Solar PV System Installation and Maintenance

Level-IV

Learning Guide -07

Unit of Competence	Prepare Job Estimation and Cost of Materials and Components
Module Title	Preparing Job Estimation and Cost of Materials and Components
LG Code	EIS PIM4 M02 LO1-LG07
TTLM Code	EIS PIM4 TTLM 0920v1

LO1: Gather information

Instruction Sheet	Learning Guide: 07

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

- Reading and understanding project plans and specifications
- Making Measurements and identifying quantities
- Obtaining labour unit cost projections and making agreement
- Obtaining and analysing logistic support contracts and supply agreements
- Obtaining details of proposed warehousing and physical distribution systems
- Converting Information in a usable form and storing ready for retrieval.

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:-

- Read and understanding project plans and specifications
- Make Measurements and identifying quantities
- Obtain labour unit cost projections and making agreement
- Obtain and analyse logistic support contracts and supply agreements
- Obtain details of proposed warehousing and physical distribution systems
- Convert Information in a usable form and storing ready for retrieval.

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

Information Sheet 1	Reading and understanding project plans and specifications

1.1 Introduction

The person(s) that will cost an off-grid PV system is not necessarily the same person that will design the system and do the installation of the system. It is therefore important for the person(s) doing the job estimation and costing to be able to read and understand the project plans and technical specifications to properly plan and cost the system. Inaccurate costing can result in the loss of the job when it is too high or the failure of the company if it is too low. EIS PIM4 M01 details the calculation of system components (PV array size, Battery size etc.) This module deals with the accurate costing and work planning for the system designed in MO1.

1.2 Project Plans and Specifications

Throughout this module, reference will be made to the 5kW off-grid system for the Adama Polytechnic as designed in Module 1 as well as design drawings for the Adama system covered in Module 3. Figure 1 shows a summary of the component sizes calculated while Figure 2 shows the wiring diagram.

Project ID: ADAMA 5kW						
Selected Components	Type	Number	Type		Properties	Total Prize
PV-Generator	Phaesun PN6M72-350 E	14	P		350.00 Wp	
Battery	Hoppecke sun power VL7-730	24	C10		546 Ah	
Charge Controller	Phocus Anygrid PSW-H-5KW-230/48V	1	V		95 V	
Inverter	Phocus Anygrid PSW-H-5KW-	1	P		450 W	
Cable	SOLAR Cable calculated leangth	4mm2 - 20m				
Cable	Other Cable	16mm2 - 8m				
Fuse K1		1	I		250 A	
Fuse K2		2	I		50 A	
System Voltage		48 V				

Figure 1: Adama summary

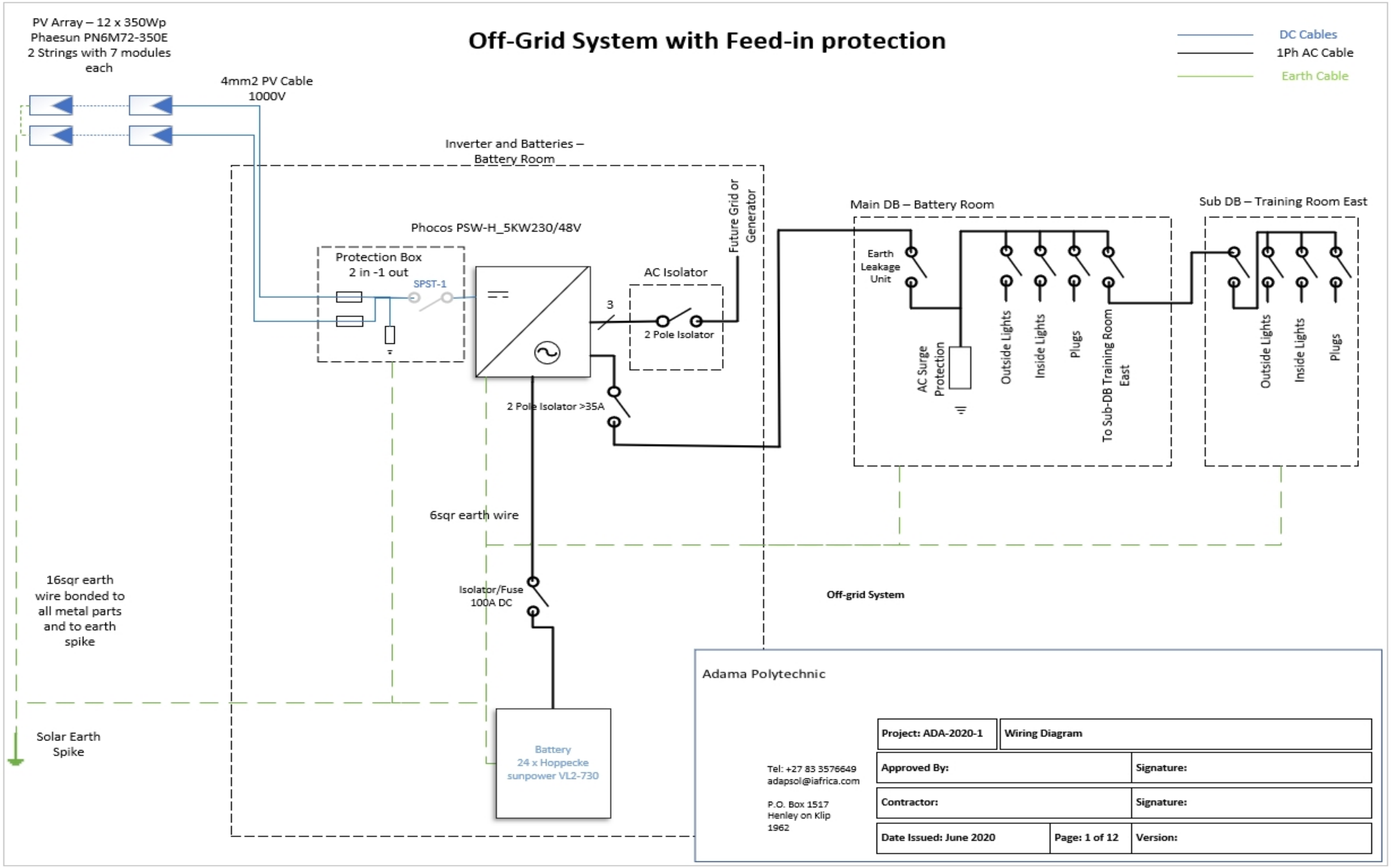


Figure 2: Adama Wiring Diagram

From the design calculations and various drawings, the costing of the system in terms of equipment, labour, material and logistics needs to be accurately calculated and estimated to be able to present a project cost to the client.

- Typically, the following needs to be estimated or calculated:
  - ✓ Quantities and costs of equipment and material;
  - ✓ Estimation of labour time and costs;
  - ✓ Cost of logistics like transport, site establishment etc.
  - ✓ Cost of warehousing and distribution;

Self-Check - 1	Written Test

Instruction: Follow the below selected instruction

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	To estimate job costs, the system design calculation and drawings needs to be understood.
2	If a job costing is too high, all that will happen is that the company makes bigger profits.

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 2	Making Measurements and identifying quantities

2.1 Introduction

The first step in costing a job is to understand the quantities and cost of equipment and materials. This is done by using all the design information and technical drawings done by the system designers.

2.2 Cost of Equipment

The main and most expensive equipment required for an off-grid solar system is the PV modules, the charge controller and inverter or (hybrid inverter) and batteries. Furthermore, the balance of system (BOS) components like cables, switches, safety devices etc. needs to be calculated as well.

2.2.1 Calculating main equipment

The main equipment probably makes up the majority of the equipment costs:

- Batteries
- Charge controller(s)
- Inverters

The system designers may specify certain equipment (see Figure 1). It is the task of the planner to determine cost and availability of the equipment. The planner may also look at alternatives (at a lower cost or that is in stock), but it should always be confirmed with the designer. For instance, the designers may specify a 546Ah battery of a certain manufacturer. The planner may find a battery with similar capacity, cycles and quality that are more freely available or that is more affordable.

2.2.2 Calculating BOS components

The BOS components need to be determined and calculated. The BOS components include:

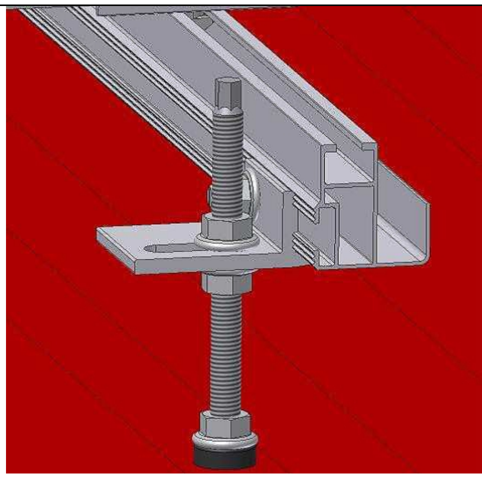
- **Mounting system**
  - ✓ Length and quantity of rails
  - ✓ Number of mid- and end clamps
  - ✓ Number of roof hooks, roof clamps or hanger bolts

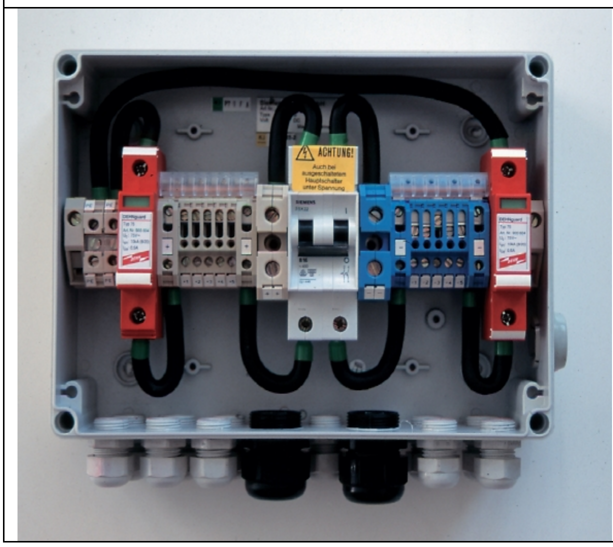
✓ Ground-mounted structures
✓ Ballast systems

- **Cables and connectors**
  ✓ Length and size of positive and negative PV cable
  ✓ Length and size of earthing cable, including earth rods
  ✓ Length and size of AC electrical cable
  ✓ Number of PV connectors e.g. MC4

- **Switches and protective equipment**
  ✓ Combiner boxes
  ✓ Light and plug outlets
  ✓ AC and DC Breakers and isolators
  ✓ AC and DC surge protection
  ✓ Fuses

- **Monitoring (if applicable)**
  ✓ On-site or remote monitoring equipment
  ✓ Data and internet connectivity costs if applicable





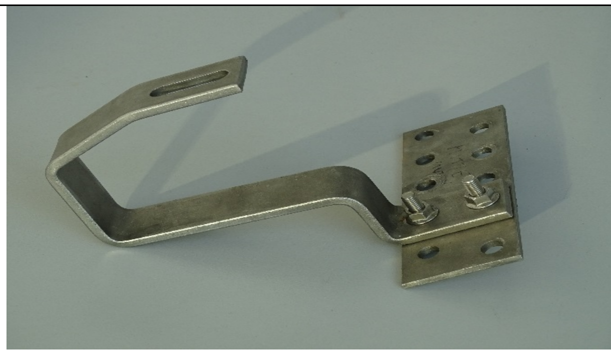


Figure 3: Some Basic operation system components (BOS)

2.3 Cost of Material

During any installation, material and accessories are used. The cost of these materials should not be ignored as it can add up to substantial amounts and needs to be recovered. Material includes:

- Nuts and bolts, screws, packers for the mounting system
- Roof penetration devices e.g. ‘Dekko’
- Cable ties
- Labels
- Lengths and sizes of trunking and conduit
- Screws for fitting of inverter and charge controllers
- Cable glands
- Other consumables like batteries for test equipment etc.

Figure 4: Dekko for tile roofs

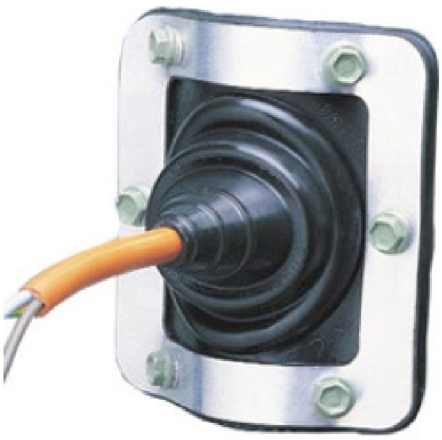


Figure 5: Dekko for corrugated roofs

Self-Check - 2	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	During any installation, material and accessories are not necessarily.
2	The first step in costing a job is to understand the quantities and cost of equipment and materials.
3	The main and most expensive equipment required for an off-grid solar system is the PV modules.

Note: the satisfactory rating is as followed

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Answer Sheet	Score = ___________ Rating: ____________
Name:______________	Date____/____/_____

Information Sheet-3	Obtaining labour unit cost projections and making agreement

3.1 Introduction

Labour cost for the installation of a system needs to be calculated, whether the company have their own full-time employees or whether they make use of sub-contracting labour. If sub-contractors are used, agreements must be in place to secure the availability of the sub-contractors.

3.2 Labour Costs

The direct labour costs involved in an off-grid PV system are the following:

- Site clearing and establishment
- Installation of roof structures
- Module installation
- Cabling and trenching
- Electrical work like wiring and connections
- Commissioning and testing

There are also some indirect labour costs that need to be recovered, normally in the mark-up portion of a quotation:

- **Marketing and Sales labour costs**
  - ✓ Visiting prospective clients
  - ✓ On-site inspections and surveys
  - ✓ Sales cost

- **Design labour**
  - ✓ Designing of a system based on survey data
  - ✓ Obtaining quotes and determining availability of equipment
  - ✓ Training on new equipment
  - ✓ Documentation

The cost of the labour will depend on the qualifications and skill level of the worker, as well as the type of work. Typically, a table will be created listing the tasks to be done or skills required, the time allocated for the task or skill, the daily or hourly rate and the total labour costs. See Table 1.

Table 1: Labour calculation table

Task or Skill	Man Hours/days estimated	Rate per hour/day	Total
Technician	2 day	$x.xx	$x.xx
Electrician	1 day	$x.xx	$x.xx

3.3 Agreements

Where sub-contractors or freelance labour is used, agreements should be reached upfront, ideally for a fixed rate for the job. Alternatively, labour rates can be negotiated for a period e.g. for the next year at a specific cost per day or per hour. Labour rates should comply with the countries labour laws in terms of minimum wages and should also make provision for travelling and subsistence allowances where required. Labour rates should ideally be on par with permanent employee’s rates which may include pension fund contributions, medical aid etc.

Self-Check - 3	Written Test

Match column A to column B for the following questions.

N°	Questions	
1	Labour cost	A. .Sales costs
2	Sales Labour cost	B. .Module installation
3	Design Labour	C. Documentation

Note: the satisfactory rating is as followed

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Information Sheet -4	Obtaining and analysing logistic support contracts and supply agreements

4.1 Introduction

Contract Logistics is defined as the comprehensive process from production to distribution at the final point of sale. This means that Contract Logistics is not simply the process of moving goods, but a far more comprehensive course of action that merges traditional logistics with supply chain management processes Finding good suppliers is very important for the success of a PV project. The first objective should always be to find suppliers that are local, have good stock levels and that can provide good support.

Supply chain management is an overarching concept that links together multiple processes to achieve competitive advantage, while logistics refers to the movement, storage, and flow of goods, services and information within the overall supply chain.

A properly written contract for supply chain management is a must if you want to achieve successful cooperation. Both supplier and the vendor need to agree to all elements listed in the contract

4.2 Finding suppliers

There are many ways to find suppliers of PV equipment:

- Use the internet to search for suppliers
- Ask other people in the industry for recommendations
- Attend trade shows
- Contact the manufacturers and ask for their local agents details

  The requirements of good suppliers are the following:

  ✓ Keep good stock levels;
  ✓ Keep good equipment;
  ✓ Provide product training;
  ✓ Provide delivery services;
  ✓ Ideally have an online portal with real-time prices and stock levels;
  ✓ Have good technical support.

Some reputable suppliers will require a company to register with them after proven PV experience and a good record of prior installations. They may also offer credit terms based on your track record with other suppliers. Once registered with a supplier, find out who the person is that is looking after your account and try to build a good relationship. Also attend training provided on the products they sell.

Self-Check - 4	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	It is important to build good relationship with suppliers.
2	Contract Logistics is an overarching concept that links together multiple Processes.
3	Contract Logistics is not simply the process of moving goods.

Note: the satisfactory rating is as followed

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Information Sheet 5	Obtaining details of proposed warehousing, physical distribution systems

5.1 Introduction

Sometimes local suppliers of your preferred products are not available. It is then important to determine how to obtain the products from other areas in your country or how to import it from other countries. It may be necessary to keep stock of the product as it may be more cost effective to import in bulk. For that, warehouse facilities may be required. The job may not be local and distribution systems need to be set up to get the equipment to site. The planning, implementation, and controlling of the physical flow of material or product from one point to another to meet the customer requirements in the market is known as physical distribution.

5.2 Importing Equipment

When equipment needs to be imported, it is important to determine how the import process works in your company. The factors to consider are:

- **Difficulty with Communication**
  - ✓ When sourcing overseas suppliers, it can be difficult to build a solid relationship purely because of their geographic location. Starting out, most companies find foreign suppliers online and once they've found a product or material they are looking to import, they order through the supplier's website. If you are thinking about importing goods using this process, it is important to source a reliable supplier.
  - ✓ If you have the resources, it is advisable to take a trip out to their premises and meet with a company representative. This enables you to test the quality of their goods first-hand; you also get to build a better relationship with your supplier if you've met them in person.
  - ✓ Language may be a huge barrier to overcome

- **Determine If You Need a License**
  - ✓ It is normally the shipper's responsibility to comply with current government regulations and applicable laws in each country. That means you should ask your supplier at the beginning of your negotiations whether you need an

import permit for the country where you intend to import and sell your product and how the company can help you obtain one.

- ✓ You may also need a license from local or state authorities to do business. Customs may ask you for your importer number.

- **Import restrictions**
  - ✓ Make sure the merchandise can freely enter your country. There may be some prohibited and restricted items which cannot be imported.
  - ✓ Make sure of import duties that may be payable.

- **Find a Transport Company That Can Help With Customs**
  - ✓ You can hire a transport company (e.g. UPS, DHL) that can take care of the transport, prepare appropriate documentation, collect payment on your behalf and oversee the customs clearance for a flat fee.
  - ✓ Calculate all costs to import the product, including transport, taxes, customs duty, the transportation company's fee and insurance (if needed).

5.2.1 Incoterms

Defining international sales contracts requires you to have a bit more knowledge about specific export and import terms. Just paying for the goods is not the end of the buyer's or the seller's responsibility. Luckily, as of 1936,Incotermsare widely recognized, and businesses frequently use them to determine the liability and accountability. After a few revisions, the latest version of these terms appeared in 2010. Incoterms define where responsibility for the goods as well as the transport of the goods is transferred from the seller to the buyer.

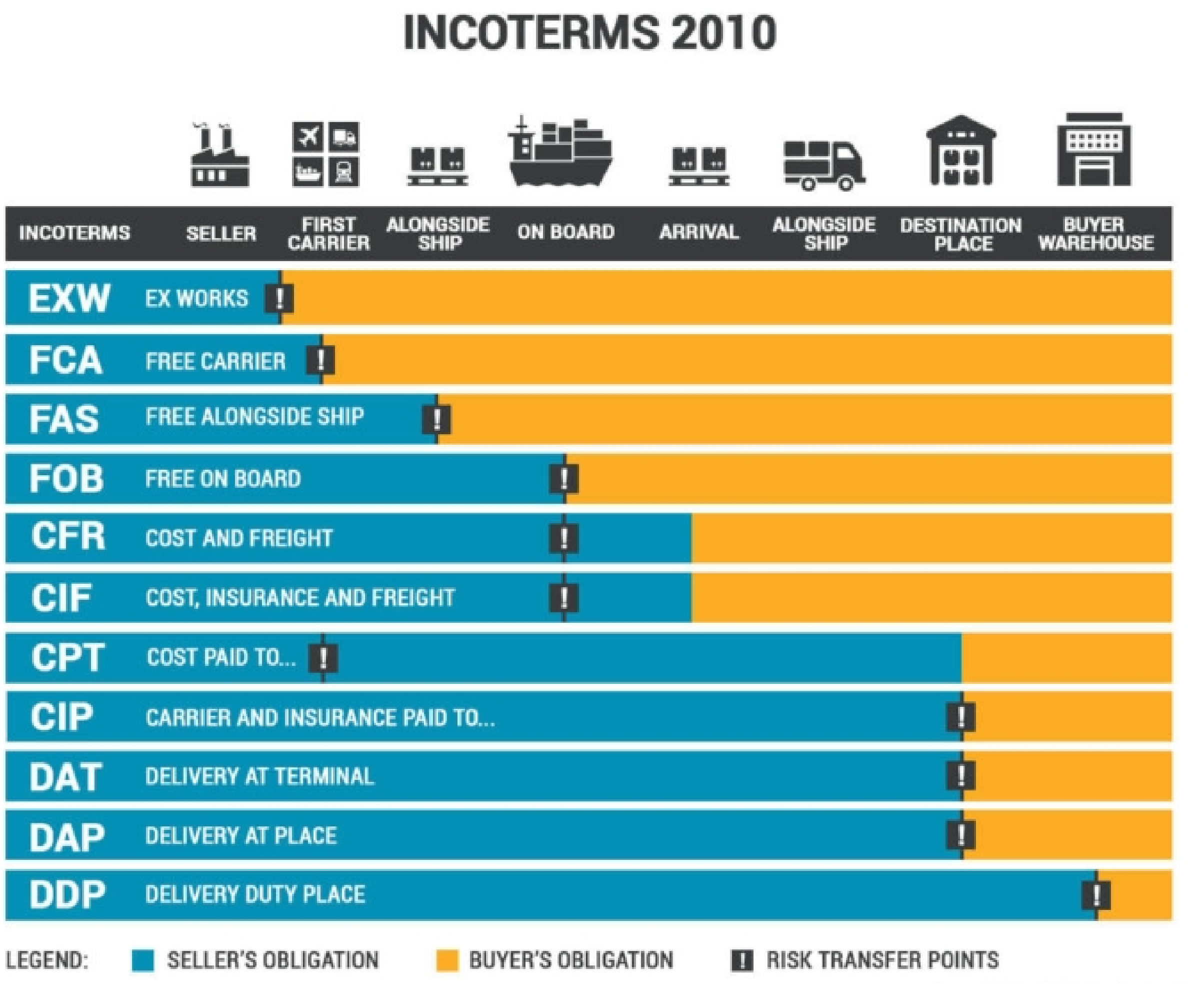


Figure 6: Incoterms

5.3 Warehouse and Distribution systems

Depending on the level of stock you need to keep, a warehouse may be required to receive stock, store stock and distribute stock to site. Warehouses can be owned or rented.

There are a number of ways to distribute equipment to site from your warehouse:

- **Own transport**
- **Client's transport**
- **Third** party transportation e.g. provided by the supplier or a courier company.

It is important to have insurance for the goods while in transit as it may get damaged or stolen.

Self-Check - 5	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Physical distribution is The planning, implementation, and controlling of the physical flow of materials**.**
2	It is important to have insurance for the goods while in transit as it may get damaged or stolen.
3	Language is one barrier for the communication skill.

Note: the satisfactory rating is as followed

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Information Sheet -6	Converting Information in a usable form and storing ready for retrieval

6.1 Introduction

Most of the items mentioned in this Learning Objective should be put in place beforehand to be ready when needed. It is important to convert the information in a usable form, store it securely and make it available for retrieval The processing, storing and retrieval of information is key in ensuring all staff can access it quickly and easily which leads to customer's requests for information being met effectively and efficiently, which in turn can assist in the customers overall positive experience of your establishment. Retrieval practice is such an effective revision technique because it requires students to recall previously learnt knowledge, which creates stronger memory traces and increases the likelihood that the information will be transferred to the long-term memory. Effective information retrieval skills can be demonstrated by: the ability to evaluate various bibliographic search strategies. The ability to select and justify the appropriate search techniques in order to carry out independent research, and. the ability to critically evaluate search results. Retrieval practice prioritizes active over passive learning, where students strengthen their memory by attempting to recall information. This tactic may also reveal gaps in learning and indicate what needs to be reviewed. Practice problems and writing prompts are two effective retrieval strategies.

6.2 Converting Information

As the type of information varies quite considerable, it is important to convert it into a format that is easily usable when needed. In its most primitive form, the information could be stored in a folder or a number of folders marked properly and separated properly into the different categories. Alternatively, the information can be stored electronically in e.g. a spread sheet format on a local or cloud-based server. It is important to ensure that the data is backed-up regularly and that there is a well-defined way of adding information and retrieving information. Some companies may implement custom software where all the required information can be stored and maintained in a database format with a user front-end.

Self-Check - 6	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Information should be stored securely.
2	The processing, storing and retrieval of information is key in ensuring all staffs.
3	Retrieval practice is such an effective revision technique.

Note: the satisfactory rating is as followed

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Solar PV System Installation and Maintenance
Level-IV
Learning Guide

Unit of Competence	**Prepare Job Estimation and Cost of Materials and Components**
Module Title	**Preparing Job Estimation and Cost of Materials and Components**
LG Code	**EIS PIM4 M02 LO2-LG08**
TTLM Code	**EIS PIM4 TTLM 0920v1**

LO2: Select components and Prepare bill of materials

Instruction Sheet	**Learning Guide-8**

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

- Selecting PV system components based on the system sizing
- Selecting components on existing safety and quality standards
- Determining quantities based on the system sizing requirements.
- Preparing bill of materials based on a prescribed format

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:-

- Select PV system components based on the system sizing
- Select components on existing safety and quality standards
- Determine quantities based on the system sizing requirements.
- Prepare bill of materials based on a prescribed format

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

Information Sheet -1	Selecting PV system components based on the system sizing

1.1 Introduction

From the site survey, environmental data and customer requirements the system designer will calculate the size of the various pieces of equipment required. From that sizing, the specific equipment can be selected based on stock availability of the suppliers. There is a great variety of components available on the market but most installers identify a brand they like to work with and use it in most of their projects. Especially for power electronics like inverters and charge controllers this has the advantage that the selection and design process is faster. One does not have to scan through hundreds of data sheets to find a product, the more experience an installer has the easier it is to say which of his commonly used models is going to fit. And the installer can also save time on site when he does not have to read new manuals every time to prepare the installation or programming of components. For modules the selection process is usually a bit easier, there are mostly no big differences between the different models, so they are mostly selected based on availability and price. For the detailed description of how to calculate the specific component sizes, see Module 1 (EIS PIM4 MO1).

1.2 PV Modules

Definition: Solar panels are those devices which are used to absorb the sun's rays and convert them into electricity or heat. These cells are arranged in a grid-like pattern on the surface of solar panels. In the case of the Adama design, the PV generator was sized according to the energy consumption, the climate data and the system efficiency: A module is a separate unit of software or hardware. Typical characteristics of modular components include portability, which allows them to be used in a variety of systems, and interoperability, which allows them to function with the components of other systems. APV module is an assembly of photo-voltaic cells mounted in a frame work for installation. Photo-voltaic cells use sunlight as a source of energy and generate direct current electricity. Arrays of a photovoltaic system supply solar electricity to electrical equipment

Table 2: Adama load table

1	2	3	4	5	6	7	8	9
Collected Information							Calculated information	
No	**Power Consumer**	**AC or DC**	**Quantity**	**Power in Watt (W)**	**Operation time (h)**	**Usage Time**	**Consumption (Wh/d)**	**Total Power in Watt (W)**
1	Lights	AC	20	18W	4	Night	1440Wh/d	360W
2	Lights	AC	9	18W	12	Night	1944Wh/d	162W
3	Computer	AC	3	250W	8	Day	6000Wh/d	750W
4	Printer	AC	1	700W	1	Day	700Wh/d	700W
5	Projector	AC	1	300W	6	Day	1800Wh/d	300W
6	Internet	AC	1	15W	24	Day/ night	360Wh/d	15W
7	Router	AC	2	15W	24	Day/ night	720Wh/d	15W
TOTAL							**12964Wh/d**	**2317W**
Total day								**1795W**
Total night								**567W**

Table 3: Adama Insolation based on specific location and roof angle/orientation

J	F	M	A	M	J	J	A	S	O	N	D	Ø
7.31 kW/ m²*d	7.61 kWh/ m²*d	7.3 kWh/ m²*d	6.28 kWh/ m²*d	5.83 kWh/ m²*d	5.68 kWh/ m²*d	5.35 kW/ m²*d	5.57 kWh/ m²*d	6.15 kWh/ m²*d	7.14 kWh/ m²*d	7.2 kWh/ m²*d	7.3 kWh/ m²*d	6.56 kWh/ m²*d

As an example, let's use the Adama design to calculate the PV array size with a daily energy consumption of 12964Wh (See Table 2), worst case peak sun hours of 5.35 (see Table 3) and 65% system efficiency:

1.3 Batteries

For the calculation of the battery, we will again use the Adama design as example. The following formula can be used to calculate the battery size:

$$C_{10} =$$

Where:

- DOD = Depth of Discharge e.g. 50%
- E = Energy consumption (daily) e.g. 5 kWh/day
- A = Autonomy days e.g. = 2 days
- V_{syst} = System Voltage DC e.g. 48 V

For the Adama design, we determined that the daily energy consumption is 12964Wh/d (see Table 2).

We decided on only 1 day of autonomy to reduce battery costs. There is grid power available to use in case of days without sunshine. We also decided on a 50% DOD since the customer requested lead acid batteries.

The required battery is therefore:

$_{10}$ = = 540.17Ah @ 48V

1.4 Charge Controller and Inverter

For the Adama Design, the peak load was calculated using a load table (see Table 2). The Calculated load was 2317W. If we apply a safety margin to it, the required peak load is:

Peak Load = 2317W x 1.3 = 3012W.

The required inverter therefore needs to be able to supply at least 2317W AC continuously. There is normally a minimum size battery specified for an inverter:

	P_{AC} Power inverter V_{Dc} System Voltage

In the case of Adama, the minimum is:

The selected battery of 541Ah is larger than 521Ah therefore ok. The charge controller is sized based on the array size. In other word, it should be able to handle the KWp rating of the PV generator. The array should then be matched to the charge controller in terms of maximum and minimum voltages, as well as maximum currents. The number of modules in series per strings, and the number of strings in parallel can then be determined.

1.5 Cable Size

The following paragraph(s) are adapted from (Dobelmann & Klauss-Vorreiter, 2009)chapter 6. The formula that can be used for cable sizing is the following:

Where

A = cross section of cable in mm^2

L = length of cable (conductor positive and negative) one way length x 2

P = Power of the cable

η_{loss} = Loss factor (0.01 for 1%, 0.02 for 2% etc.)

V = system voltage

κ = Kappa – electric conductivity

K_{Cu} = 56 m / Ω · mm^2 for copper

K_{Alu} = 34 m / Ω · mm^2 for aluminium

In practice, one can make use of tables supplied by wire manufacturers to ‘lookup’ the size of wires. For the Adama example, the following cables were calculated:

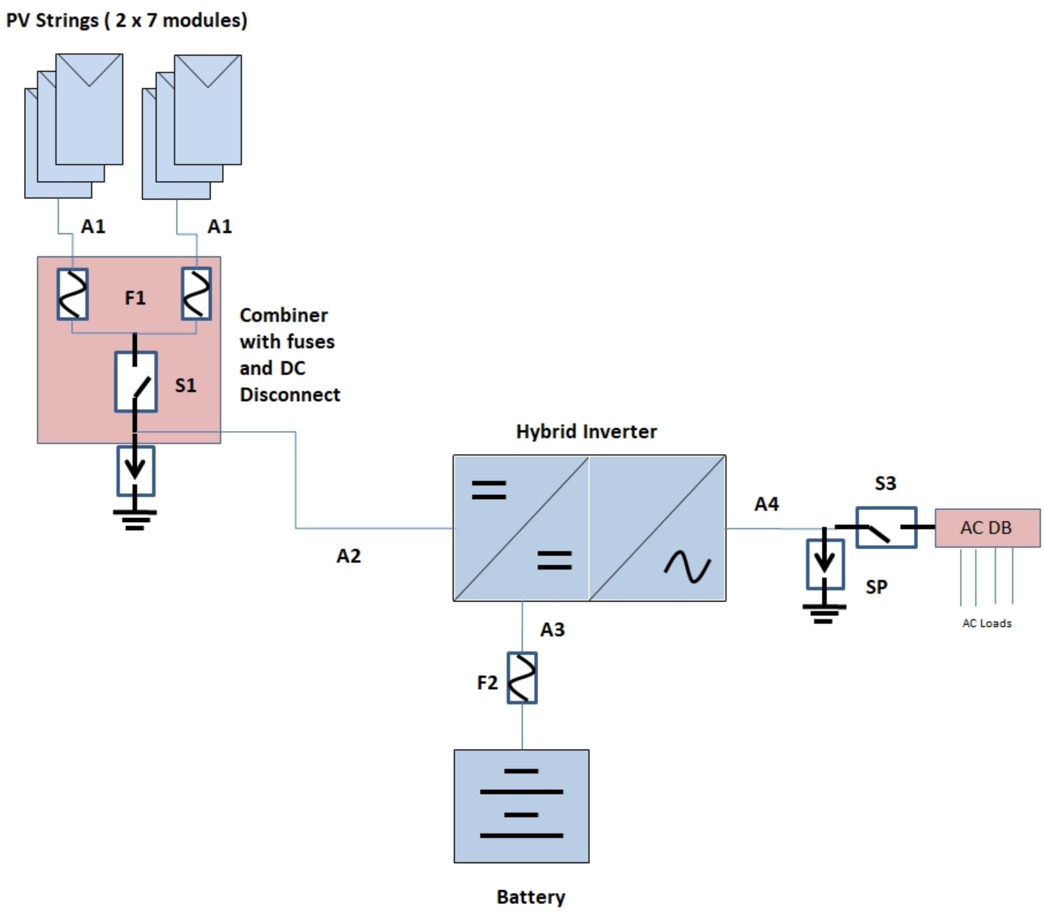


Figure 7: Adama layout

Cabling	**L Single Distance**	**LF Loss Factor**	**P_{max} Affiliated Power**	**K Conductivity**	**U_{SYS} System Voltage**
A1 Single Cable Length between Modules and combiner box (Vmpp, String) per string	5 m	1.0%	4900 W/2 strings 2450W per string	56	270.2 V
A2 Single Cable Length between combiner box and charge Controller (Vmpp, String)	5 m	1.0%	4900 W	56	270.2 V
A3 Single Cable Length between Charge Controller and Battery (PPV)	3.00 m	0.50%	4900 W	56	48 V
Material of the Cables	**Cu**				

Required cable diameters

A1 = $0.6mm^2$, selected diameter **4 mm^2 DC cable**

A2 = $1.2mm^{2,}$ selected diameter **4 mm^2 DC cable**

A3 = $45.6mm^{2,}$ selected diameter **50 mm^2 DC cable**

Double Check Inverter battery terminal size to fit cable size:

Any-Grid model	**PSW-H-5KW-230/48V**	**PSW-H-5KW-120/48V**	**PSW-H-3KW-230/24V**	**PSW-H-3KW-120/24V**
Battery cable cross-section	35 ~ 50 mm^2, AWG 0 ~ AWG 2			

1.6 Fuses

The fuse breaks the circuit if a fault in an appliance causes too much current to flow. This protects the wiring and the appliance if something goes wrong. The fuse contains a piece of wire that melts easily. To melt or make two things melt together, especially at a high temperature. The coloured glass is heated until it fuses together. A fuse(s) is needed in any electrical system (AC or DC). These protection devices react to the amount of heat being produced by electricity passing through wires and/or components. They are used so as to protect wires and components from the extreme heat produced should there be an electrical overload or short circuit.

1.6.1 Battery Fuse Calculation

Fuses are rated in amps. They are sized to 'blow' very quickly when the current is about 20 % greater than the maximum expected current in the circuit. If, for example, there is a short circuit in one of the appliances, the circuit draws much more than the rated current (i.e. more than 20 per cent higher), so the fuse rapidly heats up, 'blows' very quickly and opens the circuit. To size the battery fuse calculate the power of the loads (W) and divide it by the system voltage to get current (A). Take this current and multiply with 1.2 to get the fuse current rating.

1.6.2 PV Fuse calculation

PV Fuses are often use when there are multiple strings combined. An earth fault in one string can cause the other string currents to also flow into the earth fault. PV strings are normally calculated empirically as follows:

- $V_{P,fuse} \geq V_{OC,array}$ x 1.2
- $I_{nom,fuse} \geq I_{SC\ module}$ x 1.4

As an example, if there are a string of 4 modules (V_{OC} = 36V), and the Short circuit current I_{SC} = 10A:

- VP,fuse ≥ VOC,array x 1.2 ≥ (4 modules x 36V) x 1.2 ≥ 172.8V
- $Ino_{m,fuse} \geq I_{SC\ module}$ x 1.4 ≥ 10A x 1.4 ≥ 14A

From the fuse datasheet (Figure 8), the closest suitable fuse will be the PV-15A10F fuse.

10 x 38 PV Fuses (1000V DC)

A range of UL 2579 fast-acting 600V DC Midget fuses specifically designed to protect solar power systems in extreme ambient temperature, high cycling and low-level fault current conditions (reverse current, multi-array fault).

Product Code	Rated Current	Rated Voltage	Breaking Capacity	Dimensions	Class
PV-2A10F	2A	600V DC	30kA	10 x 38mm	gPV
PV-6A10F	6A	600V DC	30kA	10 x 38mm	gPV
PV-8A10F	8A	600V DC	30kA	10 x 38mm	gPV
PV-10A10F	10A	600V DC	30kA	10 x 38mm	gPV
PV-12A10F	12A	600V DC	30kA	10 x 38mm	gPV
PV-15A10F	15A	600V DC	30kA	10 x 38mm	gPV
PV-20A10F	20A	600V DC	30kA	10 x 38mm	gPV
PV-25A10F	25A	600V DC	30kA	10 x 38mm	gPV

Figure 8: PV Fuse selection

1.6.3 Adama example

For the Adama example, the fuse sizes were calculated as follows:

F2 Fuses from charge controller to Battery

I_{CC}= 80A (max capacity of CC)

Add safety margin of 20 % :F2=I_{CC} 1.20 = 80A * 1.20 = 96A

Fuse$_{F2}$=100A

F1 Fuses from string to combiner box

$I_{SC,\ Module}$=9.56 A

F1=I_{SC} String = I_{SC} module

F1=I_{SC} String = 9.56A

Add safety margin of 20 % :F1=I_{SC} String * 1.20 = 9.56 * 1.20 = 11.47 A

Fuse$_{F1}$=15A

Self-Check - 1	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	The fuse breaks the circuit if a fault in an appliance causes too much current to flow.
2.	Solar panels are those devices which are used to absorb the sun's rays and convert them into electricity or heat.
3	PV Fuses are often use when there are multiple strings combined.

Note: the satisfactory rating is as followed

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2points

Information Sheet 2	Selecting components on existing safety and quality standards

2.1 Introduction

Existing safety and quality standards play a big role in selecting system components. It is important to understand the local safety requirements as well as the quality standards applicable to good PV equipment.

2.2 Safety standards

Safety standards are standards designed to ensure the safety of products, activities and processes, etc. They may be advisory or compulsory and are normally laid down by an advisory or regulatory body that may be either voluntary or statutory. Safety hazards encompass any type of substance, condition or object that can injure workers. Safety is a state of being protected from potential harm or something that has been designed to protect and prevent harm. An example of safety is when you wear a seat belt. An example of safety is a safety belt. Many countries have specific requirements related to PV systems, particularly when it connects to the local electricity grid. These requirements can specify the following:

- Maximum size of systems;
- Anti-islanding regulations;
- Voltages and frequencies and points where the inverter needs to switch off.

Is landing is the condition in which a distributed generator continues to power a location even though electrical grid power is no longer present. Islanding can be dangerous to utility workers, who may not realize that a circuit is still powered, and it may prevent automatic re-connection of devices. Additionally, without strict frequency control the balance between load and generation in the islanded circuit is going to be violated, leading to abnormal frequencies and voltages. For those reasons, distributed generators must detect islanding and immediately disconnect from the circuit; this is referred to as anti-islanding (source: Wikipedia).

2.3 Quality Standards

Quality standards are defined as documents that provide requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose. Clearly defined standards and requirements make it easier for companies to meet what their consumers consider “quality” and they improve the overall vision of what the company should work toward.

Quality parameter- the size characterizing the quality level of certain consumer and production goods and processes leading to the production of a given good. Perceived quality, closely related to the product's brand and supplier's reputation. There are some international standards applicable to PV products. It is always important that the specific product required is certified under international standards (e.g. IEC) and tested by reputable testing facilities (e.g. TUV).

Some of the notable standards related to PV modules are:

- IEC 61215:2016 standard (design)
- IEC 61730:2016 standard (safety)

This edition of the two standards represents the principal references of a photovoltaic module. The modules used in the Adama example conforms to both the above standards – see Figure 9.

Technical Data		Technische Daten				PN6M72-350 E	PN6M72-360 E
Nominal voltage		Systemspannung				24	
Power		Nennleistung		Pmp	W	350	360
Voltage at max. power		Spannung bei Max. Leistung		Vmp	V	38,6	38,4
Current at max. power		Strom bei Maximalleistung		Imp	A	9,08	9,37
Open circuit voltage		Leerlaufspannung		Voc	V	47,2	46,9
Short circuit current		Kurzschlußstrom		Isc	A	9,56	9,72
Cell		Zellen				72 mono	
Cell dimension		Zellabmessung			mm	156 x 156	
Cell efficiency		Zellen Wirkungsgrad			%	20,0	20,5
Module efficiency		Modul Wirkungsgrad			%	18,0	18,5
Max. tolerance		Max. Leistungstoleranz			%	-0/+5	
Max. system voltage		Max. Systemspannung			V	1000	
Operating module temp.		Min. Betriebstemperatur			°C	-40...+85	
Front		Vorderseite				tempered glass | gehärtetes Glas	
Glass thickness		Frontglas Dicke			mm	3,2	
Backside color		Rückseite Farbe				white | Weiß	
Frame		Rahmen				clear anodized aluminium | silber eloxiertes Aluminium	
Frame color		Rahmenfarbe				silver | Silber	
By-Pass Diodes		By-Pass Dioden				3	
Junction box protection		Anschlussdose Schutzklasse				IP67	
Module cable	cross section	Modulkabel	Querschnitt		mm²	4,0	
	length		Länge	l	mm	1000	
	connector		Stecker			Standard4	
Dimension		Abmessung		X x Y x Z	mm	1956 x 992 x 40	
Mounting holes pitch		Befestigungslöcher		x1 / y / x2	mm	1176 / 942 / 1676	
Weight		Gewicht			kg	24,0	
Temperature coefficient	Power	Temperaturkoeffizient	Leistung		%/K	-0,410	
	Voc		Voc		%/K	-0,300	
	Isc		Isc		%/K	0,040	
Pallet	dimension	Paletten	Abmessung	L x W x H	mm	2025 x 1110 x 1200	
	weight		Gewicht		kg	687	
	module quantity		Anzahl Module		pcs. /Stk.	27	
Container	quantity paletts/ modules	Container	Anzahl Paletten/ Module	20 ft	pcs. / Stk.	10 / 270	
				40 ft		22 / 594	
NOCT		NOCT			°C	45 (800W/m², 1m/s, 20°Camb)	
Static / dynamic load		Statische / dynamische Last			kN/m²	5,4 / 2,4	
Hail impact		Hagelschlag				Ø 25 mm, 23 m/s	
Certificates		Zertifikate				IEC61215 (design qualification) | IEC61730 (safety)	
Article Number		Artikelnummer				310363	310364

Figure 9: Phase module certification

CE marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area(EEA).The CE marking is also found on products sold outside the EEA that have been manufactured to EEA standards. This makes the CE marking recognizable worldwide even to people who are not familiar with the European Economic Area. **RoHS** is a product level compliance based on the European Union's Directive 2002/95/EC, the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment.

UL Listing means that UL has tested representative samples of a product and determined that the product meets specific, defined requirements. These requirements are often based on UL's published and nationally recognized Standards for Safety.

Some other inverter standards that may be applicable are:

- IEC61683 – Efficiency
- IEC62109 – Safety
- IEC61000 – Electromagnetic compatibility

Self-Check - 2	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Standards are standards designed to ensure the safety of products, activities and processes is called Quality parameter.
2	A state of being protected from potential harm or something that has been designed to protect and prevent harm is called safety.
3	Documents that provide requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that materials are called standards.

Satisfactory	2 and Above 2 points
Unsatisfactory	Below2 points

Information Sheet -3	Determining quantities based on the system sizing requirements.

3.1 Introduction

On average, a good quality5kW solar system generates 22 units per day– enough to easily offset a typical Australian household's entire energy usage. The amount ofpoweryour5kW solar system generates depends on three things: location, positioning and quality. The number of batteries will depend on the DC input requirement of the inverter. Usually, a 5kW inverter will have a 24v DC input requirement. So you will need two 12vbatteries. Some models use 48V DC, in which case you will need four 12Vbatteries. Once the system sizes have been determined, component quantities can be calculated. This will be based on the equipment that is available at the time.

3.2 PV Modules

The number of PV modules is calculated based on the size of the available modules and the total size required:

For the Adama example, we calculated a total required generator capacity as 3728Wp. The available PV modules considered are the phase PN6M72-350 E modules rated at 350Wp. The minimum number of modules required therefore is:

We need at least 11 modules. Since modules degrade by approximately 20% over its lifetime, we decided to increase the number of modules by about 20% i.e. 14 modules.

Another consideration in selecting the number of modules is the number of MPPT trackers in the charge controller (or hybrid inverter in the Adama case). Since the inverter only has one input it cannot handle 14 modules in one string (see below

‘Charge controller and inverter’), more than one string will have to be paralleled. For parallel strings, the number of modules per string should be equal.

3.3 Batteries

The required battery size only indicates the capacity of the battery and not how many individual smaller batteries are required to make up the required size. For the Adama example, we required a battery size of 540.17Ah @ 48V. Based on the required battery capacity and voltage and the available battery size and voltage, we can calculate how many batteries are needed in series and in parallel. For the Adama example, we had the Hop-picker sun power VL 7-730 (C10 = 546 Ah @ 2V) available.

We therefore need 24 x Hop-picker sun power VL 7-730 (C10 = 546 Ah @ 2V), all connected in series.

3.4 Charge Controller and Inverter

A charge controller is needed to appropriately match the PV voltage to the battery and regulate charging. The inverter draws its power from a 12 Volt battery (preferably deep-cycle), or several batteries wired in parallel. The battery will need to be recharged as the power is drawn out of it by the inverter. A solar charge controller as a regulator. It delivers power from the PV array to system loads and the battery bank. When the battery bank is nearly full, the controller will taper off the charging current to maintain the required voltage to fully charge the battery and keep it topped off. The required charge controller should be compared to the required module parameters to determine if the charge controller is suitable.

Table 4: Charge controller details

Charge Controller Type	**Phaesun PSW-H-5KW-230/48V**
Nominal Power Rating	5000 W
V System	48 V

System Voltage	
Voc max MAX Open-Circuit Voltage Modules (at minimum Temperature)	450 V
Voc min MAX Open-Circuit Voltage Modules (at minimum Temperature)	120 V
Vmpp min Input	120 V
Vmpp max Input	430 V
max. Current Modules	22.5 A
max. Current Charge Controller (permanent)	22.5 A
max. Current Charge Controller (peak load)	22.5 A

Table 5: Module parameters

Available Modules	**Phaesun PN6M72-350 E**
V_{OC}	47.2 V
V_{MPP}	38.6 V
I_{SC}	9.56 A
I_{MPP}	9.08 A
α_{VOC} and α_{VMPP}	-0.3 %/K
α_{ISC} and α_{IMPP}	0.04 %/K

To calculate the maximum number of modules per string that the charge controller can handle we use the following formula:

Since we calculated 14 modules, we cannot have one string only. Since the charge controller has only one MPPT tracker, we will have to use 2 strings of 7 modules if the charge controller can handle the input current:

We therefore can use 2 strings in parallel. The only other check will be to determine if the charge controller minimum MPPT tracker voltage will be reached with 7 modules:

Since we have 7 modules in a string, we should reach the min MPPT voltage of the charge controller.

3.5 Mounting Structure

The mounting of the PV modules can be done in various ways:

- Roof parallel mounted
- Ground mounted
- Pole mounted
- Ballast or special elevated structure mounted

3.5.1 Roof Parallel

For a roof parallel system, rails are mounted and fastened to the roof structure. The PV modules are then clamped onto the rails. Each module is fastened at four fixing points. There are end clamps and middle clamps available that are used for the module fastening. When a single module is fastened or when it is at the beginning or end of a row, an end clamp or outer clamp is used that holds just the one module. If the module is mounted in a row (see Fig. 10), a middle clamp is used that fixes two modules at once. To calculate the number of clamps needed, you need to know how many modules are mounted in a row and how many rows there are. On Fig. 10 we can see that there are 8 modules in a row and 2 rows in total. Between the 8 modules of the row we have 7 gaps. In each gap we need to insert 2 middle clamps, that makes 7 x 2 middle clamps plus 4 end clamps, 2 on each side. These quantities need to be taken twice because we have two rows in total which brings us to 28 middle clamps and 8 outer clamps.

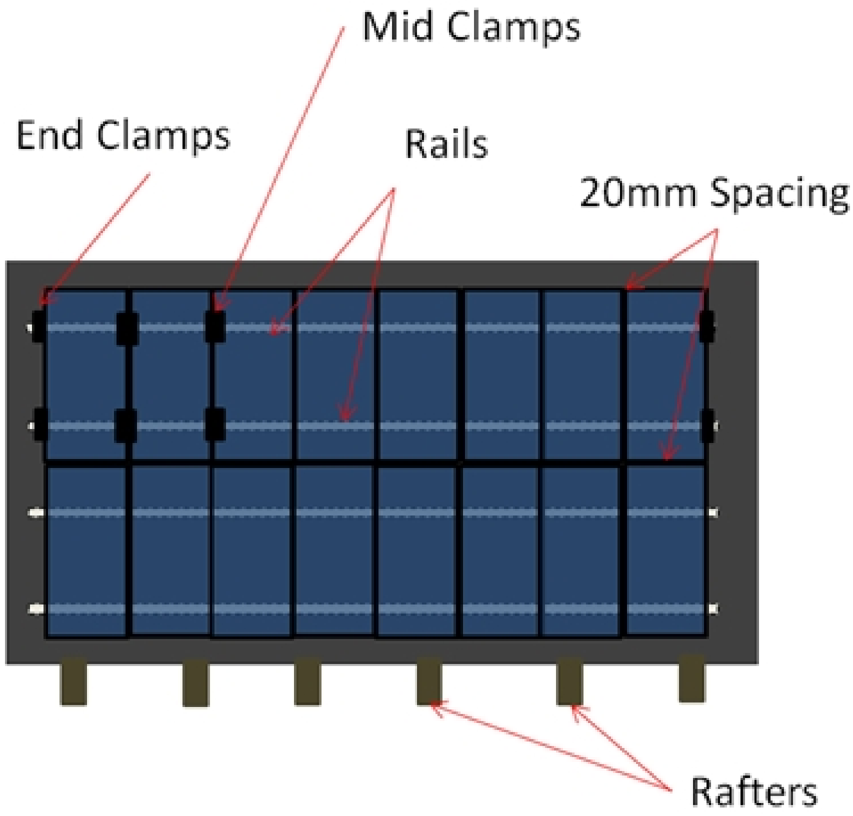


Figure 10: Roof parallel mounting

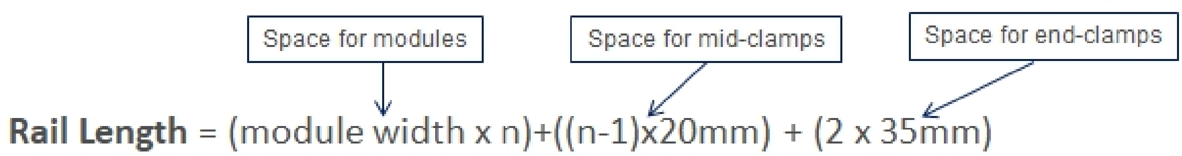


Figure 11: Calculating Rail Length

No of Rails = (2 x no of rows)

Length of Rails - Note standard lengths. Include rail joints if required

No of roof hooks = ((Rail length / rafter spacing) +1) x No of Rails

3.5.2 Elevated structures

The Adama installation will make use of an elevated structure which can also be installed flat i.e. 0 degrees elevation. It is pre-manufactured by the supplier Phaesun and sold as a package.

Figure 12: Phaesun support structure

For the Adama installation, five of these structures will be combined as depicted in Figure 13. In this case 24 outer clamps and 16 middle clamps are needed.

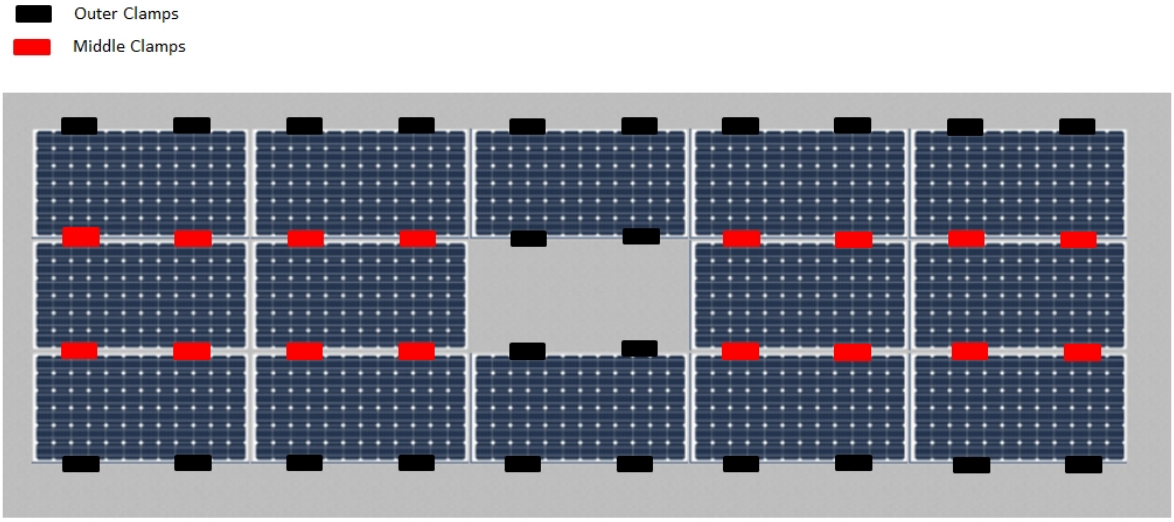


Figure 13: Adama roof layout

3.6 Cable lengths

Cable lengths are determined by taking measurements while doing a site visit. From the site visit, a site layout can be drawn up as indicated in Figure 14.

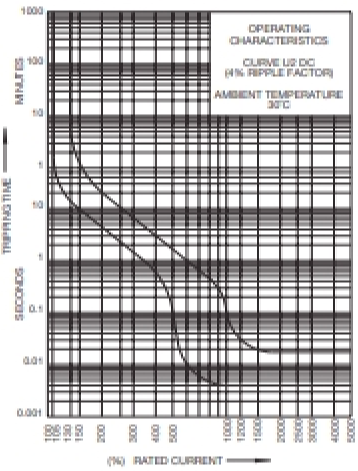
Figure 14: Site layout diagram

Battery Main Switch
PN-BMS

390758 – 390761 • 11/2014

The PN-BMS Battery main switch includes a double pole circuit breaker with a very high short circuit capacity. The BMS is designed for high nominal current to protect cables and equipment. The IP65 enclosure and glands are designed for connecting up to 95 mm². Inside busbar supports the distribution of all devices like charge controller, inverter and loads.

Der PN-BMS Batteriehauptschalter enthält eine zweipolige Sicherung mit sehr hoher Kurzschlussleistung. Der BMS ist für hohen Nennstrom konzipiert und schützt Kabel und Ausrüstung. Das IP65 Gehäuse und die Kabelverschraubungen sind batterieseitig für bis zu 95 mm² ausgelegt. Mit interner Verteilerschiene zum Anschluss sämtlicher Ausrüstungskomponenten wie Laderegler, Wechselrichter oder Lasten.



Technical Data	Technische Daten	PN-BMS 125 A	PN-BMS 150 A	PN-BMS 200 A	PN-BMS 250 A
Number of Breakers	Anzahl der Schalter	2	2	2	2
Pole	Pole	3	3	4	4
Breaker Type	Schaltertyp	QDC-3 (13)	QDC-3 (13)	QDC-4 (13)	QDC-4 (19)
Nominal current [A]	Nennstrom [A]	125	150	200	250
Nominal voltage [V]	Nennspannung [V]	80	80	80	80
Internal resistance* [mΩ]	Innenwiderstand* [mΩ]	2,5	2,5	2,5	2,5
Operating temperature [°C]	Umgebungstemperatur [°C]	–40 ... +85			
Interrupt capacity* [kA]	Schaltstrom* [kA]	10	10	10	10
In-glands	Eingangverschraubung	2 x M32 (25 – 95 mm²)			
Out-glands	Ausgangsverschraubung	6 x M25 (4 – 25 mm²)			
In - Cross section	Anschlussquerschnitt Eingang	1 x 95 mm²			
Out - Cross section	Anschlussquerschnitt Ausgang	3 x 95 mm²			
Tripping curve	Auslösecharakteristik	U2			
Technology	Technologie	Hydraulic-magnetic | Hydraulisch-magnetisch			
Tripping feature	Auslöse-Eigenschaften	precision, temp. independant, suitable for isolation | Genauigkeit, Temp. unabhängig, Trenneigenschaft			
Certificate	Zertifikate	CE, VDE, UL, IEC 60947-2, CCC, GostR			
Resistance to shock	Stoßempfindlichkeit	16,82 g			
Vibration	Vibration	2,5 g			
Art.No.	**Art.Nr.**	**390758**	**390759**	**390760**	**390761**

Figure 15: Battery Fuse

Self-Check - 3	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	A solar charge controller acts as a regulator**.**
2	Cable lengths are determined by taking measurements while doing a site visit.
3	The number of PV modules is calculated based on the size of the available modules and the total size required.

Satisfactory	2 and Above 2 points
Unsatisfactory	Below2 points

Information Sheet 4	Preparing bill of materials based on the prescribed format

4.1 Introduction

From all the previous calculations, a bill of materials (BOM) can be created. Normally provision for fixtures and fittings are made separately as a fixed cost per job or as a percentage of the BOM costs.

4.2 Bill of Materials

A bill of materials(BOM) is a comprehensive inventory of the raw materials, assemblies, subassemblies, parts and components, as well as the quantities of each, needed to manufacture a product. A bill of materials or product structure is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities of each needed to manufacture an end product. A BOM may be used for communication between manufacturing partners or confined to a single manufacturing plant. It includes all alternative and substitute part numbers and parts contained in the drawing notes. Every line of the bill of materials(BOM) includes the product code, part name, part number, part revision, description, and quantity, unit of measure, size, length, weight, and specifications or features of the product.

- **The importance of Bill of materials**
  - ✓ You get a custom-made shopping list
  - ✓ Never run out of materials again
  - ✓ Better planning
  - ✓ Better costing
  - ✓ It unites all departments
  - ✓ Easily find items using powerful attribute search
  - ✓ Drag and drop complete parts onto the BOM in a single operation
  - ✓ Identify and use only the most current data on BOMs
  - ✓ Know what changes have been made to each BOM revision (Add / Remove / No Change)

- ✓ Enforce rules for each assembly part type to ensure correct BOM evolution
- ✓ Create reports for assembly costs
- ✓ Retain a full audit trail of all changes to the BOM,
- ✓ The final BOM for the Adama design is shown in Table 6.

Table 6: Adama BOM

Pos.	Item no.	Description	Quantity	Unit
1	310363	Phaesun PN6M72-350E Modules	14	Pcs
2	340026	Battery OPzS Hoppecke sun | power V L 2-730	24	Pcs
3	321728	Inverter / Hybrid Charger Phocos PSW-H-5KW230/48V	1	Pcs
4	161103	Module Support Structure PN-ASS 03	4	
5		Middle Clamp included in 4	16	Pcs
6		End Clamp included in 4	24	Pcs
7	390003	Corrugated Sheet Roof Screw Fitting 160mm	20	bar
8	704230	SOLARFLEX ® - X PV1-F 25mm²	35	m
9	704232	SOLARFLEX ® - X PV1-F 50mm²	100	m
10	303588	Cable Solar flex-X 1x 4 black 4mm²	25	m
11	390900	PV Standard4 Connector 4-6 mm² Set WM	5	Pcs
13	500090	Connection Box GCB 5-1 200V/50A_gland	1	Pcs
14	108010	Battery Rack Kunstmann 1E.B560.R2	1	Pcs
15	Battery main switch	Battery main switch or Fuse 125 Amp DC	1	Pcs
18		Fuse 12 Amp DC	4	Pcs

Self-Check - 4	Written Test

Multiple choices.

N°	Questions
1	Which one of the following is not benefits of bill of material?
	A. Better costing B. It unites all departments C. Easily find items using powerful attribute search D. None
2	A bill of materials also known as___________ A. inventory of the raw materials B. product structure C. manufacturing partners D. sub-components
3	The BOM represents_________ A. British movement B. Bill of materials C. British module D. None of the above

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Solar PV System Installation and Maintenance
Level-IV
Learning Guide -09

Unit of Competence	**Prepare Job Estimation and Cost of Materials and Components**
Module Title	**Preparing Job Estimation and Cost of Materials and Components**
LG Code	**EIS PIM4 M02 LO3-LG09**
TTLM Code	**EIS PIM4 TTLM 0920v1**

LO3.Identify and calculate labour cost

Instruction Sheet	**Learning Guide:-09**

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

- Identifying on-site personnel and estimating the time required
- Calculating the labour hours for non-contract elements
- Estimating time requirements for work activities
- Calculating the costs or rates required on-site work
- Estimating material requirements and cost derived from produced drawing
- Calculating and fixing transport cost for material mobilization
- Estimating labour cost for installation

- Producing estimation of overall cost

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:-

- Identify on-site personnel and estimating the time required
- Calculate the labour hours for non-contract elements
- Estimate time requirements for work activities
- Calculate the costs or rates required on-site work
- Estimate material requirements and cost derived from produced drawing
- Calculate and fixing transport cost for material mobilization
- Estimate labour cost for installation
- Produce estimation of overall cost

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

Information Sheet 1	Identifying on-site personnel and estimating the time required

1.1 Introduction

Depending on the size and complexity of a PV installation, many different skills may be required on site. In this section, we will explore the type of skills required.

1.2 On-site personnel

In EIS PIM4 MO7 LO1, the following was said about skills required: The requirement on the skills usually depends on the site realities, as every site installation comes with its challenges asking for various skills. However, broadly, the following skills could be requested.

- Skilled solar energy engineer
- Skilled electrical engineer or technician
- Skilled mechanical technician
- Skilled civil technician
- Skilled security and safety technician

1.3 Time required

Initially an estimation of time required can be done based on prior jobs of similar size and type. In Information Sheet 3, we will break down the tasks and estimate time per task.

Self-Check - 1	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Depending on the size and complexity of a PV installation, many different skills may not be required on site.
2	Initially an estimation of time required can be done based on prior jobs of similar size and type.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 2	Calculating the labour hours for non-contract elements

2.1 Non-contract elements

The following was adapted from (NREL, 2017). Non-contract elements can be seen as all the tasks that needs to be done that does not form part of the direct installation of the system. These are also sometimes referred to as 'soft costs'. Think of hard costs in terms of hardware: the physical products installed to get your new solar panel system up and running. This is what you'll pay for the solar panels themselves, inverters, solar mounting racks, a battery for storage, etc. Solar panels can account for about 25 to 30 present of the total solar panel system cost.

Other hard costs include

- A solar inverter, which can account for about 10% of hard costs
- Solar mounting and electrical equipment, which can be another 10%

Figure 16 shows a useful pie graph sourced from the National Renewable Energy Laboratory:

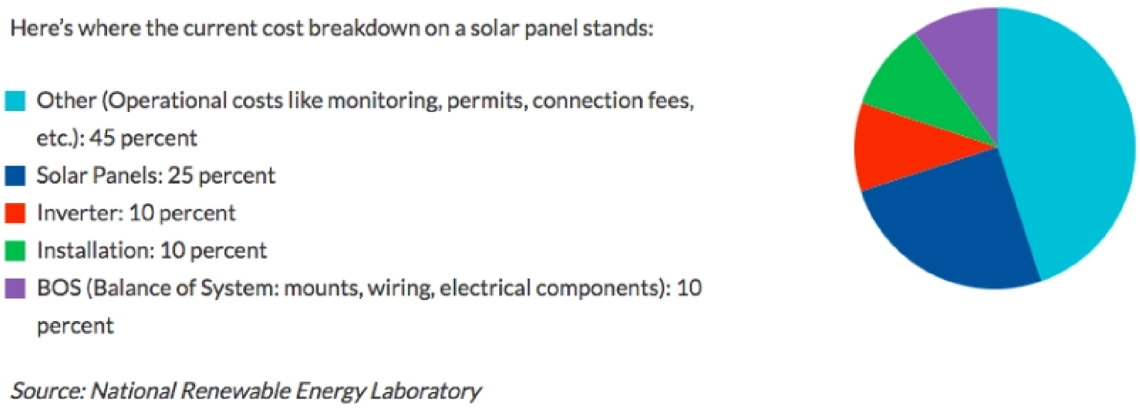


Figure 16: Cost breakdown

Soft costs include administration costs for the company, customer acquisition and marketing, system design, permits and fees for connecting to the grid, and labour for installation. Here's a soft costs break down from the Department of Energy.

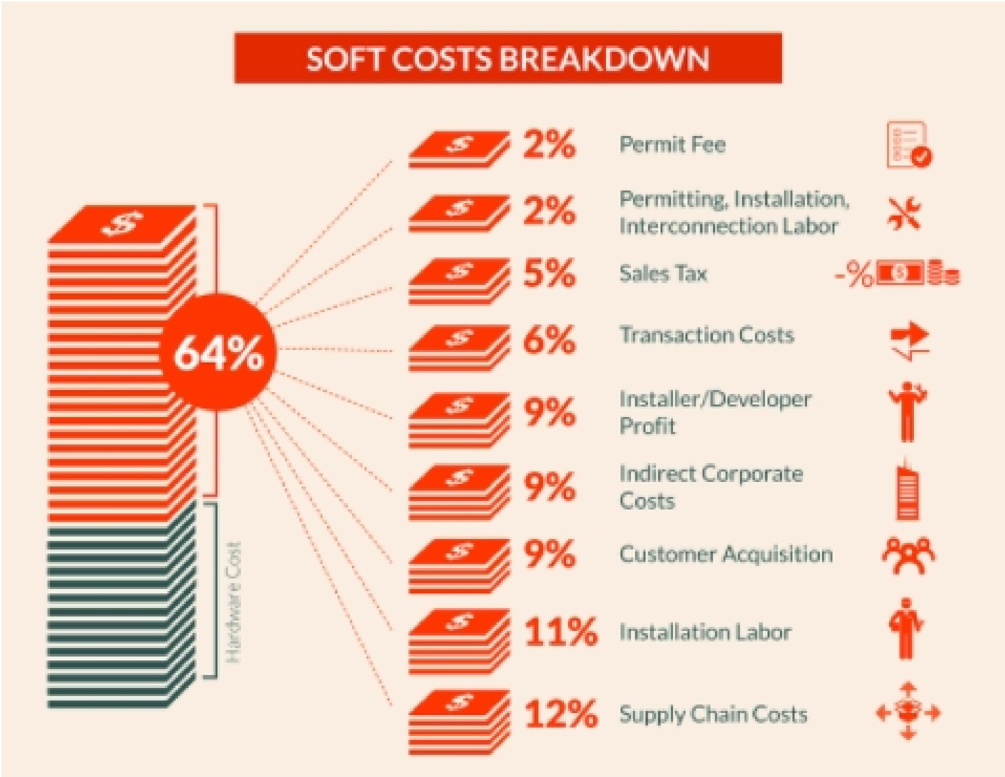


Image courtesy U.S. Department of Energy

These costs will vary from country to country and will be dependent on the type of system installed. To some degree, soft costs are simply part of running a business. In order to keep their doors open, solar energy companies have to pay employees, attract new customers and make a profit.

Self-Check - 2	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Non-contract elements are also sometimes referred to as ‘soft costs’.
2	Costs for permits are not seen as non-contracting elements.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 3	Estimating time requirements for work activities

3.1 Estimating time requirements for work activities

Time estimation depends on the experience of the company and the size of the job to be done. It is also important to track the time taken per job to use it as a base for estimation of future projects.

3.2 Estimation per task

Time estimation can be done per task. Before determining time required, one should identify each task and the skill required per task. The time per task can then be estimated as well. The following tasks were adapted from (Isiolaotan, Solar Photovoltaic Installation Supervision, 2016). This table can be adjusted to suit specific types of installations. Some of the skills can be performed by the same person.

Task	Skill/Role	Time Required
Installation		
Confirm the location where the PV modules will be installed.	Solar energy engineer	
Confirm that there is no shade or shade-causing feature, which could interfere with the irradiance that the solar panel array receives. This might include trees, buildings or other man-made structures such as electricity poles.	Solar energy engineer	
Develop a safety plan to be implemented once installation work begins.	Security and safety technician	
Determine the installation location of system components and cable routes.	Solar energy engineer	
Prepare equipment and tools to be used during installation and ensure that they are available before installation work begins.	Electrical engineer or technician Mechanical technician Civil technician	

Install conduits (pipes and trunkings) along the planned cable route.	Civil technician Mechanical technician	
Install cables in conduits.	Electrical technician	
Label all cables according to circuits.	Electrical technician	
Install solar panel mounting systems.	Mechanical technician	
Install system components in the pre-determined locations.	Mechanical technician	
Mount PV modules on structures	Mechanical technician	
Connect PV modules according to desired series/parallel connection.	Electrical technician	
Connect batteries according to desired series/parallel connection.	Electrical technician	
For an AC system, connect batteries to the inverter (input side). Ensure that the inverter output switch is in the OFF position. Ensure that the main distribution board (MDB) breaker is in the OFF position.	Electrical technician	
For an AC system, connect the inverter output to the home distribution board. Take care to ensure that only relevant circuits are connected.	Electrical technician	
Connect the battery bank to the charge controller.	Electrical technician	
If the system consists of DC loads, connect the loads to the charge controller.	Electrical technician	
Connect the solar photovoltaic array to the charge controller	Electrical technician	
Switch on the inverter	Electrical technician	
Turn on all switched off breakers on both the AC and DC sides.	Electrical technician	
Commissioning – Visual Inspection		
Number of PV modules connected in series and in parallel is correct	Solar energy engineer	
All modules are properly wired	Solar energy	

	engineer	
PV array mount is properly fastened	Solar energy engineer	
All cable conduits are properly installed	Solar energy engineer	
All cables are properly terminated and appropriately labelled.	Solar energy engineer	
Commissioning – Electrical inspection DC		
Polarity of all cables (positive and negative)	Solar energy engineer	
Open-circuit voltage of each array string	Solar energy engineer	
Short-circuit current on each array string	Solar energy engineer	
Voltage and readings at the critical connection points (junction boxes, disconnects and at the inverter) in the system	Solar energy engineer	
Correct operating voltages and system current as specified for system design	Solar energy engineer	
Wire insulation and resistance	Solar energy engineer	
Effectiveness of grounding connections	Solar energy engineer	
Commissioning – Electrical inspection AC		
Measure AC voltages along the circuit. Start at the inverter as this is the origin of the AC circuit in your PV system (ensure that the AC disconnect and MDB breaker are in the "OFF" position). If this voltage measurement is as expected, then:	Solar energy engineer	
Switch "ON" the AC disconnect and measure the output voltage and current from there.	Solar energy engineer	
Switch "ON" the main breaker on the MDB and measure the output voltage and current from there.	Solar energy engineer	
Documentation Manual		
User manual	Solar energy engineer	

When performing the first jobs, it is advisable to track the installers' productivity. Note down how much time is needed for the tasks. If tasks are performed as one activity it is not necessary to split up the time. The goal is to get an impression of how long it takes in average to finish an installation. Also, as a beginner one will probably take more than time an experienced installer. An average value should be quoted in order to remain competitive even though it means that in the beginning the hourly rate is less than desired.

3.3 Skills table example

The example below shows how the skills table can be used for an arbitrary project. The times and rates does not necessarily reflect realistic rates as labour rates varies significantly per country.

Table 7 Skills Table example

Task	Skill/Role	Time Required in hours
Installation		**64 hours**
Confirm the location where the PV modules will be installed.	Solar energy engineer	0.5
Confirm that there is no shade or shade-causing feature, which could interfere with the irradiance that the solar panel array receives. This might include trees, buildings or other man-made structures such as electricity poles.	Solar energy engineer	0.5
Develop a safety plan to be implemented once installation work begins.	Security and safety technician	2
Determine the installation location of system components and cable routes.	Solar energy engineer	2
Prepare equipment and tools to be used during	Electrical engineer or	2

installation and ensure that they are available before installation work begins.	technician Mechanical technician Civil technician	
Install conduits (pipes and trunkings) along the planned cable route.	Civil technician Mechanical technician	8
Install cables in conduits.	Electrical technician	4
Label all cables according to circuits.	Electrical technician	2
Install solar panel mounting systems.	Mechanical technician	8
Install system components in the pre-determined locations.	Mechanical technician	6
Mount PV modules on structures	Mechanical technician	6
Connect PV modules according to desired series/parallel connection.	Electrical technician	4
Connect batteries according to desired series/parallel connection.	Electrical technician	2
For an AC system, connect batteries to the inverter (input side). Ensure that the inverter output switch is in the OFF position. Ensure that the main distribution board (MDB) breaker is in the OFF position.	Electrical technician	2
For an AC system, connect the inverter output to the home distribution board. Take care to ensure that only relevant circuits are connected.	Electrical technician	2
Connect the battery bank to the charge controller.	Electrical technician	2
If the system consists of DC loads, connect the loads to the charge controller.	Electrical technician	0
Connect the solar photovoltaic array to the charge controller	Electrical technician	1
Switch on the inverter	Electrical technician	0.5

Turn on all switched off breakers on both the AC and DC sides.	Electrical technician	0.5

Summary:

Skill	Hours	Rate	Total
Solar energy engineer	3.5	$20	$75
Security and safety technician	2	$10	$20
Electrical technician	22	$12	$264
Mechanical technician	28	$10	$280

3.4 Smaller system time estimation

For smaller systems, the installation time is often quoted in terms of skilled labour hours and unskilled labour hours as shown in Figure 17. This is generally based on experience of prior projects.

Customer : Company XYZ,
cnr Hennie Alberts Webb st,
Brackenhurst,
Alberton, JHB, SA.

COSTING SHEET / SOLAR INSTALLATIONS

GPS Co-ords -26.319S, 28.096E

Z1.	5	m	25mm sprag - flexi-conduit	R2.20	R11.00
AA.	1	item	PV conduit, joiners, elbows, saddles, fasterns, sundries	R112.00	R112.00
AA1.	1	item	Roof entry point kit - weatherproof	R480.00	R480.00
AB.	3	item	MC 4 connectors - pair set	R40.70	R122.10
AC.	2	item	Roof work, scaffolding hire for 2 days	R880.00	R1,760.00
AD.	1	item	PPE allowance for roofing work	R190.00	R190.00
AE.	1	item	PV disconnect box, fuse & surge protect - off shelf	R5,500.00	R5,500.00
AF.	1	item	Inverter - SMA SunnyBoy 5.0 kW	R16,240.00	R16,240.00
AG.	1	item	Inverter Charger - SMA SunnyIsalnd 6.0	R35,565.00	R35,565.00
AH.	1	item	Li-ion battery BYD B-Box 13.8	R115,000.00	R115,000.00
AI.	1	item	Dedicated external DB - assembled	R1,580.00	R1,580.00
AJ.	1	item	Battery disconnect & fused box, 125 amp	R4,999.00	R4,999.00
AK.	5	m	70mm² battery cable - RED	R158.00	R790.00
AL.	5	m	70mm² battery cable - BLACK	R158.00	R790.00
AM.	1	item	Battery connect kit, lugs, shrink wrap, cable tie, etc	R180.00	R180.00
AN.	3	m	100 x 40 dual PVC trunking	R68.00	R204.00
AO.	1	item	Mounting sundries	R80.00	R80.00
AP.	4	m	Cable 6.0mm² GP house - RED	R4.80	R19.20
AQ.	4	m	Cable 6.0mm² GP house - BLACK	R4.80	R19.20
AR.	4	m	Cable 6.0mm² GP house - EARTH	R6.00	R24.00
AS.	1	item	RCB (earth leakage unit) - DB upgrade	R998.00	R998.00
AS1.	4	item	Circuit breakers, 20 amp, 10 amp (move or changes)	R86.00	R344.00
AT.	1	item	General, sprag, ties, straps, lugs	R220.00	R220.00
AU.	1	item	V/F relay (NRS097-1-2) & 2 pole disconnect contactor	R4,880.00	R4,880.00
AV.	1	item	In-line grid meter - two way	R1,880.00	R1,880.00
AW.	24	hrs	Labour fit, install & commission / test	R300.00	R7,200.00
AX.	24	hrs	Casual labour assist @ R55.00/hr	R55.00	R1,320.00
AY.	3	trip	Site visit - travel	R250.00	R750.00

Figure 17: Costing example

Example – Adama 5.1kWp system

The following example is based on the system to be installed at Adama. In this case the labour was quoted as a fixed amount.

Invoice No.:092A//2019

Customer

Name **Adama Poly Technic**
Address Adama
Contact Tele:+251118-697461

Solar power system for Adama Poly Technich
Proforma Invoice

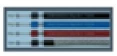
S/N	Description	QTY	Unit	Total price before VAT (Birr)
	5,1 kWp off-grid backup PV Systems			
1	Solar Module Phaesun PN6M72-350 E 350 watt 350 W, 24 VDC, Standard4, 72 cells, mono, alu frame (silver), tempered glass, back-sheet (white), cable 1250 mm / 4 mm² 	15	pcs	
2	Module Support Structure PN-ASS 03 alluminium support structure for 3 solar modules, incl. mounting clamps for modules, screws, connectors and heavy duti anker bolts 	5	pcs	
3	Inverter / Hybrid Charger Phocos PSW-H-5KW-230/48V 5000 W, 48 VDC, 230 VAC / 40 - 63 Hz, charge current 80 A PV + AC / 40 A transfer, 450 Voc, self consumption 14 W / 40 W, sinewave, electronic 	1	pcs	
4	Connection Box GCB 5-1200V/50A_ gland, 200 VDC, Input 5 x 12A, Out put 1x 50A, Switch, (1X), Cable Gland, Screwed cover (Grey), IP65, single 	1	set	
5	Corrugated Sheet Roof Screw fitting M 10 x 180mm For Coneection between crosstie profile rail and rafter including hunger bolt M10, Connecting plate, screws, nuts and V2A blocking screws 	10	set	
6	PV Standard connector 4-6 mm2 set WM30 A, 1000V, male + female, cross section 4-6 mm², cable diameter 5,0-7,5 mm, compatible with Standard4, tool free connection, IP65 	5	pcs	
7	Cable Solarflex-X 1X 4 Blackcross section 1x 4mm², outer diameter 5,4mm, 1500 VDC, 1000 VAC, CU / fine-wire / verzinnt, double isolated, protection class II, UV-resistant, ozone resistant 	100	meteres	
8	Battery OPzS Hoppecke sun /Power C L2-730 GUG, 7 340026 lead acid batteries 2 volt filled and charged 490Ah (C10) 730 Ah (C100) incl. Accessories. 	24	pc	
9	Battery Rack Kunstmann 1E.B560.R2 Steel floor rack with 2 battery rows Flamulit coated gray RAL 700,1 max. insulator load: 136kg Dimension 2400 x 586 x 90mm	1	pcs	
10	 Battery Main Switch PN-BMS 150 A	1	pcs	
11	Installation accessories			
	Sub Total (Birr)			771 903.99
7	Fright and document			85 480.00
8	Installation 5.2Kwp system			80 000.00
10	Importing and Transportation cost from customs and to Adama			119 832.00
11	Training			40 000.00
	Sub Total (service in Birr)			325 312.00
			Sub-total price Birr:	**1 097 215.99**
			VAT 15%:	**164 582.40**
			and Total cost of materials and installation Service Birr:	**1 261 798.39**

Figure 18: Adama quotation

Self-Check - 3	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Time estimation depends on the experience of the company and the size of the job to be done.
2	The goal of time estimating is to get an impression of how long it takes in average to finish an installation.

Satisfactory	2 points
Unsatisfactory	Below 2 points

4.1 Introduction

The rates for on-site work will differ from area to area and country to country. It will also depend on the size and duration of the job, where the job is and the skills required.

4.2 Calculating rates for on-site work

The rates paid for on-site work is generally a balance between recovering costs, making a profit and to be competitive with other suppliers. It is common knowledge that PV equipment prices dropped significantly over the years. With that, the installation cost also come down – see Figure 20Figure 19which gives an indication of how prices came down between 2009 and 2017.

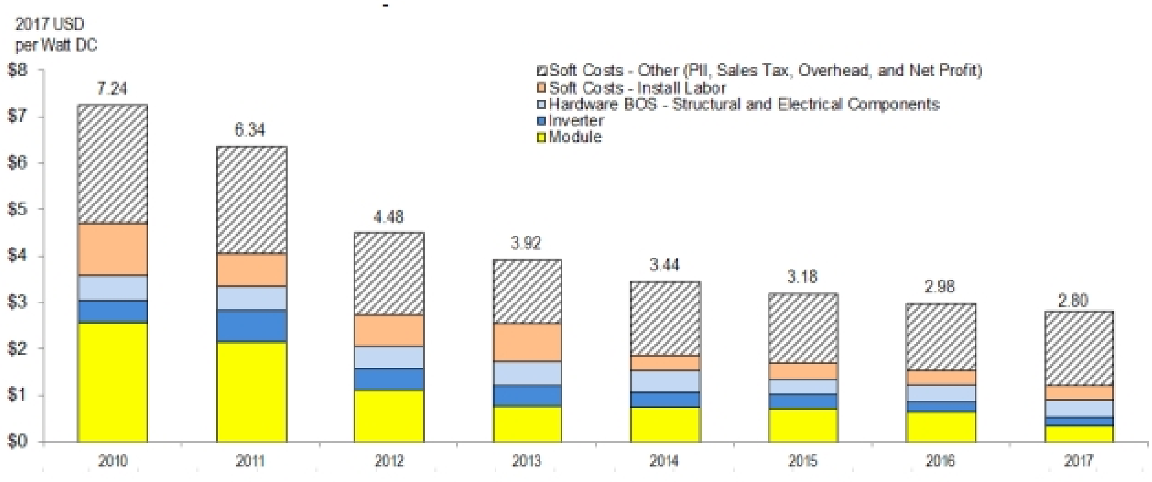


Figure 20: PV Cost breakdown

One would need to do some market research to establish what other suppliers are charging for on-site installation to be able to charge market related tariffs. However, all costs should be recovered in the tariff.

Self-Check - 4	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	The rates for on-site work will not depend on the level of skills required.
2	The rates paid for on-site work is generally a balance between recovering costs, making a profit and to be competitive with other suppliers.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 5	Estimating material requirements and cost derived from produced drawing

5.1 Introduction

In LO2, we covered the process to determine equipment required from the produced drawings. In this section, we will look at material requirements. This will include:

- Cable lengths
- Switches and safety devices
- AC Installation cable, light and plug points

5.2 Cable lengths

Cable lengths are determined by taking measurements while doing a site visit. From the site visit, a site layout can be drawn up as indicated in Figure 14.

Figure 21: Site layout diagram

5.3 Fuses and safety devices

A fuse is an electrical safety device that protects an electric circuit from excessive electric current. Circuit breakers are electrical safety devices that protect electric circuits from overload electric current conditions.

No	Circuit breaker type	Description
1	Thermal	Will respond to the excessive heat generating during overload current conditions.
2	Magnetic	Will respond to the magnetic field generated during overload current conditions.
3	Thermo-magnetic	Will respond to both the heat and magnetic field generated during overload current conditions. This is the circuit breaker equivalent to the slow blow fuse.

The number and size of fuses will be according to the closest higher available fuse based on the calculations in LO1, Information sheet 1.

The battery fuse was calculated at 100A. The closest higher fuse will be the PN-BMS 125A fuse used for the Adama installation. See Figure 15.

The fuses between the PV modules and the combiner box will be 12A. For the Adama example, the fuses will be housed in a combiner box with 5 inputs and one output via a DC isolator rated 50A.

5.4 AC Installation

Alternating current (AC) is the type of electric current generated by the vast majority of power plants and used by most power distribution systems. The AC installation is normally done by an electrician according to the countries specific regulations and should be estimated from the electrician. Electrical wiring is an electrical installation of cabling and associated devices such as switches, distribution boards, sockets, and light fittings in a structure. Wiring is subject to safety standards for design and installation. Allowable wire and cable types and sizes are specified according to the circuit operating voltage and electric current capability, with further restrictions on the environmental conditions, such as ambient temperature range, moisture levels, and exposure to sunlight and chemicals. Associated circuit protection, control and distribution devices within a building's wiring system are subject to voltage, current and functional specification. Wiring safety codes vary by locality, country or region. The International Electro technical Commission (IEC) is attempting to harmonise wiring standards amongst member countries, but significant variations in design and installation requirements still exist. Wiring for AC and DC power distribution branch circuits are colour coded for identification of individual wires.

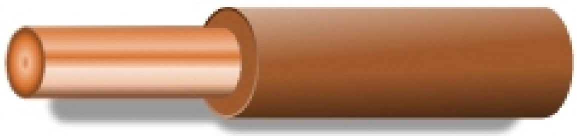
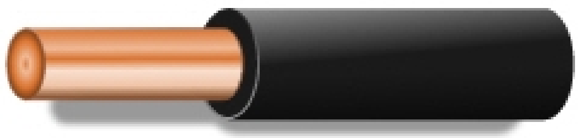
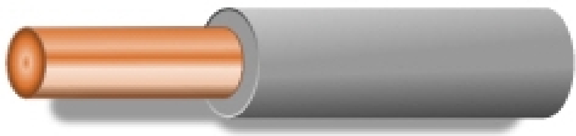
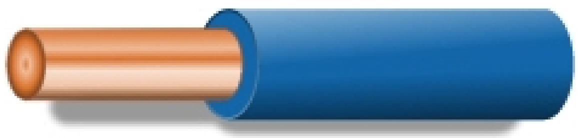
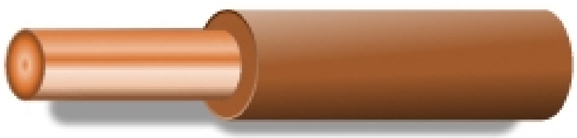
Function	***IEC Code for most of European Union***
Three Phase Line (L1)	
Three Phase Line (L2)	
Three Phase Line (L3)	
Neutral (N)	
Protective Earth or Ground (PE)	
Single Phase Line	

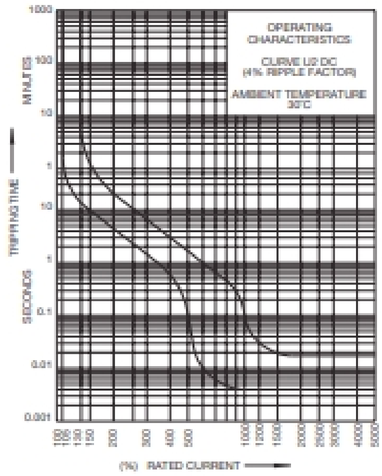
Figure 22 IEC code for most of European Union

Battery Main Switch
PN-BMS

390758 – 390761 • 11/2014

The PN-BMS Battery main switch includes a double pole circuit breaker with a very high short circuit capacity. The BMS is designed for high nominal current to protect cables and equipment. The IP65 enclosure and glands are designed for connecting up to 95 mm². Inside busbar supports the distribution of all devices like charge controller, inverter and loads.

Der PN-BMS Batteriehauptschalter enthält eine zweipolige Sicherung mit sehr hoher Kurzschlussleistung. Der BMS ist für hohen Nennstrom konzipiert und schützt Kabel und Ausrüstung. Das IP65 Gehäuse und die Kabelverschraubungen sind batterieseitig für bis zu 95 mm² ausgelegt. Mit interner Verteilerschiene zum Anschluss sämtlicher Ausrüstungskomponenten wie Laderegler, Wechselrichter oder Lasten.



Technical Data	Technische Daten	PN-BMS 125 A	PN-BMS 150 A	PN-BMS 200 A	PN-BMS 250 A
Number of Breakers	Anzahl der Schalter	2	2	2	2
Pole	Pole	3	3	4	4
Breaker Type	Schaltertyp	QDC-3 (13)	QDC-3 (13)	QDC-4 (13)	QDC-4 (19)
Nominal current [A]	Nennstrom [A]	125	150	200	250
Nominal voltage [V]	Nennspannung [V]	80	80	80	80
Internal resistance* [mΩ]	Innenwiderstand* [mΩ]	2,5	2,5	2,5	2,5
Operating temperature [°C]	Umgebungstemperatur [°C]	–40 … +85			
Interrupt capacity* [kA]	Schaltstrom* [kA]	10	10	10	10
In-glands	Eingangverschraubung	2 x M32 (25 – 95 mm²)			
Out-glands	Ausgangsverschraubung	6 x M25 (4 – 25 mm²)			
In - Cross section	Anschlussquerschnitt Eingang	1 x 95 mm²			
Out - Cross section	Anschlussquerschnitt Ausgang	3 x 95 mm²			
Tripping curve	Auslösecharakteristik	U2			
Technology	Technologie	Hydraulic-magnetic | Hydraulisch-magnetisch			
Tripping feature	Auslöse-Eigenschaften	precision, temp. independant, suitable for isolation | Genauigkeit, Temp. unabhängig, Trenneigenschaft			
Certificate	Zertifikate	CE, VDE, UL, IEC 60947-2, CCC, GostR			
Resistance to shock	Stoßempfindlichkeit	16,82 g			
Vibration	Vibration	2,5 g			
Art.No.	Art.Nr.	390758	390759	390760	390761

Figure 23: Battery Fuse

Self-Check - 5	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	A fuse is an electrical safety device that protects an electric circuit from excessive electric current.
2	Direct current (DC) is the type of electric current generated by the vast majority of power plants and used by most power distribution systems.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 6	Calculating and fixing transport cost for material mobilization

6.1 Calculating and fixing transport cost for material mobilization

Transport cost will depend greatly on the location of installation site. Transport cost can be:

- Transport of the material by courier, transport contractor or own transport;
- Transport of the installation team

A fixed rate per km can be used for own transport while external companies should provide quotations for transport. Associated with transport costs will be insurance for the equipment transported.

Self-Check - 6	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Equipment transported should only be insured if the distance transported is far.
2	Couriers can be used for transport of equipment.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 7	Estimating labour cost for installation

7.1 Estimating labour cost for installation

Once all the tasks, time per task and resources are determined, the labour cost can be estimated in different ways

7.2 Labour per task

To calculate labour based on tasks, the tasks should be defined and duration estimated to get to Task hours:

The labour cost can then be calculated per task by applying a labour rate to a task type's hours:

All the labour costs for all tasks should then be collated and added up to get the total installation labour cost.

7.3 Labour per unit

Alternatively, a cost can be calculated based on the size of the installation e.g. a price per watt for the PV installation and possibly a fixed price for the DC and AC installation. One can only work on a price/watt after carefully analysing the real labour cost over a number of projects. In the example in Figure 24the DC installation, design, project management, documentation and commissioning were based on a price per watt while the more specific AC installation was based on the actual job labour estimation.

LABOUR: Installation & Commissioning		
Design & Project Management, Procurement, Documentation per watt	R0.40	R100 000.00
Installation AC per job		R35 000.00
DC Installation per Watt	R1.10	R274 824.00
QC & Commissioning per watt	R0.40	R100 000.00

Figure 25: Labour calculation example

Self-Check - 7	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions and answers
1	The labour cost per task can be calculated by task hours divided by task labour rate.
2	All the labour costs for all tasks should then be collated and added up to get the total installation labour cost.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 8	Producing estimation of overall cost

8.1 Introduction

The estimation of overall cost needs to include all the costs discussed in this module. For this, a RAL offer generation document can be handy as a starting point.

8.2 RAL Offer generation

The RAL Quality Assurance Association (RAL) developed a guideline to be used for offer generation. While it may not be applicable for every circumstance, it can be a very good starting point for the development of an in-house template. In this section, we will list the different parts of the RAL document:

8.2.1 Heading

Proposal generation according to the Requirements of the RAL P3 GZ 966 for Photovoltaic Installations
English Version August 2012

Proposal Generation

A proposal in accordance with the requirements of the RAL P3 GZ 966 for photovoltaic installations should contain worded sentences according to the following points.
Important points are marked: →important←.

Companies can furthermore construct their offers freely. Neither the sequence nor the contents of the sections suggested below are mandatory. Where a parameter or information is "not relevant" it can simply be stated as such.

Figure 26: RAL offer headline

8.2.2 Part 1: General Data

Part 1: General data

→ Company letterhead: valid company, valid address, contact (tel, fax, email, web-address), name of management←

→ Customer: name, address, postal code, city, telephone number←

→ Location of offer, date of offer←

→ Project number←

→ Page number←

→ Point of contact←

8.2.3 Offer Content

Part 2: Offer content

→ Terms of offer (e.g. completion or part delivery, …)←

→ Array performance P_{PV} in kWp. The P_{PV} value should be provided according one of the following requirements:

- The value has minimum one post decimal position (2,5 KWp) or
- The value has no post decimal position, but the tolerance is given (5kWp - 5%) or
- The value is given as sum of the STC-nominal module power specifying the power tolerances of the modules (Power tolerance +-5%).

→ Type of system (e.g. grid-connected system, stand-alone system…)←

→ Type of mounting (e.g. roof top mounted, in-roof-mounted…)←

→ Location of the PV-system installation if no customer address←

8.2.4 Proposal Text

Part 3: Proposal text

→ Salutation←

→ Dates and specifications from the documented customer dialogue (site evaluation)←

→ Customer requirements from the site evaluation←

→ Planning aim from the documented site evaluation←

→ Relation to the RAL-GZ 966 (e.g."The universal, special regulations and test regulations of the quality seal RAL solar energy systems (RAL-GZ 966) from the areas P1 (components), P2 (planning) and P3 (execution) apply for the offered performances.)←

→ Relation to the local signals and for the observance of orders (e.g. for the implementation of the PV-system; regulations of the building code, industrial safety; accident prevention regulations of the professional associations , technical connection conditions, VDE regulations, EN and DIN-standards, etc. are kept.)←

→ Specific features/arrangements (e.g. "scaffolding shall be provided by developer / installation company"; "the surface weight of the arrangement amounts to: …"; "The customer will apply for the building permission on time/ building permission is already available / not necessary"; "The total installed PV capacity can slightly differ from the offered capacity as the installed modules are measured individually and the calculation is done with the nominal power" "The existing antenna (aerial) will be moved before the installation of the PV system by the customer as agreed"), …←

→ Information about the load-carrying capacity of the roof structure and to the statically survey. (e.g. "statically survey will be provided by the customer or by the installation company .")←

→Please place a note on the offer in case yield reducing circumstance are already known or foreseen during the planning stage (e.g. roof superstructures, shades, growing trees, building laws of neighbours which allow the neighbours the addition of another story or the construction of new buildings in front of the PV system)

→ A clear note should be given that a decrease in production is to be expected in case the calculated yield is **more than 20% lower than the max. yield** to be expected by theoretically optimized arrangement in the intended geographic location. The reason for the decrease in production must be identified (e.g. adjustment, inclination, shading, missing aeration). The yield decrease has to be calculated based on the difference of the expected yield by theoretically optimized arrangement in the intended geographic location with the yield to be expected because of the real conditions.

→ Result of a profit forecast (if it was done).←

→ Result of an economic efficiency forecast (if it was done).←

→ Evaluation of the time in which the installation should begin (information calendar week).←

→ Evaluation of the period (interval) in which the installation should take place (information days).←

8.2.5 Specifications (Bill of Quantities BoQ)

Part 4: Specifications (Bill of Quantities BoQ)

Basically the bill of quantities is made up of five sections and each of the five sections can contain several subsections.

The five sections are as follow:

1. Delivery
2. Components
3. Mounting
4. Other
5. Optional positions

It is recommended to compile each subsection individually, especially in section 5. **The price for section 2 Components and 3 Mounting can also be given as a lump sum**. Thus it is not needed to give the single prices for each of the items in those sections.

It is not recommended to combine section 2 and 3 into one all-inclusive price of both sections.

If the order is explained at the fixed price, an all-inclusive price of the whole order can be agreed.

A lump sum price for the whole offer can be given in case a guaranteed maximum price is offered. In this case the accounting has to be done based on the real costs, whereby not more than the guaranteed maximum price can be accounted.

Possible subsections to **section 1 delivery**:

Riskless and safe transport of all plant components up to the installation place, delivery at due date, transport assurance, check if all components are complete and unharmed...

Possible subsections to section **2 components**:

Modules, wiring, inverter, mounting system, protective/safety devices (e.g. DC isolater), electric material, meter place…

Possible subsections to **section 3 mounting/installation**:

Construction site equipment, mounting of the components, connection of the components to each other, grid connection…

Possible subsections to **section 4 others:**

Agreed works before installation of the PV system (construction preparation), customer briefing, registration of the whole System with the responsible net operator (e.g. Escom), final complete PV system documentation...

Possible subsections to **section 5 optional positions**:

Extension of manufacturer's guarantee, guarantee (s) of the installation company, over voltage protection, lightning protection arrangement, operation, yield and data monitoring, yield data visualization, profit forecast, economic efficiency forecast, assurance(s), new or additional meter

The choice of the offered components has to be unequivocal and binding, changes are only possible if agreed with the costumer and documented in written (both sides have to sign the minutes with the agreed changes).

However, statements like "high-class modules with suitable inverters of famous manufacturers" are not compatible with RAL solar.

Unforeseen additional expenditure caused by additional wishes of the customer (documented in writing) or by additional work of the installing company not caused by the installing company can be accounted to the customer. Hereby the actual hourly rates can be accounted (master, skilled worker, trainee and assistant).

In the example below the column "description" shows the minimum required information. However, this list does not claim to be exhaustive and is subject of individual adaptation of the user.

8.2.6 Example BoQ

Example to part 4: Specification (Bill of Quantities):

Pos. Nr.	Number	Unit	Description	Price	Total price

1st Delivery:

1	1	lump sum	**Delivery of the complete photovoltaic system** Safe transport of all plant components up to the installation place delivery at 20 June 2015 Component check (completeness and intactness)	R	R

Sure and safe transport of all plant components up to the installation place, delivery at due date, transport assurance, check if all components are complete and unharmed

			Sum Position 1: Delivery	**R**	**R**

2nd Components:

2	20	Piece	**Modules:** Manufacturer (name), type (name), nominal achievement Cell type (mono and polycrystalline / thin layer), Manufacturer's guarantee **(Technical data sheet in the appendix)**	R	R
3	1	Piece	**Solar wiring, electric material,:** Manufacturer, type (names), wire cross sections, wire lengths, wire suitability conditions (temperature, UV). **(If available data sheets in the appendix)**	R	R
4	1	Lump Sum	**Inverter:** Manufacturer, type (name), nominal power, manufacturer's guarantee time in years **(Technical data sheet in the appendix)**	R	R
5	1	Lump sum, piece	**Mounting system:** Manufacturer (name), type (name), material (stainless steel, aluminium), licensing/certification information, statically survey if available **(If available data sheet in the appendix)**	R	R
6	1	Lump sum, piece	**Safety devices:** Manufacturer (name), type (names) of DC isolator, fuses, overvoltage measurements, grounding, potential equalisation	R	R
7	1	Lump sum	**Electric material, meter place / box:** Manufacturer (name), type (name)	R	R
			Sum Position 2: Components	R	R

3rd Mounting:

8	1	Lump sum	**Building site equipment** (e.g. construction container, WC, crane, scaffolding, road-block)	R	R
9	1	Lump sum	**Mounting of the complete photovoltaic system:** Installation of the mounting system, module installation; wiring; inverter installation; connection of all components; start-up operation of the PV system.	R	R
			Sum Position 3: Mounting	**R**	**R**

4th Others:

10	1	Lump sum, hours	**Works before the installation (Construction preparation):** (e.g. documentation of the present situation, dismantling, any additional construction or renovation (to be accounted inhourly rates)	R	R
11	1	Lump sum	**Customer briefing**	R	R
12	1	Lump sum	**Registration of the whole arrangement with responsible distribution network operator (ESCOM)**	R	R
13	1	Lump sum	**PV system documentation:** Data sheets of components, certificates, guarantee certifi-cates, roof plan with module allocation, module boarding and inverter allocation.	R	R
			Sum Position 4: Others	**R**	**R**

Optional Positions:

14	1	Piece	**Extension of manufacturer's guarantee**	R	R
15	1	Piece	**Guarantee (n) of the installation company**	R	R
16	1	Lump sum, piece	**Over voltage protection** Installation location, manufacturer (names), type (names), mounting, small parts	R	R
17	1	Lump sum, piece	**Lightning protection measures** Installation location, manufacturer (names), type (names), mounting, small parts.	R	R
18	1	Lump sum, piece	**Monitoring system:** Manufacturer (name), type (name), mounting, small parts.	R	R
19	1		**Profit forecast**	R	R
20	1		**Economic efficiency forecast**	R	R
21	1		**Assurance:** Installation assurance, material assurance, yield failure/ black out assurance.	R	R
22	1	Lump sum, piece	**Customer's meter:** Manufacturer (name), type (name) mounting, small parts.	R	R

8.2.7 Conclusion

Part 5: conclusion

→ Net sum, value added tax, gross sum (in euro). ←

→ Binding period of the offer, beginning and duration (at least 4 weeks). ←

→ Naming of contract components, as far as available (e.g. construction regulations, standard terms) signed documented customer dialogue (RAL site evaluation)... ←

→ Information of the payment terms and discounts if applicable ←

→ information on the minimum requirements of the acceptance record according to the RAL Quality Label "Photovoltaic Installations" RAL GZ 966 ←

→Reservation of the property rights. ←

→ Concluding sentence under the offer. ←

→Signature. ←

8.2.8 Appendix

Part 6: appendix

→At least the following documents belong to the appendix of the offer:

Signed documented customer dialogue (RAL site evaluation), documents and data sheets of all essential components (in any case, modules and inverter), certificates, guarantee certificates, roof plan with module allocation, module cabling and inverter allocation, summary of a statics surveys(if statics survey is given or was done). ←

8.3 Costing Spread sheet example

Figure 27shows an example of a costing spreadsheet for a bigger grid-tied system. Once established, the same spreadsheet can be used for similar type of projects and eventually an accurate price/watt can be determined to be used in future projects. The spreadsheet breaks down the project in the main equipment, the BOS materials, professional fees and installation. Once the material and installation costs are determined, provision is made for a contingency amount and a mark-up amount. Finally a price per watt is established. The same process can be used for off-grid systems. A price per watt can be established for the PV generator while a price per kWh can be established for the backup battery part.

Qty	unit	Item	unit price	Total	Control
		Inverters and Modules			59.34%
249840	Wp	Canadian Solar PV Modules cs3U-360P	R4.32	R1 079 308.80	
4	unit	Huawei SUN2000 50KTL inverter	R39 312.00	R157 248.00	
3	unit	CT's + fuses	R1 000.00	R3 000.00	
1	unit	FR Relay + Contactors	R20 000.00	R20 000.00	
1	unit	Industrial switch + LAN Cable	R1 000.00	R1 000.00	
		Mounting Structure			8.48%
156	unit	Lumax Rails 5150	R311.88	R48 653.28	
152	unit	Lumax Rails 4140	R251.32	R38 200.64	
1080	unit	Cross connectors	R21.29	R22 993.20	
152	unit	Splice	R12.45	R1 892.40	
312	unit	End Clamp	R10.15	R3 166.80	
1248	unit	Centre Clamp	R10.45	R13 041.60	
616	unit	Grounding Clamp	R3.50	R2 156.00	
1080	unit	Cap screws	R1.78	R1 922.40	
80	unit	Rail earth connector 8mm Nut/bolt serated washer ss	R5.00	R400.00	
80	unit	Lugs+SS washer	R2.00	R160.00	
1080	unit	Lumax brownbuilt clamp	R38.67	R41 763.60	
150	unit	Lumax brownbuilt clamp	R38.67	R5 800.50	
		DC Wiring			4.66%
4	unit	1000v PROTECTION BOX WITH Fuses	R2 500.00	R10 000.00	
6000	m	PV Cable 4mm2 500m Helukabel Solarflex	R6.85	R41 100.00	
1	rolls	Earth Cable 6mm2 97m	R1 008.00	R1 008.00	
1	rolls	Earth Cable 16mm2 181m	R5 091.00	R5 091.00	
1	unit	Earth Spike	R61.00	R61.00	
25	pairs	MC4 TWIN PACK	R66.77	R1 669.25	
1	unit	Trunking	R40 000.00	R40 000.00	
		Other			3.06%
1		Fixtures and fittings	R20 000.00	R20 000.00	
1		IEC 62446 Test Instrument Purchase/ thermal camera	R30 000.00	R30 000.00	
1		Delivery	R10 000.00	R10 000.00	
1		S&T	R5 000.00	R5 000.00	
		Material Costs Sub Total		**R1 604 636.47**	
		Professional fees			
		Professional Fees (SSEG application, PV Greencard, Sign-off)		R10 000.00	
		LABOUR: Installation & Commissioning			
		Design & Project Management, Procurement, Documentation		R100 000.00	
		Installation AC per job		R35 000.00	
		DC Installation per Watt	R1.10	R274 824.00	
		QC & Commissioning		R100 000.00	
		Professional fees, Installation & Commissioning Sub total		**R519 824.00**	**24.47%**
		SUBTOTAL (Material and Installation)		**R2 124 460.47**	**100.00%**

Summary	Total	Control
Material	R1 604 636.47	
Professional fees, Installation & Commissioning	R519 824.00	
Sub Total	**R2 124 460.47**	84.96%
Contingency	**R50 000.00**	2.00%
TOTAL COSTS excl optional	**R2 174 460.47**	
Markup (15%)	**R326 169.07**	13.04%
Quatation Price	**R2 500 629.54**	**100.00%**
Price per Watt	**R10.01**	

Figure 28: Costing Spread sheet example

Self-Check - 8	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Once the material and installation costs are determined, provision is made for a contingency amount and a mark-up amount. Finally a price per watt is established.
2	The spreadsheet breaks down the project in the main equipment, the BOS materials, professional fees and installation.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Solar PV System Installation and Maintenance
Level-IV
Learning Guide -10

Unit of Competence	**Prepare Job Estimation and Cost of Materials and Components**
Module Title	**Preparing Job Estimation and Cost of Materials and Components**
LG Code	**EIS PIM4 M02 LO4-LG10**
TTLM Code	**EIS PIM4 TTLM 0920v1**

LO4. Identify and establish physical resource requirements

Instruction Sheet	**Learning Guide:-10**

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

- Identifying physical resource requirements
- Producing and calculating lists of materials and quantities
- Establishing quantities against project or standard construction contracts
- Obtaining and calculating supplier prices for materials

- Identifying and costing plant or equipment requirements

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:-

- Identify physical resource requirements
- Produce and calculate lists of materials and quantities
- Establish quantities against project or standard construction contracts
- Obtain and calculate supplier prices for materials
- Identify and cost plant or equipment requirements

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

Information Sheet 1	Identifying physical resource requirements

1.1 Identifying physical resource requirements

Physical resource requirements need to be identified as it will impact the project cost. Physical resources depend on the size of the project and the duration of the project. It can include:

- Site preparation resources:
  - ✓ Site clearing machinery e.g. mowers, earth work machinery etc.;
  - ✓ Cement mixers for foundations if required;
  - ✓ Fencing tools;
  - ✓ Site office;
  - ✓ Site storage;
  - ✓ Water and temporary power e.g. generator;
  - ✓ Ablution facilities;
  - ✓ Cooking facilities;
  - ✓ Temporary accommodation;
  - ✓ Earthing and lightning protection;
  - ✓ Security system;

- Installation resources:
  - ✓ Ladders;
  - ✓ Scaffolding;
  - ✓ Lifting tools like cherry pickers;
  - ✓ PPE;
  - ✓ Installation tools;

- Wiring resources:
  - ✓ Wiring tools;
  - ✓ Test equipment and meters;

•

Self-Check - 1	Written Test

Match column A to column B for the following questions.

N°	Questions	
	A	B
1	Site preparation resources	A. Installation tools
2	Installation	B. Site office
3	Wiring resources	C. Test equipment and meters

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Information Sheet 2	Producing and calculating lists of materials and quantities

2.1 Producing and calculating lists of materials and quantities

Materials for a project need to be calculated and costed. Materials include:

- Preparation materials:
  - ✓ Fencing;
  - ✓ Cement for foundations;
  - ✓ PV Structure fixtures and fittings (if not on a roof);
  - ✓ Spare tiles (if tile roof);

- Installation Material;
  - ✓ Mounting structure
  - ✓ fixtures and fittings
  - ✓ PV Modules
  - ✓ Fixing material e.g. cable ties etc.
  - ✓ Roof entry material
  - ✓ Bonding and Earthing material

- Wiring Material;
  - ✓ Connectors;
  - ✓ Cables and wires;
  - ✓ Fixtures and fittings;
  - ✓ Labels;
  - ✓ Protection materials e.g. breakers, fuses etc.
  - ✓ Junction boxes and combiner boxes
  - ✓ Trunking and conduit with glands etc.

Self-Check - 2	Written Test

Match column A to column B for the following questions.

N°	Questions	
	A	B
1	Preparation materials	A. Labels
2	Installation Material	B. fixtures and fittings
3	Wiring Material	C. Cement for foundations

Satisfactory	2 and Above 2 points
Unsatisfactory	Below 2 points

Information Sheet 3	Establishing quantities against project or standard construction contracts

3.1 Establishing quantities against project or standard construction contracts

More established companies with experience on many projects can determine material quantities based on the size and type of a project without calculating it in detail. To be able to do this, it is necessary to keep proper records of material used in prior projects.

The material can then be estimated based on the size of the PV system e.g. per KWp or size of the backup per kWh. Additional factors can be the distance between the PV system and the equipment room and the type of mounting (e.g. roof mount or ground mount) etc. This approach can save a lot of time during estimation but the estimated costs and quantities should be constantly compared to actual costs and quantities to fine tune the model for future projects. See LO3, information sheet 8.

- **How to Improve the Cost Estimation Process with Better Quantity Takeoffs**

Quantity takeoffs are essential in estimating costs most accurately in the construction industry. Along with setting the schedule for materials purchasing, it involves estimating the real costs of a construction project. When done correctly, the process can help teams stay on budget while optimizing workflows and preparing for worst-case scenarios. Nevertheless, creating quantity takeoffs is a complicated process traditionally prone to error and many changes. But setting up quantity takeoffs right from the start can provide the right foundation for a successful project. In our post, we'll discuss how businesses can improve quantity takeoffs to maximize efficiency from the very beginning of a project.

- **What Is a Quantity Takeoff?**

First, let's dive into the fundamentals of the preconstruction process, which typically starts when bidding begins. In a basic sense, a quantity takeoff is a list of all of the construction materials, including raw and prefabricated elements for a project; each quantity and amount of every material to be sourced is included in the list. Takeoffs are frequently adjusted through the estimation process. This way, when the estimators set the final price for a project, they are using the most accurate information possible. With accurate estimates, contractors are more prepared to meet project budgets and timelines. Accurate estimations also reduce construction waste, which is a considerable expense for the construction industry worldwide.

- **Why Improve Quantity Takeoffs**

Improving the quantity takeoff process for your projects can pay off significantly in the long-run. Benefits include:

✓ **Increased Budget Certainty:** For starters, improvements in takeoffs can increase budget certainty and reduce the risk of inaccurate estimates. These inaccuracies are what derail projects and cause significant cost overruns.

✓ **Save Time:** Time is a limited resource on a construction project. Having realistic and accurate takeoffs ensures a more seamless construction planning process, empowering teams to meet ambitious deadlines.

✓ **Build Trust:** Trust and communication are critical components of any project. With more accurate quantity takeoffs, a team's rapport and confidence improve, as well as relationships with vendors and clients. This makes it easier to bridge in and work with other stakeholders on future plans.

- **5 Tips to Improve Quantity Takeoffs**

Several essential steps can excel your efficiency and accuracy in the quantity takeoff process. Below, let's take a look at five leading strategies to enhance takeoffs.

✓ Reduce and Remove Manual Processes
✓ Use BIM(building information modelling)
✓ Prepare for the Worst-Case Scenario to Offset
✓ Optimize Workflows
✓ Prioritize Integrations

Self-Check - 3	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Quantity takeoffs are not essential in estimating costs most accurately in the construction industry.
2	Improving the quantity takeoff process for your projects can pay off significantly in the long-run.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 4	Obtaining and calculating supplier prices for materials

4.1 Obtaining and calculating supplier prices for materials

Supplier prices for material can be obtained in the following ways:

- Price lists catalogues from suppliers
- Online portals with prices and stock levels;
- Sending Bill of Materials (BOM) to suppliers and request a quotation;
- For larger projects, putting out the BOM on a tender;

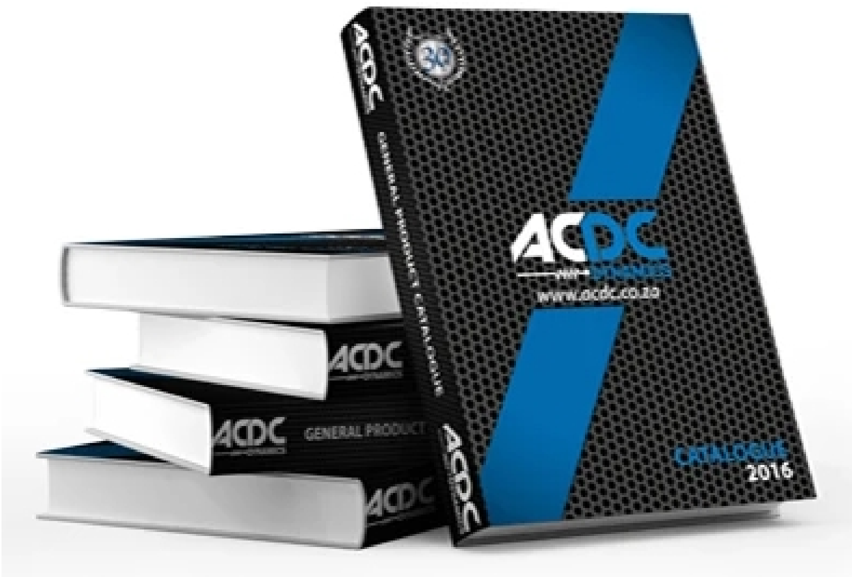


Figure 29: Catalogue from supplier

- **WHY PRICE OR COST ANALYSIS:**

The most basic reason for requiring that price or cost analyses be performed and documented is that it is a sound business practice. This, as noted above, insures that funds are expended in the most cost effective manner and conserves limited resources. A price that is excessive or unreasonable fails completely to accomplish this important goal; a price which is determined to be fair and reasonable is the fulfilment of this important objective.

- **WHAT IS A PRICE ANALYSIS?**

In simple terms, a price analysis is a review, analysis or examination of the price proposed by a supplier and an assessment or evaluation as to whether or not it is fair and reasonable. A determination that a price is fair and reasonable is really a conclusion that the proposed price is fair to both parties, considering the quality, delivery and other factors. The basis for reaching the conclusion is found in the facts and information considered and analyzed by the buyer. This is what is called price analysis.

- **WHAT IS A COST ANALYSIS:**

A cost analysis is different from a price analysis. The major difference is that a price analysis looks at the whole price. It does not involve an examination of the individual cost elements or components that collectively comprise the seller's total price. A cost analysis actually examines the individual cost elements that comprise the total proposed price. Depending on the purchase, these elements may vary but generally include such things as labor rates, material costs, overhead or indirect rates, a cost of money factor, general and administrative expenses (G&A) and a profit or fee.

- **METHODS COMMONLY USED IN PRICE ANALYSIS:**

In performing a price analysis, that is, determining a price to be fair and reasonable without examining the individual components of the price, a buyer has a wide selection of methods. Which method is used and its suitability depends on the facts or information of the individual purchase. What follows is a listing of the most common methods or criteria used to determine a price fair and reasonable by price analysis.

- ✓ Price competition
- ✓ Comparable to price sold to government.
- ✓ Catalog or established price list
- ✓ Market prices
- ✓ Historical prices
- ✓ Price based on prior competition
- ✓ Independent university (in-house) estimate
- ✓ Comparison to a substantially similar item
- ✓ Sales of the same item to other purchasers
- ✓ Award specifically identifies item/person and price

- **COST ANALYSIS:**

A cost analysis looks at the individual elements of the price (labor rates, direct & indirect materials and overhead, G&A expenses, profit/fee) and analyzes these. Overhead or indirect rates may be verified and found reasonable by verifying such rates with the awarding agency, in many cases. The number of hours proposed, not the price, should be evaluated by the technical or scientific staff. The reasonableness of the percent of fee or profit is the responsibility of the buyer. It is negotiable in most cases. An asking price is not always a taking price.

Self-Check - 4	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	A price analysis does not involve an examination of the individual cost elements or components that collectively comprise the seller's total price.
2	A price analysis is a review, analysis or examination of the price proposed by a supplier and an assessment or evaluation as to whether or not it is fair and reasonable.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 5	Identifying and costing plant or equipment requirements

5.1 Identifying and costing plant or equipment requirements

Costing for plant and equipment can be obtained in the following ways:

- Price lists catalogues from suppliers;
- Online portals with prices and stock levels;
- Sending Bill of Materials (BOM) to suppliers and request a quotation;
- For larger projects, putting out the BOM on a tender;
- Negotiations directly with the manufacturer of the equipment in the case of larger projects.

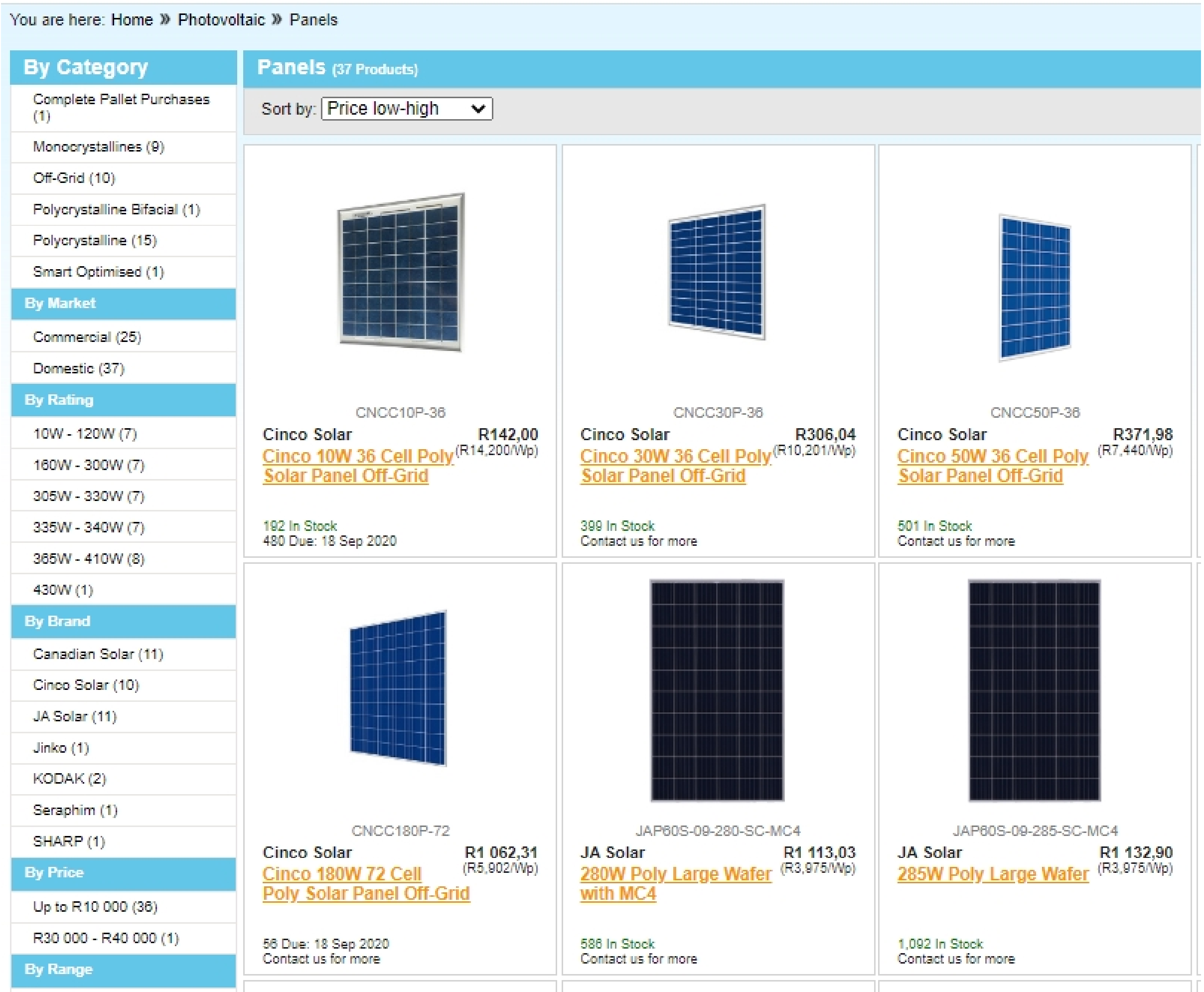


Figure 30: Online portal (Segen solar)

Self-Check - 5	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Costing for plant and equipment can be obtained by sending Bill of Materials (BOM) to suppliers and request a quotation.
2	Costing for plant and equipment cannot be obtained by Online portals with prices and stock levels.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Solar PV System Installation and Maintenance
Level-IV

Learning Guide -11

Unit of Competence	Prepare Job Estimation and Cost of Materials and Components
Module Title	Preparing Job Estimation and Cost of Materials and Components
LG Code	EIS PIM4 M02 LO5-LG11
TTLM Code	EIS PIM4 TTLM 0920v1

LO5. Develop estimated project costs

Instruction Sheet	Learning Guide:-11

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

- Selecting and applying labour rates and material costs
- Determining and applying estimates of unit costs
- Identifying and applying costs to the project of work covers
- Applying company overhead recovery and margins

- Calculating completed estimated project costs included in a tender or bill

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:-

- Select and apply labour rates and material costs
- Determine and apply estimates of unit costs
- Identify and apply costs to the project of work covers
- Apply company overhead recovery and margins
- Calculate completed estimated project costs included in a tender or bill

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

Information Sheet 1	Selecting and applying labour rates and material costs

1.1 Selecting and applying labour rates and material costs

Once all the tasks, time per task and resources are determined, the labour cost can be estimated as follows:

Labour cost = Task hours x labour rate

All the labour costs for all tasks should then be collated and added up to get the total installation labour cost. Alternatively, a cost can be calculated based on the size of the installation e.g. a price per watt for the PV installation and possibly a fixed price for the DC and AC installation. One can only work on a price/watt after carefully analysing the real labour cost over a number of projects. Also see LO4.

Self-Check - 1	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Labour costs can be calculated per task e.g. Labour cost = Task hours x labour rate
2	Labour costs cannot be based on the size of the installation and should be calculated in detail.

Satisfactory	2 points
Unsatisfactory	Below 2 points

2.1 Determining and applying estimates of unit costs

Estimates of unit costs means that instead of determining exact cost for a project precisely by listing all equipment, material and labour, the cost is estimated based on a specific unit. A unit can be based on the size of the PV system, the size of the backup system or a combination of both e.g.

Cost = KWp * x ETB

where "x ETB" is based on the unit cost per KWp of prior projects. For example, a grid-tied system can be costed at 750 ETB/KWp. This price covers labour, material as well as project mark-up. A 5 KWp grid-tied system for example would then cost 5 KWp * 750 ETB/KWp = 3,750 ETB. For off-grid systems, the price is influenced by the PV generator as well as the battery system. Therefore costs can be estimated on both:

Cost = (kWp * xETB) + (kWh * xETB)

Where x ETB is based on the unit cost per KWp for the PV generator and y ETB is based on the unit cost per KWp for the battery system. With experience of prior projects, the unit costs can be determined fairly accurately.

2.2 Unit cost example

In LO3 information sheet 8, a costing example is shown. Figure 31 shows the summary of the costing example. It can be seen that the price per Watt (calculated by dividing the total price by the Wp installed) is R10.01 or approximately 0.60 ETB per Wp or 600 ETB per KWp installed. Refining this price after a number of projects will make it easier to quote a price per KWp for future projects without detailed calculations.

Summary		Total	Control
Material		R1 604 636.47	
Professional fees, Installation & Commissioning		R519 824.00	
Sub Total		**R2 124 460.47**	84.96%
Contingency		**R50 000.00**	2.00%
TOTAL COSTS excl optional		**R2 174 460.47**	
Markup (15%)		**R326 169.07**	13.04%
Quatation Price		**R2 500 629.54**	**100.00%**
Price per Watt		**R10.01**	

Figure 31: Unit cost example

Self-Check - 2	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	For off-grid systems, the price is not influenced by the PV generator as well as the battery system.
2	Estimates of unit costs means that instead of determining exact cost for a project precisely by listing all equipment, material and labour, the cost is estimated based on a specific unit.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 3	Identifying and applying costs to the project of work covers

3.1 Identifying and applying costs to the project of work covers

There may be many additional costs for the establishment of a project that needs to be taken into account.

There are five types of project costs occurred in any project.

- Fixed Cost
- Variable Cost
- Direct Cost
- Indirect Cost
- Sunk Cost

Fixed Cost: Any Cost which is stable throughout the project life cycle and would not vary by quantity, time or any other project aspects called a fixed cost.

Variable Cost: Variable cost is a cost which changes or varies in proportion to service or product that the project produces.

Direct Costs: Costs which are directly perceptible and liable to produce the project results are called direct costs.

Indirect Costs:

Costs which do not directly donate or particular to the output of the project are known as indirect costs. It may be either fixed or variable

Sunk Costs:

Sunk Costs are costs which are previously spent, but failed to acquire any business value and cannot be recuperated and permanently lost.

Total Project Cost:

Calculating Total Project Cost (TPC) is an important step for any project. Total Project Cost should consist of all the costs (fixed and variable) of the project. The calculation should contain the total estimated cost (TEC) and other project costs (OPC). I.e., it includes but not partial to activities Costs such as feasibility, pre-planning, operating cost, risk analysis, commissioning, contingency, design, development, maintenance, etc. If Total Project Cost is not calculated precisely, the project will have to face thoughtful consequences. It will have a direct effect on the project schedule, scope, and quality. This will affect to cost overrun.

Environmental protection agency requirements

In many countries, environmental impact assessments needs to be done specifically for larger projects that may impact on ecological sensitive areas e.g. swamps, forests etc. This type of impact assessment should be done by professionals and will cover the impact on the soil, water, fauna and flora. The assessment needs to be presented to an Environmental protection agency which will then give permission to go ahead or not. Often the process also needs input from affected parties in a public participation process. The cost of this type of assessment should be factored into the project cost.

Seeking approvals

Depending of the type of project, approvals may need to be obtained from various parties e.g.:

- Municipality for the erecting of a ground mounted structure;
- Energy supplier for connection to the electricity network;
- Management of residential and commercial complexes which may have specific rules around the aesthetics etc. of their complexes.

Waste management site fees

Getting rid of waste (specifically hazardous waste) can be costly. For instance, if the roof that will be used for the PV installation is made from asbestos, specialist will have to be contracted to remove the asbestos in a safe way. Other waste from site also needs to be removed, often at a cost.

Self-Check - 3	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	Sunk costs any Cost which is stable throughout the project life cycle and would not vary by quantity, time or any other project aspects called a fixed cost.
2	Variable cost variable cost is a cost which changes or varies in proportion to service or product that the project produces.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 4	Applying company overhead recovery and margins

4.1 Applying company overhead recovery and margins

The direct cost of a project e.g. cost of material, labour etc. directly related to the project is called ‘cost of goods sold’ or COGS. COGS need to be recovered from a project. The revenue from a project minus the COGS is the gross profit. Only recovering the cost of a project will mean that a company will fail as there are many other fixed or overhead cost in running a business. Companies need to make a profit in order to grow and supply employment to people. Therefore companies should recover all their overhead costs and make a profit from projects. The overhead costs can be:

- Cost of advertising;
- Warehousing and storage costs;
- Office costs;
- Administration costs;
- Cost of vehicles and transport;
- Running costs e.g. accounting fees, water and electricity, municipal levies and taxes etc.
- Cost of sales e.g. visiting clients, attending trade shows etc.

Margin and Mark-up

Typically, the profit margin refers to the gross profit margin for a specific sale, which is revenue minus the cost of goods sold, but the difference is shown as a percentage of revenue.

Mark-up is the amount by which the cost is increased on a product to arrive at the selling price.

For example, if a company earned 110,070 ETB in revenue and the cost to produce it was36,690 ETB, the gross profit would be 73,380 ETB and the gross profit margin would be 66.6%(110,070 ETB – 36,690 ETB) / (110,070 ETB). The mark-up will be 200% (73,380 ETB / 36,690 ETB).

The gross margin is a very important metric when evaluating the financial performance of a company because it tells whether the company is making or losing money on sales, which is a very crucial aspect of business, since a business that is not making money on sales is failing. In addition, the gross margin is a useful indicator of how efficient the management of the company is in using supplies and labour in the production process. Nett margin is an indication if a company makes a profit or not and is defined as the total revenue minus total costs (project costs and overhead costs) compared to the total revenue.

Self-Check - 4	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	The gross margin is a useful indicator of how efficient the management of the company is in using supplies and labour in the production process.
2	Gross margin is the amount by which the cost is increased on a product to arrive at the selling price.

Satisfactory	2 points
Unsatisfactory	Below 2 points

Information Sheet 5	Identifying and costing plant or equipment requirements

5.1 Calculating completed estimated project costs included in a tender or bill

The calculation of the cost included in a tender, quotation or bill should include all the costs previously mentioned e.g.:

- The project costs
  - ✓ Cost of materials and equipment;
  - ✓ Cost of labour;
  - ✓ Other administrative costs like approvals, permits etc.
- The margin to recover overhead costs and to make profit.

Once the total cost is established, it should be presented to the client in the form of a quotation or submitted in a tender document to the tender adjudication panel. In order to give the client sufficient information on the product and service you are selling, the quote should not only state “1 PV system” and the overall cost but should contain some more details. In LO4, information sheet 8 the RAL form on offer generation includes suggestions on which information to include. It is important that the client gets enough information to compare the quote with others to take a decision. Naming installers and brands on a quote can also be part of the sales strategy, the client can see that quality brands are used instead of cheap products and that he can expect a well working system. Listing details like material and labour separately indicates that the installer knows what he is doing and gives the client the feeling that he can expect a good installation. Figure 32 shows an example of costing done for a backup PV system. This detailed list is created for internal use. It is recommended to not put all the details on the quote, otherwise the client might use it as a shopping list to buy the materials himself or to get a cheaper price from a competitor.

5.2 Purpose of the estimate

The objective of the estimate is to provide the most realistic prediction possible of the total cash expenditure and time that will be necessary to complete the project ready for operation. Cost estimates provided for road projects in developing countries in the past have generally proved to be wildly inaccurate, with two main results:

- Tendered contract bids have often proved to be considerably higher than the engineer's feasibility study estimate
- Considerable cost over runs have occurred during projection execution

Customer : Company XYZ,
cnr Hennie Alberts Webb st,
Brackenhurst,
Alberton, JHB, SA.

COSTING SHEET / SOLAR INSTALLATIONS

GPS Co-ords -26.319S, 28.096E

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Z1.	5	m	25mm sprag - flexi-conduit	R2.20	R11.00
AA.	1	item	PV conduit, joiners, elbows, saddles, fasterns, sundries	R112.00	R112.00
AA1.	1	item	Roof entry point kit - weatherproof	R480.00	R480.00
AB.	3	item	MC 4 connectors - pair set	R40.70	R122.10
AC.	2	item	Roof work, scaffolding hire for 2 days	R880.00	R1,760.00
AD.	1	item	PPE allowance for roofing work	R190.00	R190.00
AE.	1	item	PV disconnect box, fuse & surge protect - off shelf	R5,500.00	R5,500.00
AF.	1	item	Inverter - SMA SunnyBoy 5.0 kW	R16,240.00	R16,240.00
AG.	1	item	Inverter Charger - SMA Sunnylsalnd 6.0	R35,565.00	R35,565.00
AH.	1	item	Li-ion battery BYD B-Box 13.8	R115,000.00	R115,000.00
AI.	1	item	Dedicated external DB - assembled	R1,580.00	R1,580.00
AJ.	1	item	Battery disconnect & fused box, 125 amp	R4,999.00	R4,999.00
AK.	5	m	70mm² battery cable - RED	R158.00	R790.00
AL.	5	m	70mm² battery cable - BLACK	R158.00	R790.00
AM.	1	item	Battery connect kit, lugs, shrink wrap, cable tie, etc	R180.00	R180.00
AN.	3	m	100 x 40 dual PVC trunking	R68.00	R204.00
AO.	1	item	Mounting sundries	R80.00	R80.00
AP.	4	m	Cable 6.0mm² GP house - RED	R4.80	R19.20
AQ.	4	m	Cable 6.0mm² GP house - BLACK	R4.80	R19.20
AR.	4	m	Cable 6.0mm² GP house - EARTH	R6.00	R24.00
AS.	1	item	RCB (earth leakage unit) - DB upgrade	R998.00	R998.00
AS1.	4	item	Circuit breakers, 20 amp, 10 amp (move or changes)	R86.00	R344.00
AT.	1	item	General, sprag, ties, straps, lugs	R220.00	R220.00
AU.	1	item	V/F relay (NRS097-1-2) & 2 pole disconnect contactor	R4,880.00	R4,880.00
AV.	1	item	In-line grid meter - two way	R1,880.00	R1,880.00
AW.	24	hrs	Labour fit, install & commission / test	R300.00	R7,200.00
AX.	24	hrs	Casual labour assist @ R55.00/hr	R55.00	R1,320.00
AY.	3	trip	Site visit - travel	R250.00	R750.00
AZ.	1	item	JOB PROFIT - 8% mark-up on all materials	R262,000.00	R20,960.00

Customer : Company XYZ,
cnr Hennie Alberts Webb st,
Brackenhurst,
Alberton, JHB, SA.

COSTING SHEET / SOLAR INSTALLATIONS

GPS Co-ords -26.319S, 28.096E

6:49 AM20/03/2020

TOTAL CONTRACT PRICE INCLUSIVE OF VAT @15% R297,396.42

ITEM	QTY	UNIT	DESCRIPTION	ITEM PRICE	SUB TOT
A.	2	trip	Initial site visit - travel	R250.00	R500.00
B.	3	hrs	Initial site visit - labour (requirements discussion)	R300.00	R900.00
C.	1	hrs	Qualified electrician initial inspection of DB (quote)	R680.00	R680.00
C1.	1	item	Qualified electrician POST JOB COC (quote)	R1,500.00	R1,500.00
D.	1	hrs	Structural engineer inspection of roof (quote)	R2,250.00	R2,250.00
E.	2	hrs	Builder for post install remedial repairs (quote)	R650.00	R1,300.00
F.	3	hrs	Quotation preparation	R300.00	R900.00
G.	2	hrs	Materials collection - items not delivered	R300.00	R600.00
H.	0	item	PV Panles - 240 watt		R0.00
I.	0	item	PV Panles - 245 watt		R0.00
J.	0	item	PV Panles - 250 watt		R0.00
K.	0	item	PV Panles - 325 watt		R0.00
L.	13	item	PV Panles - 330 watt	R1,440.00	R18,720.00
M.	0	item	PV Panles - 335 watt		R0.00
N.	0	item	PV Panles - 340 watt		R0.00
O.	4	item	6600mm aluminium mounting rails & in-line joiners	R668.00	R2,672.00
P.	4	item	End clamps	R22.00	R88.00
Q.	24	item	Middle clamps	R24.50	R588.00
R.	8	item	Rail connectors	R38.00	R304.00
S.	36	item	Roof hooks	R86.00	R3,096.00
T.	36	item	Mounting rail sundries, shims, screws, bolts, nuts etc	R9.98	R359.28
U.	1	item	Roofing repairs - waterproofing, new fasteners	R550.00	R550.00
V.	30	m	PV 6.0mm² earth cable	R3.80	R114.00
W.	1	item	PV earth kit, spike, lugs, clamps, bolts & nuts	R338.00	R338.00
X.	50	m	PV 6.0mm² cable RED (dual run)	R8.82	R441.00
Y.	50	m	PV 6.0mm² cable BLACK (dual run)	R8.82	R441.00
Z.	26	m	25mm PVC conduit	R1.80	R46.80

Figure 33: Costing example for a backup PV System

Figure 34 shows an example of a quotation generated for the Adama 5kWp installation. The main components are listed including information on size and type but the accessories are listed as accessories only.

Invoice No.:092A//2019

Customer

Name: Adama Poly Technic
Address: Adama
Contact: Tele:+251118-697461

Solar power system for Adama Poly Technich

Proforma Invoice

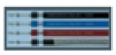
S/N	Description	QTY	Unit	Total price before VAT (Birr)
	5,1 kWp off-grid backup PV Systems			
1	Solar Module Phaesun PN6M72-350 E 350 watt 350 W, 24 VDC, Standard4, 72 cells, mono, alu frame (silver), tempered glass, back-sheet (white), cable 1250 mm / 4 mm² 	15	pcs	
2	Module Support Structure PN-ASS 03 alluminium support structure for 3 solar modules, incl. mounting clamps for modules, screws, connectors and heavy duti anker bolts 	5	pcs	
3	Inverter / Hybrid Charger Phocos PSW-H-5KW-230/48V 5000 W, 48 VDC, 230 VAC / 40 - 63 Hz, charge current 80 A PV + AC / 40 A transfer, 450 Voc, self consumption 14 W / 40 W, sinewave, electronic 	1	pcs	
4	Connection Box GCB 5-1200V/50A_ gland, 200 VDC, Input 5 x 12A, Out put 1 x 50A, Switch, (1X), Cable Gland, Screwed cover (Grey), IP65, single 	1	set	
5	Corrugated Sheet Roof Screw fitting M 10 x 180mm For Coneection between crosstie profile rail and rafter including hunger bolt M10, Connecting plate, screws, nuts and V2A blocking screws 	10	set	
6	PV Standard connector 4-6 mm2 set WM30 A, 1000V, male + female, cross section 4-6 mm², cable diameter 5,0-7,5 mm, compatible with Standard4, tool free connection, IP65 	5	pcs	
7	Cable Solarflex-X 1 X 4 Blackcross section 1x 4mm², outer diameter 5,4mm, 1500 VDC, 1000 VAC, CU / fine-wire / verzinnt, double isolated, protection class II, UV-resistant, ozone resistant 	100	meteres	
8	Battery OPzS Hoppecke sun /Power C L2-730 GUG, 7 340026 lead acid batteries 2 volt filled and charged 490Ah (C10) 730 Ah (C100) incl. Accessories. 	24	pc	
9	Battery Rack Kunstmann 1E.B560.R2 Steel floor rack with 2 battery rows Flamulit coated gray RAL 700,1 max. insulator load:136kg Dimension 2400 x 586 x 90mm	1	pcs	
10	 Battery Main Switch PN-BMS 150 A	1	pcs	
11	Installation accessories			
	Sub Total (Birr)			**771 903.99**
7	Fright and document			85 480.00
8	Installation 5.2Kwp system			80 000.00
10	Importing and Transportation cost from customs and to Adama			119 832.00
11	Training			40 000.00
	Sub Total (service in Birr)			**325 312.00**
	Sub-total price Birr:			**1 097 215.99**
	VAT 15%:			**164 582.40**
	·and Total cost of materials and installation Service Birr:			**1 261 798.39**

Figure 35: Adama example quotation

Self-Check - 5	Written Test

Write true if the statement is correct and write false if the statement is wrong.

N°	Questions
1	The calculation of the cost in a tender, quotation or bill should not include all the costs of the project costs.
2	The objective of the estimate is to provide the most realistic prediction possible of the total cash expenditure and time that will be necessary to complete the project ready for operation.

Satisfactory	2 points
Unsatisfactory	Below 2 points

List of reference materials

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NREL. (2017). solar-panel-installation-cost. Retrieved from https://www.solar.com: https://www.solar.com/learn/solar-panel-installation-cost/