Solar PV System Installation and Maintenance

Level-III

Learning Guide -22

Unit of Competence	Determine PV system Customer Requirements
Module Title	Determining PV system Customer Requirements
LG Code	EIS PIM3 M06 LO1 LG-22
TTLM Code	EIS PIM3 TTLM 0920v1

LO1:-Assess current and future electrical needs of customer and site characteristics

Instruction Sheet	Learning Guide 22

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Company standards & procedures
- Accomplishing forms for site assessment
- Accomplishing forms load assessment
- Conducting interviews
- Conducting assessment within the prescribed time.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to: -

- Understand company standards & procedures
- Accomplish forms for site assessment
- Accomplish forms load assessment
- Conduct interviews
- Conduct assessment within the prescribed time.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

Information Sheet	Company standards & procedures

1.1. Introduction

The assessment of the needs of the customer and the so-called side survey is the most important part of designing a PV system. Only a proper side survey can assure that the system will meet the requirements of the customers. That the PV-generator is big enough to cover the electricity demand, the battery is big enough to provide electricity during days without sunshine and the inverter is big enough to operate all devices. But also, that the system fits to the financial situation of the customers. The main points to survey are:

- General Information (where, what, when)
- Technical information (size of the PV system and battery bank and electricity demand)
- Financial information (budget, funding, loans)

Fig1: Performing a site survey

The chapter “Assess current and future electrical needs of customer and site characteristics” gives you an introduction on which tools to use to perform a proper site survey.

1.2. Company standards & procedures

There are existing forms and procedures for the performance of a site survey. However, every company has its own procedures and forms to be used for site surveys. Companies develop site survey forms in order to record any of the information they need to acquire while conducting a site survey. Standardized site survey forms keep employees on track by reminding them what to collect and giving a place to write all that down. It also improves the quality of information one walks away with, and saves time when a client whom one employee of a company quoted a PV system two years ago suddenly calls and says that he's ready to buy. With all the necessary information recorded on your site survey form you can save yourself another trip out to the site.

A good site survey form should easily be replicated by all employees within one organization. Word or Excel forms can be printed out to be completed as hard copies, or computer aided forms to be completed in mobile apps on smart phones or tablets are usually used.

1.3. Forms Content

The following points should be borne in mind during the on-site visit and recording of data, which will form the basis for good planning:

- Customers' wishes in respect of PV system (module type, system concept, method of installation, etc); the client energy use and expectations; desired energy yield;
- The financial framework, taking the respective subsidy conditions into account
- Data on roof: Usable roof, façade, open space surfaces, type of roofing and roof structure, roof's orientation and slop, etc
- Data on shading: daily, seasonal,
- Data on installation: PV generator installation layout, junction box and wiring routes, locations for controller and battery bank, appliances disposition and indoor wiring route; etc
- Important necessary documents: site plan and construction of housing; photographs of the roof and other meter construction.
- The items to be carried to on-site visit: checklists for recording; information material on PV: general information (national guidance, for example); company leaflets; products description; photo of existing PV systems; relevant handbooks
- Tools and equipment: compass, altimeter, folding ruler, protractor, tape measure, pocket torch, shading analyser, digital camera, etc . In order to collect all information, one must go very prepared to a client consultation /site survey. A site survey form is therefore the most essential tool to use to document all data collected during an on-site visit. Manufacturers and wholesalers provide templates for companies, like the one from SMA below. When going for a site survey one has to make sure to use the right form. In the case where the company has no form in place, it is recommended to develop a form with the team based on public available forms and the specific

requirements of the company. Word or even excel are suitable programmes to develop a company template.

SMA

Off-Grid Questionnaire

General Data							
Project/Use						☐ New plant	
Customer						☐ Refurbishment	
Site data							
Country			City				
Latitude			Longitude				
	Altitude		AMSL				
	Ambient temperature		°C minimal			°C maximal	
Plant data							
Grid	Voltage (L-N):		VAC	☐ Island system	or	☐ Backup	
	Frequency:		Hz	☐ 1-phase	or	☐ 3-phase	
Battery	Capacity:		Ah	or autonomy time			days
Energy sources	☐ Generator	☐ PV		☐ Others			
Communication	☐ Remote access						
Loads / Users							
	Daily	Summer		Winter		Yearly	
Energy	kWh/d		kWh/d		kWh/d		kWh/a
Nominal load	kW		kW		kW		kW
Maximal load	kW		kW		kW		kW
When runs the main load?							

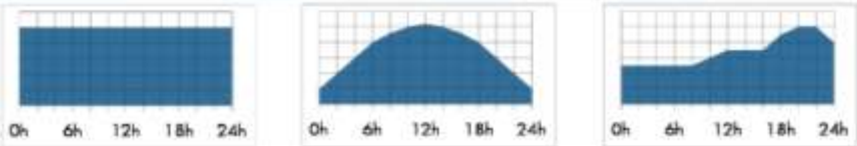


Fig2:Off- Grid Questionnaire (source: www.sma.de)

1.4. Form templates

The following template has been developed by the team of the German Solar Energy Society, short DGS, during the last years while working In Africa, Asia and Latin America. It is especially designed to be used for teams. As it is very comprehensive and enables companies to assign one person to go for the site survey and another person to do the planning and design.

1.4.1 CHECKLIST Location Evaluation PV-plants

1.4.1.1 General Information

Name, given name	
Address	
Phone	
Fax	
Email	

1.4.1.2 Location of PV power

Address		
GPS Coordinates		
Altitude		
Picture (photo or link)		
Internet connection		
		Available with limitless data flat rate
		Available with limited data flat rate of: ....GB
		Available without data flat rate
		Not available
Type of internet connection		DSL connection
		ADSL connection
		Dial up internet
		ISDN
		Other:

Prices and flat rates -Would your connection allow a permanent internet connection of the PV monitoring device with high up- and download traffic?

1.4.1.3 Building and Roof Drawings and Pictures

Please provide drawings and insert pictures of the following spots:

Building	Roof
installation location (roof)	cable path
Electricity meter	Electricity meter cabinet
Electricity meter (type name)	
Access to the roof	relevant wiring situation

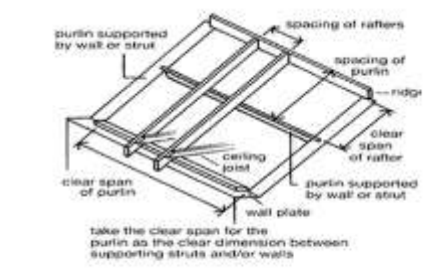
Please describe the present situation of the building (type of building, number of floors, usage, electricity installation) as focusing on the existing electrical installation in a few words:

1.4.1.4 Location and Size of the Roof/side for the PV system

Mounting area*:	
Existing mounting frame:	
Roof area available for the PV system:	
Shading (Is there any other building, tries, etc. which shades the roof area?)	
Further information:	

*pitched roof, flat roof, open space, other

1.4.1.5 Roof structure, Roof Covering and Roof Waterproofing

	
Roof height A:	
Roof width B:	
Height Attica D (if existing):	
Building height C:	
Slope of the roof β:	
Roof orientation: 0° (North), 90° (East), 180 (South), 270° (West)	
Roof inclination β: 0° (Horizontal) to 90° (Vertical)	
Rafter size:	
Rafter cm wide / high/length in cm	
Spacing of rafters in cm:	
Amount of rafters:	
Tile/Brick material*:	
Tile/ Brick size in cm:	
Roof age in years: Please indicate if correct figure or estimated	

* clay, concrete, fibre cement, concrete, roofing paper, reinforce concrete, fibre cement, Hollow concrete blocks, gravel, Reed, bitumen, others

Please provide any further information:
Designed and erected mounting is needed

1.4.1.6 Power Consumption

The building is used as:

Residence

Office

Other:

No.	Technical device	AC or DC	Quantity	Power [W]	Operation time [h]	Operation hours a day or night, please describe the usage patterns
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						

1.4.1.7 Only for advanced users Loads/consumptions

	Daily	Summer	Winter	Yearly
Energy consumption in kWh/d				
Nominal total load in kW				
Maximum load in kW				
Minimum load in kW				
Please provide more information on load peaks or consumers with high starting currents if available				

☐	Please tick if you attach load curves	☐	Please tick if you attach electricity bills

1.4.1.8 Customer Requirements (please tick)

Type of plant	☐	Off-grid	☐	On-grid	☐	combined
	☐	hybrid	☐	Other:	☐	
Type of mounting	☐	Roof-top installation	☐	In-roof installation	☐	Erected-mounting
	☐	Facade-mounted	☐	Portable	☐	Other:
System design constraints:	☐	Design for max. income	☐	Design with max. investment costs of:	☐	Design for max. use of area
	☐	Design for self-consumption	☐	Other:		

1.4.1.9 Given Electrical Conditions on Site

Present electricity costs	..../kWh	
Grid connection		Yes
		No
Type of grid	Voltage in V:	
	Frequency in Hz	
	Phases:	
	Other relevant information:	
Electricity meter		Yes
		No
	Type of meter	
	Can the meter count in 2 directions?	
Grid feeding systems		Yes
		No
Is there lightning protection?		Yes
		No
Where can the PV array be grounded?		

1.4.1.10 Existing power generators

	Existing generators	**Power in kW**	**Voltage in V**	**Frequency in Hz**	**Phases**	**Manufacturer**	**Model**
	Diesel generator						
	PV						
	Wind						
	Others:						

Please provide any further information on Existing Power Generators, Grid Power cuts, usage patterns.

1.4.1.11 Technical Planning (Batteries)

Is there a room for batteries?		Yes
		No
Where is the room?		
Distance to the PV modules in m		
Distance to the inverters in m		
How is the		

ventilation of the room, windows?	

1.4.1.12 Picture of the room:

1.4.1.13 Technical Planning inverter

Can the inverter be installed in the battery room?

yes		No
If no, where can they be installed?		
Distance to the PV modules in m		
Distance to the batteries in m		
How is the ventilation of the location? (windows, air-conditioning, ...)		

1.4.1.14 Picture of the room:

1.4.1.15 Technical planning grid connection

Only electricians are allowed

How are the feed in regulation?	
Who will do the AC installation?	
Whom we have to inform to connect the system to the grid?	

1.4.1.16 Additional notes by the customer:

1.4.1.17 Attachments

Self-Check - 1	Written Test

The following are true or false items, write true if the statement is true and write false if the statement is false.

1 Site surveys are the last step of PV installation project.

2 It is important to collect all information needed to evaluate the electricity consumption of the customer.

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 2	Accomplishing forms for site assessment

2.1. Accomplishing forms for site assessment

A professional site assessment is the first important step in the process of selection, design and installation of an appropriate renewable energy production system for your home or business. The assessment starts with phone or email conversations with you, includes an in-person site visit, and results in the delivery to you of a carefully written report. The report will help you to design a solar system which meets the requirements of the customer. Every site is different and needs evaluation specific to the site--there is no "one-size-fits-all solution" when it comes to renewable energy systems.

2.2. Objective of a site assessment

According to the German Solar Energy Society, installers have to consider the following points while performing a site assessment (DGS, 2010):

- Customers' wishes with regard to module type, system concept and method of installation.
- Desired PV power or the desired energy yield.
- The financial framework, taking the respective subsidy conditions into account.
- Usable roof, facade and open space surfaces.
- Orientation and angle of inclination.
- Roof shape, roof structure, roof substructure and type of roofing.
- Usable roof openings (vent tiles, free chimney flues, etc.).
- Data on shading.
- Installation sites for PV combiner/junction boxes, isolating facility and inverter.
- Meter cupboard and space for extra meters.
- Cable lengths, wiring routes and routing method.
- Access, particularly when equipment is required for installing the PV array (crane, scaffolding, etc.). Forms to collect all the above listed information for site surveys are provided in LO1.

These forms are an essential tool to record all data gathered during a site assessment. They have to be filled out on site and ideally should be even signed by the customer. Forms can be printed out, but also completed digitally.

2.3. Tools for a site assessment

The most important tool for a site survey is your camera, or nowadays your smart phone. Pictures help you to memorize the site, but also to plan the system. You phone gives you the GPS of the location, but you also could use it as compass or even to complete the site survey form if your company provides you with a smart phone app to do so. You could even use your phone for a quick pre-planning, irradiation evaluation or inclination measuring.

What should one take with?

- Compass (or smart phone)
- Tape measure (up to 25 m), yardstick
- Digital camera (or smart phone)
- Inclinometer for finding the slope of the roof (or smart phone)
- Calculator (or smart phone)
- A shading-analysis tool (if available)
- Screwdriver or multi tool
- Flashlight (a headlight would give you the opportunity to note and see, as it keeps your hands free)
- Ladder (either you bring your own, or you make sure that the client provides one)
- Clipboard and notebook with pens and pencils
- Survey form
- Data sheets for modules, inverters, substructures (if you work with standard products)
- Semples, if avalable(i.e. substructures, modules, cells, ...)

Ryan Mayfield, recommends in his handbook "Photovoltaic for Dummies" to use a survey bag to ensure that you can carry all needed tools while climbing roofs, leaders and speaking with the client.

2.4. Procedure

The site survey form is your guideline to collect all relevant data. How to use it is explained in this information sheet. Please follow the following procedure to collect your data:

- Sit down with the client, get to know him and understand where he is coming from.

- Start to complete the form during the discussion and explain the client why you collect all these data.
- Visit the side with the client, make notes and take pictures
- Sit down again with the client, go through the notes, complete the notes, get additional information.
- Get the signature from the client on the site survey form

The two most important things is to:

- Get familiar with the client and to listen to what he really wants and
- To get his signature and thus his confirmation on the collected data.

But why do you need the signature of the client. You need it as proof, that the collected data is correct and to make sure that all that you agree with the client is documented.

Read the following example to understand why the client signature is so important.
Dave is a PV installer. 2015 he visited his client the first time. His client had no access to electricity and wanted to investigate solar as an option for him. Dave completed the site survey and discussed possible options for the client. But there was a big tree in front of the house of the client which caused shadows on the roof of the house. Dave explained to the client that this shadow will reduce the electricity production of the solar system and the client said that he wanted to cut down the tree anyhow. Dave noted this information in the site survey form and both, Dave and the client, signed the form. In 2016, Dave installed the system and the tree was still there, but the client confirmed again that he will cut it. In 2018 the client called Dave and He was very angry as the system did not perform as predicted and he even wanted his money back. Dave went on-site and the tree was still there. Dave explained to the client that the tree is the reason for the bad performance and the client complained, that Dave should have said this earlier. Dave showed the client the signed site assessment form and thus could proof that he informed the client already during the site survey. This saved his reputation and his money.
This example should show you how important it is to have a good documentation and even get the approval from the clients.

2.4.1. General Information

First you have to collect general information about your customer, which you need to prepare a quote. But you also need to know exactly where the location is and if there is an internet connection. The internet connection is important in case you plan to run or monitor the system remotely. You need to collect:

- Name and address of the customer
- Location of PV power plant (GPS Coordinates, Altitude, photo)
- Internet connection (type, costs, accessibility)

The best tool to get the exact location are tools like Google maps.

2.4.2. Building and Roof Drawings and Pictures

In order to plan the PV system, one needs to know not only where to mount the modules, but also where to mount or place the inverter and the batteries, how to connect the system to existing electrical installations and generators and where to mount the equipment. Pictures of the following have to be taken and copied in the site survey form:

- Building
- Roof
- Access to the roof
- installation location (roof)
- cable path
- relevant wiring situation
- Electricity meter
- Electricity meter cabinet
- Electricity meter (type name)
- Existing electricity supply (batteries, generator…)

Please describe the present situation of the building (type of building, number of floors, usage, electricity installation) as focusing on the existing electrical installation in a few words.

2.4.3. Location and Size of the Roof/side for the PV system

One has to document with a little drawing the area dedicated for the PV system. Solar modules could be mounted on a roof, on a pole or even get ground mounted. This drawing will be the basis for the planning on how and where to install the PV system. It is always good to make some drawing, even additionally to pictures. Here it is always good to have as much information as possible relevant for the PV system. Where is which tree, is it a deciduous tree or a conifer, what else can put shadow on the PV array. Such a drawing should include the following data Included in the drawing:

- Roof area (with attention to the orientation)
- Usable area for the PV system (situate the middle of the PV system at the coordinate origins, additional photos can be taken)
- Chimney, antenna, satellite systems
- Near lying buildings (approximate distance and height)
- Trees (approximate distance and height)
- Freestanding cables (i.e. electricity or telephone lines)
- Other shading sources: building projections, etc...

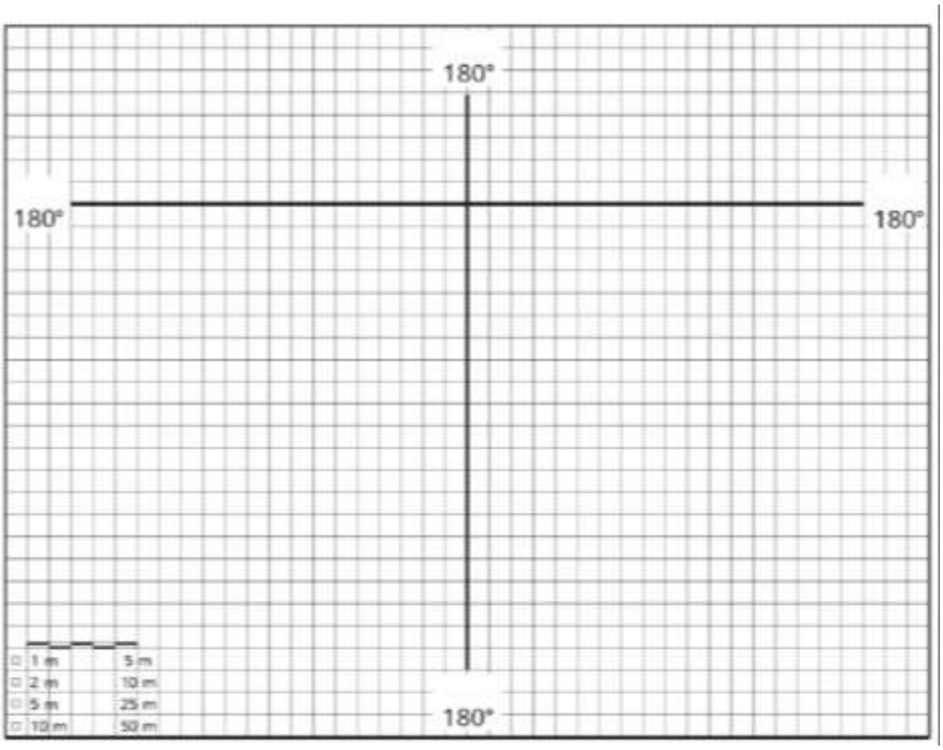


Fig : Template to draw site

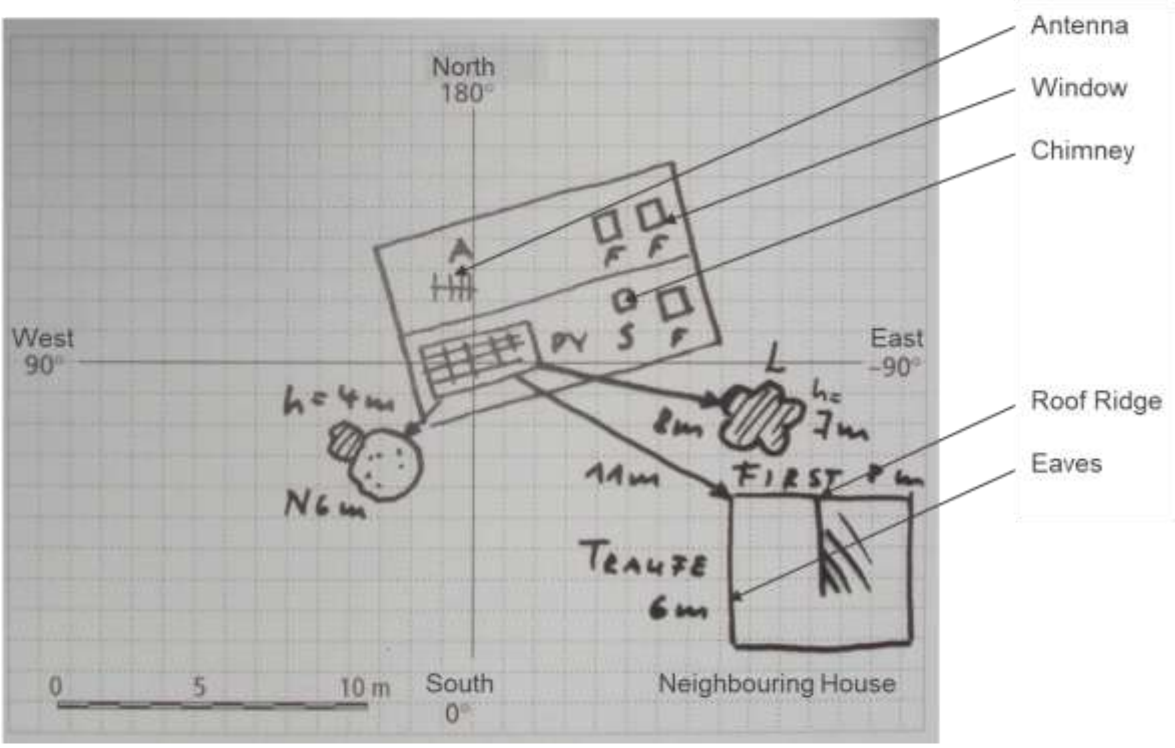


Fig: Example for a site drawing

Additionally, the following information has to be documented in the site survey form:

- Mounting area (pitched roof, flat roof, open space, other)
- Describe if there is an existing mounting frame
- Describe if there is a roof area available for the PV system
- Describe the Shading (Is there any other building, tries, etc. which shades the roof area?)
- Describe any further information relevant information.

2.4.4. Roof structure, Roof Covering and Roof Waterproofing

When you can mount the PV system on the roof you need a detailed description of the roof, as you need to plan how to mount the PV array on the roof. The following paragraphs give you more background information on why and what is important to document. They are taken from [Mayfield, 2010, chapter 5, page 85] and adapted for Africa by the authors.

How much physical space is available for the installation? Typically, PV systems are installed on the roofs of buildings or on free land space. Your task during the site survey is to make sure the space available will suffice for the client's desired PV system. Your client may have an idea of where he wants the array to go, but it's your job to make sure a better alternative doesn't exist.

The area you have your eyes on may be the same as someone else. Always verify that other plans don't exist for the space you want to use, such as plans for solar thermal collectors or skylights. Here are some additional structural and mechanical questions that you should ask if the array will likely be mounted to a roof:

- **What are the dimensions and shape of the roof area available?**

Takingthe dimensions of the roof area you plan to install on will help you sketch out the roof later when you're ready to plan how the array will be arranged on the roof. During the site-survey process, you also need to identify obstructions (such as plumbing vents, chimneys, and attic vents) on the roof as well as their locations.

- **What condition is the roof material in, and how old is the roof covering?**

Placing an array on a roof that will need to be replaced in a few years doesn't make a lot of sense. If a reroof is in order, suggest it be done now and be sure to work closely with the client and the refer to coordinate phases of the project so you can continue with the PV system design and installation in a timely fashion.

- **What's the roof framing like?**

The roof's framing plays an important role. Most modern homes and commercial buildings tend to have roof framing that's adequate for a PV array mounted parallel to the roof so long as a single layer of lightweight roofing material (such as composition cement fiber shingles or wood shake) is used as the roof covering. Why? Because the roofs of modern homes are designed to handle multiple lightweight roof layers. As long as only one layer is present, adding the weight of a PV array will be less than the structure's limitations.

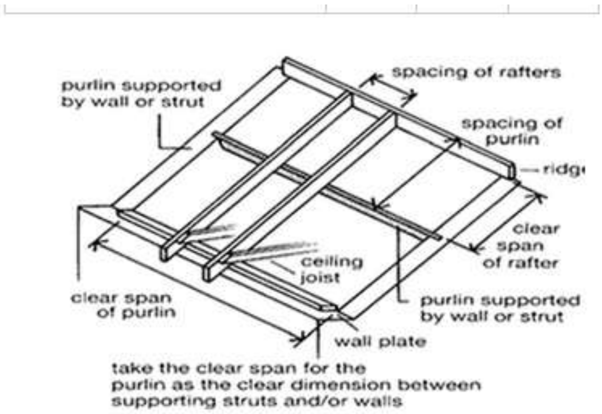
It is always recommended to involve a structural engineer to evaluate the roof for you and outline any changes you need to make to safely support the array. Make sure this consultation happens as early as possible in the system design process.

Note: Simple huts in uniform settlements or rural areas are often not suitable to carry any extra load. In this case pole or ground mounting is the only way to install a PV array.

- **What are the dimensions and spacing of the roof framing?**

Some buildingshave lumber, similar to residential roofs; others use very large wood supportmembers; and some use steel supports. Consequently, you should take the time to verify the roof structure in order to properly attach the array in any system that's being installed on a commercial roof. You have to identify the roof type, used material and dimensioning. Always do your best to verify the roof framing composition and orientation when conducting your site survey. Be sure to carefully evaluate rafters that are over spanned — a situation where the rafter has too much space between vertical support members.

Different spans are allowed based on lumber type and roof-loading restrictions, but as a general rule, if the rafters have a span of more than2 meters between supports, you should investigate the need for adding support by consulting a structural engineer. After roofs, ground mounts are the most popular type of racking system. Unless your client's site has unusually loose soil (like sand), you can work with a racking company (and maybe an engineer, if necessary) to determine the best possible mounting solution for the array Of course, before you start talking to a racking company, you need to make sure the location is suitable for mounting an array. The site survey form will help you to collect all information as described by Mayfield above.

	
Roof height A:	
Roof width B:	
Height Attica D (if existing):	
Building height C:	
Slope of the roof β:	
Roof orientation: 0° (North), 90° (East), 180 (South), 270° (West)	
Roof inclination β: 0° (Horizontal) to 90° (Vertical)	
Rafter size:	
Rafter cm wide / high/length in cm	
Spacing of rafters in cm:	
Amount of rafters:	
Tile/Brick material*:	
Tile/ Brick size in cm:	
Roof age in years: Please indicate if correct figure or estimated	

* clay, concrete, fibre cement, concrete, roofing paper, reinforce concrete, fibre cement, Hollow concrete blocks, gravel, Reed, bitumen, others .Please note all information you can get in the form an ask if there are any drawings available.

Self-Check –2	Written Test

Say true if the statement correct or say false if the statement is wrong

1 Site assessment is the first important step in the process of selection, design and installation of an appropriate renewable energy production system.

2 A drawing will be the basis for the planning on how and where to install the PV system.

3 The most important tool for a site survey is your camera, or nowadays your smart phone.

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

3.1. Accomplishing forms load assessment

Typical customers of small off-grid systems, also known as Solar Home Systems (SHS) are:

- Households without electricity.
- Households or commercial customers who use any off-grid electricity source, typically those are diesel generators or batteries, but sometimes also wind or water turbines.
- Households or commercial customers with unreliable grid-connection who want to go off the grid.

The load assessment will give us an insight in the present and planned electricity use of the customer. It is crucial to get a realistic picture of the future demand. It is always easier to collect information when the customer already uses electricity as in this case you can survey the electricity consumption and document all loads. Loads are electricity consuming appliances, such as lamps, fridges, computers and so on. In order to dimension the system according to the needs of the customer it is important to know the power of every load and the usage time.

You have to cross-check if all the loads the customer wants to operate. You have to understand when the customer uses the loads, every day, once a week, in the morning, in the night and so on. The design will then be made based on the daily consumption. If you have a consumer you only use e.g. once a week you do not have to consider it in the calculation or if you want to be 100% sure just take a fractional part of the amount of energy it requires. In most cases the dimensioning of a SHS only considers daily requirements and during the daily use, the users find out how much more consumers they can connect additionally without running out of electricity. Here are the stepson how to check the customer's energy consumption:

1) **How much power does the device consume? Look at the number of Watts (W) on the packing or the description directly on the device.**

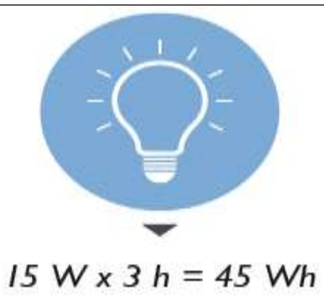
2) **How many hours do the customer want to use the consumer?**

3h	1h	2h
15 W	60W	60W

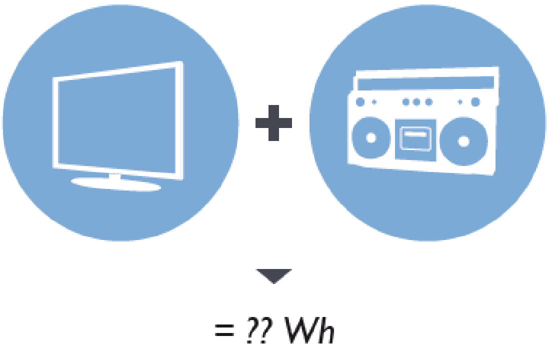
3) **How much energy would the customer need per day?**

Multiply the power by the time of usage that means the Watt by the hours.

The result is the amount of energy and has the unit Wh.



4) Repeat this calculation for every consumer you want to use.



5) Sum up all the results to get the total amount.

3hx15W+1hx60W+2hx60W=225Wh

6)Calculate the total Power

15W+60W+60W=135W

In case the customer already uses electricity, you can survey the electricity consumption with electricity meters, simple tables to document meter readings or fuel consumption. But this will not replace the evaluation of the devices.

Fig: Electricity meter (OWL) to monitor the electricity consumption

maxx-solar energy PTY Ltd. consumption monitoring template

Client: Dominican-Gromby Meter number: 3197-56

Week: 9 - 15 November

Please write the kWh from the display of your meter every full our in the table

Time	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saterday
1:00 AM							
2:00 AM							
3:00 AM							
4:00 AM							
5:00 AM							
6:00 AM	19246	19211	19216	19223	19227	19235	19240
7:00 AM							
8:00 AM							
9:00 AM							
10:00 AM	19247	19213	19219	19224	19230	19237	NOT READ
11:00 AM							
12:00 PM							
1:00 PM							
2:00 PM	19247	19213	19219	19225	19232	19237	19242
3:00 PM							
4:00 PM							
5:00 PM							
6:00 PM	19248	19214	19221	NOT READ	19232	19238	19243
7:00 PM							
8:00 PM							
9:00 PM							
10:00 PM							
11:00 PM							
12:00 AM							

* NOTE: We began on Monday 9 NOVEMBER.

Fig: Meter reading and documentation in a table

The two important questions to answer are:

- How much electricity (Wh) consumes the customer?
- What is the sum of the power (W) of the loads to be used at the same time?

The electricity consumption is important for the sizing of the PV generator and the battery and the power of the loads is important for the sizing of the inverter. Wrong assumptions will lead to failure of the system!

3.2. Power Consumption

During the site survey you have to complete the power consumption table and collect general information like: The building is used as residence or office or for other purposes. And you have to document all loads, also called appliances or technical devices in order to understand the daily load energy demand, which is the amount of energy required each day to power all loads. The paragraph below describes the use of the table and the definitions where prepared based on the definitions given by Hankins, 2010. Column 1: Number of the entries from 1 to n. Column 2: Individual load description. List all the lamps and appliances to be powered by the system here When listing appliances, you should consider all the appliances to be powered by the system, even those that will be purchased in the future. Column 3: Note if it is an AC or DC appliance. DC appliances are those that run e.g. at 12V DC or the system voltage and AC appliances are those that will run through an inverter. AC appliances are standard appliances used everywhere, where we have a grid, whereby DC appliances are typically used in boots, camping, trucks and PV systems. In case you install the system for a customer who has no electricity so far and no appliances the use of DC appliances and the use of a pure DC system should be considered.

Column 4: Number of same appliances, appliances with the same characteristics. 15 and 20 W lamps e.g. can't be mixed. Column 5: Individual lamp and appliance power. List the power in watts for each appliance and lamp. Usually, the manufacturer indicates the power rating on the appliance itself. With better information about your appliance, you can accurately predict your demand. Try to get actual ratings of the power use of appliances from labels or manufacturers' data. Table and Table(LO2) list the power ratings of common lamps and appliances – if you do not have information about your appliances, use these when making calculations. Betteryet, measure the actual DC current consumption of your lights and appliances using a multimeter or a clamp-on amp-meter.

Do not guess! (The actual power consumption of AC appliances can be measured quite accurately using plug-in watt-meters, but it is best to use them on the mains – the wave form of an inverter may interfere with an accurate reading. Remember that in an off-grid PV system the appliance will consume more electricity because of inverter inefficiency.)

Column 6: Individual lamp and appliance use (hours per day). Estimate the number of hours per day that each lamp and appliance is used. If the appliance is only to be used a few times per week (e.g. a sewing machine might only be used on weekends), estimate the number of hours it is used per week, divide by7 and write the number of hours per day in Column 6. Column 7: Discuss with the customer if he uses the appliance only during the day or only during the night or both. This information will help you to understand the usage pattern better and to estimate the max power in total, but also during the day and the night. Lamps e.g. are only used during the night, whereby Computers are often used both, night and day.

Table : Table to document the Technical devices used by a customer

1	2	3	4	5	6	7
No.	Technical device	AC or DC	Quantity	Power [W]	Operation time [h]	Operation hours a day or night, please describe the usage patterns
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

1	2	3	4	5	6	7
No.	Technical device	AC or DC	Quantity	Power [W]	Operation time [h]	Operation hours a day or night, please describe the usage patterns
13						

It is important to not only document existing devices but also discuss in detail with the client which devices he wants to use/operate with the PV system.

3.3. Loads/consumptions

For a detailed planning it is not only important to know the power and energy demand but also to know when the energy is used and if there are differences in summer and winter or day and night. Weekend houses e.g. are usually only used in Summer, telecommunication towers have the same electricity consumption 24/7 and families usually need more electricity in the evening.

To get this figures we can either ask the customers or we could evaluate the data collected with a meter, see Fig: Electricity meter (OWL) to monitor the electricity consumption or manual reading, see Fig: Meter reading and documentation in a table. The load curves show us when the loads are used and thus when which amount of power and electricity is needed.

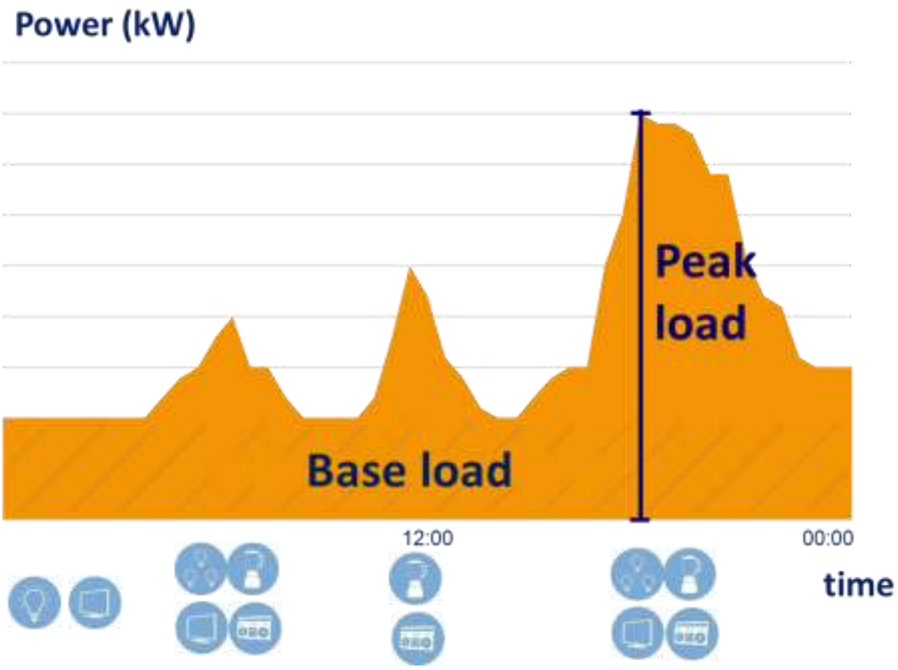


Fig: Load curve of a rural household

For the planning we need to understand when we can use electricity directly and how much electricity has to be stored in the batteries to be used in the night or during days without sunshine. The figure below shows the load curve of a customer with an overall energy consumption of 42 kWh per day. The load curve or load profiles is a graph of the variation in the electrical load versus time. The figure below compares the load curve with a typical solar profile and thus shows us which electricity can be used directly.

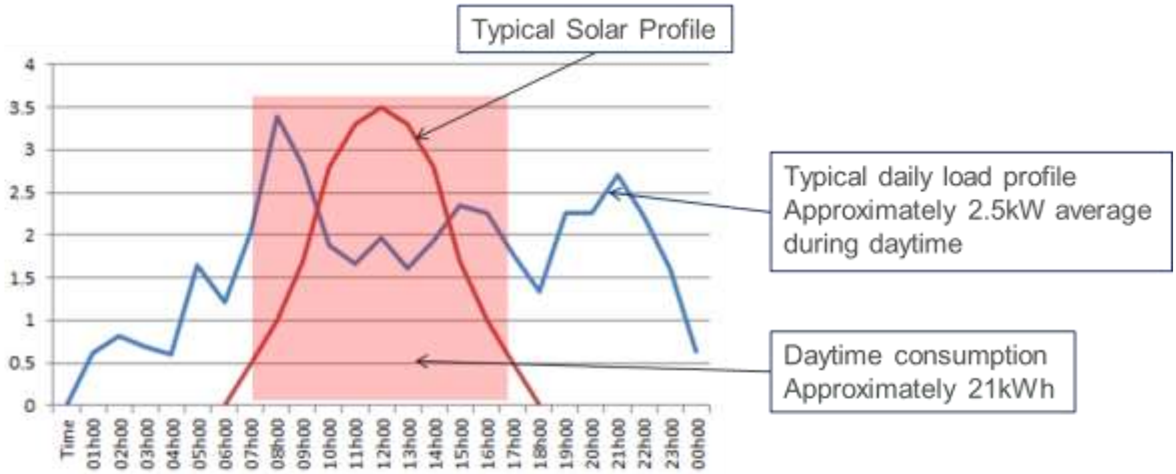


Fig: Solar profile vs load profile of a customer with 42kWh/day consumption

One needs to understand the usage patterns to design the system, but especially the batteries. The table below will help to collect the needed information.

Table1:Table to document seasonal usage patterns

	Daily	Summer	Winter	Yearly
Energy consumption in kWh/d				
Nominal total load in kW				
Maximum load in kW				
Minimum load in kW				
Please provide more information on load peaks or consumers with high starting currents if available				
☐ Please tick if you attach load curves		☐ Please tick if you attach electricity bills		

3.4. Customer Requirements

It is also important to discuss with the customer the type of PV system he has in mind. One has to discuss the different option with the client and note the requirements in the site survey from.

- Type of plant
  - ✓ Off-grid
  - ✓ On-grid
  - ✓ combined
  - ✓ hybrid
  - ✓ Other:
- Type of mounting
  - ✓ Roof-top installation
  - ✓ In-roof installation
  - ✓ Erected-mounting
  - ✓ Facade-mounted
  - ✓ Portable
  - ✓ Other:

- System design constraints
  - ✓ Design for max. income
  - ✓ Design with max. investment costs of:
  - ✓ Design for max. use of area
  - ✓ Design for self-consumption
  - ✓ Other

3.5. Given Electrical Conditions on Site

In case the customer already uses electricity, you have to analyse the sources to understand how to connect or integrate the PV system. You must evaluate the conditions on site. Once you collected all data you can come up with strategic decision:

- Should the PV system replace the existing systems, e.g. old diesel generators or batteries?
- Can the PV system be used additionally?
- How should integration work?
- Which source should be the main source?

One can only answer all those questions if one has a clear picture on the existing electricity sources. Thus, it is very important to collect as much information as soon as possible.

3.5.1. Electricity Grid

The description below is taken from [Mayfield, 2010, chapter 5, page 86] and adapted for Africa by the authors. For utility-interactive systems (whether grid-direct or battery-based), you have a number of items to review while you're on-site because you either want to connect the PV system to the utility or you want to replace this connection and use the existing cabling and DB board.

- **What are the specifications for the main distribution panel (MDP) or distribution board (DB) and the main circuit breaker protecting the panel?**

The ratings on the DB and the main circuit breaker play a major role in determining a PV system's maximum size. When looking at the existing electrical service, you need to document the specifics on the DB and any subpanels you want or need to use, including their physical locations. The standard voltage is 220 V and the standard frequency is 50

Hz. Usually small houses use one phase systems. Bus bars are the pieces of metal in the back of the DB that connect the circuit breakers in the panel to the wires coming from the utility (you can't see them when the cover of the DB is on). Every DB has a rating for its bus bars on the label attached to the inside of its cover. This rating is a value for the amount of current that can flow on the bus bars inside the panel without causing any problems.

The other specification for the MDP (and any subpanel used) is the rating of the main circuit breaker protecting the panel. For the MDP, this is often the same size as the bus bar rating. The ratings for circuit breakers in subpanels vary based on the loads located in the subpanels.

- **Are there any open breaker spaces on the main electrical panel?**

Look in the MDP or subpanels to check for available space to put a breaker, as the electrician need to connect the inverter's output wires to one of these panels by placing a breaker in the panel and wiring the inverter to it. (This process is similar to putting a breaker in the panel for a new set of outlets or a new load except that the electrons are running in the opposite direction.) If the panel is full, you need to either make room or replace the existing panel with a larger panel. Take as much pictures as needed and add all needed information in the site survey from:

- Document the electricity costs price per kWh and ask for an electricity bill to be able to evaluate all involved costs.
- Ask if the client wants to connect its system to the grid
  - ✓ Evaluate the type of grid:
  - ✓ Voltage in V:
  - ✓ Frequency in Hz
  - ✓ Phases:
  - ✓ Other relevant information, such as load shedding schedules and power failures.
- Meter specifications:
  - ✓ Type of meter
  - ✓ Can the meter count in 2 directions?
  - ✓ Is grid feeding allowed
- Lightning protection and grounding
  - ✓ Availability and location of lightning protection

- ✓ Where can the PV array be grounded?

Fig: Pictures from distribution board and meter

3.5.2. Existing power generators

Some customers already use generators or other renewable energy sources. During the site survey you have to document those generators and discuss with the customers how they want to use the systems in the future. Should a diesel generator e.g. only be a backup for the solar system or should solar be used during the day and diesel during the night. Please use the table below to collect as much information as possible from the existing generator and take pictures of the name plates and the complete system.

	Existing generators	**Power in kW**	**Voltage in V**	**Frequency in Hz**	**phases**	**Manufacturer**	**Model**
	Diesel generator						
	PV						
	Wind						
	Others:						

Please provide any further information on Existing Power Generators, Grid Power cuts, usage patterns.

Generator 1	Generator 3
	

Fig: Typical pictures from a site survey

3.6. Technical Planning (Batteries and Inverter)

The final question to be answered is the location where to install the batteries and the inverter. Please take into consideration, that the batteries perform best at 25°C. Ambient temperatures above 20°C have an influence on the lifetime of the batteries. The corrosion rate of the electrodes doubles every 10°C increase (Arrhenius-equation).

Inverters produce not only electricity but also heat but this heat influences the performance of the inverter. Thus, one must make sure that the inverter is placed in a location where cooling or at least the escape of the produced heat is possible. Another important point is the distance to the PV modules. A long distance means more cable, which increases the costs, but also thicker cable as the cable diameter is direct proportional to the cable length. Use the table below to collect information about possible locations for the batteries and the inverters.

3.7. Technical Planning (Batteries)

Is there a room for batteries?		Yes
		No
Where is the room?		
Distance to the PV modules in m		
Distance to the inverters in m		
How is the ventilation of the room, windows?		

3.8. Picture of the room:

3.9. Technical Planning inverter

Can the inverter be installed in the battery room?

Yes	No	
If no, where can they be installed?		
Distance to the PV modules in m		
Distance to the batteries in m		
How is the ventilation of the		

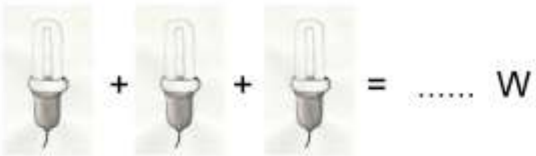
location? (windows, air-conditioning, ...)	

Picture of the room:

Self-Check - 3	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	
1	**Please calculate the total power of the following loads using the below given power per load:** 
A	
B	
C	

2	**Convert the following values:**
A B C D	1 W = ………… kW; 1kW=……………. W 1500 W= ………. kW 1.05 kW=………… W
3	**Calculate the Consumption and the total Watt for a customer with the following loads?**

N°	Existing Consumers	Power in Watt	Amount	Operation Hours per day	Usage Time	Consumption [Energy]	Total Power in Watt
		[W]	[qty.]	[h/d]		[Wh/d]	[W]
1	Illumination	15	2	3.0	night		
2	55" led tv	60	1	3.0	night		
3	decoder	45	1	3.0	night		
4	Laptop	65	1	2.0	day		
5	Charge Controller	0.15	1	4.0	Day/night		
6	Inverter standby	0.5	1	20.0	Day/night		
7	Inverter ON	6	1	4.0	Day/night		
8							
9							
10							
11							
Total:						Wh/d	W

A3	Energy Consumption [E]	Wh/d

A4	Total Power in Watt [W]	W
A5	Total Power per Day in Watt [W]	W
A6	Total Power per Night in Watt [W]	W

Note: the satisfactory rating is as followed

Satisfactory	26 points
Unsatisfactory	Below 13 points

4.1. Conducting interviews

The paragraphs below are taken from [Mayfield, 2010, chapter 5, page 79]. One of, if not the most exciting portions, of the overall system installation process is the site survey. Why? Because you get to work with a blank slate (after all, the client shouldn't have another PV system anywhere on his building or property) and create a PV system from the ground (or roof) up. As the person who performs the site survey, you need to be able to identify any potential trouble spots and the best ways to address the issues they pose from the beginning of the project.

The site survey is generally your one chance to obtain all the required information about the site to create a proposal that works for both you and the client. It's also the only time you can really work with your client to establish his goals and expectations for his PV system before you're too far along in the process. When you're at a client's house or business to perform a site survey, you must be diligent about collecting the information you need. You don't want to leave out any information that may prove critical for you to provide an estimate and a quality design for your installation crew. Return trips to gather information that should've been collected the first time around do nothing but waste your time and risk making you look less than professional.

The planning and construction of a PV system is generally initiated by a customer's enquiry. As well as the quotation, consultation with the customer is an important and essential step before commissioning the construction of a PV system. In discussion with the customer, the tradesmen should find out about the customer's expectation and wishes. Competent advice to the customers is vital, as tradesmen are often the first point of contact for questions on solar energy use. As well as technical knowledge concerning structure, function, sizing and the installation of PV systems, they should also possess knowledge about costs/subsidies and the global significance of solar energy use.

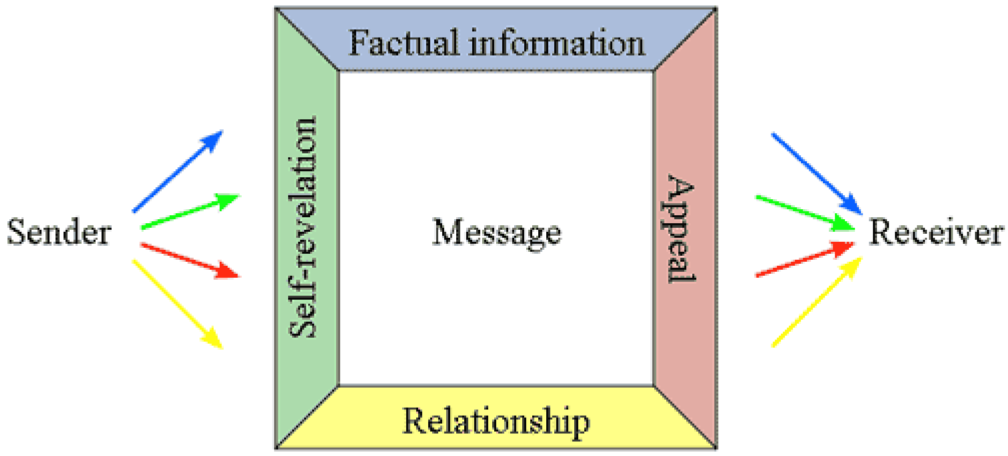
The aim is to win the customers as active dialog partners and to answer their questions in a way that is comprehensible for the non-expert. Here it is helpful to use diagrams as explanatory aids.

4.2. Four side model

The paragraphs below are taken from www.skepticalscience.com/The-four-sides-model-for-improving-climate-communication.html and adapted from the authors. A classical way to analyse communication is by the "four sides model" by the German psychology professor and expert on inter personal communication Friedman Schulz von Thun. Let me explain the model in a few words. For simplicity, let's talk about a 'sender' saying something and a 'receiver' who is listening. Schulz von Thun postulates that there are four channels that we communicate on simultaneously, namely:

- **Fact channel:** the facts communicated
- **Self-revealing channel:** what the sender says about him or herself
- **Relationship channel:** what is being said about the relationship
- **Appeal channel:** what the sender wants the receiver to think or do

Table: Fours side model communication model



Simply speaking, in good communication, we neither have a mix of channels (sender said something on channel A, but receiver listened on channel B), nor a misunderstanding of the content communicated in each channel. Of course, the channels have two ends: four mouths and four ears! That means that the sender speaks in all four channels simultaneously and the receiver hears with all four ears at the same time.

Let's look at an example from debating about sceptic arguments. Imagine you're saying: "The earth is dramatically heating, that's obvious." Depending on how you're saying this and the context, the listener may be hearing very different things. Maybe you are trying to communicate the Fact channel and would like to quote all the different studies on the earth's heat in the last 100 years. But what if the listener hears "You shouldn't fly!" (Appeal channel) or "I think you are stupid not to know this by now!" (Self-revealing channel). I hope you are getting the point of the model. Now, how can we avoid this type of miscommunication? A good start is to keep this model in the back of your head and try to communicate clearly in all those channels and follow the following advices:

- Focus on the fact channel and formulate the messages as such (e.g.do not use rhetorical elements like "that's obvious!" or “as you know”). Sceptical Science is a very good role model for this. If you don't know an answer to an argument immediately, defer answering and take your time to research, instead of inadvertently switching to other channels.
- Use "I" sentences, when communicating on the Self-revealing channel. I find this channel less problematic. Let people know when you are concerned about the earth, the future or your children.
- The appeal channel is more complicated. I think that a lot of miscommunication happens on this channel, as the receiver's bad conscience is very likely to hear a lot of things on this channel that were not really said. Maybe you would really love to see the other person immediately starting to be proactive in protecting the climate ASAP, but you can't expect for people to change in a second. My personal feeling is that the facts are so clear that your appeal will come if you succeed communicating the facts.
- Most dangerous is the relationship channel. You should ensure that you do not make any difference in your relationship to your communication partner, whatever the reactions to your arguments are. This is especially important for very close people. If you are soft on the person, you can be hard about the facts. So keep on listening, don't raise your voice unnecessarily, watch your face expressions, fit in a joke at times, and don't mix up other things with the debate (like indicating not going to lunch with a co-worker, because he or she didn't accept what you said about a sceptic argument).

It is difficult to follow the advice given above, because the channels are never so clearly defined and it's complicated to focus on all of these things at once, while discussing the complex matters. The most important information out of the communication model is only because you (as sender) say something this does not mean that the client (as receiver) understand exactly the same and vice versa. You have to double check facts with questions, and you can use the side survey form to document all details. Another very important point is that the client and only the clients knows what he wants, and he will tell it to you. Do not make the mistake to move him in another direction, focus on listening. You are the subject matter expert; thus, you can explain to the client what a PV system is and how it works and which one could be suitable for him, but the client makes the decision at the end. Do not try to sell him your idea, understand his idea and develop a concept for him from his idea.

Self-Check – 4	Written Test

Instruction: Follow the below selected instruction

B	For each of the following question choose the best answer and circle the letter of your choice.

N°	Questions and answers	
1	**The four channels of communication according to Schulz von Thun are?**	
	A: Fact channel Self-revealing channel Relationship channel Appeal channel:	B: Telefon Mobil Internet E-Mail
	C: Wifi 3G LTE Modem	D: TV Radio YouTube Netflix

Note: the satisfactory rating is as followed

Satisfactory	1point
Unsatisfactory	Below 1point

1.1. Conducting assessment within the prescribed time

The paragraph below is taken from [Mayfield, 2010, chapter 5, page 79/80] and adapted for Africa by the authors. You can't conduct a solid site survey without allowing yourself ample time and staying focused. If through preliminary phone or in-person conversations with the client you get a feeling that he'll require extra time, then schedule yourself enough time to answer his questions while leaving enough time to collect the information you need. Speaking of questions, the one you'll hear most often (aside from "What's the average cost?") is "Can I run my fridge/computer/lamps/AC?" Although this can be a difficult question to answer without knowing a number of specifics, you should have an answer for it. You have to be familiar with what a 1 kW PV array can produce in the client's area and how many days a battery bank has to last without sunshine. Figuring out what a 1 kW system can produce means you can easily do the math to adjust the values for your client's site. You even can look for tools, such as the SMA app or the PV Solar online calculator: http://pvsol-online.valentin-software.com. One of the best features of this tool is the ability to vary input factors such as the direction you want your array to point or what tilt angle you want it to have. With just a few mouse clicks, you can run some scenarios and be able to determine the best solution for your site

Normally, we start with a short phone conversation or discussion by email where we can get some general information about the goals of the customer, the site and the current energy requirements. A site visit by the assessor is arranged for at this time.

The site visit takes two to four hours during which you have to make site and usage observations, measurements, and can further discuss goals and options with the client.
Make sure that you complete all questions of the site survey form and that the client gave you all needed information. To understand the wish of the client is crucial, however you should limit the site assessment to max 4 hours.

Self-Check –5	Written Test

For each of the following question choose the best answer and circle the letter of your choice.

1 How long should a site assessment take?

A – 30 Minutes B – 2 to 4 hours

C – 5-6 hours D – 1 day

2 We can get some general information about the goals of the customer by phone conversation or email where.

a. True
b. false

Note: the satisfactory rating is as followed

Satisfactory	1point
Unsatisfactory	Below 1point

Operation sheet 1	Accomplishing forms load assessment

Method of preparing site survey form & collect all needed information and collect all needed information to plan a PV system

- Step1: Sit down with the client, get to know him and understand where he is coming from.
- Step2: Start to complete the form during the discussion and explain the client why you collect all these data.
- Step3: Visit the side with the client, make notes and take pictures
- Step4: Sit down again with the client, go through the notes, complete the notes, get additional information.
- Step5: Get the signature from the client on the site survey form

LAP Test	Practical Demonstration

Name:		Date:	
Time started:		Time finished:	

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 2 hour.

Task 1:

Your instructor will give you a site survey form and tell you for which building of the school you have to prepare a site survey. Complete the form and collect all needed information to plan a PV system for the selected building.

Solar PV System Installation and Maintenance

Level-III

Learning Guide -23

Unit of Competence	Determine PV system Customer Requirements
Module Title	Determining PV system Customer Requirements
LG Code	EIS PIM3 M06 LO1 LG-23
TTLM Code	EIS PIM3 TTLM 0920v1

LO2: -Recommend options for simple solar home and institution system

Instruction Sheet	Learning Guide 23

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Gathering information for system recommendation
- Approving recommendation to the customer requirement.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to: -

- Gather information for system recommendation
- Approve recommendation to the customer requirement.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

1.1. Gathering information for system recommendation

The main source for this chapter is chapter 12 of Mayfield's Book "PV Design and Installation for Dummies". Some paragraphs are taken from [Mayfield, 2010, chapter 12, page 203], some are adapted for Africa by the authors and some are added by the authors.

In this information sheet we show how to read and evaluate the data form site surveys. We show how to perform a load analysis, what are the important parameters to size the PV generator, the Inverter, the charge controller and the batteries and how to select the appropriate system for the client, AC or DC-coupled, ground, roof or pole mounted, hybrid or stand alone.

Table: Types of off-grid PV systems

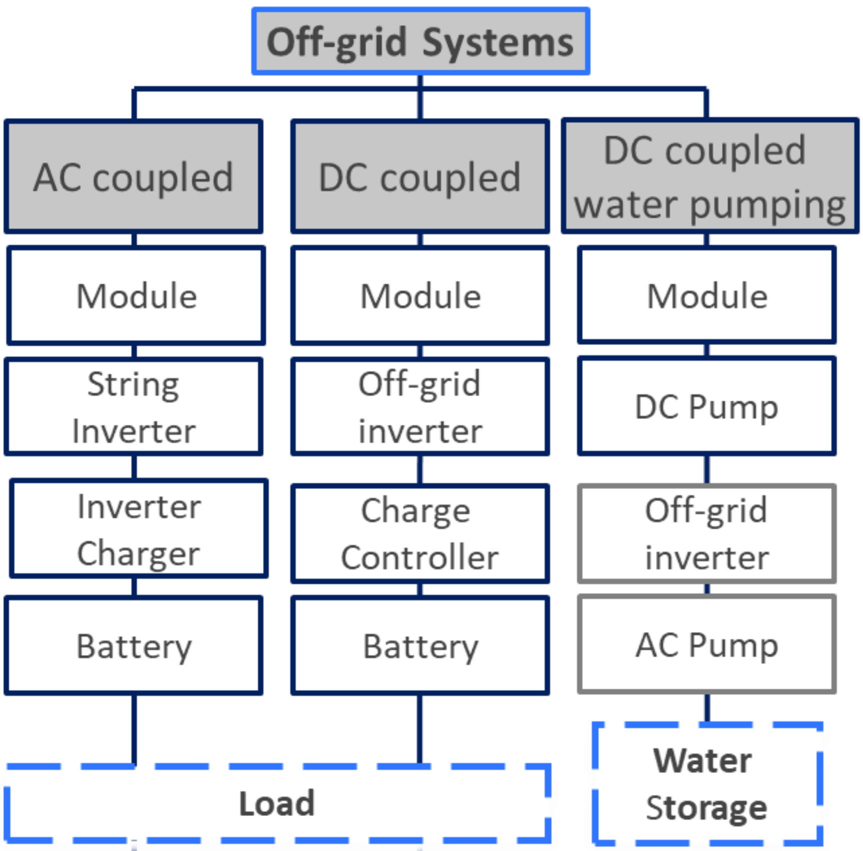
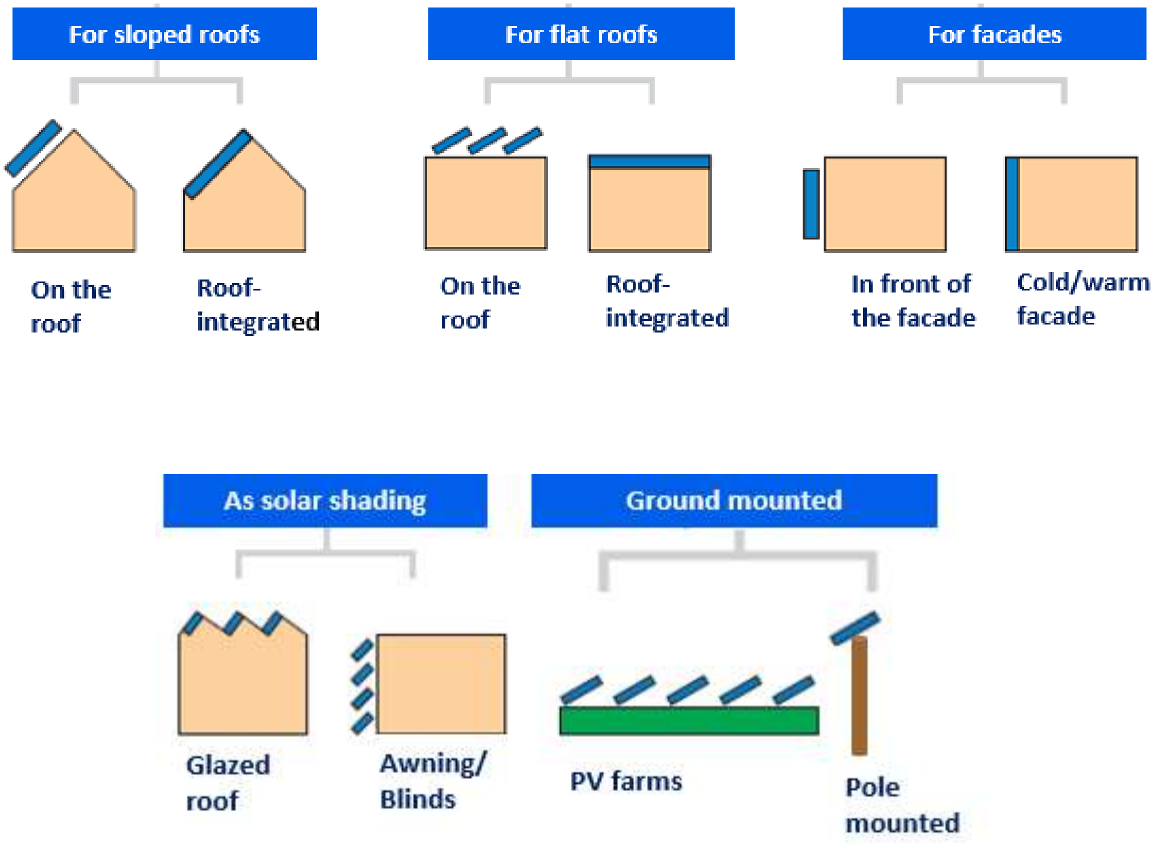


Table: Types of PV mounting systems

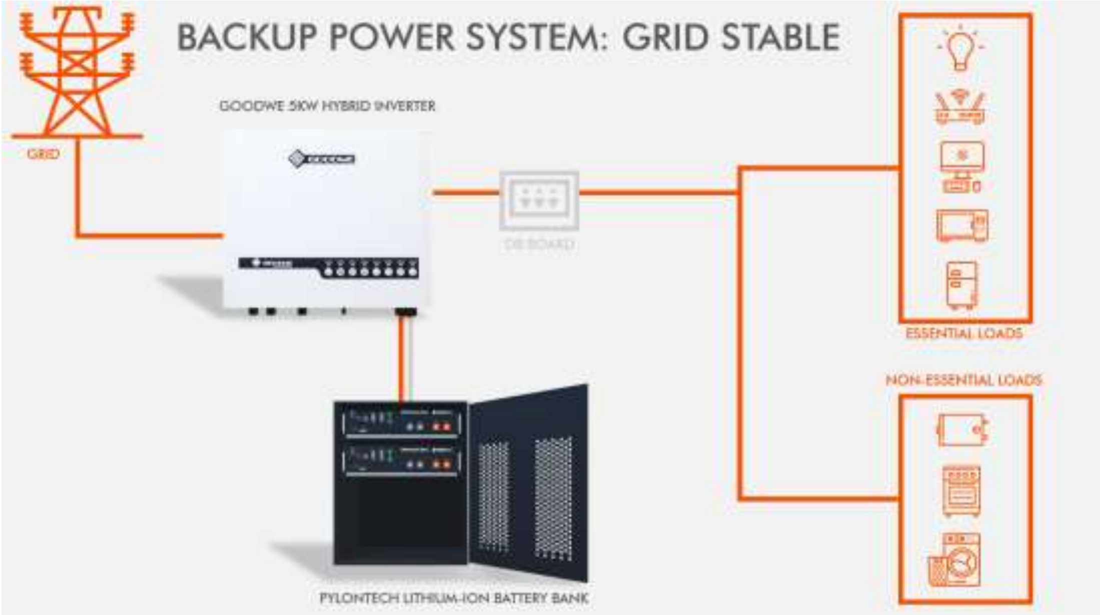


1.2. Performing a load analysis

A load is any piece of electrical equipment people want to use in their homes and offices as described in chapter 3.3Loads/consumptions. When sizing a battery-based system, you need to establish exactly what loads your client wants to run and how long they plan to run those loads. This information serves as the basis for all of your other calculations throughout the design process.

For utility-interactive, battery-based systems, the battery bank provides power for essential loads (loads that the client wants to have on regardless of the utility availability). In this scenario, you have two load centres: the main distribution panel (MDP) and the backup subpanel. Any of the loads connected to the backup sub-panel will always be available, whereas the essential loads connected to the MDP will only be powered when the grid is present.

Table: Backup system for essential loads (Sinetech, 2020)



For stand-alone, battery-based systems, the battery bank is designed to power all the electrical loads the client wants to run.

1.3. Evaluating the loads that the battery bank must serve

After determining your client's budget and available space, your next task when sizing any battery-based system is to evaluate the loads the batteries will be serving. When I say loads, I mean all the loads — everything from the barely-there energy drain (think small cell phone chargers) all the way up to the electrical hogs (think air-conditioning units). When using batteries to power loads, you have to generate and store every watt-hour (Wh) used, which means you also need to find out whether a more efficient alternative exists. For example, compact fluorescent light bulbs (CFLs) produce the same amount of light as incandescent lights, but they use a lot less power. If you can convince your client to replace her incandescent bulbs with CFLs, her battery bank will be able to deliver power for more loads due to the reducedpower requirements. Ultimately, the less energy your client consumes, the less expensive the system will be to install and maintain.

If the client has no access to electricity so far you should even consider to offer him a complete DC system with decent DC devices. This only makes sense, if DC loads are available locally, if the customer has the budget to invest in DC loads and if the customer does not intend to use AC loads or to connect to the grid. People from rural areas often rely on their relatives who work and live in the City. In this case they usually get the old devices (computer, TV, fridges) from the relatives, which are always AC devices. Make sure that this is not the case, as it would be very frustrating for the client if he would have a DC system and then not be able to operate those AC loads. Following are some points to consider about the common loads powered entirely or partially by battery banks:

- **Well Pumps**

In many situations, a well pump is the sole source of water for a home. Well pumps can be large electrical loads with the potential to cause problems for the inverters and batteries in a battery-based system. With advancements in inverter technologies, however, inverters are much better at running these large pumps.

Look at the well pump's power draw and try to determine the energy consumption (see the next section for details). If the pump is being replaced or hasn't been installed, try to work with the pump supplier to get the most energy-efficient version available. DC pumps are especially interesting as you can run them directly with a solar module. The American company, SHURflo, is one company which offers great solutions for remote water pumping. One can use these pumps by only connecting the solar module with the pump, in case both have the same voltage. If not, a pump controller could be needed. In any case no extra battery is needed. The water is pumped when the sun is shining and stored in a tank. This can either operate automatically using water level sensors or purely manually using a person to switch on and off the system.

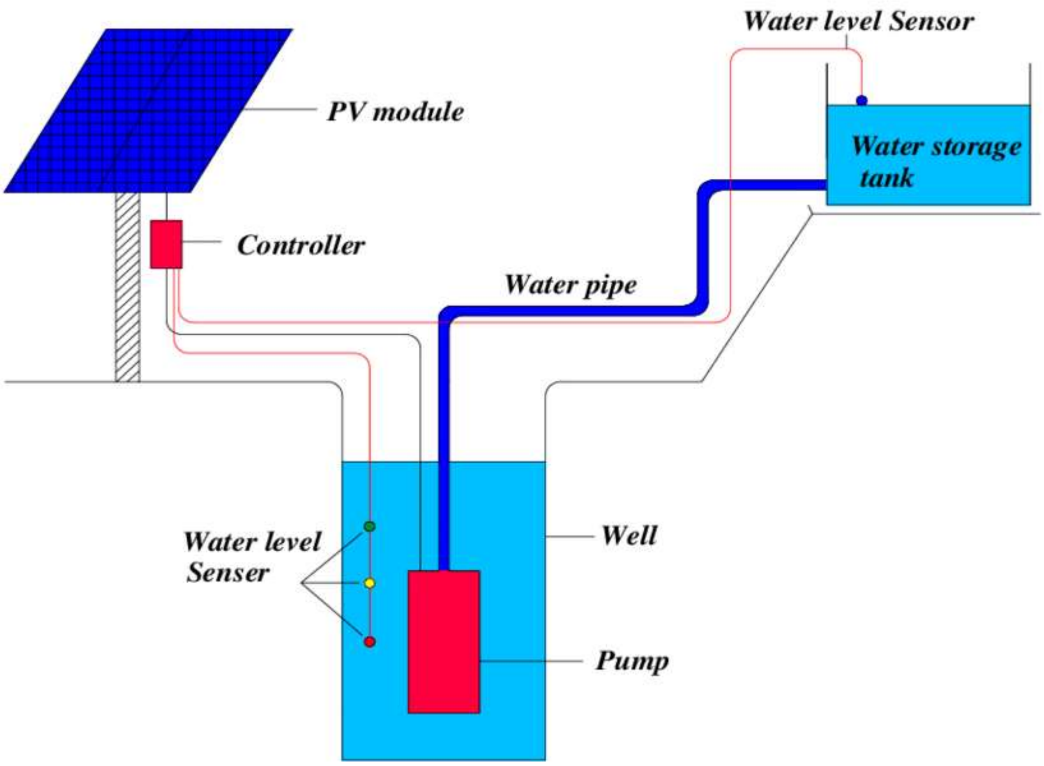


Fig: Principle of solar water pumping using a submersible pump

- **Refrigeration and lighting**

Refrigeration and lighting will be present in most homes or offices, so you need to be able to account for them accurately. In the next section, I show you how to account for the energy consumed by these appliances and how to make sure you design the battery system to handle these loads.

- **Phantom loads**

The small loads that are on 24/7 are the so-called phantom loads. Many televisions and entertainment centers draw power even when they're "off," and chargers for small electronic devices and digital clocks incorporated in microwaves and stoves can cause major problems. If these small loads are always present, then the inverter can never turn off and must always supply power. Therefore, the inverter requires a small amount of power to produce a low level of power, causing it to operate at its worst efficiency level.

The solution to phantom loads? When no major loads are running, allow the inverter to go to sleep by unplugging the phantom loads. By removing these small loads, the inverter can go to sleep and wake up (and operate more efficiently) when the larger loads are turned on.

1.4. Loads one should not operate with PV systems

One type of load that should never be placed on a battery bank is anything that uses electricity to generate heat (these are called resistive loads). That rules out water heating, space heating, and electric stoves (incandescent lights also fall into this category). In a stand-alone, battery-based system, petroleum-based fuels generally support resistive loads, with propane being one of the most common in off-grid applications. For people connected to the grid with a utility-interactive, battery-based system, these loads can still be present; you can't just back them up with the batteries.

- **Back-up systems**

In back-up systems, also called utility-interactive, battery-based system, loads served by the batteries should generally be kept to a minimum; the batteries should only supply power to loads that are truly necessary (which means you need to have a frank conversation with your client to help her evaluate what's reallynecessary in her daily life). This is because the utility grid is the primary power source, and the batteries are merely the backup power source.

When talking about utility-interactive, battery-based systems, people often refer to loads the battery bank needs to back up when the grid fails as critical or essential loads, see Table.

- **Typical and Essential Loads**

Only the customer can decide which loads are critical or essential for him. Sometimes it is an electric fence, sometimes light, sometimes TV. Typical essential loads in Ethiopia are light, internet, mobile phone charger, computers, TVand printers.

You must be careful though; if you make it too easy to pull power from the battery bank, the system owner will do exactly that and then be disappointed in the lack of time that the batteries back up those "few" loads.

For a stand-alone battery-based system, a load is just a plain old load, not a backup load or a critical load. People who live in off-grid homes typically have major lifestyle differences from people who live in homes that are onthe grid. They have to evaluate the necessity of anything that requires electricity to run because they don't have unlimited access to electricity. This doesn't mean that your client can't lead a "normal" life (whatever that means anymore); she just has to become selective in her electrical consumption.

- **DC Loads**

Some clients with stand-alone systems may want to run some loads straight from the DC electricity stored in the battery bank. Nowadays, you can find almost any load you need for rural areas as DC loads, whereby the most common loads are lamps and fridges. giz published 2016 a catalogue of DC-Appliances under the title “Photovoltaic for Productive Use Applications”

Fig: Typical DC Loads from the company Solar Works

These DC loads are nice in the sense that they can pull power directly from the battery bank without the help of an inverter, which increases the overall efficiency of the system because the loads use the same type of electricity produced by the PV array and stored in the batteries. However, DC loads are found in special locations and must be matched to the voltage available from the batteries and the clients need to have the budget to invest in those loads as described above. Keep DC loads separate on your list of loads. When you have to account for system efficiencies, you’ll use the DC loads in your calculations.

1.5. Calculating the energy required during an outage for utility-interactive systems

For a utility-interactive, battery-based system, you need to know how much energy your client will need to use over a very short period of time. After all, most people experience power outages that are measured in hours (or a few days at the most). On top of the short duration, typically only a few loads need to be backed up during an outage. If, however, your client insists on powering the entire house/office or a number of major loads, you need to incorporate a generator into the system design When designing a back-up system, look at the loads the client wants to run during an outage and estimate how much energy they'll consume during the specific amount of time required. You can do this by multiplying the total drawn watts for a load by the number of hours it needs to run during a utility outage to find the total energy consumption during the outage. Generally, 24 hours is enough, except for those clients who want to have multiple days of backup.

1.6. Determining the average daily energy consumption for stand-alone systems

After you've identified all the loads (both AC and DC), you need to evaluate how much energy each load consumes in order to begin the process of sizing all the required components. Going through the load analysis may seem like a real pain, but if you don't take the time to estimate each load's energy consumption, the installed system will be either grossly under- or oversized for your client's needs. Both situations result in a waste of time and money.

To determine the amount of energy consumed by each AC load in kilowatt- hours (kWh), you need to know the number of watts the load draws, the amount of time it runs each day, and the number of days it's used each week. Certain loads may only run a few times a week, whereas others may run daily. By averaging out the loads over a week's time, you can establish a consistent pattern of energy consumption. Use the following equation:

Energy (in watt-hours) = (Watts × Hours per day × Days per week) ÷ 7 days per week

When estimating weekly energy consumption, include all the watts drawn. For example, if you're looking at lighting, don't just calculate the energy based off of one light — look at all the lights that will be on at the same time. Please also consider the usage time, is the load being used in the night or in the day only, or even permanently.

The source to calculate the energy and the power you need is the consumption table from the site survey.

1.7. Example, family house in Adama

The Kebebe family (2 adults and 4 kids) lives in the Adama region in a town house without electricity. They called the PV Installer Dave and ask him if he could deliver a solar system for their house. They know about Dave as he installed a system for Mr.

Kebebe's brother. Dave explained to him that one cannot sell a PV system as if it were a TV, as the system has to be adapted to the requirement of the individual family and they agreed that Dave comes for a site survey.

Fig: The house of the Kebebe family in Adama

During the site visit, Dave discussed the electricity use with the Kebebe's and documented the power consumption as part of his site survey, see raw 1 to 7.

Table1: Electricity consumption overview of the Kebebe family

1	2	3	4	5	6	7	8	9
Collected Information							Calculated Information	
No.	Technical device	AC or DC	Quantity	Power [W]	Operation time [h]	Usage Time	Consumption [Wh/d]	Total Power in Watt
1	Illumination	AC	4	3	6	night	72	12
2	19" led tv	AC	1	15	7	night	105	15
3	decoder	AC						
4	Laptop	AC	1	65	2	Day	130	65
6	Charge Controller	DC	1	0.15	24	Night/day	3.6	0.15
7	Inverter standby							
8	Inverter ON							

TOTAL	310.6Wh/d	92.15W
Total day		92.15W
Total night		27.15W

As a first step Dave has to calculate the total consumption of the Kebebe family and note his results in column 8 and 9. Kebebe use 4 lamps that draw 3 W for 6 hours. They run 7 days a week, thus you can determine the average daily energy value by multiplying the number of lamps, the power drawn and the number of hours to get

4 lamps x 3 W × 6hrs. = 72Wh, or 0.72 kWh So, the operation of the lamps consumes 0.72 kWh every day. The overall electricity consumption is 310.6Wh/d with a max. power of 92.15W.

The Kebebe family only uses AC loads, as they already got all devices from their relatives, thus, it was easy to evaluate the overall energy consumption. Sometimes the clients have not yet purchased their devices, then you could estimate loads using typical devices. See some examples below.

Table2: Performance of typical 12V lamps (Hankins, 2010)

Table 6.1 *Performance of typical 12V lamps*

Lamp type	Rated watts (W)	Light output lumens (lm)	Efficacy (lm/W)	Lifetime (Hours)	Light colour (K)
Incandescent Globe	15	135	9	1000	2700–3000K
Incandescent Globe	25	225	9	1000	2700–3000K
Halogen Globe	20	350	18	2000	2700–3000K
Batten-type Fluorescent (with ballast)	6	240	40	5000	4100–6300K
Batten-type Fluorescent (with ballast)	8	340	42	5000	4100–6300K
Batten-type Fluorescent (with ballast)	13	715	55	5000	4100–6300K
PL-type Fluorescent (with ballast)	7	315	45	10,000	4100–6300K
LED Lamp	3	180	30–100	>50,000	Depends on lamp type

Table3: Approximate power and energy requirements for common off-grid appliances (Hankins, 2010)

Table 6.3 *Approximate power and energy requirements for common off-grid appliances*

Appliance	Typical daily usage time	Power rating (W)	Typical daily energy use (Wh)	Notes
Sewing machine	2 hours	80	50	Motor is engaged only 25% of time
14in colour television	2 hours	80	160	More efficient versions available!
14in black-and-white television	2 hours	24	48	
Radio	3 hours	3–30	9–90	Power draw depends on volume setting
Music system	2 hours	10–40	20–80	Power draw depends on volume setting
Electric iron	30 minutes	300	150	Not recommended for PV systems
Soldering iron	10 minutes	200	45	
Electric drill	5 minutes	150	30	
Computer and monitor	2 hours	80–150	160–300	
Laptop computer	2 hours	25–40	50–80	
Fan	continuous	60	1440	
Water pump	3 hours	450	1000	
DC Refrigerator	continuous	100–150	300–450	Actual energy use depends on ambient temperature. Refer to datasheets

1.8. Autonomy days

The number of days your client wants their battery bank to sustain their electrical lifestyle is known as the days of autonomy. In other words, it's the number of days the client expects their battery bank to provide her with her average daily energy requirements without needing to be recharged by the PV array and the charge controller, generator, or utility. This number is completely up to the system owner but you (as the system designer) should offer suggestions that will keep your client satisfied. The local climate usually plays a major role in this decision, as does the available budget for the project. As you can imagine, the more days of autonomy, the more batteries you need and the higher the system cost climbs.

Off-grid system for telecommunication towers usually need up to 5 days to secure the on-going performance, as usually technicians come max. one per year for maintenance purposes. Households can sometime deal with 1 ore 2 autonomy days as they life with their system and could decide to use less loads during days with less sunlight.

1.9. Determining the PV generators' capacity

The relevant values to size the PV generator are:

- The energy consumption of the customer
- The insolation or sunshine hours and
- The usage time of the PV system (permanently, seasonally, selected days only…)

1.10. Introduction

When the battery-based system you're sizing is of the stand-alone variety, the PV array needs to produce an amount of energy equal to your client's average daily energy consumption (as calculated in the earlier section).If it doesn't, the battery bank will never be able to recharge fully. In addition, the array should be able to help recharge the battery bank after there has been little to no charging by any source (such as the PV array or a generator) and the battery bank has dipped into the reserve supplied by your client's desired days of autonomy, see 0.

In reality, the amount of energy consumed isn't a constant value; it changes throughout the year. Depending on the size of the house and the location, people may have a different energy consumption in the different seasons. Some houses use fans or air conditioners, but only in the warm months. In some regions the days are much shorter inwinter and the families need less light at night. You have to consider all those facts while evaluating the electricity consumption and determining the PV generator.

The advantage of most of the regions in Africa is that the high energy consumption related to hot summers correlates with high solar resources. In Europe usually high consumption is related to winter. This situation presents a problem for the PV system designer. If you design the PV array around the scenario of high consumption and low solar resource, you'll end up with a PV array that's very large. Come summertime, when the energy consumption is reduced and the solar resource is increased, the PV array will be oversized and have the batteries charged very early in the day, which is bad because the PV array will be underutilized those times of the year, and the initial system cost will be outrageous.

To determine the appropriate array size in watts, you need to evaluate the information about the site you gathered during the site survey and make some assumptions regarding the operation of the system. These values will help you estimate the array size needed based off of the total energy consumption you calculated in the very beginning of the process.

The power of the PV generator is calculated as follows:

$$P_{PV} = \frac{E}{G \times h} = \frac{\text{Energy Consumption in } [\frac{Wh}{d}]}{\text{Peak Sun Hours in}[h] \times \text{System Efficieny}}$$

You need to know the:

- Energy consumption (to be calculated based on the data collected during the site survey).
- the solar irradiation in the respective region; the “fuel” which is available in peak sun hours and (to be researched using tools like PVG is or PV Sol)
- the system efficiency (to be calculated)

The approach is simple, you calculate how many modules you need to produce enough electricity to fuel your hour loads.

The Energy consumption is the electricity you need.

The peak sun hours is the electricity the sun is sending.

And you simply divide these 2 values by each other. To ensure that you really have enough electricity you multiply the PSU with the system efficiency. Meaning you say that you can never use 100% of the solar electricity which arrives on the PV modules, but only less, typically 65%.

1.11. PV Generator for the Kebebe Family

Dave investigated the weather conditions in Adama and found the following information:

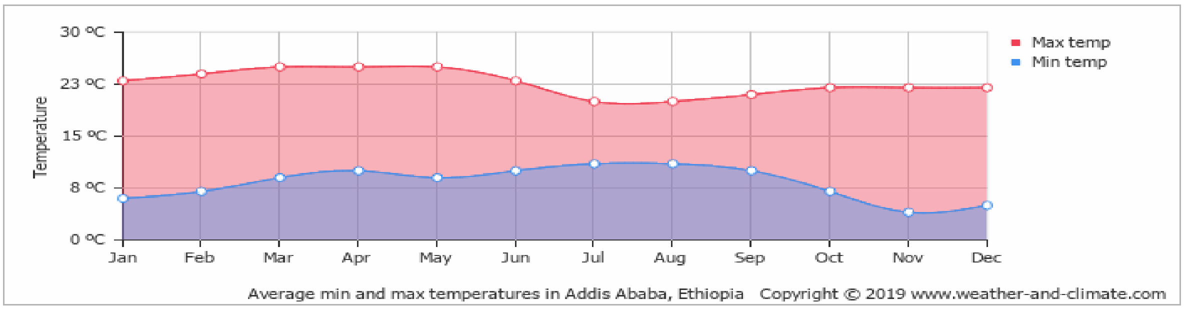


Fig20: Average max and min Temperature in Addis Ababa

Fig21: Average sun hours in Addis Ababa

Furthermore, he checked the average peak sun hours with the PV GIS tool.

Peak Sun Hours: Mekele Optimal (Slope: 11 degrees, Azimuth 12 degrees)

J	F	M	A	M	J	J	A	S	O	N	D	Ø
6.96	7.43	7.35	6.56	6.24	6.13	**5.63**	5.75	6.23	7.05	6.93	6.93	6.6

He decided to design the system based on the minimum peak sun hours5.63 h, as the yearly changes are not that high.

$$P_{PV} = \frac{E}{G \times h} = \frac{180.6\ \frac{Wh}{d}}{5.63 \times 0.65} = \mathbf{84.87Wp}$$

Dave always works with a system efficiency of 65%,as this is a proven value. How to calculate the system efficiency is explain in module 1 level 4.

1.12. System Voltage

For any battery-based system you install, you need to look at battery bank nominal voltages of 12, 24, or 48 V_{DC}. The basis for the selection of the battery bank voltage is the system voltage, which depends on the PV array capacity and needed power. The table below shows suggested system voltages for different inverter power.

Table4: System Voltages of PV systems

System voltage*	**12 V**	**24 V**	**48 V**
Limiting power generator/inverter	**Up to 1 kW**	**1-5 kW**	**5 kW & over**

According to Hankins, 2010 “system voltage is the nominal voltage at which the batteries, charge regulator and solar array operate. Also, system appliances often operate at the system voltage. Most small off-grid PV systems (especially solar home systems below

100Wp) use 12V DC as their system voltage. This means batteries are configured at 12V DC and the charge regulators and modules are rated at 12V DC. Lights are normally 12V DC in such small systems. If there is a need for AC power, an inverter is used to convert 12V DC electricity from the battery to the desired AC voltage.

Sometimes 24 and 48V DC system voltage is used. In such cases, batteries and solar modules are wired in series or series-parallel so that they are 24 or 48V, and 24 or 48V charge regulators and inverters must be selected. Such systems have less voltage drop in wire runs, so they are often selected to save on cable costs (48V DC systems are common in off-grid telecom systems). However, note that 24 or 48V DC appliances are not readily available, so 12V DC system voltage is usually preferred. MPPT charge controllers accept electricity from the array at a range of voltages (i.e. from 15 to over 100V) and deliver it to the battery at 12 or 24V. Many charge regulators and inverters can operate at either 12 or 24V DC. They sense the system voltage and adjust to it automatically. Even though an inverter is used to convert power from DC to AC on the distribution side, the system voltage will still be between 12V and 48V."

1.13. Determining the battery bank's capacity

The relevant values to size the battery banks are:

- System voltage
- Autonomy days
- The energy consumption of the customer

After you know what your client's electrical lifestyle is on an average day, you need to translate that into the amount of energy stored in her battery bank (also known as the battery bank's capacity). For any battery-based system — whether utility-interactive or stand-alone — when you size the battery bank, you take the view that no other source of power exists (at least for a certain amount of time) and that the battery bank is the primary source of energy (the PV array, a generator, or the utility merely replenishes the battery bank when it discharges). Consequently, you need to size the battery bank to run the electrical loads your client wants, when she wants — which means you need to establish some criteria that you expect the battery bank to follow. All of the following dictate the battery bank capacity you're looking for:

- The efficiency of the inverter

- The number of days you expect the battery bank to last without recharging
- The batteries' operating temperature and voltage
- How much of the battery bank your client is willing to use
- The voltage at which you want the battery to operate

When you buy batteries to make up the entire battery bank, you have a few options. The most common battery type for battery-based PV systems is a 6 V nominal battery (This battery has three individual cells in it that are all wired internally to deliver 6 V across the terminals.). You then take these batteries and wire them in a series-parallel arrangement to achieve the voltage and capacity characteristics you're after. Other options include 12 V nominal batteries as well as individual 2 V cells in their own plastic cases; these cells look like batteries, but because there's only one cell, technically they're cells and not batteries. (Batteries also come in 4 V and 8 V nominal arrangements, although these are less common.)

1.14. Making sure the inverter fits

The relevant value to size the inverter is:

- Maximum power of all consumers per day.
- Capacity of the battery

You must discuss which load is relevant to design the inverter and select an inverter with a continuous power which is higher than the relevant max power of the loads.

$P_{INV, continuous} > P_{loads}$

To ensure that the loads do not harm the inverter we even include a safety margin of 30% in this calculation.

$P_{INV, continuous} > (1,3xP_{loads})$

The Mekele family you should design the inverter based on the power P_{loads}= 92.15W.

$P_{INV, continuous} = P_{loads}$= 92.15Wx1,3=120 W

You should suggest to the Mekele family an inverter with a load of 120W. Off-grid inverter loads are usually given for continuous 30s and 5 s operation. This means you can operate higher loads for a short time so that short peaks do not destroy your inverter. It is important that your customer understands that a 120W inverter could not operate a 500W boiler. Cheap ones will break, better quality ones with overload protection will switch off. However, these overloads should be avoided.

All inverters are rated by their maximum continuous power output, which is measured in watts or kilowatts (More often than not, this number is incorporated into the inverter's model number, giving you a quick idea of the inverter's rating.). This value is the AC power output. Inverters limit their power output, so you can use this value to figure out the maximum power input coming into the inverter from the PV array. During the detailed design process, you also have to consider that the module ratings fit to the inverter and that the battery bank is big enough to ensure inverter stability.

1.15. Calculating required charge controller

The relevant value to size the charge controller is:

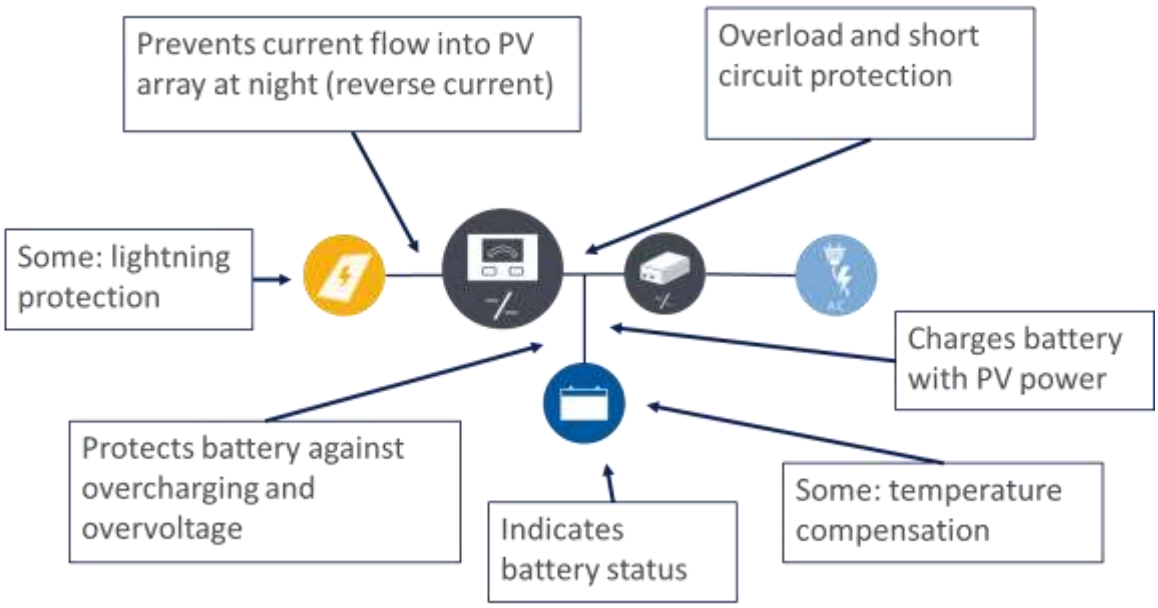
- The system voltage (Series and Shunt charge controller)
- The output of the PV generator and
- The Capacity of the battery
- The temperature variation of the modules

There are 2 main types of Charge Controllers, PWM and MPPT Controller. The right Charge Controller is chosen considering budget, climate zone, module availability and required power.PWM charge controllers work on system voltages and can operate systems with 12, 24 or 48 V modules. MPPT chargers are preferable when using solar panels with more than 36 cells in a 12V system or 72 cells in a 24V system or when using 60 cell modules as they work on system voltages.

Depending on the energy demand, the budget of the customer and the availability of material, especially modules, you would suggest either a simple system with PWM charge controller or a more complex system with the MPPT charge controller. The Charge Controller is the “brain“ of a PV off-grid solar system. It controls how much energy from the Module is forwarded to the battery to optimize the charging process. It also protects the battery from deep discharge by showing you how much energy is in the battery. And it monitors the discharge, but only of the DC loads. The figure below shows the tasks a charge controller takes over in a DC coupled off-grid system. The arrows in the picture show where the charge controller has an impact.

The charge controller is the “brain” of the system that interprets the needs of the battery so it has many tasks. All the programming regarding the charging is done at the charge controller, such as nightlight function e.g. In general, the main task of the charge controller is charging the battery and keeping it “healthy “.

Table22: Functions of a charge controller in an off-grid system



Self-Check – 1	Written Test

Instruction: Follow the below selected instruction

Say true if the statement is write say false if the statement is wrong

1 A load is any piece of electrical equipment people want to use in their homes.

2 For a utility-interactive, battery-based system, you need to know how much energy your client will need to use over a very short period of time.

3 There are 2 main types of Charge Controllers, PWM and MPPT Controller.

4 The right Charge Controller is chosen considering budget, climate zone, module availability and required power.

Note: the satisfactory rating is as followed

Satisfactory	2points
Unsatisfactory	Below 2points

Information Sheet 2	Approving recommendation to the customer requirement

2.1. Approving recommendation to the customer requirement

If your client wants to buy an off-grid PV system you have to decide which type and size of system he needs. The main criteria are how many Watt the consumer wants to operate and how much time he wants to use them. Also, you can vary the capacity of the battery, the power of the inverter and the power of the modules to adjust them to the requirements of the customer.

Other important points are the budget of the customer and the available space. Customers usually have different reasons why to invest in a PV system and you have to understand where your customer is coming from. Here are 6reasons for buying a SHS:

- **Financial Savings.** With an off-grid solar system one is independent from rising electricity costs; the power of the sun is free!
- **Security.** When the public grid breaks down one still has energy.
- **Independence.** Even when one lives in remote areas without a connection to the public grid you have electricity from your off-grid solar system.
- **Mobility.** When one travels a lot and needs electricity wherever a small portable SHS is comfortable.
- **No disposable batteries.** With an off-grid solar system one can operate directly radios or lamps at home or charge small rechargeable batteries to run these mobile devices. No more money to spend on disposable batteries and saving the environment.
- **Flexibility** One can start with a small off-grid solar system but systems can be upgraded if you need to provide more electricity.
- **Green energy.** Using the renewable energy of the sun without affecting the environment.

Once you have evaluated the site survey and prepared all input data for the system design, you have to decide if you want to suggest to the client a DC or an AC coupled system and what components you would suggest.

The main source for the description of DC and AC coupled systems is chapter 4 of Louie's Book "Off-Grid Electrical Systems in Developing Countries". Some paragraphs are taken from [Louie, 2018, chapter 4, page 88], some are adapted for Africa by the authors and some are added by the authors.

2.2. System coupling (AC/DC)

There are two types of coupling: AC and DC-coupled systems. The type of couplingdependsonhowtheenergysourcesareconnected,independentofwhether the load is AC or DC.

2.2.1. DC Coupling

DC coupled Systems were the first off-grid systems in use. They can run DC loads, as shown in Fig23: Basic DC-coupled system, only DC electricity useFig, but also operate AC loads as shown in figure Fig. To run AC loads the DC electricity has to be converted to AC using an inverter. The term DC coupled refers to the connection of the PV system. As the term implies, DC-coupled systems are connected to the DC side of the PV system. In DC-coupled systems, the energy sources are connected in parallel DC bus. In most off-grid systems, there is a single DC bus. DC-coupled systems almost always include a battery. AC components must include an inverter or rectifier to be integrated into a DC-coupled system. The battery sets the DC bus voltage. Although the problem with forming and maintaining the frequency of the ACbusiseliminated(unlessmultipleinvertersareconnectedinparallel),thebattery must be protected from being over- or undercharged. For this reason, a system with a DC bus should have charge controllers or diversion loads and diversion load controllers.

A charge controller limits the current supplied by a source; a diversion load provides a parallel path for the current, reducing the current into the battery. The DC-coupled architecture issued in smaller capacity mini-grids and in solar lanterns and solar home systems.

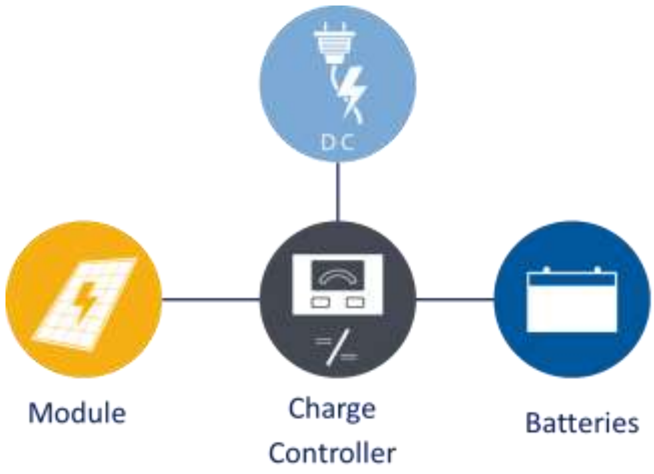


Fig23: Basic DC-coupled system, only DC electricity use

In order to run AC devices one has to add an inverter or work with an inverter charger. The simplest and most used option is to connect an inverter to the battery or with or often even without, a battery monitor. The main problem with these solutions is that without battery monitor there is no link between the charge controller and the inverter, hence the electricity drawn by the inverter out of the battery can't be monitored by the charge controller.

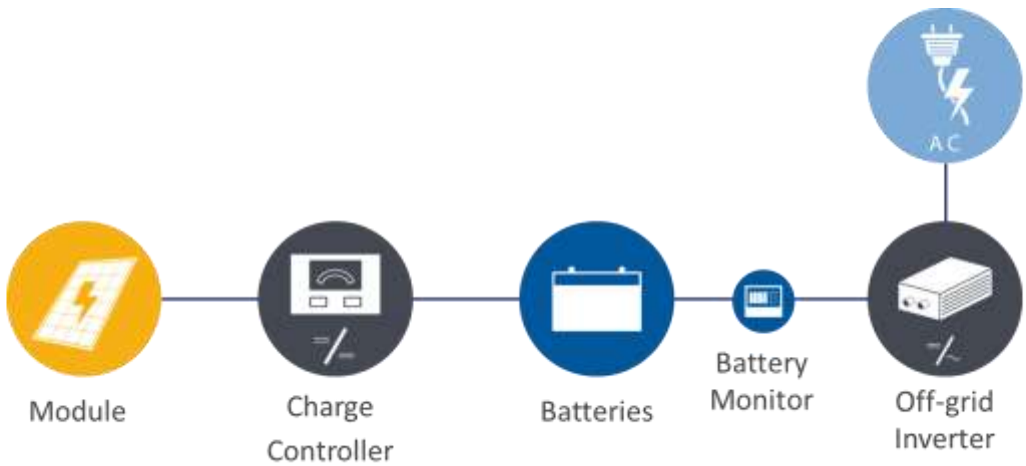


Fig24: Basic DC-coupled system, with AC conversion

2.2.2. AC Coupling

The central feature of an AC-coupled system is the AC bus. Note that the schematics shown in is intended to be illustrative only— it is possible, for example, for an AC-coupled system to have somewhat different components. The schematics show the high-level connection of the components, with the arrows indicating the possible flow of power. For clarity, the distribution and end-use systems are not shown. Do not confuse the schematics with circuit models, even though at times the same symbols are used in both. In electrical terms, a bus is simply a node in the system where various components are connected. National grids can have thousands of buses; mini-grids often have just one. The AC Bus is often just a copper bar inside the circuit breaker box with several cables and switches or circuit breakers attached. All the components connected to the AC bus are in parallel, and so they operate at the same voltage frequency and magnitude. This means that the voltage output by the generators must be synchronized.

DC components cannot be used unless they are connected to the AC bus through a rectifier or an inverter. The voltage frequency and magnitude at the AC bus should beapproximatelyconstant.Certainsensitiveloadscannottoleratedeviationsbeyond a few percent without damage or malfunction. Other loads such as heaters and incandescent lights are more robust and can tolerate variation in the voltage and frequency. Control of the AC bus voltage frequency and magnitude is an important aspect inconsideration of AC-coupled systems. Normally, one component is controlled so that it resembles a voltage source. This component is said to be "forming" the AC bus. The other sources must be able to synchronize to the AC bus voltage and are controlled as current sources to inject power into the bus. For reasons discussed in Louie's Book "Off-Grid Electrical Systems in Developing Countries", only energy conversion technologies capable of adjusting their power output on demand and that have a voltage control system can be used to form the AC bus. This functionality is usually found in conventional- and biomass-fueled internal combustion engines and certain MHP systems. Inverters are also capable of forming the AC bus. One reason why WECSs and PV modules cannot be used to form the AC bus is that they are only capable of producing power when there is sufficient wind speed or sunlight. However, they can be integrated into the system as long as some other source forms the AC bus voltage. AC-coupled systems can be easily expanded by connecting additional load and generation to the AC bus.

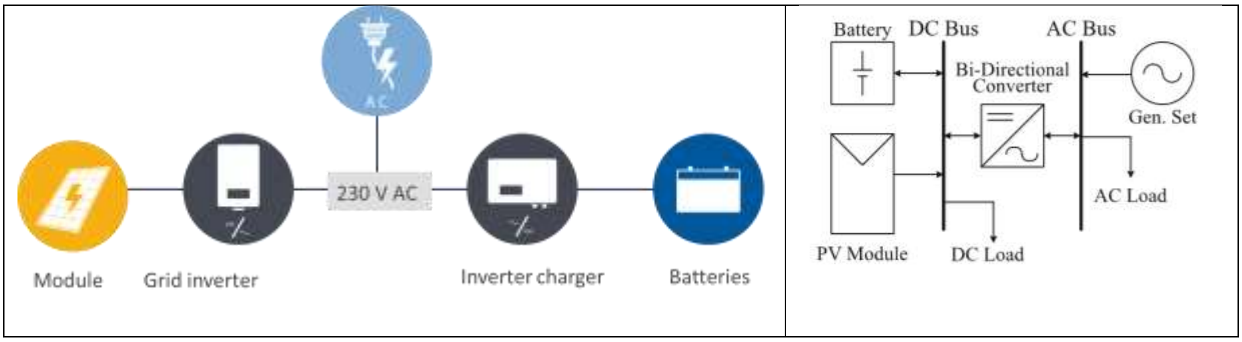


Fig25: Typical AC-coupled system

The main advantage of AC coupled systems is the use of components, especially modules, which are used in grid-tied systems. A disadvantage is, that you either need 2 inverters or expensive inverter chargers, such as SMA's sunny island. In the last years MPP charge controllers are more and more available for DC coupled systems. They also operate with standard modules. Hence, the advantage to use standard modules is now also available with some DC-coupled systems.

2.3. Component selection

When selecting the components, you have to decide if you want to offer an AC or DC coupled system. The size of the system, the operation time, the budget of the client and the availability of material are main points which should influence your decision. Please see below a matrix which should help you to select the right system for your client.

Table5: Choosing the Right System AC or DC

Requirements	AC Coupling	DC Coupling
Installation	++ Standard	- Specific
Distance	+ Up to 1 km (230 V)	-- Up to 50 m (24 V)
Expandability	++ No limit	0 Very limited
Costs	+ Standard product, modular, but 2 inverters	+ for small SHS no yet standard products, but less components
Loads to be supplied	++ All	+ Small loads only (household level)

Fig shows you the efficiency of the DC and AC coupled system.

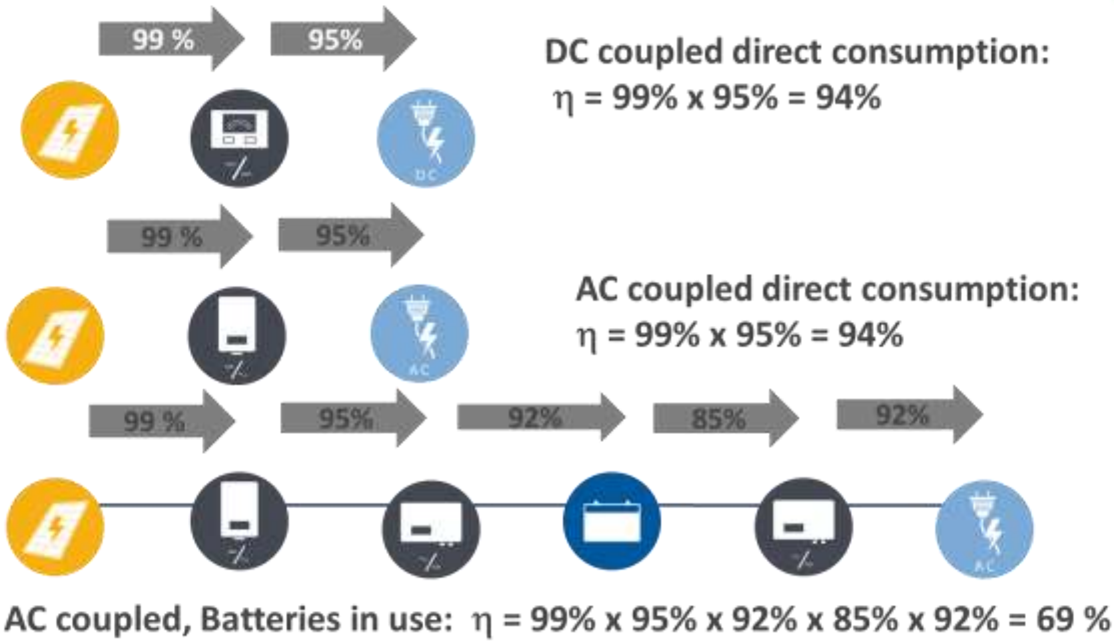


Fig26: Efficiency of DC and AC coupled Systems

The selection of the right system and the right components depend on a lot of different factors. The main questions to be answered are listed again below:

- What is the budget of the client?
- What is the total consumption of the client?
- Does the client already have loads (electrician devices) he wants to use?
- What is the total power of the loads?
- When will the electricity be used?
- Which components are available in my region and how are the warranty terms?
- Is there a second electricity source (diesel generator, wind turbine) to be integrated?
- How many days of autonomy have to be served?

With the years a solar installer learns what system to offer to which client. It is suggested to consult experienced installers when you implement your first projects. Usually you also can ask wholesalers and manufacturers to review you design or even to assist with the design.

Self-Check - 2	Written Test

Instruction: Follow the below selected instruction

A	The following are true or false items, write true if the statement is true and write false if the statement is false.

1 **A typical reason to buy an off-grid PV system is to become independent and to have access to electricity:**

True or false:

2 **DC coupled system can also run AC loads.**

True or false:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below1points