	Cable Connector for dead end and clamp for ABC cable	Set			
17	Service wire, concentric 6mm²	Km			
18	150kVA Transformer and all complete set	Set			
19	Lightning Arrestor, 9kV, 10kA	Set			
20	Lightning Arrestor, 0.5kV, 1.5kA	Nos			
21	Stay Set with accessories for 16 meter Pole	Set			
22	Stay Set with accessories for 11 meter Pole - hot dipped galvanized (stay plate of area 600mm*600mm and thickness 6mm, thimble, stay wire stranded, turnbuckle and stay rod of dia 19mm, length1.8m etc all complete)	Set			
23	Stay Set with accessories for 9 meter Pole - hot dipped galvanized (stay plate of area 300mm*300mm and thickness 6mm, thimble, stay wire stranded, turnbuckle and stay rod of dia 16mm, length1.8m etc all complete). Galvanized stay wire should be stranded by 7 wires of sizes 8 SWG	Set			
24	Tool Box (Insulating Gloves, Crimping Tool, 3-phase Digital Clamp meter etc.)	Set			
25	Aluminum Foldable Pole Ladder of Extended Length Minimum 9 meter	No			
26	Pre-paid Smart Energy Meter 5-32 Amp, 230VAC 50Hz, Class 1	Nos			
27	Pre-paid Smart Energy Meter 25Amp, 400VAC 50Hz, Class 1	Nos			
28	MCB 5-16Amp DP 230VAC for Households	Nos			
29	MCB Holders Boxes for Households	Nos			
30	MCB 32Amp DP 230VAC for Households/Businesses	Nos			
31	MCB 16Amp DP 230VAC for Households/Businesses	Nos			
32	MCB Holders Boxes for Households/Businesses	Nos			
33	MCB 16Amp DP 230VAC with pole mounted distribution box of IP65	Nos			
34	MCB 16Amp DP 230VAC with pole mounted distribution box of IP65	Nos			
35	MCB 32Amp DP 230VAC for School with pole mounted distribution box of IP65	Nos			
36	MCCB 63Amp TPN for 400VAC Loads with pole mounted distribution box of IP65	Nos			
37	LED Lamp 7 Watt 230VAC	Nos			
38	LED Lamp 5 Watt 230VAC	Nos			
39	LED Street Light 230VAC 20Watt with photo sensors and mounting arms	Nos			
	Sub-total of Goods (NPR)				

PRICE SCHEDULE FOR SERVICES TO BE OFFERED

Item No	Item Description	Unit of Measurement	Quantity	Unit Price (NPR)	Total Price (NPR)
1	Erection and Installation of 16 meter Poles with Concreting Works all complete	Set			
2	Erection and Installation of 11 meter Poles with Concreting Works all complete	Set			
3	Erection and Installation of 9 meter Poles with Concreting Works all complete	Set			
4	Transformer Erection, Installation Cabling and Charging all complete	Set			
5	Conductor stringing with LA fitting (11 KV Three Phase) and line charging	Km			
6	Conductor stringing with LA fitting (Three Phase)	Km			
7	Conductor stringing with LA fitting (Single Phase)	Km			
8	Earthing set installation all complete	Set			
9	Stay set installation all complete	Set			
10	Civil works for 110kWp solar PV array foundations including material and workmanship	LS			
11	Fence for PV array & Powerhouse (Chain Link Mesh Size of 2"*2" with Iron Angle Post of 50mm*50mm*5mm size at interval of 2m c/c of height 1.5m from ground level with concrete base of 0.2m*0.2m cover & 0.5m depth)	Meter			
12	Installation, Commissioning and Testing of 110kWp Solar Mini Grid Subproject	LS			
13	Construction of Powerhouse with Truss Roof Cover as per the technical specifications (Size: 16 m * 3 m * 3 m internal height)	m^2			
14	Construction of Toilet as per the technical specification with inner dimensions (1.5m length * 1.5m width * 2m internal height)	LS			
15	Transportation of all goods from Supplier's warehouse to subproject site	LS			
16	Insurance	LS			
17	Site Development	LS			
18	Environmental and Social Management Plan (ESMP)	LS			
	Sub-total of Services (NPR)				

Summary of the Schedules, Goods and Services (Including Applicable TAX):

Schedule No.	Title	Total Price in (NPR)
A	Price Schedule for the Solar Mini Grid System Goods to be offered	-
B	Price Schedule for the Solar Mini Grid System Services to be offered	-
C	**Total (A+B)**	-
D	**Value Added Tax in applicable items (VAT) 13%**	-
E	**Grand Total in NRs (C+D)**	-

ANNEX 3 - GLOSSARY

Absorption coefficient:
The fraction of incident solar irradiance that is absorbed by a photovoltaic cell. This in turn contributes significantly to the cell temperature under operational conditions. Light with a shorter wavelength (and more energy) has a large absorption coefficient and light with a longer wavelength (and less energy) has a low absorption coefficient.

Absorption depth:
The distance into a material at which light drops to ~36.79% (or more precisely, 1/e) of its original intensity. It is the inverse of the absorption coefficient. Light with a shorter wavelength (and more energy) has a shorter absorption depth and light with a longer wavelength (and less energy) has a longer absorption coefficient.

Actual battery capacity:
Depending on how a battery's control electronics are programmed, the actual battery capacity varies from nominal capacity.

Absorbed Glass Mat:
A newer type of battery construction that uses saturated absorbent glass mats rather than gelled or liquid electrolyte. Somewhat more expensive than flooded (liquid), but offers very good reliability.

Air mass (AM):
The length which light travels through the atmosphere to reach a solar cell divided by the shortest possible length for light to travel (i.e. when the sun is directly overhead). It can be expressed as 1 divided by the cosine of the zenith angle.

Alternating current:
An electric current that reverses its direction periodically, typically at 50 or 60 hertz. In electric applications it usually has a sinusoidal waveform.

Amorphous silicon (a-Si):
The non-crystalline allotrope of silicon. It is deposited as a thin film to produce a-Si solar cells.

Amortization period:
The period of time it takes for a solar installation to pay back its initial cost. Subsequent to this period, the installation generates profit.

Ampere (A):
The SI (International System of Units) base unit of electric current. A current of one ampere is equivalent to one coulomb of electric charge going past a given point per second.

Ampere hour (Ah):
A unit of electric charge equal to 3,600 coulombs.

Angle of incidence:
The angle between the sun's rays and a line perpendicular to a given solar module's surface. Thus, a module that faces directly toward the sun has an angle of incidence of 0° and is capturing the most possible energy.

Array:
A group of multiple photovoltaic modules, usually connected to the same inverter.

Autonomous system:
A stand-alone PV system that has no back-up generating source. May or may not include storage batteries. Most battery systems are designed for a certain minimum "days of autonomy" - which means that the batteries can supply sufficient power with no sunlight to charge the batteries. This varies from 3-5 days in the Sunbelt, to 5 to 10 days elsewhere.

Azimuth:
The angle between the point on the horizon directly beneath the sun and true south.

Balance of System (BOS):
Typically this means all of the additional interconnection hardware and equipment in a solar PV system that is not considered the primary components. Primary components are solar modules, framing, inverters, and batteries. BOS is typically cables and interconnection boxes, conduits/raceways etc.

Base load:
The electricity generation resources on a given grid that operate continuously without downtime. Base load power plants only stop for maintenance or unexpected outages. Also see peak load.

Baseline performance value:
Initial values of Isc, Voc, Pmp, Imp measured by the accredited laboratory and corrected to Standard Test Conditions, used to validate the manufacturer's performance measurements provided with the qualification modules per IEEE 1262.

Battery capacity:
The amount of electric charge a battery is able to deliver at its rated voltage.

Battery management system (BMS):
Manages and optimizes the way a battery is used in a PV system. A BMS may also attempt to extend the life of the battery by preventing unfavorable operating conditions such as deep discharge and overcharge.

Bi-directional inverter:
An inverter that functions in both directions. Thus, it can draw AC power from the grid and feed it as DC power into the battery, on top of its regular function of converting DC power from the PV modules or battery into AC power.

Blocking diode:
A diode wired in series with PV modules and a battery. It allows energy to pass from the modules into the battery, but prevents energy from the battery flowing back out into the modules.

Busbars:
Strips of conductive metal that run along PV cells to carry electric charge.

Bypass diode:
A diode that allows current to pass around one or more shaded cells if they are receiving less sunlight than other cells, thus preventing hot spots from occurring.

Cathodic protection:
A method of preventing oxidation (rusting) of exposed metal structures, such as bridges and pipelines, by imposing between the structure and the ground a small electrical voltage that opposes the flow of electrons and that is greater than the voltage present during oxidation.

C-rate:
A measure of how quickly a battery, with regards to its capacity, is discharged. A C-rate of C10 means the battery discharges completely within ten hours. The energy available to be drawn is also dependent on the C-rate.

Cell:
A photoelectric cell which generates an electric current when exposed to light, usually from the sun. Cells are connected and packaged into a solar photovoltaic module.

Cell efficiency:
The percentage of incident energy in the form of sunlight reaching a solar cell that is converted into electrical output.

Charge controller:
limits the rate at which electric current is fed to or drawn from a battery or storage system, in order to prevent overcharging and overvoltage, which may damage a battery or reduce its lifespan.

Degradation:
The process of a solar module losing efficiency as it is exposed to the elements over time. Common contributors to degradation include reduced adherence of contacts or corrosion due to water vapor; metal migration through the p-n junction; and deterioration of the anti-reflection coating.

Deep discharge:
Discharging a battery to 20-percent or less of its full charge.

Depth of discharge (DOD):
The battery capacity that has been discharged, expressed as a percentage of maximum capacity. A discharge to at least 80% is termed as a deep discharge.

Diffuse radiation:
solar radiation (i.e. sunlight) that has been scattered by particles in the Earth's atmosphere. On overcast days with significant cloud cover, direct sunlight is reduced meaning that most visible light is diffuse radiation. Some solar modules perform better than others in diffuse light conditions. Also see direct radiation and reflected radiation.

Diode:
A semiconductor device with two terminals, which allows current to flow in one direction only. The anode is the electrode through which current flows into the diode, and the cathode is the electrode through which current flows out of the diode. Note that electron flow is, by convention, opposite to the electric current, so electrons flow from the anode toward the cathode.

Direct current (DC):
An electric current flowing in one direction only.

Direct radiation:
solar radiation (i.e. sunlight) that hits the earth without being scattered by clouds or particles in the Earth's atmosphere. Also see diffuse radiation.

Distributed systems:
Systems that are installed at or near the location where the electricity is used, as opposed to central systems that supply electricity to grids. A residential photovoltaic system is a distributed system.

Dual-axis tracking:
Tracking that tilts on both the up-down axis and left-right axis. Also see tracking.

Economic payback:
The time taken for a solar photovoltaic system to have paid off all its system costs with the income it has generated. Subsequent to the economic payback period, the system is then generating profits for its owner.

Efficiency of a battery:
Typically this is a value expressed as a percentage which illustrates the losses in discharging and recharging a battery or battery bank, as a battery ages the efficiency will decrease, this is demonstrated through more power being lost during discharge, and more power being used during recharge. When batteries are new the efficiency will be higher, when batteries are old the efficiency will be lower, at a certain point, the battery efficiency is so poor that it is better to replace the batteries.

Electrolyte:
A chemical compound that ionizes when dissolved or molten to produce an electrically conductive liquid or gel.

Energy payback:
The time it will take for a solar photovoltaic system to generate an equal amount of energy to that which was used in its construction and mounting. Subsequent to the energy payback period, the system is generating excess electricity for its owner.

Equalization:
An overcharge performed on a flooded lead acid battery that is fully charged, in order to remove sulfate crystal build-up on the plates and reverse various other negative chemical effects. Various manufacturers recommend equalization anywhere from monthly to yearly.

Export tariff:
An added payment for electricity that is exported to the grid, rather than consumed on-site.

Feed-in tariff (FIT):
An economic policy designed to promote active investment in renewable energy technologies. Typically a FIT comprises long-term contracts that guarantee a certain price for energy from renewable sources. Often they are different depending on the type of renewable energy technology utilized.

Flat-plate PV:
Refers to a PV array or module that consists of no concentrating elements. Flat-plate arrays and modules use direct and diffuse sunlight, but if the array is fixed in position, some portion of the direct sunlight is lost because of oblique sun-angles in relation to the array.

Float:
Charging energy into a battery at the same rate as its self-discharge rate, hence keeping it in a fully charged state. Also called float charge or trickle charge.

Fuel cell:
A device that converts the energy of a fuel directly to electricity and heat, without combustion. Because there is no combustion, fuel cells give off few emissions; because there are no moving parts, fuel cells are quiet.

Generation capacity:
The maximum rated output of all the inverters in a power plant. Also see nameplate capacity.

Gel-type battery:
Lead-acid battery in which the electrolyte is composed of a silica gel matrix.

Gigawatt (GW):
A unit that is equal to one billion watts. See watt.

Gigawatt hour (GWh):
A unit that is equal to one billion watt hours. See watt hour.

Gigawatt peak (GWp):
A unit that is equal to one billion watts peak. See watt peak.

Grid:
An interconnected electricity network for delivering electricity to consumers.

Grid-connected adj.:
Used to describe a photovoltaic system that is connected to the grid, as opposed to an off-grid system.

Grid-tied adj.:
See grid-connected.

Ground loop:
An undesirable feedback condition caused by two or more circuits sharing a common electrical line, usually a grounded conductor.

Hybrid system:
A system that combines more than one type of energy generation (e.g. solar and wind).

Inverter:
An electrical power converter that takes direct current (DC) as an input and outputs alternating current (AC).

Insolation:
The amount of solar radiation falling upon a given area, usually measured in watt hours per square meter (Wh/m^2).

Irradiance:
The power of electromagnetic radiation per unit area falling on a given surface, usually measured in watts per square meter (W/m^2).

Irradiation:
See insolation.

I-V curve:
A graphical presentation of the current versus the voltage from a photovoltaic device as the load is increased from the short circuit (no load) condition to the open circuit (maximum voltage) condition. The shape of the curve characterized cell performance.

I-V data:
The relationship between current and voltage of a photovoltaic device in the power-producing quadrant, as a set of ordered pairs of current and voltage readings in a table, or as a curve plotted in a coordinate system.

Junction box:
A PV generator junction box is an enclosure on the module where PV strings are electrically connected and where protection devices can be located, if necessary.

Junction diode:
A semiconductor device with a junction and a built-in potential that passes current better in one direction than the other. All solar cells are junction diodes.

Kilowatt (kW):
A unit that is equal to one thousand watts. See watt.

Kilowatt hour (kWh):
A unit that is equal to one billion watt hours. See watt hour.

Kilowatt peak (kWp):
A unit that is equal to one billion watts peak. See watt peak.

Large-scale adj.:
Used to describe a solar photovoltaic installation above a specified capacity, which varies depending on the market but typically in tens or hundreds of kilowatts.

Levelized cost of energy (LCOE):
The price at which electricity generated from a given source must be sold in order for the project to break even over its lifetime. This factors in all the costs over a project's lifetime and makes it possible to compare the cost of different energy generation technologies.

Light-induced defects:
Defects, such as dangling bonds, induced in an amorphous silicon semiconductor upon initial exposure to light.

Load simulation:
A process carried out by a computer program that models a PV system and a building's energy requirements, so as to optimize the size of the system.

Low-light conditions:
Conditions in which there is little solar radiation. These conditions are also simulated in photovoltaic module testing procedures.

Maximum continuous discharge current:
The maximum current at which a battery can be discharged continuously. This is usually defined by the manufacturer to prevent excessive discharge rates that can damage the battery or reduce its capacity.

Maximum power point tracking (MPPT):
The process of optimizing the power output of a solar photovoltaic system to work most effectively with a storage system or grid, via the use of a DC to DC converter.

Maximum power point tracking charge controller:
A high frequency DC to DC converter that optimizes the current and voltage output of a photovoltaic system to maximize the current, and thus power, fed into the battery. Also see maximum power point tracking.
Megawatt: A unit that is equal to one million watts. See watt.

Megawatt hour (MWh):
A unit that is equal to one million watt hours. See watt hour.

Megawatt peak (MWp):
A unit that is equal to one billion watts peak. See watt peak.

Module:
A packaged, interconnected assembly of solar cells.

Module efficiency:
The efficiency at which a module converts incident sunlight into electric energy. For example, if 100 watts of sunlight hits a module's surface and it outputs 20.1 watts of electric energy, then it has a module efficiency of 20.1%. Note that a module's efficiency is always slightly lower than the efficiency of each of the cells that make it up, mainly due to the unused spaces between cells.

Mono-like adj.:
describes a type of crystalline silicon ingot used to manufacture solar cells, which is largely monocrystalline, although with some polycrystalline regions. The technology was first developed by BP in 2006 and produces cells with higher efficiencies than polycrystalline silicon at lower costs than monocrystalline silicon.

Monocrystalline silicon (mono-Si):
Silicon in a crystalline lattice that is completely unbroken and continuous to its edges.

Monolithic:
Fabricated as a single structure.

Monosilicon:
See monocrystalline silicon.

Mounting system:
The components that fasten solar modules in place, whether it be on a roof, carport, facade or the ground. This includes mounting racks, cross beams, fasteners, clamps and any other components which function solely to mount solar photovoltaic modules.

Multicrystalline silicon:
See polycrystalline silicon.

n-type cell:
A solar cell made from the rarer n-type silicon instead of the more dominant p-type silicon. Both types of cell are derived from a silicon feedstock, although during crystallization phosphorus is used as a dopant to produce n-type silicon crystals, whereas boron is usually used to produce p-type silicon crystals. The advantages of n-type cells are that they do not suffer from light-induced degradation (LID) and they are less sensitive to impurities present in the silicon feedstock.

Nameplate capacity:
The total rated power output of all photovoltaic panels in a power plant. This is the theoretical maximum output of the panels in a power plant, but in practice this is rarely, if ever, reached. Also see generation capacity.

Net metering:
A government policy in various electricity markets that allows generation of renewable energy to feed electricity into the grid at a set price. Most net metering policies reimburse the generator with either the retail rate, a fraction of the retail rate, or compensation at avoided cost.

NOCT:
Nominal Operating Cell Temperature. The solar cell temperature at a reference environment is defined as 800 W/m^2 irradiance, 20°C ambient air temperature, and 1 m/s wind speed with the cell or module in an electrically open circuit state. Nominal battery capacity: Amount of electrical charge that can be stored without taking into account that it should not be discharged to 100%.

Nominal voltage:
The reference voltage of a battery.

Off-grid adj.:
Used to describe a renewable electricity generating system which is not connected to the electricity grid.

On-grid adj.:
Used to describe a renewable electricity generating system which is connected to the electricity grid and can feed electricity into the grid.

One-axis tracking:
See single-axis tracking.

Open circuit voltage (VOC):
The difference in electrical potential between the two terminals of a battery or solar cell when it is not connected to an external load. In the case of a solar cell, it is the maximum voltage available, which occurs at zero current.

p-type cell:
A solar cell made from the more dominant p-type silicon instead of the rarer n-type silicon. Both types of cell are derived from a silicon feedstock, although during crystallization boron is usually used to produce p-type silicon crystals, whereas phosphorus is used as a dopant to produce n-type silicon crystals. The advantages of p-type cells are that they are less sensitive to cosmic rays, which meant they were much better suited toward space applications such as satellites. Thus, p-type solar cells have become the dominant technology in the market. Also see n-type cell.

Panel:
See module.

Panel efficiency:
See module efficiency.

Parallel connection:
A way of joining two or more electricity-producing devices (i.e., PV cells or modules) by connecting positive leads together and negative leads together; such a configuration increases the current.

Payback time:
This term is used in the context of solar photovoltaics to refer to either the time taken for the energy payback or the time taken for the economic payback of a given solar system. See energy payback and economic payback.

Peak load:
The electricity generation resources on a given grid that operate intermittently. These include resources such as wind and solar energy that are unpredictable, and peaking power plants that are only run at times of high demand, such as during summer afternoons when the use of air conditioning increases.

Peak saving:
The process of shifting electricity consumption from periods of peak demand, when the electricity prices are also at their peak, to off-peak periods in order to consume the same amount of electricity for a lower cost. This can be achieved by scheduling certain energy-intensive devices, such as dishwashers, washing machines or dryers, to run in off-peak periods.

Phase shifting transformer:
A device that controls the power flow through various lines in an electrical grid in order to prevent overload. It does this by inserting a voltage with a selected phase angle into the power system, which can redirect power to more desirable pathways that are less at risk of overload.

Photovoltaic (PV):
Pertaining to the direct conversion of light into electricity.

Photovoltaic (PV) array:
An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module.

Photovoltaic (PV) cell:
The smallest semiconductor element within a PV module to perform the immediate conversion of light into electrical energy (dc voltage and current).

Photovoltaic (PV) conversion efficiency:
The ratio of the electric power produced by a photovoltaic device to the power of the sunlight incident on the device.

Photovoltaic (PV) efficiency:
The ratio of electric power produced by a cell at any instant to the power of the sunlight striking the cell. This is typically about 9% to 14% for commercially available cells.

Photovoltaic (PV) generator:
The total of all PV strings of a PV power supply system, which are electrically interconnected.

Photovoltaic (PV) module:
The smallest environmentally protected, essentially planar assembly of solar cells and ancillary parts, such as interconnections, terminals, [and protective devices such as diodes] intended to generate DC power under concentrated sunlight. The structural (load carrying) member of a module can either be the top layer (superstrate) or the back layer (substrate).

Photovoltaic (PV) panel:
Often used interchangeably with PV module (especially in one-module systems), but more accurately used to refer to a physically connected collection of modules (i.e., a laminate string of modules used to achieve a required voltage and current).

Photovoltaic (PV) peak watt:
Maximum "rated" output of a cell, module, or system. Typical rating conditions are 0.645 watts per square inch (1000 watts per square meter) of sunlight, 68 degrees F (20 degrees C) ambient air temperature and 6.2 x 10-3 mi/s (1 m/s) wind speed.

Photovoltaic (PV) system:
A complete set of components for converting sunlight into electricity by the photovoltaic process, including the array and balance of system components.

Photovoltaic-thermal (PV/T) system:
A photovoltaic system that, in addition to converting sunlight into electricity, collects the residual heat energy and delivers both heat and electricity in usable form. Also called a total energy system.

Polycrystalline silicon (poly-Si):
A material made up of small silicon crystals. Unlike monocrystalline silicon, it is not continuous and unbroken.
Polysilicon n. See polycrystalline silicon (poly-Si).

Power conversion system (PCS):
A system used to convert electric energy from one form to another, either by converting from direct current to alternating current, altering the voltage or frequency, or incorporating a number of these processes. Examples of power conversion systems include DC to DC converters, inverters and voltage stabilizers.

Power management system (PMS):
A management platform that governs energy distribution in a photovoltaic system, which may also include energy storage and can be on or off-grid. A power management system controls when energy is sent to or drawn from the battery, how energy is harvested from the photovoltaic system, and when energy is sent to or drawn from the grid.

Power-to-weight ratio:
See specific power.

Power factor:
The ratio of the average power and the apparent volt-amperes. Affected by the inductance and capacitance of the load. A pure resistance, such as an electric heater would have a power factor of 1.00.

Pulse-width-modulated (PWM):
A function of many of the newer charge controllers and battery chargers which instead of applying a steady DC voltage to the battery, sends out short pulses. The width of the pulses varies with the battery state of charge.

PV:
Abbreviation for photovoltaic(s).

Pyranometer:
An instrument used to measure hemispherical solar radiation on a given plane.

Pyrheliometer:
An instrument used to measure solar direct normal irradiance (DNI) on a given plane.

Qualification test (PV):
A procedure applied to a selected set of PV modules involving the application of defined electrical, mechanical, or thermal stress in a prescribed manner and amount. Test results are subject to a list of defined requirements.

Reactive power:
The power in an alternating current electric network that is temporarily stored in inductors and capacitors and returned back to the network, also known as volt-ampere reactive (VAR) power. Reactive power strongly influences voltage levels across the entire electric network.

Resistance (Ω):
The opposition of a material, usually a conductor, to the flow of electric current. Resistance is measured in ohms (Ω).

Resistive voltage drop:
The voltage developed across a cell by the current flow through the resistance of the cell.

Reflected radiation:
Solar radiation that has reflected off non-atmospheric things, such as trees, terrain, buildings or the ground. Also see direct radiation and diffuse radiation.

Self-discharge:
The rate at which a battery, without a load, will lose its charge. This can vary considerably depending on the type of battery and age. It can be as low as 3% a month for a new AGM battery, and as high as 10% a week for an older Lead-Antimony (industrial) battery.

Series connection:
A way of joining photovoltaic cells or batteries by connecting positive leads to negative leads; such a configuration increases the voltage.

Series resistance:
Parasitic resistance to current flow in a cell due to mechanisms such as resistance from the bulk of the semiconductor material, metallic contacts, and interconnections.

Shelf life of batteries:
The length of time, under specified conditions, that a battery can be stored so that it keeps its guaranteed capacity.

Shading:
The shadows that fall upon a given solar photovoltaic system from surrounding objects such as trees or buildings.

Shadowing:
See shading.

Short-circuit current (Isc).
The current flows freely from a photovoltaic cell through an external circuit that has no load or resistance; the maximum current possible.

Solar energy:
Energy from the sun. The heat that builds up in your car when it is parked in the sun is an example of solar energy.

Solar noon:
That moment of the day that divides the daylight hours for that day exactly in half. To determine solar noon, calculate the length of the day from the time of sunset and sunrise and divide by two. Solar noon may be quite a bit different from 'clock' noon.

Solar spectrum:
The total distribution of electromagnetic radiation emanating from the sun.

Single-axis tracking:
Tracking on one axis to tilt a solar array toward the sun, so as to maximize solar irradiation and hence energy output. Single-axis trackers can be oriented on a horizontal, vertical or tilted axis, depending on the application.

Stand-alone (PV system):
An autonomous or hybrid photovoltaic system not connected to a grid. May or may not have storage, but most stand-alone systems require batteries or some other form of storage.

Stand-off mounting:
Technique for mounting a PV array on a sloped roof, which involves mounting the modules a short distance above the pitched roof and tilting them to the optimum angle.

Standard Test Conditions (STC):
An industry standard for measuring the DC power output of solar modules. The module is placed in a flash tester with a temperature of 25°C, an air mass of 1.5 and the equivalent of 1,000 W/m² of sunlight intensity.

State of charge (SOC):
The present battery capacity expressed as a percentage of the maximum capacity.

Stand-alone system:
An off-grid system, usually in an area which is not serviced by any electrical grid. See off-grid.

String:
A group of solar modules connected in series in order to obtain a higher voltage. A number of strings are then connected in parallel in order to generate a greater current.

Sulfation:
The reaction of lead and lead dioxide with sulfuric acid in a lead-acid battery, producing lead sulfate, which reduces the battery's capacity and performance. Sulfation is most common in batteries left discharged for long periods and can be mitigated by recharging a battery as soon as possible after a discharge cycle.

Temperature coefficient:
The rate of change of a solar module's power output as a function of its operating temperature. As a module's temperature rises, its efficiency diminishes due to the drop in open circuit voltage. This effect is more pronounced in silicon-based solar cells than thin film-based solar cells.

Temperature cycling:
See thermal cycling.

Thermal cycling:
A testing process which involves subjecting a solar photovoltaic module to rotating hot and cold cycles in order to test its durability under normal climatic conditions. The current International standard test (IEC 61215) defines five major visual defects that may arise as a result of thermal cycling: broken, cracked or torn external surfaces; bent or misaligned external surfaces; a crack in a cell that could remove more than 10% of that cell's area from the electrical circuit of the module; bubbles or delamination between the electrical circuit and the module edge; and loss of mechanical integrity.

Tracker:
A device that tilts a solar array over the course of the day, so as to orient it toward the sun and maximize energy yield. Also see single-axis tracking and dual-axis tracking.

Transformer substation:
A large transformer for either stepping up or stepping down the voltage in an electric grid.

Tracking array:
See tracker.

Thin film:
A thin layer of photovoltaic material (for example, amorphous silicon or cadmium telluride) that is then deposited onto a substrate or wafer. In terms of market share, thin film solar cells are the main competitors to the much more dominant crystalline silicon solar cells.

Tilt:
The degree of the angle by which a module is tilted relative to a horizontal plane parallel to the earth's surface. In general, PV arrays should be tilted toward the average elevation of the sun for a given latitude. Fixed arrays are non-adjustable and must be installed at the optimum position for year-round production, whereas adjustable mounting systems allow system operators to adjust the tilt for various seasons as the sun's angle changes.

Two-axis tracking:
See dual-axis tracking.

Utility-interactive inverter:
An inverter that can function only when tied to the utility grid, and uses the prevailing line-voltage frequency on the utility line as a control parameter to ensure that the PV system's output is fully synchronized with the utility power.

Utility-scale:
See large-scale.

Voltage drop:
The loss of electrical potential (i.e. voltage) that occurs across the conductive elements of an electrical system, resulting in loss of electrical energy. Voltage drop can also cause inverters to function less effectively or stop functioning altogether.

Watt (W):
A derived unit in the International System of Units (SI) for measuring power. One watt is the rate at which work is done when one ampere (A) of current flows through an electric potential difference of one volt (V). Also see gigawatt, megawatt, and kilowatt.

Watt hour (Wh):
A unit of energy that is equal to one watt of power expended for one hour of time. Also see gigawatt hour, megawatt hour, and kilowatt hour.

Watt peak (Wp):
A measure of the maximum power output of a photovoltaic device or system under standard test conditions (STC). In practice, these nameplate capacities are rarely reached due to less than ideal conditions, module degradation, imperfect alignment of the module in tilt or azimuth, and a less than ideal temperature. Also see nameplate capacity.

Zenith angle:
The angle between the center of the sun and a line that is perpendicular to a horizontal plane at the earth's surface. Thus, if the zenith angle is 0° then the sun is directly overhead and if it is 90° then the sun will be on the horizon and soon after sunrise or soon before sunset.

ANNEX 4 - WIND GLOSSARY

Airfoil:
The cross section profile of the leeward side of a wind generator blade, designed to provide low drag and good lift. Also found on an airplane wing.

Anemometer:
An instrument used to measure the velocity, or speed, of the wind.
Angle of attack. The angle of relative air flow to a wind turbine's blade.

Armature:
The moving part of an alternator, generator or motor. In many alternator designs, it carries the magnets and is attached to the blades and hub. Also called a Rotor.

Availability factor:
The percentage of time that a wind turbine is able to operate and is not out of commission due to maintenance or repairs.
Average capacity (also known as capacity factor): A measure of a wind turbine's productivity, calculated by the amount of power that a wind turbine produces over a set time period, divided by the amount of power that would have been produced if the turbine had operated at full capacity during that same time interval.

Average wind speed (velocity):
The mean wind speed over a specified period of time.

Balancing:
Adjusting wind turbine blades' weight and weight distribution through two axes so that all blades are the same. Unbalanced blades create damaging vibration.

Blades:
The flat panels on a wind turbine that are connected to a center shaft that converts the push of the wind into a circular motion in a wind turbine.

Braking system:
A device to slow a wind turbine's shaft speed down to safe levels (electrically or mechanically).

Capacity factor:
See average capacity.

Chord:
The width of a wind turbine blade at a given location along the length.

Commercial scale wind:
Wind energy projects greater than 100 kilowatts in which the electricity is sold rather than used on-site. This category includes large arrays of 100 or more turbines owned by large corporations and a single locally-owned wind turbine greater than 100 kilowatts in size.

Cut-in speed:
The wind speed at which the turbine blades begin to rotate and produce electricity, typically around 10 miles per hour.

cut-out speed:
The wind speed, usually around 55 to 65 miles per hour, at which some wind turbines automatically stop the blades from turning and rotate out of the wind to avoid damage to the turbine.

Distributed generation:
A small-scale power generation technology that provides electric power at a site closer to customers than central power plant generation. The term is commonly used to indicate non-utility sources of electricity, including facilities for self-generation.

Downwind turbine:
Refers to a horizontal-axis wind turbine in which the hub and blades point away from the wind direction; the opposite of an upwind turbine.

Furling:
The act of a wind generator yawing out of the wind, either horizontally or vertically, to protect itself from high wind speeds.

Grid-connected system:
A residential electrical system, such as solar panels or wind turbines, which is connected to the electric utility system. The utility system serves as a backup source of electricity if the residential system is not producing power.

Guy anchor:
A concrete or metal base that secures wind tower guy wires to the earth.

Guy wire:
A strong metal cable or wire that attaches some towers (typically those of small residential wind turbines) to the ground.

Horizontal axis wind turbine:
A wind turbine design in which the shaft (axis of rotation) is parallel to the ground and the blades are perpendicular to the ground.

Hub:
The central part of the wind turbine, which supports the turbine blades on the outside and connects to the low-speed rotor shaft inside the nacelle.

Hub height:
Measuring from the ground, the tower height of the hub, or central part of a horizontal-axis wind turbine.

Hybrid system:
The combination of multiple energy-producing technologies such as photovoltaic solar electric systems combined with small wind turbine systems.

Installed capacity:
The total capacity of electrical generation devices in a system.

Met tower:
A tower with a group of instruments (including anemometers and wind vanes) attached that collectively measure various meteorological parameters such as wind speed, wind direction, and temperature at various heights above the ground. The term met is short for meteorological.

Nacelle:
The structure at the top of the wind turbine tower just behind (or, in some cases, in front of) the wind turbine blades. It houses the key components of the wind turbine, including the rotor shaft, gearbox and generator.

Peak wind speed:
The maximum instantaneous wind speed (or velocity) that occurs within a specific time period.

Power curve:
A graphic displaying the instantaneous power output of a specific turbine design at various wind speeds; used with wind resource data to determine the potential for electricity generation at a project site.

Rated wind speed:
The wind speed at which a wind turbine reaches its nameplate-rated level of power production. For most small wind turbines, this is around 30 to 35 miles per hour.

Rotor:
The visible spinning parts of a wind turbine, including the turbine blades and the hub.

Start-up speed:
The wind speed at which a wind turbine rotor starts to rotate. The turbine does not necessarily produce any power until the wind reaches cut-in speed.

Thrust bearing:
A bearing that is designed to handle axial forces along the centerline of the shaft; in a wind generator, the axial force is the force of the wind pushing back against the blades.

Tower:
The base structure that supports and elevates a wind turbine rotor and nacelle.

Turbine:
A device for converting the flow of a fluid (air, steam, water or hot gases) into mechanical motion that can be utilized to produce electricity.

Twist:
In a wind generator blade, the difference in pitch between the blade root and the blade tip. Generally, the twist allows more pitch at the blade root for easier startup and less pitch at the tip for better high-speed performance.

Utility-scale wind:
Wind energy projects greater than 100 kilowatts in capacity in which the electricity is sold rather than used on-site. This category includes large arrays of turbines owned by corporations and a single locally-owned wind turbine greater than 100 kilowatts in size.

Vane:
A large, flat piece of material used to align a wind turbine rotor correctly into the wind. Usually mounted vertically on the tail boom. Sometimes called a tail.

Variable pitch turbine:
A type of wind turbine rotor where the attack angle of the blades can be adjusted either automatically or manually.

Vertical axis wind turbine:
A wind generator design in which the rotating shaft (axis of rotation) is perpendicular to the ground and the cups or blades rotate parallel to the ground.

Wind monitoring system:
An instrument or group of instruments (including anemometers and wind vanes) that collectively measure various meteorological parameters, such as wind speed, wind direction and temperature at various heights above the ground.

Wind power class:
A system designed to rate the quality of the wind resource in an area, based on the average annual wind speed. The scale ranges from 1 to 7 with 1 being the poorest wind energy resources and 7 representing exceptional wind energy resources.

Wind resource:
The wind energy available for use based on historical wind data, topographic features and other parameters.
Wind resource assessment: The process of characterizing the wind resource and its energy potential for a site of geographical area. Wind resource maps for the U.S. are available here.

Wind rose:
A circular plot used to portray certain characteristics about wind speed and direction observed at a monitoring location.

Wind shear:
A term and calculation used to describe how wind speed increases with height above the surface of the earth. The degree of wind shear is a factor of the complexity of the terrain as well as the actual heights measured. Wind shear increases as friction between the wind and the ground becomes greater. Wind shear is not a measure of the wind speed at a site.

Wind speed:
The rate at which air particles move through the atmosphere, commonly measured with an anemometer.

Wind vane:
A device used to measure wind direction.

Windmill:
A device that uses wind power to mill grain into flour. Informally used as a synonym for wind generator or wind turbine, and to describe machines that pump water with wind power.

Yaw:
The rotation of a horizontal-axis wind turbine about its tower or vertical axis