Rooftop Solar PV Project Planning, Design, Installation, and Operations and Maintenance Manual

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List of Abbreviations

AC	-	Alternating current
CCT	-	Condominium Certificate of Title
DAS	-	Distribution Assets Study
DC	-	Direct current
DIS	-	Distribution Impact Study
DOE	-	Department of Energy
DPWH	-	Department of Public Works and Highways
DSOAR	-	Distribution Services and Open Access Rules
DU	-	Distribution utility
ECE	-	Electronics and Communications Engineer
ERC	-	Energy Regulatory Commission
FI	-	Financing institution
IEC	-	International Electrotechnical Commission
ISO	-	Organization for Standardization
kW	-	Kilowatt
kWh	-	Kilowatt-hour
LGU	-	Local government unit
ME	-	Module efficiency
MPP	-	Maximum power point
NBCDO	-	National Building Code Development Office
NEA	-	National Electrification Administration
NGCP	-	National Grid Corporation of the Philippines
NM	-	Net-Metering
NPC	-	National Power Corporation
NREB	-	National Renewable Energy Board
OBO	-	Office of Building Official
pa	-	Per annum
PCAB	-	Philippine Contractors Accreditation Board
PEE	-	Professional Electrical Engineer
PIOU	-	Privately-owned investor utility
PRC	-	Professional Regulation Commission
PV	-	Photovoltaic
QE	-	Qualified end-user
RA	-	Republic Act
RE	-	Renewable energy
REE	-	Registered Electrical Engineer
RES	-	Renewable energy system
RME	-	Registered Mechanical Engineer
ROI	-	Return on investment
RPS	-	Renewable Portfolio Standard
STC	-	Standard test conditions
TCT	-	Transfer Certificate of Title
UPS	-	Uninterrupted power supply

Acknowledgements

This Rooftop Solar PV Project Planning, Design, Installation, and Operations and Maintenance Manual was made possible under the UNDP DREAMS project with the Philippine Department of Energy in cooperation with the International Copper Association, CORE, ACMEE, and the support of the Provincial Government of Iloilo for conducting the pilot training for its local government units.

1 Introduction

1.1 Background

The UNDP and DOE through the DREAMS project has completed the Iloilo Provincial Renewable Energy Plan (I-PREP). This is a pilot project towards the "localization" of renewable energy policies and programs as contained in the National RE Plan 2020-2040. The I-PREP project aims to strengthen the capacity of local government units in Iloilo in contributing to the achievement of national renewable energy targets. I-PREP itself is a long-term plan that will serve as a tool in fulfilling this role.

Integrated in the I-PREP is the Capacity Building Plan that seeks to address gaps in the capacity of the Iloilo Provincial Government (IPG) and Iloilo LGUs in renewable energy policy, planning, regulation, permitting, and project development. In this regard, the capacity building plan recommends short-term and continuing training programs based on Training Needs Assessment that was conducted as part of the I-PREP.

One of the short-term trainings identified during the consultations with the LGUs and Electric Cooperatives is a "Training on Net Metering and Electrical Safety Inspection of Rooftop Solar PV Systems". Part of the outputs of the training is the development of this training manual to help training personnel in conducting the solar training for their respective areas in the promotion of solar technology for clean energy generation and in establishing safety standards for the design, installation, operation, and maintenance of the PV system.

The development of the content of this manual was coordinated with the International Copper Association (ICA) and the Cornerstone of Rural Electrification (CORE). The Association of City and Municipal Electrical Engineers and Electricians (ACMEEE) were also be consulted in the training design and the preparation of the manual. ICA and CORE provided advisory and expert services in the design and implementation of the training program using this manual.

1.2 Objectives of the Rooftop Solar PV Training Manual

The Solar PV Training Manual will be used be technical trainings personnel to manage the design and implementation of the training program. There are two general training objectives using this manual.

The first objective is to increase the knowledge of Technical Staff of LGUs Engineering Office and Office of Building Official (OBO) on the regulatory requirements of net metering and installing rooftop solar PV systems in general and build their capacity in electrical safety inspection based on the requirements of the Philippine Electrical Code, National Building Code, and Philippine Green Building Code.

The next objective it to teach the technical aspects on the basics of rooftop solar PV design and installation and in-depth knowledge and skills in rooftop solar PV project planning, operation, and maintenance in view of ongoing and planned rooftop solar PV projects that will be owned and operated by the LGUs.

1.3 Using this Training Manual

This training manual can be used in developing training programs for Solar PV rooftop implementation. The manual uses PowerPoint slides with narratives that can be used by the trainer to explain the slides. Other references can be used by the trainer for further explain the topics. Hands-on checklists are also provided with instructions on how this will be filled by the trainees with the practical activities to be conducted.

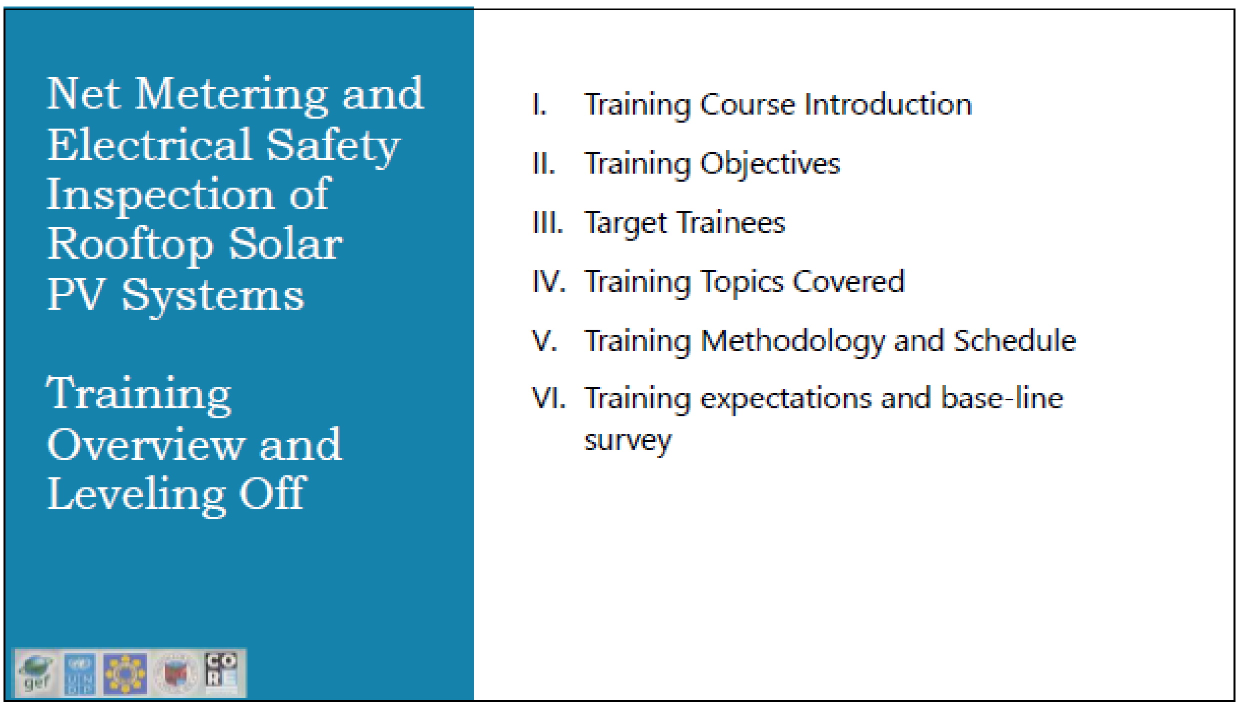
The participants targeted for this training are technical personnel from the offices of the municipal or city planning and development, engineering, and building officials. These are the personnel that are involved in the planning, design, procurement, installation, inspection, permitting, commissioning, operation, and maintenance of the solar PV installations of the LGUs. However, this manual was designed to be used for all technical personnel that have roles in the implementation of solar PV rooftops projects in general.

2 Lecture Training Materials

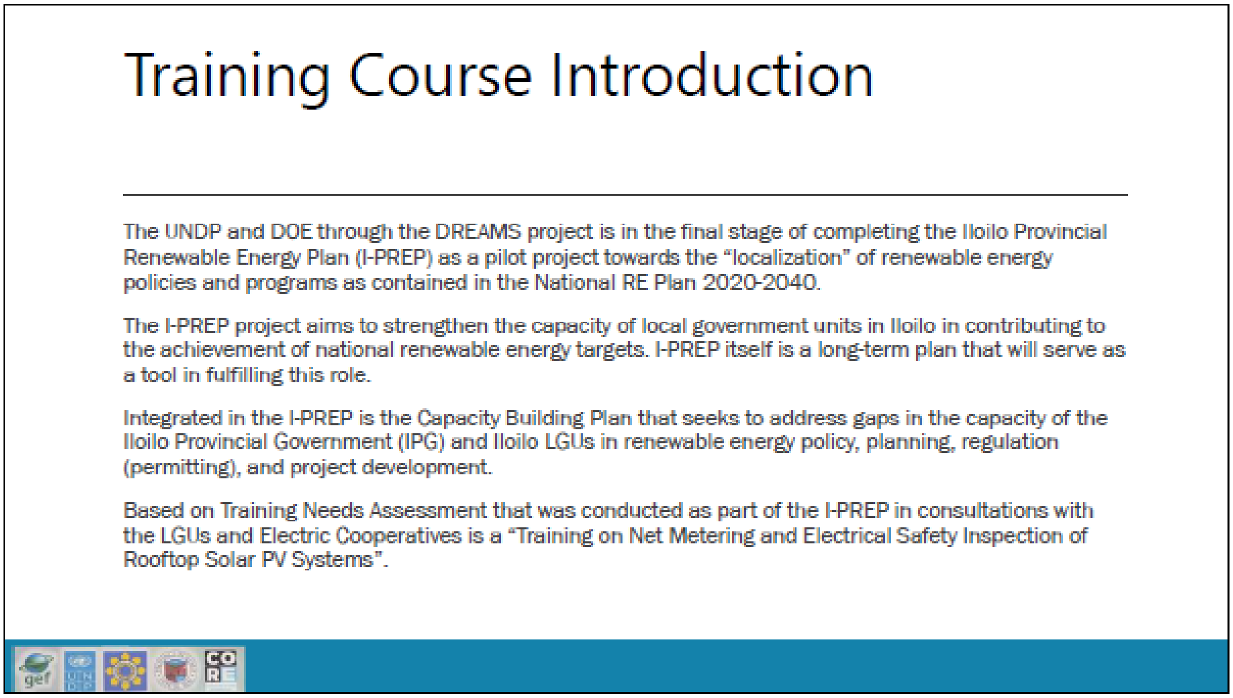
These training materials are composed of Power Point slides and presentation notes that the trainer can use in its lecture. Additional materials can be used to supplement the information provided in the slides. There are five sets of slides that can be used per lecture session with two sets of slides that will be used for the actual inspection of the solar installation. The lecture slides are recommended to the used in the sequence provided for the progression of the knowledge shared to the trainees.

2.1 Session 1 – Training Introduction

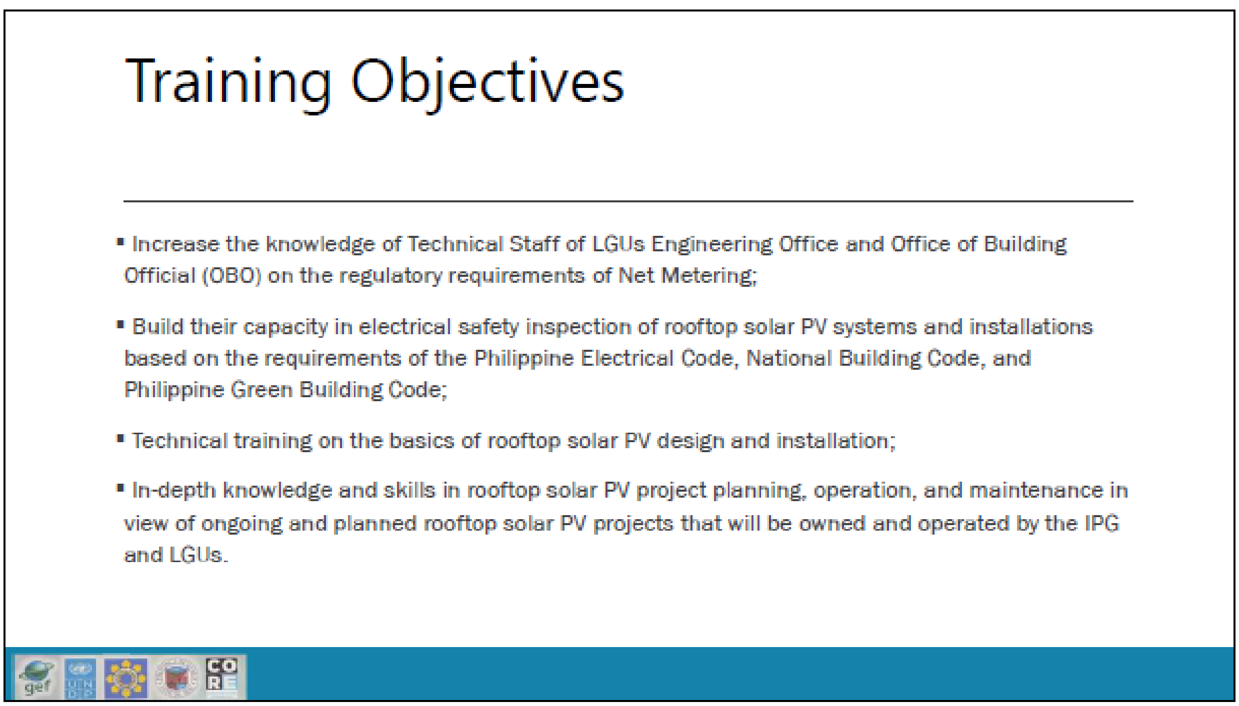
This is the training course introduction that shows the contents of the training.



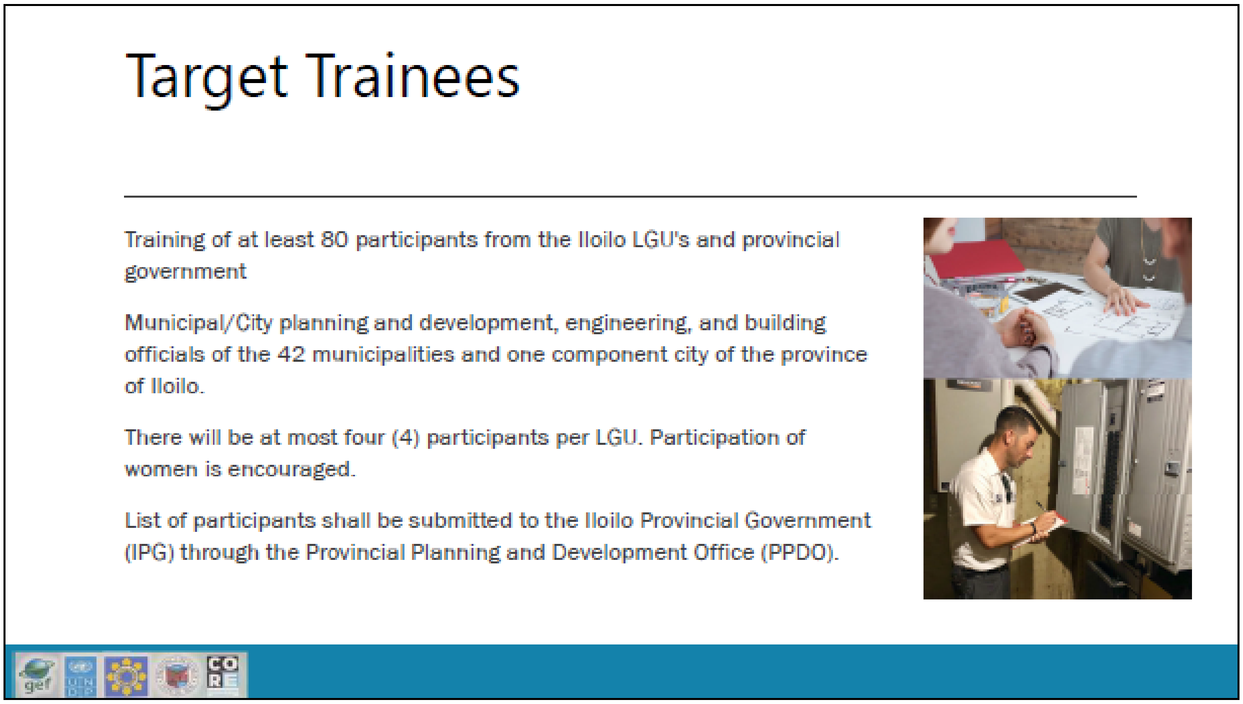
The outline provides the coverage of the training with Training Course Introduction, Objectives, Target Trainees, Training Topics Covered, Training Methodology and Schedule, Training expectations and base-line survey.



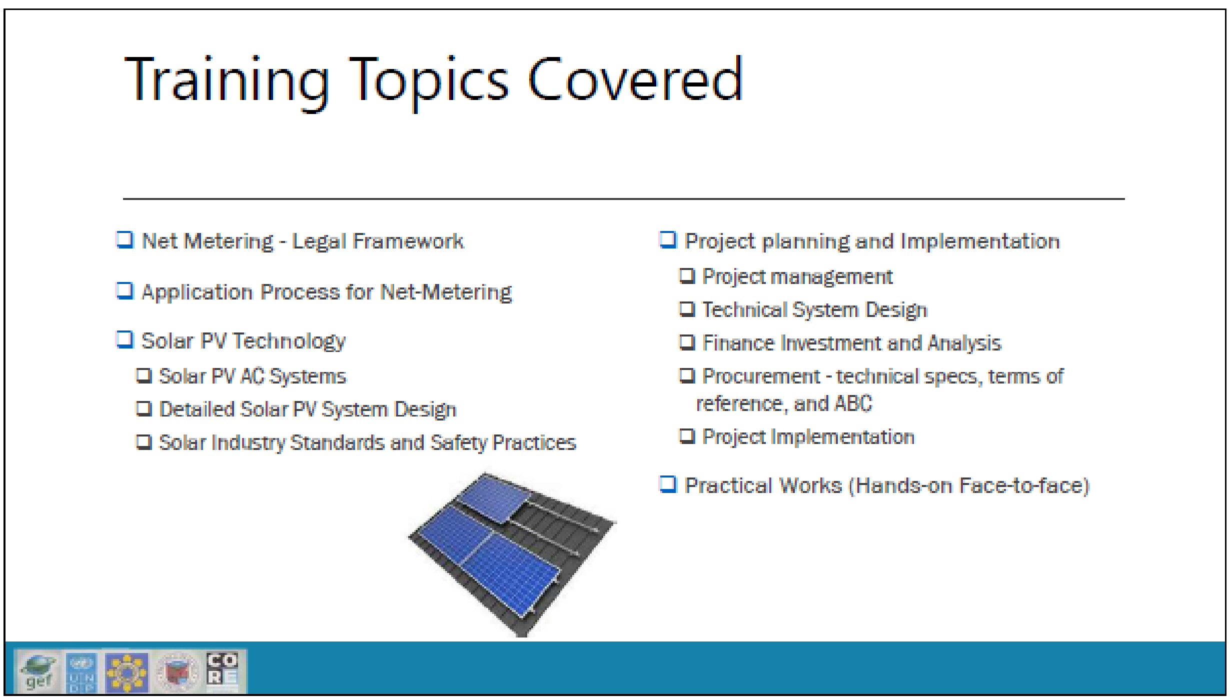
The background of the training course is presented as a result the UNDP DREAMS project with the Iloilo Provincial Renewable Energy Plan (I-PREP) as a pilot project towards the "localization" of renewable energy policies and programs as contained in the National RE Plan 2020-2040.



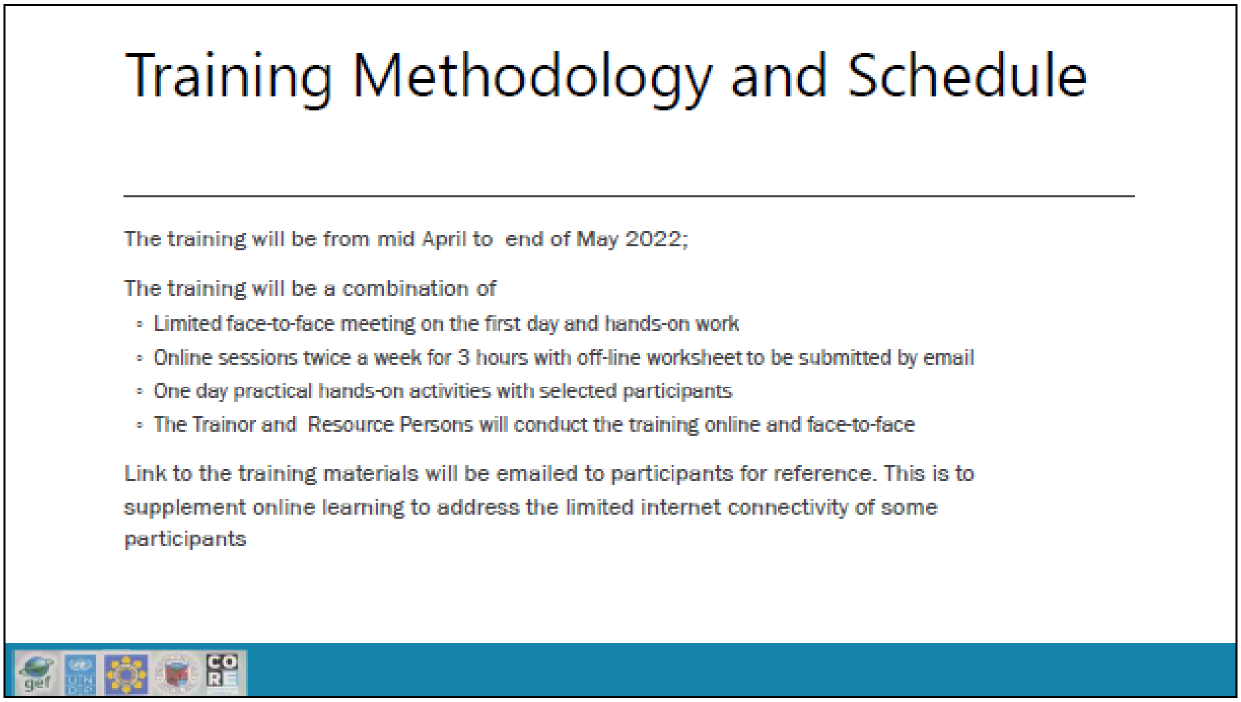
The training objective is to build capacity for the LGU staff on the regulatory requirements for Net Metering and solar rooftop technology.



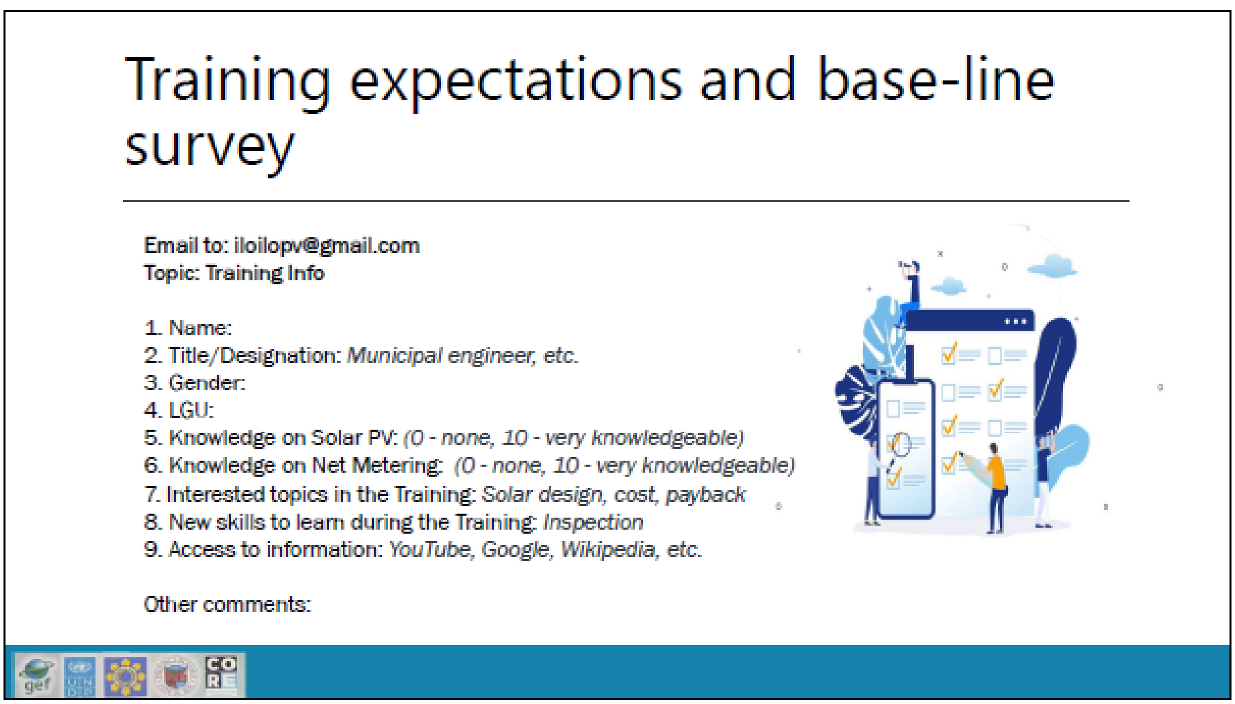
The target trainees were the technical staff of the LGUs in Iloilo province. Specific target groups can also be trained using these training materials.



The training covers the policy framework for the Net Metering scheme as well as the technical aspects of solar rooftop technology planning, design, implementation, and actual hands-on inspection.



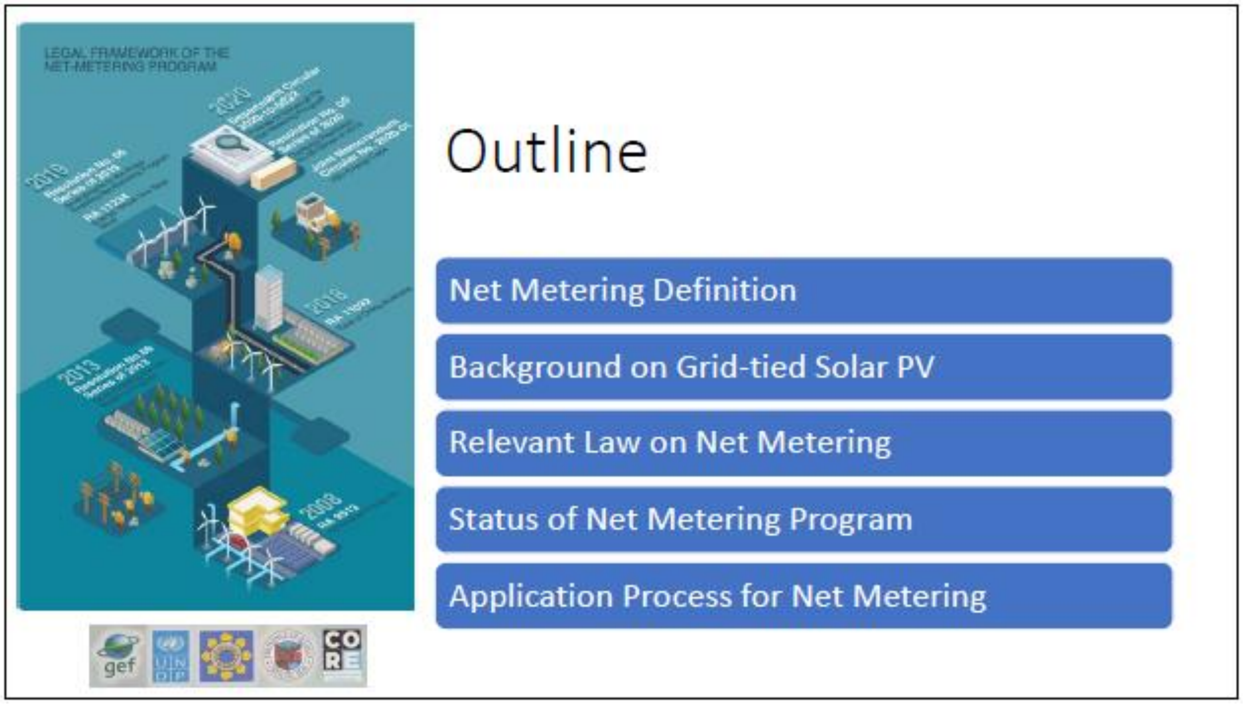
The training was designed with online lectures with limited face-to-face hands-on activities. The online lectures were limited to three hours with a break in the middle to avoid stress on the part of the online participants. Lectures can be extended when conducted on a face-to-face setting. Online materials were also made available for the participant to download as references.



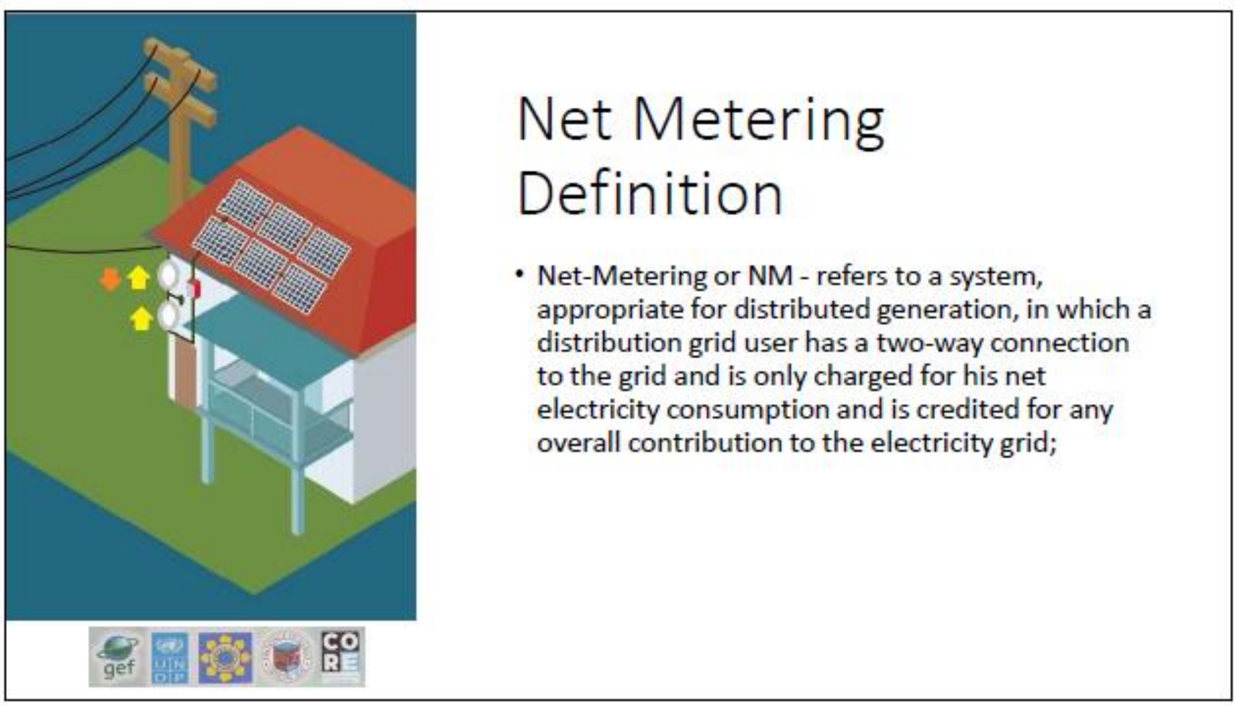
An online survey is conducted to have a baseline information on the level of knowledge and interest of the participants. It also seeks the topics and skills that the participants wanted to gain during the training.

2.2 Session 2 - Net Metering Legal Framework

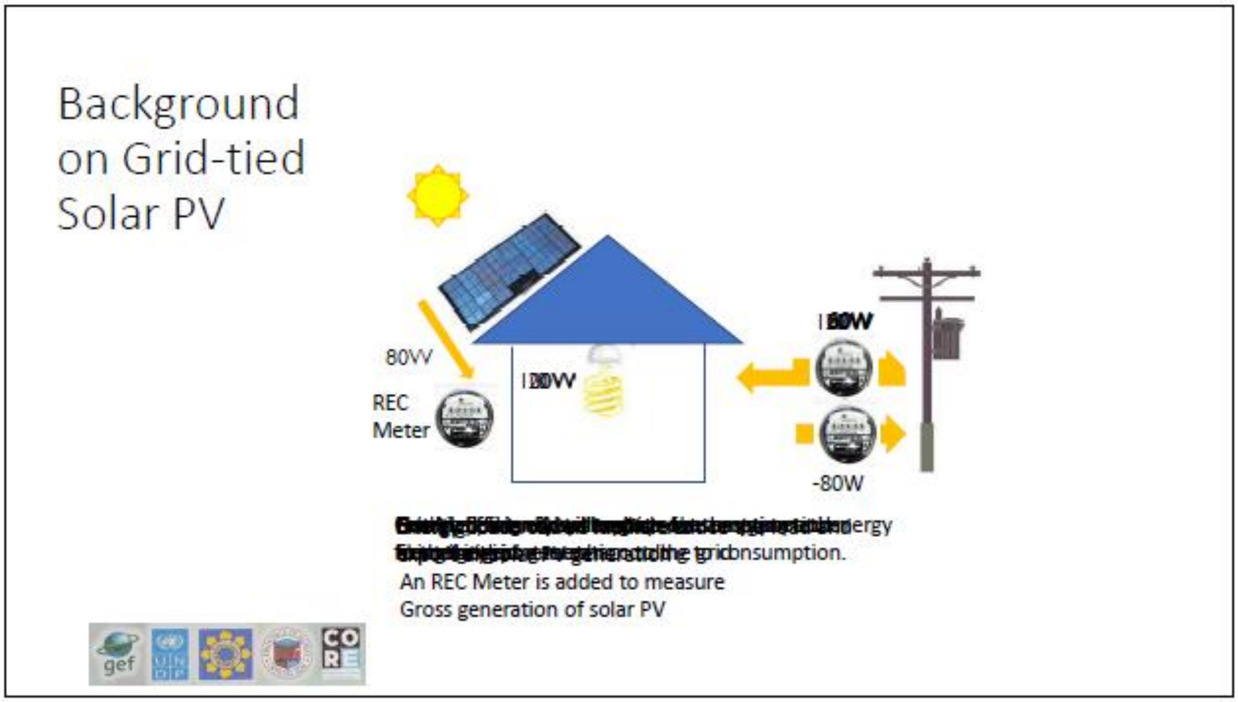
This session focuses on the policy and legal framework as the basis for Net Metering



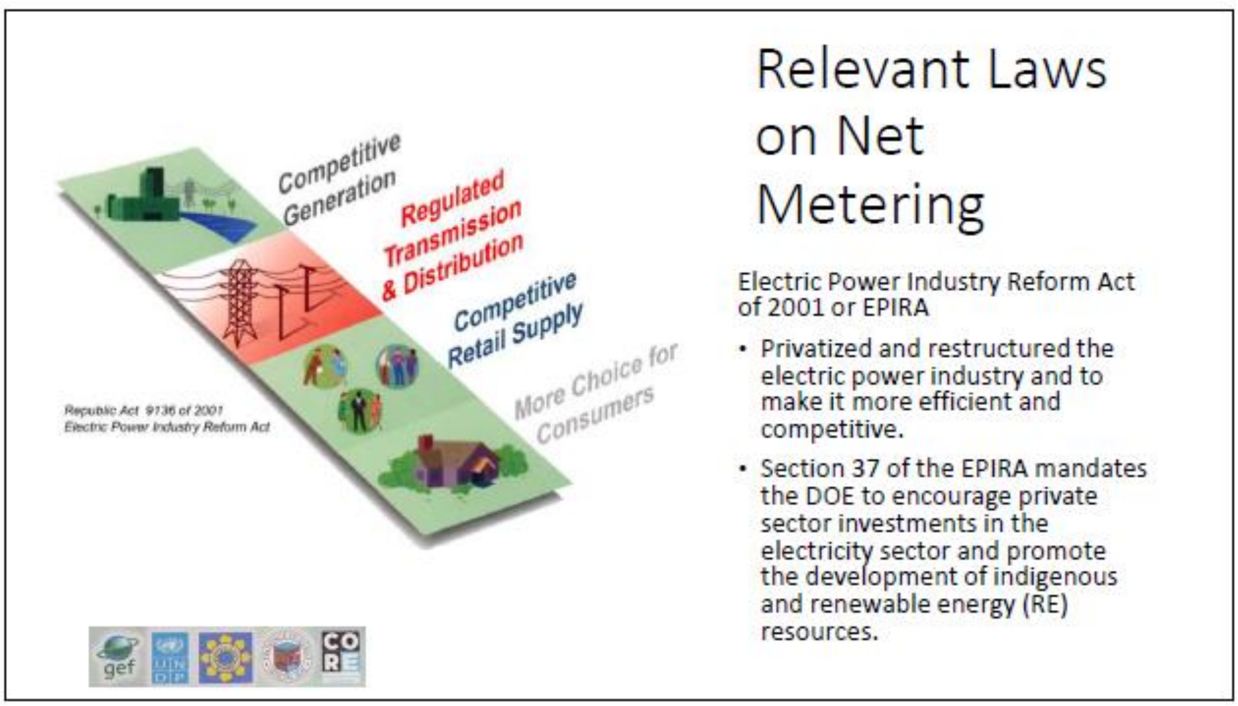
The outline for this session



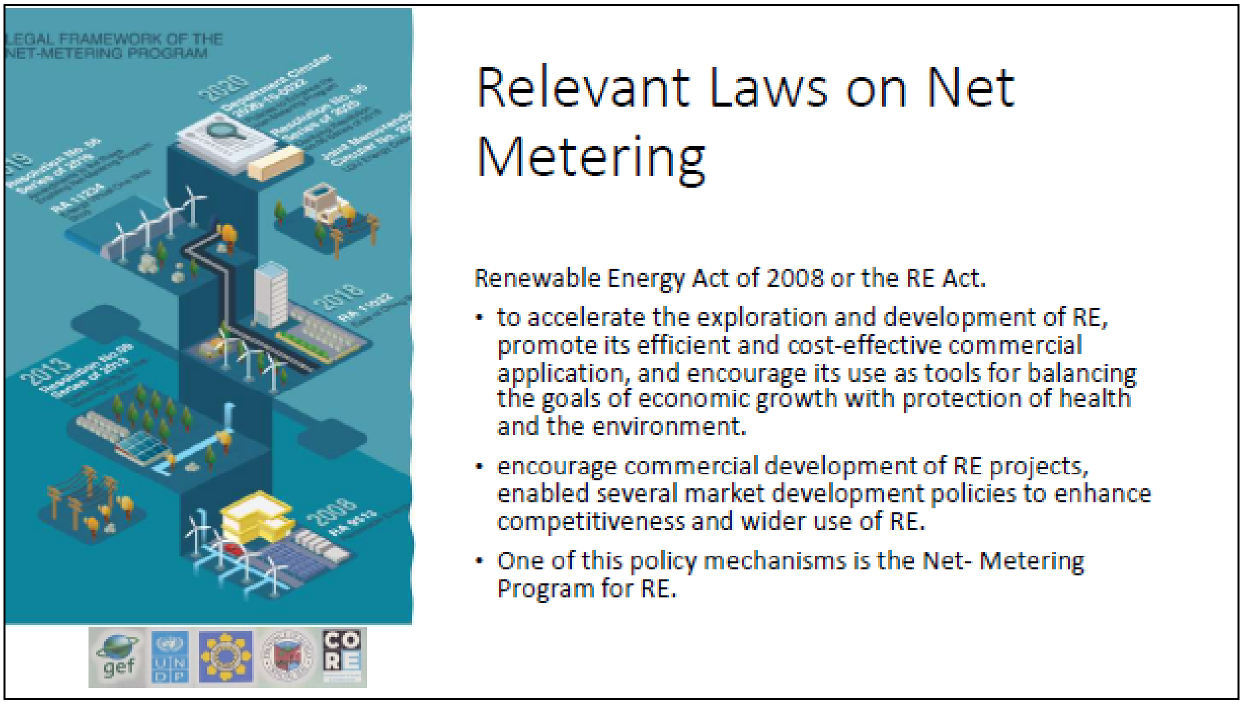
This slide provides the definition of Net Metering as defined in the Renewable Energy Law of 2008.



This animated slide illustrates the basic principle of how electricity is delivered to the house by the electric utility, energy efficiency measures using efficient lighting, and the use of solar energy under the Net Metering program.

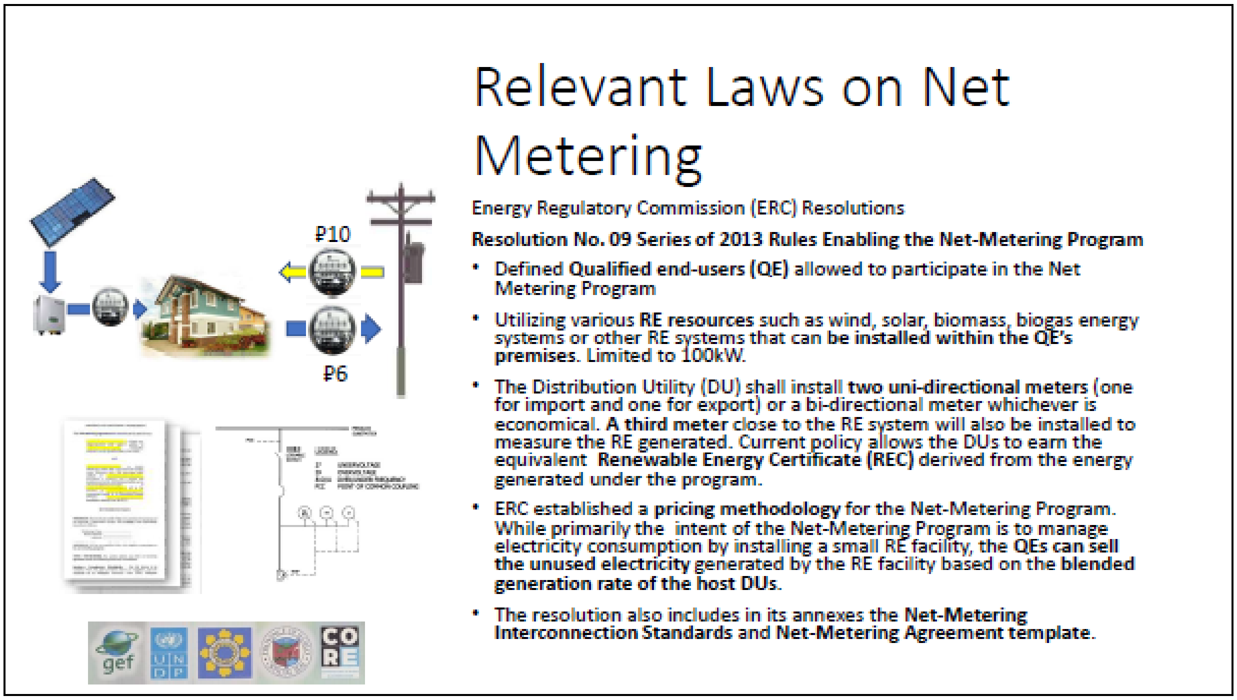


A deeper introduction to the Philippine energy industry is explained under the EPIRA.

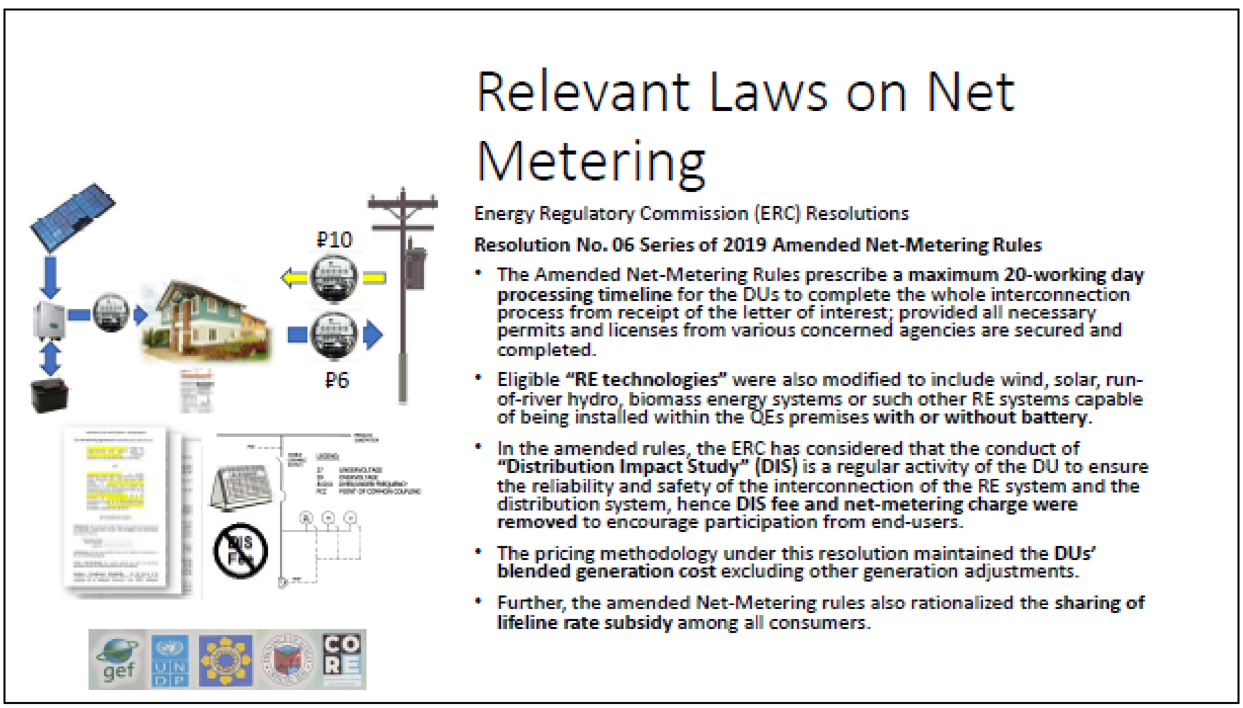


Net Metering is explained as part of the RE Act of 2008

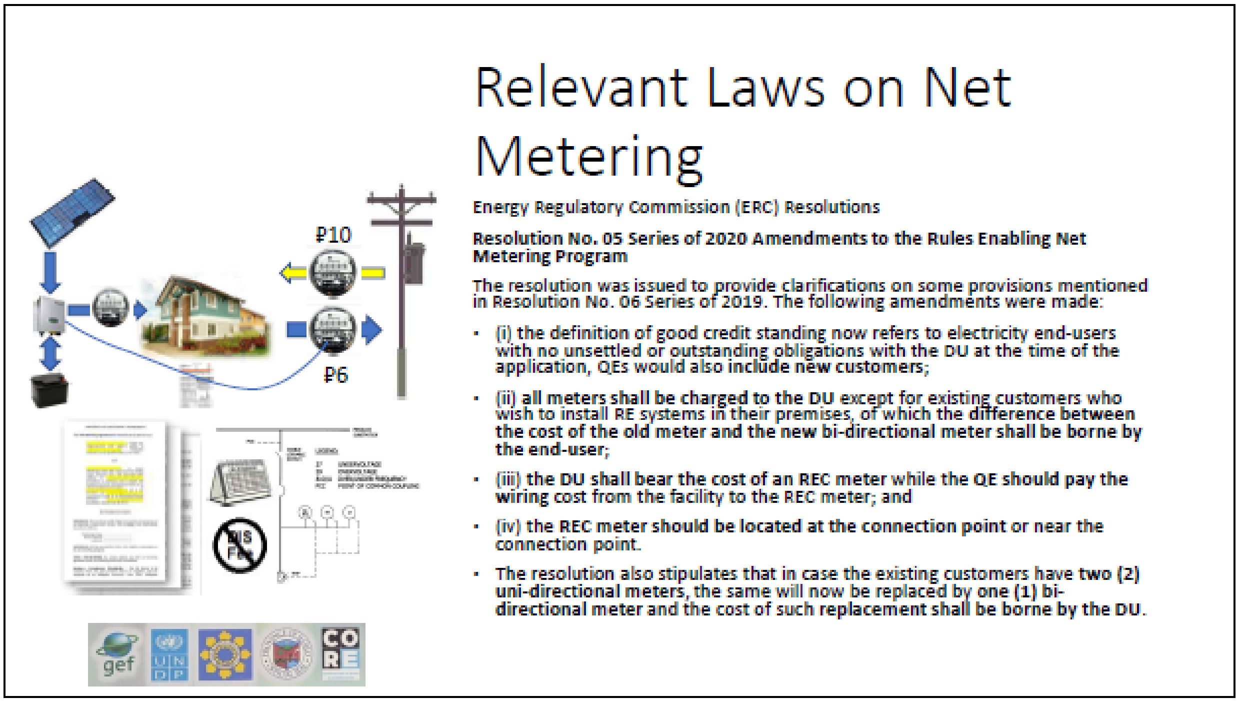
An animated video of the renewable energy sources and their applications is presented. BIGSHOW is used to remember the major renewable energy sources namely Biomass and biogas, Geothermal, Solar, Hydro, Ocean, and Wind energy



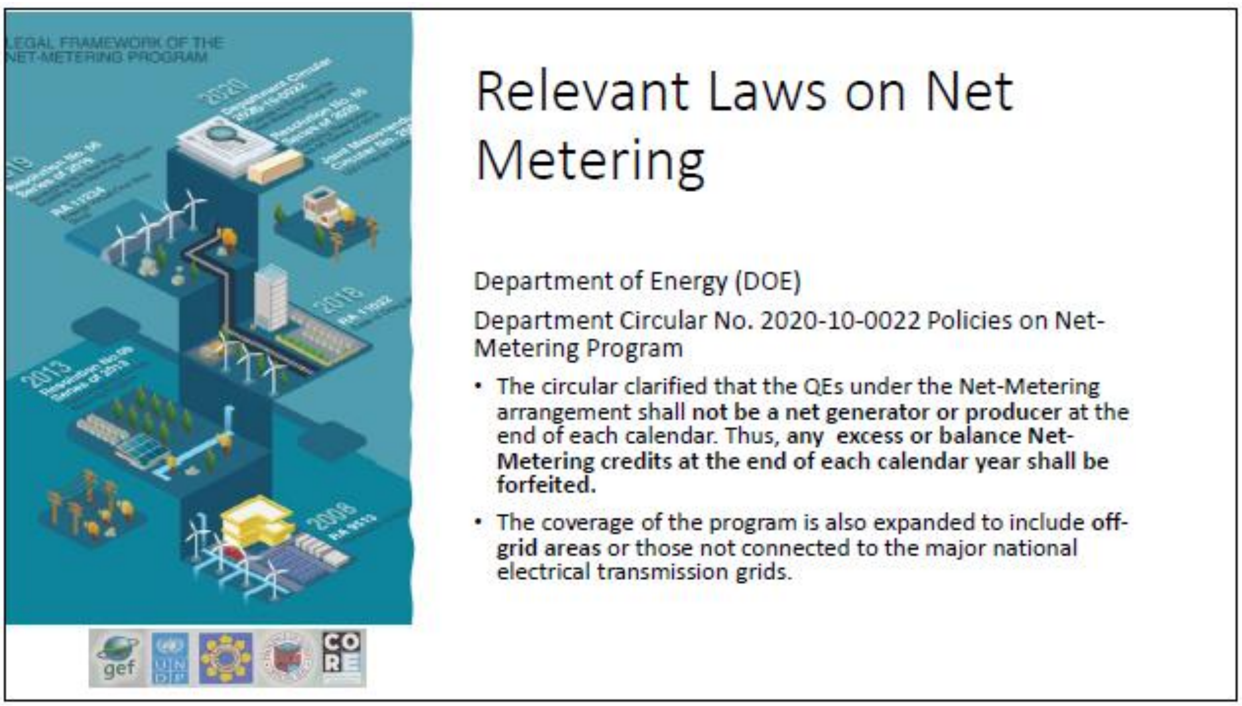
The ERC Resolution No.9 Series of 2013 provided the initial guideline in the implementation of Net Metering. The capacity of PV systems under Net Metering is 100kW.



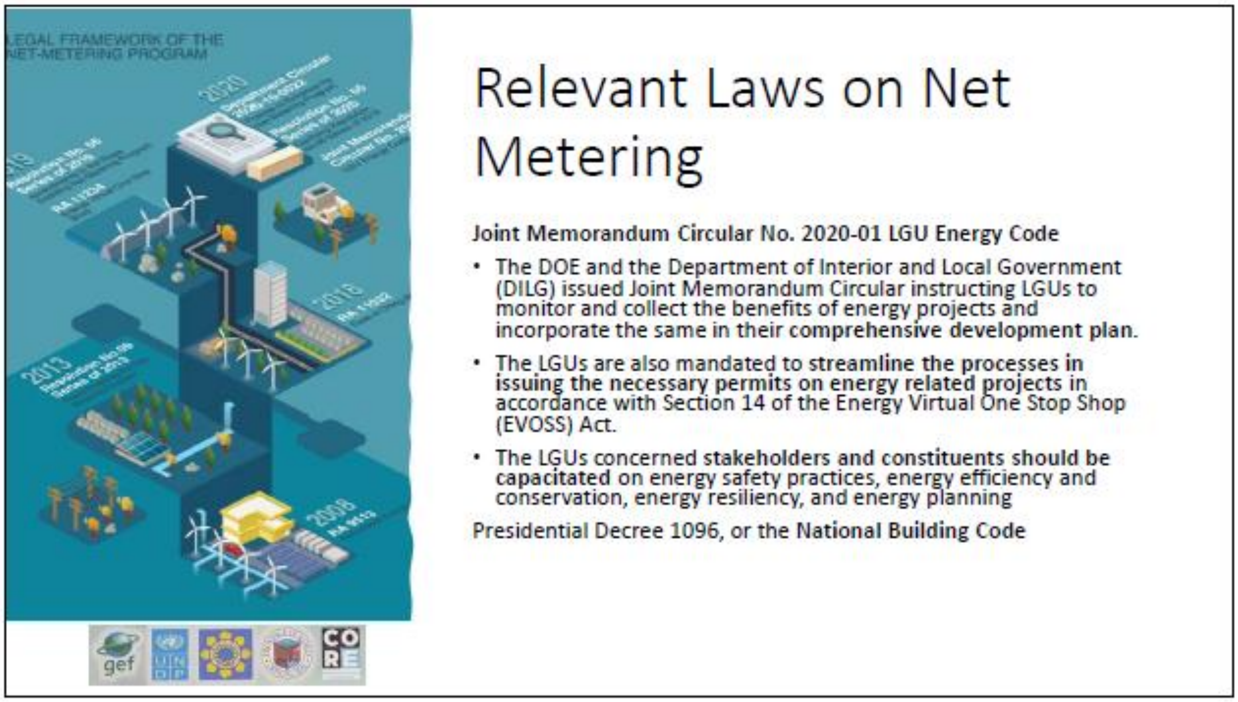
Amendment to the Net Metering rules were provided by ERC Resolution No.6 Series of 2019.



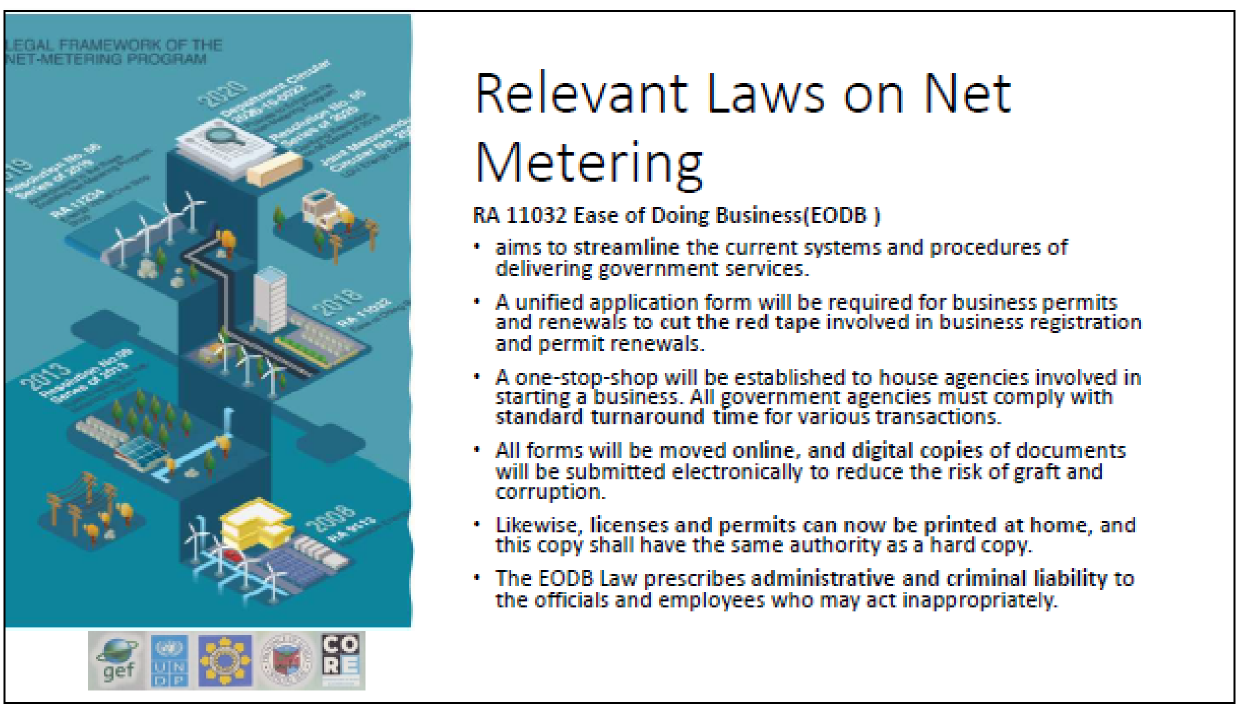
The Net Metering rules were further amended by ERC Resolution No.5 Series of 2020.



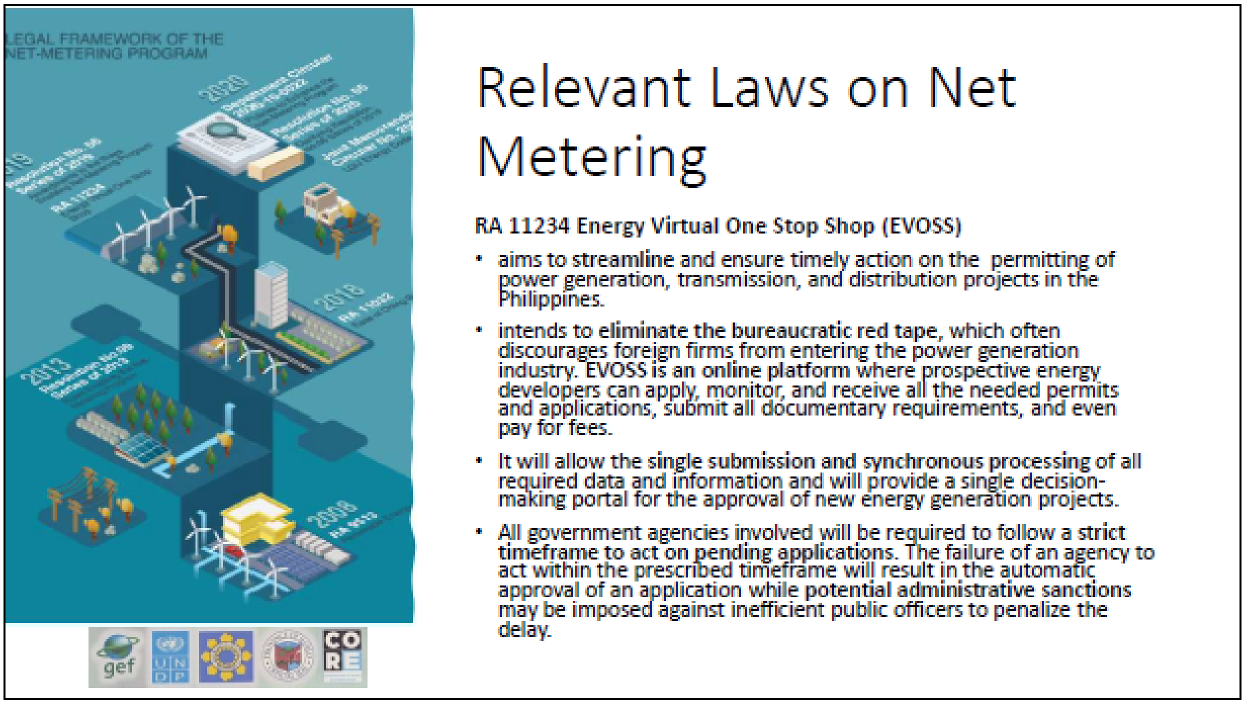
The Department of Energy issued the Department Circular No. 2020-10-0022 Policies on Net-Metering Program emphasizing that Net Metering Qualified End users should be net consumers and has further expanded Net Metering to off-grid areas.



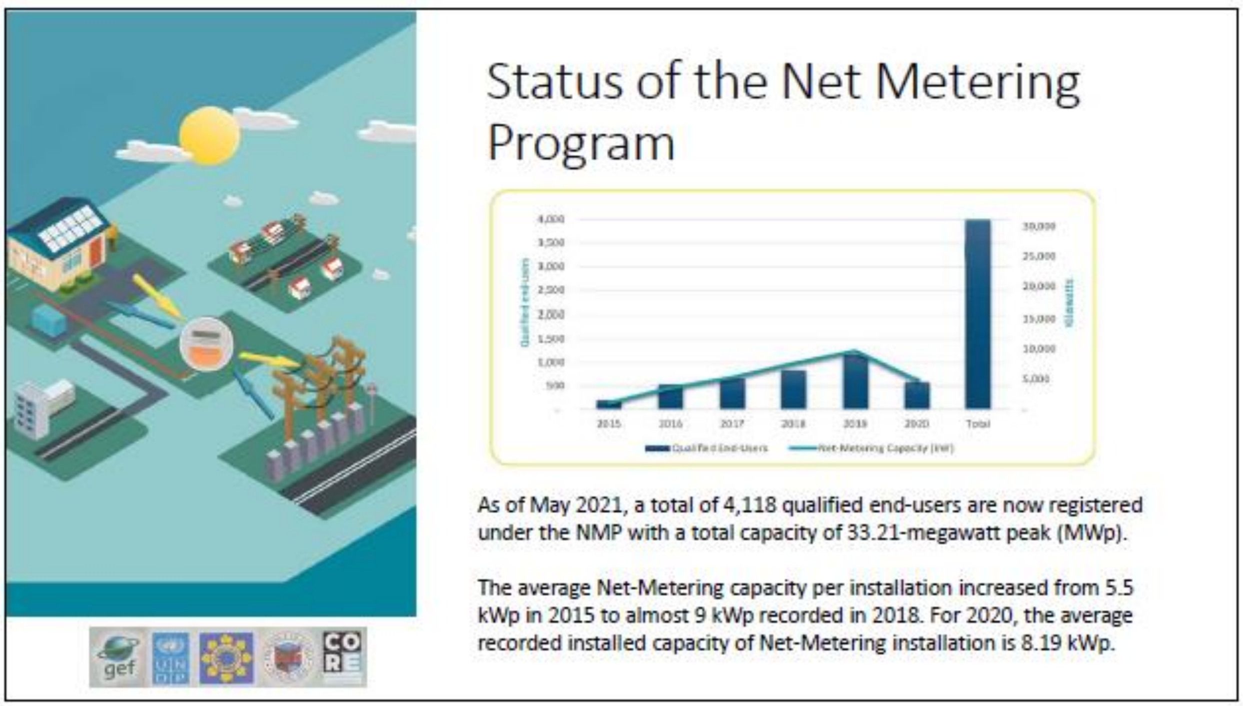
A Joint Memorandum Circular No. 2020-01 LGU Energy Code between DOE and DILG was issued supporting Net Metering.



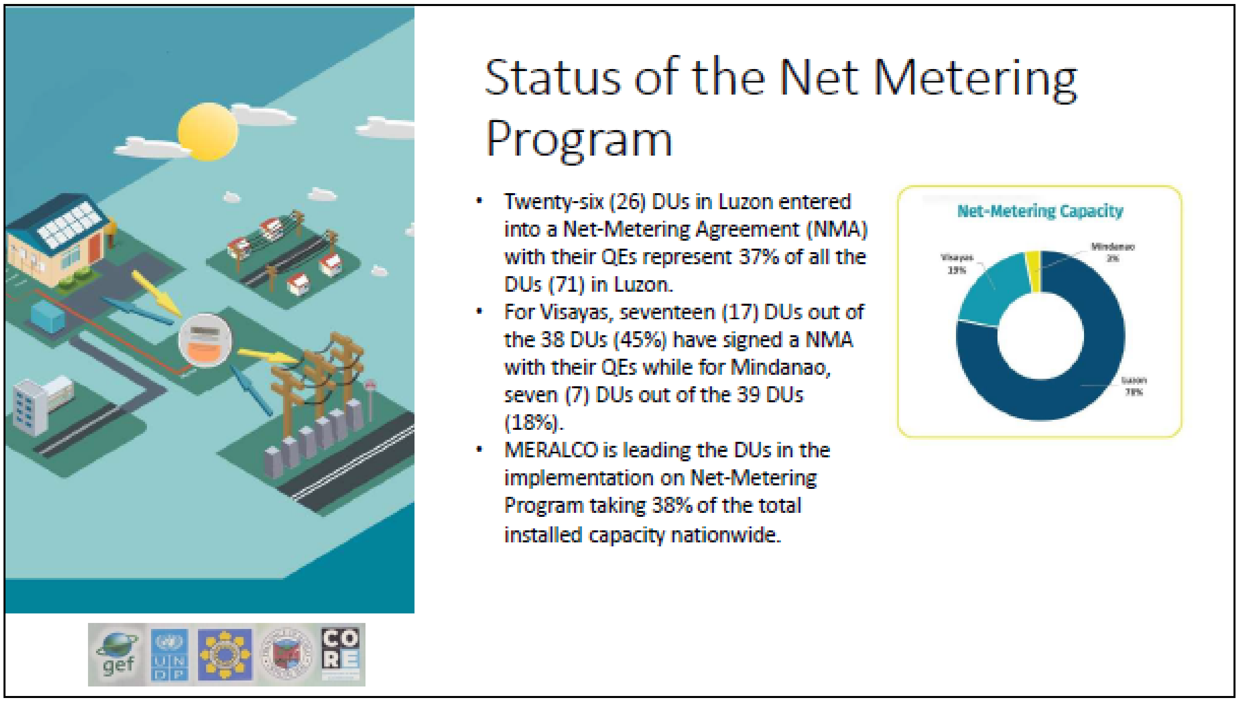
RA 11032 Ease of Doing Business promotes the facilitation of Net Metering applications through the issuance of permits by the LGU.



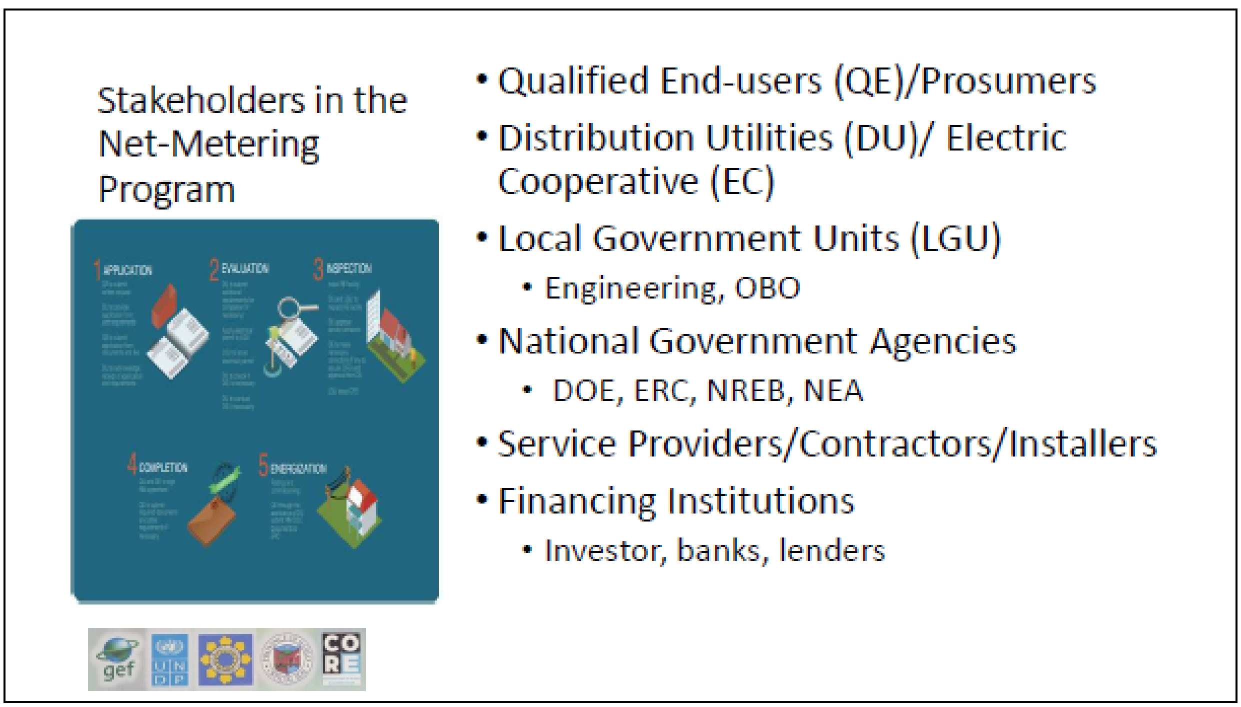
The RA 11234 streamlines the process for the application and approval of energy projects.



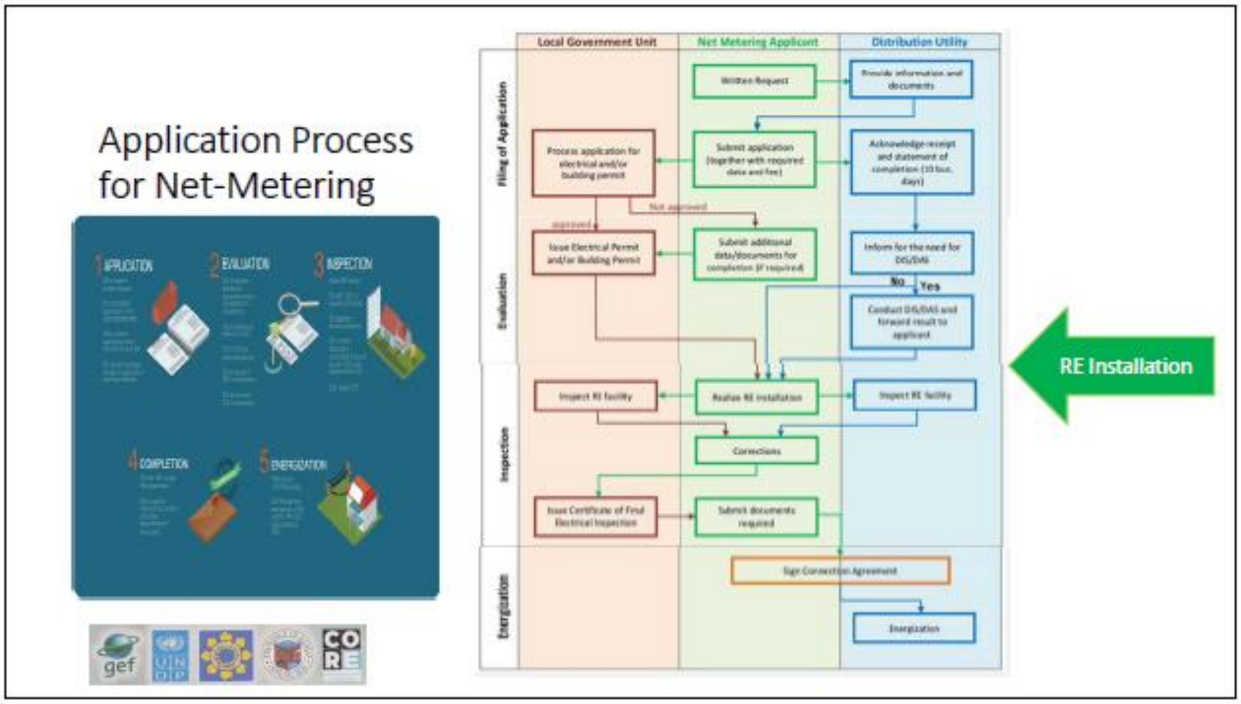
The status of the Net Metering program already reached 33.21MWp of capacity from 4,118 qualified energy users as of May 2021.



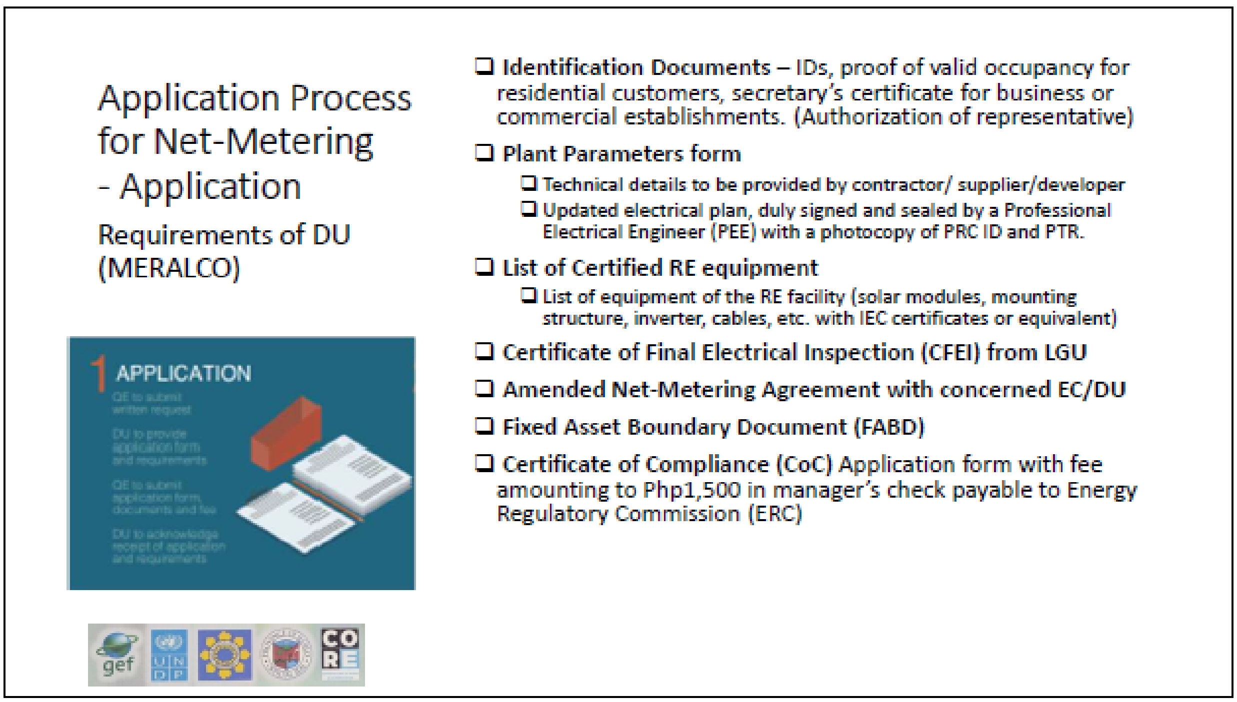
The Net Metering program is participated by 26 distribution utilities in Luzon, 17 in the Visayas, and 7 in Mindanao with 38% of the Net Metering capacity installed under MERALCO.



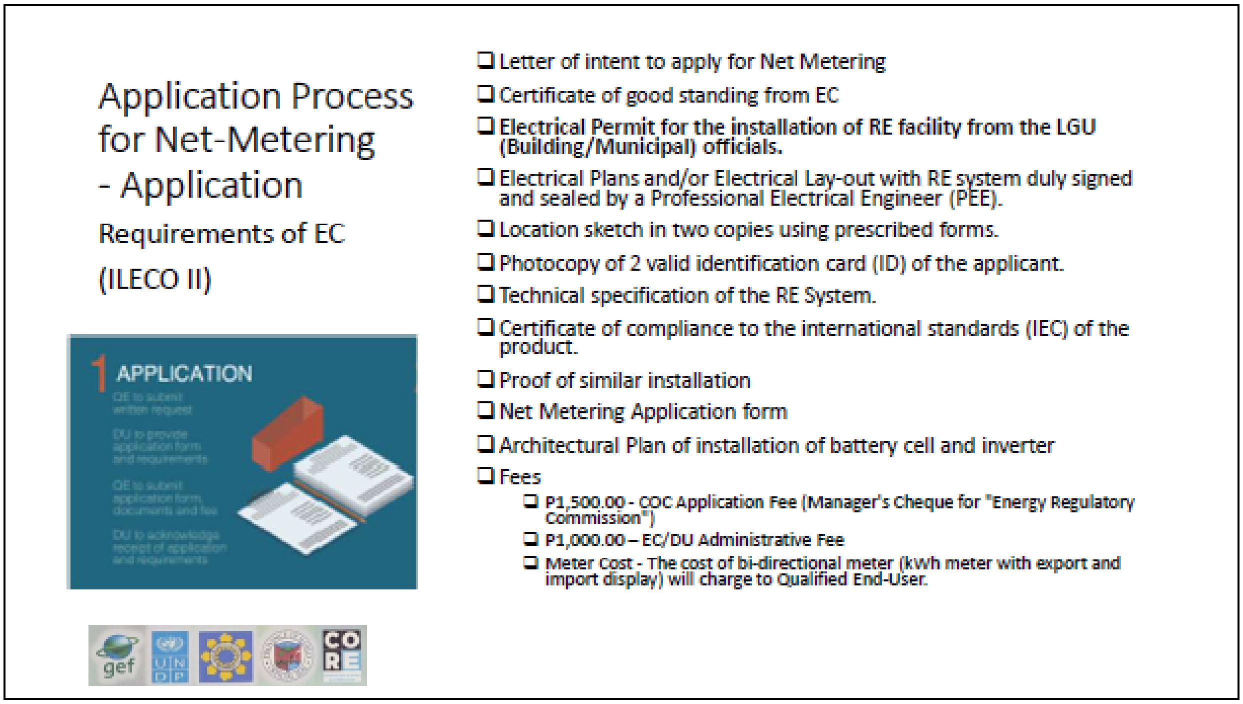
The roles of Net Metering stakeholder are presented.



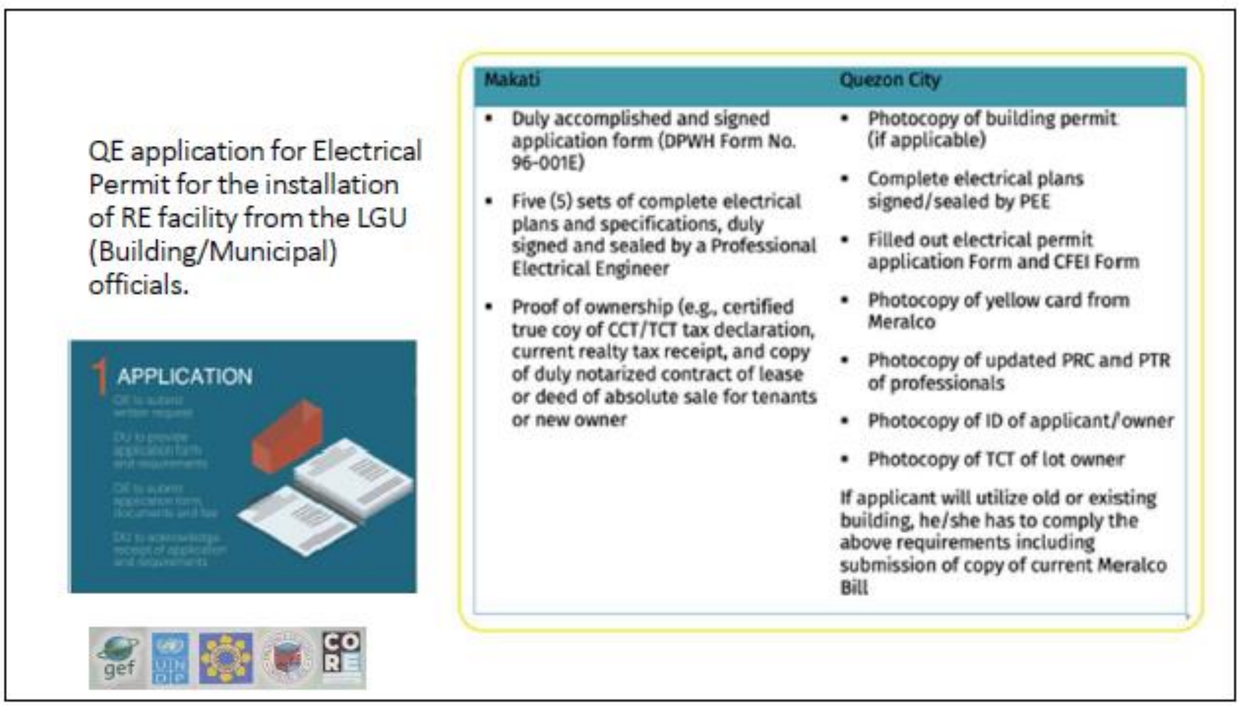
This is the Net Metering application process



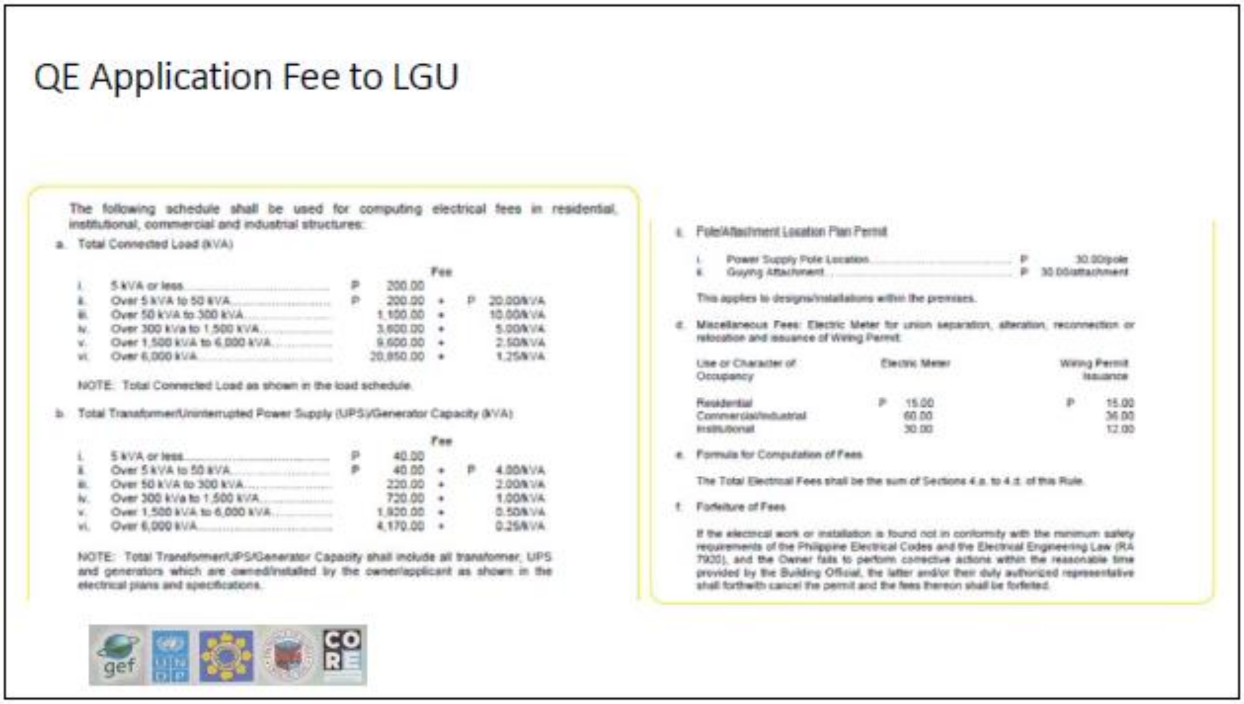
These are the list of requirements for Net Metering application under MERALCO



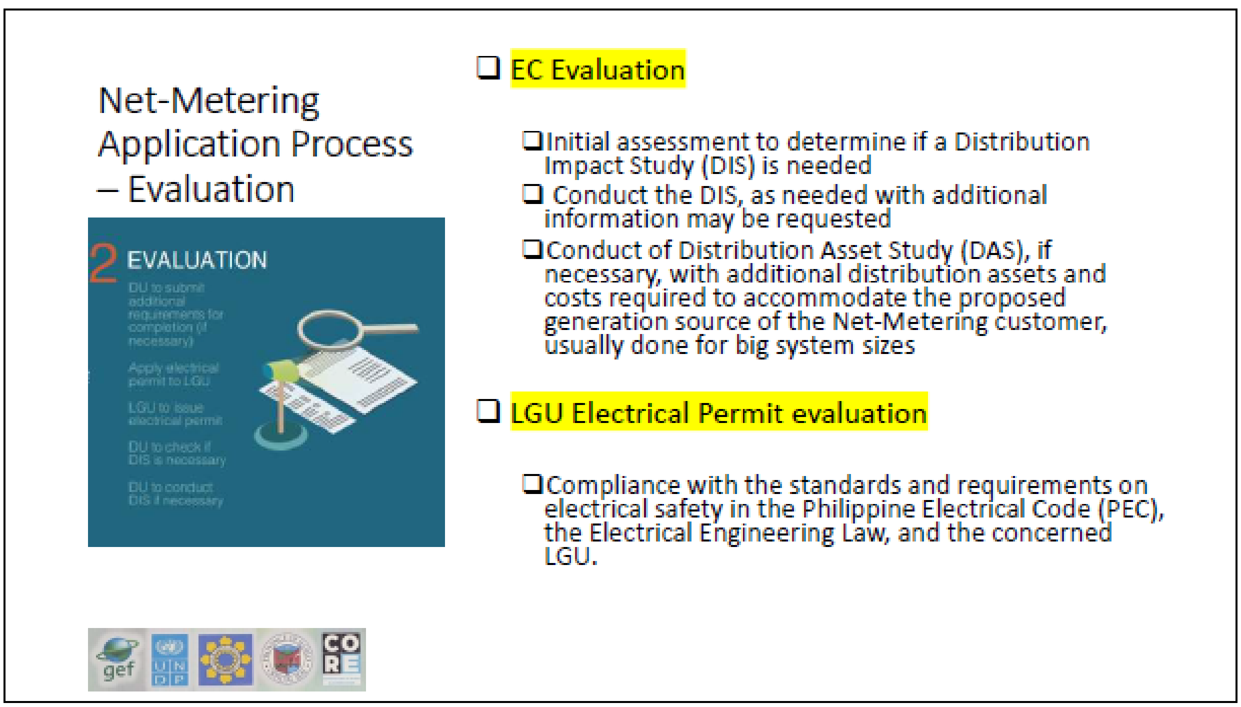
A comparative list of requirements for Net Metering application under ILECO II is presented



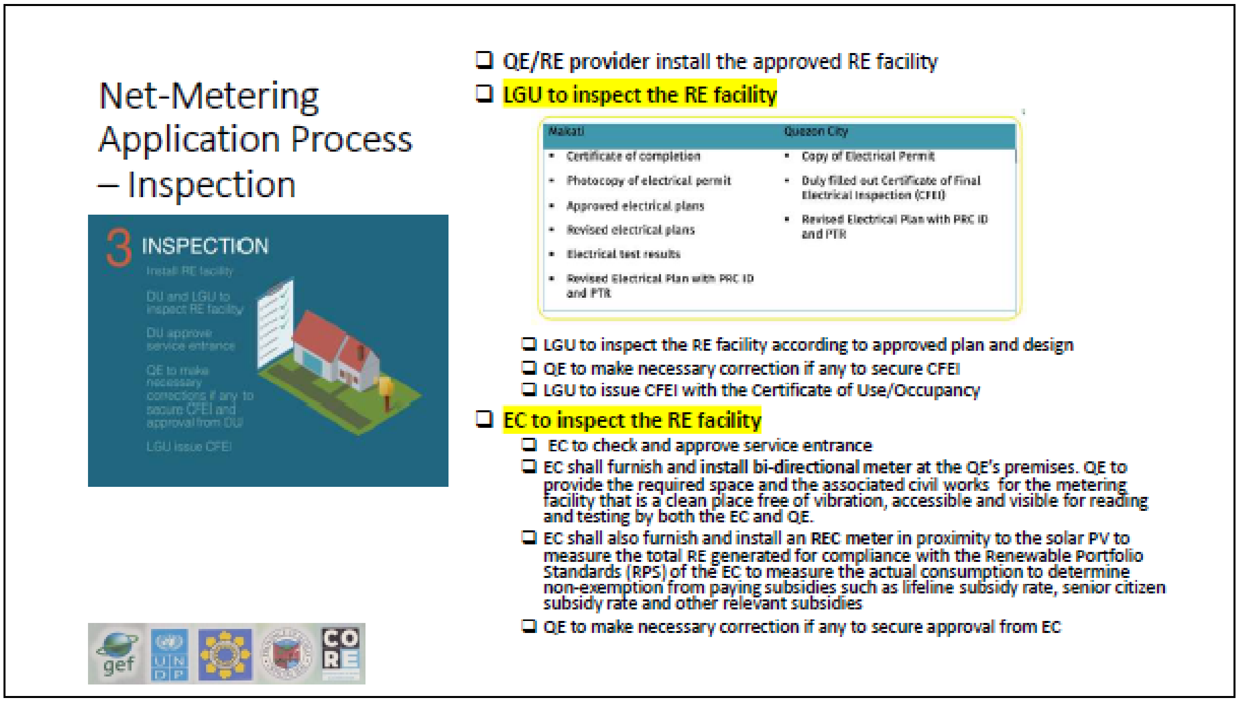
A comparative list of requirements for Net Metering application between Makati and Quezon City



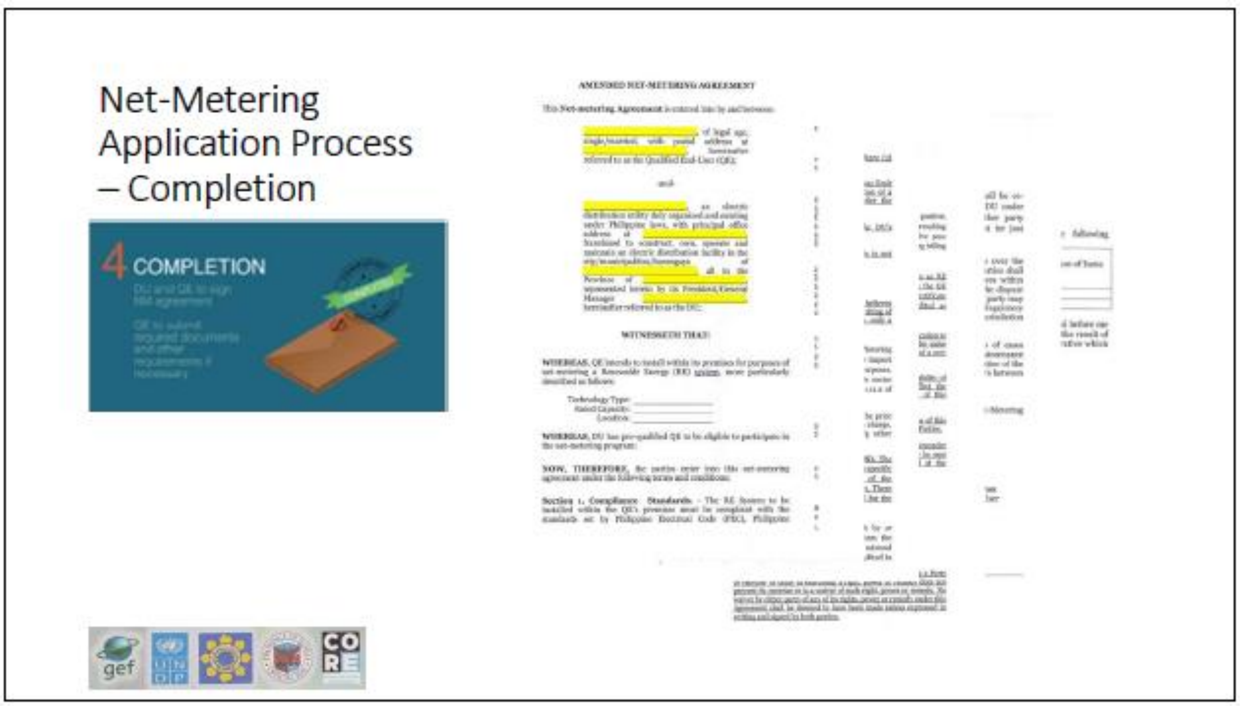
These are the fees from the LGU for the application of the Certificate of Final Electrical Inspection.



Net Metering application is evaluated by the Electric Cooperative and the LGU for the electrical permit



This is the Net Metering inspection process and checklist



Upon completion of the Net Metering application, a Net Metering agreement between the DU and the QE is signed and submitted to ERC.

Net-Metering Application Process – Energization

- The EC testing and commissioning process consists of the following:
  - Verification and inspections
  - Reactive power test
  - Protection tests
  - Reconnection timing test (blocking test)
  - Synchronization test
- QE through the assistance of the EC, submit NM COC documents to ERC

Once the Net Metering installation is completely inspected, the system is ready for energization

Offline Worksheet
Guide for Installation of the Renewable Energy Systems

Guide for LGU Permitting of Renewable Energy Systems Installation (expand table as needed)

Step #	Activity/ Stake Holder (QE, EC, LGU)	Requirements	Timeline (days)	Fees (Php)
1				
2				
3				
4				
5				
6				

Email to iloilopv@gmail.com with subject: NM guide for RE
Include Name, designation, LGU

The participants are to fill-in the form as a guide in the Net Metering application stating the requirements, the timelines, and the corresponding fees for the application process.

2.3 Session 3 - Solar PV Technology Basics

Basic Electricity

To prepare the trainees regarding solar energy, an introduction to the basics of electricity is needed for those that have limited technical background. The figure below can help illustrate the terms used in electricity.

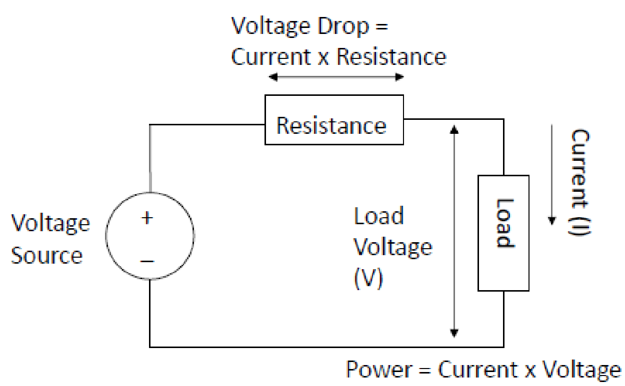
Voltage
Also known as electromotive force (emf).
It is measured in *volts*(V)

Power
The value of current times the voltage.
It is measured in wattage or *watts*(W)

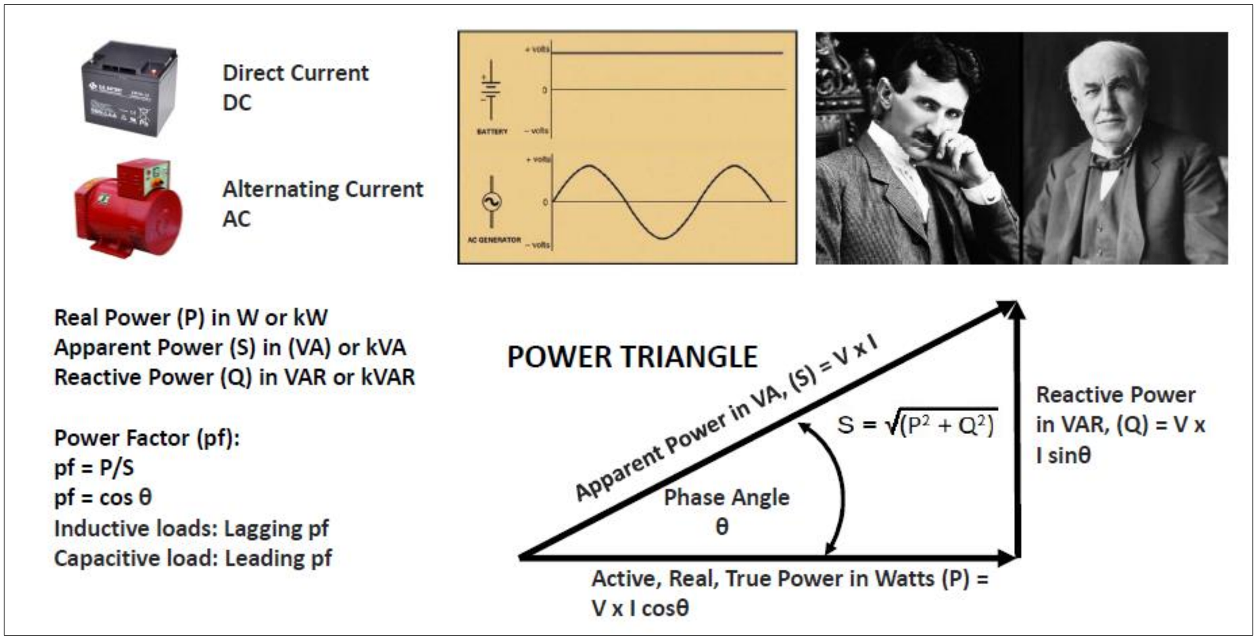
Energy
The value of Power times the operating time (hours).
It is measured in watt-hours (Wh) or kilo-watt-hours (kWh)

Current
The amount of electrical charge moving past a given point in an electrical circuit per unit of time.
It is measured in amperes(A)

Resistance
That characteristic which opposes the flow of electrical current through itself.
It is measured in ohms(Ω)



An electric circuit can be composed of a voltage source and conductors to supply power to a load. The conductors have resistance, and a voltage drop can develop across the conductor according to the resistance and the current flowing on the circuit.

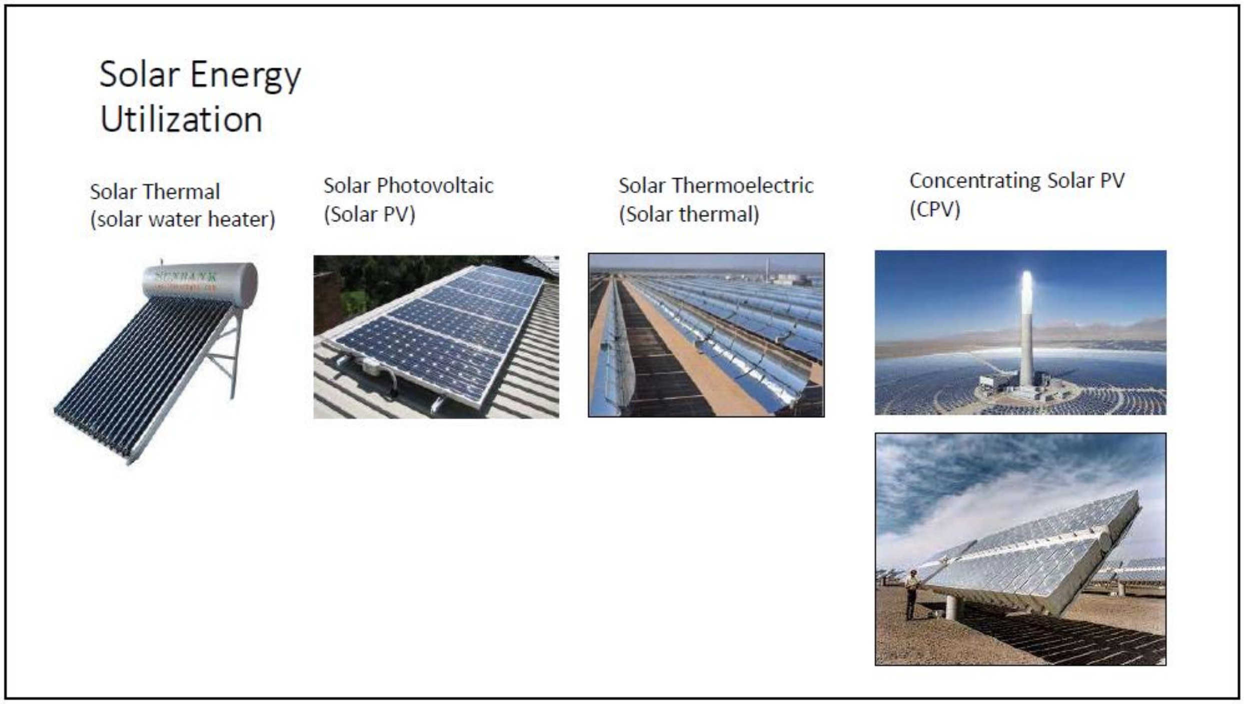


Direct Current (DC) electricity is commonly produced by batteries with a steady positive (+) and negative (-) polarities of its output terminals. Alternating Current (AC), on the other hand; is produced by a dynamo with a spinning rotator that changes its voltage polarity as the rotor spins. The output voltage follows a sinusoidal wave that goes from zero to positive, zero to negative, then back to zero again.

Thomas Edison promoted the use of DC electricity while Nicolai Tesla used AC electricity in the transmission and distribution of electricity. Tesla used transformers step-up the AC voltage for transmission and step-down the voltage for distribution and consumption.

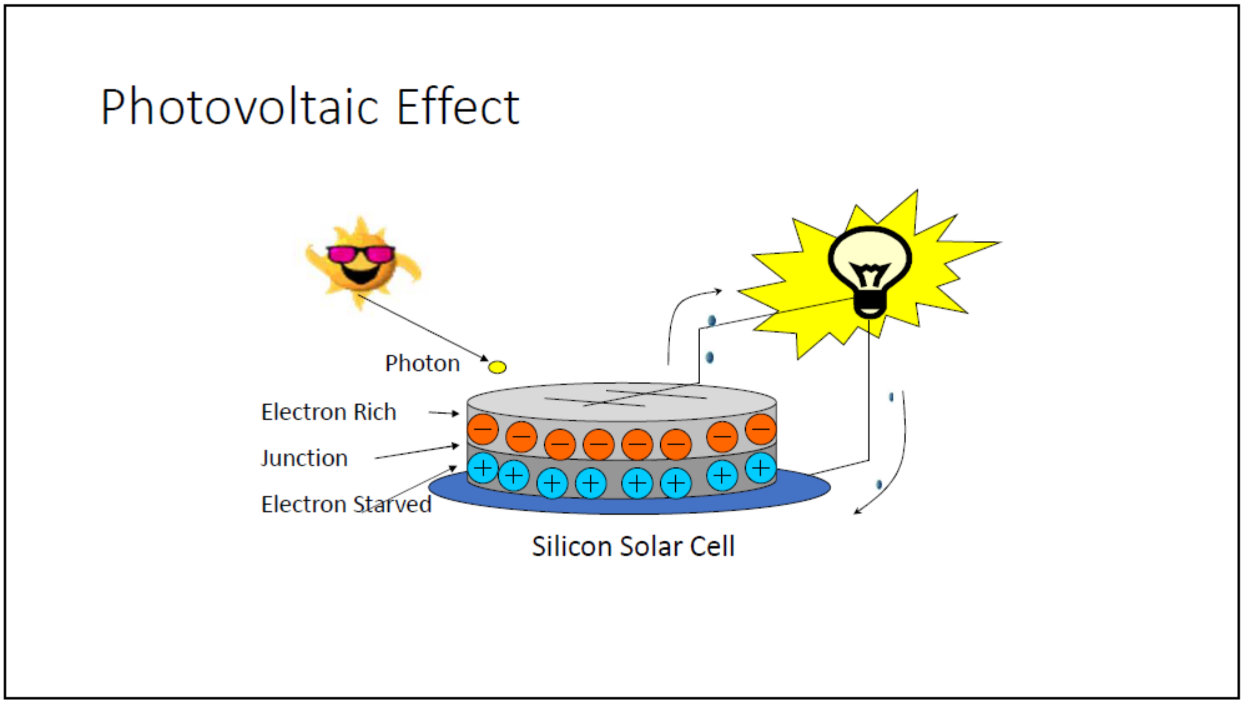
As the AC electricity flows in the circuit, inductive load current lags the voltage while capacitive load leads the voltage creating Reactive Power along the circuit in addition to the Real Power delivered to the load. The net effect of these two powers which are 90 degrees apart in a sinusoidal wave result to the Apparent Power measure in Volt-Amperes with a net angle relative to the voltage. The power factor (PF) is the ratio of the Real Power over the Apparent Power.

In a purely resistive circuit, the power factor is one or unity where Real Power is equal to Apparent Power with no Reactive Power. A lagging power factor is experienced when the circuit have inductive characteristics such as conductors arranged in coils in transformers or loads with electric motors. This results to a relatively higher circuit current compared to a purely resistive circuit. This higher current also results to voltage drop along the transmission line that needs to be compensated with capacitor banks to offset the effects of the reactive power. Advanced solar PV inverters can also be programmed to feed reactive power to the circuit to bring the power factor close to unity.

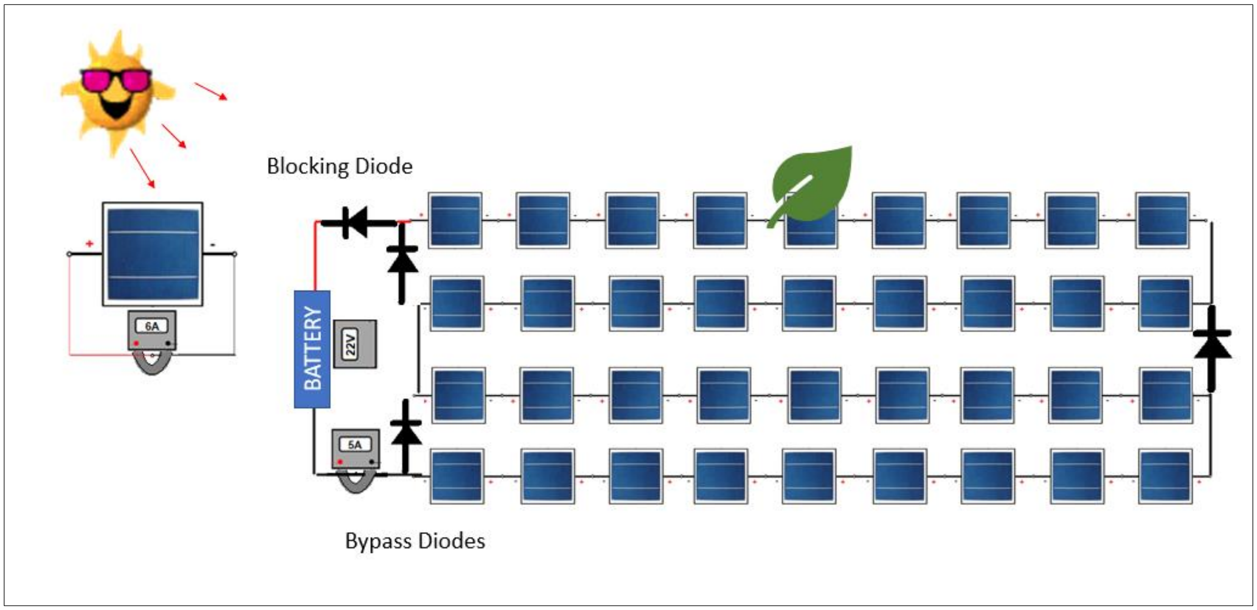


Solar energy can be utilized using solar thermal applications with solar water heaters. The heat of the sun is used to raise the temperature of water for domestic and commercial applications. Photovoltaic cells use the light component of sunlight to produce electricity with photovoltaic cells.

Solar thermal applications can concentrate sunlight using parabolic trough, mirrors, and lenses to focus sunlight in a small area to raise the temperature of a working fluid such molten salt to generate steam to drive a turbine and produce electricity. Concentrating solar PV (CPV) also increase the output of the solar cell with concentrated sunlight. However, concentrating the moving rays of sunlight as the sun crosses the sky will require trackers to follow the sun or use multiple mirrors to concentrate sunlight at any given time of the day.



Photovoltaic (PV) effect is the generation of electricity of a material when struck by light. The most common material used as a PV cell is silicon. A thin wafer purified silicon is doped with impurities to have excess electrons on one side and less electrons on the other side. An electric circuit can be connected between the two sides of the cell. Once the cell is struck by light, the electrons flow along the circuit producing electricity. Since the electrons only flow in one direction across the solar cell, direct current (DC) is produced.

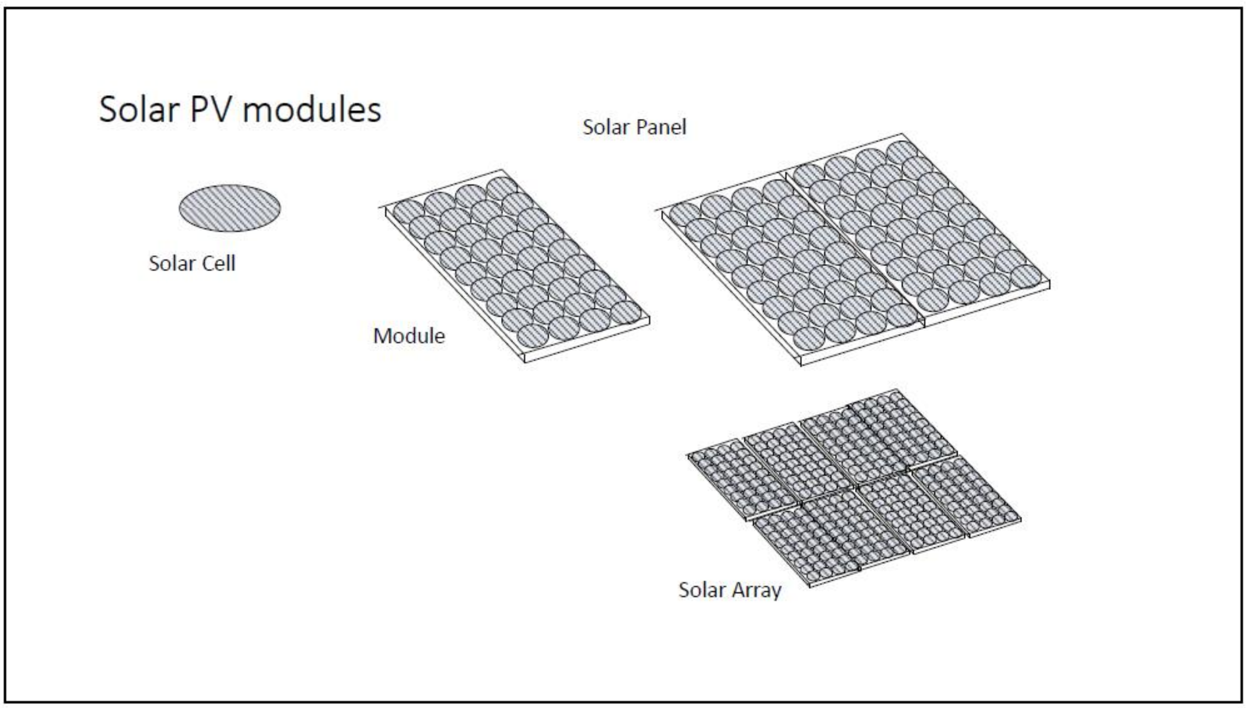


The electricity produces by a single solar cell is characterized with a low voltage by high current. The voltage is only around 0.5V while the current can be as high as 5A depending on the surface area of the cell and the type of solar cell when exposed to full sunlight at noontime.

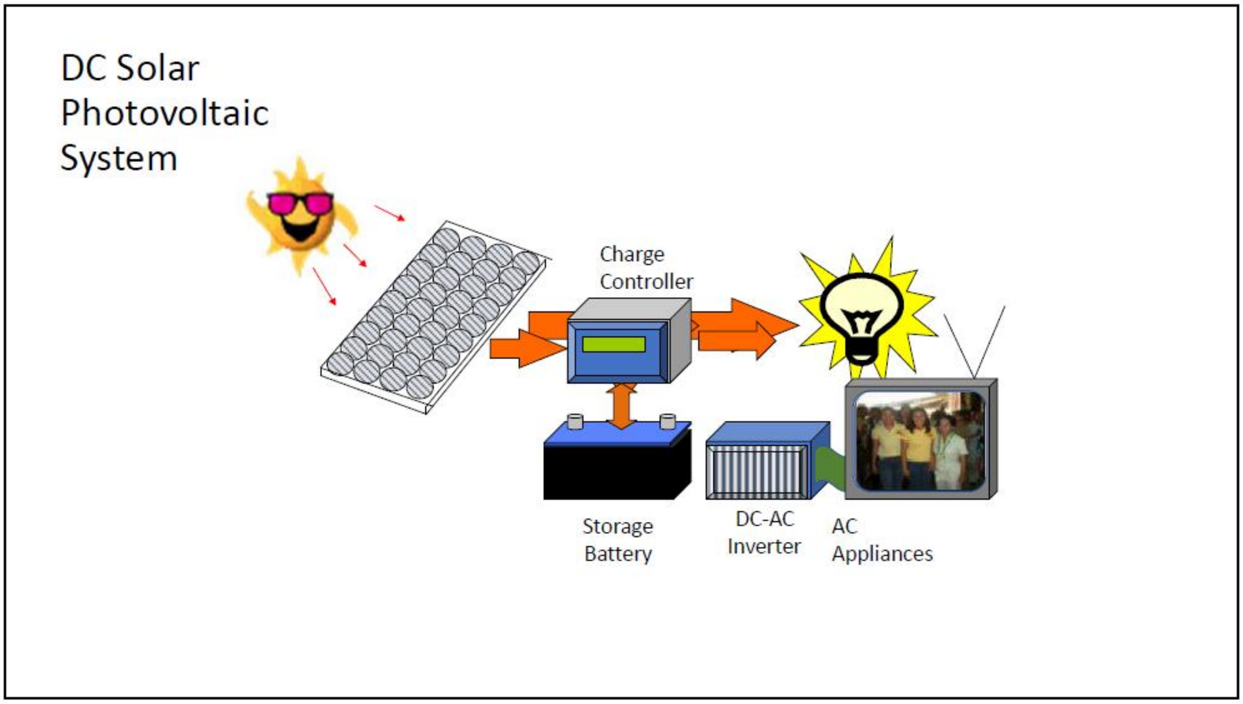
For the solar cell to charge a typical 12V battery, the cells are connected in series to produce a higher voltage than the terminals of the battery. With the solar cells connected in series, the voltages of the cells are added while the current is the same across the cells. Typically, 36 silicon cells are connected in series to charge a 12V battery. The extra voltage is needed to compensate for the drop in output voltage of the solar cell when the cell temperature increases due to the heat of the sun.

As the cell as connected in series as a string, the current of the whole string drops once any of the cells are shaded (e.g., leaves, etc.) Bypass diodes are used to allow an alternative current path from the section of the string that have shaded cells. Usually, the string is divided into three sections with a bypass diode connected in parallel to the section as an alternative current path.

A blocking diode is used to prevent current from flowing to the cells from the battery at night when the voltage of the battery is higher than the cells. This will prevent the battery from being drained when the solar cells are not generating electricity.

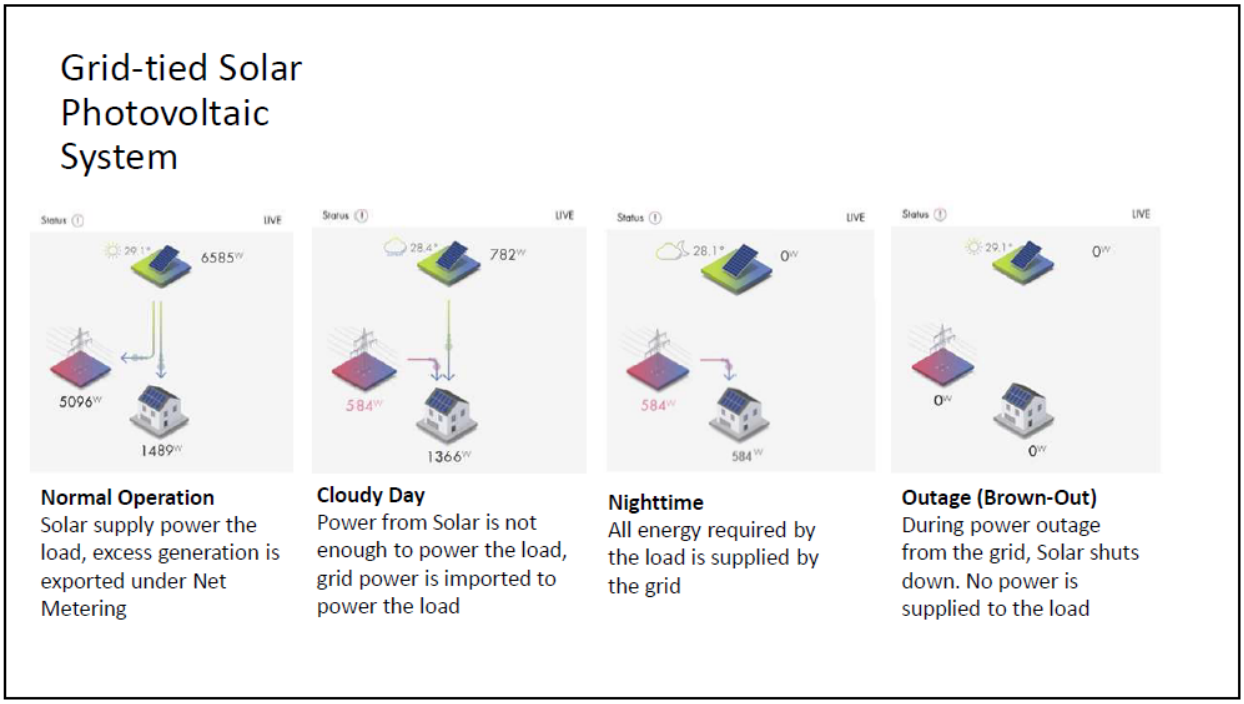


From a Solar cell, the cells are combined, encapsulated, and framed as Solar Module. Several solar modules are combined to form as Solar Panel. Often, a single solar module is incorrectly called a solar panel. Several solar panels when combined in large quantities are called solar arrays.



A typical stand-alone DC Solar PV System is composed of a solar module, a storage battery, a charge controller, DC loads, a DC-AC inverter to power the AC appliances.

The solar module can power the DC loads during the day but will need a storage battery to store energy during the day to be used a night. The charge controller regulates the charging of the battery to protect it from being over charged by the solar modules and also prevents the battery from being deeply discharged by cutting off the load when the battery state of charge is low. To power regular AC appliances in the house, an DC-AC inverter is connected to the battery to convert the DC voltage from the battery to AC electricity.



Grid-ties Solar PV Systems takes advantage of the grid connection to eliminate the use of batteries in using PV systems. This is made possible with the advancement of inverter technology that converts varying DC electricity from the solar panels to AC electricity in synchronous to the grid. With the parallel operation of the solar the grid electricity, the consumption from the grid is reduced with the amount of energy generated by the solar installation.

In a normal sunny day, the solar can produce more than the demand of the load. Excess electricity can be sold to the grid under a Net Metering arrangement with the Distribution Utility (DU).

During cloudy days, solar generation may not be enough to meet the demand. Additional power is drawn from the grid to meet the demand and supplement the solar generation. Grid consumption is reduced compared to systems without solar installations. At night when there is not solar generation, all of the energy requirement of the load is supplied by the DU.

Since there is no energy storage device in this solar installation, the system shuts-down during a power outage (brown-out) of the DU even during a sunny day. The grid-tied solar inverters are programmed to disconnect from the grid using outages for safety purposes. This is to prevent export of electricity during an outage to protect linemen who could be fixing the line during maintenance. This also protects the inverter from being overloaded with the demand that the utility cannot supply. Grid-tied inverters shall follow the operating requirement set by the Philippine Distribution Code, Philippine Grid Codes, and the Small Grid Guidelines.

Hybrid Solar Photovoltaic System

Normal Operation
Solar supply power the load, charge the BESS, export excess generation under Net Metering

Cloudy Day
Solar supply power the load, BESS can supply the load to reduce import from the Grid

Outage (Daytime)
Solar supply power the load. BESS charged by excess generation and supply the load when solar output is low

Outage (Nighttime)
Stored energy in the BESS supply the load

Hybrid Solar PV Systems uses energy storage devices (batteries) to make power available during outages. It can also store excess generation during the day to used at night and during power outages.

When an outage happens during a sunny day, the hybrid system can work as a stand-alone system to power the load without draining the battery during the day. Stored energy can be used for outages at night.

The hybrid system with grid-feeding capability using its battery can perform peak shaving functions for commercial consumers that pay demand charge. The system can be programmed to activate stored battery energy when a high demand is detected.

Excess energy generated during the day can be stored in the battery instead of being exported under Net Metering to have a higher monetary value as a form of energy arbitrage. The financial and economic advantage of this system should be carefully considered as the cost reduction on electricity expenses with the DU may be offset by the cost of the investment on the battery and its future replacements costs.

Off-Grid/ Stand-Alone System
Major components:
Solar Modules
Mounting Structure
Storage Battery
Charge Controller
DC to AC Inverter (Optional)
Feature:
No grid requirement

Hybrid System
Major components:
Solar Modules
Mounting Structure
Storage Battery
Charge Controller
Hybrid Inverter (Battery input)
Feature:
Grid-tied with back-up power

On-Grid System
Major components:
Solar Modules
Mounting Structure
Grid-tied Inverter
Feature:
Lowest cost (no back-up)

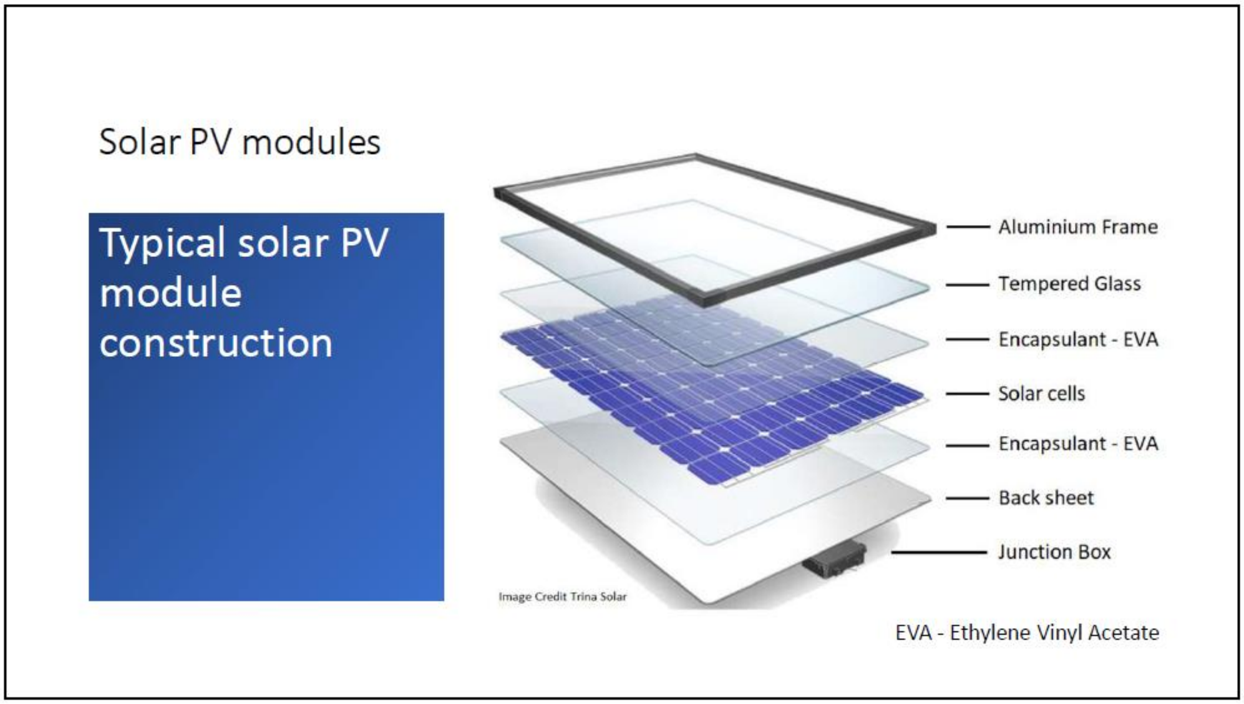
Solar PV System Components

The three classifications of solar installation are the 1) Off-Grid/Stand-Alone system 2) Hybrid System and 3) On-Grid System. They have specific components and characteristics.

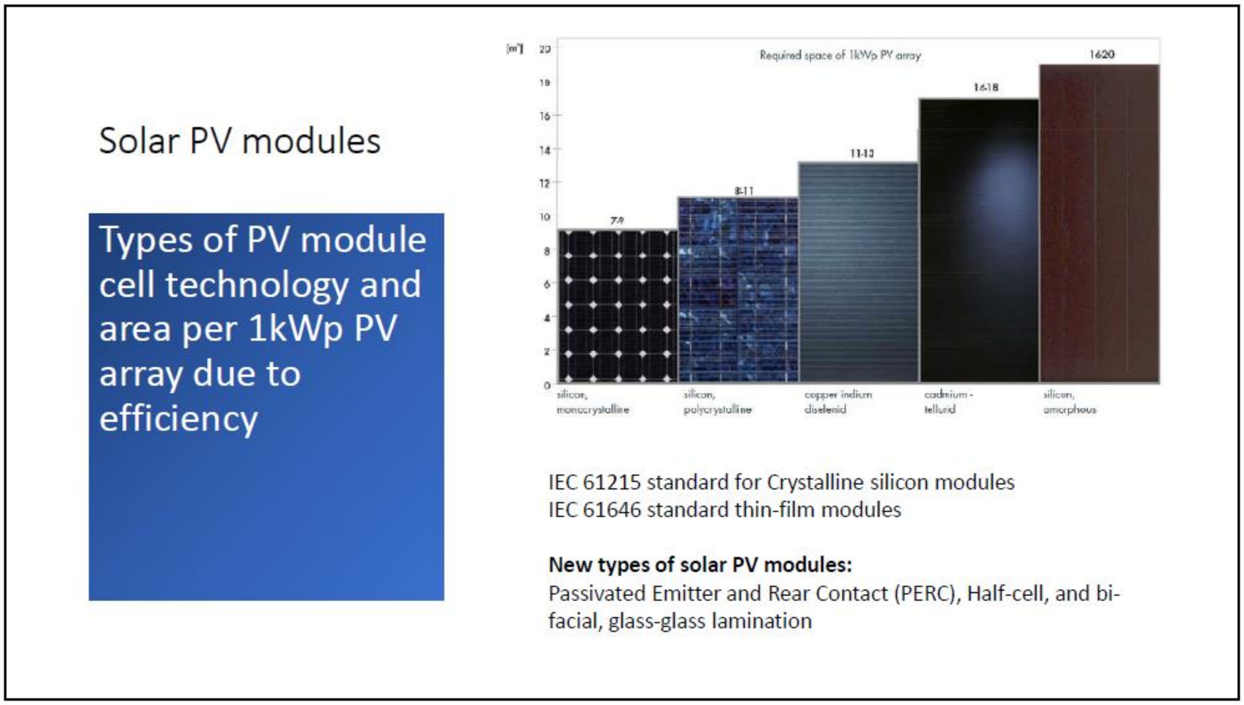
1) Off-Grid/Stand-Alone systems can be installed anywhere under the sun. This is also similar to solar streetlights with all components necessary for its full operation without the grid. Among the three types, this is the most expensive with all the capacity requirement of the load has to be met by the solar installation.

2) Hybrid System is a practical type of solar installation that has the flexibility of using the grid whenever it is available and having the solar panels to reduce the consumption at night. With the battery, the system can provide back-up power during power outages and can store excess solar generation to be used at night or during power outages.

3) On-Grid System is the cheapest type of solar installation with very few components. It also has the shortest payback based on the savings on electricity. However, this type of system needs alternative back-up power during brownouts and long outages after major disasters before the grid is restored.

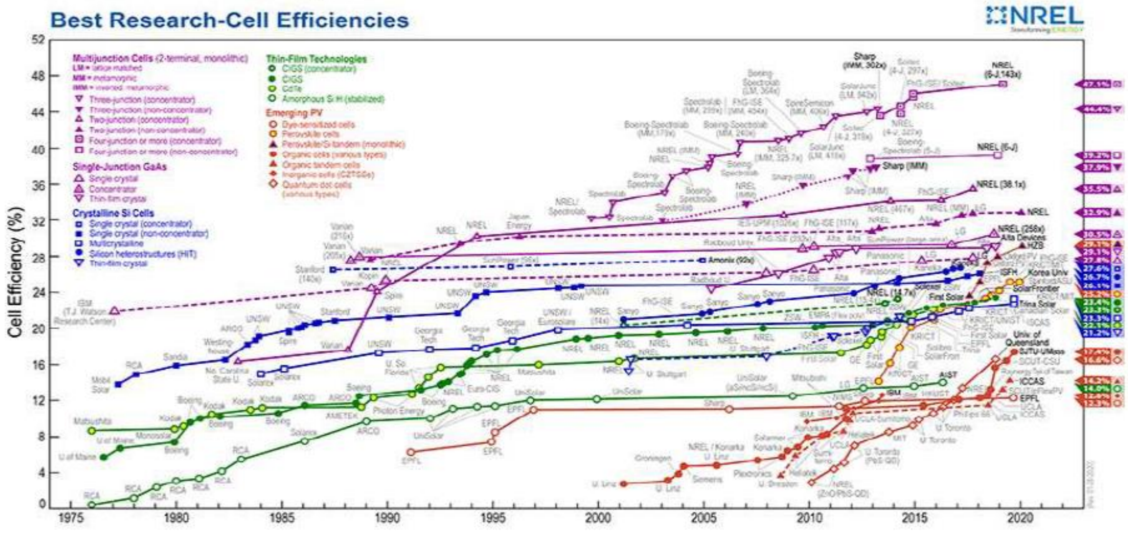


This is the typical construction of a mono-facial solar module. It is composed of solar cells connected in string with electrical termination at the junction box. The cells are encapsulated with ethylene vinyl acetate (EVA), back sheet, low carbon tempered glass, and supported by an aluminium frame.



There are several solar cell technologies with different conversion efficiencies. The most efficient is the monocrystalline, followed by the poly crystalline, then the amorphous silicon cells. There are several types of thin film solar technologies with varying efficiencies and costs. Newer solar cell technologies include Passive Emitted and Rear Contact (PERC), Half-cut cells, and bi-facial cells with glass-glass lamination. IEC standards for solar modules are IEC 61215 for crystalline silicon modules and IEC 61646 for thin-film modules. Solar module efficiency affects the area required per kilowatt capacity of installation.

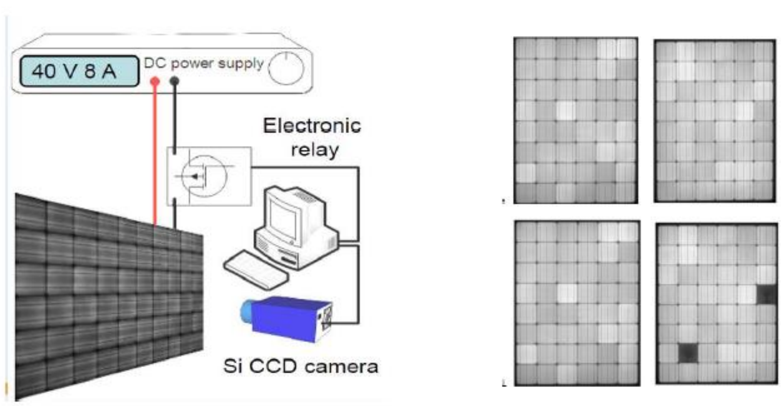
• **PV Cell Efficiency increase over time**



Solar PV Module Efficiencies

Solar PV module efficiencies has increased over time since 1975 to post 2000. Solar cell technologies are categorized as crystalline silicon cells, single-junction cells, multi-junction cells, thin-film technologies, and emerging technologies.

PV Quality Tests



Electro luminescence Test

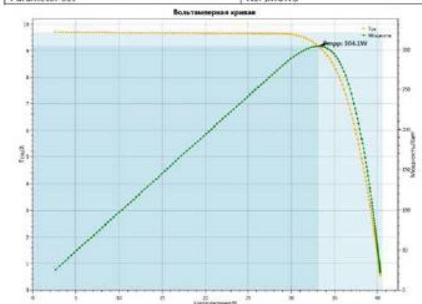
Solar PV Module Quality Tests

Solar module quality is tested using the Electro Luminescence Test where the solar cell is treated as a light-emitting-diode (LED) and is supplied with a DC voltage to generate light. A special camera is used to check of defective cells that does not illuminate due to physical cracks.

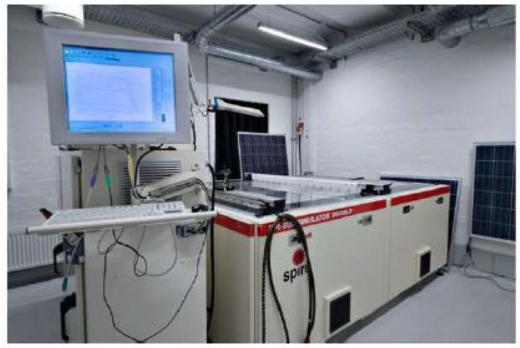
PV Quality Tests

Power Measurement

Power Maximum Power Point	304.12 W
Open Collector Voltage	40.57 V
Short Circut Current	9.71 A
Flash time	90 ms
Module Temperature	24.15 °C
Monitor Cell Temperature	19.17 °C
Monitor Cell Power	1013.91 W
Approved by Module ID	
Time of Approval	
Parameter Set	NSP,MONO



Flash Test (IV Curve)

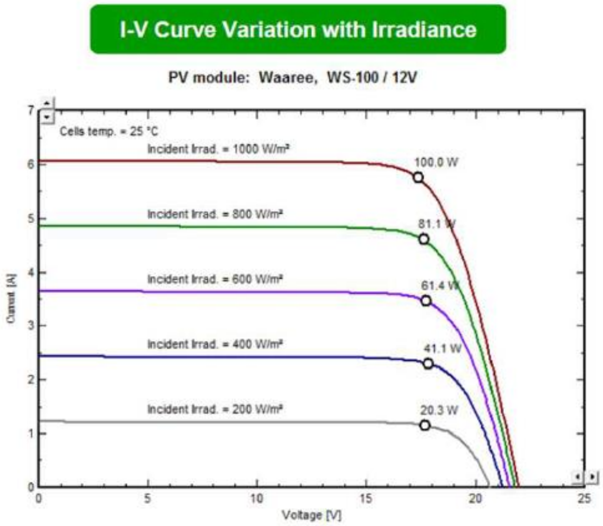


Flash Test Equipment

https://www.energy.aau.dk/laboratories/renewable-energy-conversion-storage/pv-systems-laboratory/

Solar PV Module Quality Tests

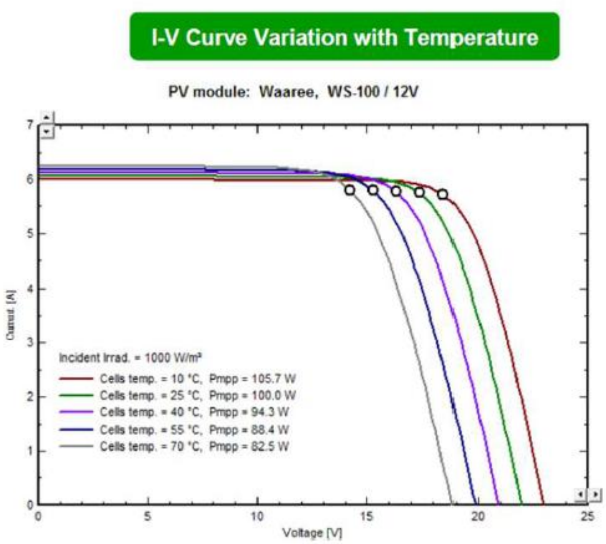
The voltage and current output characteristics of the solar module is tested using an IV (current voltage) curve tester with a light source flashed on the solar module under test. This test validates the actual capacity of the solar module a provided on its data sheet under Standard Testing Condition of 25^0C cell temperature, $1000w/m^2$ irradiation, and Air Mass of 1.5.



Electrical Characteristics*	
Nominal Maximum Power (P_m) in Watts	100
Power tolerance	0 / + 5 W
Open Circuit Voltage (V_{oc}) in Volts	21.97
Short Circuit Current (I_{sc}) in Amps	6.07
Voltage at Maximum Power (V_{mp}) in Volts	17.46
Current at Maximum Power (I_{mp}) in Amps	5.73
Maximum System Voltage in Volts	1000
Module Efficiency (%)	12.88
Maximum Series Fuse Rating (A)	15

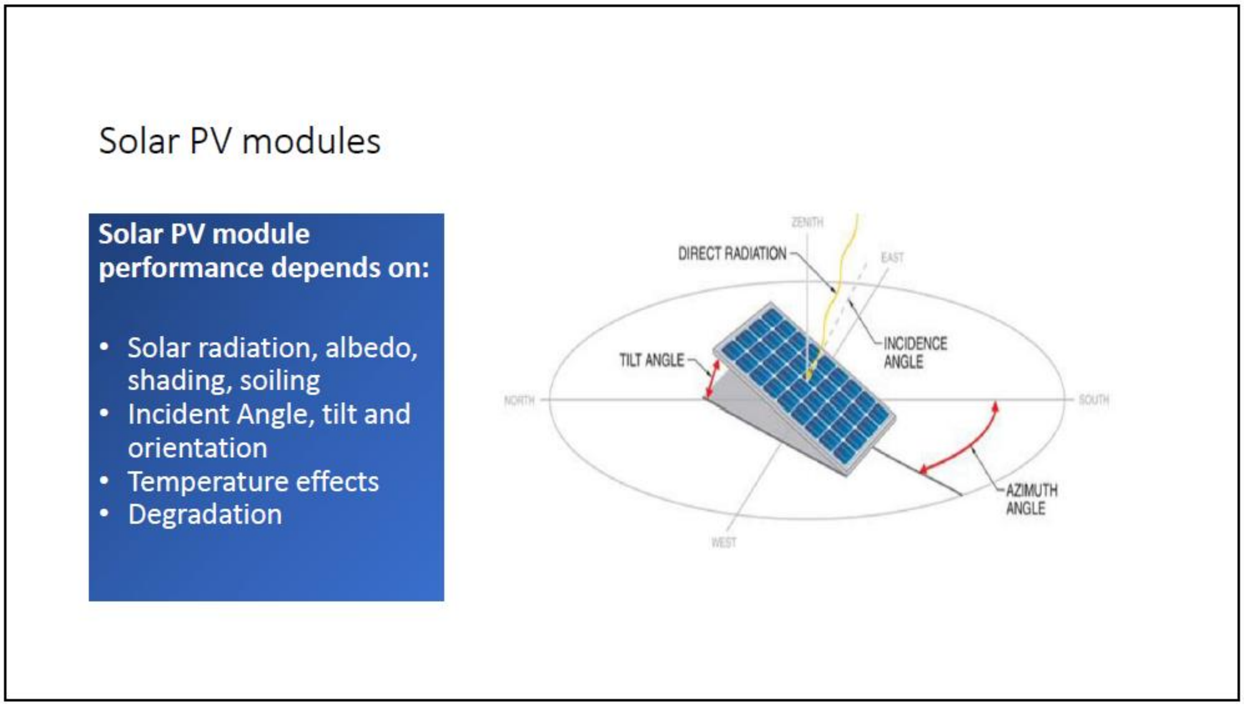
*Under Standard Test Conditions (STC) of 1000 W/m² irradiance, AM 1.5 spectrum and 25°C cell temperature.

A sample datasheet of a 100W solar module shows its output characteristics under various irradiation levels. The voltage remained above 20 volts while the current is high dependent on the irradiation level. The general information provided includes nominal power in watts, open circuit voltage, short circuit current, voltage at maximum power, current at maximum power, maximum system voltage, maximum series fuse.

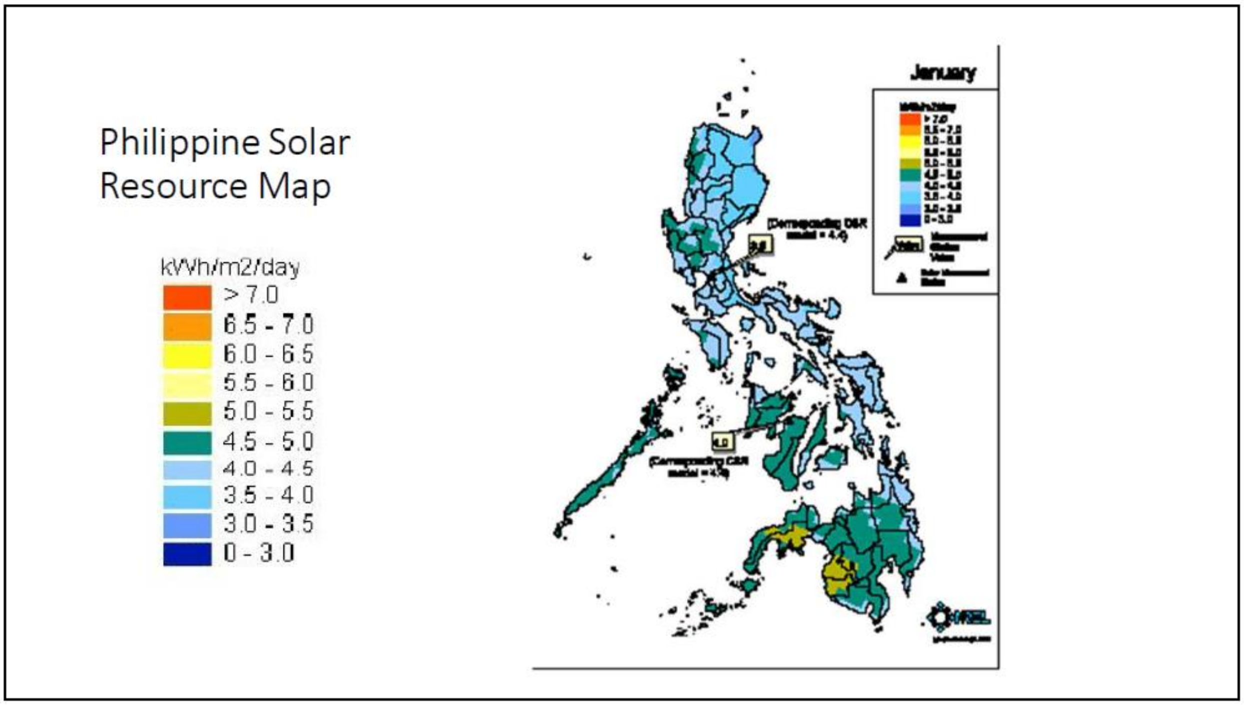


Thermal Characteristics	
Temperature coefficient of Current (I_{sc}), α (%/°C)	0.0681
Temperature coefficient of Voltage (V_{oc}), ß (%/°C)	-0.2941
Temperature coefficient of Power (P_m), γ (%/°C)	-0.3845
NOCT (°C)	46 ± 2
Operating temperature range (°C)	-40 to 85

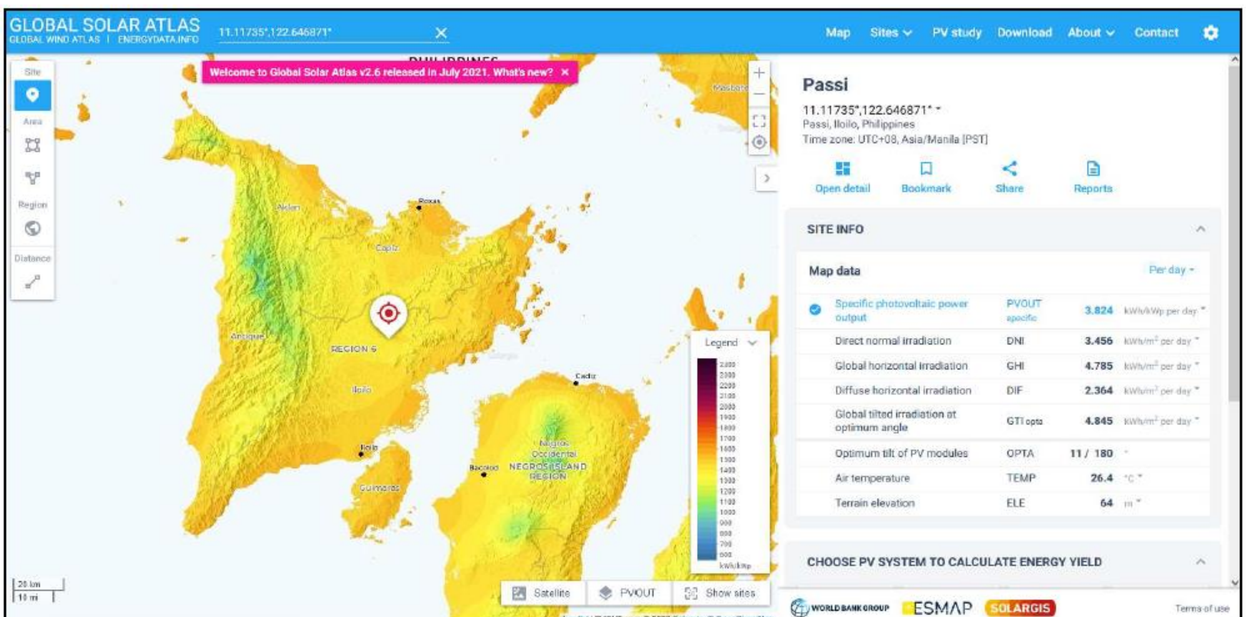
Solar module output is also affected by its cell temperature. Voltage reduces with the increase in cell temperature while there is slight increase in current. The overall temperature coefficient of power shows a reduction of power for the increase in cell temperature.



The output of the solar module is affected by the amount of light it receives depending on its orientation and the combination of radiation sources, and cell temperature. The common practice for solar installation is to orient the slope of the solar module towards the equator. This is tilting the modules south for locations north of the equator and north for locations south of the equator at an angle equal to the latitude of the location. For multiple rows of module, the east-west orientation of the solar modules is adapted to install the most capacity for a given area.



The Philippine Solar Resource Map developed by the National Renewable Energy Laboratory (NREL) of the US DOE shows an average solar radiation data of 4.5 to 5.5 kWh/m^2/day with seasonal variations.



Global Solar Atlas - https://globalsolaratlas.info/map

Another source of solar irradiation data is the Global Solar Atlas as https://globalatlas.info/map.

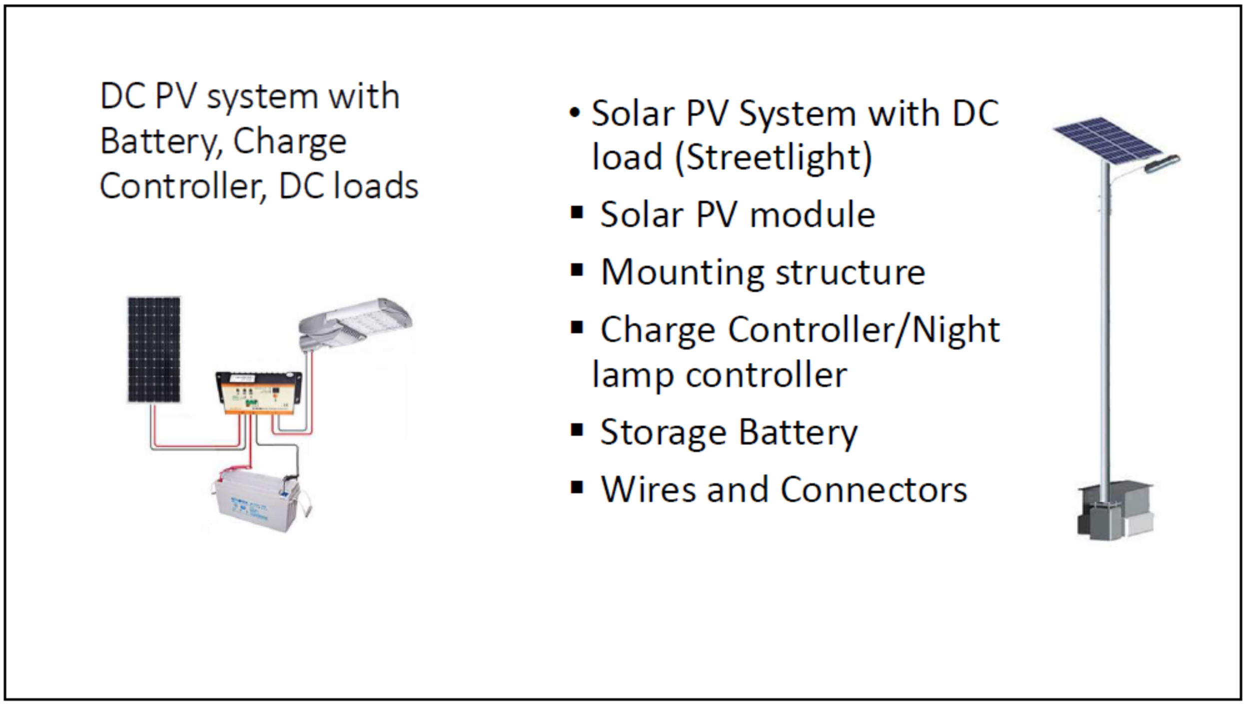
Global Solar Atlas - https://globalsolaratlas.info/map

The Global Solar Atlas website also provides seasonal information of the solar radiation of the location. This is helpful in determining the basis for the design of the solar installation considering the seasonal variation of the solar radiation.

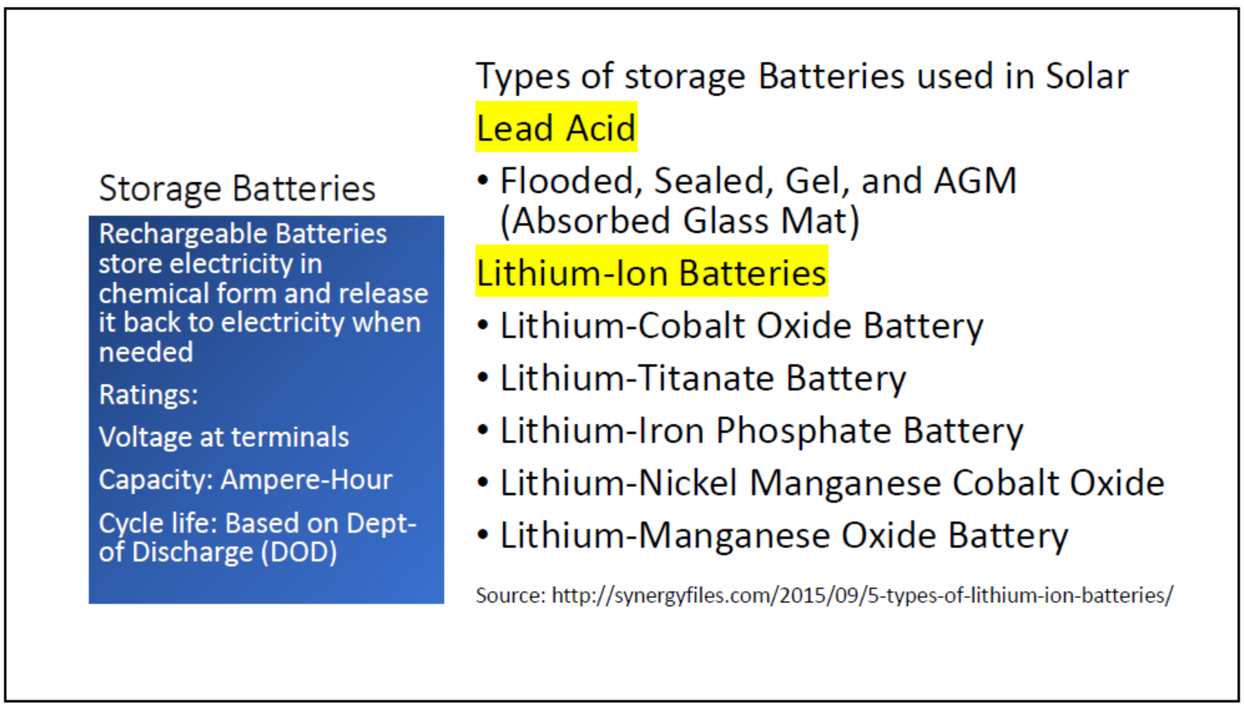
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6				6	30	25	10	8	9	11		
6 - 7	45	72	176	287	283	223	160	166	172	216	203	123
7 - 8	235	322	383	437	398	325	253	276	268	338	362	280
8 - 9	250	332	383	420	453	389	314	333	333	376	359	301
9 - 10	267	317	366	420	462	414	346	379	370	384	346	298
10 - 11	259	300	353	422	455	416	361	397	378	380	345	292
11 - 12	264	334	380	440	428	404	343	377	363	376	345	314
12 - 13	269	353	404	461	426	381	328	357	323	346	355	299
13 - 14	284	368	425	484	416	339	291	330	282	305	363	311
14 - 15	265	365	419	456	349	281	239	255	211	251	336	301
15 - 16	243	343	398	410	290	214	172	195	159	211	298	262
16 - 17	187	282	332	356	214	155	117	137	107	144	216	189
17 - 18	30	110	146	156	98	79	61	65	17	15	13	16
18 - 19												
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	2598	3499	4165	4756	4303	3646	2997	3275	2992	3352	3540	2986

Global Solar Atlas - https://globalsolaratlas.info/map

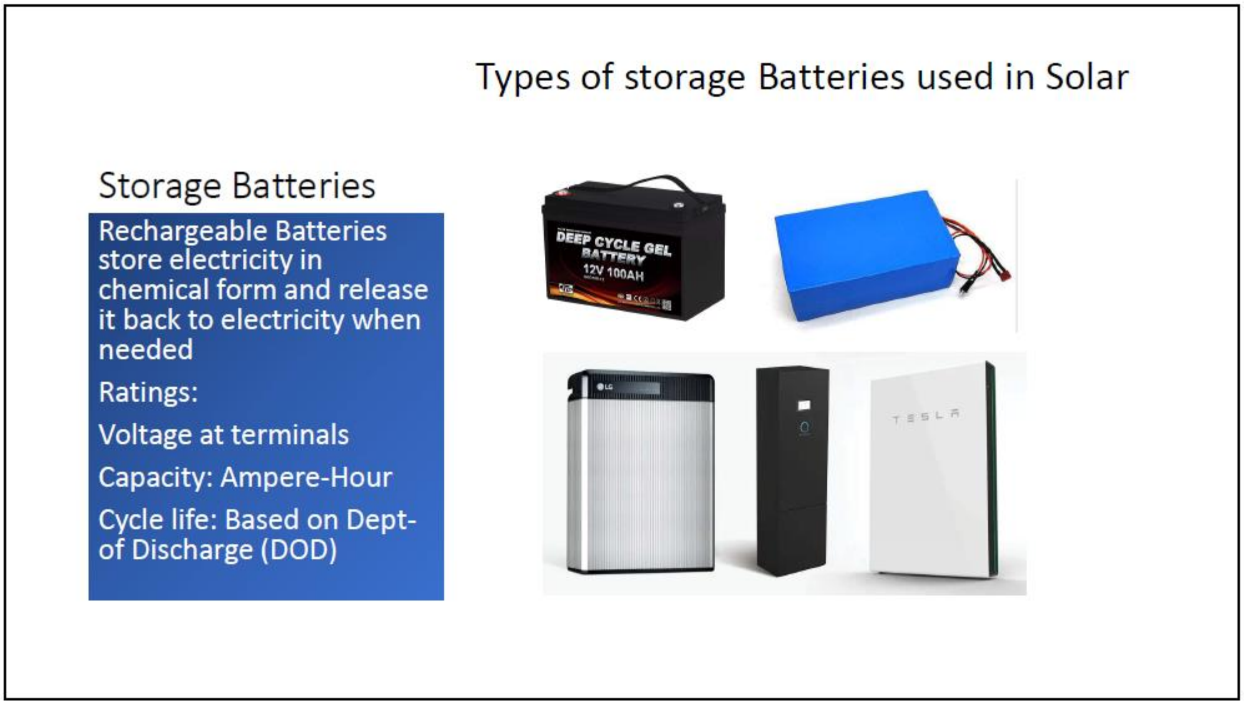
Average hourly solar radiation data on a monthly basis is also provided in the Global Solar Atlas website. This shows more detailed characteristics of the solar considering the hourly variation of the solar radiation every month. This is useful for battery sizing and designing solar water pumping systems.



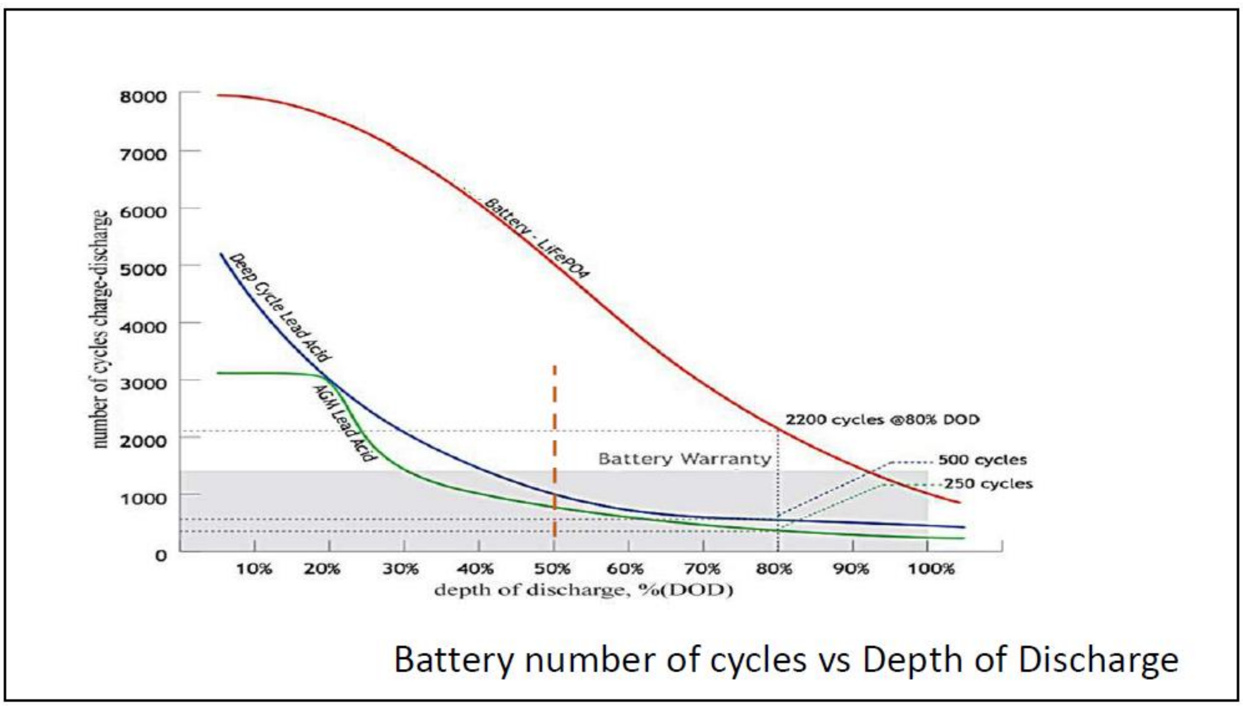
A stand-alone DC PV system such as a solar streetlight has a solar module with mounting structure, battery, charge Controller with night switch, and a DC load which is usually composed of an LED lamp.



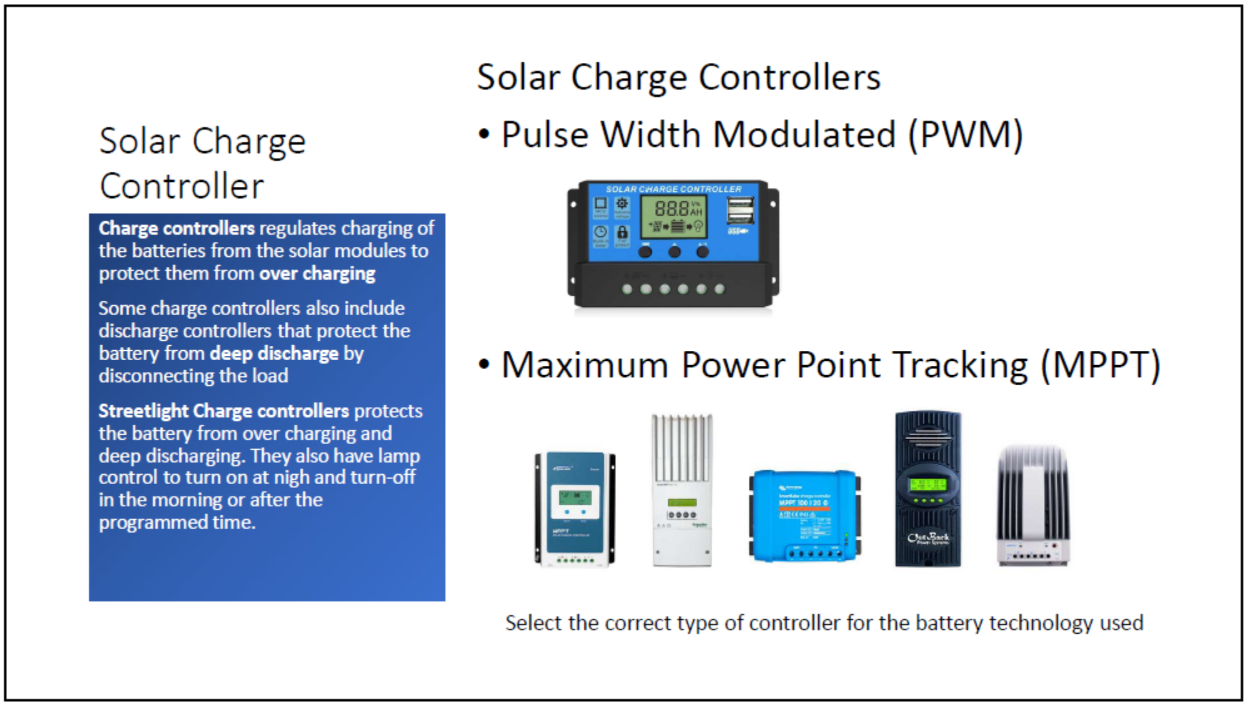
Rechargeable Batteries store electricity in chemical form and release it back as electricity when needed. The most popular types of batteries used are the Lead Acid and the Lithium-Ion batteries. Their technical specifications include their Voltage rating, capacity in Ampere-Hour, Cycle life Based on Depth of Discharge (DOD).



These are photos of the batteries used in solar installations.



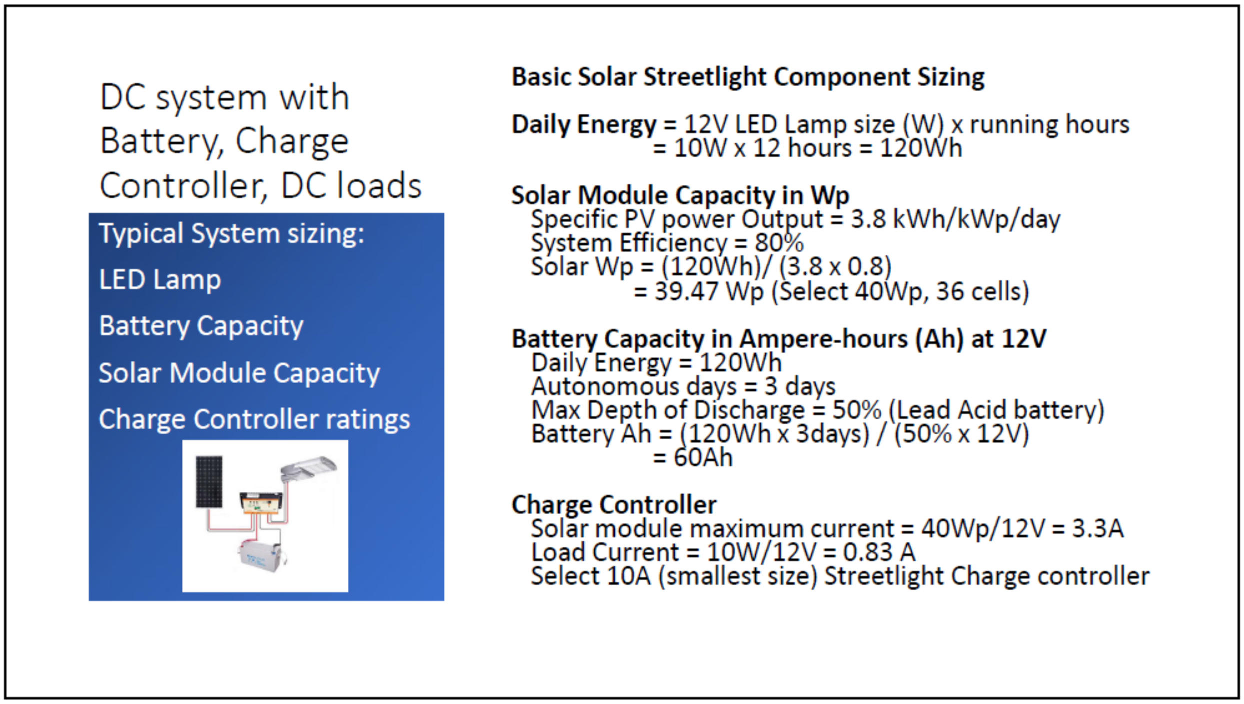
Battery service life is determined by the number of cycles depending on the depth of discharge of the battery. The graph shows the number of cycles (vertical axis) that the $LiPO_4$ (red line), deep-cycle lead-acid (blue line), and the AGM Lead acid (green line) batteries can take over the depth of discharge (DOD) (horizontal axis). At 80% DOD, the deep-cycle lead-acid battery can only take 500 cycles, the AGM Lead acid battery can take 250 cycles, while the $LiPO_4$ battery can take 2,200 cycles. If cycle is equivalent to single day, the deep-cycle lead-acid battery only last a year and four months, the AGM Lead acid battery only lasts 8 months, while the $LiPO_4$ battery can last 6 years.



Charge controllers regulates charging of the batteries from the solar modules to protect them from over charging. Some charge controllers also include discharge controllers that protect the battery from deep discharge by disconnecting the load. Streetlight Charge controllers have lamp controller to turn on at night and turn-off in the morning or after the programmed time.

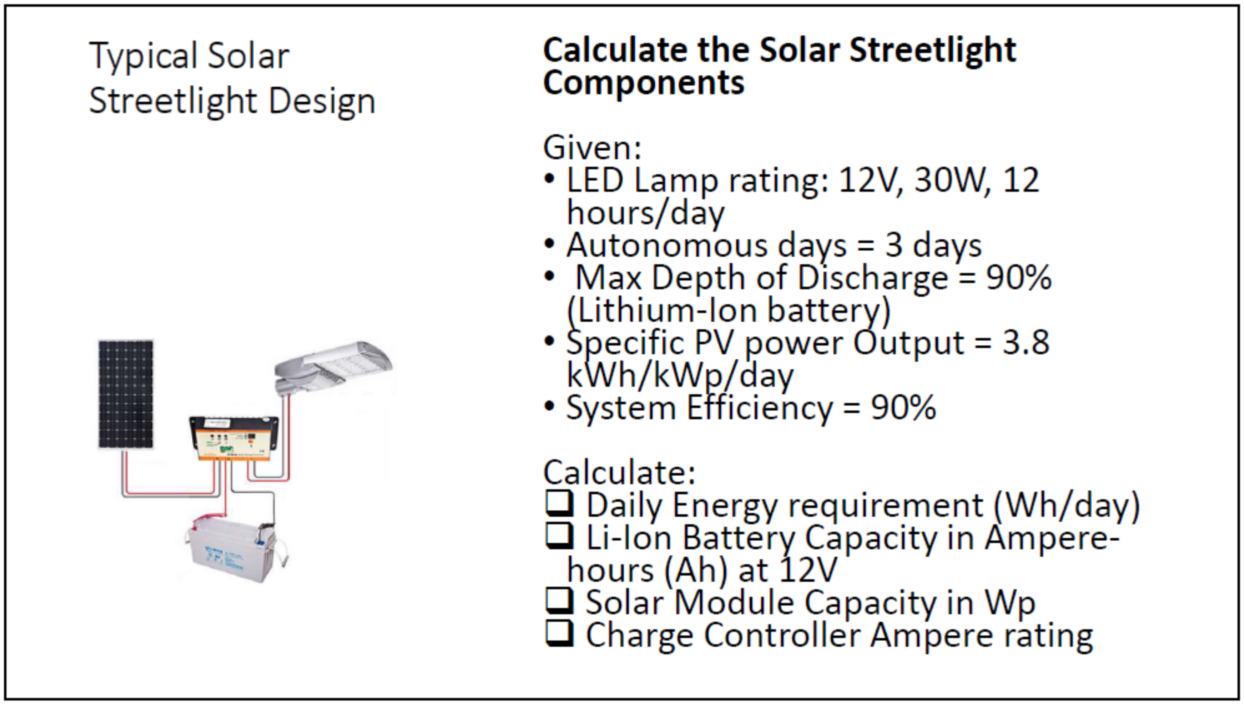
Pulse Width Modulated (PWM) charge controller regulates charging by pulsing the current from the solar module to the battery and regulates the charging by changing the duration of the pulse. A 12V battery will only need a PWM controller when a 36-cell solar module is used or charging a 24V battery bank using 60-cell or 72-cell solar modules.

A Maximum Power Point Tracking (MPPT) charge controller also works similarly with the PWM controller but operates on a wider and higher input voltage from the solar modules. A 12V battery can be charges with 60-cell or 72-cell solar modules using the MPPT charge controller.

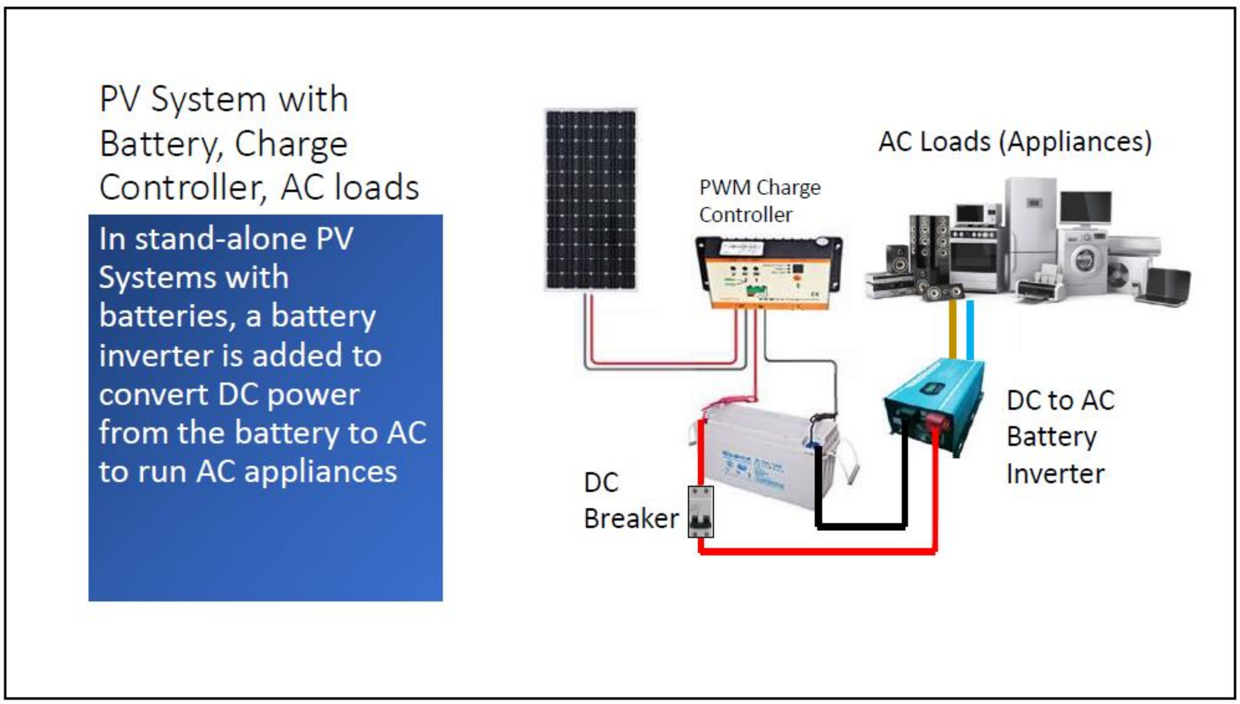


This is a basic Solar Streetlight Component Sizing:

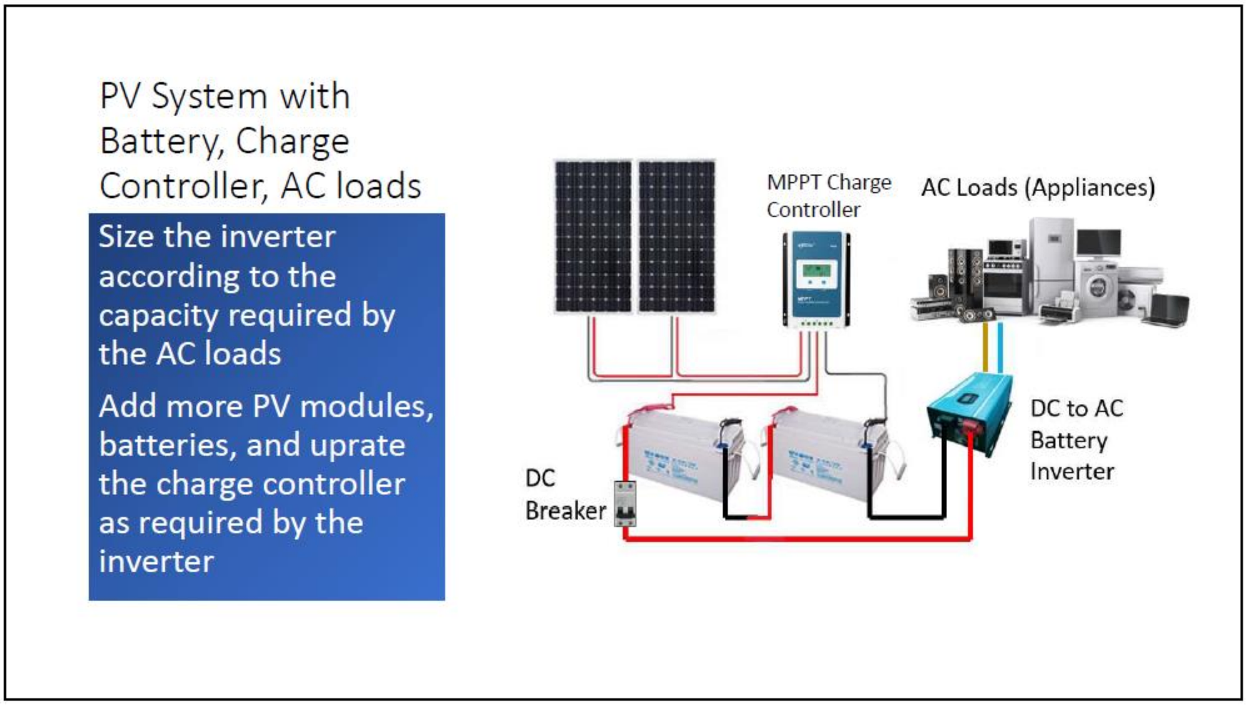
Daily Energy requirement: 12V/10W LED Lamp x 12 running hours
    120Wh
Solar Module Capacity in Wp
    Select 40Wp, 36 cells
Battery Capacity in Ampere-hours (Ah) at 12V
    60Ah at 12V
Charge Controller
    Select 10A (smallest size) 12/24V Streetlight Charge controller



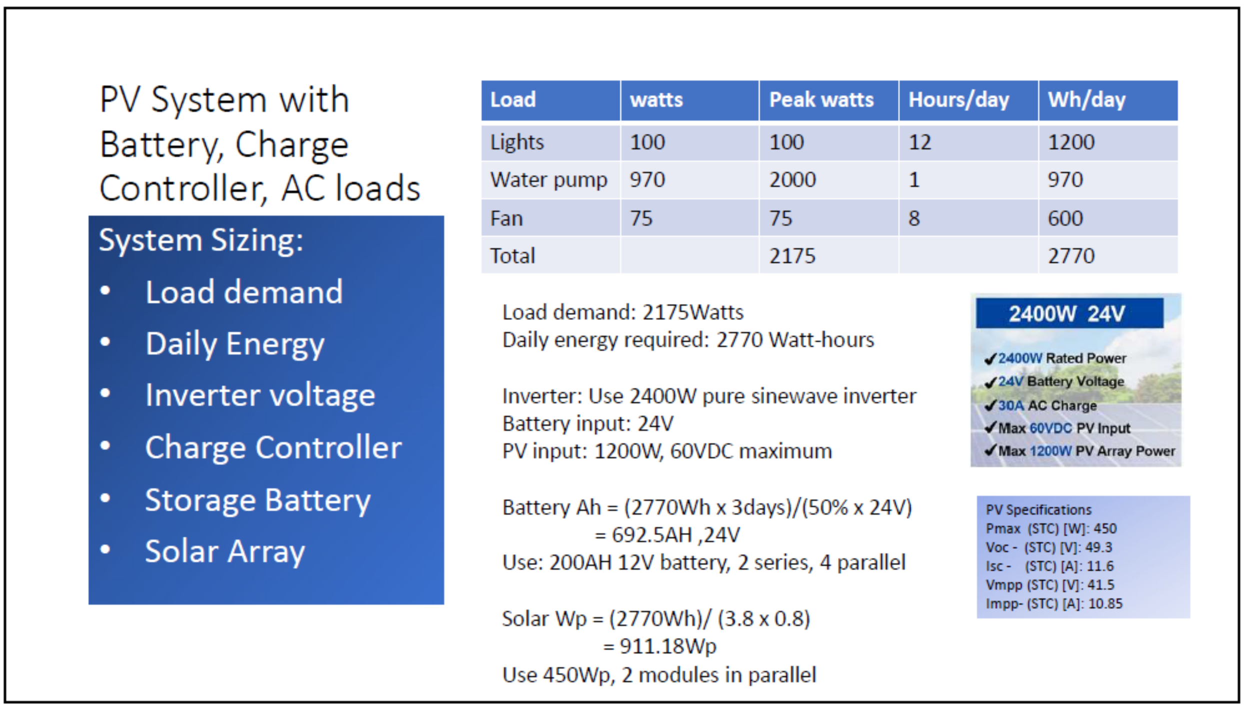
Sample Solar Streetlight Design Problem to be solved by the participants



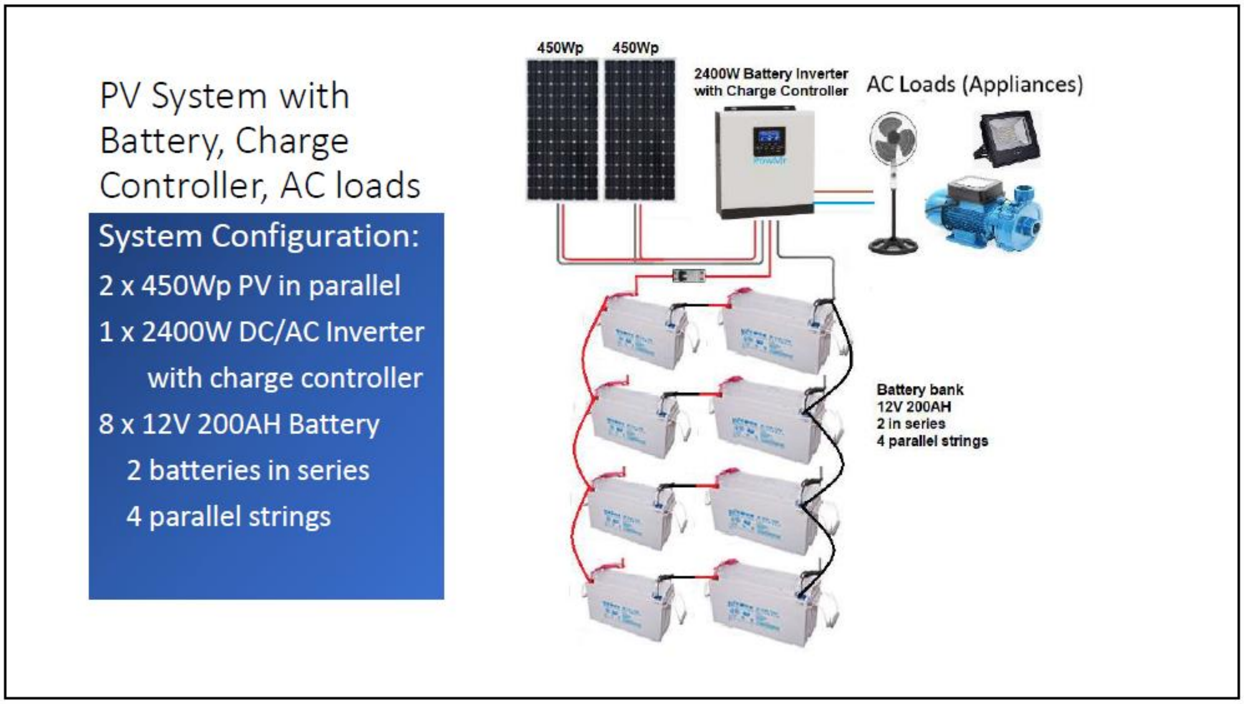
Stand-Alone Solar PV System with AC load (appliances). Small PV system using PWM charge controller and a single battery with DC-AC inverter.



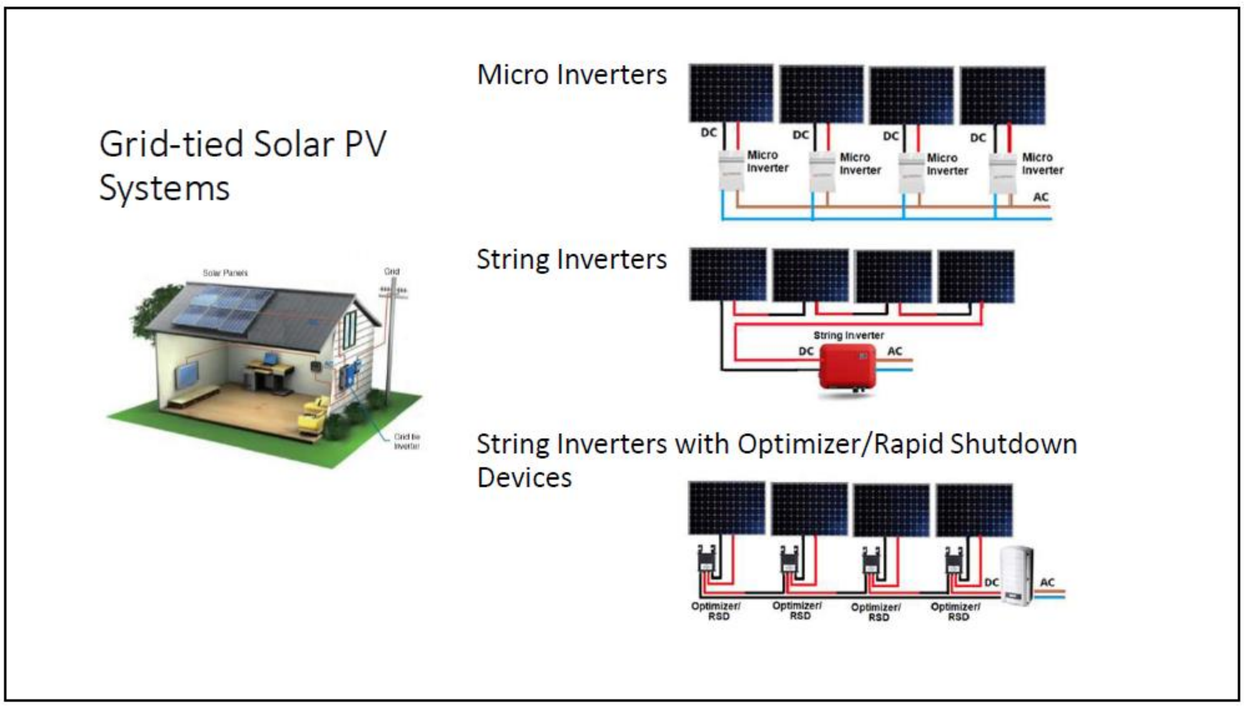
Stand-Alone Solar PV System with more AC load (appliances). Larger PV system using MPPT charge controller with two batteries in series and larger DC-AC inverter.



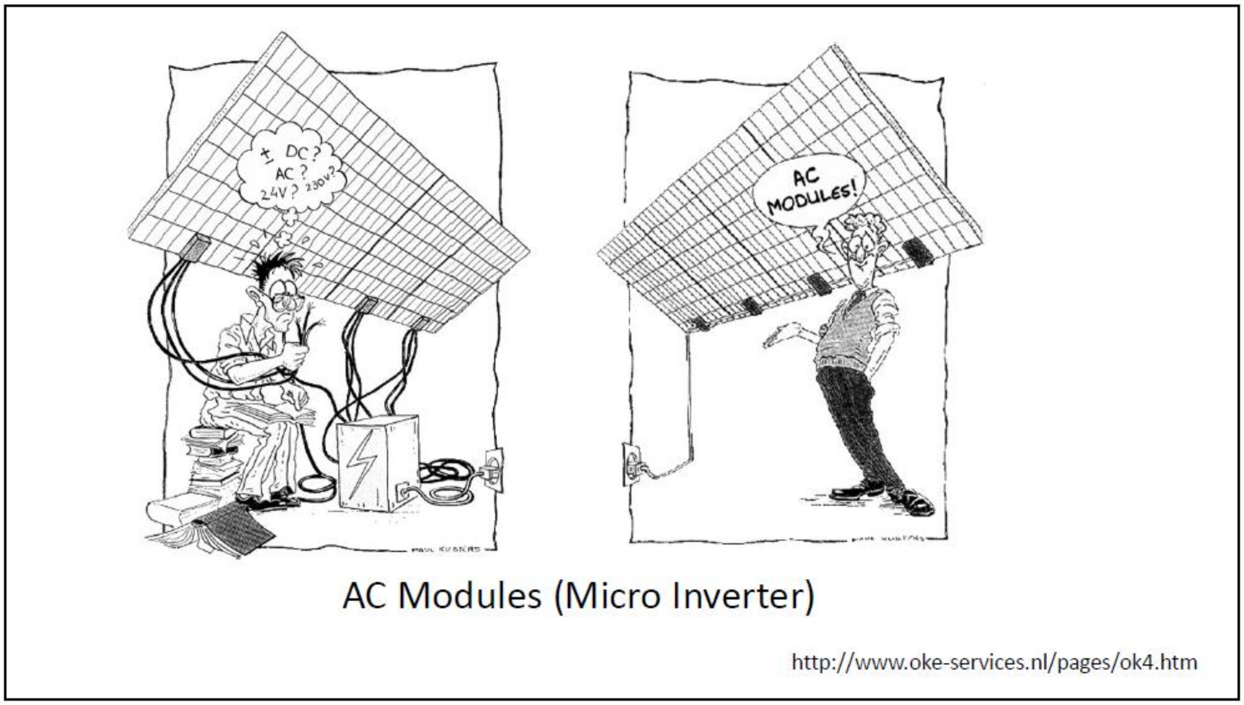
Sample Stand-alone PV System design with defined loads



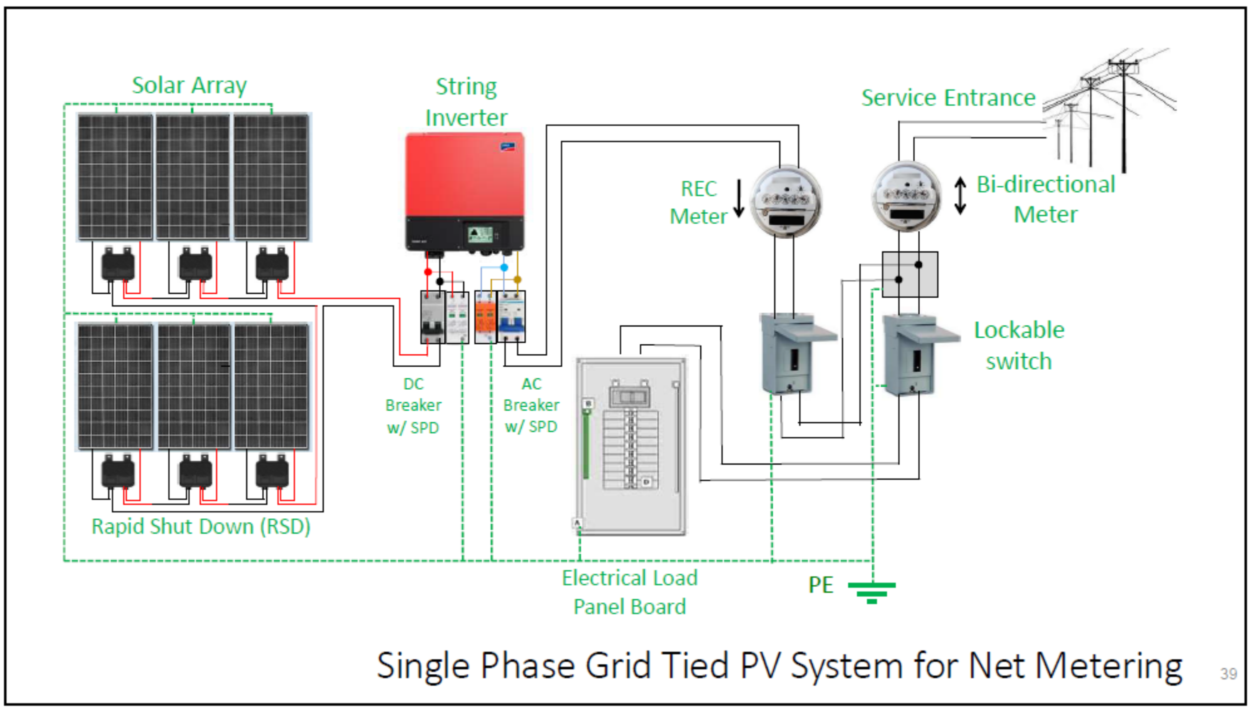
Resulting Stand-alone PV System to meet the capacity and energy requirements of the defined loads



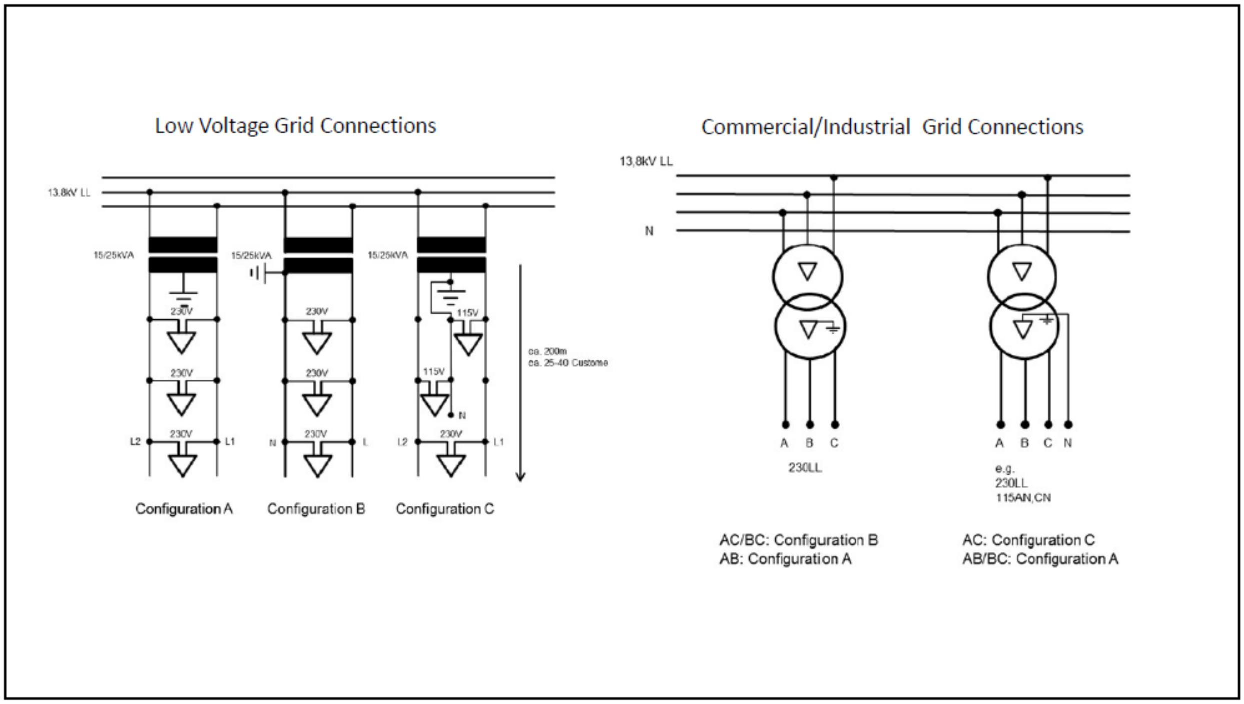
Types of inverters used in Grid-tied PV Systems
Micro Inverters
String Inverters
Optimizers/RSD with String Inverter



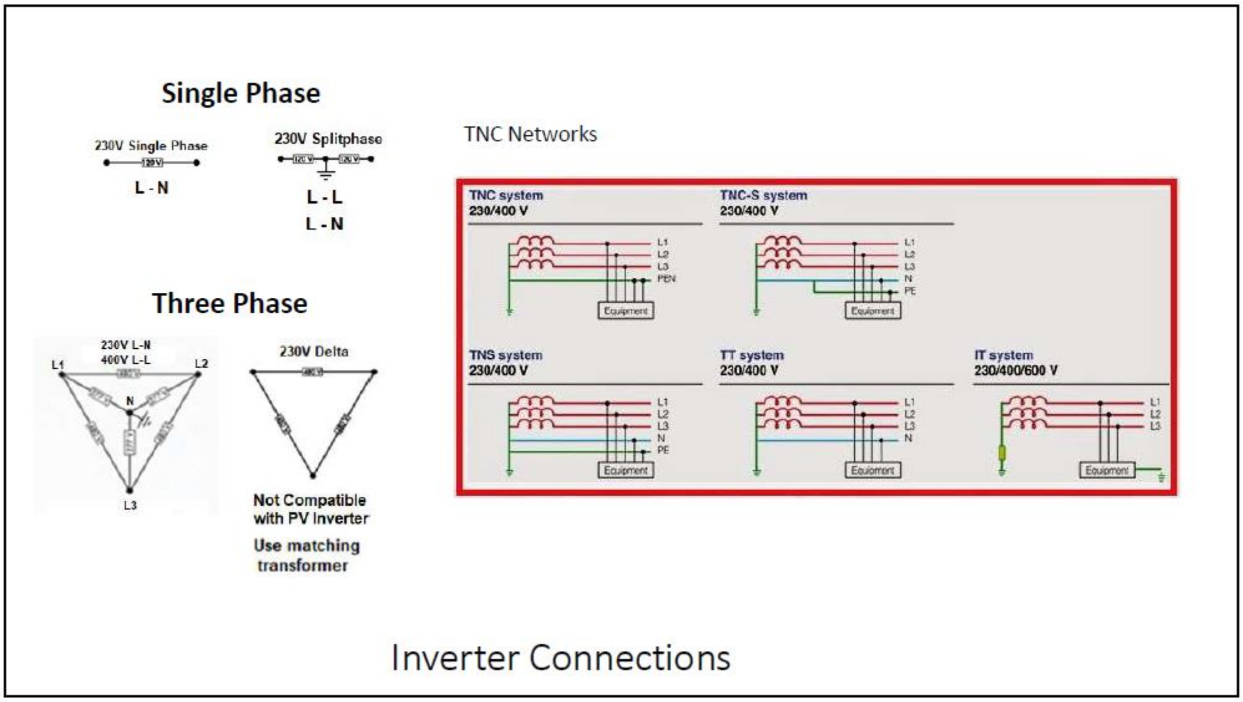
Concept of AC Modules (Micro Inverters) in simplifying grid-tied solar installation vs string inverters.



Typical Grid-tied Solar PV System configuration for single-phase installations using a string inverter for Net Metering. The solar modules are equipped with Rapid Shut Down (RSD) switches, DC breaker to isolate the solar modules, DC Surge Protective Device (SPD), AC SPD, AC breaker to isolate the Inverter from the AC line, lockable switches for the inverter and service equipment, bi-directional meter for Net Metering, and Renewable Energy Certificate (REC) meter. The system is also equipped with grounding system.



Low voltage grid connections in the Philippines.



Grid forms to be considered in Inverter connections. Not all three phase inverters are compatible with 230V delta connection. Use of matching transformer is recommended.

The Phase Grid Tied PV Inverters

Typical three-phase inverters from Inverter manufacturers Solaredge and SMA

	SE50K(1)	SE55K	SE82.8K	
OUTPUT				
Rated AC Power Output	50000(2)	55200	82800	VA
Maximum AC Power Output	50000(2)	55200	82800	VA
AC Output Voltage — Line to Line / Line to Neutral (Nominal)	380/220 ; 400/230			Vac
AC Output Voltage — Line to Line Range / Line to Neutral Range	304 - 437 / 176 - 253 ; 320 - 460 /184 - 264.5			Vac
AC Frequency	50/60 ± 5			Hz
Maximum Continuous Output Current (per Phase) @Vac,nom	76	80	120	A
Grids Supported — Three Phase	3 / N / PE (WYE with Neutral)			V
Maximum Residual Current Injection	250 per unit(3)			mA
Utility Monitoring, Islanding Protection, Configurable Power Factor, Country Configurable Thresholds	Yes			

Full Inverter rating with 3/N/PE (WYE with Neutral)

	SE50K(1)	SE55K	SE82.8K	
OUTPUT				
Rated AC Power Output	29000	32000	48000	VA
Maximum AC Power Output	29000	32000	48000	VA
AC Output Voltage — Line to Line / Line to PE	220 / 127 ; 230 / 133			Vac
AC Output Voltage — Line to Line Range	184 - 264.5			Vac
AC Frequency	50/60 ± 5			Hz
Maximum Continuous Output Current (per Phase) @Vac,nom	76	80	120	A
Grids Supported — Three Phase	3 Lines / PE (Delta: corner grounding not supported)			
Maximum Residual Current Injection	250 per unit(2)			mA
Utility Monitoring, Islanding Protection, Configurable Power Factor, Country Configurable Thresholds	Yes			

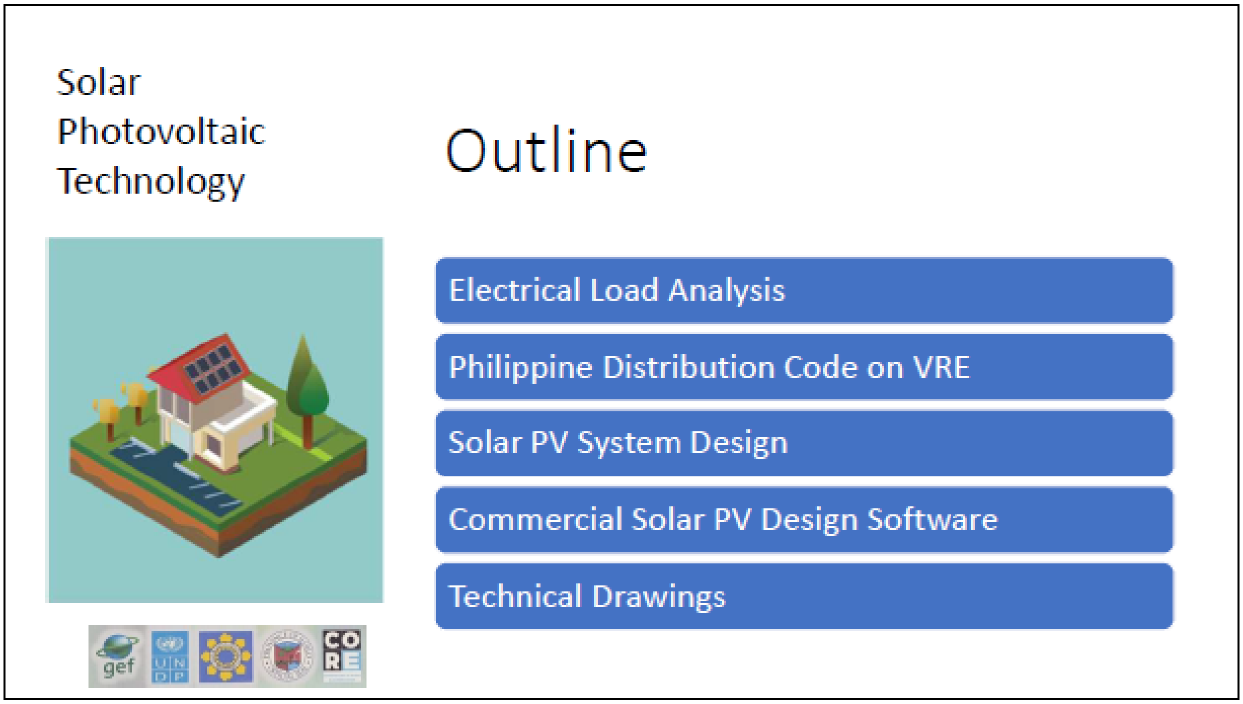
60% Inverter rating with 3 lines /PE (Delta)

Belgium, Norway, Taiwan & Philippines

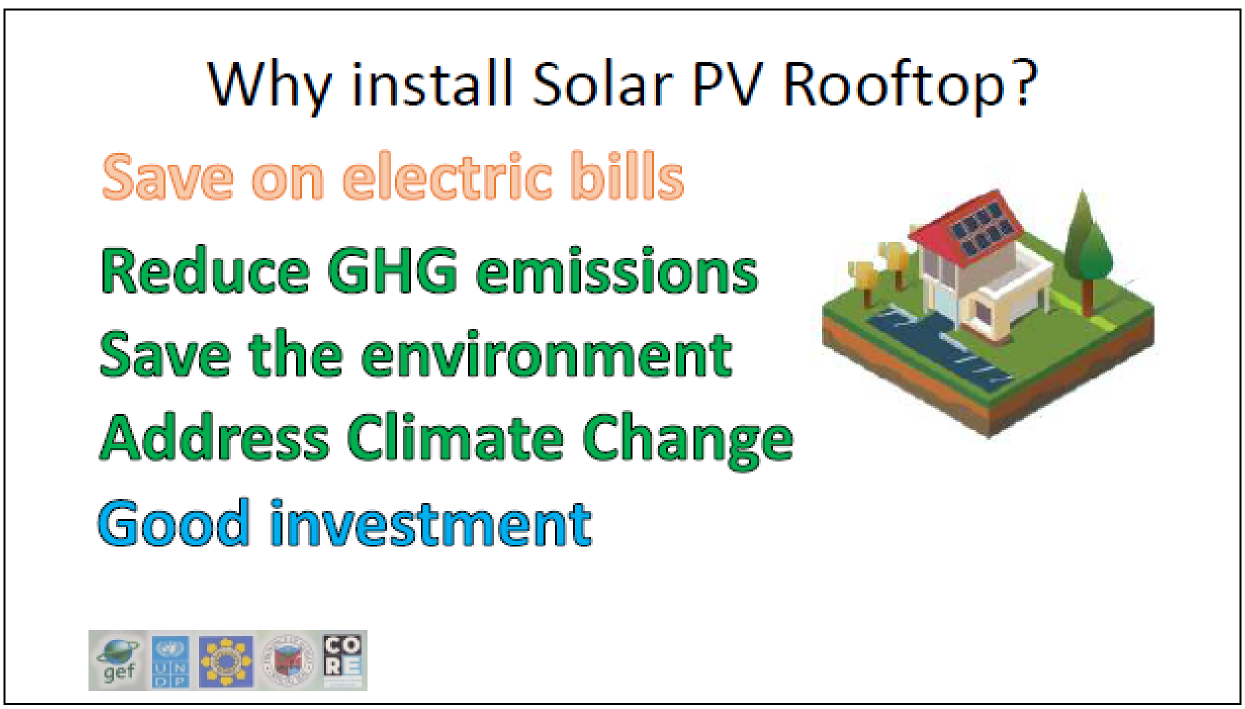
Three phase inverter derating with Delta grid

Three-phase inverter, such as Solaredge SE50K, SE55K, SE82.8K can be installed on both wye and delta secondary three-phase connection. However, the rated output of the inverters has to be derated at 60% when connected on a delta grid.

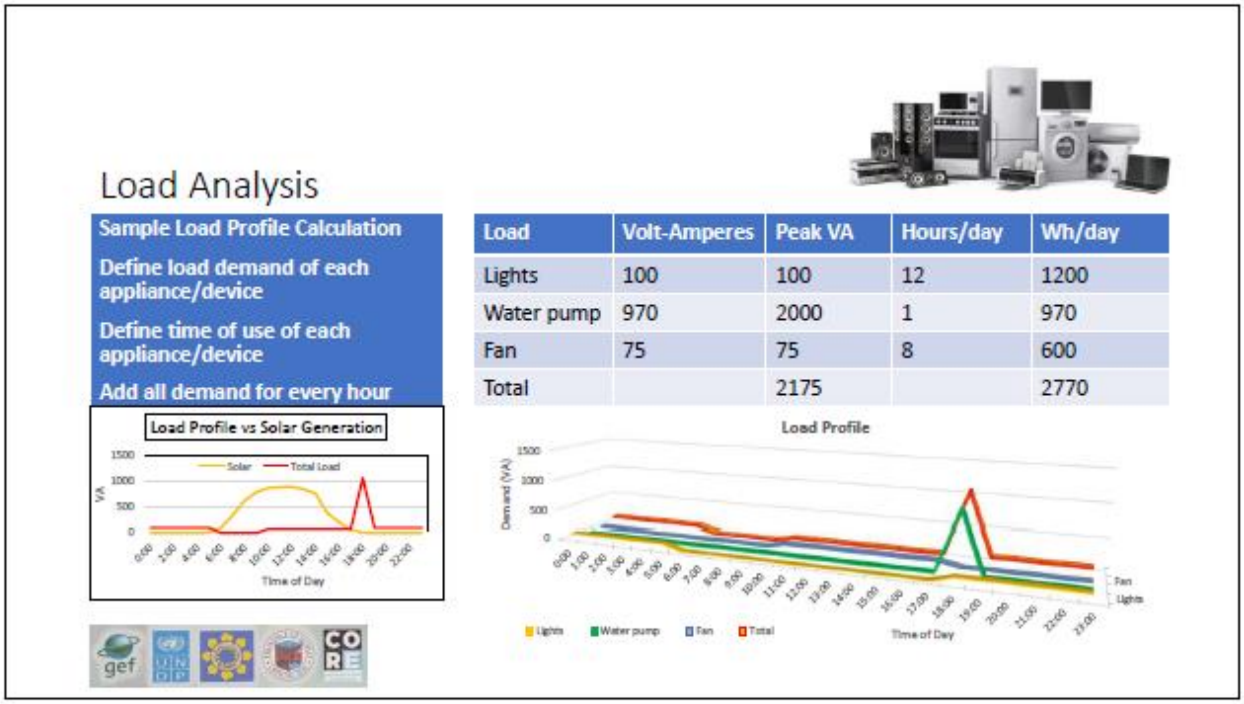
2.4 Session 4 - Solar PV Technology System Design



Outline for the Solar PV Technology System Design session

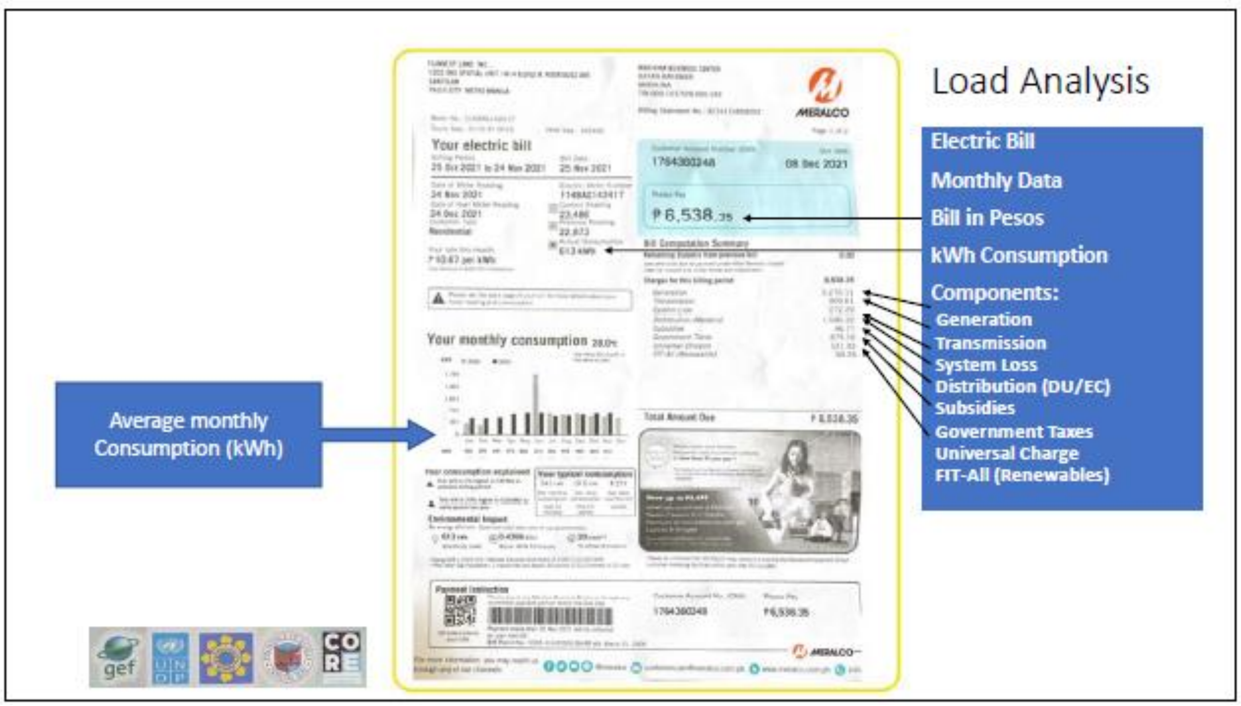


To design a PV system, the motivation for the solar rooftop installation has to be defined to be the basis for the design criteria



Load	Volt-Amperes	Peak VA	Hours/day	Wh/day
Lights	100	100	12	1200
Water pump	970	2000	1	970
Fan	75	75	8	600
Total		2175		2770

The appliances on a typical hour can be listed to calculate the electrical demand and energy based on the operating hours of the appliances. The total demand and energy requirement of a house can then be calculated. The time when these appliances are used can be compared the available power from the solar installation that is dependent on sunlight.



The electricity consumption can also be determined using the monthly electric bill from the utility.

Basic PV System Sizing

Using the average monthly energy consumption from the electric bill

Example:

Monthly consumption = 541kWh

$$\text{Daily kWh} = \frac{541\text{kWh}}{\text{month}} * \frac{\text{month}}{30\text{ days}} = 18.06\text{ kWh per day}$$

To adopt the example computation by a distribution utility in Net-metering
Solar PV Capacity Factor: 16%

$$\text{Size of the PV system} = \frac{\text{average daily kWh requirement}}{24\text{ hrs} * \text{capacity factor}}$$

$$\text{Size of the PV system} = \frac{18.06\text{ kWh}}{24\text{ hr} * 0.16} = 4.84\text{ kWp}$$

A simple way of estimating the solar PV capacity needed to meet the energy requirement of the load can be calculated using these formulas.

Load Analysis

Using Electric Bill with Demand Charge

PRESENT	PREVIOUS	MULTIPLIER	KWH USED
READING			
18129.40	17821.70	210	64617.00
DEMAND READING			KW USED
0.61	0.00		129.09

Monthly Energy Consumption: 64167kWh
Peak Monthly Demand: 129.09kW

Convert monthly consumption to daily consumption by dividing 30 days per month:

Daily consumption = 64,167kWh ÷ 30days = 2,138.9kWh

Specific photovoltaic power output: 3.936 kWh/kWp per day
Solar PV Capacity = 2,138.9kWh ÷ 3.936 kWh/kWp per day = 543kWp
Warning: At 20% system loss, the AC output of the system is

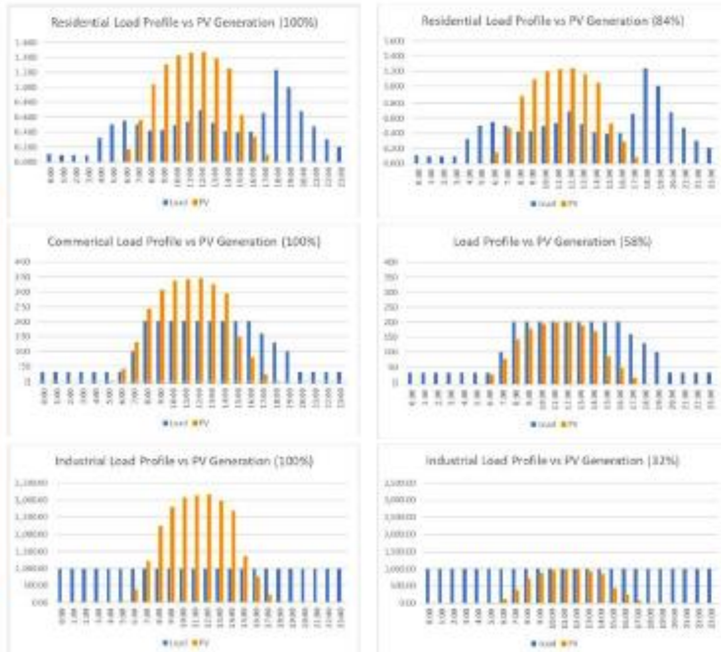
kW_{AC} = 543kWp x (1-20%) = 434.4kW

Inverter output at 434.4kW is greater than 129.09kW peak demand
Check if electrical system can accommodate 434kW or
use 129.09kW as the maximum inverter output

Care should be taken when using the simple formula for solar PV capacity calculation because the resulting solar capacity could be greater than the peak demand of the facility and exceeds the electric system limits and the capacity of the distribution transformer.

Electrical System Review

- Load profiles
- Peak Demand
- Solar PV Peak Generation
- Solar PV Energy/Consumption



Different load profiles will have different peak demand that does not already match the peak solar generation. To avoid export of excess generation, the peak generation of the solar should not exceed the peak demand of the load. This limitation results to a lower reduction of consumption displaced by the solar generation.

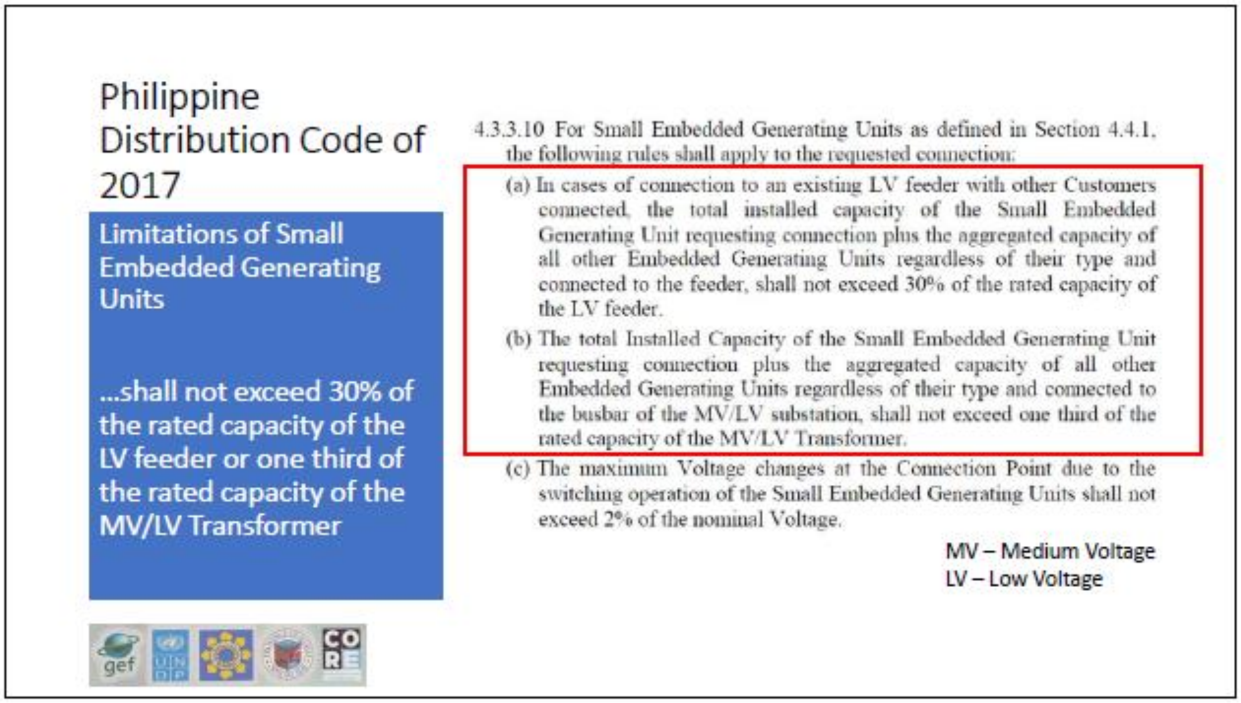
Philippine Distribution Code of 2017

Classification of Variable Renewable Energy according to Capacity

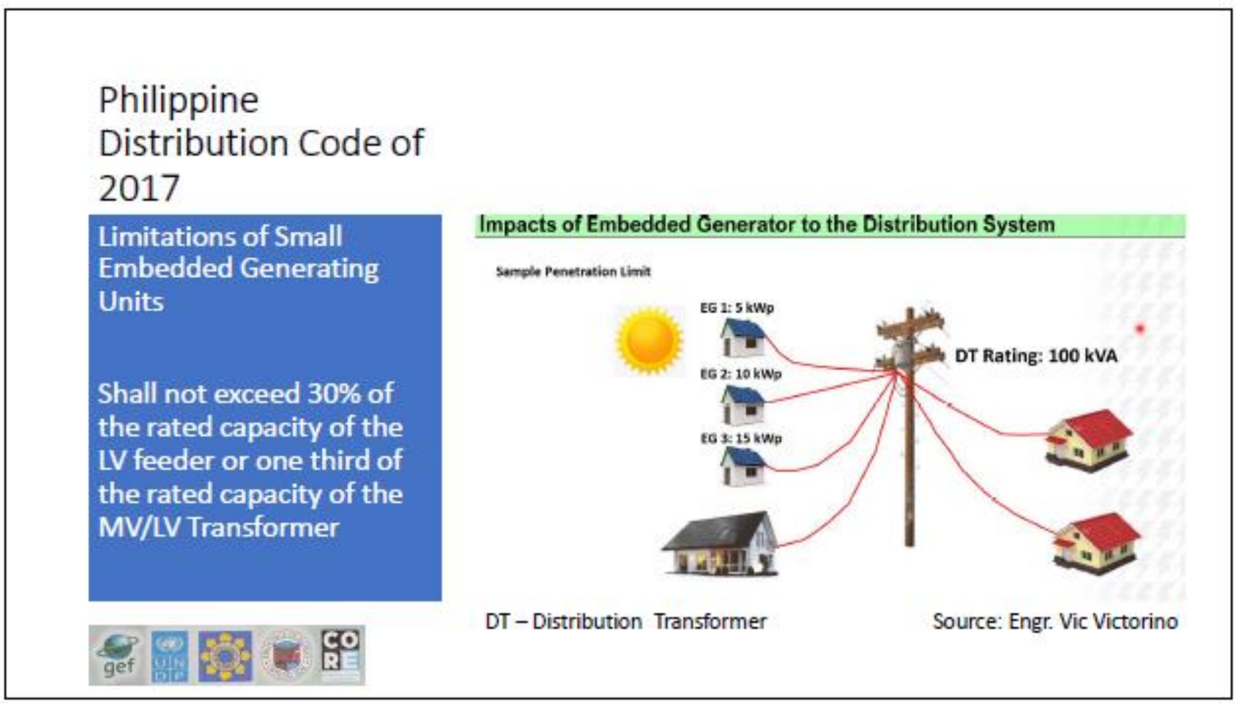
TABLE 4-1 CLASSIFICATION OF EMBEDDED GENERATING PLANTS

Category	Installed Capacity and Characteristics
Large Conventional	Conventional Embedded Generating Plant with an aggregated Installed Capacity of 10 MW or more.
Large VRE	VRE Embedded Generating Plant with an aggregated Installed Capacity of 10 MW or more.
Medium	Conventional or VRE Embedded Generating Plants with Installed Capacity larger than 1 MW which do not qualify as Large Embedded Generating Plant.
Intermediate	Conventional or VRE Embedded Generating Plants with Installed Capacity larger than 100 kW and equal to or less than 1 MW; and Conventional Embedded Generating Plants with Installed Capacity lower or equal to 100 kW connected to MV networks.
Small	Embedded Generating Plant with Installed Capacity larger than 10 kW and equal to or less than 100 kW connected to LV networks.
Micro	Embedded Generating Plants with Installed Capacity lower or equal to 10 kW connected to LV networks.

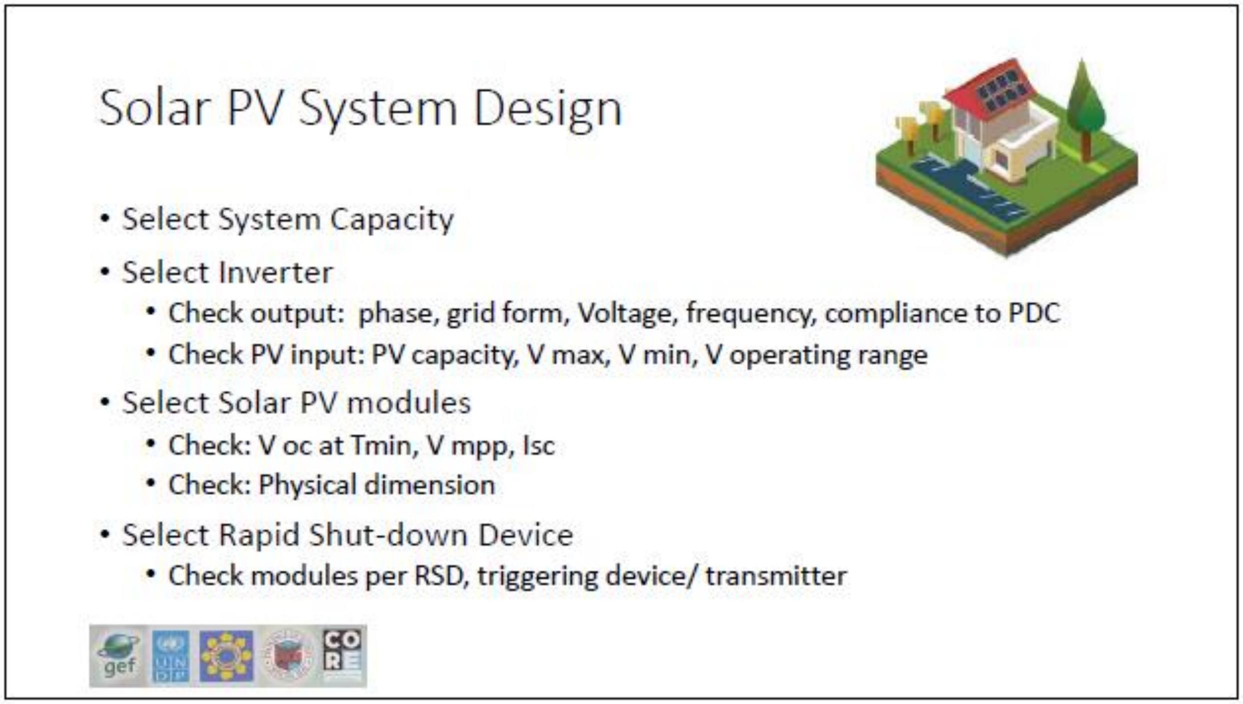
The Philippine Distribution Code of 2017 classifies 10kW to 100kW solar installation as Small while 10kW and smaller installation as Micro.



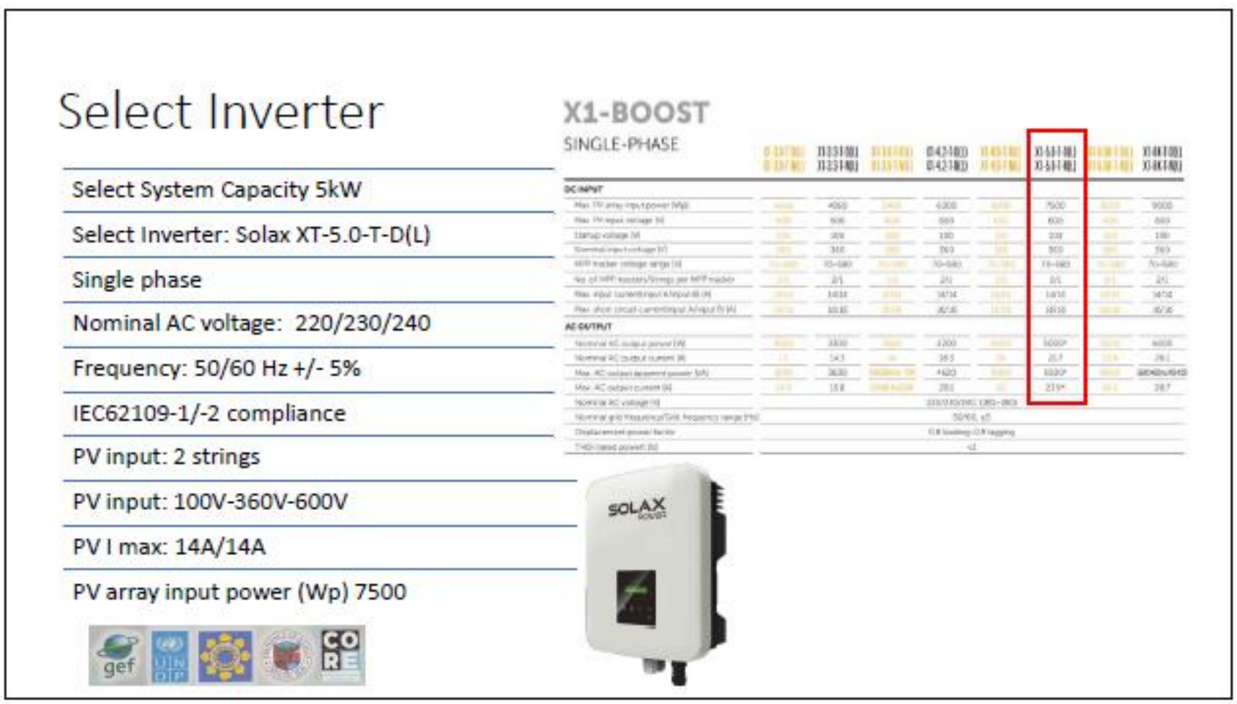
The Philippine Distribution Code of 2017 also sets a limit to embedded generating units regardless of their type not to exceed one third of the rated capacity of the Medium/Low voltage distribution transformer.



The limitation set by the Philippine Distribution Code of 2017 is illustrated in this slide



These are the steps in designing a solar PV system



The grid-tied inverter is a crucial device in the PV system that can be selected first to ensure that it is compatible to the grid where it will be connected. The rest of the solar components will be designed around the inverter.

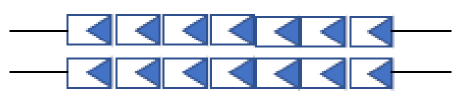
Select Solar PV modules

- Back Sheet Module 500W
- Voc (V) = 51.7
- Isc (A) = 12.13
- V_{MPP} (V) = 42.8
- I_{MPP} (A) = 11.69
- Module dimension 2176 × 1098 × 35 mm

Back Sheet Module	485W	490W	495W	500W	505W
Voc (V)	51.1	51.3	51.5	51.7	51.9
Isc (A)	12.01	12.05	12.09	12.13	12.17
Vmp (V)	42.2	42.4	42.6	42.8	43.0
Imp (A)	11.49	11.56	11.63	11.69	11.76
Module dimension	2176 × 1098 × 35 mm				

The solar PV module can be selected, and its data sheet should be checked to design the solar array on the number of modules in series per string and the number of strings in parallel per inverter input.

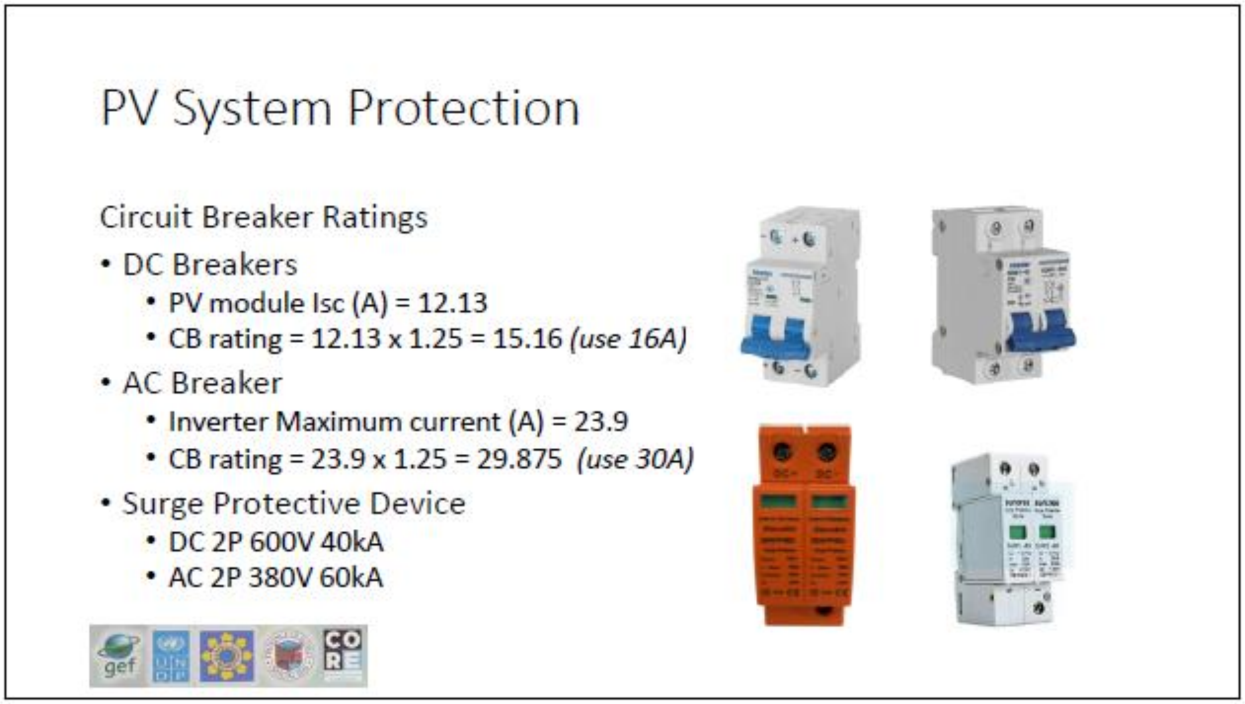
PV String Design



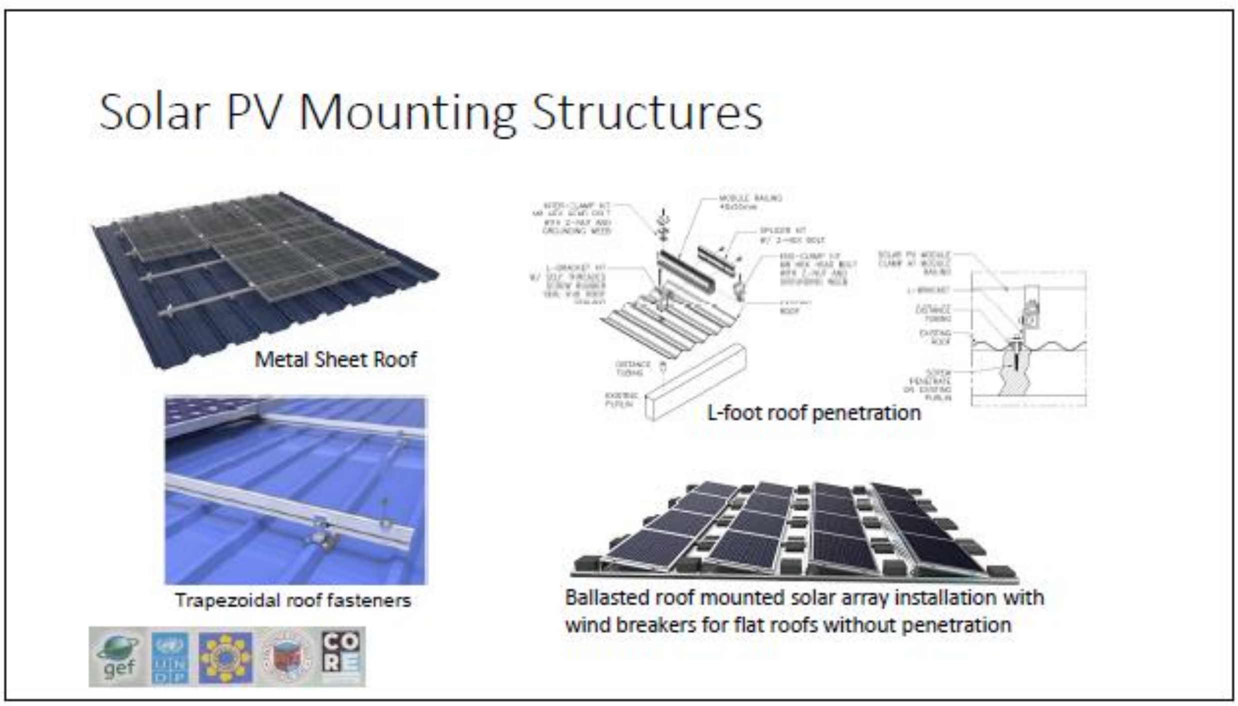
Inverter PV input requirement

- V input: 100V-360V-600V
  - Modules in series = 360V ÷ 42.8V = 8.4 *use 8 modules/string*
  - Max string voltage = 8 x 51.7V = 413.6V *(OK – below V max 600V)*
  - Max Current per string = 11.69 *(OK – below I max 14A)*
  - Power per string = 8 x 500Wp = 4000Wp
  - Total power = 2 strings x 4000Wp = 8000Wp *(exceeds 7500W limit)*
    - Use 7 modules per string, V_{MPP} = 7 x 51.7V = 361.9V *(OK – below V max 600V)*
    - Power per string = 7 x 500Wp = 3500Wp
    - Total PV Power = 2 string x 3500Wp/string = 7000Wp *(OK – below V max 7500Wp)*
  - PV Array configuration: 2 strings x 7 (500Wp) modules in series = 14 modules

For the selected invert and solar module, the voltage input of the inverter with a minimum of 100V, an operating voltage of 360V, and a maximum of 600V will require connecting 8 solar modules in series as a string. To meet the capacity requirement of 3500Wp per inverter input, two strings can be connected in parallel for each input of the inverter but only 7 modules per string is used. With two inputs, the total rated capacity of the PV system is 7kWp.

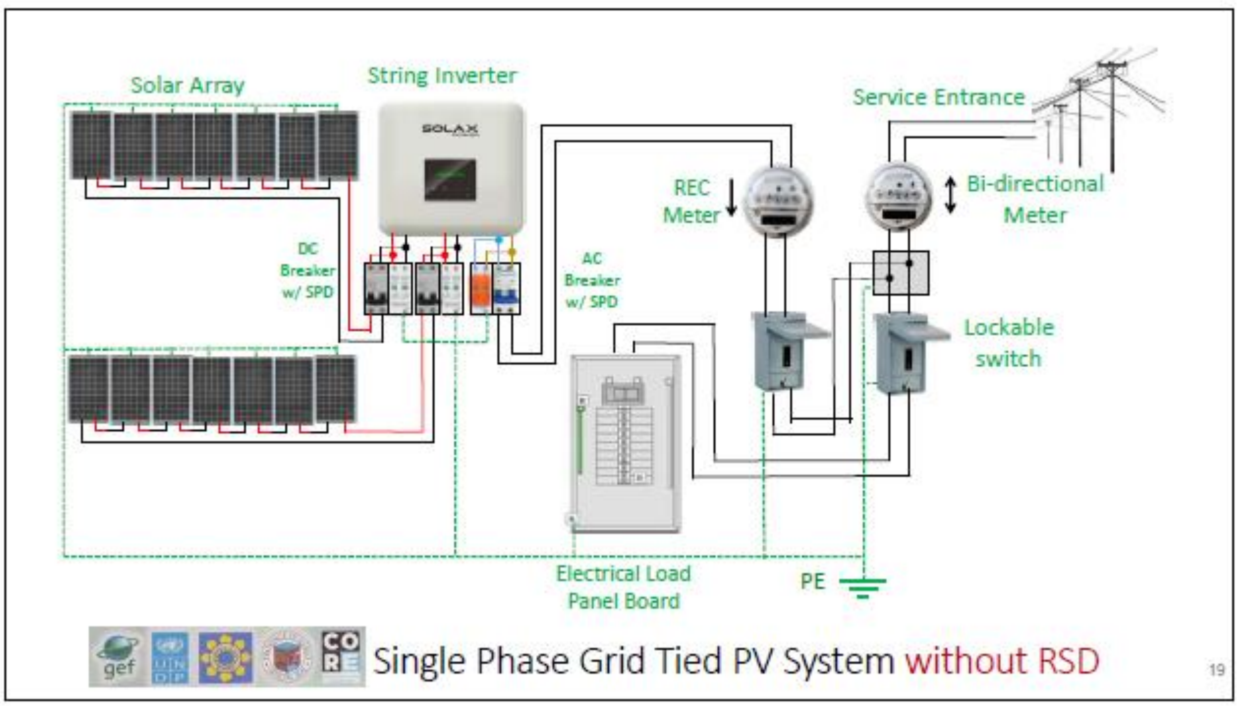


Protective devices are used in the PV system for overcurrent protection and over voltage both on the DC and AC side using Circuit Breakers and Surge Protective Devices, respectively.

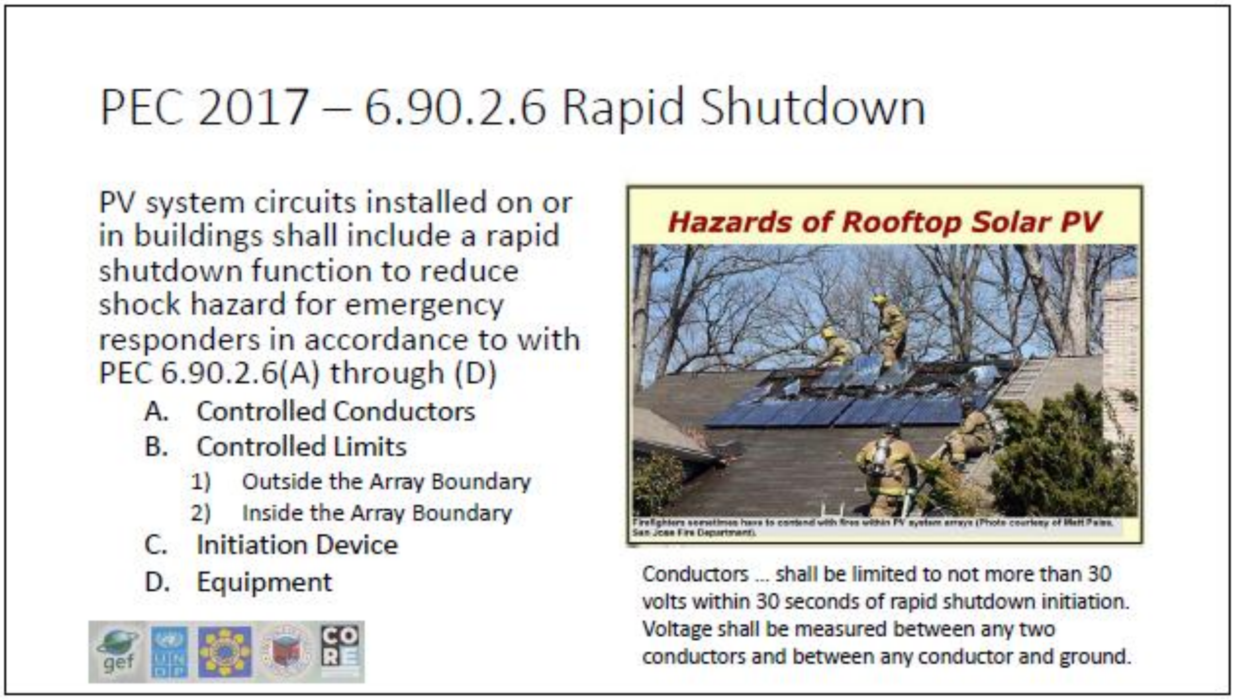


Solar modules are mounted on the roof using racking systems. A suitable racking system can be used depending on the type of roof. This can be a metal sheet roof or a flat roof.

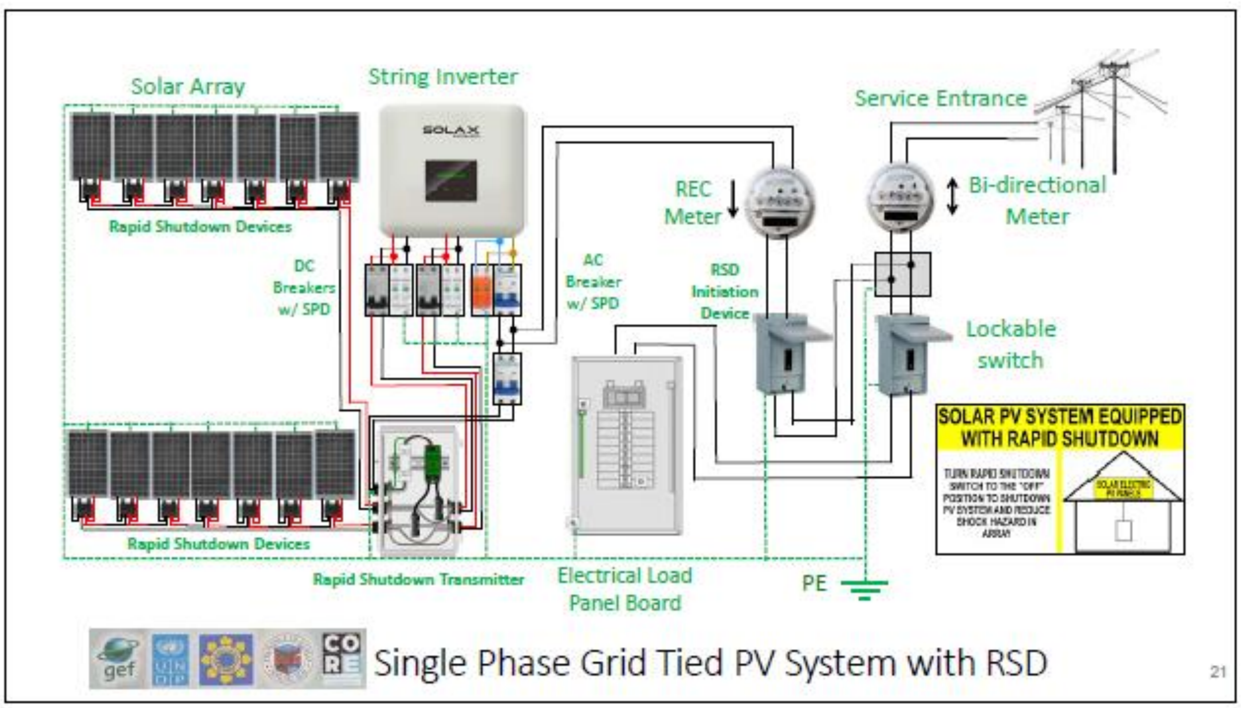
For inclined metal roofs, these are the mounting hardware that are used to securely mount the solar module from the roof substructure. Three railings instead of two can be used to hold large solar modules in areas exposed to strong winds.



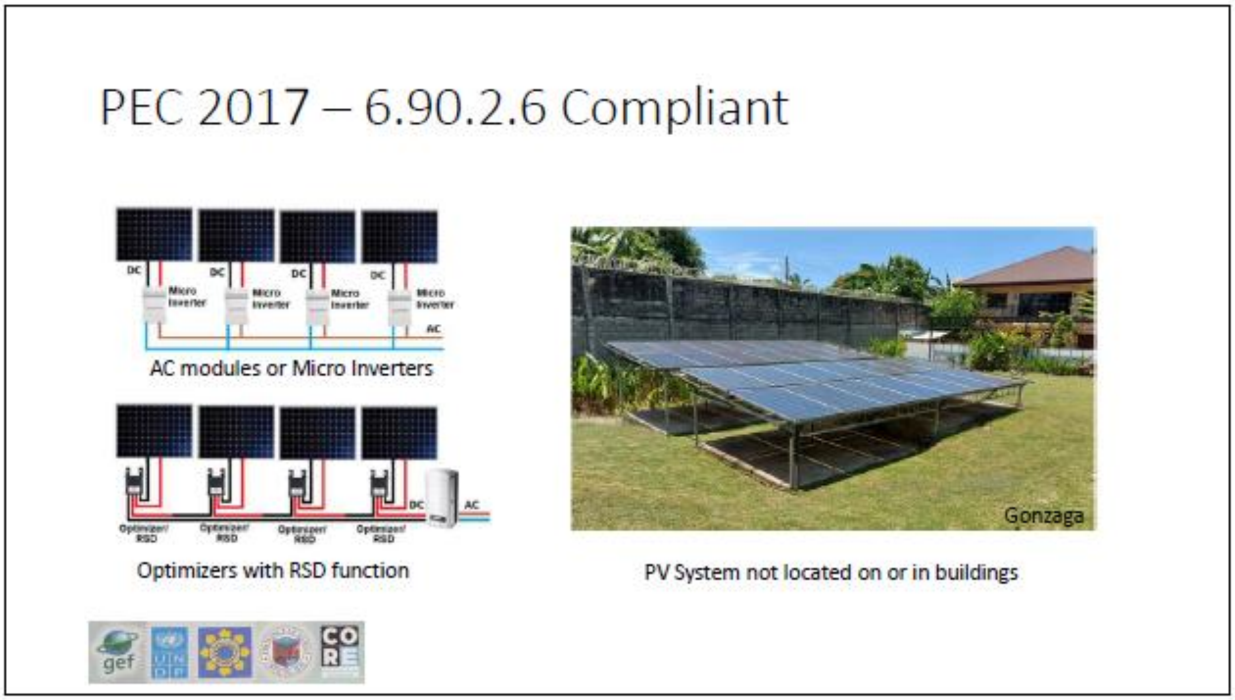
This is a typical single-inverter grid-tied PV system before the rapid shut down (RSD) switch was required.



The Philippine Electrical Code of 2017 Article 6.90.2.6 required the use of Rapid Shut Down switch to protect first responders when putting off the fire on the roof with solar arrays. The RSD should disconnect the solar modules so the no voltage between any conductors exceeds 30 volts within 30 seconds.

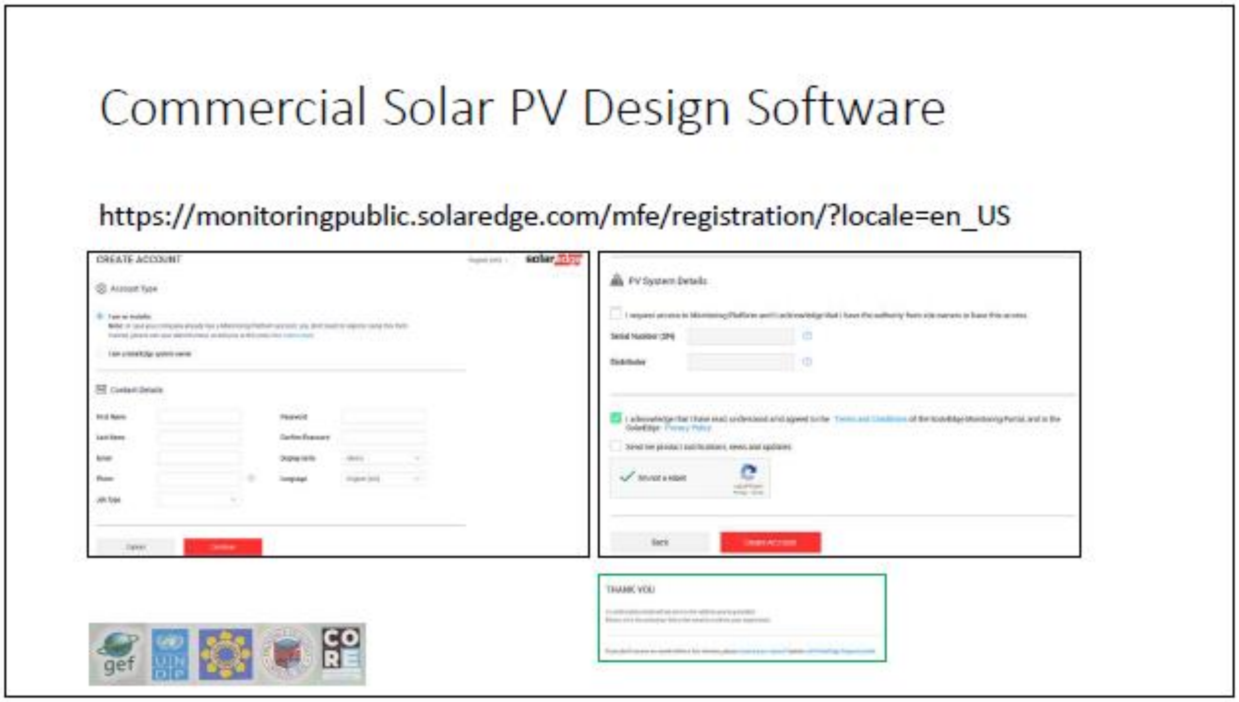


An RSD system is added to the PV installation to comply with the PEC 2017 safety requirement.

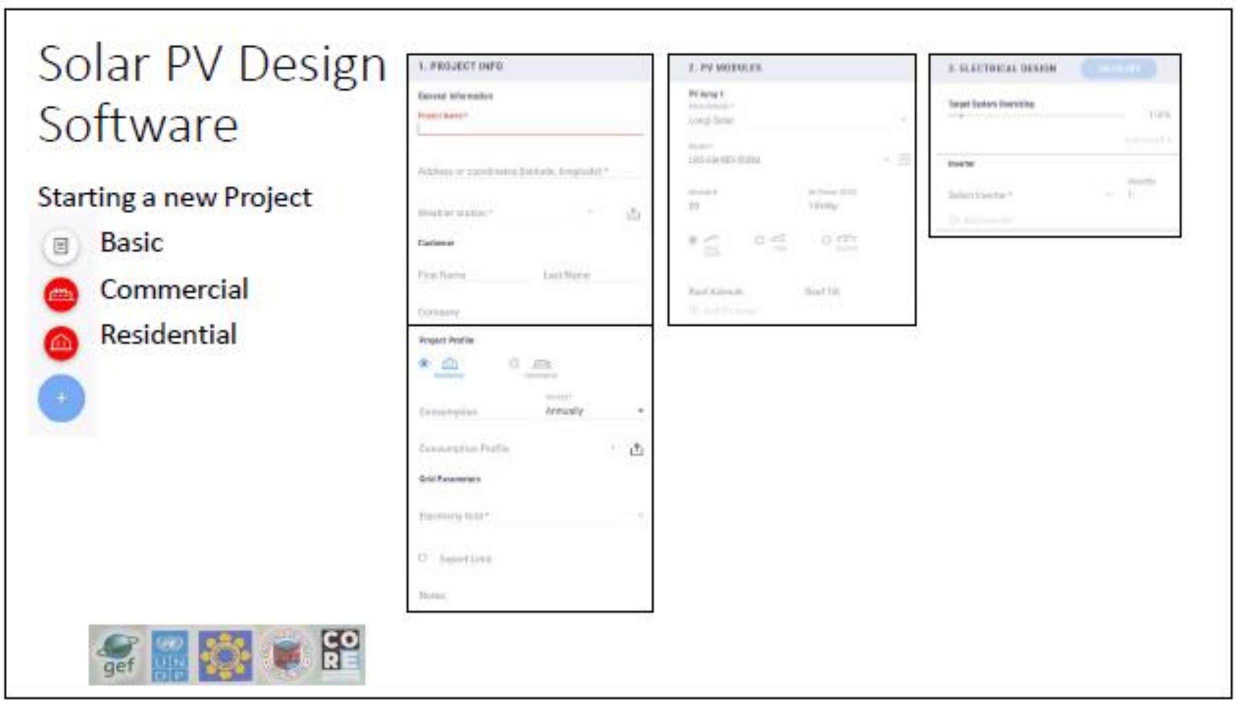


There are exemptions to the RSD requirements as allowed by the PEC 2017 for solar arrays that are ground mounted and not installed in buildings. Using micro inverter and optimizer with RSD function are also allowed by the PEC 2017.

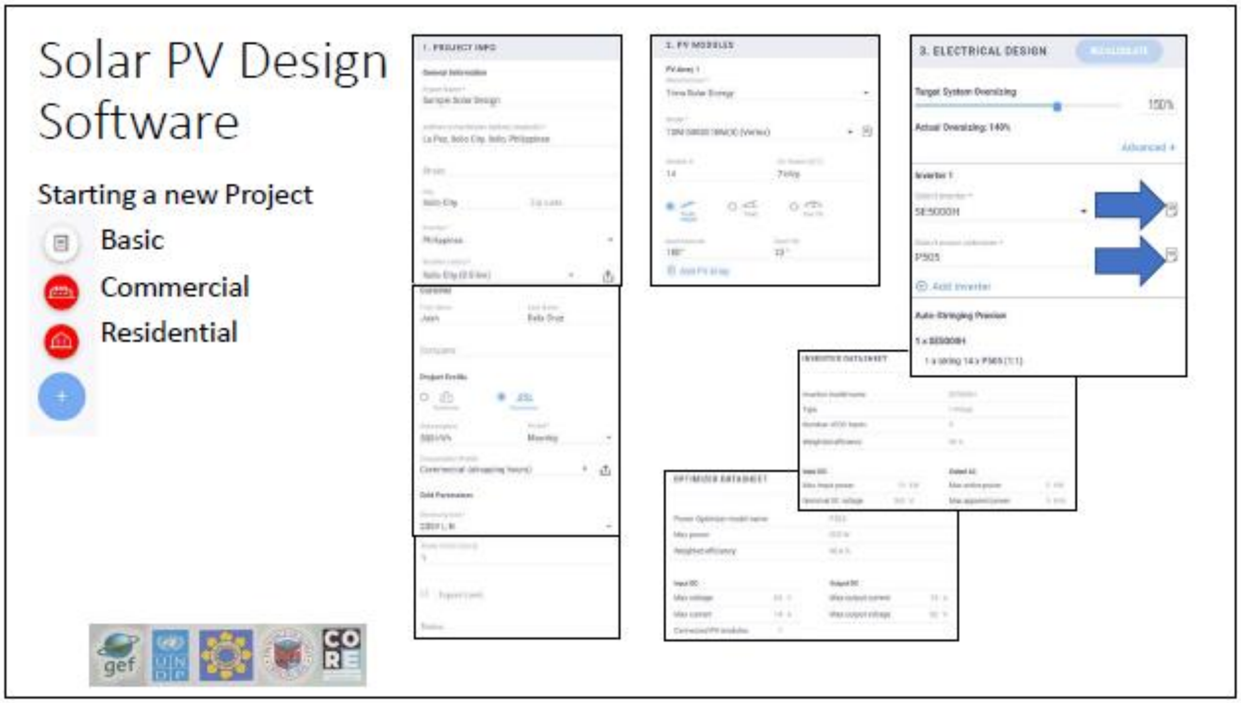
There are commercial solar design software applications are freely available on the web for designers to use.



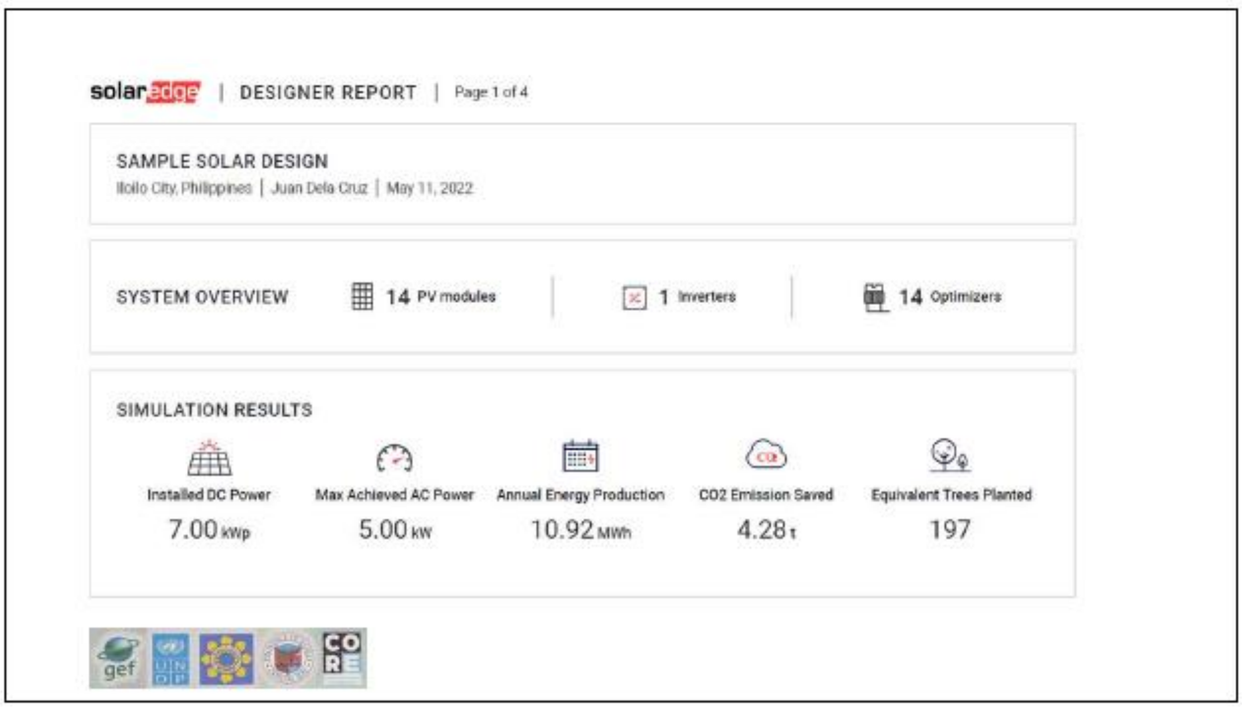
The Solaredge design software can be used by going to its website and register as a user



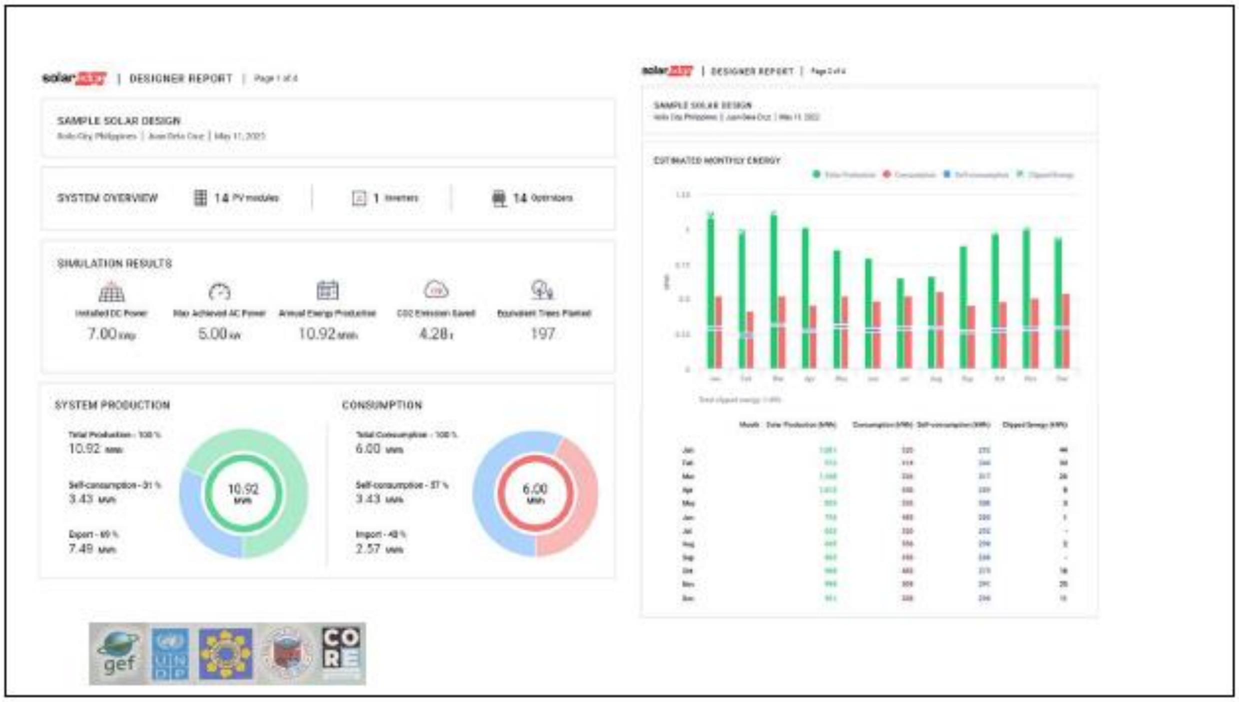
The design software will require the needed inputs regarding the facility for the solar installation



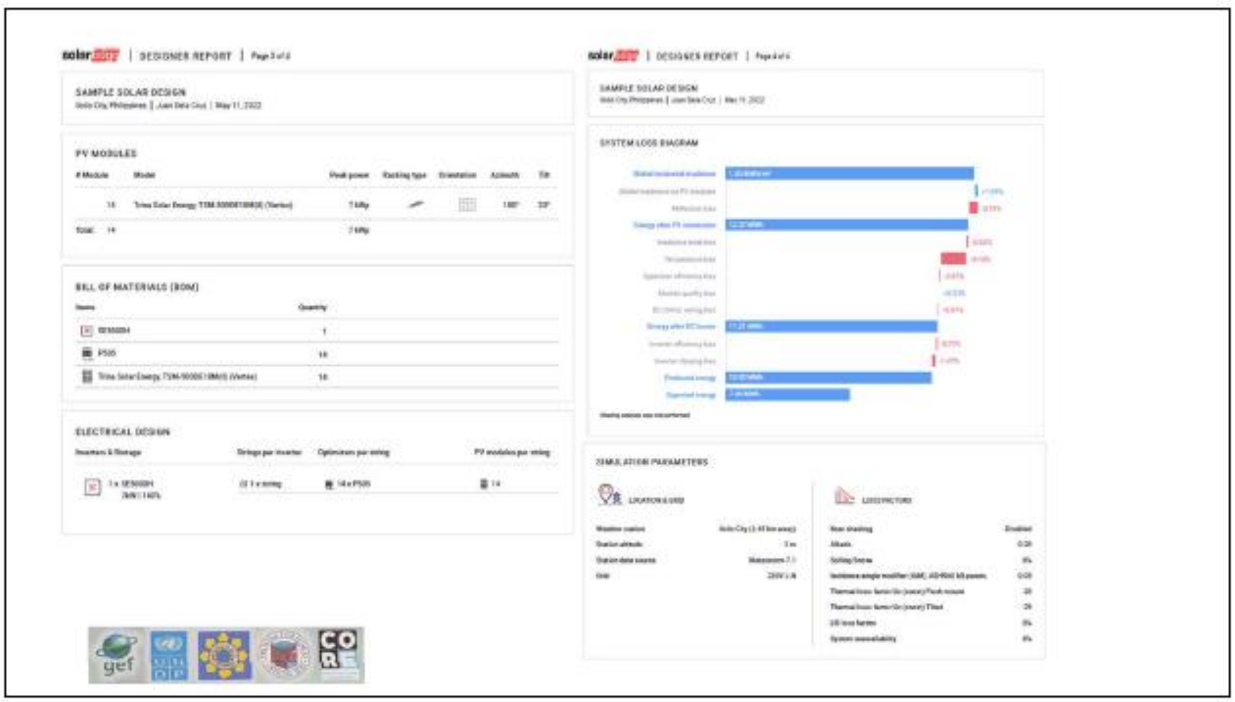
The software will guide the designer to select possible options on the design



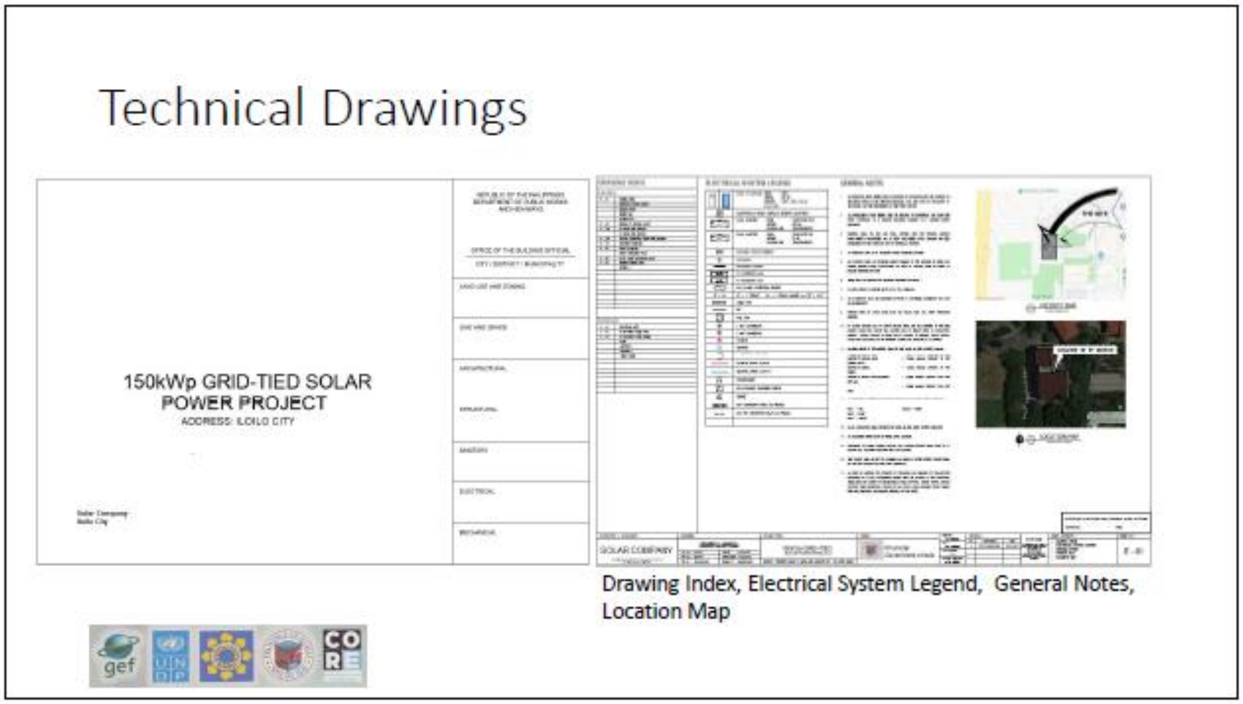
The result is presented with the solar capacity installed, the energy produced annually with equivalent CO2 emissions avoided and trees planted



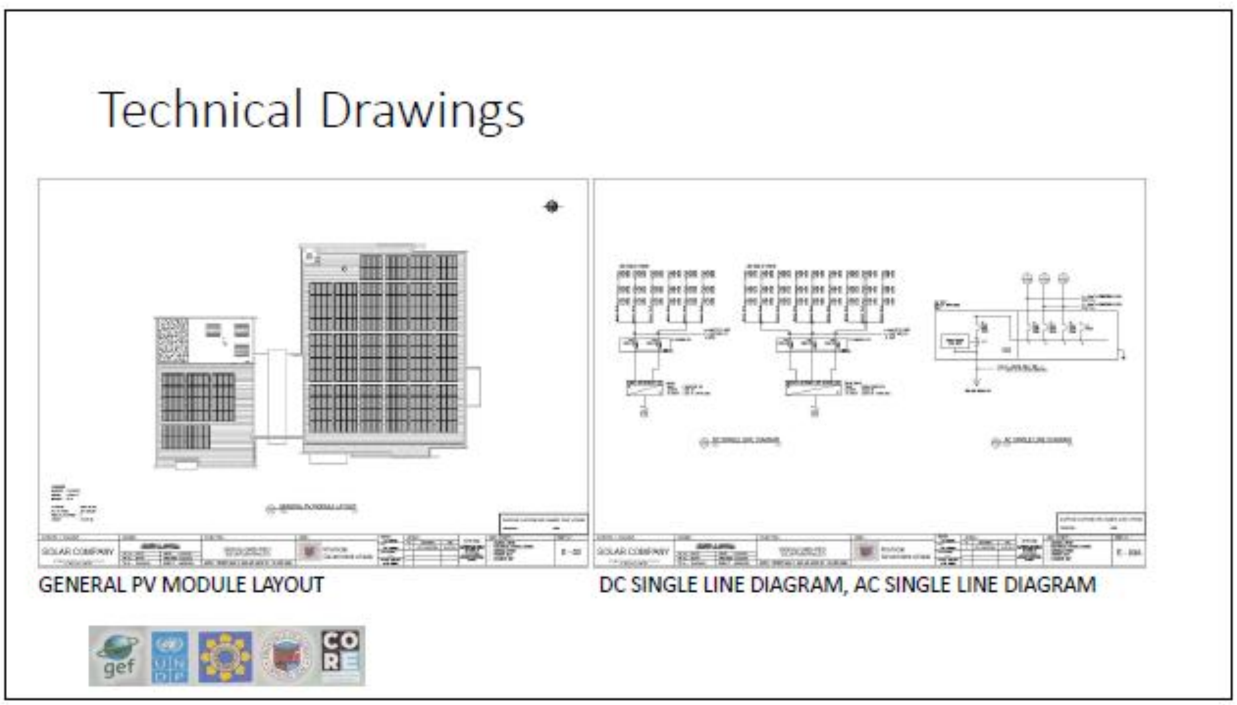
More results can be presented by the software such as system production, own consumption, import from the grid and possible export to the grid. Monthly generation, consumption, and savings can also be displayed in graphical form or in table form to be exported for financial calculations.



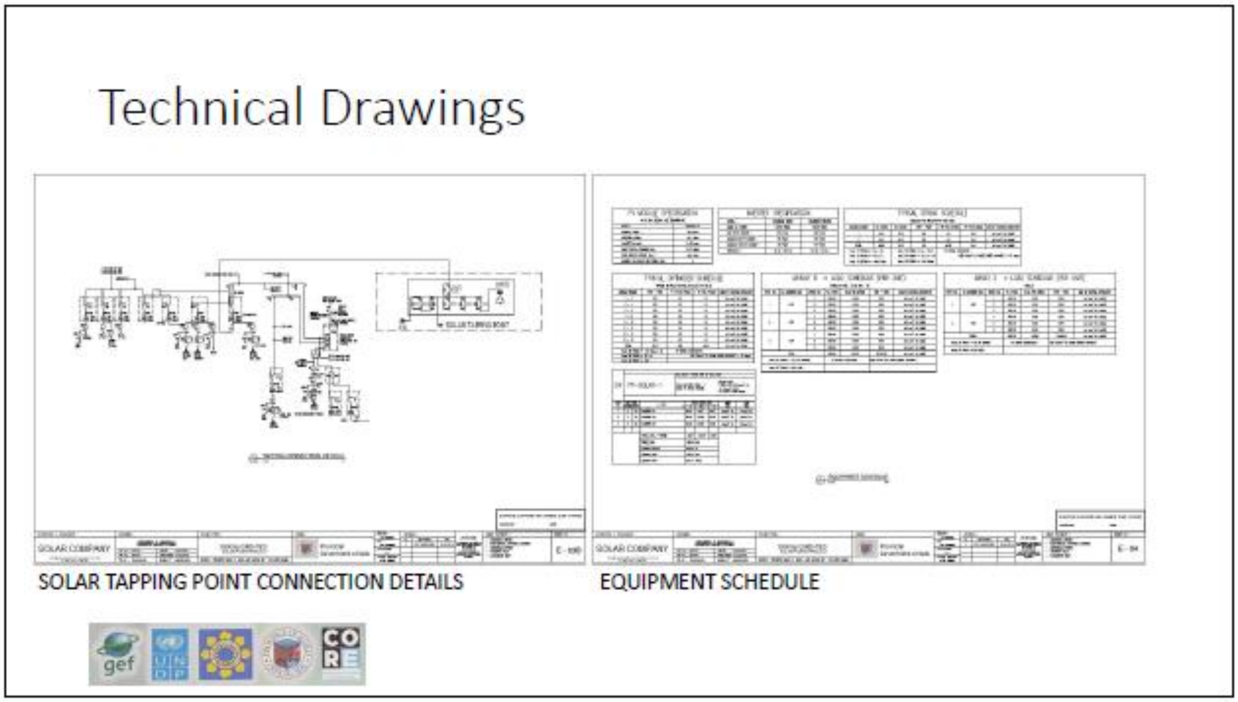
The software can also show other technical parameters such as the bill of materials, the technical specifications of the components, and the loss diagram for the projection of net generation.



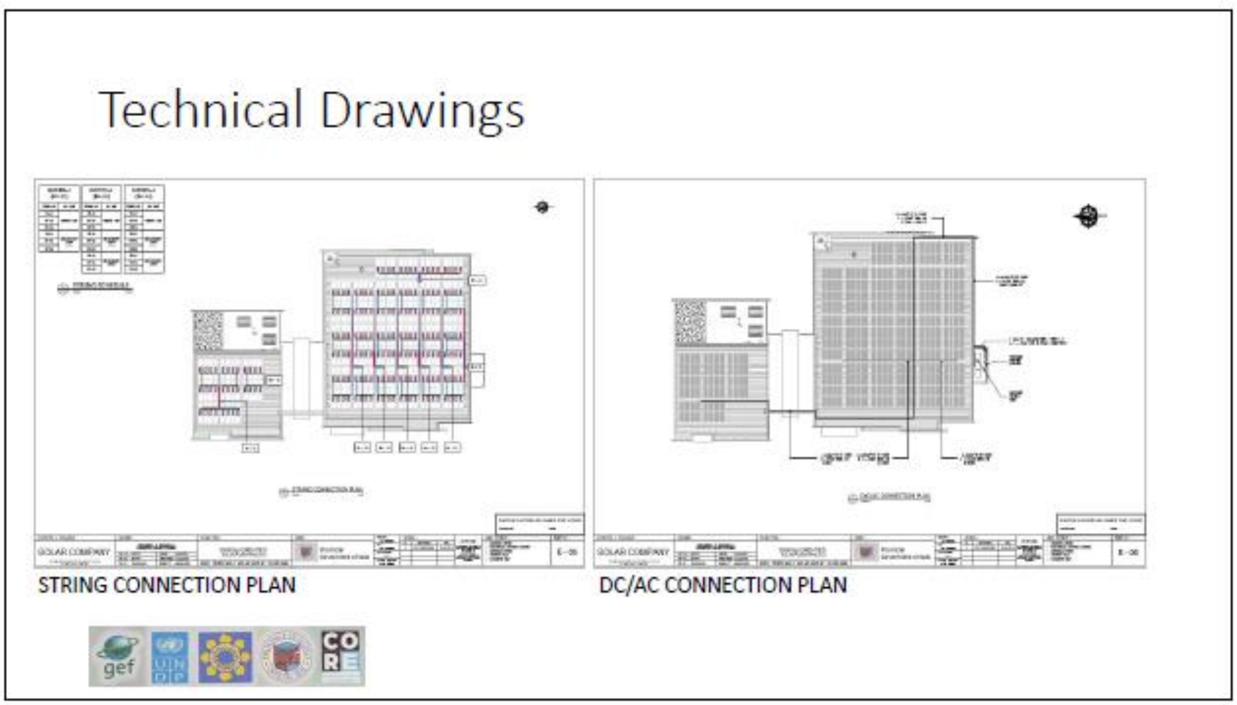
A Sample Technical Drawing for submission to the DU and the OBO for permitting and approval shows the following electrical system general notes and location map



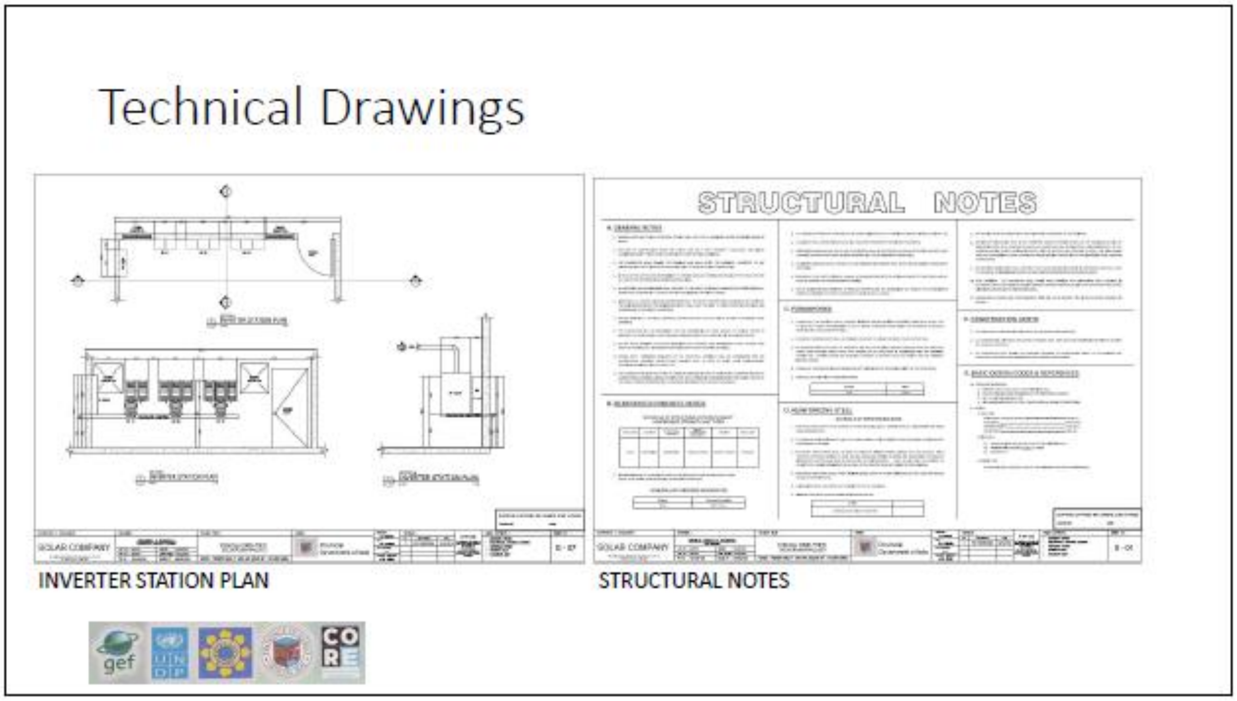
The technical drawing shows the PB module lay-out on the roof and the single line diagram of the of the solar installation signed and sealed by a Professional Electrical Engineer (PEE)



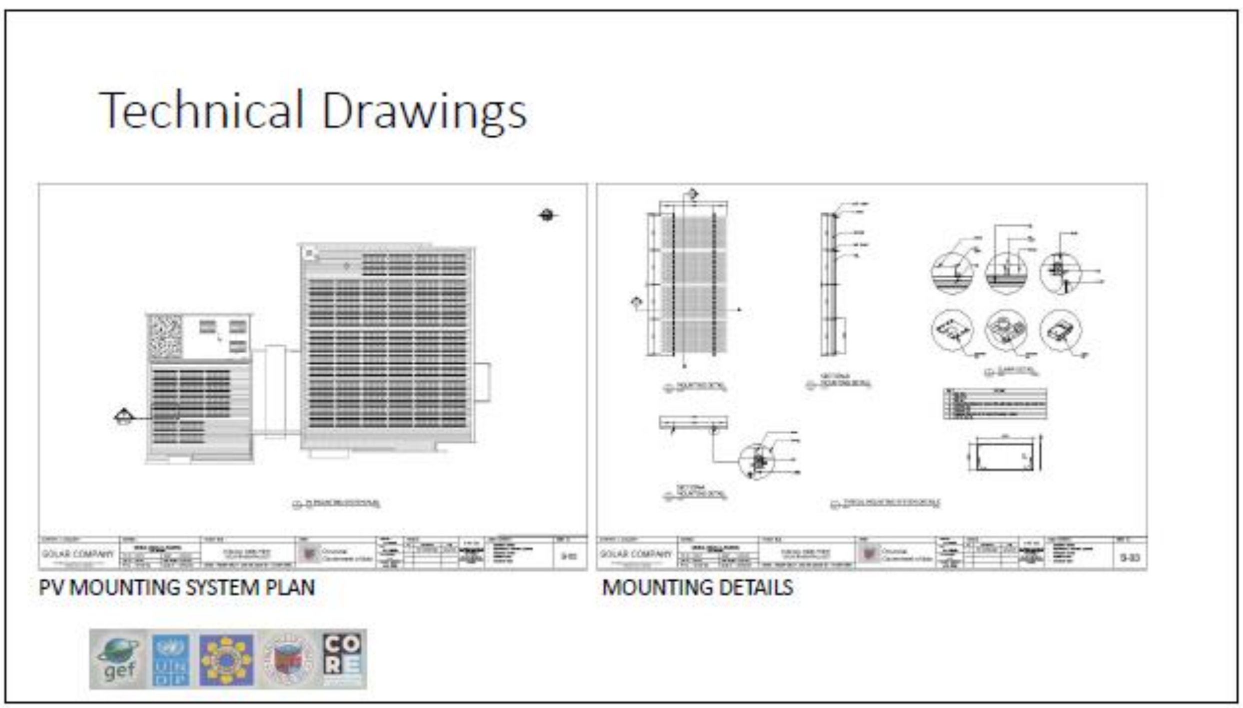
The technical drawings also show the tapping points for the electrical connection of the solar installation and the equipment schedule.



The technical drawings show the string connection plan for the solar modules and their respective inverters, and the connection plan for the DC and AC side of the installation.



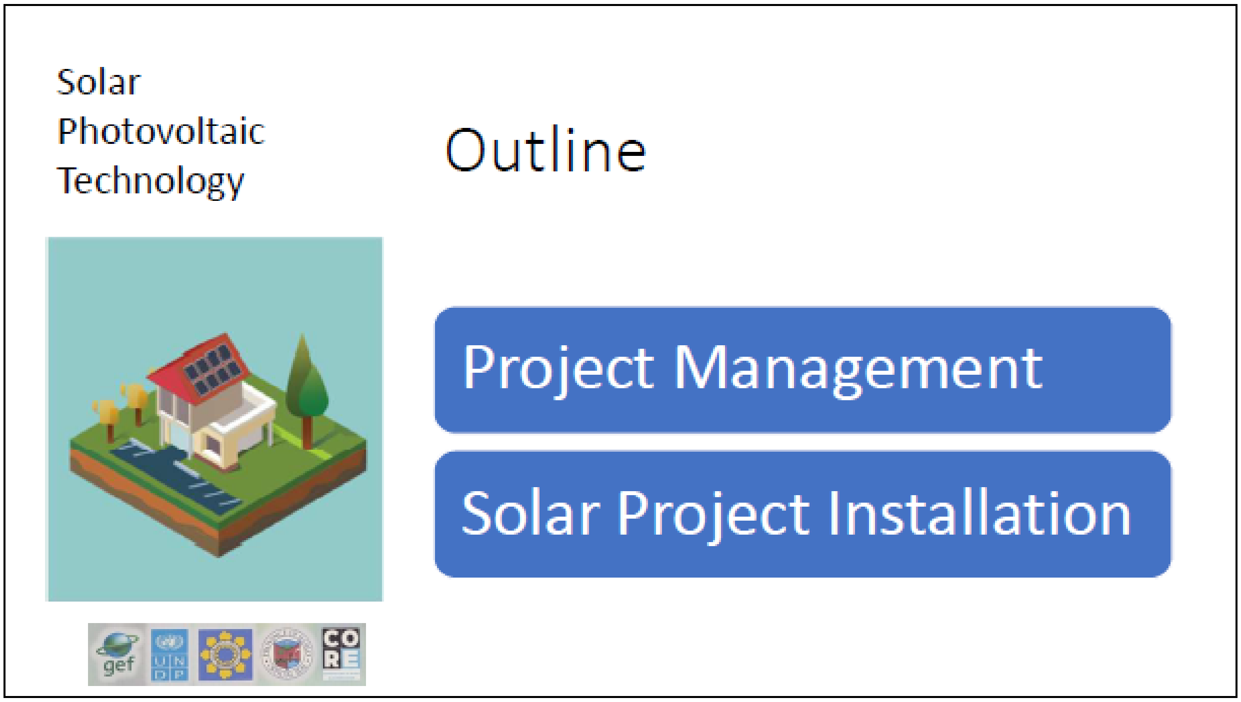
The technical drawings include the structural notes for the physical installation of the PV system.



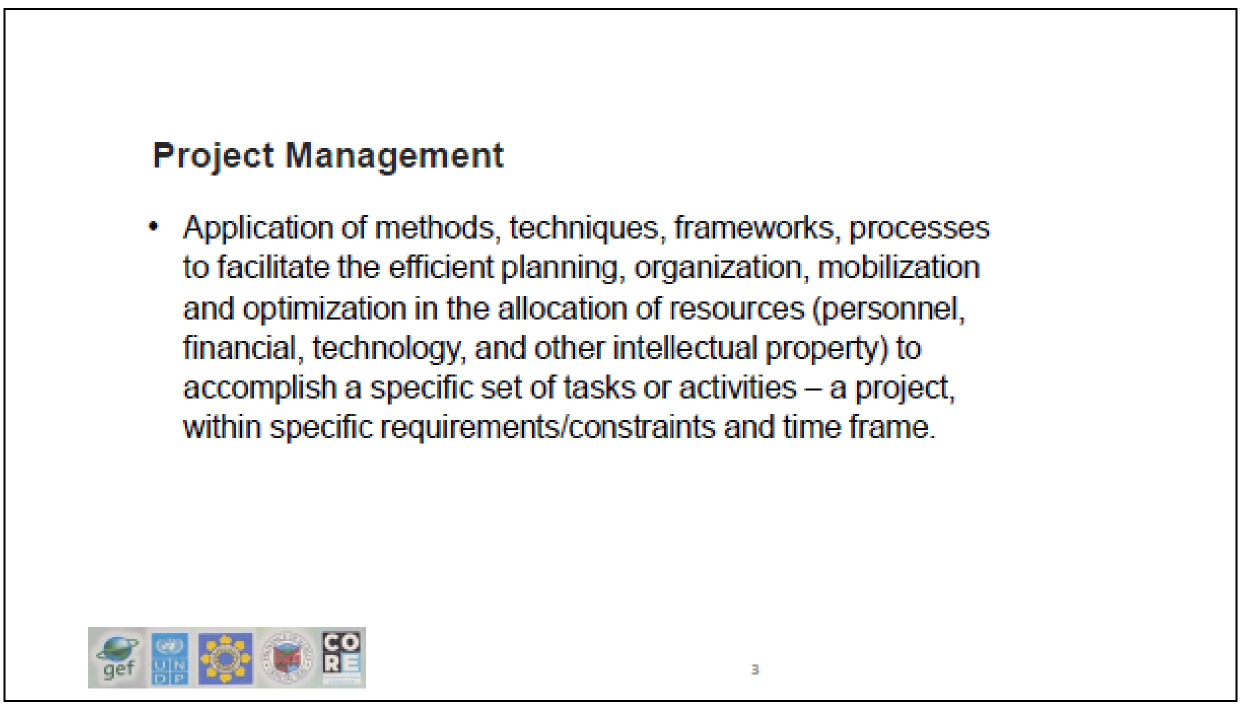
Details of the mounting of PV modules, the inverters, and other electrical equipment are presented in the technical drawings.

2.5 Session 5 - Solar PV Project Management

This session provides the trainees inputs in managing a solar projects and guidelines in solar installations.



Session outline on Project Management and Solar Project Installation



Project Management defined

Need for Project Management

Projects such as rooftop solar PV systems need management for the following:

- Ensure that the project remains on time and on budget;
- Efficiently manage allocation and utilization of resources;
- Monitor the progress of project implementation; and
- Evaluate the conduct of the project periodically, in terms of compliance to set benchmarks, milestones, and overall project targets.

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The need to manage a solar project

Project Management Process

- **Planning:** Most critical process and gets the least amount of time;
- **Organizing**: Structuring (Contingent/Prerequisites);
- **Monitor and Control**: Critical in order to use limited resources wisely;
- **Measurement**: To determine if project accomplished the set objectives and/or met the target.

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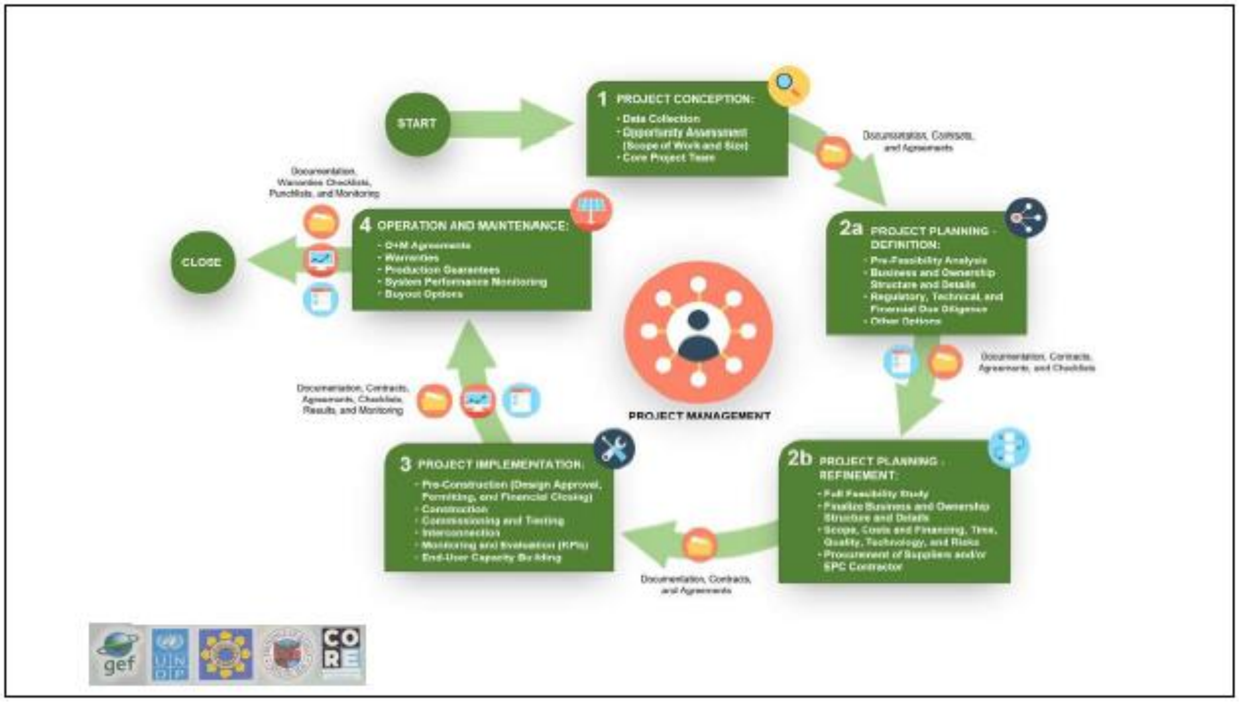
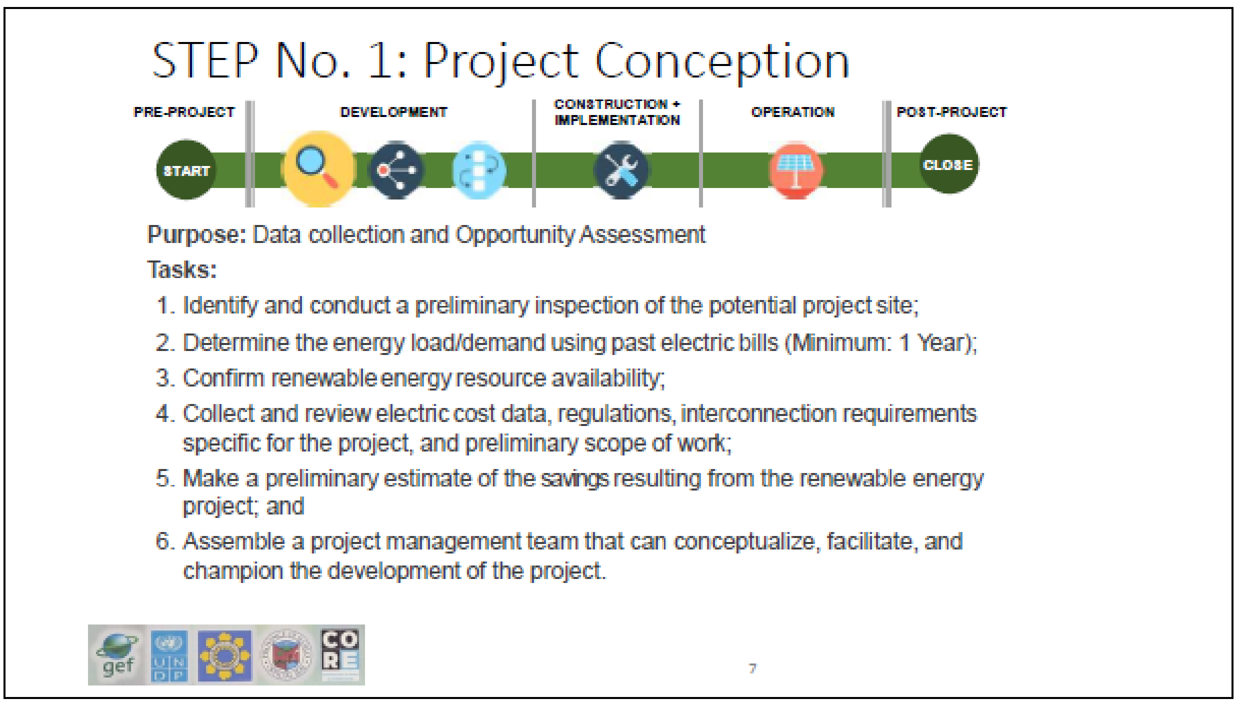
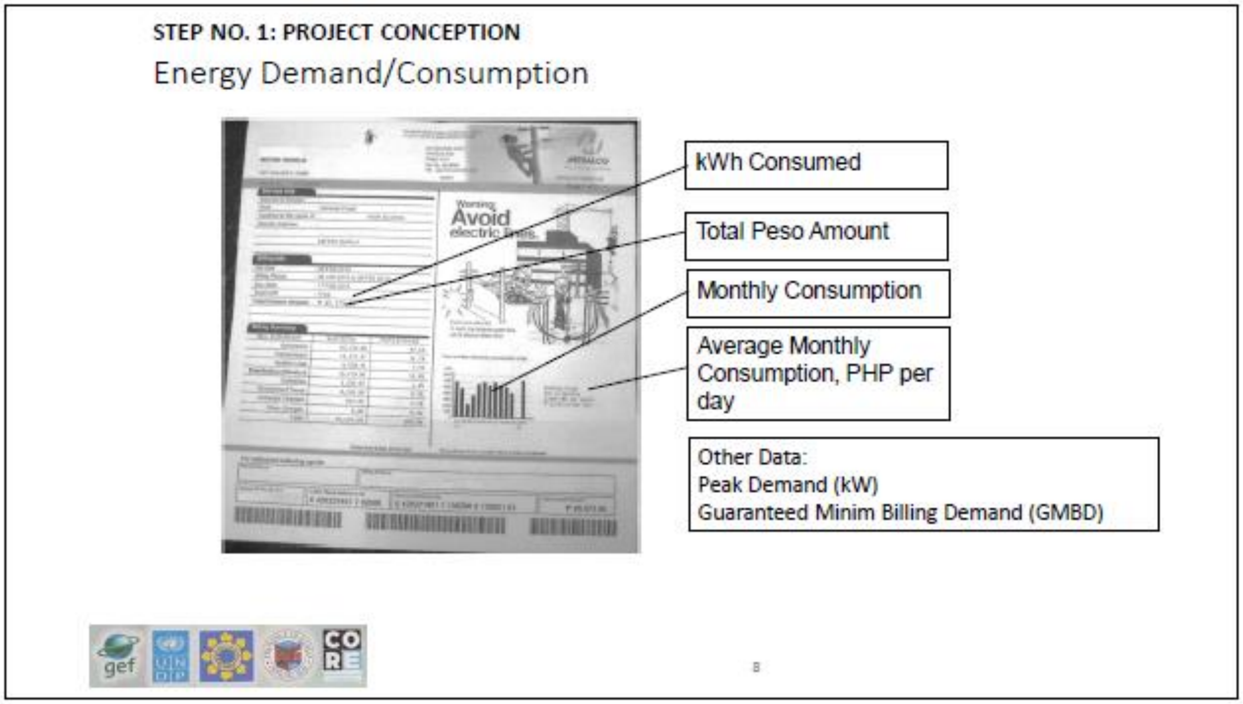
Project Management Process



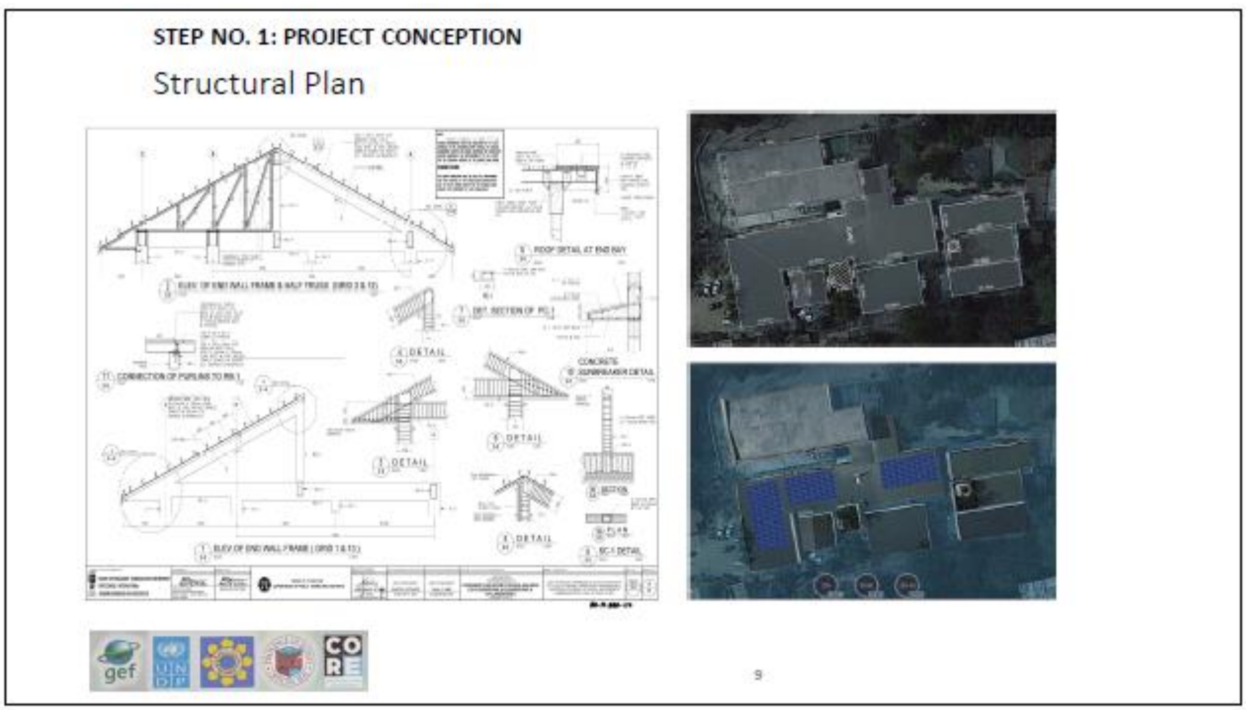
Project Management Cycle



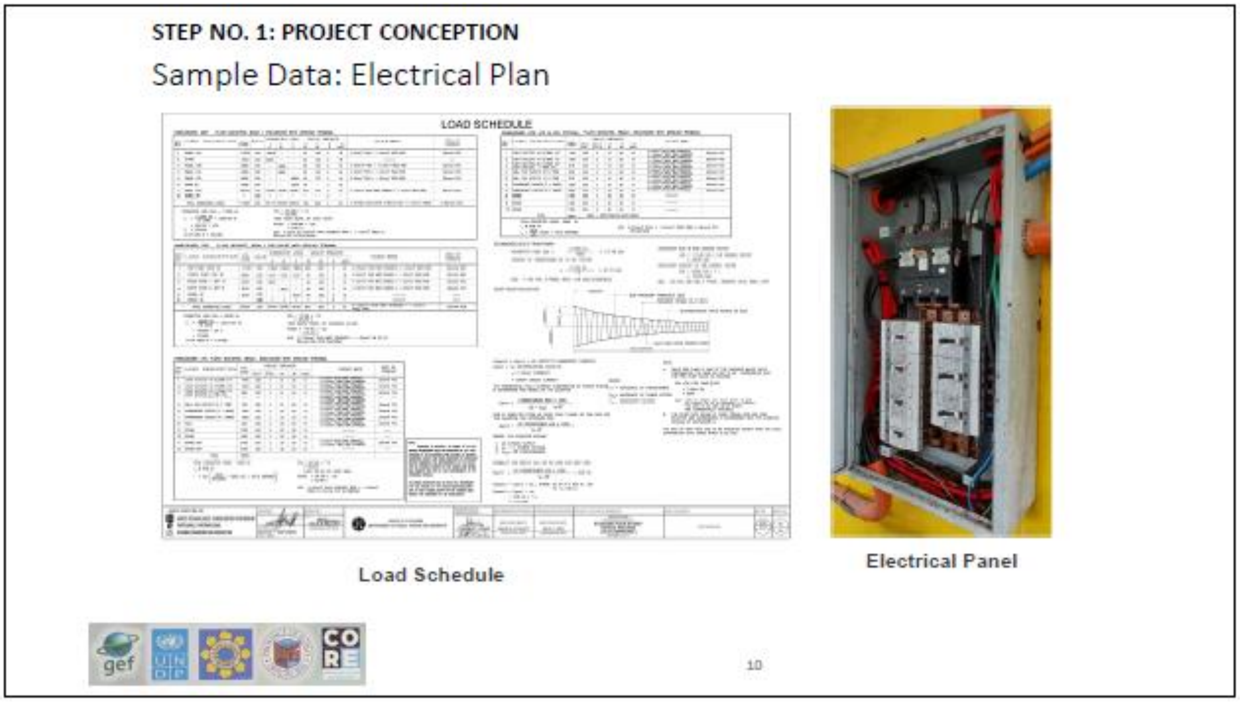
Project Conception



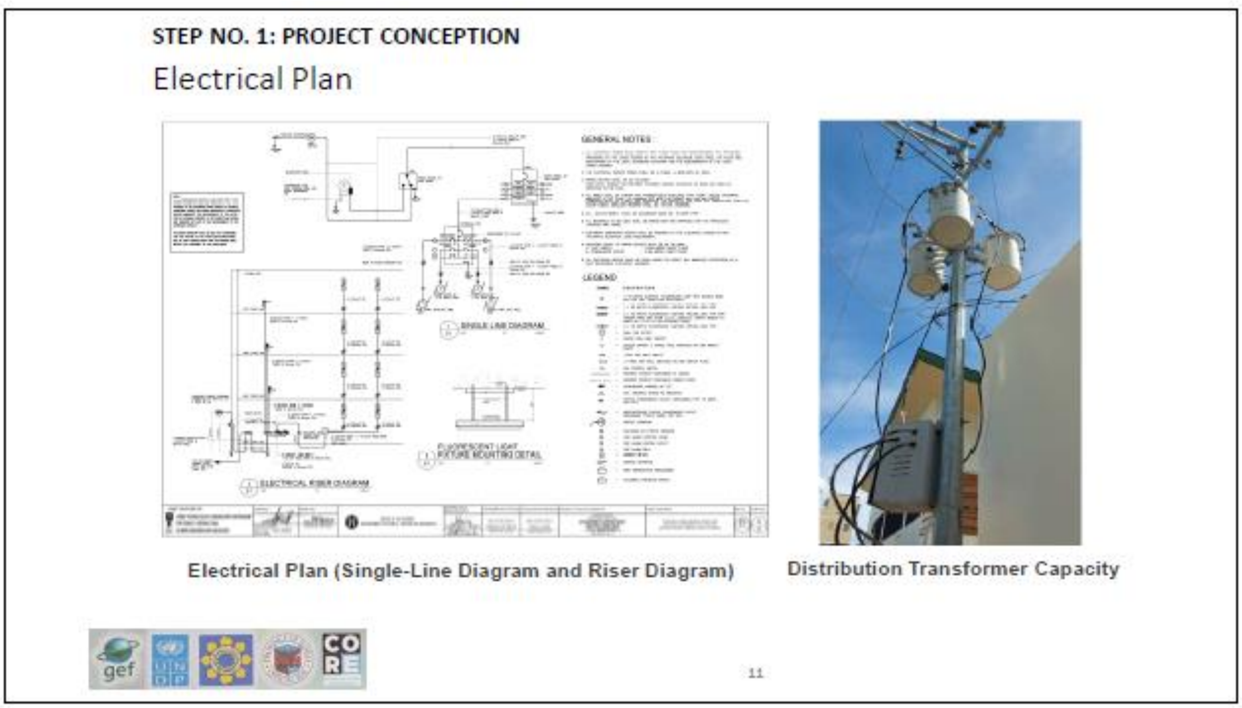
Establish the baseline energy consumption and expenses using the electric bill



Validate the structural plans if the roof can accommodate the solar panels and define the area available for solar panel installation with considerations to shading and future expansion plans.

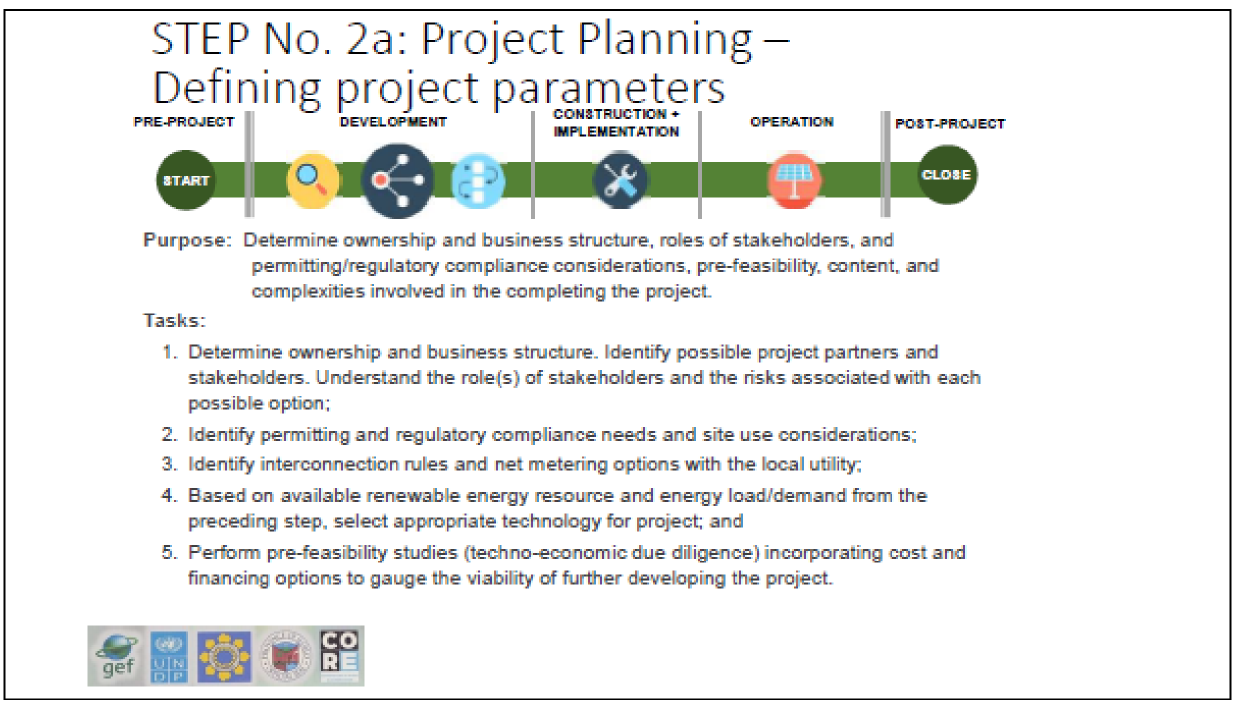


Study the electrical connections, load schedules, and diagrams to determine the capacities and limits of the solar installation.

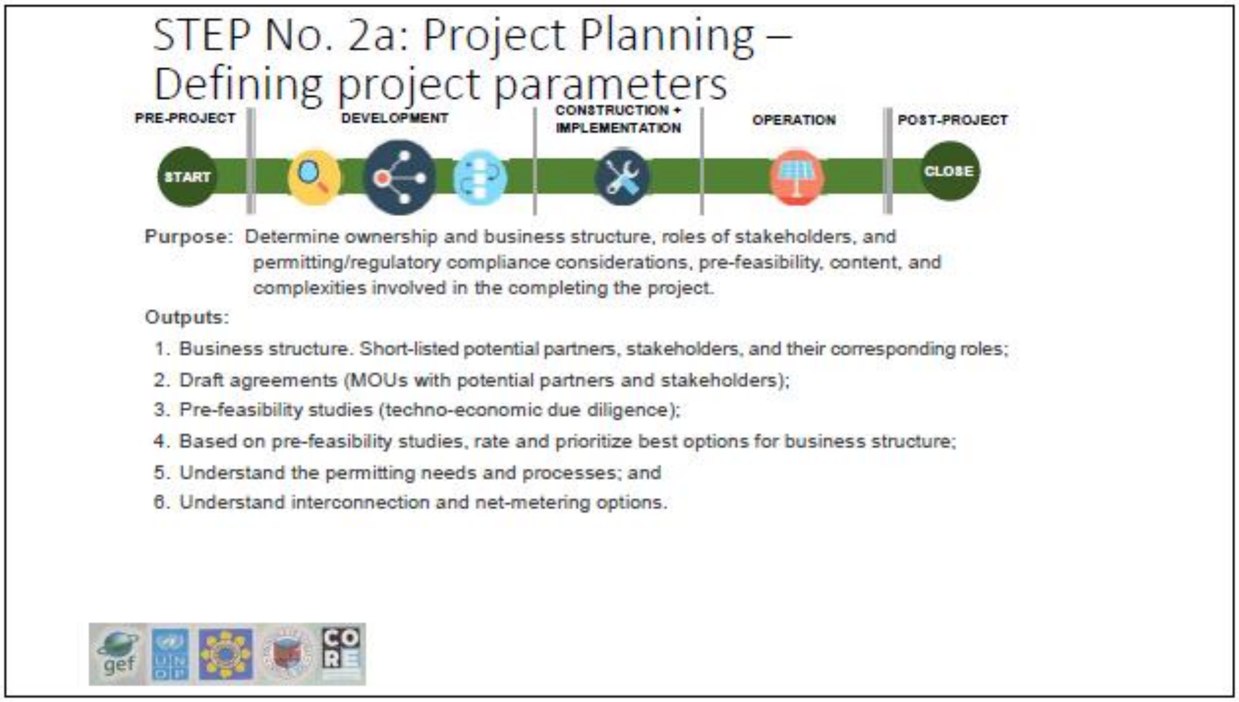


Check the service connections to comply with the electrical standards defined in the Philippine Distribution Code and other requirements that the DU may impose.

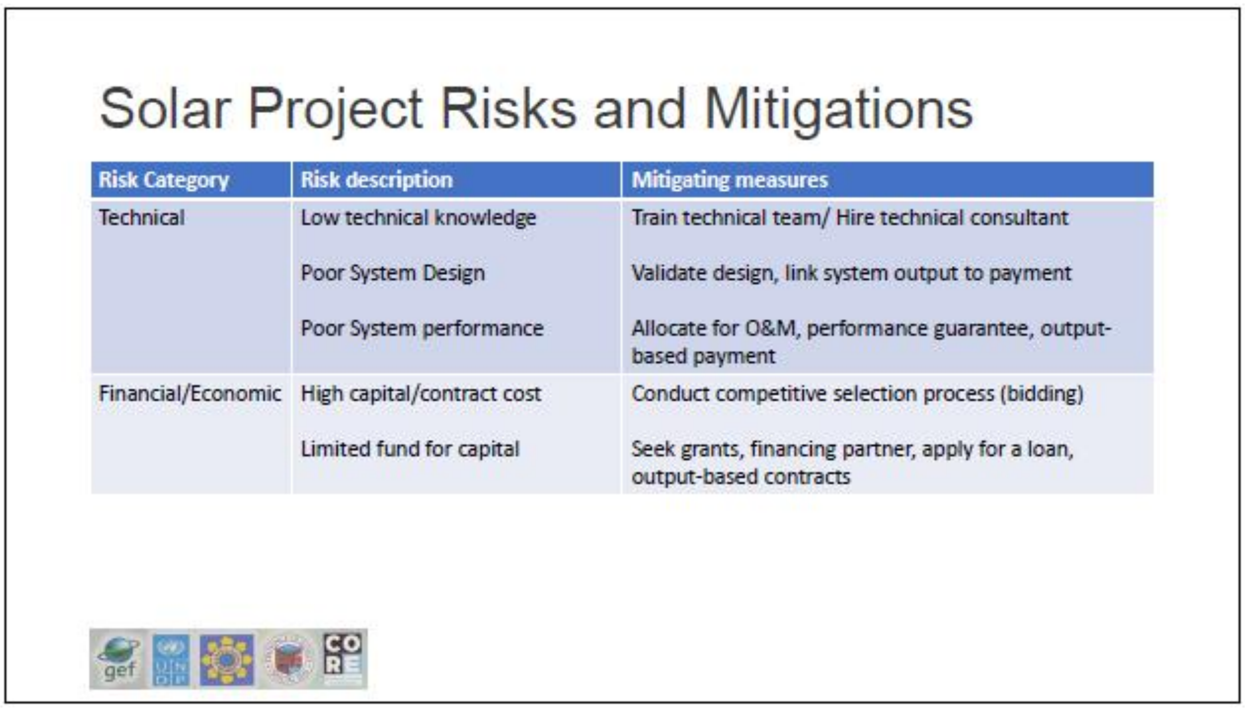
Using the solar design software, make the initial estimates for the system capacity and simulate the system to calculate the potential savings of the solar project



Setting up the Project Management and Implementation Structure

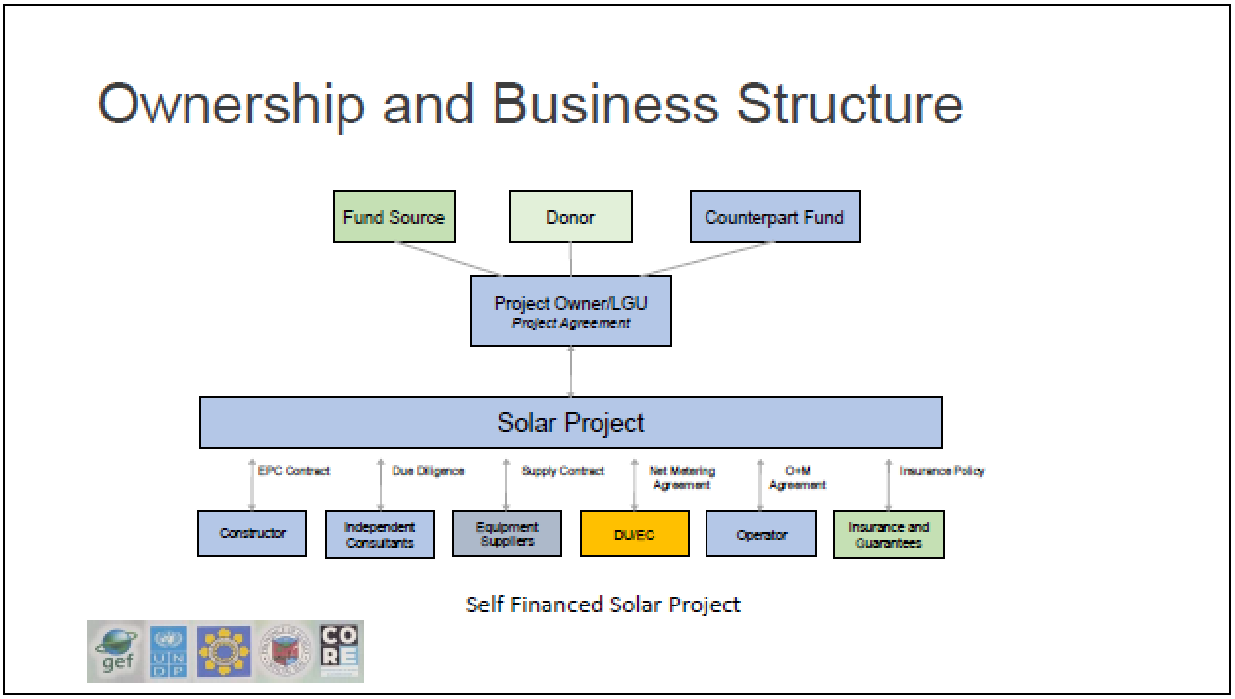


Outputs of the Project Planning stage

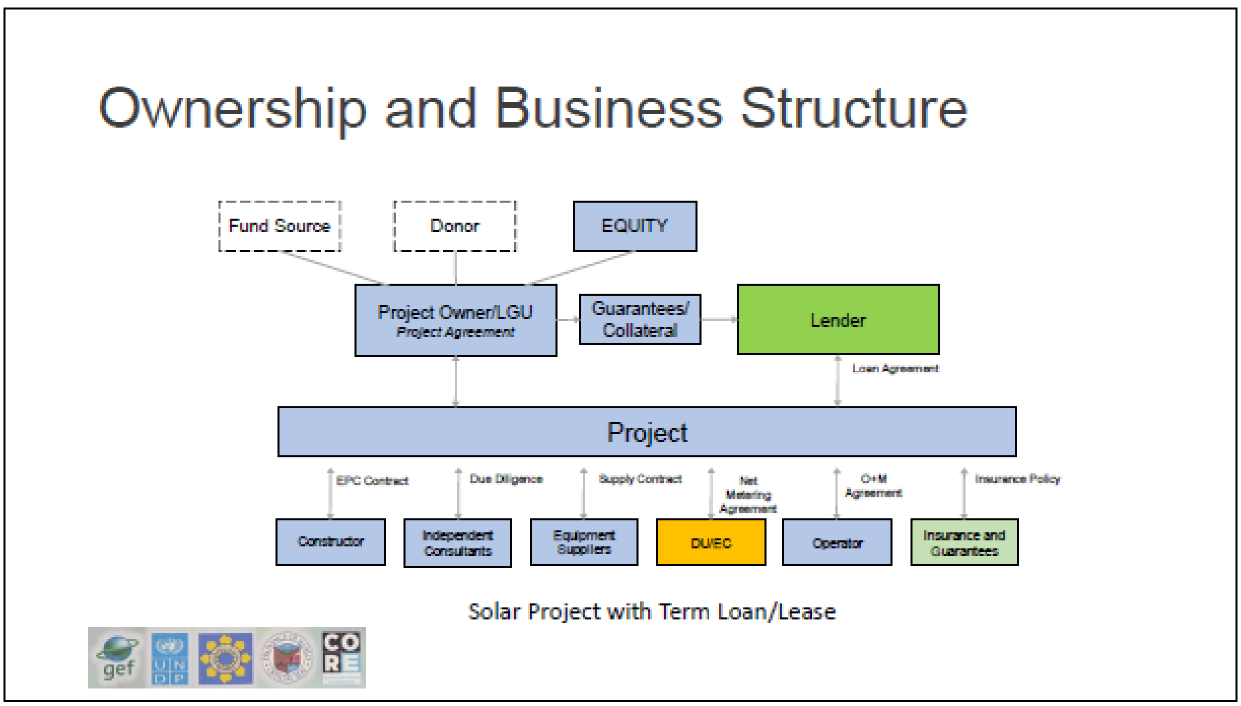


Risk Category	Risk description	Mitigating measures
Technical	Low technical knowledge	Train technical team/ Hire technical consultant
	Poor System Design	Validate design, link system output to payment
	Poor System performance	Allocate for O&M, performance guarantee, output-based payment
Financial/Economic	High capital/contract cost	Conduct competitive selection process (bidding)
	Limited fund for capital	Seek grants, financing partner, apply for a loan, output-based contracts

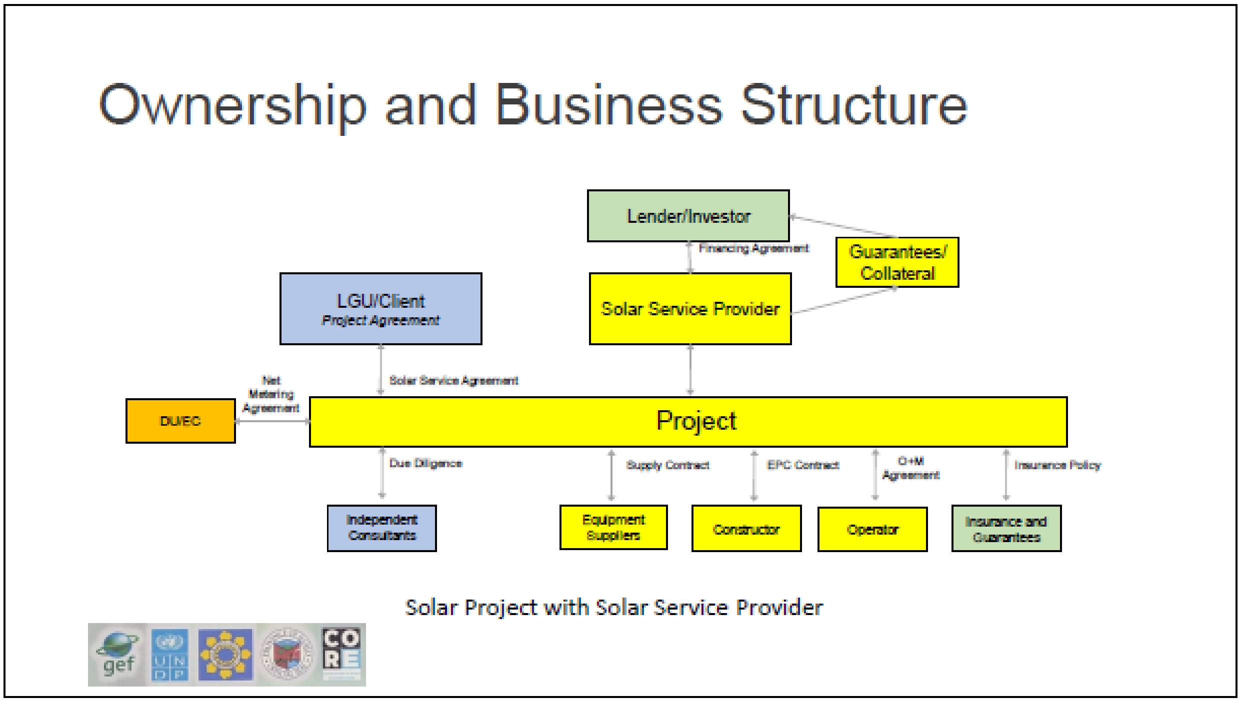
Solar project risk identification and mitigating measures



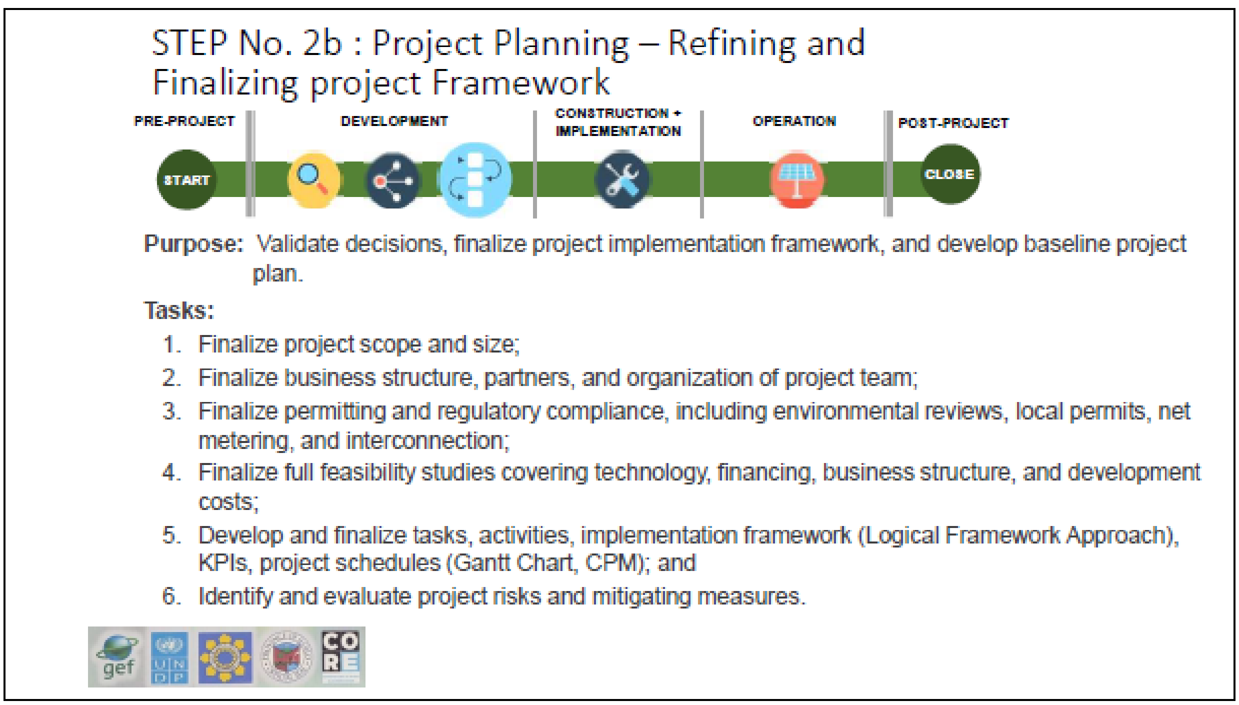
Sample Solar project Ownership and Business Structure for a Self-financed project



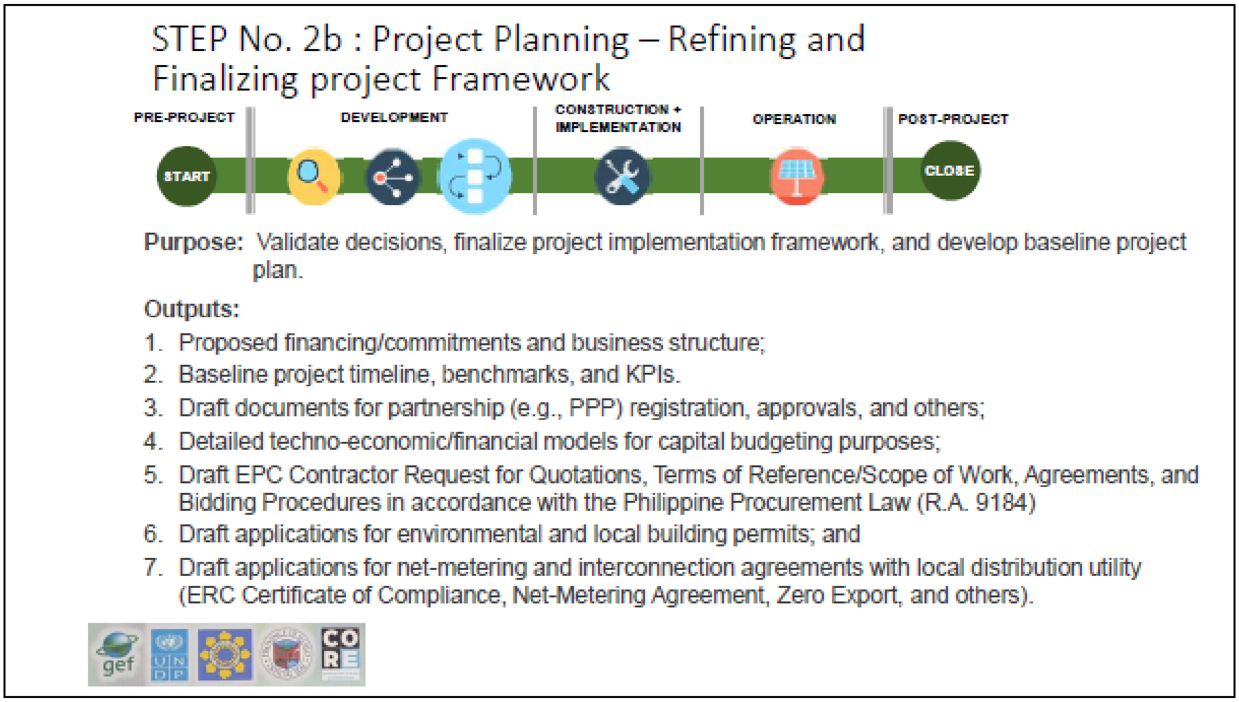
Sample Solar project Ownership and Business Structure for a project with a Loan or Lease Agreement



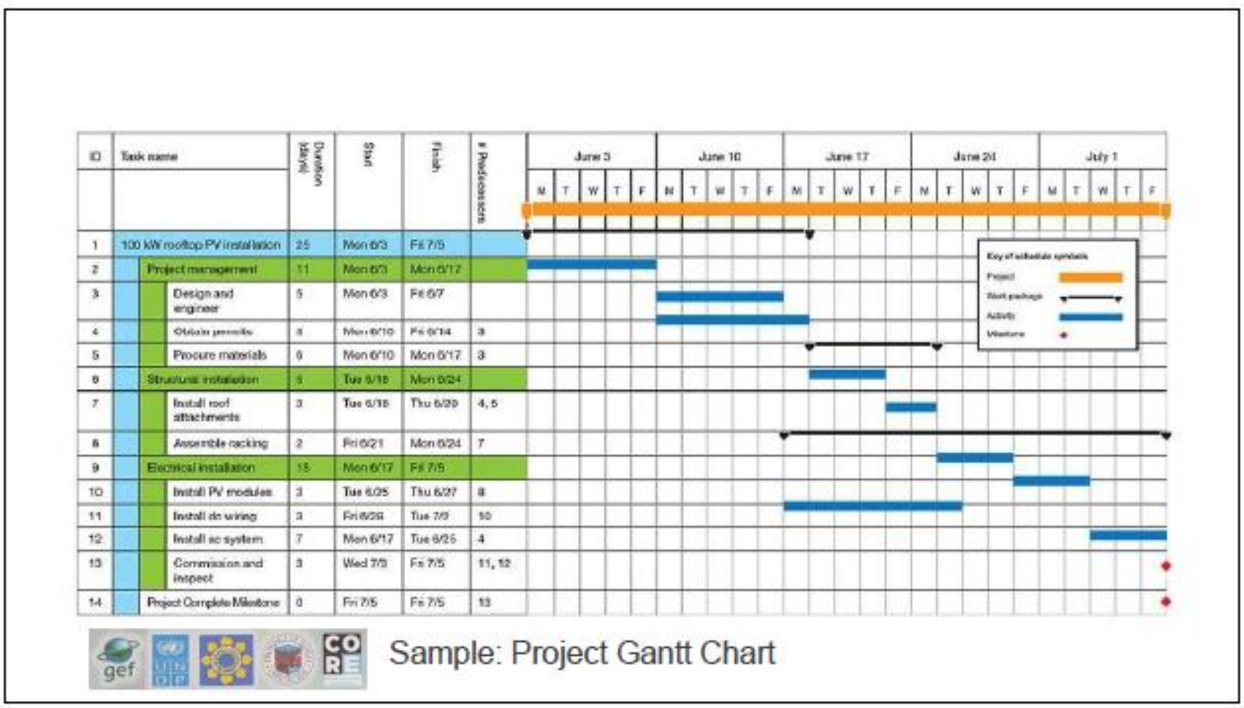
Sample Solar project Ownership and Business Structure for a project with a Third-Party Solar Provider



Refining and finalizing the project framework



Outputs for the refined and finalized project framework



ID	Task name	Duration (days)	Start	Finish	# Predecessors
1	100 kW rooftop PV installation	25	Mon 6/3	Fri 7/5	
2	Project management	11	Mon 6/3	Mon 6/17	
3	Design and engineer	5	Mon 6/3	Fri 6/7	
4	Obtain permits	5	Mon 6/10	Fri 6/14	3
5	Procure materials	6	Mon 6/10	Mon 6/17	3
6	Structural installation	5	Tue 6/18	Mon 6/24	
7	Install roof attachments	3	Tue 6/18	Thu 6/20	4, 5
8	Assemble racking	2	Fri 6/21	Mon 6/24	7
9	Electrical installation	15	Mon 6/17	Fri 7/5	
10	Install PV modules	3	Tue 6/25	Thu 6/27	8
11	Install dc wiring	3	Fri 6/28	Tue 7/2	10
12	Install ac system	7	Mon 6/17	Tue 6/25	4
13	Commission and inspect	3	Wed 7/3	Fri 7/5	11, 12
14	Project Complete Milestone	0	Fri 7/5	Fri 7/5	13

Sample Gantt Chart for the project implementation

	Objectives	Measurable Indicators	Means of Verification	Important Assumptions
Overall Objective	Establish economically viable, socially acceptable, and environmentally-sound energy services to local communities through the use of solar PV resources and technologies and underpin efforts to considerably reduce the effects of climate change, catalyze the utilization of clean energy technologies, and ensure sustainable resilient development.			
Specific Objectives: Outcomes	Outcome 1: Design and deployment of grid-connected rooftop solar PV systems located in various public school buildings in Metro Manila as a way toward generating energy savings, further mitigating local GHG emissions, and enhancing the reliability of electricity supply; Outcome 2: Capacity building and training for community livelihood development and management.	Indicative project target of deploying grid-connected solar PV rooftop systems with a maximum aggregate installed capacity amounting to 1MW, constructed for a minimum of 5[illegible] schools and buildings, including the capacity enhancement of a minimum of 150,000 students, school personnel, and end-users. The project has been estimated to reduce GHG emissions up to 6,467 CO2e annually.	Hand over documents and records of the LGU and recipient schools; Monitoring and evaluation documentation of donors; Proceedings of Training Workshops, Manuals, IEC Materials, and Billing Records from the local Distribution Utility (DU).	LGU, recipient schools, and other stakeholders will sustain the operation and management of the deployed solar PV systems; Solar PV Rooftop Systems have the capacity towards effectively decreasing the cost of electricity for the schools and other buildings included in the project; and Distribution grid interconnecting the schools and buildings have the capacity to accept the energy produced by the facilities and DU approves the necessary regulatory compliance agreements.
Results and Deliverables	Result 1: Establishment of consortium/joint-ventures/PPPs to administer and manage the implementation of the project;	Approved and registered project organization	PPP/joint-venture/corporate partnership agreements and contracts; SEC Registration and local business permit documents; Business plan and structure/modality; and Financing structure and loan agreements	PPP/JV and other corporate formations will be approved by regulatory agency, such as the SEC, DTI, DBM, PPP Center, CDA, DOE, and other government institutions; and LGU will streamline and support the issuance of permits and certifications.
	Result 2: Design, development, and installation of grid-connected solar PV rooftop systems with aggregate installed capacity of [illegible] buildings;	Techno-economic feasibility studies conducted for all selected schools and buildings; Detailed engineering designs finalized; Equipment procurement completed; Construction, testing, and commissioning of all solar PV systems conducted by EPC Contractor	Engineering plans and as-built technical drawings; Functional Test Reports; Commissioning and Inspection Reports; EPC Contractor Agreements	Project organization established and registered; EPC Contractor selected and engaged; and Selected schools and buildings have been evaluated as capable of structurally supporting solar PV systems and technically feasible in terms of interconnection with the DU.
	Result 3: Develop appropriate business frameworks to ensure techno-economic and financial feasibility and operational sustainability;	Interconnection/Net Metering connection approved and finalized by the DU; Financial models show appropriate revenue and cost streams for the project; Stakeholders roles properly identified and codified in signed agreements	Interconnection/Net Metering Connection Agreements for all selected schools and buildings approved and signed; Feasibility Studies; Business plan and structure/modality; Financing structure and loan agreements	Project techno-economically and financially feasible; DU will approve the Interconnection/Net Metering Connection Agreements with the project organization; and Necessary agreements, permits, and contracts secured.
	Result 4: Strengthen the capacity of stakeholders in design, operation, and management of solar PV systems.	Conduct of training sessions on the following topics: (i) Introduction to Solar Resources and Technologies; (ii) Project Management of Solar PV Projects; (iii) Testing and Commissioning of Solar PV Projects; (iv) Operations and Maintenance of Solar PV Projects; and (v) Sustainable Energy Development for Students, Teachers, and End-Users.	Proceedings of Training Workshops, Manuals, Presentations, IEC Materials, and Signature/Attendance Sheets.	

Sample: Logical Framework Approach - Matrix

Use of Logical Framework for the project

Debt Ratio	-
Equity Ratio	-
Loan Amount	-
Interest rate	-
Tenor (Years)	-
FIRR	13.82%
Payback Period	6.00

Year	Annual Electricity Consumption	Annual Energy Production from Solar PV System	Electricity Tariff	Solar PV Utilization Tariff	Annual Cost of Electricity	Avoided Cost from Using Solar PV System	Cost from Utilizing Solar PV System (O&M)	Total Savings	Accumulated Savings	Loan Repayment	Investment	Cash Flow	Investment Payback
	kWh/a	kWh/a	PHP/kWh	PHP/MWh	PHP/a	PHP/a	PHP/a	PHP/a	PHP/a	PHP	PHP	PHP/a	PHP/a
0	-	-	-	-	-	-	-	-	-	-	(7,043,286.32)	(7,043,286.32)	(7,043,286.32)
1	175,476.00	114,587.78	11.52	2.58	2,021,477.39	1,319,816.84	295,818.03	1,023,998.81	1,023,998.81	-	-	1,023,998.81	(6,019,287.51)
2	176,353.38	113,984.94	11.64	2.66	2,051,900.63	1,326,349.93	303,169.10	1,023,180.83	2,047,179.64	-	-	1,023,180.83	(4,996,106.68)
3	177,235.15	113,424.97	11.75	2.74	2,082,781.73	1,332,915.38	310,702.86	1,022,212.51	3,069,392.15	-	-	1,022,212.51	(3,973,894.18)
4	178,121.32	112,857.84	11.87	2.82	2,114,127.60	1,339,513.29	318,423.82	1,021,089.47	4,090,481.62	-	-	1,021,089.47	(2,952,804.71)
5	179,011.93	112,293.55	11.99	2.91	2,145,945.22	1,346,143.89	326,336.65	1,019,807.23	5,110,288.85	-	-	1,019,807.23	(1,932,997.47)
6	179,906.99	111,732.09	12.11	2.99	2,178,241.69	1,352,807.30	334,446.12	1,018,361.18	6,128,650.03	-	-	1,018,361.18	(914,636.30)
7	180,806.52	111,173.43	12.23	3.08	2,211,024.23	1,359,503.69	342,757.11	1,016,746.59	7,145,396.62	-	-	1,016,746.59	102,110.29
8	181,710.56	110,617.56	12.35	3.18	2,244,300.14	1,366,233.24	351,274.62	1,014,958.62	8,160,355.23	-	-	1,014,958.62	1,117,068.91
9	182,619.11	110,064.47	12.47	3.27	2,278,076.86	1,372,996.09	360,003.79	1,012,992.30	9,173,347.53	-	-	1,012,992.30	2,130,061.21
10	183,532.20	109,514.15	12.60	3.37	2,312,361.92	1,379,792.42	368,949.89	1,010,842.53	10,184,190.06	-	-	1,010,842.53	3,140,903.74
11	184,449.87	108,966.58	12.73	3.47	2,347,162.96	1,386,622.39	378,118.29	1,008,504.10	11,192,694.16	-	-	1,008,504.10	4,149,407.84
12	185,372.12	108,421.74	12.85	3.57	2,382,487.77	1,393,486.18	387,514.53	1,005,971.64	12,198,665.81	-	-	1,005,971.64	5,155,379.48
13	186,298.98	107,879.64	12.98	3.68	2,418,344.21	1,400,383.93	397,144.27	1,003,239.66	13,201,905.47	-	-	1,003,239.66	6,158,619.15
14	187,230.47	107,340.24	13.11	3.79	2,454,740.29	1,407,315.83	407,013.30	1,000,302.53	14,202,208.00	-	-	1,000,302.53	7,158,921.67
15	188,166.62	106,803.54	13.24	3.91	2,491,684.13	1,414,282.05	417,127.58	997,154.46	15,199,362.46	-	-	997,154.46	8,156,076.14
16	189,107.46	106,269.52	13.37	4.02	2,529,183.98	1,421,282.74	427,493.20	993,789.54	16,193,152.00	-	-	993,789.54	9,149,865.67
17	190,052.99	105,738.17	13.51	4.14	2,567,248.19	1,428,318.09	438,116.41	990,201.68	17,183,353.68	-	-	990,201.68	10,140,067.35
18	191,003.26	105,209.48	13.64	4.27	2,605,885.28	1,435,388.27	449,003.60	986,384.66	18,169,738.34	-	-	986,384.66	11,126,452.01
19	191,958.27	104,683.43	13.78	4.40	2,645,103.85	1,442,493.44	460,161.34	982,332.09	19,152,070.43	-	-	982,332.09	12,108,784.11
20	192,918.07	104,160.02	13.92	4.53	2,684,912.67	1,449,633.78	471,596.35	978,037.43	20,130,107.86	-	-	978,037.43	13,086,821.54
21	193,882.66	103,639.22	14.06	4.66	2,725,320.60	1,456,809.47	483,315.52	973,493.95	21,103,601.81	-	-	973,493.95	14,060,315.48
22	194,852.07	103,121.02	14.20	4.80	2,766,336.68	1,464,020.67	495,325.91	968,694.76	22,072,296.57	-	-	968,694.76	15,029,010.24
23	195,826.33	102,605.41	14.34	4.95	2,807,970.04	1,471,267.58	507,634.76	963,632.81	23,035,929.38	-	-	963,632.81	15,992,643.06
24	196,805.46	102,092.39	14.48	5.10	2,850,229.99	1,478,550.35	520,249.49	958,300.87	23,994,230.25	-	-	958,300.87	16,950,943.92
25	197,789.49	101,581.93	14.63	5.25	2,893,125.95	1,485,869.18	533,177.69	952,691.49	24,946,921.74	-	-	952,691.49	17,903,635.41

Sample Life-Cycle Analysis - Without Loan

Financial Analysis for self-financed project

Debt Ratio	70.0%
Equity Ratio	30.0%
Loan Amount	4,930,300.43
Interest rate	7.0%
Tenor (Years)	10.00
FIRR	19.0%
Payback Period	6

Year	Annual Electricity Consumption	Annual Energy Production from Solar PV System	Electricity Tariff	Solar PV Utilization Tariff	Annual Cost of Electricity	Avoided Cost/Savings Using Solar PV System	Cost/Savings Utilizing Solar PV System	Total Savings	Accumulated Savings	Loan Repayment	Investment	Cash Flow	Investment Payback
	kWh/a	kWh/a	PHP/kWh	PHP/kWh	PHP/a	PHP/a	PHP/a	PHP/a	PHP/a	PHP	PHP	PHP/a	PHP/a
0	-	-	-	-	-	-	-	-	-	-	(2,112,985.90)	(2,112,985.90)	(2,112,985.90)
1	175,476.00	114,587.78	11.52	2.58	2,021,477.39	1,319,818.84	295,818.03	1,023,998.81	1,023,998.81	(701,963.88)		322,034.95	(1,790,950.95)
2	176,353.38	113,994.94	11.64	2.66	2,051,800.63	1,326,349.93	303,169.10	1,023,180.83	2,047,179.64	(701,963.88)		321,216.95	(1,469,733.98)
3	177,235.15	113,424.97	11.75	2.74	2,082,761.73	1,332,915.38	310,702.86	1,022,212.51	3,069,392.15	(701,963.88)		320,248.64	(1,149,485.34)
4	178,121.32	112,857.84	11.87	2.82	2,114,127.60	1,339,513.29	318,423.82	1,021,089.47	4,090,481.62	(701,963.88)		319,125.61	(830,359.73)
5	179,011.93	112,293.55	11.99	2.91	2,145,945.23	1,346,143.89	326,336.65	1,019,807.23	5,110,288.85	(701,963.88)		317,843.37	(512,516.36)
6	179,906.99	111,732.09	12.11	2.99	2,178,241.69	1,352,807.30	334,446.12	1,018,361.18	6,128,650.03	(701,963.88)		316,397.32	(196,119.04)
7	180,806.52	111,173.43	12.23	3.08	2,211,024.23	1,359,503.69	342,757.11	1,016,746.59	7,145,396.62	(701,963.88)		314,782.73	118,663.68
8	181,710.56	110,617.56	12.35	3.18	2,244,300.14	1,366,233.24	351,274.62	1,014,958.62	8,160,355.23	(701,963.88)		312,994.75	431,658.44
9	182,619.11	110,064.47	12.47	3.27	2,278,076.86	1,372,996.09	360,003.79	1,012,992.30	9,173,347.53	(701,963.88)		311,028.43	742,686.87
10	183,532.20	109,514.15	12.60	3.37	2,312,361.92	1,379,792.42	368,949.89	1,010,842.53	10,184,190.06	(701,963.88)		308,878.67	1,051,565.54
11	184,449.87	108,966.58	12.73	3.47	2,347,162.96	1,386,622.39	378,118.29	1,008,504.10	11,192,694.16	-		1,008,504.10	2,060,069.64
12	185,372.12	108,421.74	12.85	3.57	2,382,487.77	1,393,486.18	387,514.53	1,005,971.64	12,198,665.81	-		1,005,971.64	3,066,041.29
13	186,298.98	107,879.64	12.98	3.68	2,418,344.21	1,400,383.93	397,144.27	1,003,239.66	13,201,905.47	-		1,003,239.66	4,069,280.95
14	187,230.47	107,340.24	13.11	3.79	2,454,740.29	1,407,315.83	407,013.30	1,000,302.53	14,202,208.00	-		1,000,302.53	5,069,583.48
15	188,166.62	106,803.54	13.24	3.91	2,491,684.13	1,414,282.05	417,127.58	997,154.46	15,199,362.46	-		997,154.46	6,066,737.94
16	189,107.46	106,269.52	13.37	4.02	2,529,183.98	1,421,282.74	427,493.20	993,789.54	16,193,152.00	-		993,789.54	7,060,527.47
17	190,052.99	105,738.17	13.51	4.14	2,567,248.19	1,428,318.09	438,116.41	990,201.68	17,183,353.68	-		990,201.68	8,050,729.15
18	191,003.26	105,209.48	13.64	4.27	2,605,885.28	1,435,388.27	449,003.60	986,384.66	18,169,738.34	-		986,384.66	9,037,113.82
19	191,958.27	104,683.43	13.78	4.40	2,645,103.85	1,442,493.44	460,161.34	982,332.09	19,152,070.43	-		982,332.09	10,019,445.91
20	192,918.07	104,160.02	13.92	4.53	2,684,912.67	1,449,633.78	471,596.35	978,037.43	20,130,107.86	-		978,037.43	10,997,483.34
21	193,882.66	103,639.22	14.06	4.66	2,725,320.60	1,456,809.47	483,315.52	973,493.95	21,103,601.81	-		973,493.95	11,970,977.28
22	194,852.07	103,121.02	14.20	4.80	2,766,336.68	1,464,020.67	495,325.91	968,694.76	22,072,296.57	-		968,694.76	12,939,672.05
23	195,826.33	102,605.41	14.34	4.95	2,807,970.04	1,471,267.58	507,634.76	963,632.81	23,035,929.38	-		963,632.81	13,903,304.86
24	196,805.46	102,092.39	14.48	5.10	2,850,229.99	1,478,550.35	520,249.49	958,300.87	23,994,230.25	-		958,300.87	14,861,605.73
25	197,789.49	101,581.93	14.63	5.25	2,893,125.95	1,485,869.18	533,177.69	952,691.49	24,946,921.74	-		952,691.49	15,814,297.22

Sample Life-Cycle Analysis with Loan payment

Financial Analysis for projects with a Loan

1. Apply and obtain the construction/renovation/building permit and ancillary permits at the Office of the Building Official (OBO). Specific ancillary permits for rooftop solar PV systems, may include civil/structural permit and electrical permit.

   The applicant must submit the following requirements:

   a. Certified true copy of Original Certificate of Title (OCT)/TCT on file with the Registry of Deeds;
   b. Photocopy of tax declaration;
   c. Construction/renovation/building permit application form;
   d. Five (5) sets of survey plans, design plans, specifications and other related documents (specifically civil/structural documents and electrical documents); and
   e. Locational clearance from the MPDO/CPDO.

   After the construction/renovation permit application has been approved, the OBO makes an assessment and issues an order of payment to pay at the City Treasurers Office (CTO). Present the official receipt to the Receiving/Releasing Section of the OBO for issuance of the permit.

2. After the completion of installation, apply for the Certificate of Final Electrical Inspection (CFEI) at the OBO. The CFEI certifies that a final inspection of the electrical installation has been conducted and that such installation has been completed in accordance with the approved plans and specifications on file with the OBO and the provisions of the Philippine Electrical Code.

Permitting: Construction/renovation/ CFEI

Solar Project Permitting Requirements

Requirements	Net-Metering	Interconnection/Zero-Export
Identification documents Letter of Intent Residential Customers - ID and Proof of Valid Occupancy Business Customers - Secretary's Certificate		
Plant Parameters Form (PPF)	Secure form from DU. Please ask your solar installer to fill out.	
Certification of RE Facility Equipment	From RE Installer	
Distribution Impact Study and Distribution Asset Study	Conducted by the DU/EC	
Updated Electrical Plan, duly signed and sealed by the Professional Electrical Engineer (PEE)	Secure from PEE	
Certification of Final Electrical Inspection (CFEI)	Secure from LGU	
Amended Net-Metering Agreement (Amended NMA)	Secure form from DU. Fill out, sign, and have it notarized.	Not Applicable
Fixed Asset Boundary Document (FABD)	Secure form from DU. Fill out and sign.	
Certificate of Compliance (COC) Form 1 - Applies to individuals Form 2 - Applies to non-individuals (Corporations, Organizations, and others) PHP 1,500.00 COC Application fee paid to ERC	Secure ERC form from Meralco. Fill out and pay fees.	
Application Form for Interconnection of RE Facility		Secure form from DU. Fill out and sign.

Net Metering/Interconnection with DU/EC

Interconnection requirements of the DU for Net Metering connection

Request for Proposals/Quotation for EPC Contractor and/or Equipment Suppliers

1. Draft and approve Request for Proposals/Quotations
   a. Objectives and Project Description
   b. Terms of Reference
      - Scope of Work
      - Technical and Operational Requirements (Compliance to codes and standards, Component specifications, and others)
      - Design Guidelines (Roof size, Energy requirements, Potential connection points, System performance benchmarks, and others)
   c. Evaluation Criteria (Technical and Financial)
2. Publish Request for Proposals/Quotations
3. Administer the Request for Proposals/Quotations
   a. Conduct procurement/pre-tender meeting(s) to clarify procurement process
4. Evaluate proposals and quotations using the published evaluation criteria
5. Award Contract

Request for Proposals/Quotation

Project Procurement with request for proposal/quotation from qualified EPC Contractors

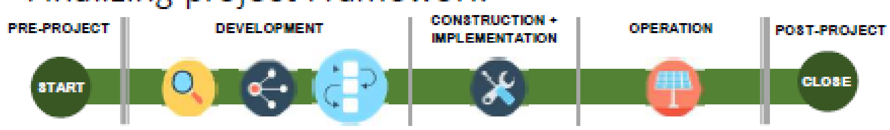
Scope of Work *(sample)*

1. **Project Preparation**
    a. Survey and discussion with Client to validate energy consumption
    b. Assessment of technical, operational, and economic related issues
    c. Check for the possibility of using energy efficiency schemes to further reduce consumption
    d. Proposal submission, including recommended size, technical implementation, expected energy production, and project financials and economics
    e. Fine tune proposal in cooperation with Client
    f. Contract negotiations, including financing arrangements
2. **Project Implementation**
    a. Detailed engineering design
    b. Preparation for construction works (Permitting and regulatory compliance requirements)
    c. Procurement and supply of solar PV modules and other components
    d. System integration
    e. Performance tests, commissioning, and turn-over
3. **Support and Maintenance**
    a. Operation and maintenance training for Client
    b. Operations, maintenance, and management contract

Scope of Work

Sample Scope of Work for a solar project

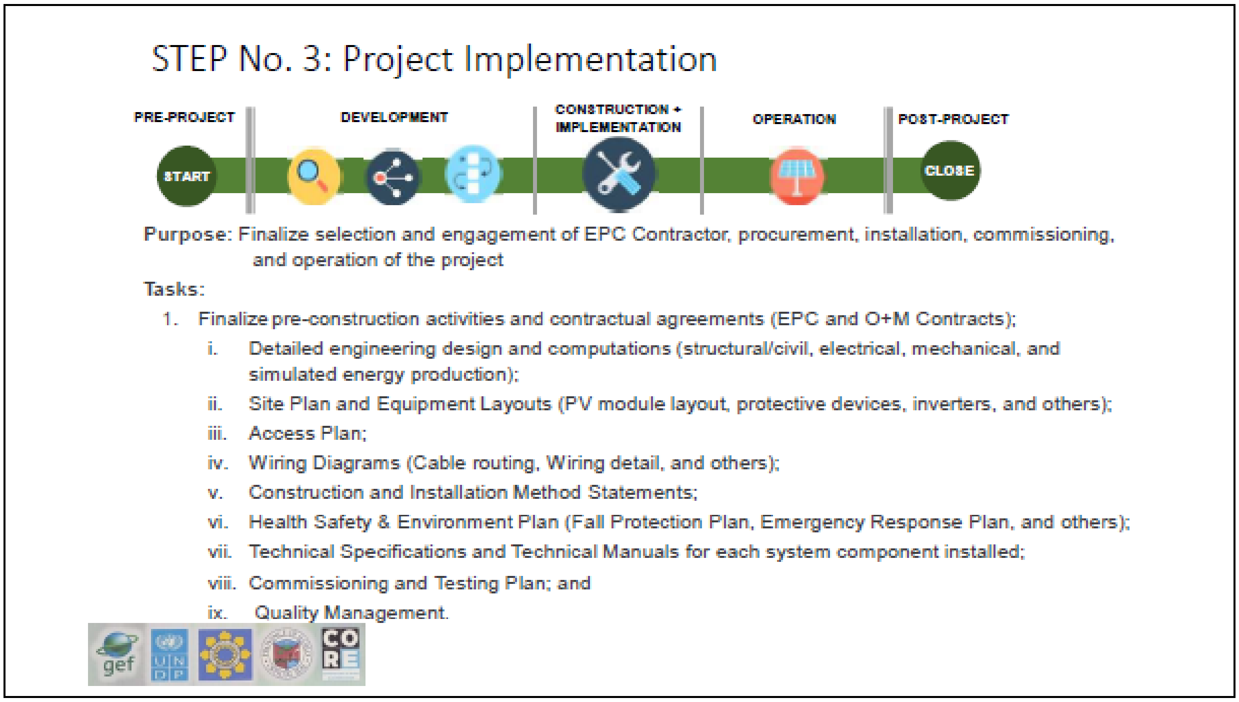
STEP No. 2b : Project Planning – Refining and Finalizing project Framework



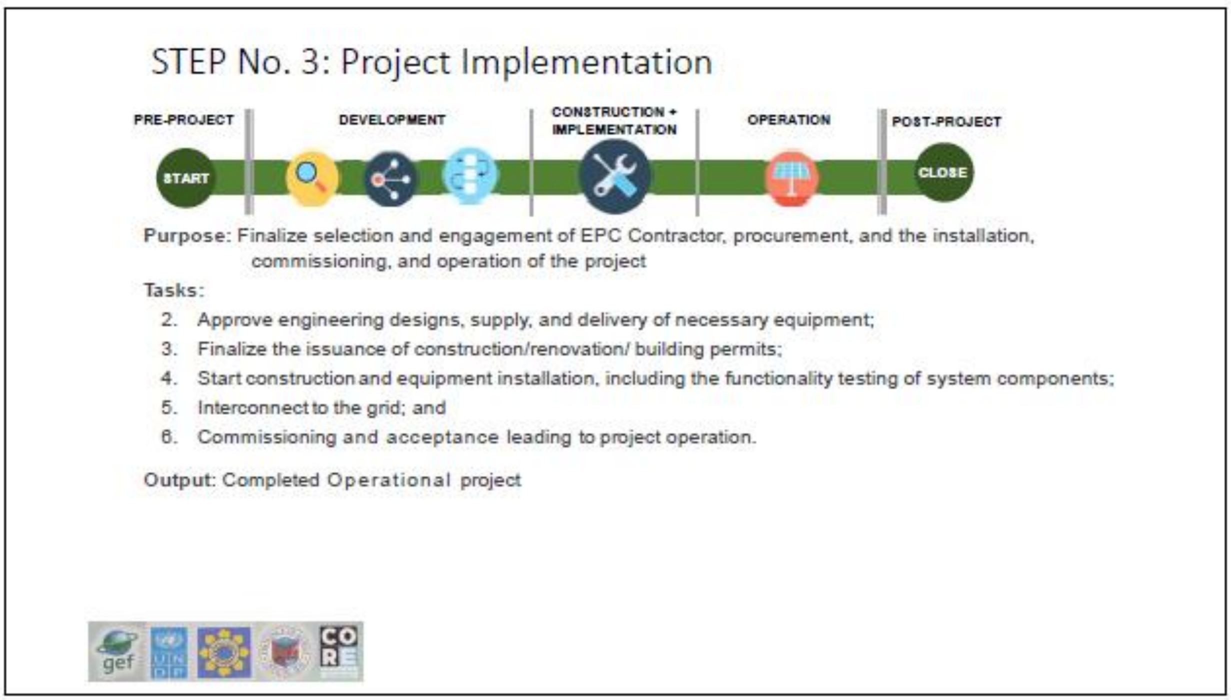
Notes on Project Planning

1. Developing a great project plan will minimize risks and uncertainties associated with the technology, business structure, budget, financing, timing, potential energy production, and revenue stream of the project;
2. Engage with stakeholders early in the process, particularly in ensuring end-user acceptance, sounding out of potential partners and investors, and interconnection with Distribution Utilities/Electric Cooperatives;
3. Set measurable and realistic time frames and corresponding milestones; and
4. Expect the planning process to be iterative and dynamic through each phase of project development.

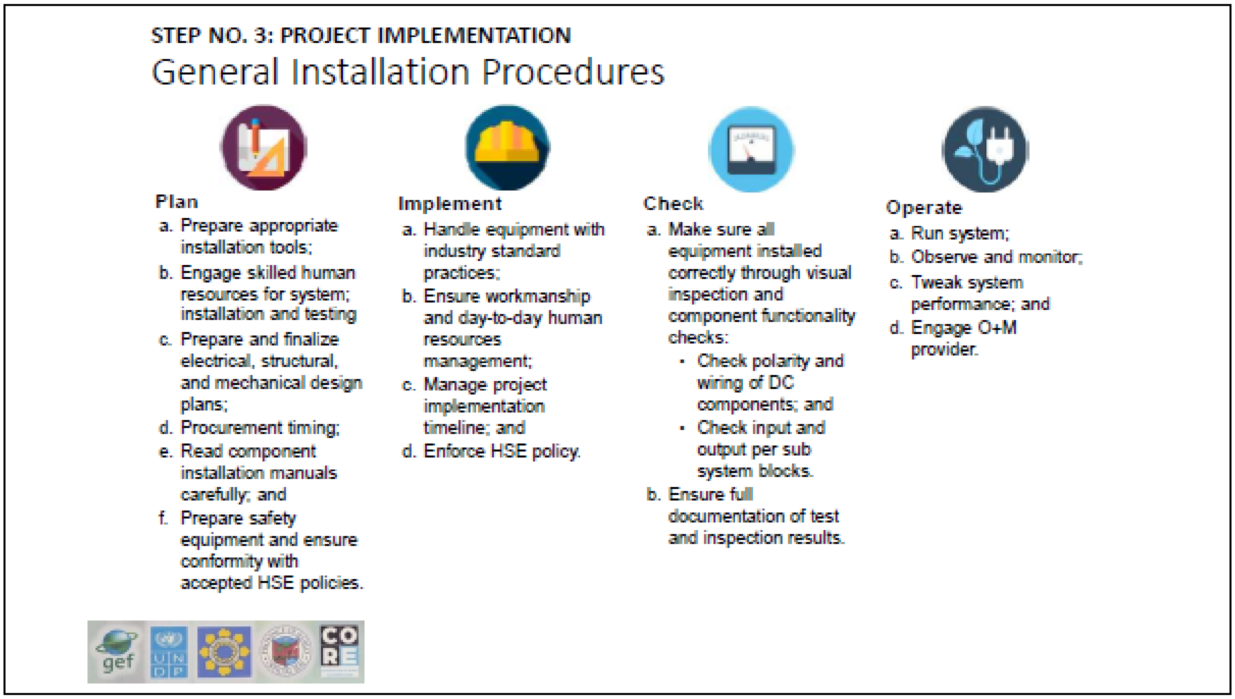
Preparations for the solar project implementation



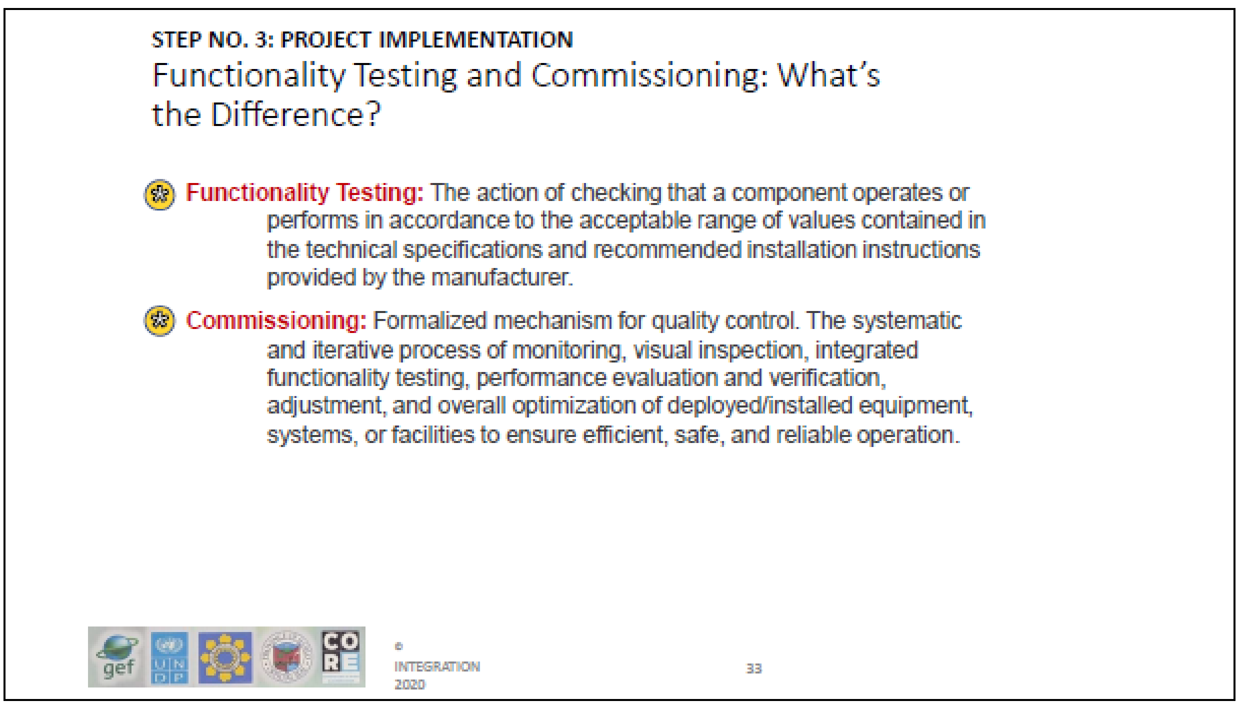
Checklist for Pre-construction of the solar installation



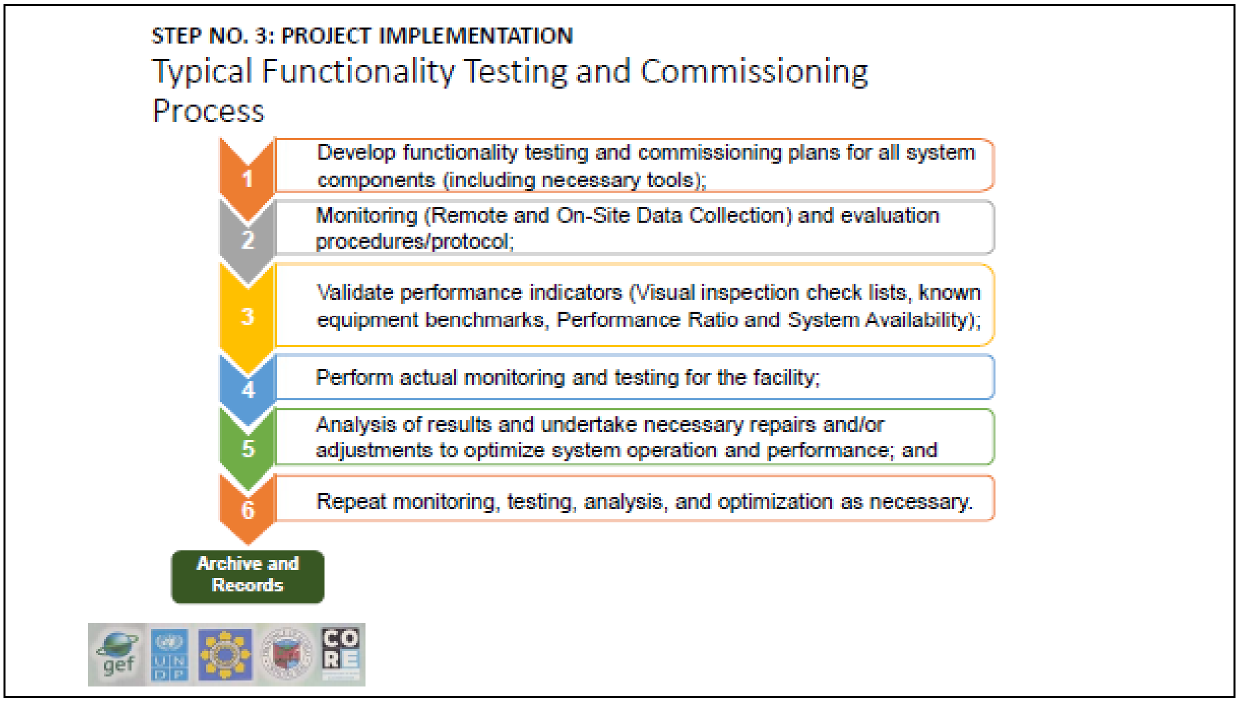
Approval of technical design and permitting



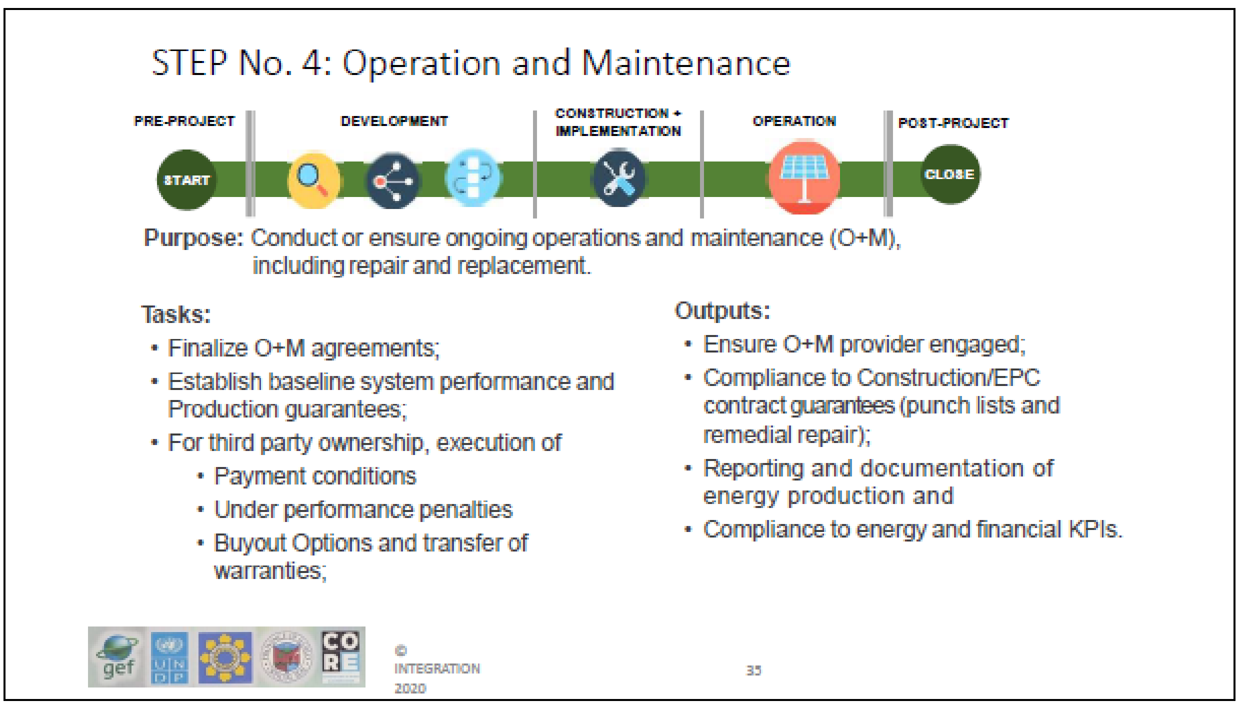
Solar Project Installation Procedures



Solar Project Functionality Test and Commissioning



Checklist for Functionality test and Commissioning



Solar Project Operations and Maintenance

STEP NO. 4: OPERATIONS AND MAINTENANCE

Rationale for Enhancing Operation and Maintenance

- Increase efficiency and energy delivery (kWh/kW);
- Decrease downtime (hours/year);
- Extend system lifetime (25 to 30+ years);
- Reduce costs of O+M (PHP/kW/year);
- Ensure safety and reduce risk to people and property; and
- Ensure that the facility complies with financial KPIs (revenue stream) and equipment/system warranty terms.

The need for Operation and Maintenance of the Solar project

STEP NO. 4: OPERATIONS AND MAINTENANCE

Operation and Maintenance Costs Dependencies

Location
- Remote
- Controlled access
- Restricted hours of operation

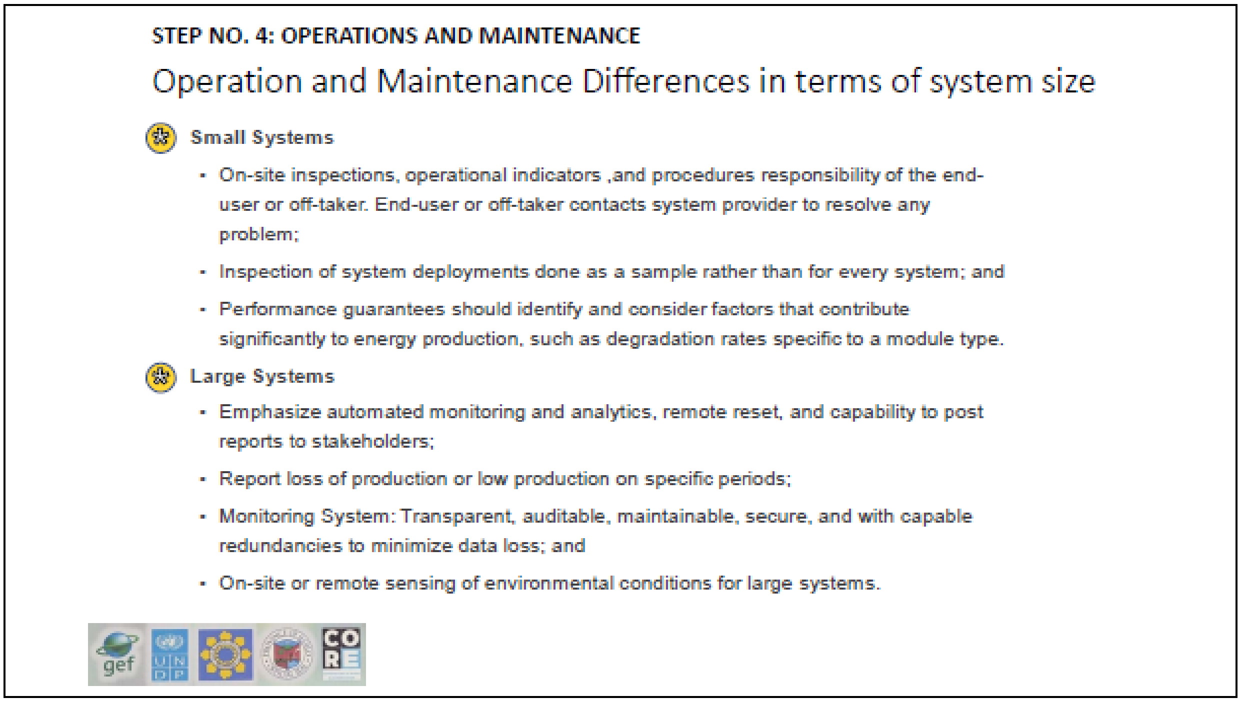
System Type
- Roof-Mount
- Ground-Mount

Components
- Number of modules
- Number of combiner boxes
- Number and type of inverters
- Number of transformers
- Number of AC and DC panel boards

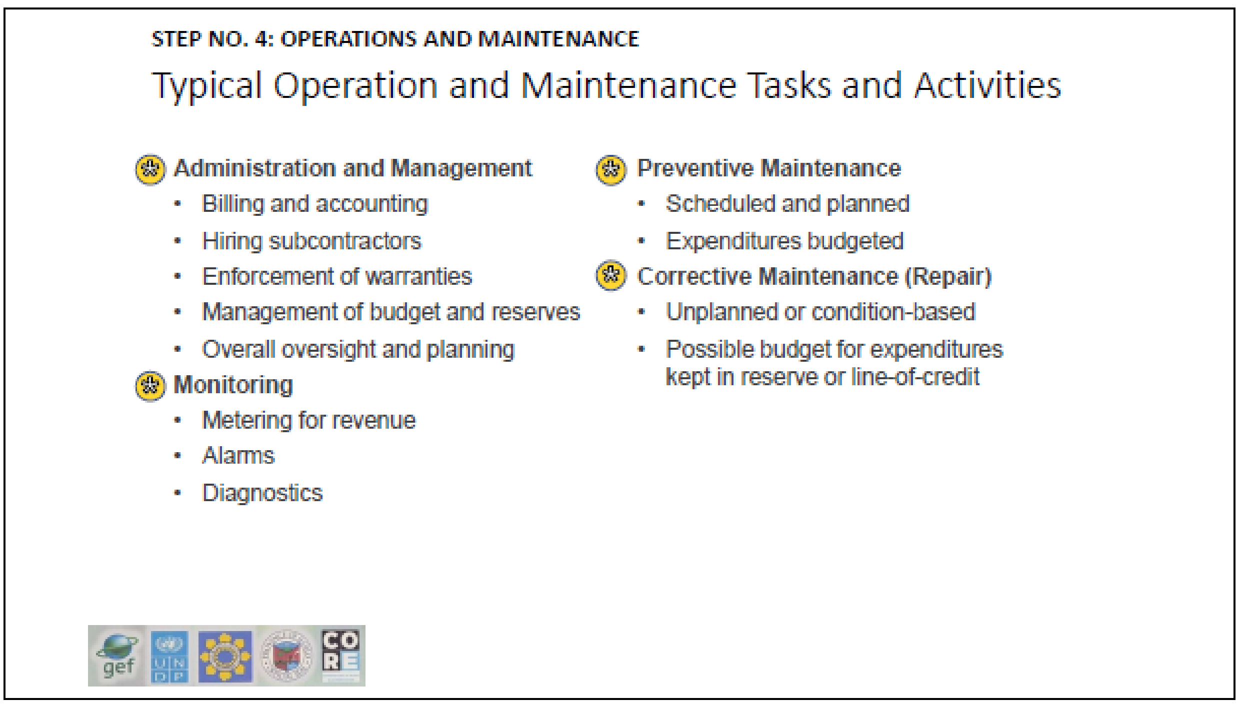
Warranty Coverage

Environmental Conditions
- Pollen
- Bird populations
- Sand/Dust
- Humidity
- High temperatures
- Adverse weather conditions
- Salt air
- Air pollution and emissions

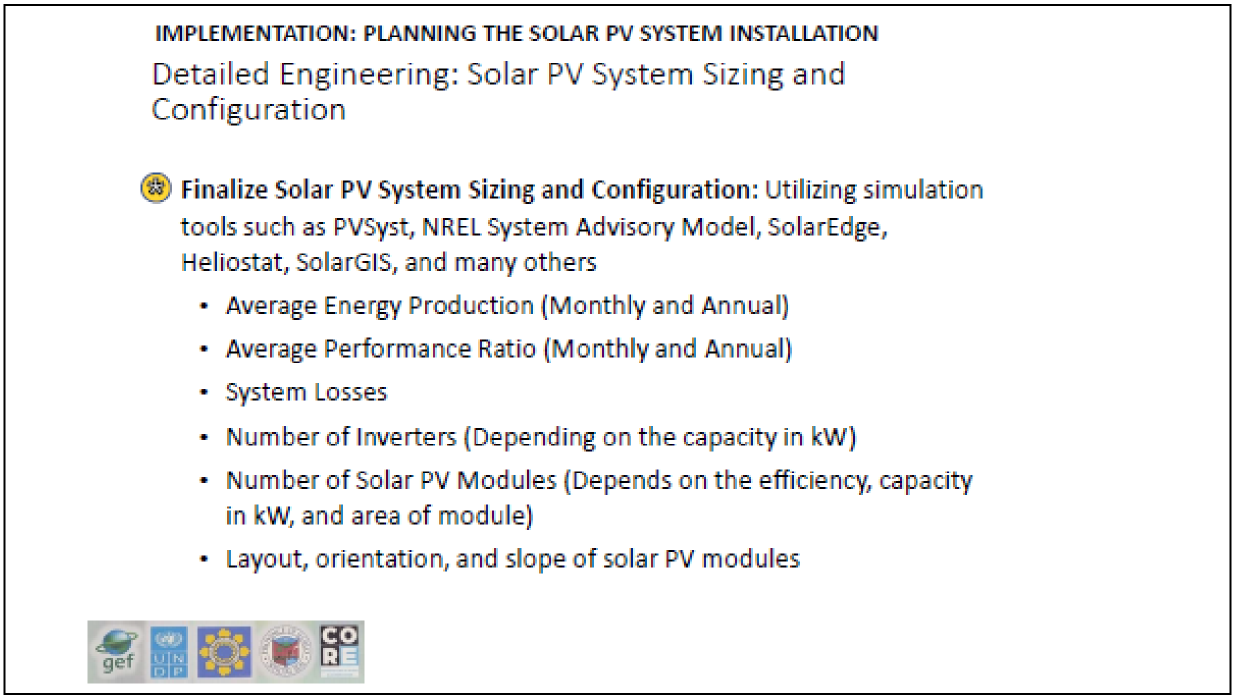
Factors to consider in costing the maintenance operation



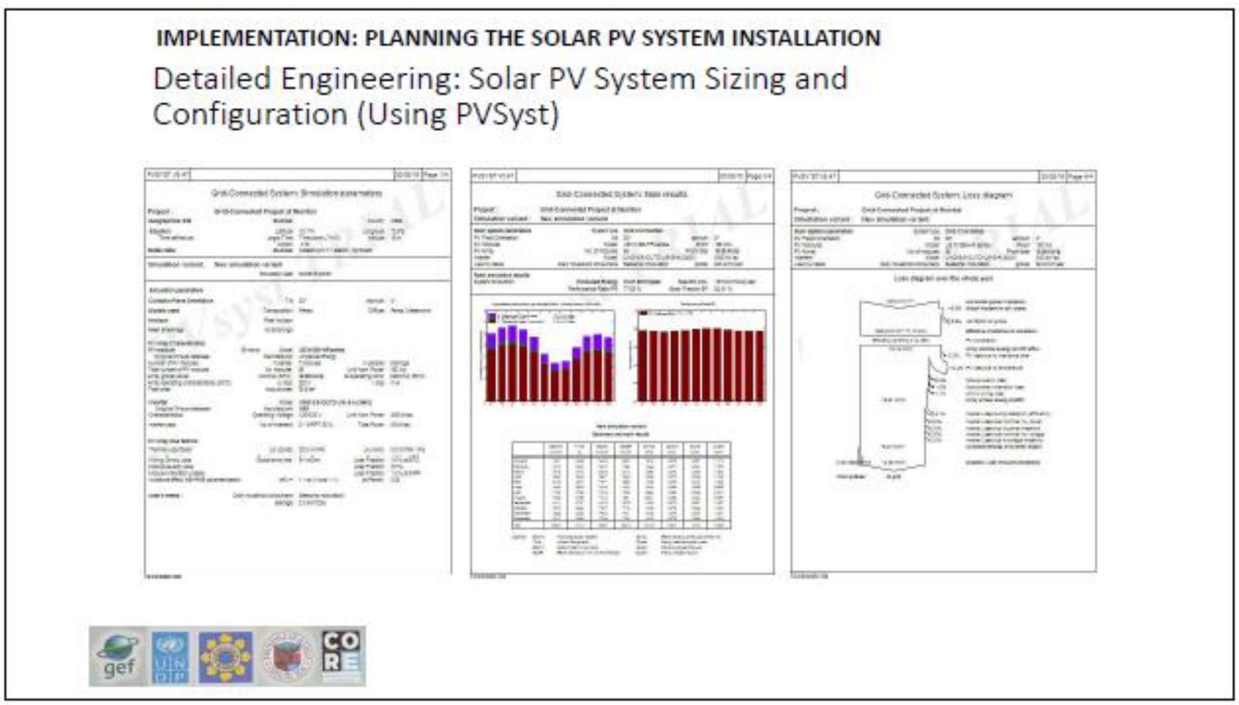
Impact of the system size on the Operation and Maintenance



Typical Tasks for Operation and Maintenance Activities



Use of Commercial software in planning and designing of PV systems



Sample output of commercial sola design software

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Detailed Engineering: Construction IMPLEMENTATION (civil and Mechanical)

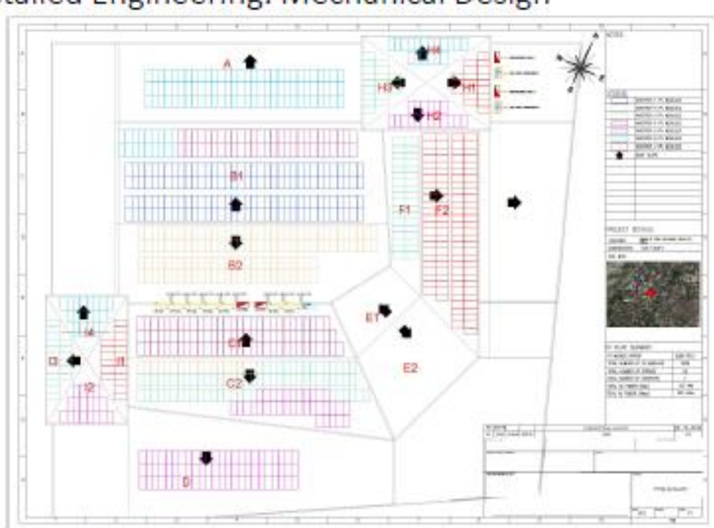
Finalize detailed civil and mechanical designs:

- Layout of solar PV modules on roof
- Site Development and Access Plan
- Equipment layout (Placement of inverters with mounting frames, combiner boxes, DC electrical panels, AC electrical panels, and others)
- Maintenance walkways, ladders, and anchor points (temporary or permanent)
- Solar PV array cleaning system (Optional)

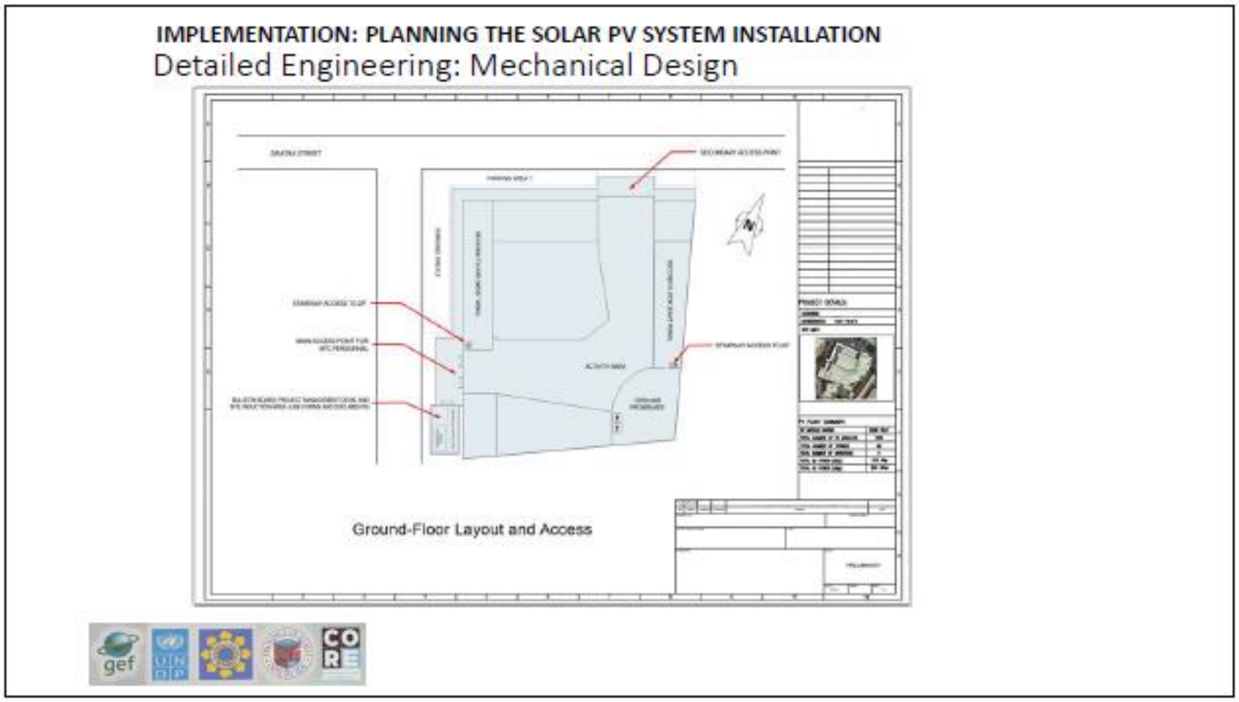
Finalize Civil and Mechanical Design

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

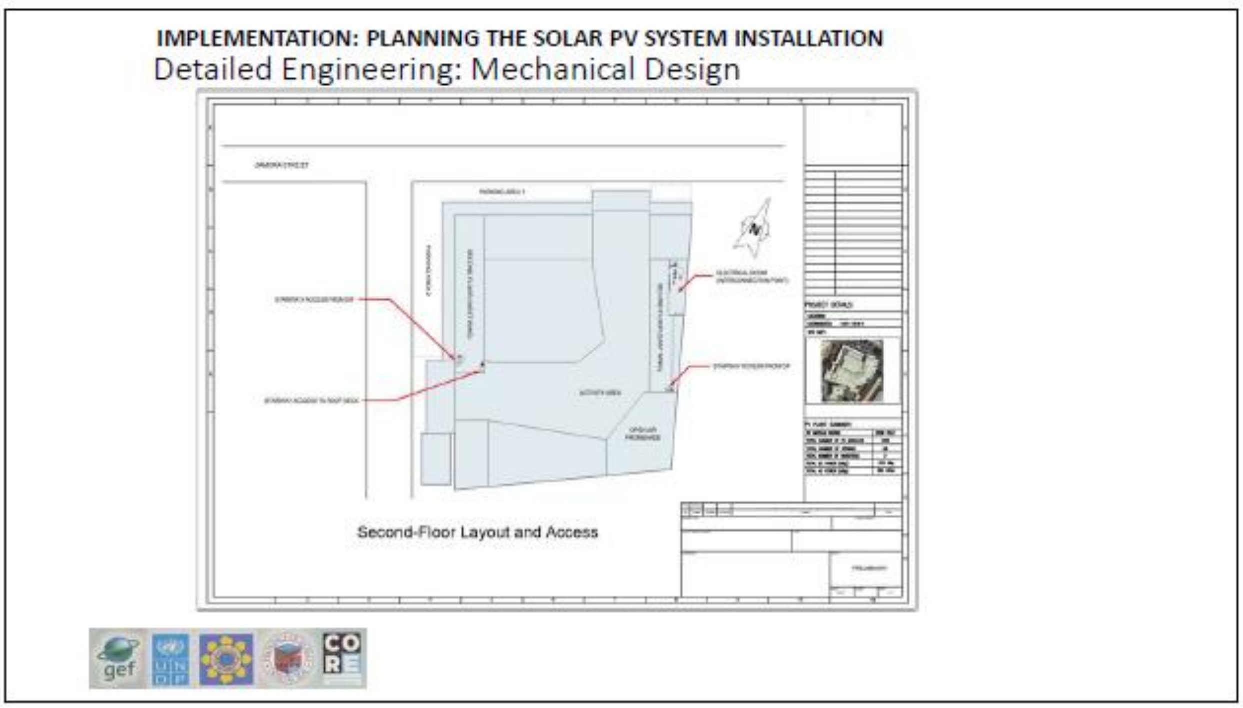
Detailed Engineering: Mechanical Design



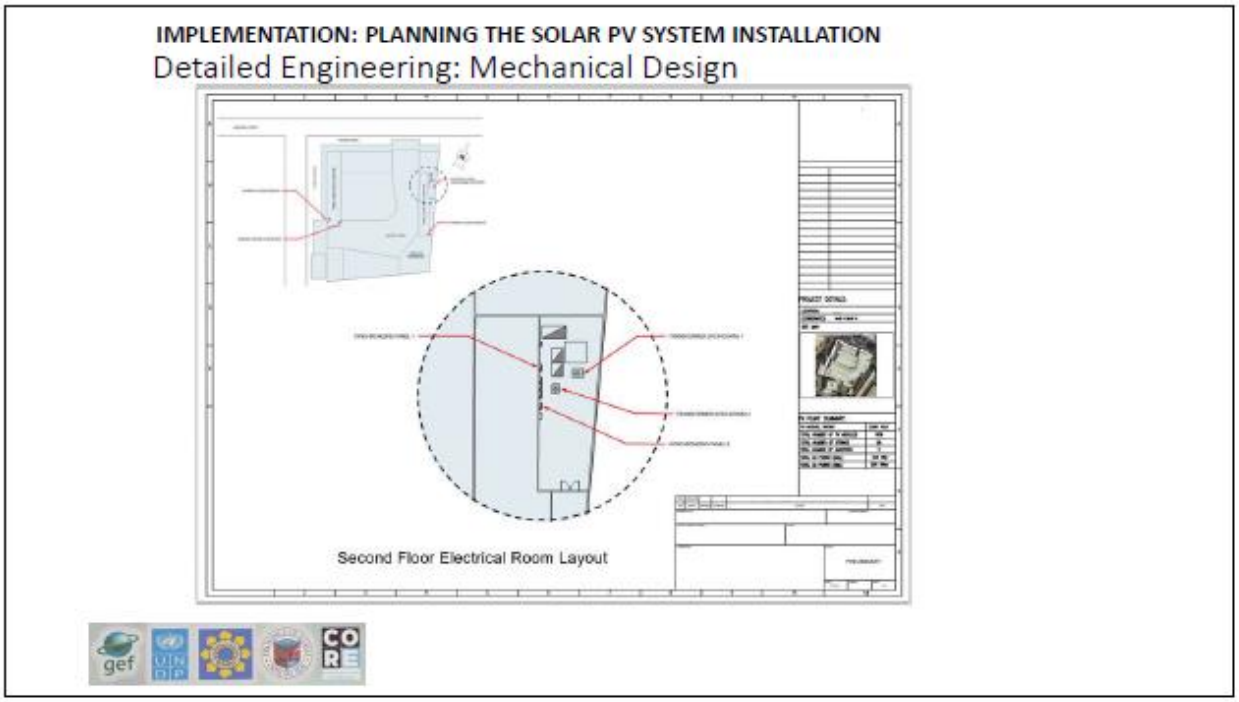
Sample Detailed Engineering: Mechanical Design – solar module lay-out



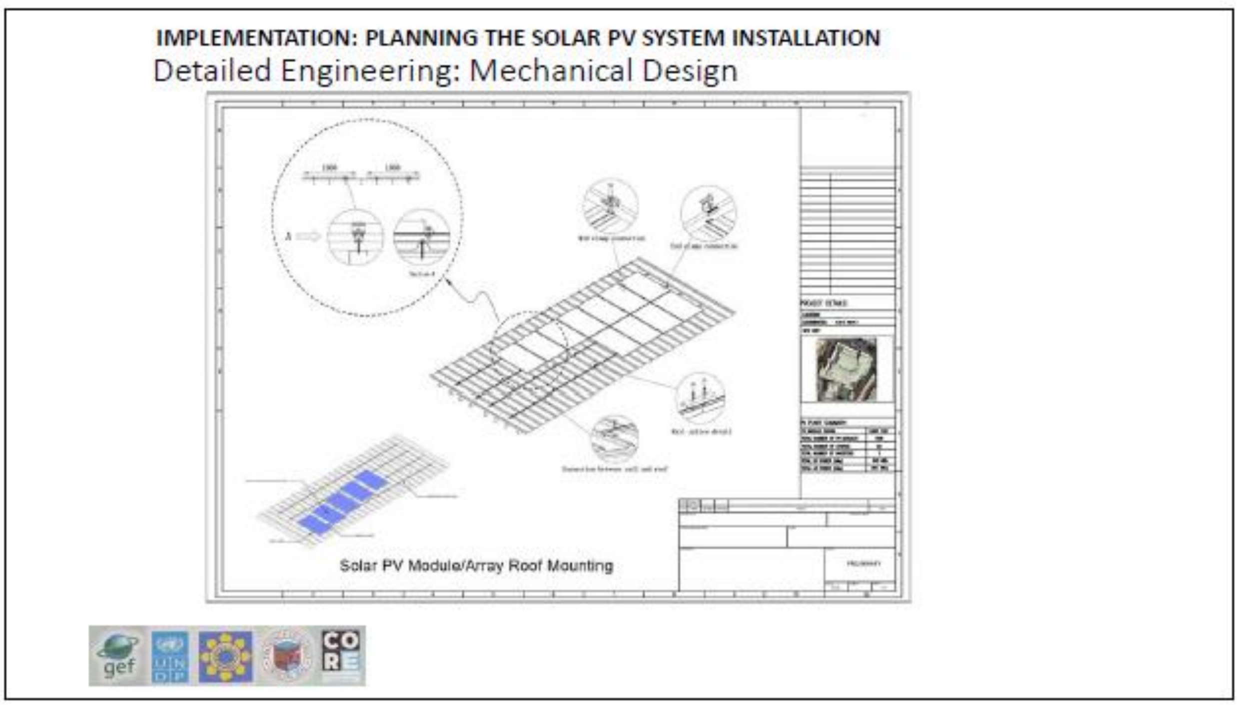
Sample Detailed Engineering: Mechanical Design – electrical lay-out



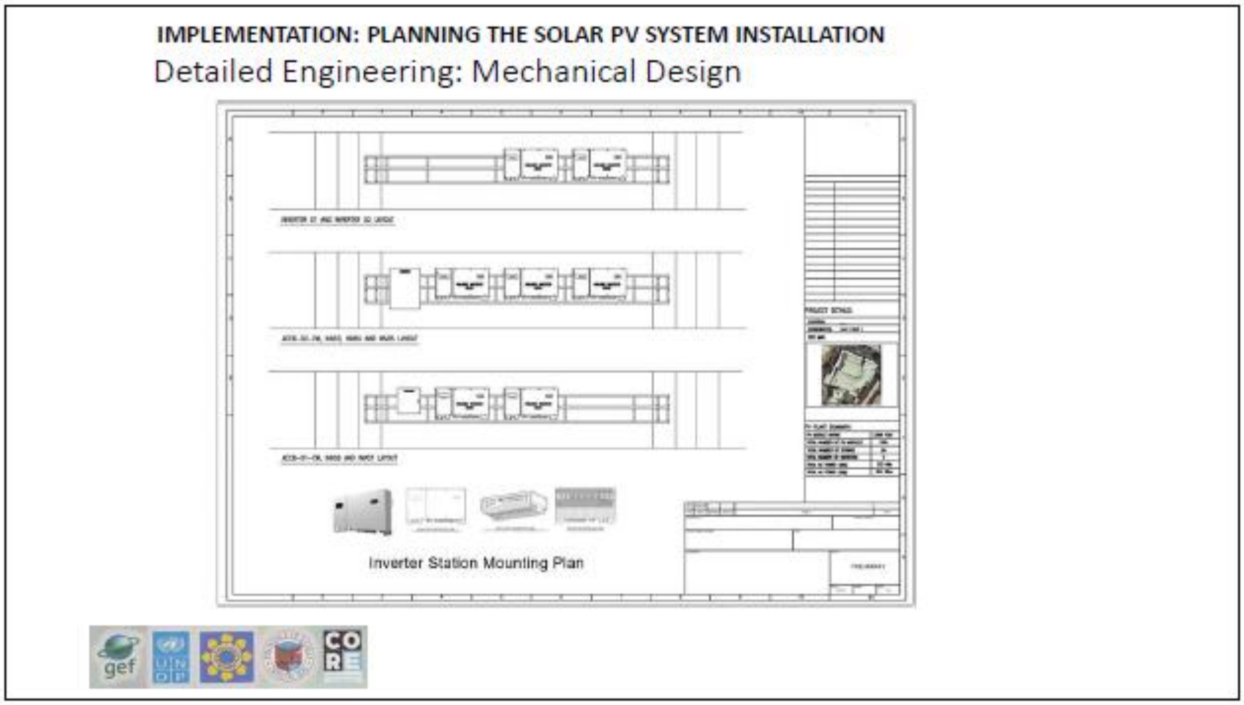
Sample Detailed Engineering: Mechanical Design – mechanical lay-out



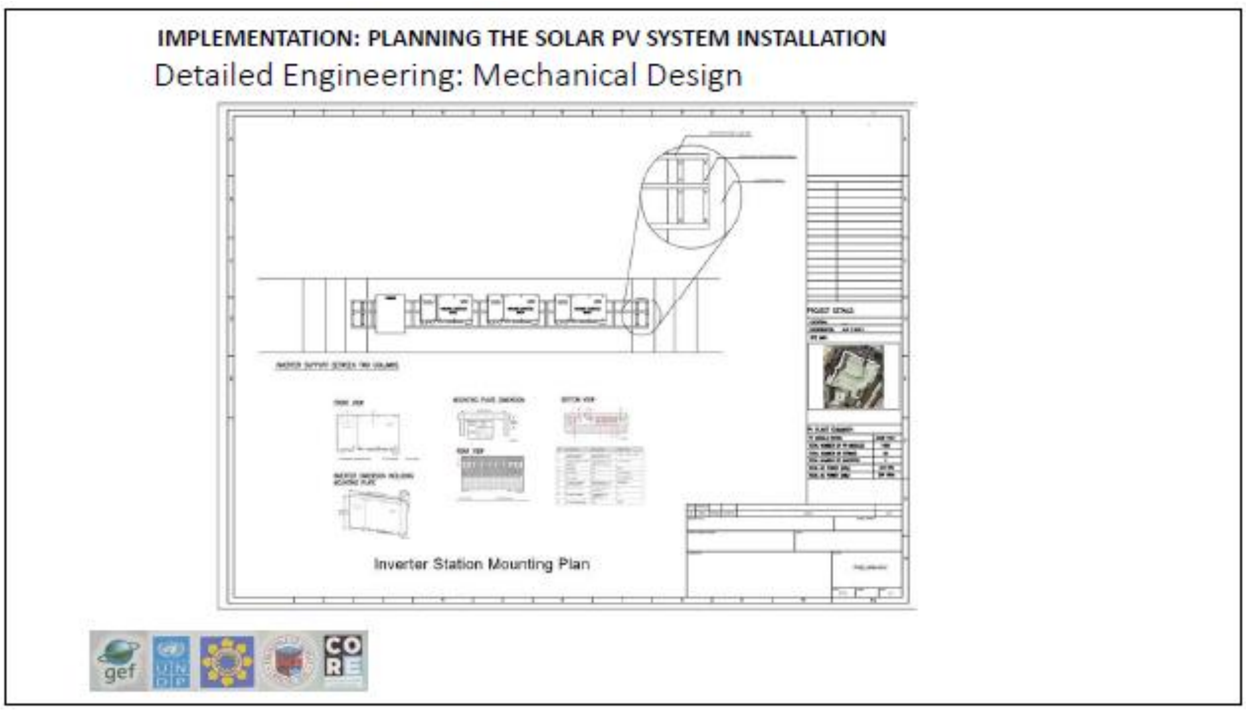
Sample Detailed Engineering: Mechanical Design – electrical room lay-out



Sample Detailed Engineering: Mechanical Design – solar module roof mounting details



Sample Detailed Engineering: Mechanical Design – solar inverter mounting details



Sample Detailed Engineering: Mechanical Design – solar inverter mounting frame details

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Detailed Engineering: Structural Design

Finalize structural design (National Building Code of the Philippines):

- Verify the structural loading capacity of the roof (including dead, live, seismic, and wind loads) for solar PV array, mounting frames, and maintenance walkways/safety anchor points

Finalization of Structural Design in compliance to the National Building Code of the Philippines

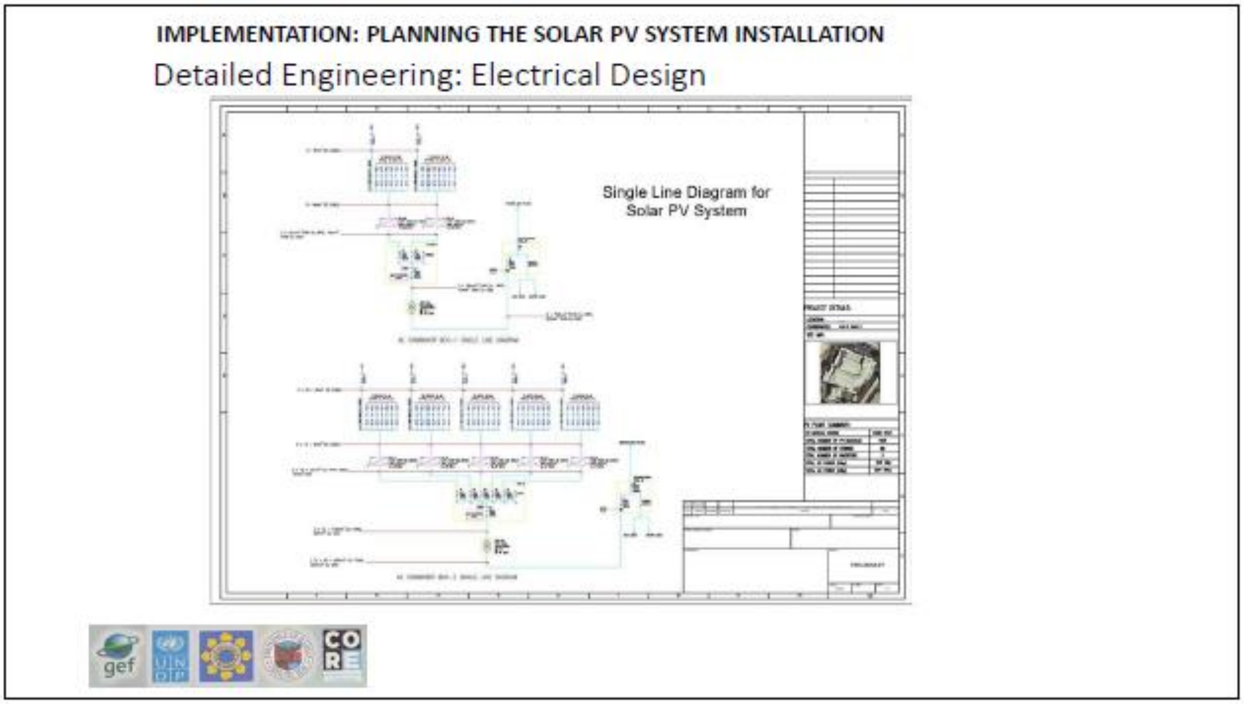
IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Detailed Engineering: Electrical Design

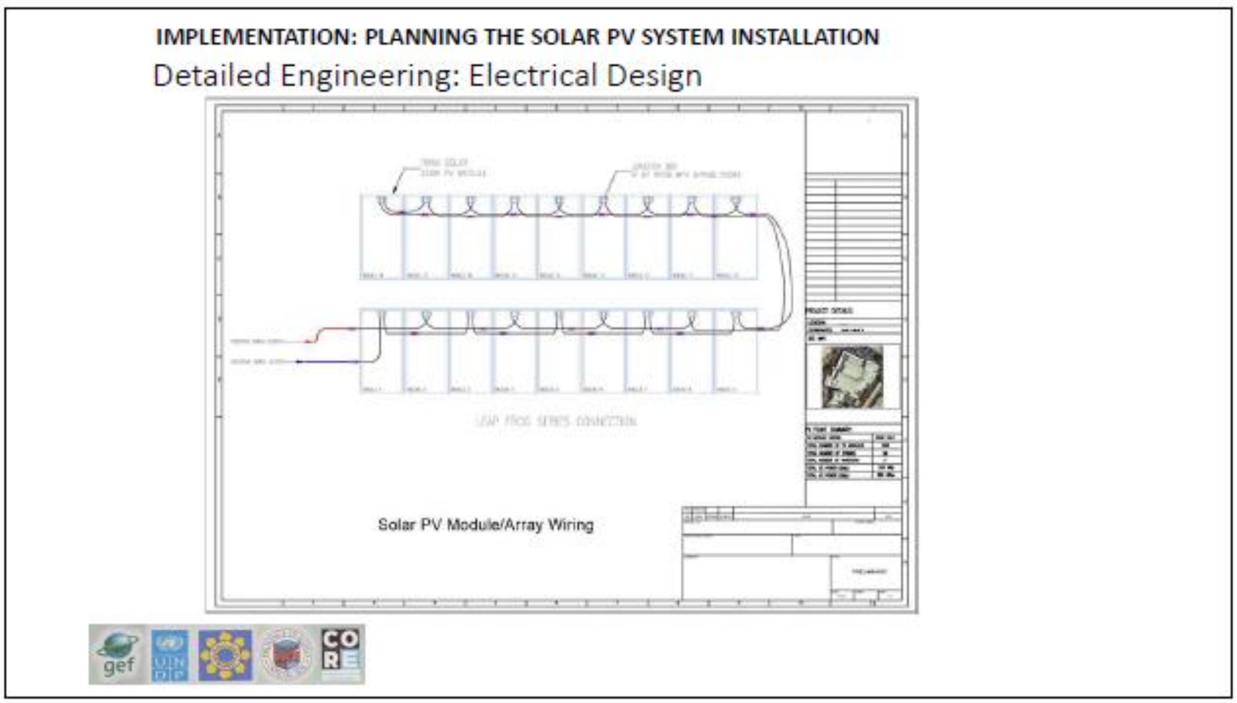
Finalize detailed electrical design (Philippine Electrical Code 2017 Edition):

- Cable routing, sizing of conduits, raceways, and cable trays
- DC cable sizing and selection (Calculation of maximum allowable continuous current and maximum voltage drops)
- AC circuit breaker sizing (per circuit breaker)
- AC cable sizing and selection (Calculation of cable current carrying capacity and voltage drops)
- Transformer sizing and selection
- Synchronizing panel sizing
- System grounding and short-circuit and thermal overload protection
- Single-Line Diagram

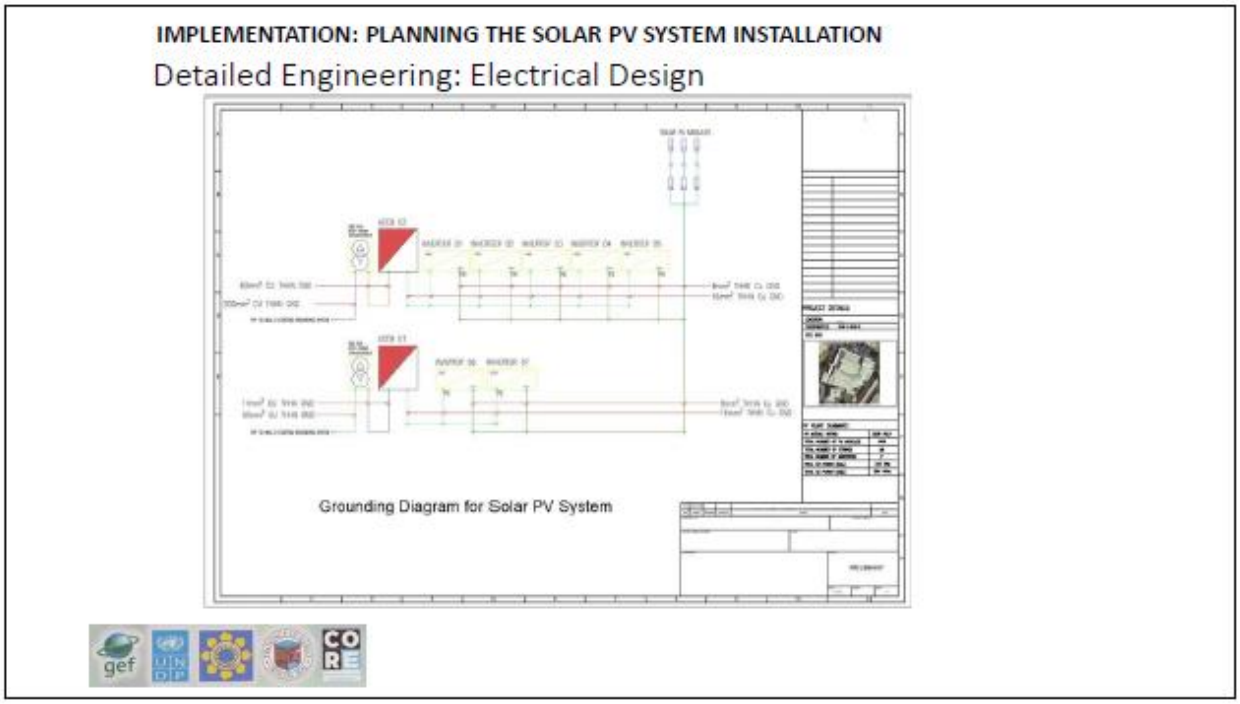
Finalization of Electrical Design in compliance to the Philippine Electrical Code of 2017



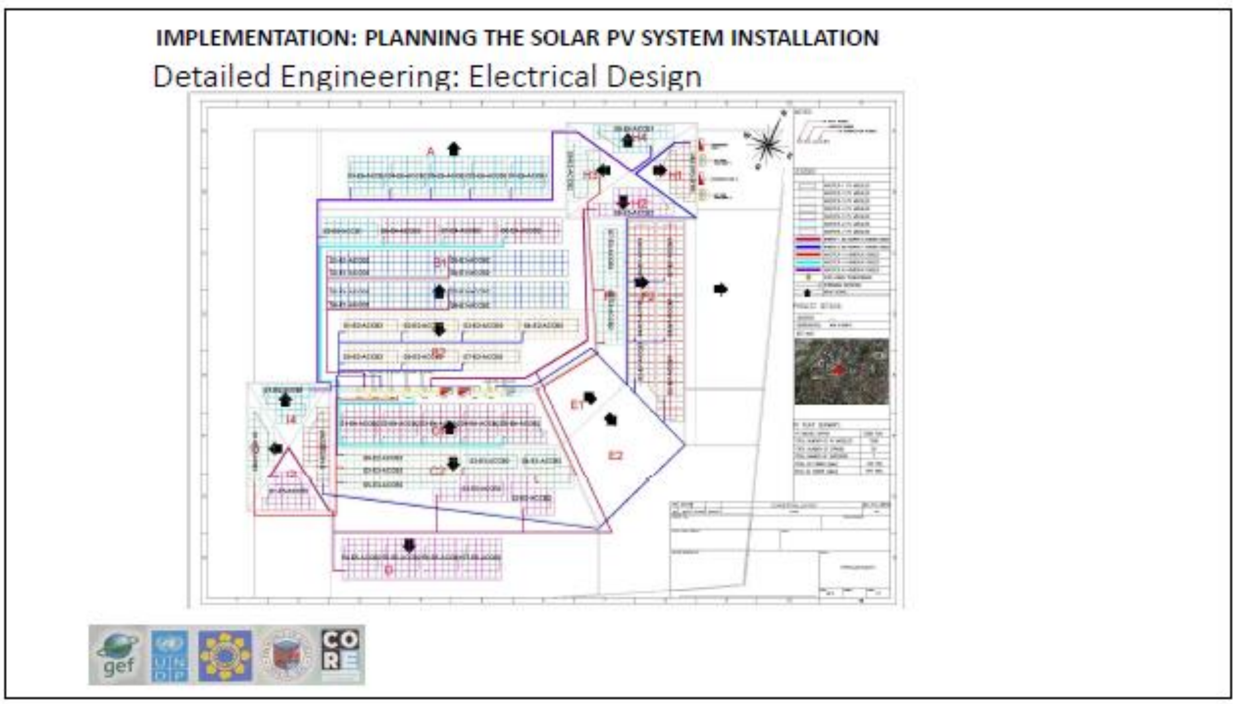
Sample Single Line Diagram of a PV System



Sample detailed wiring diagram and methodology of a solar array



Grounding Diagram of a PV System



Detailed Electrical Lay-out of a PV System

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Construction Safety, Health, and Environment

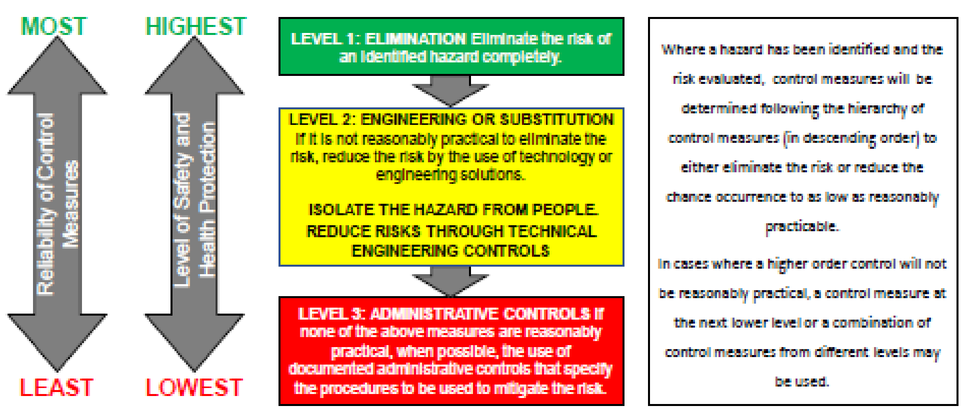
Finalize Construction Safety, Health, and Environmental Plan (Occupational Safety and Health Law and DOLE Department Order No. 13, Series of 1998):

- Identification and selection of certified Construction Occupational Safety and Health (COSH) Officers to form the Site Construction Safety and Health Committee
- Development of the Construction Safety, Health, and Environmental Plan
    a. Safety Rules and Regulations for Construction Team and Visitors
    b. Use of Personal Protective Equipment (PPEs)
    c. Emergency Procedures and Quick Response Plan
    d. Fall Protection Plan
    e. Fire Protection Plan (Section 10.2.19.9 of the Revised Implementing Rules and Regulations, Fire Code of the Philippines
    f. Welfare and First-Aid Facilities
    g. Housekeeping Rules and Procedures
    h. Safety Hazards and Risk Assessment
    i. On-Site Safety and Health Promotion (Conduct of daily tool box meetings and site induction and safety orientation)
    j. Waste Disposal and Treatment Plan

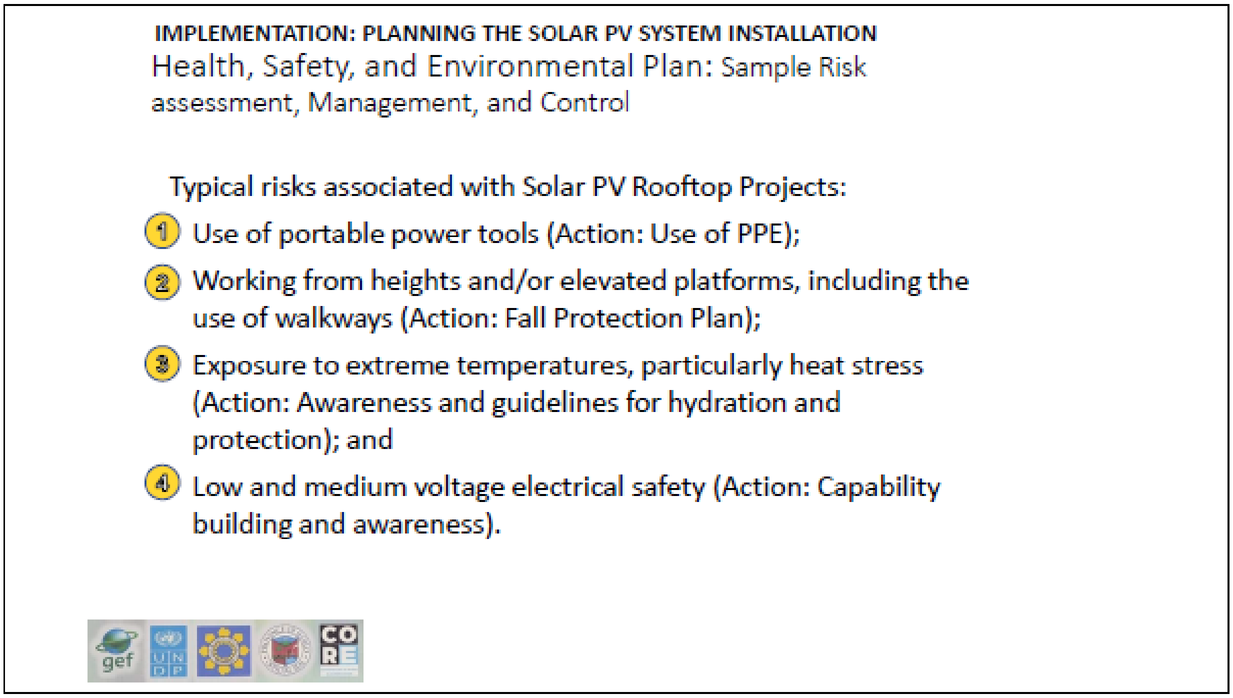
Construction Safety, Health, and Environment guidelines

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

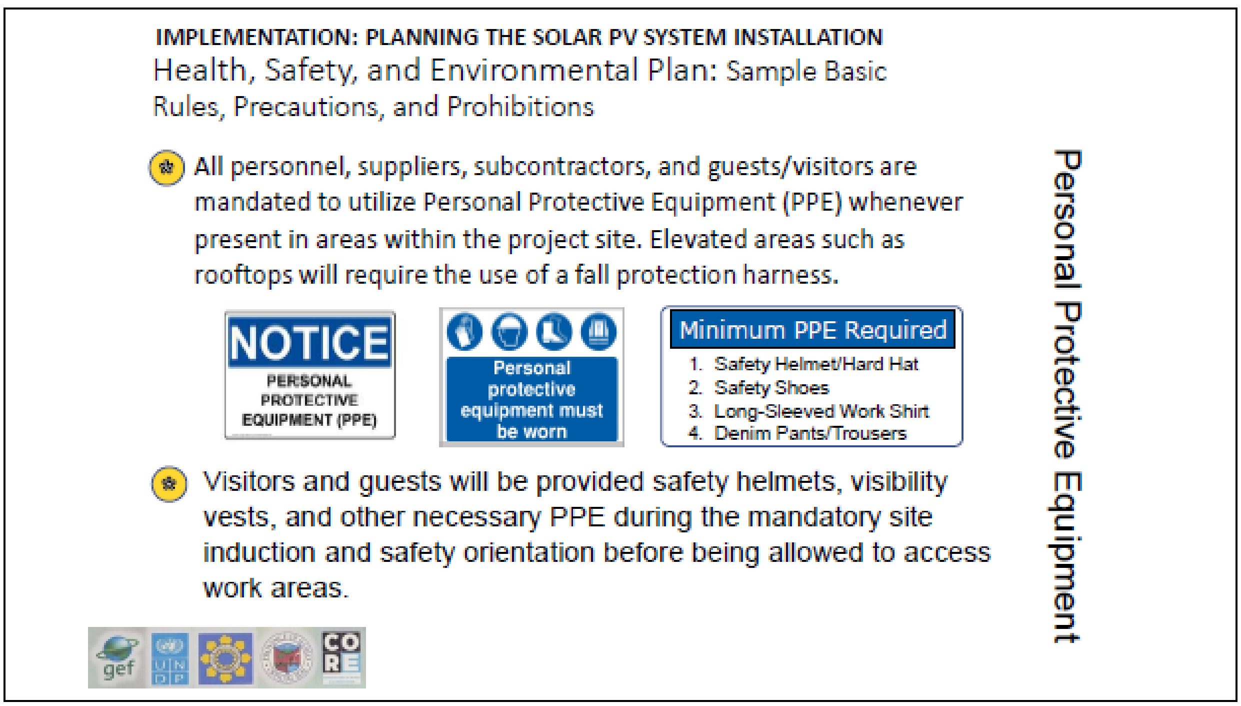
Health, Safety, and Environmental Plan: Sample Risk assessment, Management, and Control



Construction Safety, Health, and Environment – Risk Management



Construction Safety, Health, and Environment – Common Risks in solar installations



Construction Safety, Health, and Environment – Rules, Precautions, and Prohibitions

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Health, Safety, and Environmental Plan: Sample Basic Rules, Precautions, and Prohibitions

Electrical Safety

- Always treat electricity and electrical equipment with respect;
- Discard any piece of equipment that gives you even the slightest shock. If the resistance through your body is lowered (i.e. standing in water or touching metal), even the slightest shock can be deadly;
- Check constantly that equipment cables and extension cords are not damaged or worn;
- Keep trailing equipment cables and extension cords off the ground and away from water if possible;
- Never overload or use makeshift plugs and fuses; and
- Only trained personnel and electricians should service electrical equipment and fixtures.

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Construction Safety, Health, and Environment – Electrical Safety

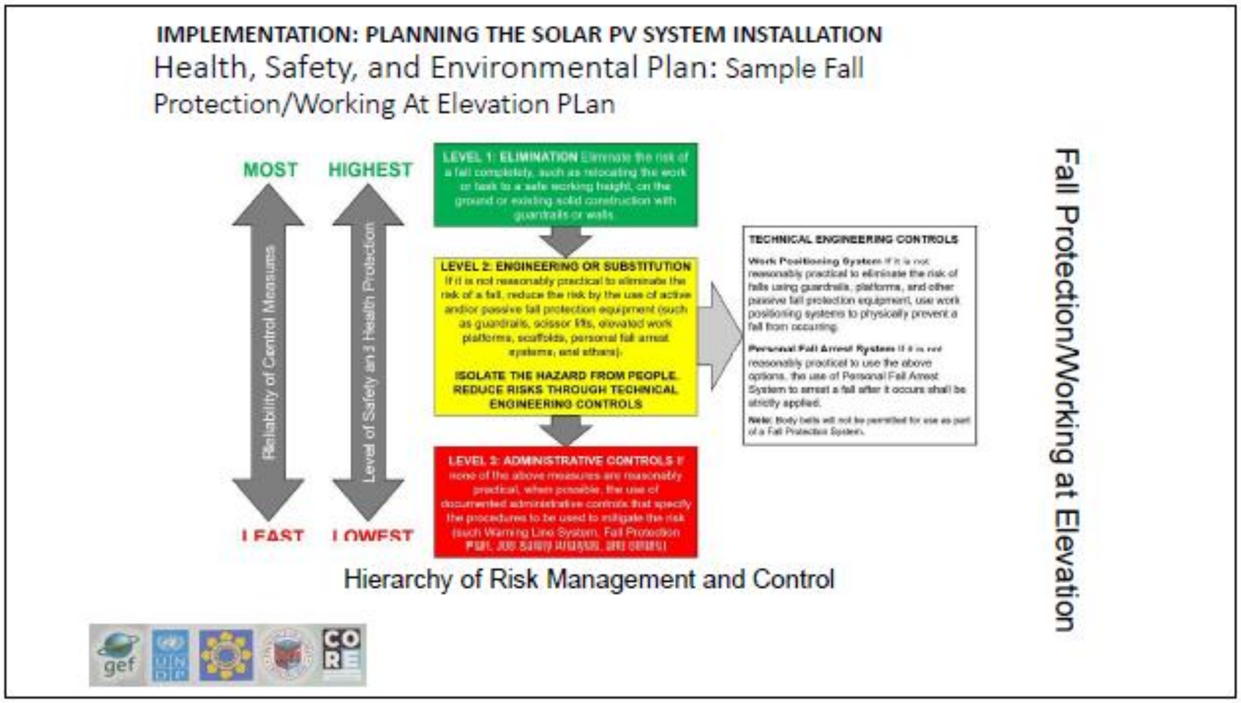
IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Health, Safety, and Environmental Plan: Sample Fall Protection/Working at Elevation Plan

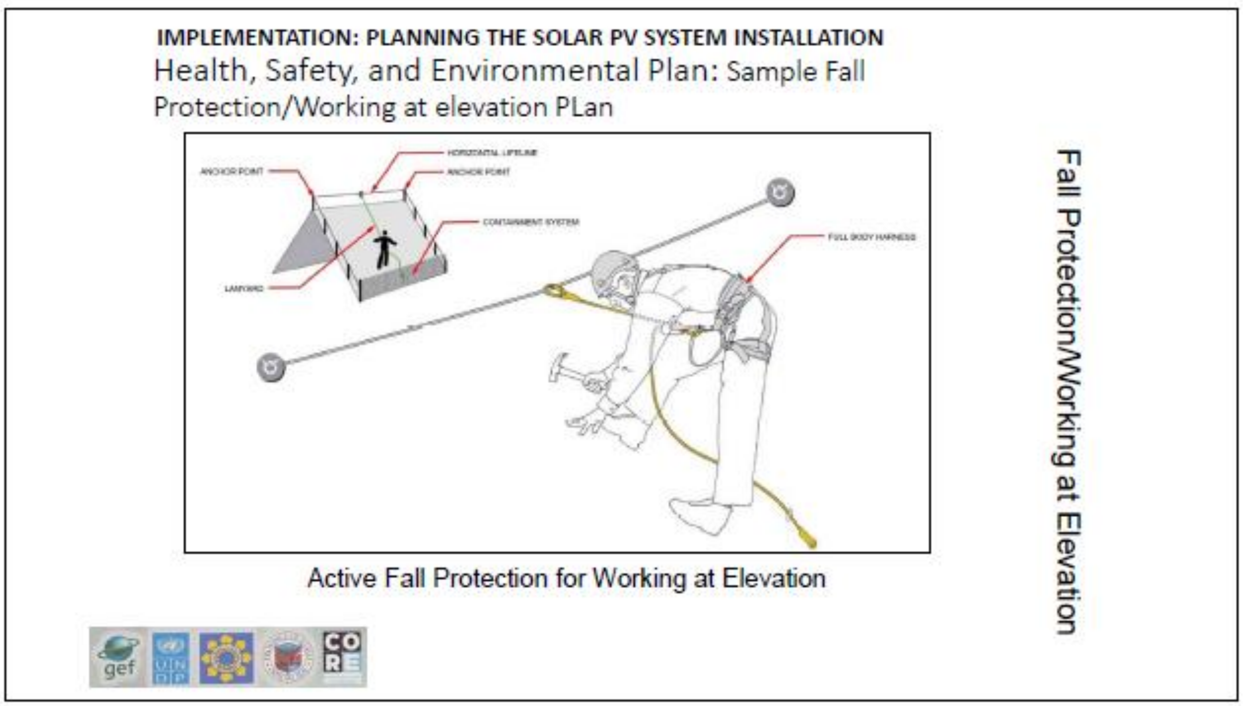
Fall Protection/Working at Elevation

- Personnel, subcontractors, and suppliers working at heights above **1.20 meters** for normal activities or **1.80 meters** for construction related activities must take into consideration any risk of a falling and the control measures to be implemented.
- Personnel will not be required, nor allowed to perform any duties which require getting closer than **3.00 meters** to an unprotected edge, opening, platform, walkway, or utilize elevated equipment unless they are properly secured from falling.
- Warning systems will be put in place on a roof at least **3.00 meters** from the edge to warn personnel that they are approaching an unprotected edge or opening. These warning systems designate an area where solar PV installation work may only take place with the use of personal fall arrest systems and lifelines secured to dedicated anchor points on the elevated structure.

Construction Safety, Health, and Environment – Fall protection



Construction Safety, Health, and Environment – Fall protection plan



Construction Safety, Health, and Environment – Fall protection plan

IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Health, Safety, and Environmental Plan: Sample

Emergency Response and Crisis Management Plan

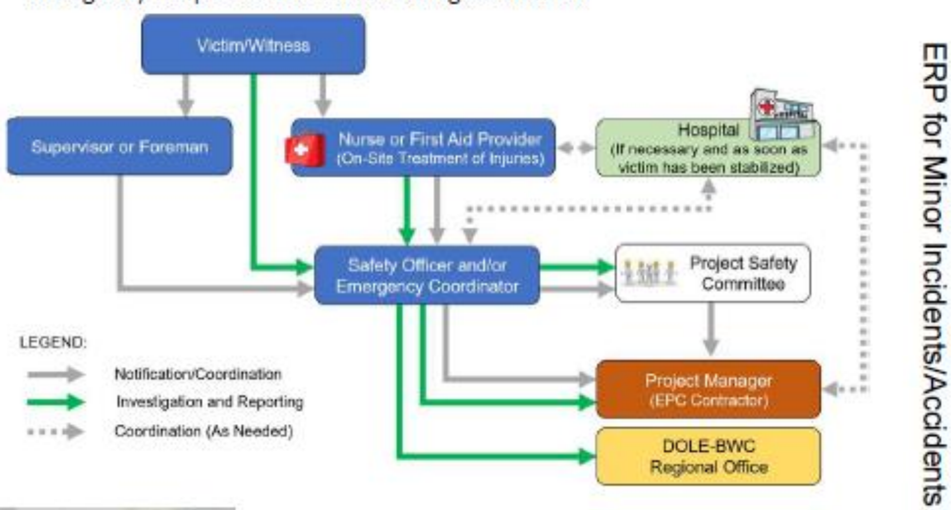
- The Emergency Response Plan (ERP) will be drafted to assist employees, subcontractors, suppliers, and management in making quality decisions during times of crisis and emergencies and contains guidance in determining the appropriate actions to be undertaken to prevent injury and property loss.
- During the occurrence of major and minor incidents/accidents, including (i) fire and explosion; (ii) structural failure; (iii) equipment failure; (iv) accidental falls, personal injury, sickness, and exposure to extreme temperatures; (v) natural calamities, including flooding, earthquakes, and adverse weather conditions.

Construction Safety, Health, and Environment – Emergency Response and Crisis Management Plan

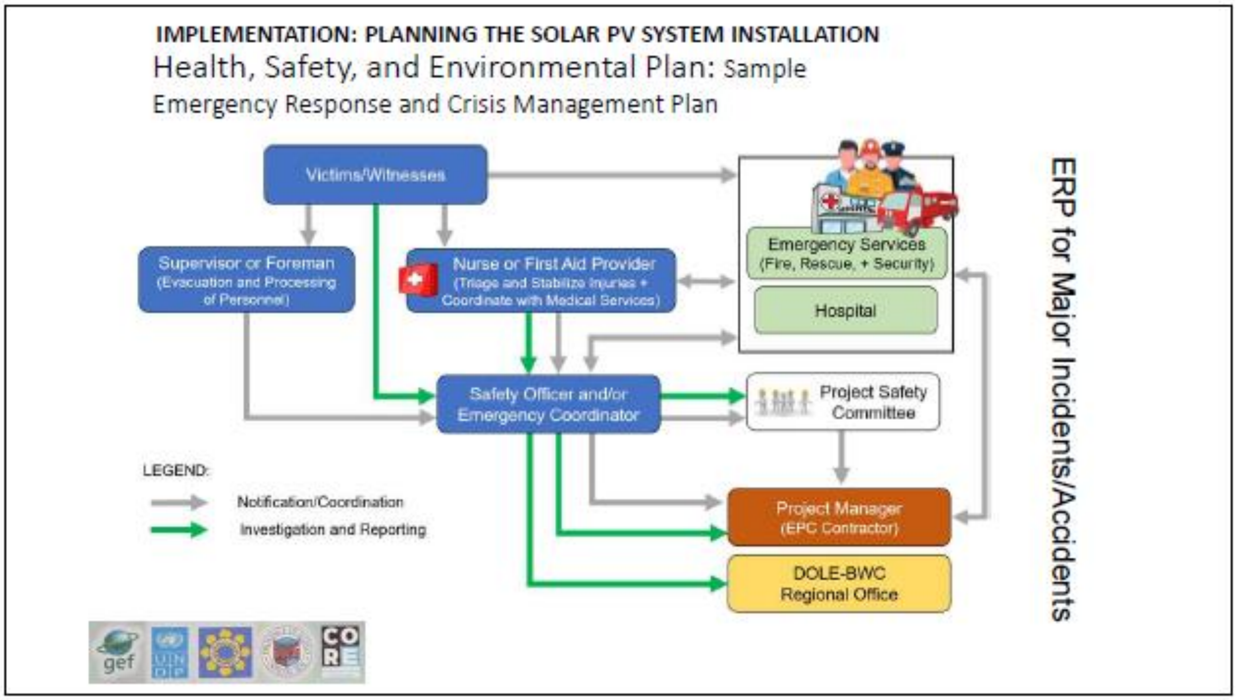
IMPLEMENTATION: PLANNING THE SOLAR PV SYSTEM INSTALLATION

Health, Safety, and Environmental Plan: Sample

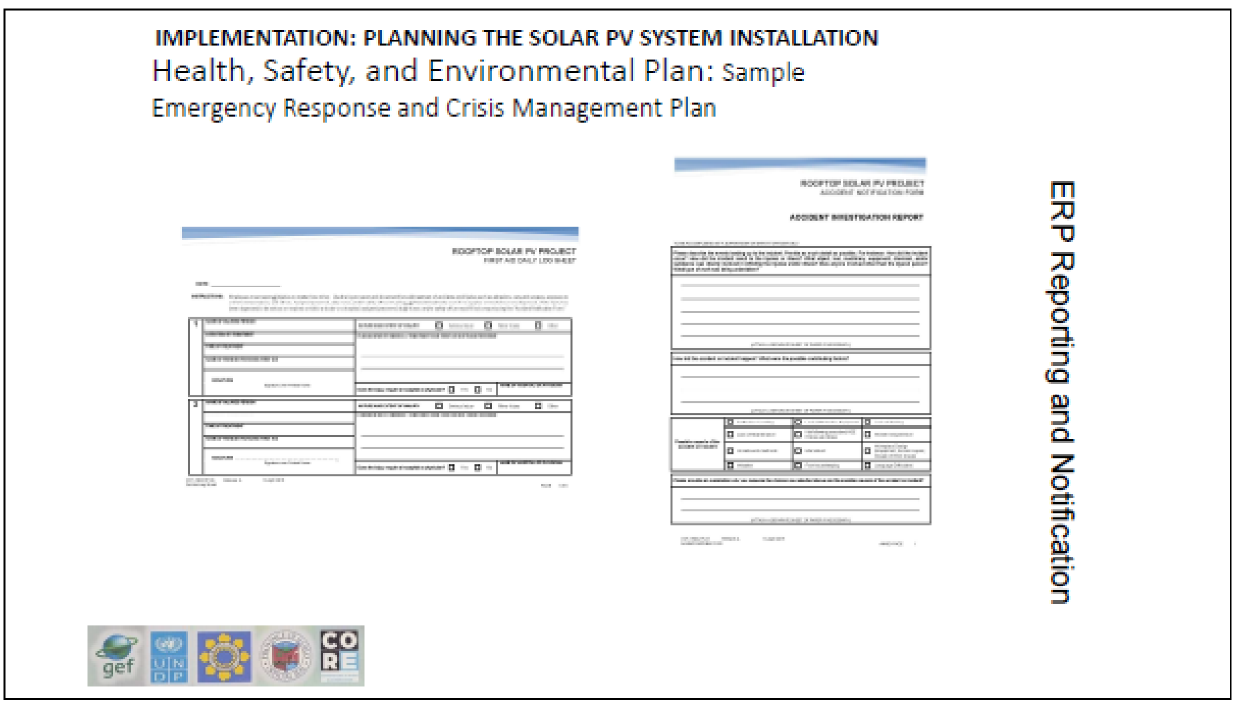
Emergency Response and Crisis Management Plan



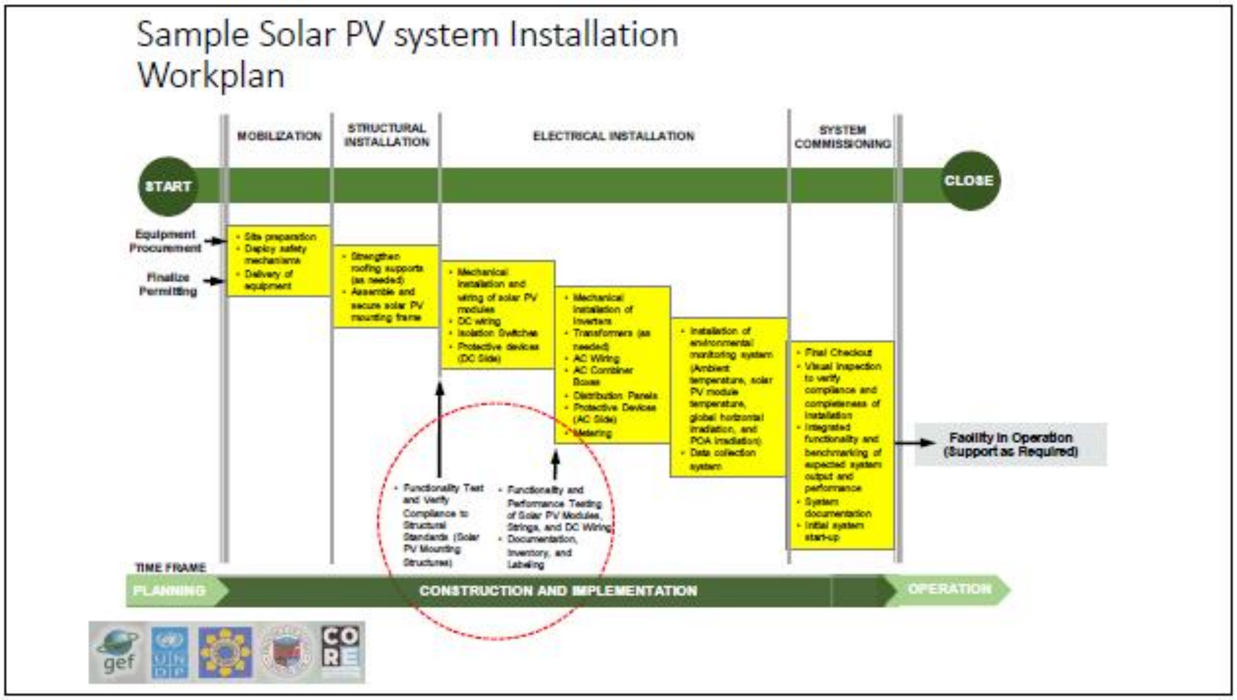
Construction Safety, Health, and Environment – Emergency Response and Crisis Management Plan



Construction Safety, Health, and Environment – Emergency Response and Crisis Management Plan



Construction Safety, Health, and Environment – Emergency Response and Crisis Management Plan



Solar PV Installation Workplan

CONSTRUCTION AND INSTALLATION OF THE SOLAR PV SYSTEM

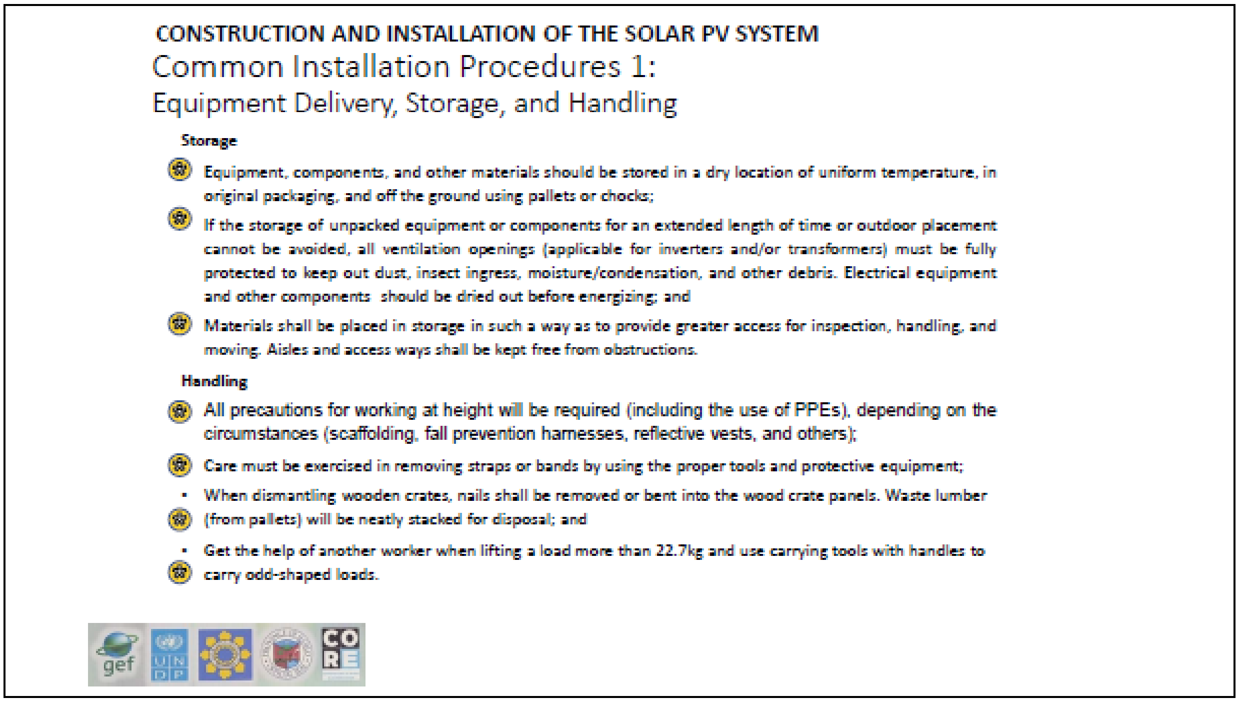
Common Installation Procedures 1:
Equipment Delivery, Storage, and Handling

Procurement and delivery of necessary equipment must be strictly set to prevent any delays in project implementation

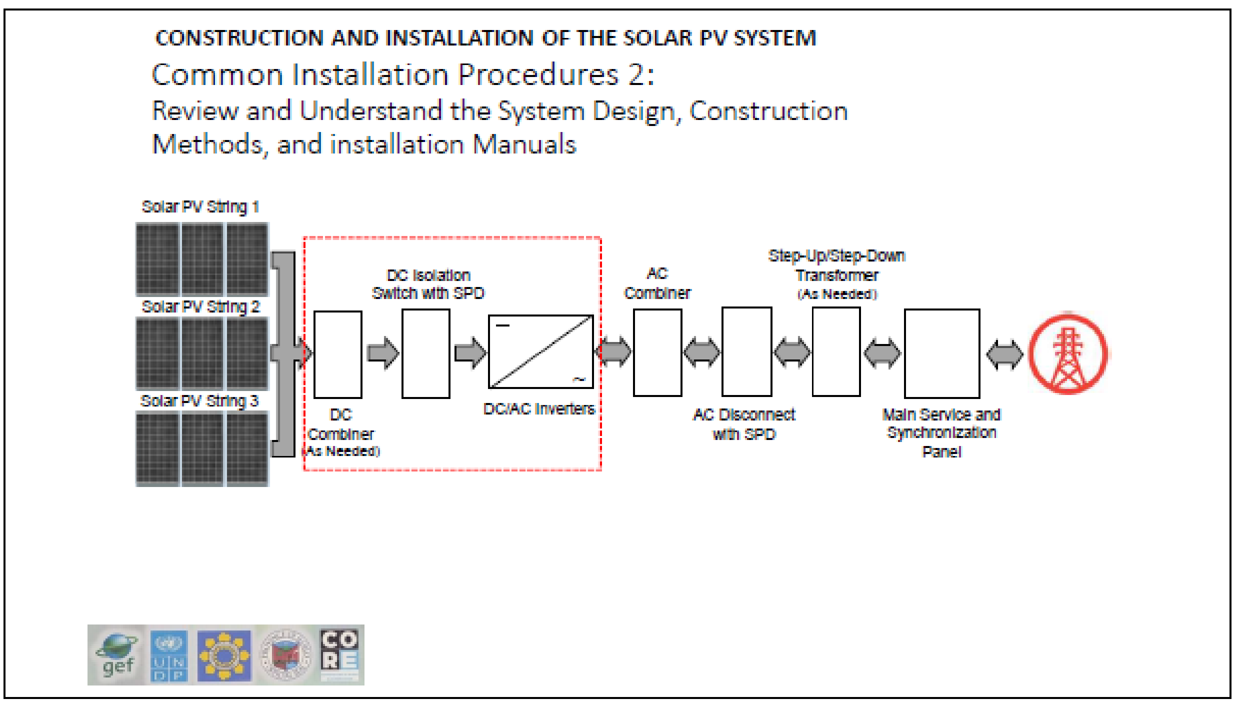
Inspection upon Receiving

- The characteristics (model and serial number) and technical specifications of each component (based on the name plate or labeling) should coincide with the data listed in the delivery/inventory list and other documentation;
- Check for all relevant safety warnings;
- Check the general physical state of each component for observable (minor and major) damages, as delivered;
- Check all of the accessories necessary for the operation of each component has been included in the package; and
- Before unpacking each component for installation, especially during inclement weather when the difference in temperature and humidity may be considerable, a period of time should be allowed before installation and energization to minimize the occurrence of condensation on any electrical contact.

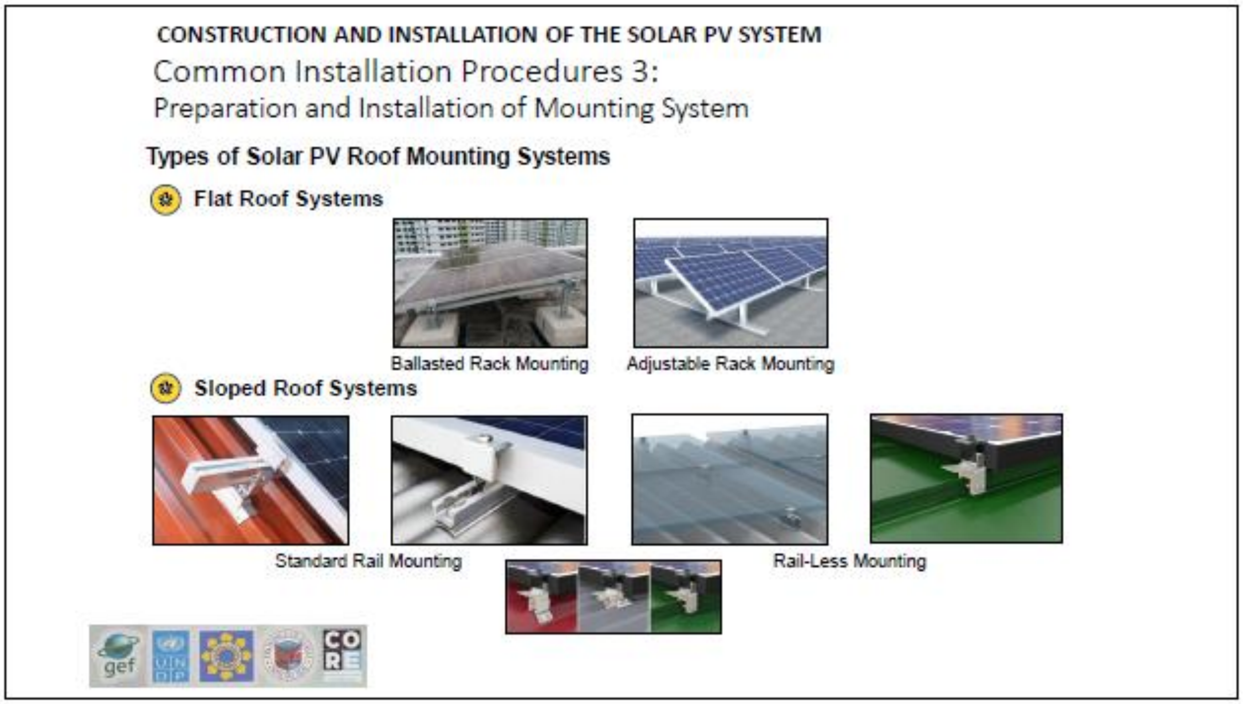
Solar PV Installation Workplan: Equipment delivery, storage, and handling



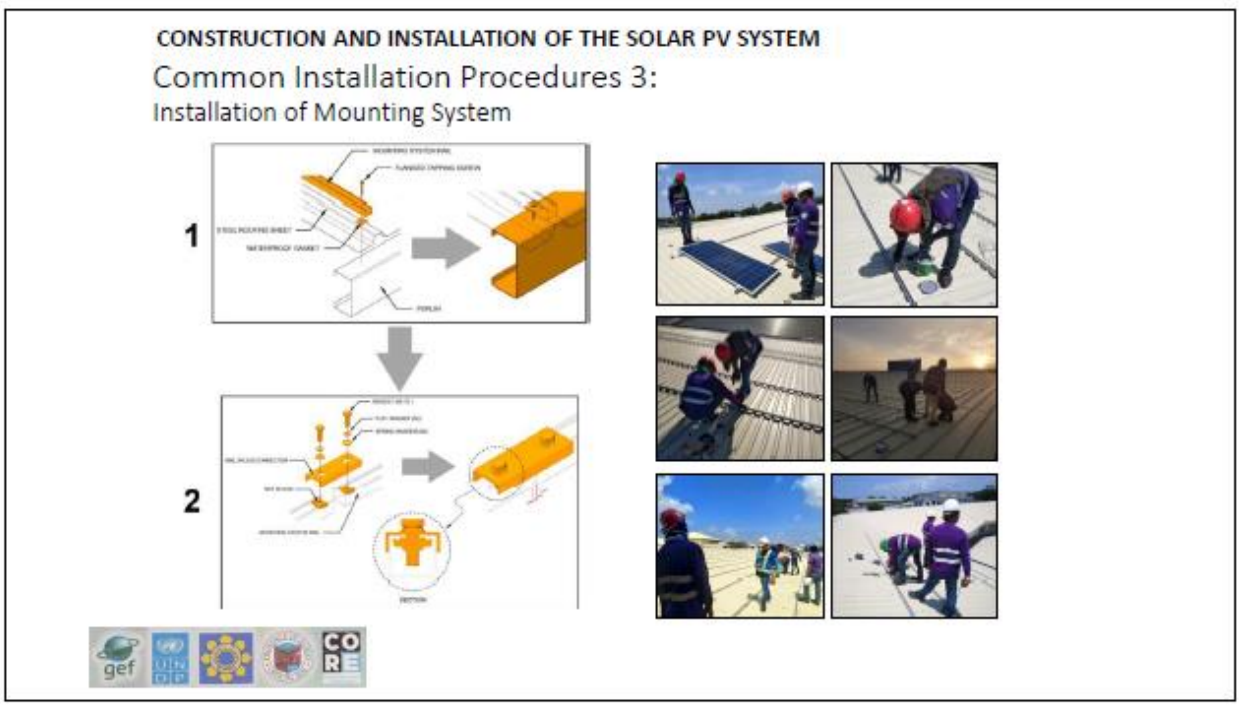
Solar PV Installation Workplan: Storage



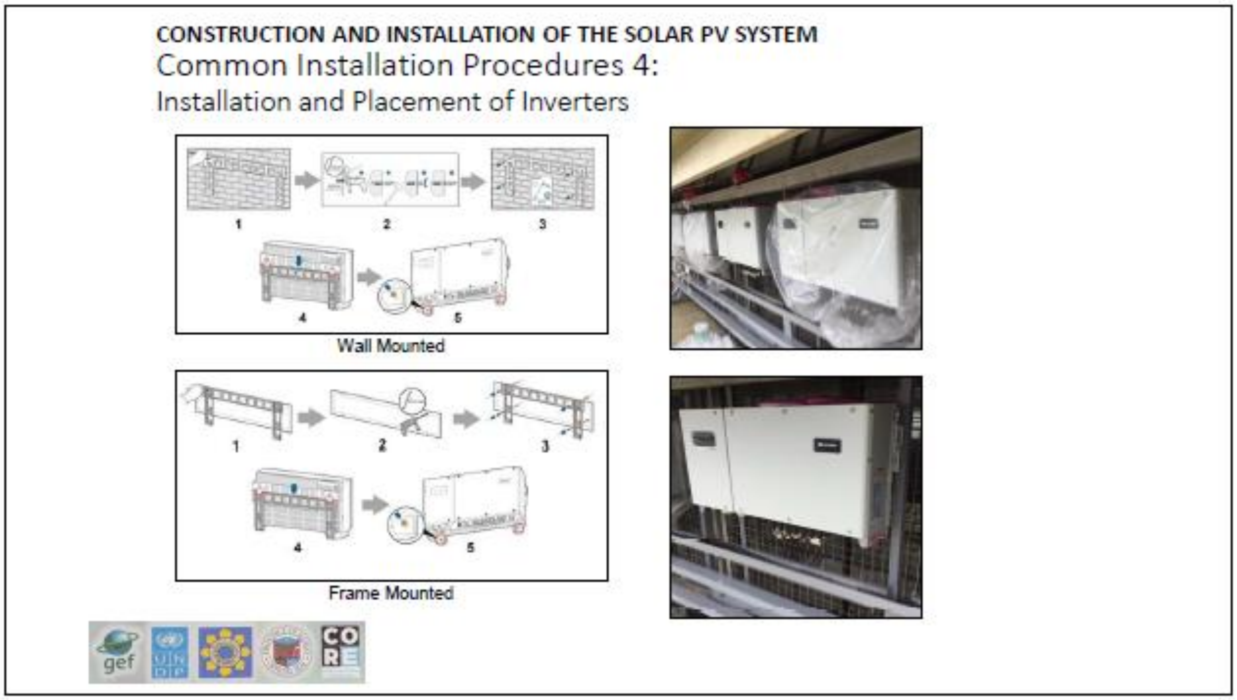
Solar Project Construction and Installation



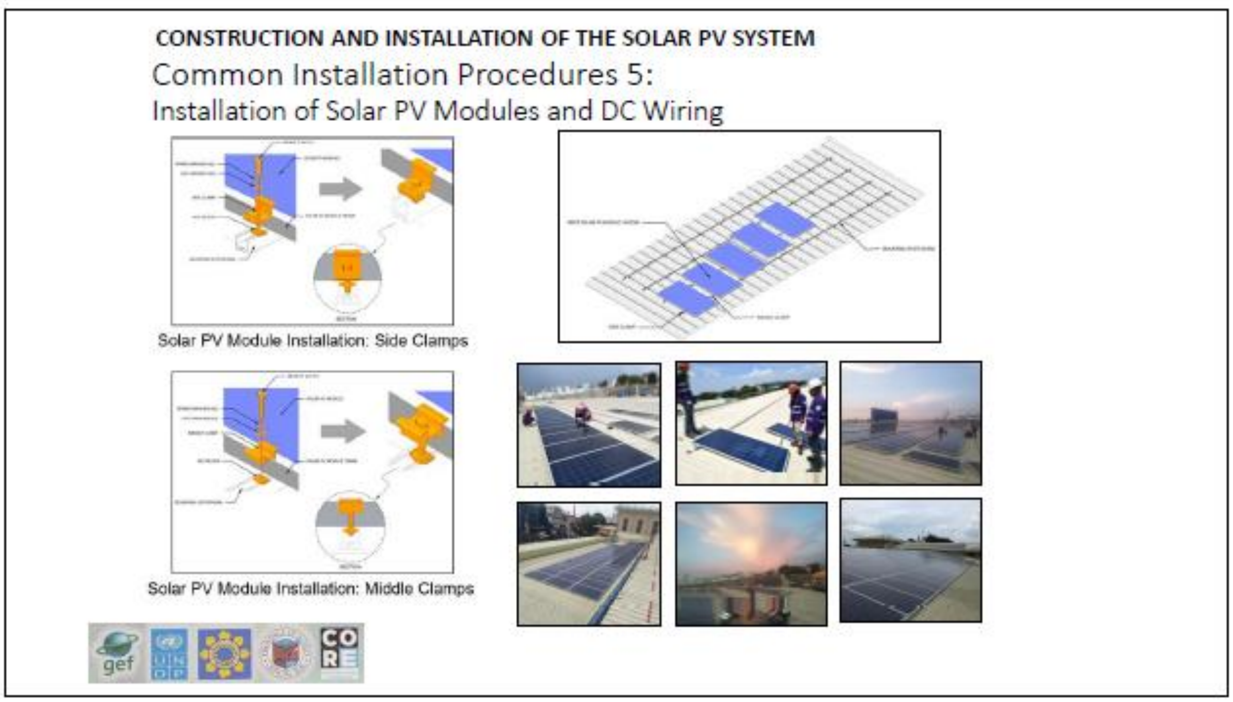
Common Solar PV module mounting procedures



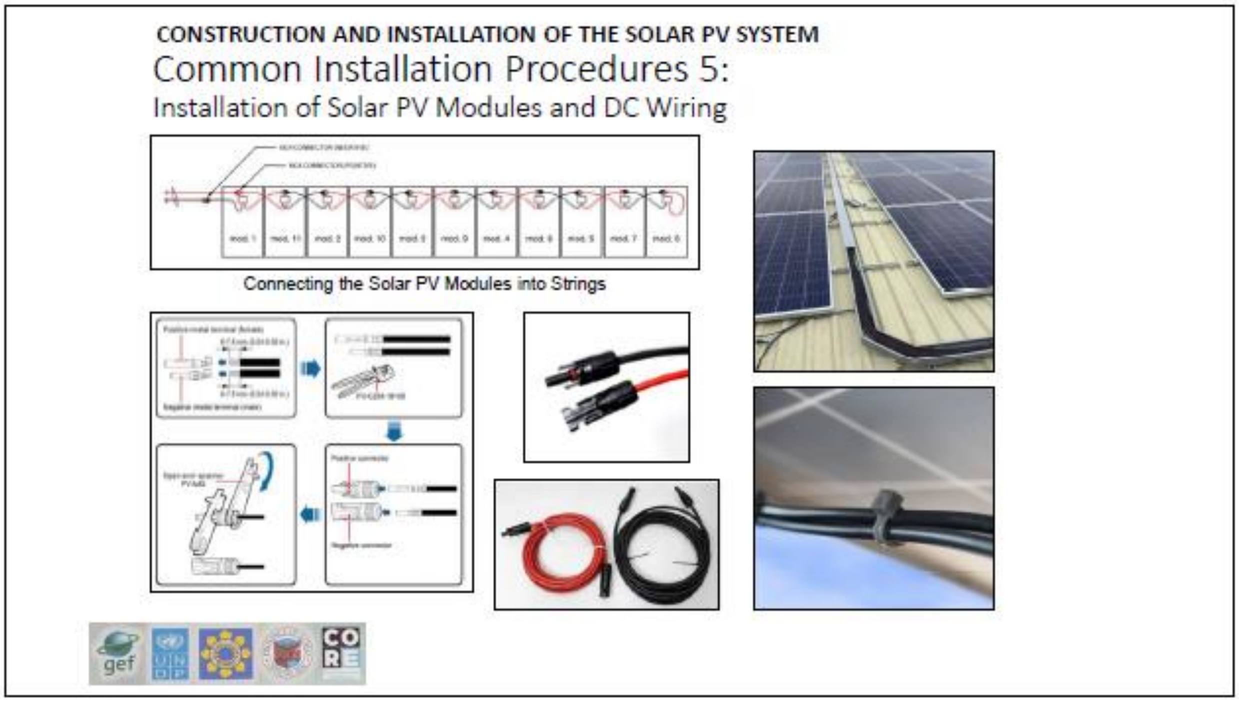
Solar PV module mounting procedures on metal roofs



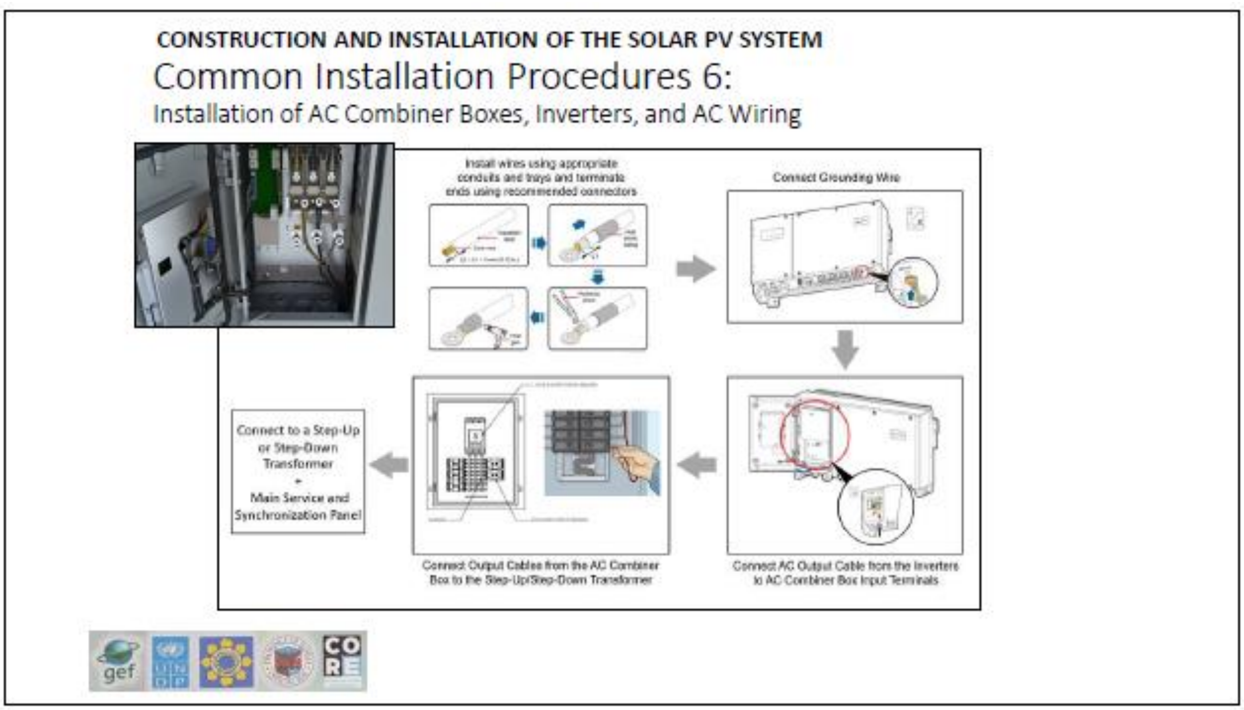
Inverter mounting procedures



Solar Array mounting procedures



Solar module string wiring procedure and cable runs

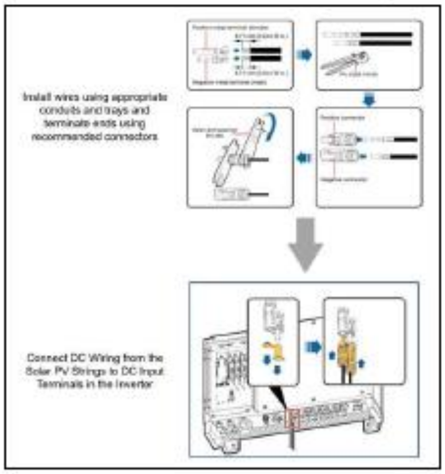


Solar inverter wiring and AC combiner boxes

CONSTRUCTION AND INSTALLATION OF THE SOLAR PV SYSTEM

Common Installation Procedures 7:

Connect the Solar PV DC Wiring to inverters



Connection of Solar PV Strings to the Inverter

Solar inverter wiring and DC combiner boxes

CONSTRUCTION AND INSTALLATION OF THE SOLAR PV SYSTEM

Common Installation Procedures 8:

utility Interconnection

- Interconnection will be completed under the supervision and with the coordination of mandated distribution utility (DU) or electric cooperative (EC) for the particular franchise area;
- Expect the DU or EC to replace, upgrade, and/or install additional electric meters for the facility in order to monitor any occurrence of energy export into the distribution system; and
- The DU or EC will obligate the testing and commissioning of the solar PV system for compliance to standards and guidelines contained in the Philippine Grid and Distribution Codes, Net-Metering Rules, and others.

Connection of PV system to the utility

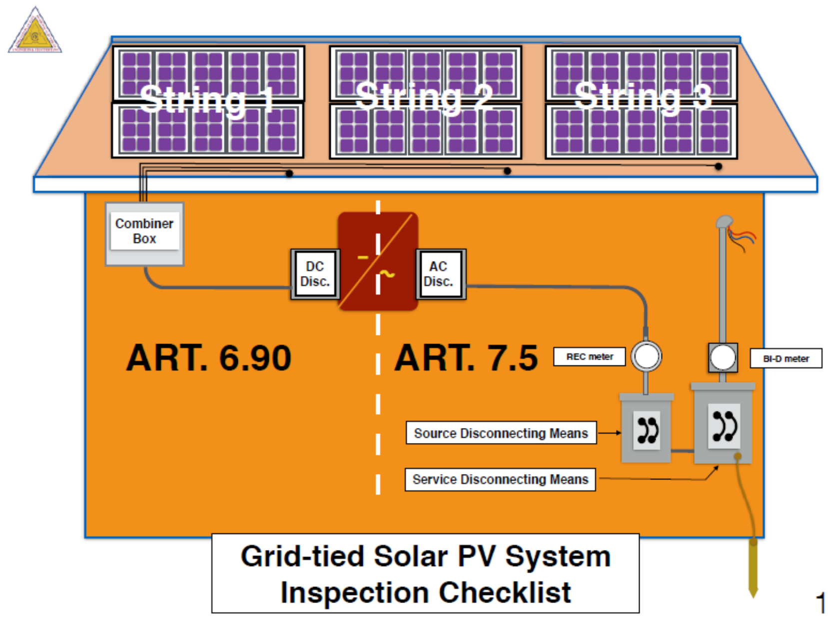
Installation Notes

- Always read and understand installation manuals for each of the solar PV system components;
- "Plan your work… Work your plan;"
- Drawings, plans, method statements, inspection checklists, manuals, and other project documentation will always be necessary for the efficient operation, maintenance, and regulatory needs of the solar PV system (must be provided by the EPC contractor during project hand-over and acceptance);
- Always check and update project timelines and plans to avoid delays;
- Check and compare delivered components and supplies with bill of materials, technical specifications, and drawings; and
- Safety (particularly working from elevation, electrical safety, and material handling) should always be a priority.

Installation Notes

3 Hands-on Training Materials

These presentation slides provide the trainees the background for the inspection of the solar PV installations to check for its safety compliance of the Philippine Electrical Code and the National Building Code of the Philippines. A check list is included as a guide for the inspector in validating the safety compliance of the solar installation on the DC side and on the AC side of the installation.



3.1 Part 1: DC CIRCUITS INSPECTION CHECKLIST based on PEC Article 6.90

By Engr. ERNESTO C. VALDEZ

Sec 5.1- Solar PV DC Circuits Inspection Checklist

DC Circuits Checklist

Item No.		Checklist Activity	Reference	Compliant ? Yes	Compliant ? No
5.1.1		Check dc PV power source info is visible	PEC 6.90.6.3		
	5.1.1a	Check dc maximum voltage is posted	PEC 6.90.2.1		
	5.1.1b	Check dc maximum current is indicated	PEC 6.90.2.2		
5.1.3		Ungrounded Conductor Checklist	PEC 6.90.2.2 (B)		
	5.1.3a	Check Conductor ampacity is 1.56 x *Isc*	PEC 6.90.2.2 (B) (1)		
	5.1.3b	Check PV label, Voltage Rating	PEC 6.90.2.1		
5.1.5		Wiring Methods Checklist	PEC 6.90.4		
	5.1.5a	Check circuits are not readily accessible to unqualified persons	PEC 6.90.4.1, 1.10.2.2 (A)		
	5.1.5b	Check PV source Cable supports are adequate	PEC 3.34.2.21		
	5.1.5c	Check cable enter raceway or metallic enclosures in approved fittings	PEC 3.0.1.16 (A)		
	5.1.5d	Check Wiring method is metallic up to first dc Disconnect	PEC 6.90.4.1(G)		
	5.1.5e	Check Wiring Method is labeled	PEC 6.90.4.1(G)(3) & (4)		
	5.1.5f	For multi strings, Check circuits are tagged in common raceways & enclosures	PEC 6.90.4.1(B)		
	5.1.5g	Check enclosures are listed and of approved type	PEC 1.10.2.3, Table 1.10.2.3		

Continued on next page

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Sec 5.1- Solar PV DC Circuits Inspection Checklist

DC Circuits Checklist

Item No.		Checklist Activity	Reference	Compliant ? Yes	Compliant ? No
5.1.7		Grounding Checklist	PEC 6.90.5		
	5.1.7a	Check size of String Equipment Grounding Conductor (EGC)	PEC 6.90.5.5, Table 2.50.6.13		
	5.1.7b	Check EGC connections are listed and Identified for the purpose	PEC1.10.1.15		
	5.1.7c	Check String EGC homeruns are routed in the same raceway or cable tray	PEC 6.90.5.3(C)		
	5.1.7d	If Inverter is Grounded, Check GEC is wired at the inverter	PEC 6.90.5.2, 6.90.5.7(A)		
	5.1.7e	Check EGC terminal bar is provided in metallic enclosures	PEC 4.8.3.11		
5.1.9		Inverter Disconnecting Means	PEC 6.90.3		
	5.1.9a	Check Inverter Disconnecting Means (IDC) is of the approve type	PEC 6.90.3.D		
	5.1.9b	Check IDC is within sight of equipment	PEC 6.90.3.1(D), 6.90.3.3 (A)		
	5.1.9c	Check Warning Label is provided at each DC Disconnecting Means	PEC 6.90.3.1(B)		
5.1.11		Overcurrent Protection	PEC 6.90.2.3		
	5.1.11a	Check OCPD rating is consistent with specified module maximum rating	PEC 6.90.2.3		
	5.1.11b	Check OCPD markings are visible and durable, listed for PV system	PEC 6.90.2.3 (B) PEC 2.40.7.4		
5.1.13		Check Inverter Enclosure Is appropriate for Its location	PEC 1.10.2.3, Table 1.10.2.3		
5.1.15		Check Rapid Shutdown Label Is provided, If equipped	PEC 6.90.6.6		

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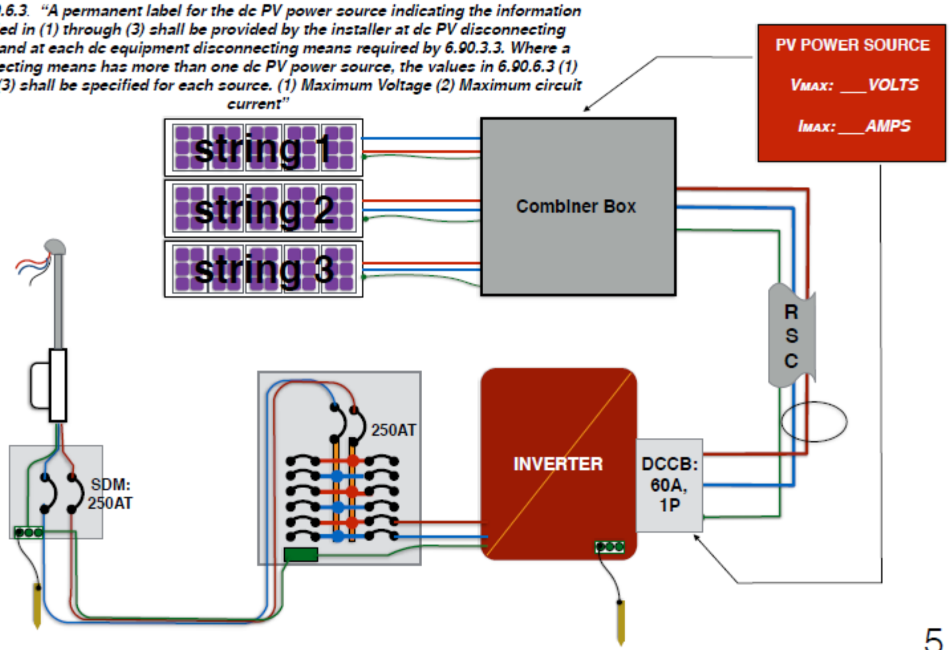
5.1.1		Check DC PV Power Source label is visible
	5.1.1a	Verify dc maximum voltage information
	5.1.1b	Verify dc maximum current information

PEC 6.90.6.3. "A permanent label for the dc PV power source indicating the information specified in (1) through (3) shall be provided by the installer at dc PV disconnecting means and at each dc equipment disconnecting means required by 6.90.3.3. Where a disconnecting means has more than one dc PV power source, the values in 6.90.6.3 (1) through (3) shall be specified for each source. (1) Maximum Voltage (2) Maximum circuit current"



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5.1.3	String Conductor Checklist
5.1.3a	Check Conductor ampacity is 1.25 x *Imax*

Table 310.15(B)(16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C to 90°C, Not more than Three Current-Carrying Conductors in Raceway, Cable, or Earth(directly Buried), Based on Ambient Temperature of 30°C (86°F)

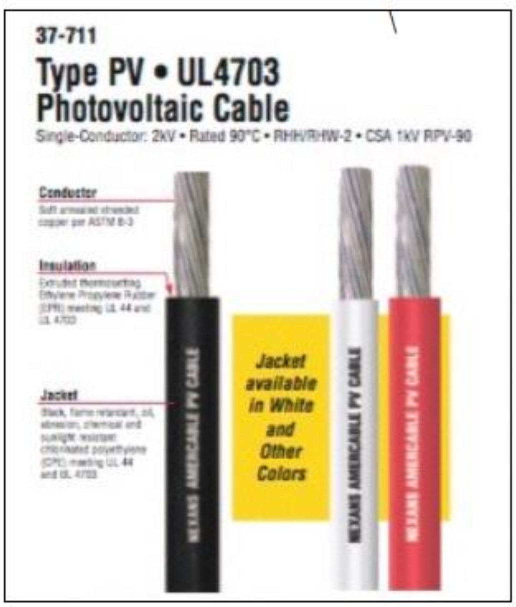
Conductor Size mm²	Temperature Rating of Conductors: 60°C	75°C	90°C
			Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
18			14
16			18
2.0			25
3.5			30
5.5			40
8			55
14			75

CABLE RATING TABLE

Cable Cross Sectional Area (mm²)	Typical Current Rating (amps)	Recommended Circuit Breaker Rating (amps)
1.5 mm²	7.9 - 15.9A	8A
2.5 mm²	15.9 - 22A	15A
4 mm²	22 - 30A	20A
6 mm²	30 - 39A	30A
10 mm²	39 - 54A	40A
16 mm²	54 - 72A	60A

PEC 6.90.2.2(B)(1). Before application of adjustment and correction factors. One hundred twenty five percent of the maximum current…

5.1.3	Ungrounded Conductor Checklist
5.1.3b	Check PV label, Voltage Rating



Applications

Nexans AmerCable's Type PV is a single-conductor cable that meets the newest standards as introduced in National Electrical Code (NEC) Article 690. Applications include connection to module junction boxes; required cable routing in balance of system (BOS) integration; and where also allowed by the NEC.

Features

- A two layer construction of flame retardant, oil and sunlight resistant Chlorinated Polyethylene (CPE) over an Ethylene-Propylene Rubber (EPR) inner layer. This design is based on a construction allowed for use on ungrounded systems as described in NEC Article 690 without the need for conduit when installed exposed.
- Provides superior protection from ozone weather and abrasion than other single layer constructions while maintaining flexibility for ease of installation
- Suitable for continuous operating temperature of 90°C wet or dry
- Direct burial 2kV
- Cold bend and impact: -40°C
- UL listed as Sunlight Resistant
- Flame Resistance: UL VW-1
- Compatible with all major connectors

5.1.5	Wiring Methods Checklist	
	5.1.5a	Check circuits are not readily accessible to unqualified persons

PEC 6.90.4.1(A)“where PV source and output circuits operating at voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be guarded or installed in Type MC cable or in a raceway”

Exhibit 5.1.3a -1

Approved method

Exhibit 5.1.3a -2

Unapproved method

PEC 1.10.2.2.(A)(4) Minimum Clearance to live Parts	
Height above floor	Voltage Between Ungrounded Conductors
2500 mm	up to 300 Volts
2600 mm	301 - 600 Volts
2620 mm	601 - 1000 Volts

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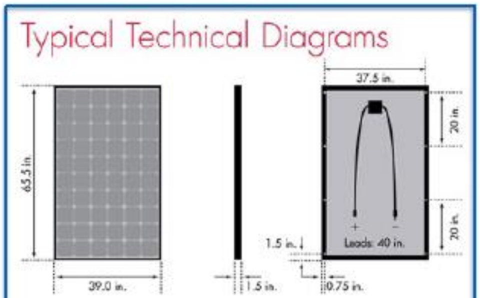
5.1.5	String Wiring Methods Checklist	
	5.1.5b	Check PV source Cable supports are adequate



MECHANICAL CHARACTERISTICS	
Dimensions (A x B x C to the right)	39.1" x 64.6" x 1.8"/994 x 1640 x 46 mm
Cable Length (G)	43.3"/1100 mm
Output Interconnect Cable	12 AWG with *SMK Locking Connector
Hail Impact Resistance	1" (25 mm) at 52 mph (23 m/s)
Weight	41.9 lbs / 19.0 kg
Max Load	50 psf (2400 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C

PEC 3.34.2.21 NonMetallic-Sheathed Cable: Type NM, NMC, and NMS. Securing and Supporting. *“Nonmetallic-Sheathead cables shall be supported and secured by staples; cable ties listed and identified for securement and support; or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1400 mm and within 300 mm of every cable entry into enclosures such as outlet boxes, junction boxes, cabinet or fittings…”*

7

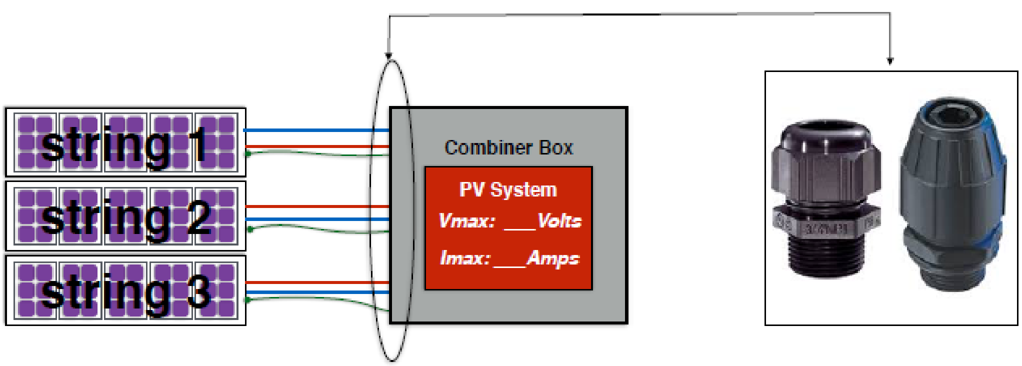
5.1.5	String Wiring Methods Checklist	
	5.1.5b	Check PV source Cable supports are adequate


Single-cable clip support

Twin-cable & multi-cable clip

8

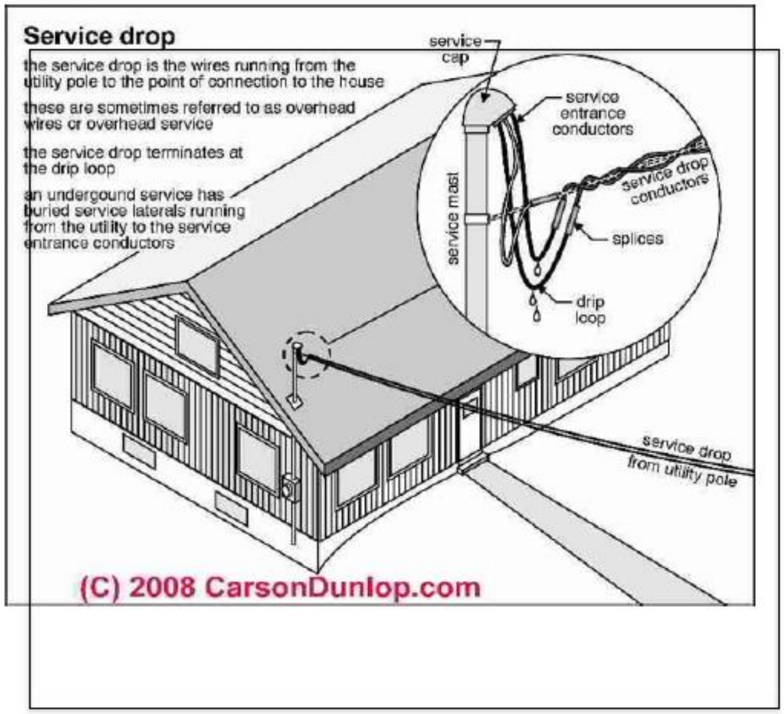
5.1.5	Wiring Methods Checklist	
	5.1.5c	Check cable enter raceway or metallic enclosures in approved fittings



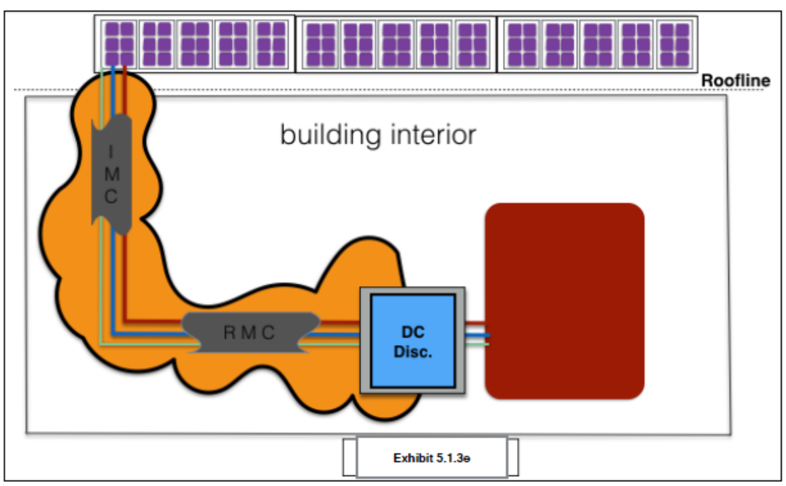
Whenever a change in the wiring method is made at any part of the installation ***PEC 3.0.1.16 (A) Box, Conduit Body, or Fitting*** provides the guidance. It states that ***"a box, conduit body, or terminal fitting having a separately bushed hole for each conductor shall be used whenever a change is made from conduit, electrical metallic tubing, electrical nonmetallic tubing, nonmetallic-sheathed cable, Type AC cable, Type MC cable, or mineral-insulated, metallic-sheathed cable and surface raceway to open wiring or to concealed knob-and-tube wiring"***.

9

5.1.5	Wiring Methods Checklist
5.1.5c	Check cable enter raceway or metallic enclosures in approved fittings



5.1.5	Wiring Methods Checklist
5.1.5d	Check Wiring Method is metallic up to first DC disconnect



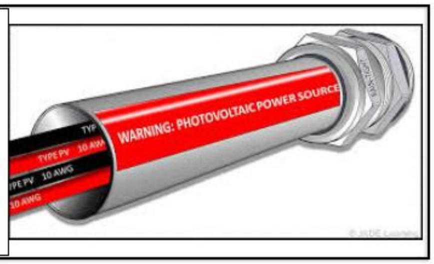
PEC 6.90.4.1 (G) "Where PV system DC circuits run inside a building, they shall be contained in metal raceways. Type MC metal-clad cable that complies with 2.50.6.9(10), or metal enclosures from the point of penetration of the surface of the building to the first readily accessible disconnecting means".

10

5.1.5	Wiring Methods Checklist
5.1.5e	Check Wiring Method is labeled with approved markings

Label Standard
PEC 6.90.4.1 (G)(4)

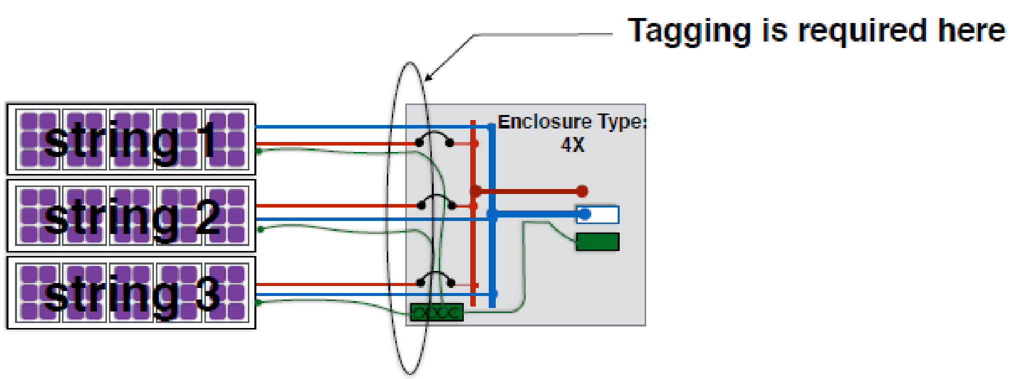
*Red background
*White lettering
*Minimum 9.5 mm" letter height
*All CAPITAL letters
*Reflective, weather resistant material



PEC 6.90.4.1(G)(3). Marking and Labeling Required. ...Wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the following wording: WARNING; PHOTOVOLTAIC POWER SOURCE by means of permanently affixed labels or other approved permanent marking...

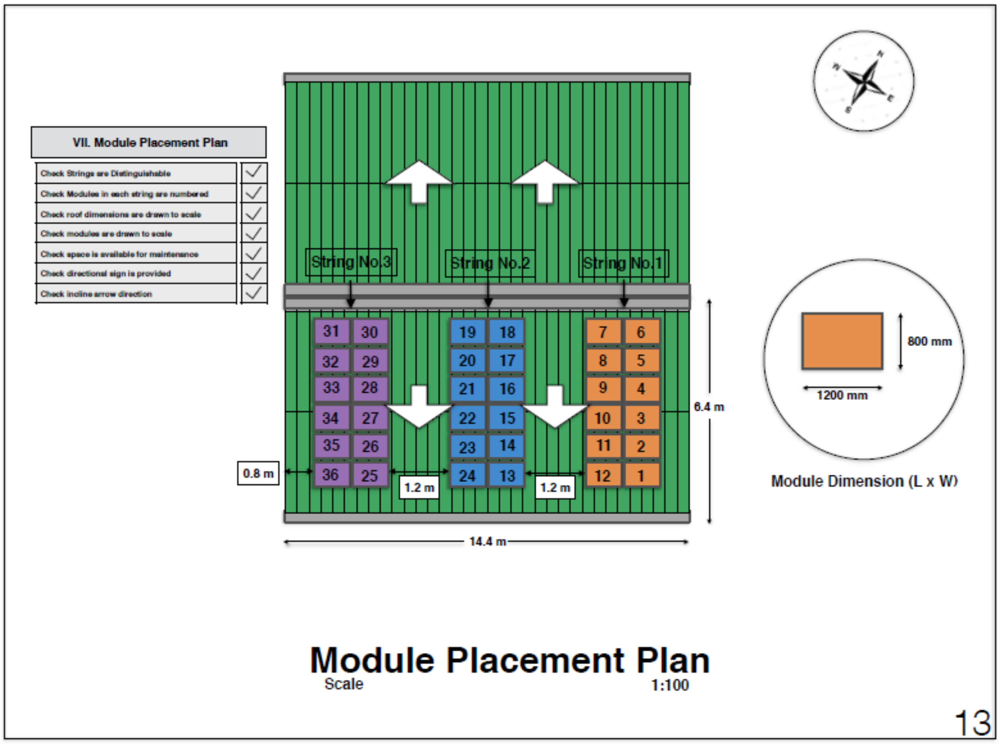
11

5.1.5	Wiring Methods Checklist
5.1.5f	For multi strings, Check circuits are tagged in common raceways & enclosures



PEC 6.90.4.1 (B) (1) Identification. PV system circuit conductors shall be identified at all accessible points of termination, connection, and splices.

12



5.1.5	Wiring Methods Checklist	
	5.1.5g	Check enclosures are listed and of approved type

"All equipment and materials to be used shall be of the approved type for location and purpose intended."

PEC 1.10.2.3 ...enclosure shall be marked with an enclosure type number...

14

5.1.5	Wiring Methods Checklist
5.1.5g	Check enclosures are listed and of approved type

First digit - protection from foreign body and particulate ingress	
0	Not rated (or no rating supplied) for protection against any ingress
1	Protection against solid objects larger than 50 mm (accidental hand contact with open palm), but not agains deliberate body contact
2	Protection against solid objects larger than 12 mm (accidental finger contact)
3	Protection against solids larger than 2.5 mm (tools and wires)
4	Protection against solids larger than 1 mm (fine tools and wires, nails, screws, larger insects and other potentially invasive small objects)
5	Partial protection against dust and other particulates, such that any ingress will not damage or impede the satisfactory performance of internal parts
6	Full protection against dusts and other particulates, including a vacuum seal, tested against continuous airflow

Second digit - protection from moisture ingress	
0	Not rated (or no rating supplied) for protection against ingress of this type.
1	Protection against vertically falling droplets, such as condensation, sufficient that no damage or interrupted functioning of components will be incurred when an item is upright
2	Protection against water droplets deflected up to 15° from vertical
3	Protected against spray up to 60° from vertical.
4	Protected against water splashes from all directions. Tested for a minimum of 10 minutes with an oscillating spray (limited ingress permitted with no harmful effects)
5	Protection against low-pressure jets (6.3 mm) of directed water from any angle (limited ingress permitted with no harmful effects).
6	Protection against direct high pressure jets.
7	Protection against full immersion for up to 30 minutes at depths between 15 cm and 1 metre (limited ingress permitted with no harmful effects)
8	Protection against extended immersion under higher pressure (i.e. greater depths). Precise parameters of this test will be set and advertised by the manufacturer and may include additional factors such as temperature fluctuations and flow rates, depending on equipment type.
9	Protection against high-pressure, high-temperature jet sprays, wash-downs or steam-cleaning procedures

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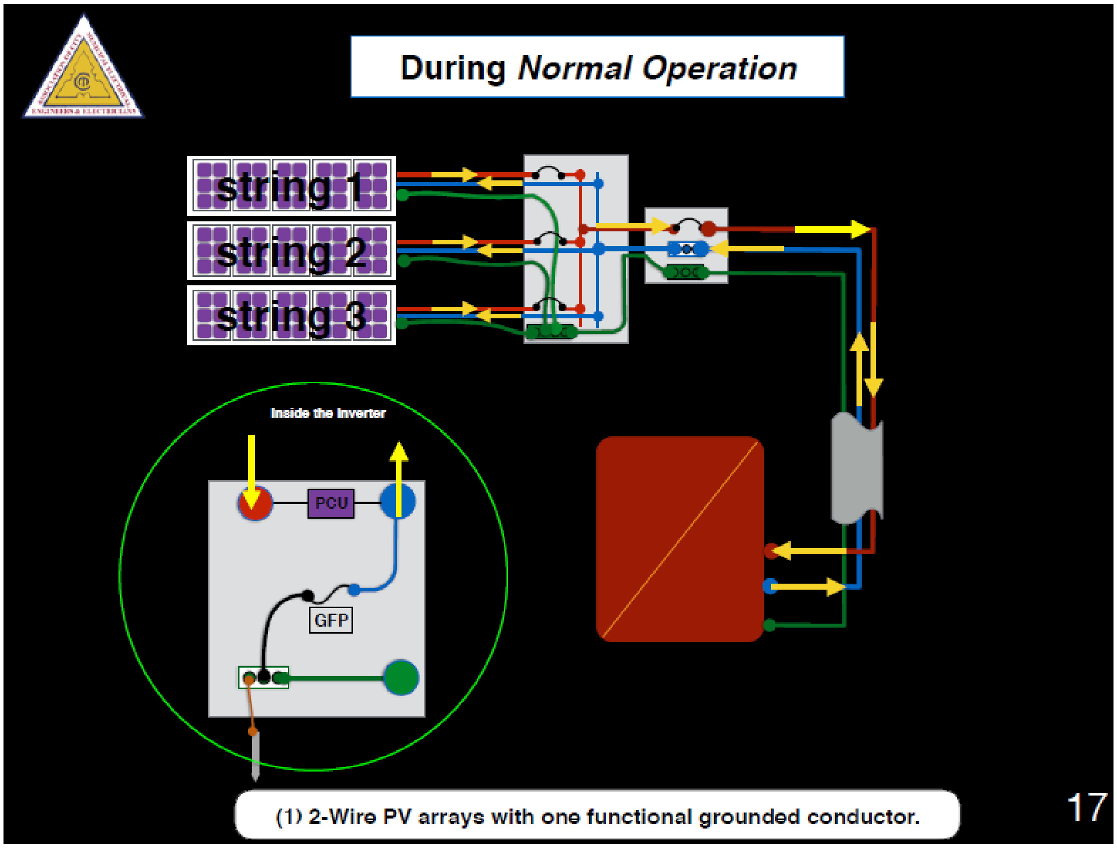
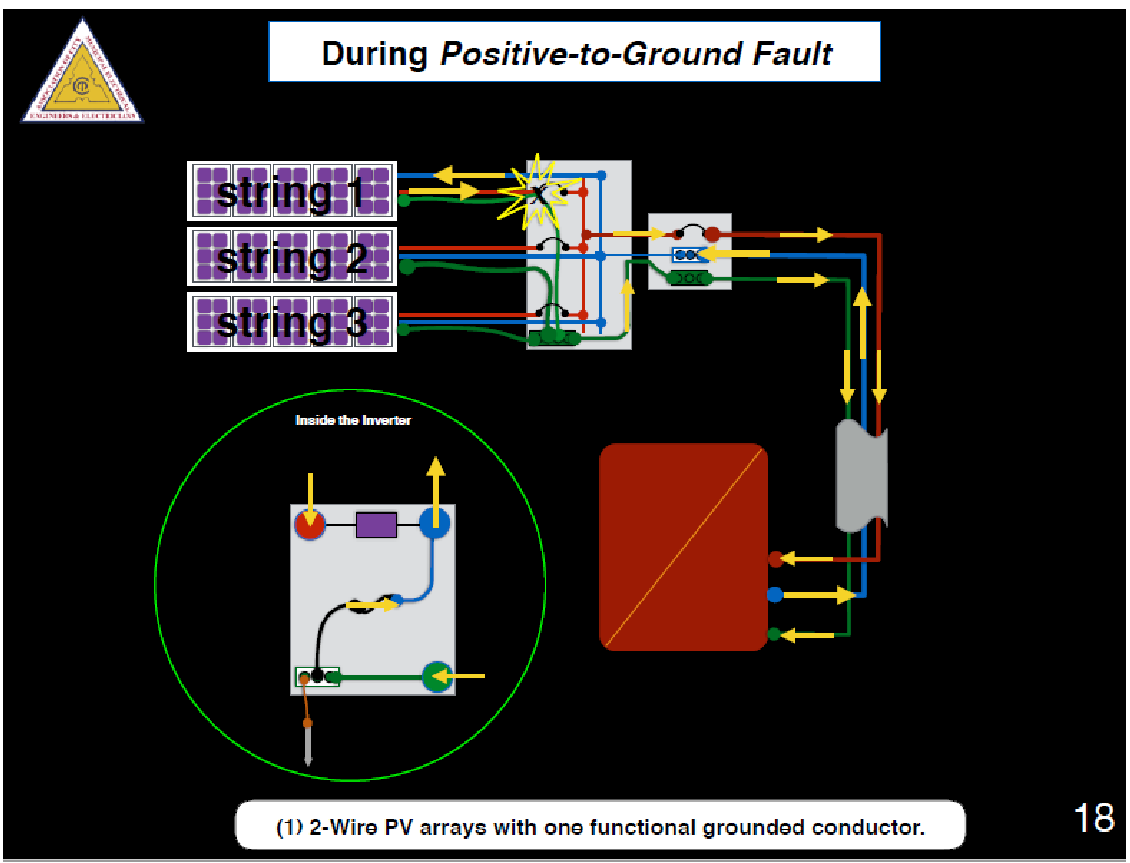
5.1.7	Grounding Checklist
5.1.7a	Check size of String Equipment Grounding Conductor (EGC)

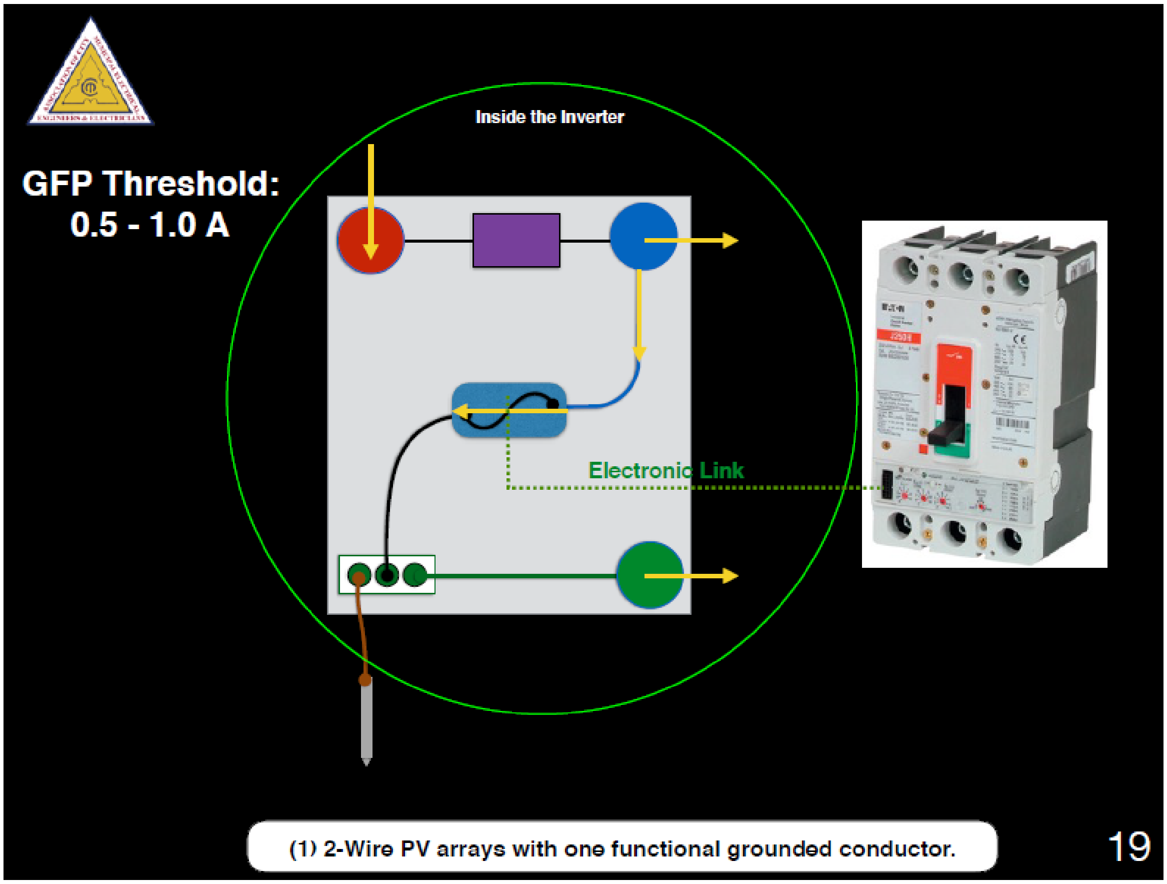
TABLE 2.50.6.13 MinimumSize of Equipment Grounding Conductors for Raceway and Equipment		
Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc. Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum
15	2.0(1.6)	3.5(2.0)
20	3.5(2.0)	5.5(2.6)
30	5.5(2.6)	8.0(3.2)
40	5.5(2.6)	8.0(3.2)
60	5.5(2.6)	8.0(3.2)
100	8.0(3.2)	14

PEC 6.90.5.5 "Equipment grounding conductors for PV source and PV output circuits shall be sized in accordance with 2.50.6.13. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated in accordance with 6.90.2.3(B) shall be used when applying Table 2.50.6.13.

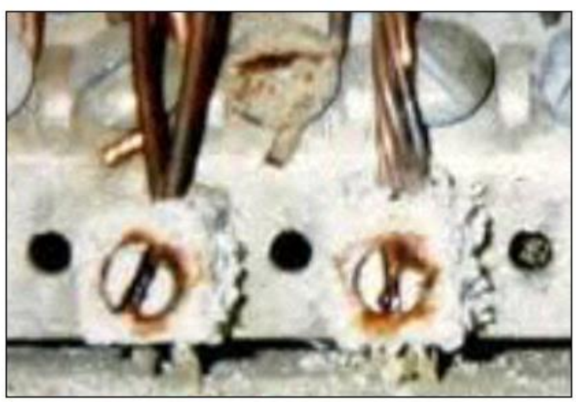
16


During Normal Operation
string 1
string 2
string 3
Inside the Inverter
PCU
GFP
(1) 2-Wire PV arrays with one functional grounded conductor.
17


During Positive-to-Ground Fault
string 1
string 2
string 3
Inside the Inverter
(1) 2-Wire PV arrays with one functional grounded conductor.
18



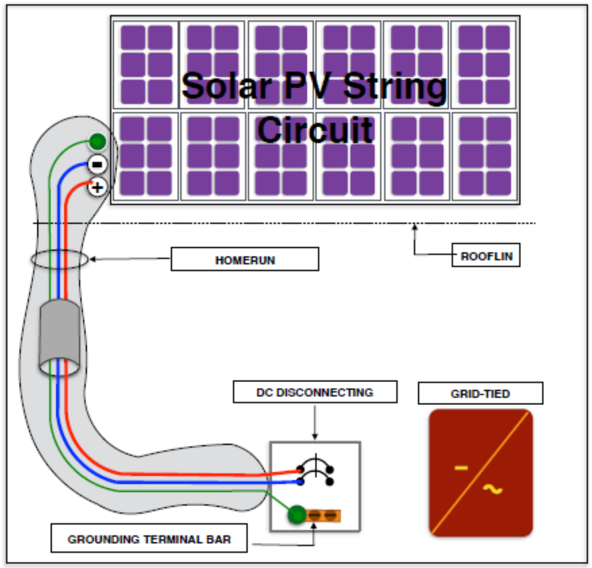
5.1.7		Grounding Checklist
	5.1.7b	Check EGC connections are listed and identified for the purpose



PEC 1.10.1.15 Electrical Connections. Because of different characteristics of dissimilar metals, devices such as pressure terminals or pressure splicing connectors and soldering lugs shall be identified for the material of the conductor and shall properly installed and used. Conductors of dissimilar metals shall not be intermixed in a terminal or splicing connector where physical contact occurs between dissimilar conductors (such as copper and aluminum, copper and copper-clad aluminum, or aluminum and copper-clad aluminum), unless the device is identified for the purpose and conditions of use"…

20

5.1.7	Grounding Checklist
5.1.7c	Check String EGC homeruns are routed in the same raceway or cable tray



PEC 6.90.5.3 (C) With Circuit Conductors. "Equipment grounding conductors for the PV array and the support structure (where installed) shall be contained within the same raceway, cable or otherwise run with the PV array circuit conductors when those circuit conductors leave the vicinity of the PV array"

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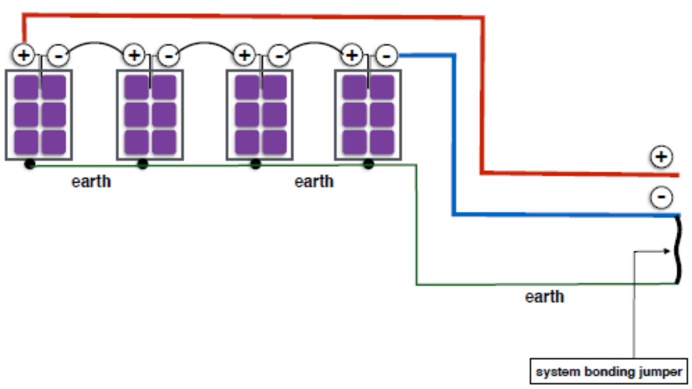
5.1.7	Grounding Checklist
5.1.7d	If Inverter is Grounded, Check GE & GEC is terminates at Inverter

The Grounded System



Grounded System - An electrical system that is characterized by a connection of one of the systems' current-carrying conductors to 'earth' by means means of a **system bonding jumper**, thus gaining an earth potential or zero potential difference with respect to earth.

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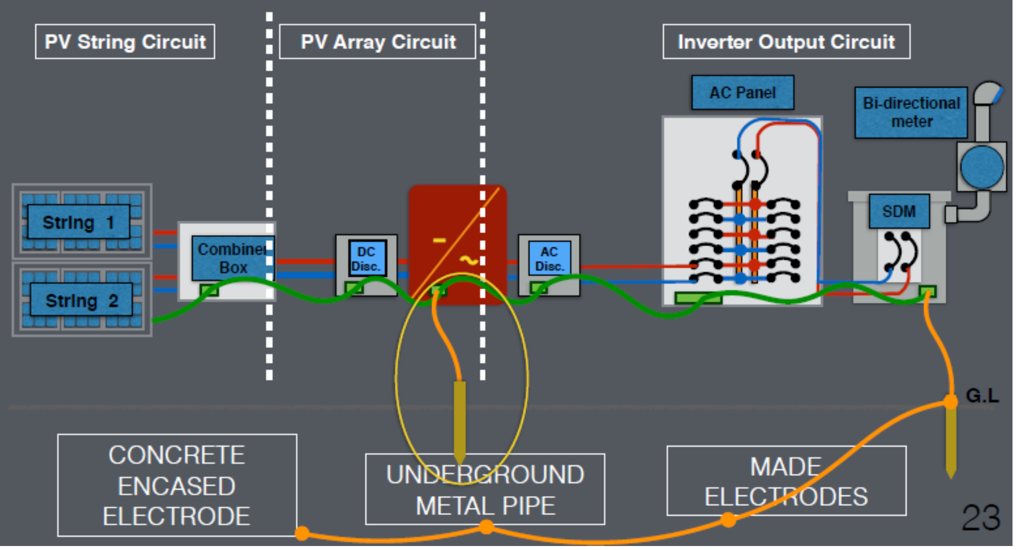
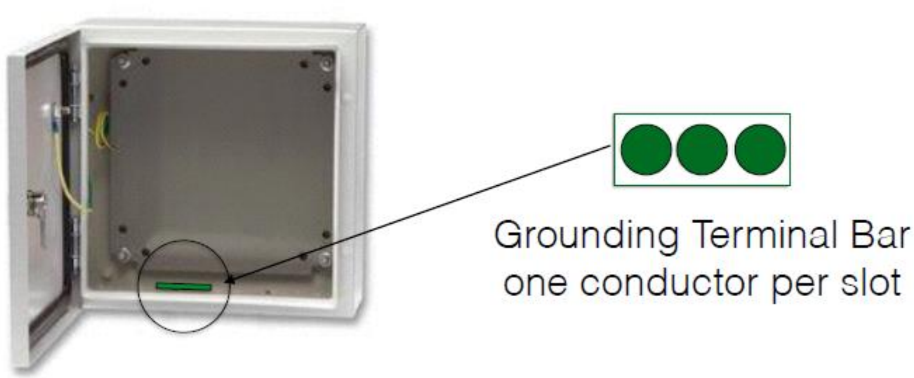
5.1.7	Grounding Checklist	
	5.1.7d	If Inverter is Grounded, Check GE & GEC is terminates at Inverter

PEC 6.90.5.7. For solidly grounded PV systems, the grounded conductor shall be connected to a grounding electrode system by means of a grounding electrode sized in accordance with 2.50.8.7



23

5.1.7	Grounding Checklist	
	5.1.7f	Check EGC terminal bar is provided in metallic enclosures



PEC 4.8.3.11 Grounding of Panelboards. Panel board cabinets and panel board frames, if of metal, shall be in physical contact with each other and shall be connected to an equipment grounding conductor...where separate EGC are provided, a terminal bar shall be secured inside cabinet.

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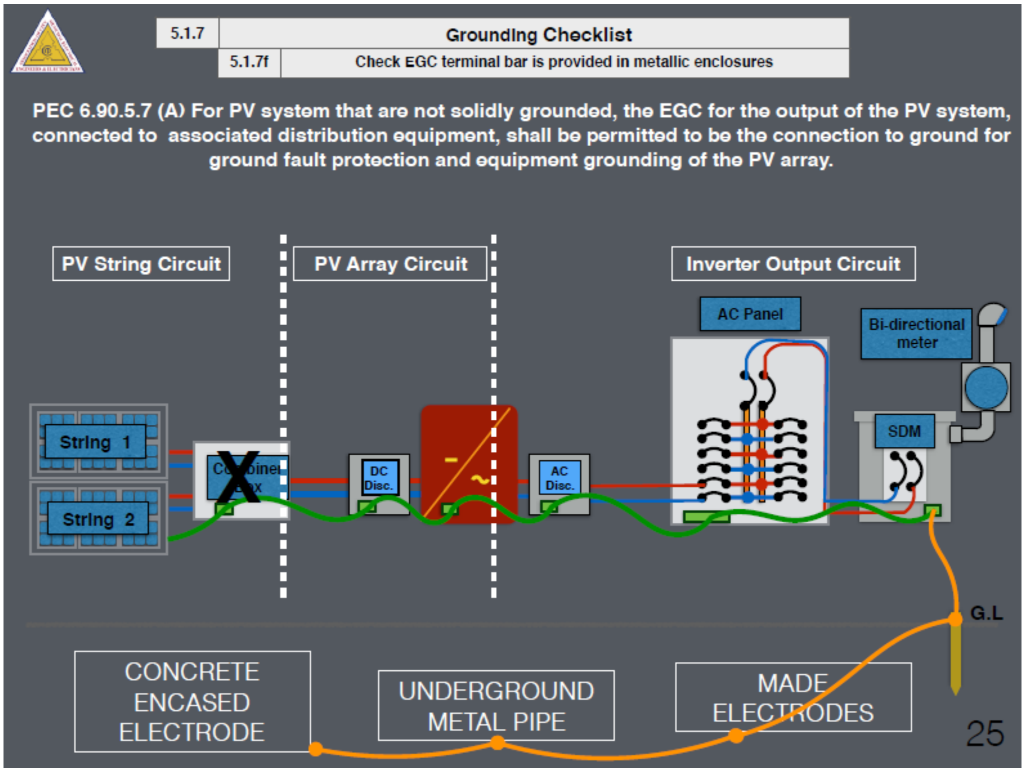

5.1.9	Inverter Disconnecting Means (IDC) checklist
5.1.9a	Check Inverter Disconnecting Means (IDC) is of the approve type
	Simultaneously disconnect all ungrounded conductors

No common trip bar

with common trip bar

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5.1.9		**Inverter Disconnecting Means (IDC)**
	5.1.9a	Check Inverter Disconnecting Means (IDC) is of the approve type
		Simultaneously disconnect all ungrounded conductors
		Externally operable without exposing operator to live parts

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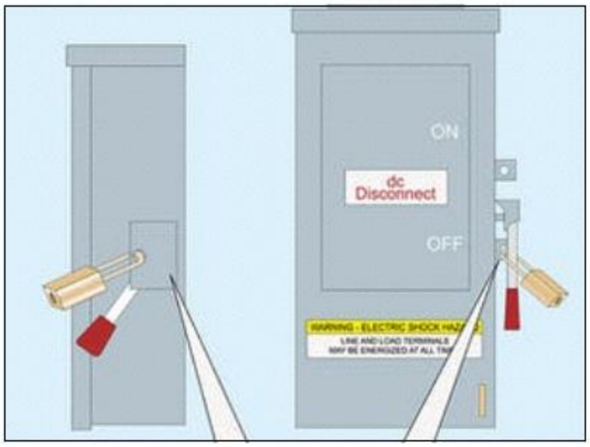
5.1.9		**Inverter Disconnecting Means (IDC)**
	5.1.9a	Check Inverter Disconnecting Means (IDC) is of the approve type
		Simultaneously disconnect all ungrounded conductors
		Externally operable without exposing operator to live parts
		Shall indicate whether in the off or on position

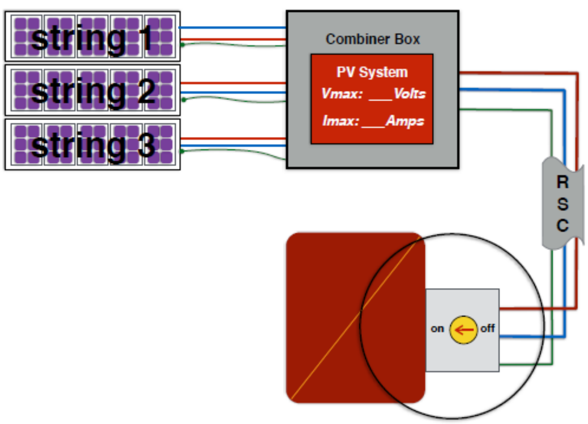
28

5.1.9	Inverter Disconnecting Means (IDC)
5.1.9a	Check Inverter Disconnecting Means (IDC) is of the approve type
	Simultaneously disconnect all ungrounded conductors
	Externally operable without exposing operator to live parts
	Shall indicate whether in the off or on position
	Lockable in the off position



29

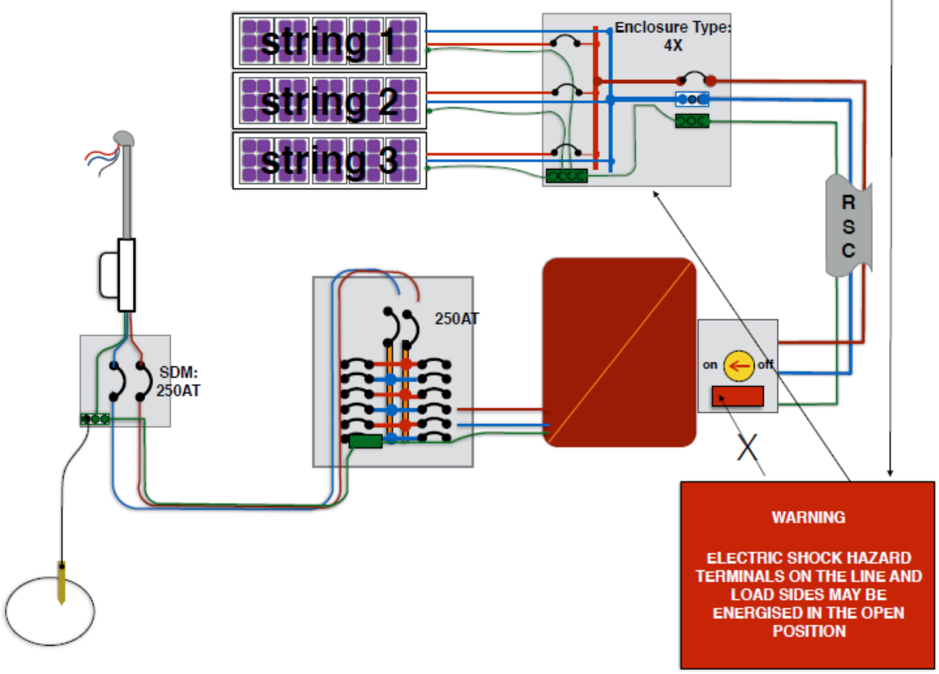
5.1.9	Inverter Disconnecting Means (IDC)
5.1.9b	Check IDC is within sight of equipment



PEC 6.90.3.3 (A). Location. Isolating devices or equipment disconnecting means shall be installed in circuits connected to equipment at a location <u>within the equipment, or within sight and within 3000mm of the equipment.</u>

30

5.1.9	Inverter Disconnecting Means (IDC)
5.1.9c	if required ,Check Inverter Disconnecting Means (IDC) Warning Label



31

5.1.11	Overcurrent Protection
5.1.11a	Check OCPD rating is consistent with specified module OCPD rating

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5.1.11	Overcurrent Protection	
	5.1.11b	Check OCPD markings are visible and durable, listed for PV system

PEC 2.40.7.4 (A). Durable and Visible Markings. Circuit breakers shall be marked with their ampere rating in a manner that will be durable and visible after installation.

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At the instant a line-to-line fault has occurred in String2 between its Red (+) and Blue (-) conductors, shown in **Exhibit 3.3.2** as point **X,** we can see back-feeding currents from the unfaulted strings. Assuming a low-impedance at the fault point that approximates a bolted-fault, the magnitude of $I_{string1}$, $I_{string2}$, and $I_{string3}$ will be approximating their rated short-circuit currents, I_{sc}. $I_{string1}$ which, initially, is the generated current at normal condition for string1 becomes I_{sc1}. $I_{string2}$ which, initially, is the generated current for string2 at normal condition becomes I_{sc2}. $I_{string3}$ which, initially, is the generated current at normal condition for string3 becomes I_{sc3}.

At this instant, I_{sc1} and I_{sc3} will be changing its direction and back-feeds the faulted String2 circuit, traversing the positive busbar of the combiner and the Red (+) conductor of String2, seen in the figure as the yellow arrow. The two back-feeding current, I_{sc1} *and* I_{sc3} also passes thru ***OCPD1.*** Since the capacity of the back-feeding currents equals $I_{sc1} + I_{sc3}$ or twice that of I_{sc2} that should be above the trip setting of ***OCPD2***, it must initiate the opening of the ***OCPD2***.

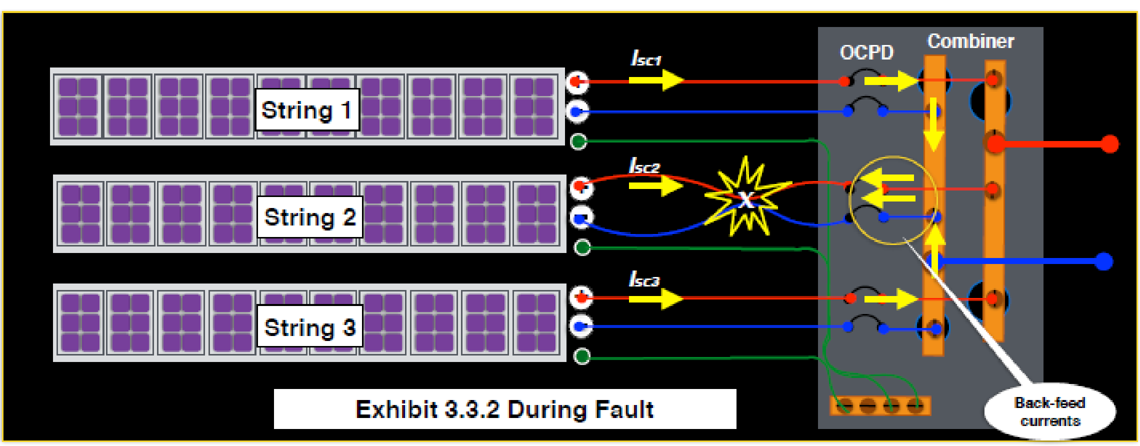

Exhibit 3.3.2 During Fault

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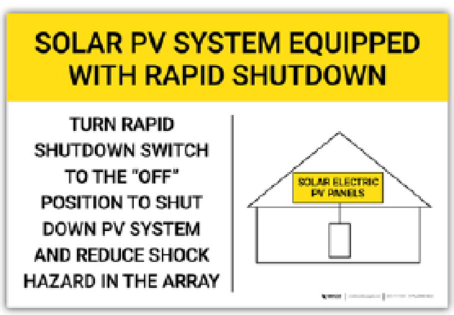
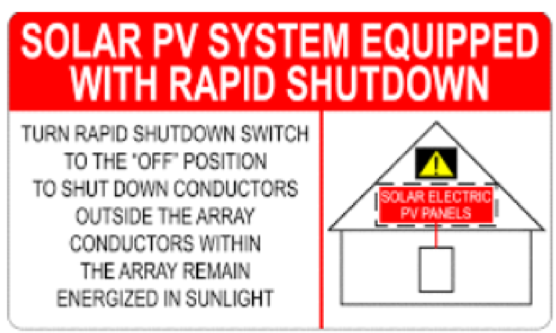
5.1.13	Check Inverter Enclosure Is appropriate for Its location

	SB 5000US
Recommended Maximum PV Power (Module STC)	6250 W
DC Maximum Voltage	600 V
Peak Power Tracking Voltage	250 - 480 V
DC Maximum Input Current	21 A
Number of Fused String Inputs	3 (inverter), 4 x 20 A (DC disconnect)
PV Start Voltage	300 V
AC Nominal Power	5000 W
AC Maximum Output Power	5000 W
AC Maximum Output Current (@ 208, 240, 277 V)	24 A, 21 A, 18 A
AC Nominal Voltage Range	183 - 229 V @ 208 V 211 - 264 V @ 240 V 244 - 305 V @ 277 V
AC Frequency: nominal / range	60 Hz / 59.3 - 60.5 Hz
Power Factor (Nominal)	0.99
Peak Inverter Efficiency	96.8%
CEC Weighted Efficiency	95.5% @ 208 V 95.5% @ 240 V 95.5% @ 277 V
Dimensions: W x H x D in inches	18.4 x 24.1 x 9.5
Weight / Shipping Weight	141 lbs / 148 lbs
Ambient Temperature Range	-13 to 113 °F
Power consumption at night	0.1 W
Topology	Low frequency transformer, true sinewave
Cooling Concept	OptiCool™, forced active cooling
Mounting Location: indoor / outdoor (NEMA 3R)	●/●

5.1.15	Check Rapid Shutdown Label Is provided, If equipped



Label for PV systems that shutdown the Array and the Conductors Leaving the Array



Label for PV systems that shutdown the Conductors Leaving the Array

PEC 6,90.6.6 (C)(1)…The Rapid shutdown label shall be located on or no more than 1000 mm from the Service Disconnecting Means to which the PV systems are located…

3.2 Part 2: PV AC CIRCUIT INSPECTION CHECKLIST for INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES

By Engr. ERNESTO C. VALDEZ

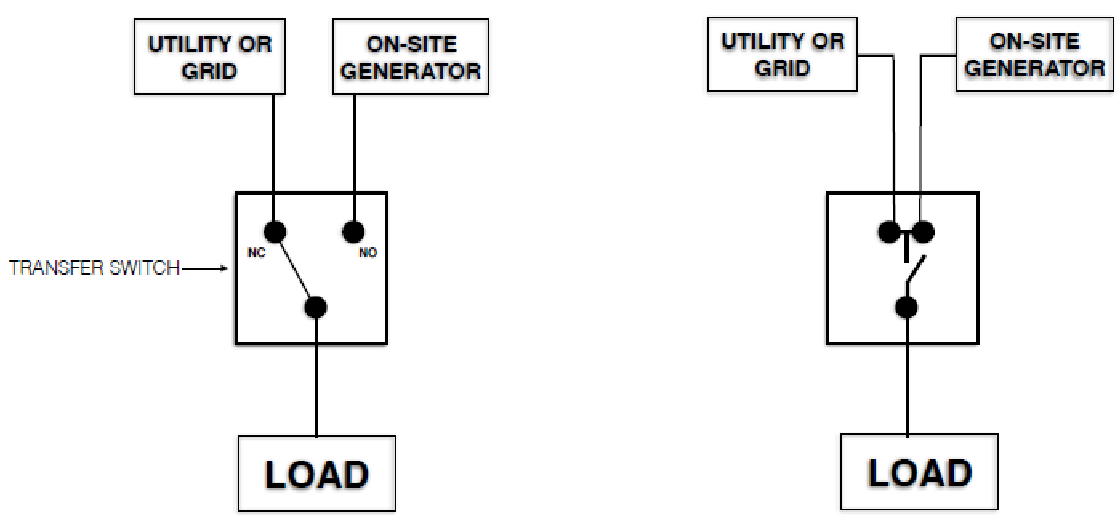
Definition

- ONE OR MORE **POWER PRODUCTION SOURCES** THAT OPERATES IN PARALLEL WITH A **PRIMARY SOURCE OF ELECTRICITY.**

PRIMARY SOURCE OF ELECTRICITY - **UTILITY**

POWER PRODUCTION SOURCE - **SOLAR PV SYSTEM**

BACK- UP POWER SOURCE V. INTERCONNECTED POWER SOURCE



Sec 5.3 - Solar PV
PV AC Circuit Inspection Checklist

Inverter Output Circuit Cheklist

Item No.		Checklist Activity	Reference	Compliant ? Yes	No
5.3.1		**Check AC output conductor ampacity is ≥ than 125%*Io***	7.5.2.1 (A)(2)		
5.3.3		**Check a disconnecting means is within sight of Inverter**	7.5.1.21		
5.3.5		**If Inverter disconnect is required, check the following**	7.5.1.21		
	5.3.5a	Check cable enters the enclosure in approved fittings	3.0.1.4		
	5.3.5b	Check Disconnecting means is of the approved type	7.1.22		
	5.3.5c	Check Warning Sign label	6.90.3.1 (B)		
5.3.7		**At REC metering location, check the following**	ERC Reso No. 6 S2019		
	5.3.7a	Check REC meter is adjacent to Bi-D meter	REC Meter Standard		
	5.3.7b	Check REC meter wiring method is exposed RIGID metallic	REC Meter Standard		
	5.3.7c	Check PV output Disconnect is approved type	7.5.1.22		
	5.3.7d	Check PV output Disconnect enclosure is appropriate for intended location	Table 1.10.2.3		
	5.3.7e	Check PV output Disconnect OCPD trip rating, kAIC is indicated	1.10.1.22		
	5.3.7f	Check PV output Disconnect Warning Sign	6.90.3.1 (B)		
	5.3.7g	Check EGC terminates at Service equipment ground terminal bar	2.50		
	5.3.7h	Check PV AC output is wired to loadside of OCPD	7.5.1.12 (B)		

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Sec 5.3 - Solar PV
PV AC Circuits Inspection Checklist

Inverter Output Circuit Cheklist

Item No.		Checklist Activity	Reference	Compliant ? Yes	No
5.3.9		**At Point of Interconnection (P of I), check the following**			
	5.3.9a	Check terminal lug at SDM is appropriate	1.10.1.15(A)		
	5.3.9b	Check SDM enclosure is approved type, in NEMA 3R	1.10.1.25, Table 1.10.2.3		
	5.3.9c	Check Equipment Grounding terminations	2.50.6		
	5.3.9d	Check grounding Electrode integrity	PEC 6.90.5.7(A), 2.50.3		
5.3.11		If P of I is at Loadside, Check Feeder ampacity is ≥ SDM OCPD + 125% Output Current	7.5.1.12 (B)		
5.3.13		If P of I is at Lineside, Check PV output OCPD is ≤ OCPD Rating of the Service	7.5.1.12 (A)		
		End of Checklist			

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5.3.1	Check AC output conductor ampacity is ≥ 125% *Io*

5.3.1	Check AC output conductor ampacity is ≥ 125% *Io*

PEC 7.5.2.1 (A)(2) Inverter Output Circuit Current. The maximum current shall be the inverter continuous output current rating

$$\text{Conductor Ampacity} = 1.25\%\ I_o$$
$$= 1.25 \times 29\ \text{A}$$
$$= 36.25\ \text{A}$$

Table 310.15(B)(16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C to 90°C, Not more than Three Current-Carrying Conductors in Raceway, Cable, or Earth(directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size AWG or kcmil	Temperature Rating of Conductors		
	60°C	75°C	90°C
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
	COPPER		
2.0	15	20	25
3.5	20	25	30
5.5	30	35	40
8	40	50	55
6	55	65	75

Use: 2 # 5.5 mm² type THWN 75°C

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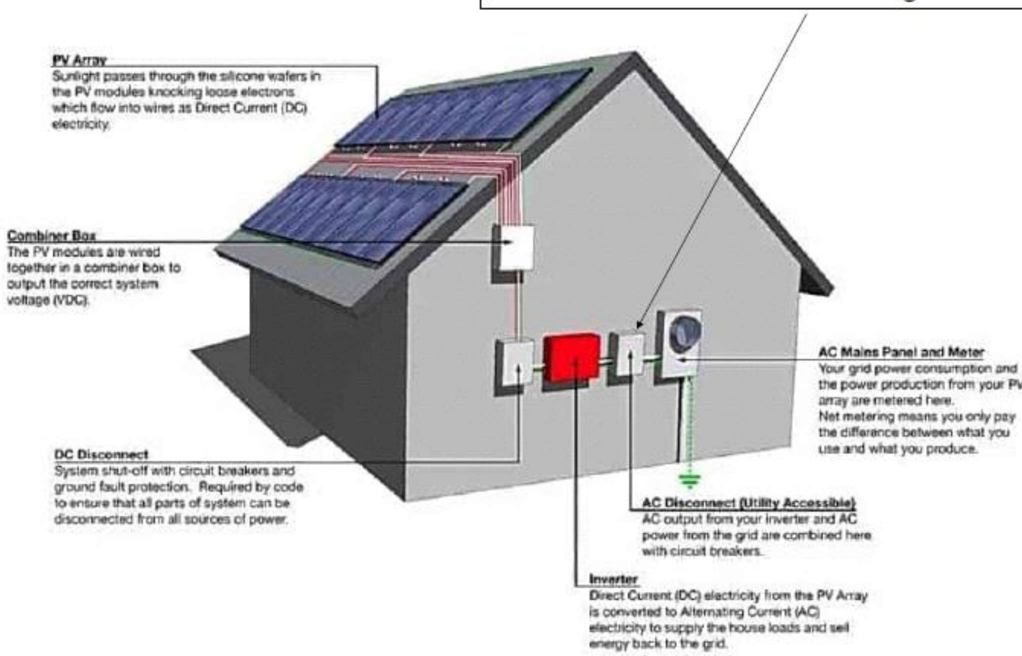
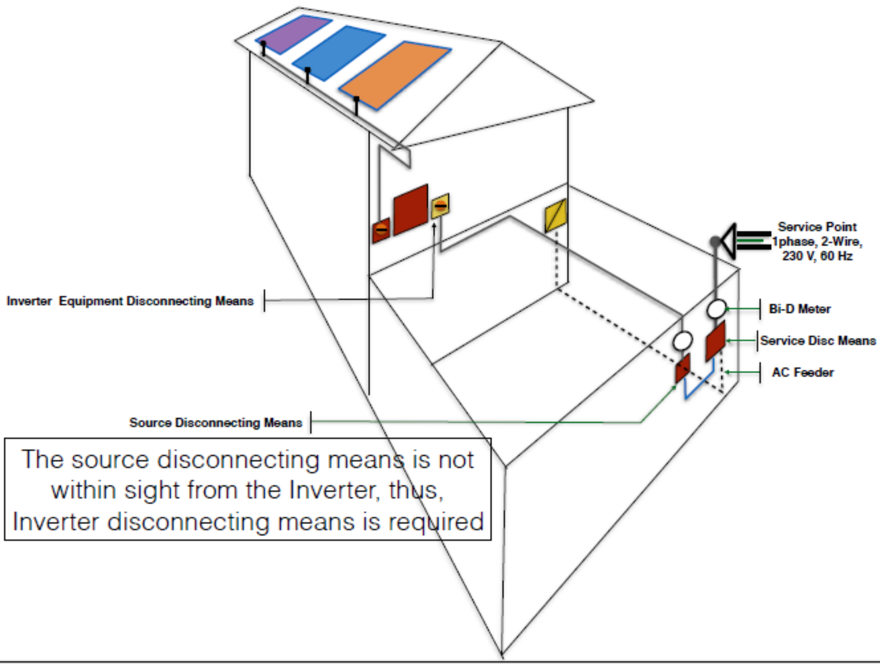
5.3.3	**Check a disconnecting means is within sight of Inverter**

The source disconnecting means is within sight from the Inverter, thus, can also function as Inverter disconnecting means



31

5.3.3	Check a disconnecting means is within sight of Inverter



The source disconnecting means is not within sight from the Inverter, thus, Inverter disconnecting means is required

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5.3.5	If Inverter disconnect is required, check the following	
	5.3.5a	Check cable enters the enclosure in approved fittings

GENERAL RULE

PEC 3.0.1.4 Protection Against Physical Damage. Where subject to Physical damage, conductors, raceways, and cables shall be protected.

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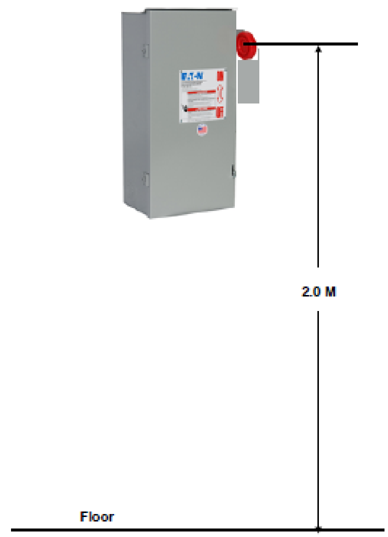
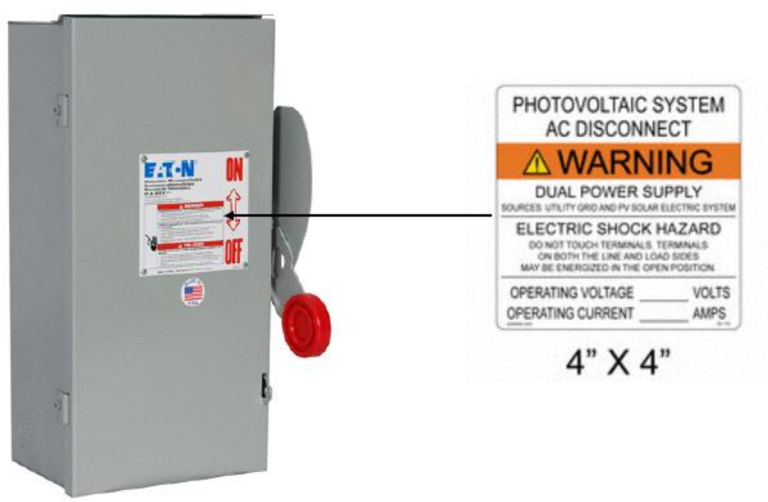
5.3.5		If Inverter Disconnect is required, check the following
	5.3.5b	Check Inverter Disconnecting Means (IDC) is of the approve type
		Simultaneously disconnect all ungrounded conductors
		Externally operable without exposing operator to live parts
		Shall indicate whether in the off or on position
		Lockable in the off position
		Readily Accessible

PEC 240.2.5 Accessibility
Overcurrent Devices shall be readily accessible so that the center of the grip of the operating handle, when its in the highest position, is not more than 2.0m above the floor or working platform

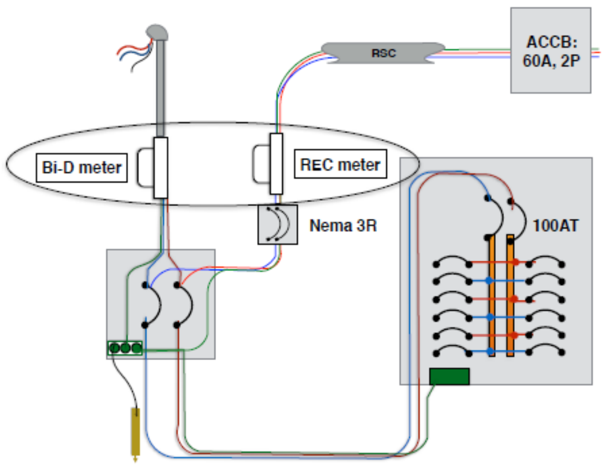


5.3.5		If Equipment disconnect is required, check the following
	5.3.5c	Check Warning Sign label.



35

5.3.7	At metering location, check the following
5.3.7a	Check REC meter is adjacent to Bi-D meter
5.3.7b	Check REC meter wiring method is exposed RIGID metallic
5.3.7c	Check REC meterDisconnect is approved type
5.3.7d	Check REC meter Disconnect enclosure is appropriate for intended location



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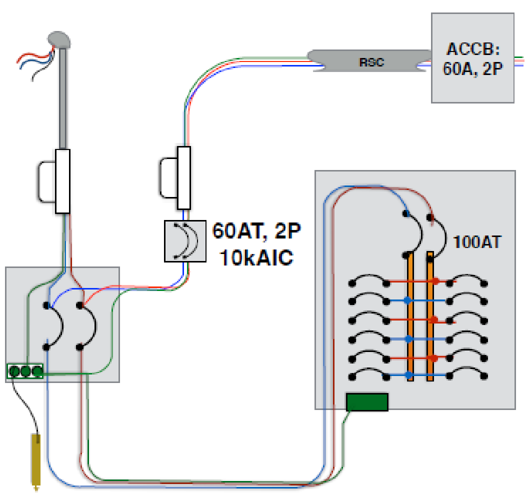
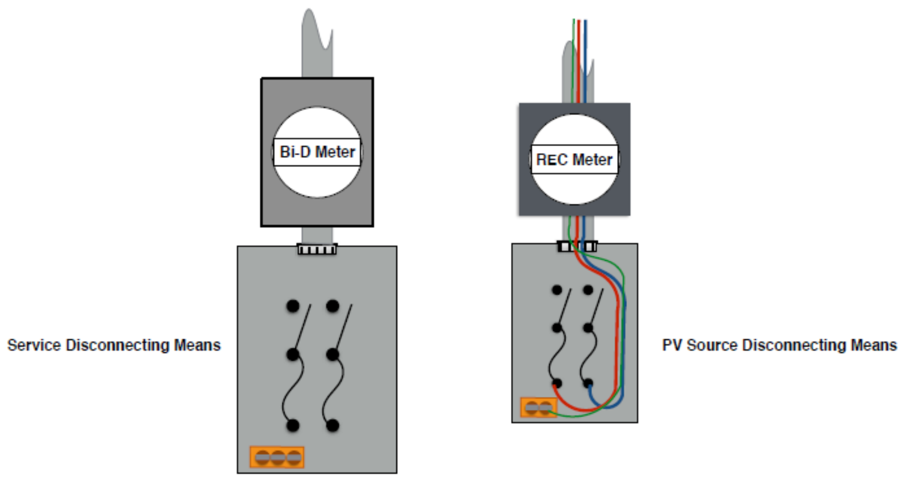
5.3.7	At metering location, check the following
5.3.7e	Check REC meter Disconnect OCPD trip rating, kAIC is indicated
5.3.7f	Check REC meter Disconnect Warning Sign
5.3.7g	Check EGC terminates at Service equipment ground terminal bar



4" X 4"

37

5.3.7	At metering location, check the following
5.3.7h	Check PV AC output is wired to loadside of OCPD



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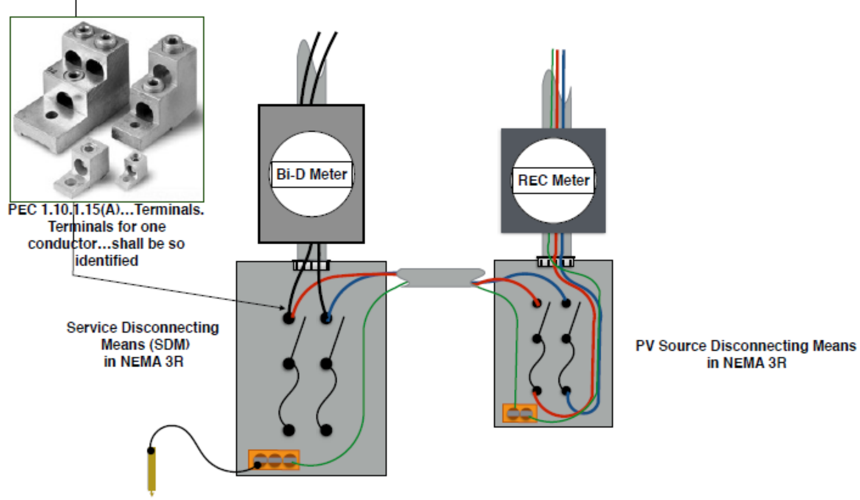
5.3.9	At Point of Interconnection, check the following
5.3.9a	Check terminal lug at SDM is appropriate
5.3.9b	Check SDM enclosure is approved type, in NEMA 3R
5.3.9c	Check Equipment Grounding terminates at grounding Bus
5.3.9d	Check grounding Electrode integrity



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5.3.11	If P of I is at Loadside, Check Feeder ampacity is ≥ SDM OCPD + 125% Output Current

LOAD SIDE INTERCONNECTION GUIDELINES

PEC 7.5.1.12 (B)(1) **Dedicated Overcurrent and Disconnect** . Each source interconnection of one or more power sources installed in ounce system shall be made at a dedicated circuit breaker or fusible disconnecting means.

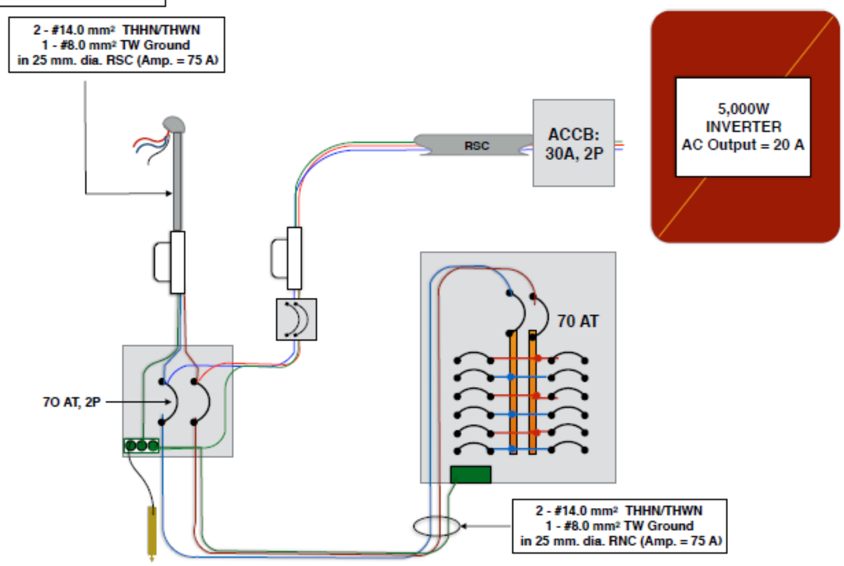
PEC 7.5.1.12 (B)(2) **Bus or Conductor Ampere Rating**. General Rule

Ampacity shall not be less than the sum of the primary source overcurrent device and 125 percent of the power source output circuit current.

Feeder Ampacity = Rating of OCPD + 125% Inv. AC Output

15

Sample Problem 1



Feeder Ampacity ≥ Rating of OCPD + 125% Inv. AC Output

75 ≥ 70 + 125% 20

75 ≥ 70 + 25 (UNTRUE)

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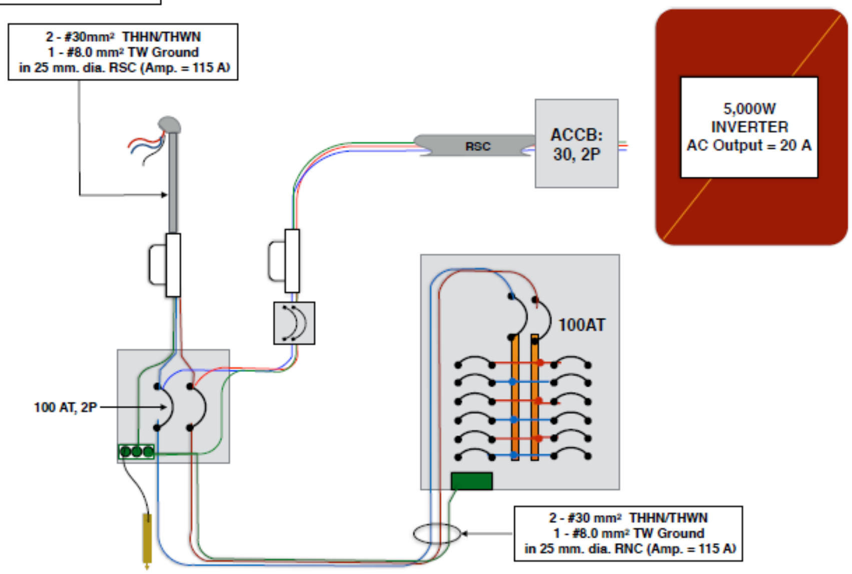
Sample Problem 2



Feedar Ampacity $\geq$ Rating of OCPD + 125% Inv. AC Output

115 $\geq$ 100 + 125% 20

115 $\geq$ 100 + 25 (UNTRUE)

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5.3.13	If P of I is at Lineside, Check PV output OCPD is ≤ OCPD Rating of the Service

LINE SIDE INTERCONNECTION GUIDELINES

PEC 7.5.1.12 (A) **Supply Side**. An electric power production source shall be permitted to be connected to the supply side of the service disconnecting means as permitted in 2.30.6.13(16). The sum of the ratings of all overcurrent devices connected to power production sources shall not exceed the rating of the service.

Ampere Rating of INVERTER (S) $\leq$ Ampere Rating of SERVICE

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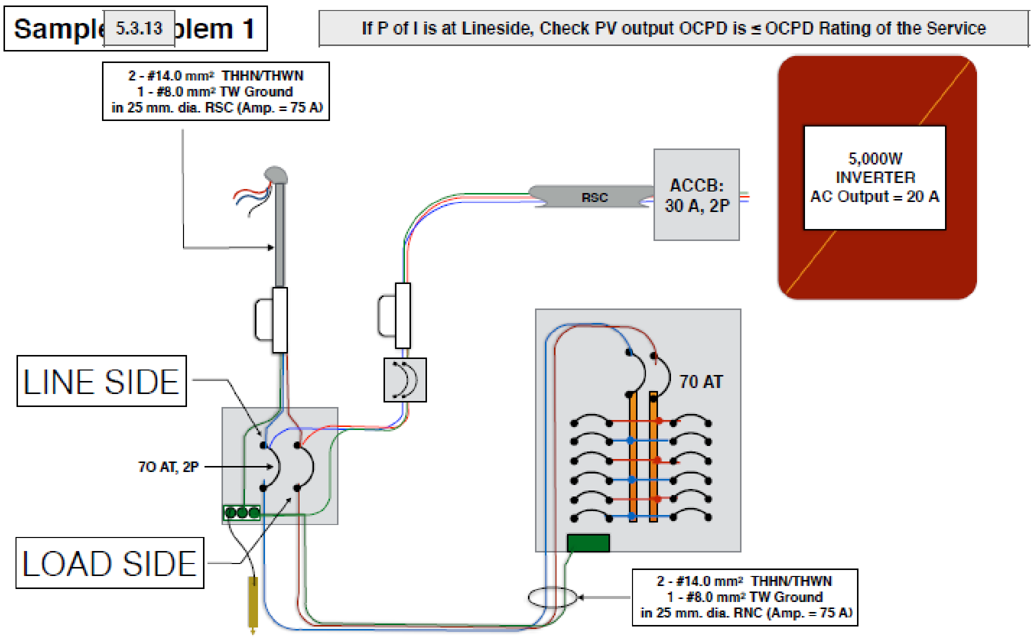
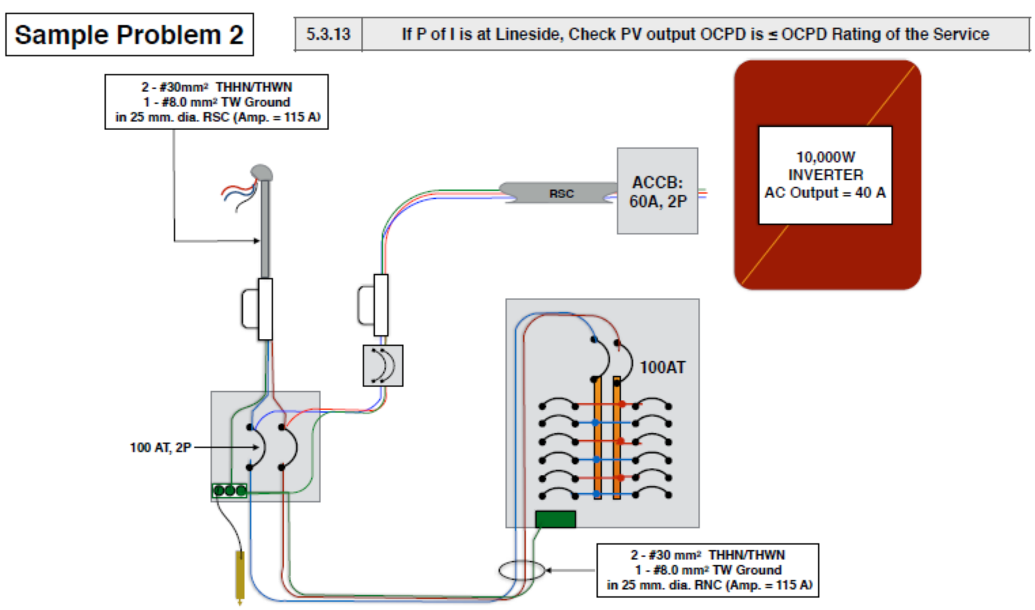


Ampere Rating of Inverter(s) ≤ Ampere Rating of the Service

20 A ≤ 70 (TRUE)

23



Ampere Rating of INVERTER (S) ≤ Ampere Rating of SERVICE

40A ≤ 100A (TRUE)

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Feeder Ampacity = Rating of OCPD + 125% Inv. AC Output

Item No.	Size of Service Entrance/Feeder Type THHN/THWN	Allowable Ampacity Table 3.10.2.6(B)(16)	Rating of OCPD	Rating of Inverter allowed for Interconnection at Load Side	Rating of Inverter allowed for Interconnection at Line Side
1	# 8.0 mm^2	55 A	50 AT	4A or 920W	
2	# 8.0 mm^2	55 A	60 AT	not allowed	
3	# 14.0 mm^2	75 A	70 AT	4A or 920W	
4	# 14.0 mm^2	75 A	75 AT	not allowed	
5	# 22 mm^2	95 A	100 AT	not allowed	
6	# 30 mm^2	115 A	100 AT	12A or 2760W	
7	# 38 mm^2	130 A	125 AT	4A or 920W	
8	# 50 mm^2	150 A	150 AT	not allowed	

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Feeder Ampacity = Rating of OCPD + 125% Inv. AC Output

Item No.	Size of Service Entrance/Feeder Type THHN/ THWN	Allowable Ampacity Table 3.10.2.6(B)(16)	Rating of OCPD	Rating of Inverter allowed for Interconnection at Load Side	Rating of Inverter allowed for Interconnection at Line Side
1	# 8.0 mm^2	55 A	50 AT	4A or 920W	50A or 11500W
2	# 8.0 mm^2	55 A	60 AT	not allowed	
3	# 14.0 mm^2	75 A	70 AT	4A or 920W	70A or 16,100W
4	# 14.0 mm^2	75 A	75 AT	not allowed	
5	# 22 mm^2	95 A	100 AT	not allowed	
6	# 30 mm^2	115 A	100 AT	12A or 2760W	100A or 23,000W
7	# 38 mm^2	130 A	125 AT	4A or 920W	
8	# 50 mm^2	150 A	150 AT	not allowed	

CONCLUSION: **THE CAPACITY OF A SOLAR PV SYSTEM THAT CAN BE INTERCONNECTED IS MUCH HIGHER WHEN THE POINT OF INTERCONNECTION IS MADE AT THE LINE SIDE.**

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4 References

Asian Development Bank. 2014.Handbook for Rooftop Solar Development in Asia. Manila. https://hdl.handle.net/11540/2497

Department of Energy, “DOE Net Metering Guidebook”, March 2022

Energy Regulatory Commission. 2013. ERC Resolution No. 09 Series of 2013 “Net-Metering Interconnection Standards”. Manila. http://www.erc.gov.ph/Files/Render/issuance/511

Energy Regulatory Commission. 2014. ERC Resolution No. 16 Series of 2014 is the “Resolution Adopting the 2014 Revised Rules for the Issuance of Certificates of Compliance (COCs) for Generation Companies, Qualified End-Users and Entities with Self-generation Facilities.” Manila. https://www.erc.gov.ph/Files/Render/issuance/6276

Energy Regulatory Commission. 2019. ERC Resolution No. 06 Series of 2019 “A Resolution Adopting to the Amendments to the Rules Enabling the Net Metering Program for Renewable Energy”. Manila. https://www.erc.gov.ph/Files/Render/issuance/29981

Energy Regulatory Commission. 2020. ERC Resolution No. 05 Series of 2020 “A Resolution Clarifying the ERC Resolution No. 6 Series of 2019 entitled A Resolution Adopting to the Amendments to the Rules Enabling the Net Metering Program for Renewable Energy”. Manila. https://erc.gov.ph/Files/Render/issuance/30414

GIZ. 2013. Net Metering Reference Guide: How to avail solar roof tops and other renewables below 100 KW in the Philippines. Manila. https://www.doe.gov.ph/sites/default/files/pdf/netmeter/net-metering-reference-guide-philippines-E.pdf

Philippine Electrical Code (PEC) 2017 Part 1. Institute of Integrated Electrical Engineers of the Philippines, Inc., 2000

Philippine Distribution Code (PDC), Energy Regulatory Commission, December 2017