SYLLABUS AND
TEACHERS' REFERENCE

# SOLAR PHOTOVOLTAIC INSTALLATION

European Union

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DEUTSCHE ZUSAMMENARBEIT

USAID
FROM THE AMERICAN PEOPLE

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## Solar Photovoltaic Installation

Syllabus and Teacher's Reference for a 160-hours training course for technicians
3rd Edition • March 2017
Developed in pursuit of conformity with the Nigerian Competency Standards for Clean Energy | Release 2016 in the domain "Solar PV System Installation with Focus on Domestic and Smaller Commercial Solar Systems"

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## Developed by

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# Content

# ABOUT

This document seeks to guide trainers on the delivery of the training course Solar PV Installation. The topics and subjects contained are a result of the needs expressed by the clean energy private sector in Nigeria in 2014 and Competency Standards evolved together with industry in 2015 and 2016. This document is expected to be reviewed periodically to reflect changing needs of the Nigerian market.

| | |
|---|---|
| ***Course objective*** | Enable **electricians** with **informal educational background** to install, troubleshoot and maintain domestic and smaller commercial solar photovoltaic systems – in conformity with the requirements of the Nigerian Competency Standards for Clean Energy \| Release 2016 in the domain "*Solar Photovoltaic System Installation with Focus on Domestic and Smaller Commercial Solar Systems*". |
| ***Target group*** | **Technicians** |
| ***Recommended entry criteria*** | Must be within age group 18-40 years, possess the ability to read and write basic English and solve basic arithmetic. Must show competence as an electrical installer. |
| ***Duration*** | 160 hours recommended (equivalent to 20 training days at 8 hours per day) |
| ***Classroom size*** | A maximum of 20 trainees is recommended |
| ***Expected tasks and duties*** | ▪ Plan work<br>▪ Install smaller systems<br>▪ Assist in installing PV systems<br>▪ Assist in performing maintenance and troubleshooting tasks<br>▪ Observe safety regulations |
| ***Teaching methods*** | ▪ Highly practical orientation<br>▪ Lectures (presentations and videos)<br>▪ Practical work<br>▪ Simulations<br>▪ Group work (homework, role play, presentation)<br>▪ Pop-quiz<br>▪ Laboratory-experiments and workshops<br>▪ Hand outs<br>▪ Field trips<br>▪ Demonstration<br>▪ Discussion |
| ***Assessment methods*** | ▪ Practical examination<br>▪ Oral examination<br>▪ Written examination |

## 1.1 USING THE SYLLABUS

The content of each course module is broken down to topical levels. Key information guides the trainer on the following:

- **Competency levels** the student is expected to attain at the end of the module. There are four levels of competency detailed in this document:
  - Skills and competencies required by the trainee for knowledge purposes only are classified as "**To know**". This is the simple most level.
  - Skills and competencies required for explaining to third parties are classified as "**To understand**".
  - Skills and competencies required for day-to-day work on an as-is basis in respect of the handbook are classified as "**To use**". Training on practical examples, for instance, is essential to attain this.
  - Skills and competencies for day-to-day work which need to be adapted to practical contexts are classified as "**To apply**". This level is the most demanding and requires application in areas beyond what has been learned.
- Appropriate **teaching techniques** and methods for effective delivery of contents.
- **Activities** to aid effective knowledge transfer.
- **Materials and equipment** required for training activities.
- **Key resources** for trainers to study to ensure the depth and breadth of their knowledge exceeds that of the Course Handbook.

## 1.2 COURSE DURATION

The recommended contact hours for delivery of this course is **160 hours**. This would translate into 20 days of training for a fulltime delivery of 8 hours per day.

For effective delivery, the course is designed in modules, each with recommended duration of delivery. The recommended amount of time to be spent by the students in specific learning environments is suggested in the following groups:

- **Classroom:** Duration suggested in a classroom setting where techniques such as discussions, role plays, and interactive sessions, exercises presentations are deployed to *engage* the students apart from traditional teaching.
- **Lab/workshop, field trips:** Duration suggested for engaging in practical aspects. This could be field trips, site visits, laboratory experiments or any other form of engagement *practical* in nature.
- **Spare time:** Contingency kept aside to use at discretion of the trainer. The trainer decides what environment to use the spare time for based on the response of the class to course content.
- **Additional self-study:** Duration the student is expected to engage in self-study and research complementing classroom and practicals time.

## 1.2 ACTIVITIES

Various activities are required for the successful delivery of the course. These include:

- **Demo:** Concepts or aspects are being demonstrated to students.
- **Exercise:** Activities that require the student to solve problems in the classroom.
- **Workshop:** The student engages in practical exercises meant to imitate real world conditions.

- **Experiment:** Carry out practical exercises in a controlled environment, usually the laboratory.
- **Interactive session:** Sessions where students are engaged in open discussions to share their views with the class, thus sparking intellectual debates.
- **Role play:** Students to perform roles they are expected to assume or encounter in the workplace.
- **Site visit:** Field trips that serve as a means of buttressing the point made in class by providing the students with tangible evidence/experience of concepts taught.
- **Video:** For introduction and support of concepts taught in class.

**SPECIAL SYMBOLS**

⌘ Indicates *material* available in softcopy in the package folder.

♦ Indicates *resources* available in softcopy in the package folder.

## 1.4 MATERIALS AND FACILITIES

To successfully deliver this training course – particularly in view of the skills acquisition, certain materials and equipment are required. A careful review of this section is strongly recommended well ahead of the delivery of the course to ascertain availability, verify operating status, initiate procurement or repairs and provide alternatives wherever the originally recommended item is unavailable. The success of this training course vitally depends on practice on such material and equipment encompassing:

- Power tools (drill, grinder, heat blower, cutting machine, etc.)
- Digital clamp meter with DC current measurement capability
- Complete electricians' toolbox – 1 per 5 participants
- 2 roof types
- Space for on-ground-modules
- Rig labs
- Inverters
- Charge controllers
- Batteries
- PV modules
- Mounting clamps

| *Minimum requirements for a class of 20 students* | *Quantity* | *Estimated unit cost (NGN)* | *Estimated cost (NGN)* |
|---|---|---|---|
| Cardboard strips | | | |
| Pin board | 2 | | |
| Laptop for trainer | 1 | | |
| Projector | 1 | | |
| Whiteboard | 1 | | |
| Whiteboard markers | Lot | | |
| Coloured pins | Lot | | |
| Loud speaker | 1 | | |
| Complete electricians toolbox | 4 | 47,000 | 188,000 |

| *Minimum requirements for a class of 20 students* | *Quantity* | *Estimated unit cost (NGN)* | *Estimated cost (NGN)* |
|---|---|---|---|
| Power drill with bits | 4 | 19,000 | 76,000 |
| 5 m measurement tape | 4 | 600 | 2,400 |
| AC/DC digital multimeter with clamp | 4 | 10,000 | 40,000 |
| Roofed barn structure | 1 | | |
| 100 $W_P$ solar panels | 4 | 20,000 | 80,000 |
| 180 $W_P$ solar panels | 4 | 38,000 | 152,000 |
| 1.5 kVA inverter | 2 | 55,000 | 110,000 |
| 45A charge controller | 2 | 53,000 | 106,000 |
| 100 Ah battery | 8 | 35,000 | 280,000 |
| 63A MCCB | 2 | 8,000 | 16,000 |
| 32A MCCB | 2 | 5,000 | 10,000 |
| 3 m step ladder | 2 | 45,000 | 90,000 |
| 6 m extension ladder | 1 | 60,000 | 60,000 |
| Safety goggles | 20 | 500 | 10,000 |
| Hard helmets | 20 | 500 | 10,000 |
| Insulated hand gloves | 1 per student | | |
| Insulated safety boots | 1 per student | | |
| Spirit level | 4 | 2,000 | 8,000 |
| Compass | 4 | 10,000 | 40,000 |
| Electricians chalk line | 4 | 3,000 | 12,000 |
| Fishing tape | 4 | 500 | 2,000 |
| Long nose plier | 4 | 1,000 | 4,000 |
| Cable cutting plier | 4 | 1,000 | 4,000 |
| Set of screwdrivers | 4 | 4,500 | 18,000 |
| Set of spanners | 4 | 5,000 | 20,000 |
| Body harness | 2 | 2,500 | 5,000 |
| Class E fire extinguisher | 1 | 9,000 | 9,000 |
| 2.5 $mm^2$ cables | 50 m | 100 | 5,000 |
| 4 $mm^2$ cables | 50 m | 140 | 7,000 |
| 6 $mm^2$ cables | 50 m | 300 | 15,000 |
| 10 $mm^2$ cables | 50 m | 500 | 25,000 |
| 16 $mm^2$ battery bank interconnection cables | 4 pairs | 2,000 | 8,000 |
| Cable lugs for 16 $mm^2$ | Lot | 70 | 560 |
| Crimping tool with dies | 2 | | |
| Screws for wood/plastic/metal sheet | Lot | | |
| Nuts and bolts | Lot | | |
| Insulation tape | Lot | | |
| Cable lugs for sizes 2.5 $mm^2$ -10 $mm^2$ | Lot | | |

*Prices are as at March 2016*

## 1.5 TRAINING COURSE OVERVIEW

| **Module 1. The solar resource** | *8 hours* |
|---|---|
| ***Content*** | 1.1. The sun as a source of energy<br>1.2. Estimating available solar energy |
| ***Recommended time allocation*** | 0 hour Classroom<br>6 hours Lab/workshop, field trip<br>2 hours Spare time<br>+4 hours Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Understand the basics of solar photovoltaics<br>▪ Explain how solar resource is distributed across the climatic zones of Nigeria |

| **Module 2. Workplace safety** | *16 hours* |
|---|---|
| ***Content*** | 2.1. Risks and dangers<br>2.2. Personal safety<br>2.3. Rooftops and facades<br>2.4. Fire hazards<br>2.5. Site safety<br>2.6. Lifting<br>2.7. Injuries<br>2.8. First aid |
| ***Recommended time allocation*** | 12 hours Classroom<br>2 hours Lab/workshop, field trip<br>2 hours Spare time<br>+0 hour Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Know common workplace safety rules and regulations<br>▪ Assess possible health and safety threats and how to avoid them<br>▪ Identify the different types of protective clothing and equipment<br>▪ Identify the different methods of firefighting<br>▪ Recognise the signs and symbols in safety |

| **Module 3. Components of solar systems** | *16 hours* |
|---|---|
| ***Content*** | 3.1. Solar panels<br>3.2. Inverters<br>3.3. Batteries<br>3.4. Charge controllers<br>3.5. Protective devices<br>3.6. Grounding |
| ***Recommended time allocation*** | 6 hours Classroom<br>9 hours Lab/workshop, field trip<br>1 hours Spare time<br>+4 hours Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Distinguish between DC and AC loads<br>▪ Describe the basic functions of solar system components |

- Identify the different configurations for solar panel and battery interconnection

| **Module 4. Solar PV system configuration** | *8 hours* |
|---|---|
| ***Content*** | 4.1. Grid connected systems<br>4.2. Off-grid systems<br>4.3. Hybrid systems |
| ***Recommended time allocation*** | 3 hours Classroom<br>3 hours Lab/workshop, field trip<br>2 hours Spare time<br>+0 hour Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Identify the various configurations of solar power systems<br>▪ Suggest an appropriate configuration for a solar power system based on application |

| **Module 5. Basic system sizing** | *16 hours* |
|---|---|
| ***Content*** | 5.1. Electrical loads<br>5.2. Step-by-step calculations |
| ***Recommended time allocation*** | 12 hours Classroom<br>2 hours Lab/workshop, field trip<br>2 hours Spare time<br>+8 hours Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Distinguish between DC and AC loads<br>▪ Describe the basic functions of the components of a solar system<br>▪ Identify the different configurations for solar panel and battery configuration |

| **Module 6. Installing a 1 kW$_P$ solar system** | *56 hours* |
|---|---|
| ***Content*** | 6.1. Required tools<br>6.2. Suitable surfaces<br>6.3. Working with batteries<br>6.4. Working with solar panels<br>6.5. Installing solar panels on a roof<br>6.6. Connecting system components<br>6.7. Step-by-step installation |
| ***Recommended time allocation*** | 0 hour Classroom<br>52 hours Lab/workshop, field trip<br>4 hours Spare time<br>+24 hours Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Install solar power systems for domestic and smaller commercial applications |

| **Module 7. Maintenance and troubleshooting** | *24 hours* |
|---|---|
| ***Content*** | 7.1. Maintenance<br>7.2. Troubleshooting |
| ***Recommended time allocation*** | 4 hours Classroom<br>16 hours Lab/workshop, field trip<br>4 hours Spare time<br>+0 hour Additional self-study |
| ***Learning outcomes*** | At the end of the module the learner is able to:<br>▪ Explain the steps involved in carrying out maintenance work on each solar system component<br>▪ Outline the procedure for maintaining the different PV system components<br>▪ Outline the procedure for testing different PV system components<br>▪ Identify the different types of tools/equipment used for maintenance and repair |

| **Practice Test – In preparation of national certification** | *16 hours* |
|---|---|
| ***Purpose*** | At the end of the course, the aptitude of each trainee should be assessed through a practice test in preparation of National Certification. The test should be based on the same benchmark: **Nigerian Competency Standards for Clean Energy** \| Release 2016 in the domain "Solar photovoltaic systems installation with focus on domestic and smaller commercial solar systems". |
| ***Recommended duration and weightage*** | **Duration** – **Examination type** – **Weightage**<br>1 hour – Written examination – 20%<br>7.5 hours – Oral examination – 40%<br>7.5 hours – Practical examination – 40% |
| ***Grading*** | A candidate is deemed to have completed the course successfully (passed) if candidates attains a cumulative average **score of 70% or above**. |
| ***Recommended certificate*** | Certificate of participation |

# MODULE 1: THE SOLAR RESOURCE

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **1.1. The sun as a source of energy (3 hours workshop)** | | | Competency level: To know |
| Introduction | - Common terminologies used in solar energy | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards<br><br>**Activities**<br>Video 1.1-1: How light reaches the Earth from the sun<br><br>Video 1.1-2: How electricity is generated from solar panels<br><br>⌘Workshop 1.1-1: Students measure direct and diffuse irradiance | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| Energy from the sun | - Radiation and irradiance | | |
| **1.2. Estimating available solar energy (3 hours workshop)** | | | Competency level: To know |
| Estimating the available solar energy | - Annual received solar energy<br>- Solar resource distribution in Nigeria<br>- The concept of peak sun | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards<br><br>**Activities**<br>⌘Workshop 1.2-1: Students determine the optimal array orientation | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| Photovoltaic principle and solar cells | - Semiconductors<br>- The photovoltaic principle<br>- Solar cells, panels and arrays | | |

# MODULE 2: WORKPLACE SAFETY

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **2.1. Risks and dangers (2 hours classroom)** | | | Competency level: To apply |
| General risks | - Injuries while working<br>- Minimising danger of electrical hazards | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Interactive session 2.1-1: Teacher engages students to share experiences of accidents that have occurred on site<br><br>Video 2.1-1: Teacher shows students accidents that occur on installations sites | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **2.2. Personal safety (2 hours classroom)** | | | Competency level: To apply |
| Safety equipment | - Personal protective equipment (PPE) | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards, Eye goggles, Hand gloves<br><br>**Activities**<br>Demo 2.2-1: Teacher introduces students to the different PPE and showing students how to use them<br><br>Video 2.2-1: Teacher shows students the risks and dangers of not using PPE | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **2.3. Rooftops and facades (2 hours workshop)** | | | Competency level: To apply |
| Working at heights | - Fall protection<br>- Using a ladder | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards, Ladder, Body harness<br><br>**Activities**<br>Demo 2.3-1: Teacher introduces students to the different types of ladders and how to use them safely<br><br>Video 2.3-1: Teacher shows the risks and dangers of not using adequate fall protection | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **2.4. Fire hazards (1 hour classroom)** | | | Competency level: To apply |
| Types | - Classes of fire extinguishers<br>- Using a fire extinguisher | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards, E fire extinguisher<br><br>**Activities**<br>Demo 2.4-1: Teacher shows the students a typical Class E fire extinguisher<br><br>Video2.4-1: Teacher shows students how to use fire extinguishers<br><br>Video 2.4-2: Teacher introduces students to the different types of fire extinguishers | 1. www.mfs.fire-extinguishers.co.uk<br>2. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>3. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>4. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>5. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **2.5. Site safety (1 hour classroom)** | | | Competency level: To apply |
| Safety symbols | - Interpreting safety symbols | **Methods**<br>Instruction, Discussion | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc. |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| | | **Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Interactive session 2.5-1: Students briefly discuss their experience with site safety | 2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **2.6. Lifting (1 hour classroom)** | | | Competency level: To apply |
| Manual lifting | - Factors that make lifting dangerous<br>- Safe lifting practices | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Interactive session 2.6-1: Teacher invites students to lift a heavy load using proper lifting posture | 1. ♦*Electrical workers safety handbook* • E-Contractors<br>2. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>3. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>4. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>5. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **2.7. Injuries (1 hour classroom)** | | | Competency level: To apply |
| | - Factors that may cause injuries on a construction site<br>- Common injuries | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards | 1. ♦*Electrical workers safety handbook* • E-Contractors<br>2. *Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **2.8. First aid (4 hours classroom)** | | | Competency level: To apply |
| What to do | - Bleeding<br>- Burns<br>- Electrocution<br>- Shock | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards, First aid kit<br><br>**Activities**<br>Demo 2.8-1: Teacher shows students procedures for basic first aid for common construction site injuries | 1. ♦*Electrical workers safety handbook* • E-Contractors<br>2. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>3. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>4. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>5. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

# MODULE 3: COMPONENTS OF SOLAR SYSTEMS

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **3.1. Solar panels (1 hour classroom + 5 hours workshop)** | | | Competency level: To apply |
| Factors affecting energy output | - Limitations of solar energy | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards, solar panels, Digital multimeter, Complete electricians toolbox<br><br>**Activities**<br>⌘Workshop 3.1-1: Students measure the *Isc* and *Voc* of various solar panels<br><br>⌘Workshop 3.1-2: Students interconnect solar panels in various series/parallel combinations and measure the *Isc* and *Voc*<br><br>⌘Workshop 3.1-3 Students connect mismatched solar panels and measure the *Isc* and *Voc*<br><br>Workshop 3.1-4 Students investigate the effect of irradiance on solar panel output<br><br>Workshop 3.1-5 Students investigate the effect of temperature on voltage<br><br>⌘Workshop 3.1-6 Students investigate the effect of temperature on current<br><br>⌘Workshop 3.1-7 Students investigate the effect of temperature on power | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| Types and technologies | - Monocrystalline<br>- Polycrystalline<br>- Amorphous (thin-film) | | |
| Connecting solar panels together | - Connecting similar panels in an array<br>- Mismatching solar panels in an array<br>- Important parameters of a solar panel<br>- Measuring short circuit current (Isc)<br>- Measuring open circuit voltage (Voc) | | |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **3.2. Inverters (1 hour classroom)** | | | Competency level: To apply |
| Function of inverters | | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards, inverter, connecting cables | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| Classification | - Based on input source<br>- Based on output waveform | | |
| Inverter datasheet | - Interpreting | | |
| **3.3. Batteries (1 hour classroom + 3 hours workshop)** | | | Competency level: To apply |
| Common types and technologies | - Lithium ion<br>- Lead-acid battery | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards, Deep cycle batteries, Connecting cables, Digital multimeter<br><br>**Activities**<br>⌘Workshop 3.3-1: Students interconnect batteries in various series/parallel combinations<br><br>⌘Workshop 3.3-2: Students investigate the battery capacity discharged using | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| Classification | - Based on usage/application<br>- Based on cell type | | |
| Connecting batteries together | - Connecting similar batteries in series<br>- Connecting similar batteries in parallel<br>- Mismatching batteries in a battery bank | | |
| Battery datasheet | - Interpreting | | |
| **3.4. Charge controllers (1 hour classroom + 1 hour workshop)** | | | Competency level: To apply |
| Types and functions | - Pulse width modulation<br>- Maximum power point tracker | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards, PWM charge controllers, MPPT charge controllers | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| Inverter datasheet | Interpreting | | |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| | | **Activities**<br>Demo 3.4.1: Teacher passes around the two different types of charge controller for students to familiarise themselves with physical appearance<br><br>⌘Workshop 3.4-1: Students investigate the operation of charge controller | 3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| **3.5. Protective devices (1 hour classroom)** | | | Competency level: To know |
| Types and functions | - Circuit breaker<br>- Disconnects<br>- Combiner box<br>- Junction box | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Speakers, Whiteboard, Markers, Metaplan cards, Metaplan pin boards, electrical protective devices<br><br>**Activities**<br>Demo 3.5.1: Teacher passes around various electrical protective devices (each one clearly labelled) for students to familiarize themselves | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| **3.6. Grounding (1 hour classroom)** | | | Competency level: To know |
| Reasons for grounding | - Lightning protection<br>- Protection against electrocution | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Interactive session 3.6-1: Teacher invites up to 5 students to share their experiences both positive and negative with grounded and ungrounded systems | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |
| Types of grounding | - System grounding<br>- Component grounding | | |

# MODULE 4: SOLAR PHOTOVOLTAIC SYSTEM CONFIGURATION

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **4.1. Grid connected systems (1 hour classroom)** | | | Competency level: To understand |
| Components of grid connected systems | - Solar panel<br>- Inverters<br>- Cables | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| Types of grid connected systems | - Directly connected to national grid (no batteries)<br>- National grid back-up (battery) | | |
| **4.2. Off-grid systems (1 hour classroom)** | | | Competency level: To know |
| Components of an off-grid system | - Solar panel<br>- Inverter<br>- Battery<br>- Cable<br>- Charge controller | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook or recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| Types of off-grid systems | - System without battery storage and only DC load<br>- System with battery storage and only DC loads<br>- System with only AC loads<br>- System with both DC and AC loads | | |
| **4.3. Hybrid systems (1 hour classroom + 3 hours workshop)** | | | Competency level: To know |
| Components of a hybrid system | - Introduction | **Methods**<br>Instruction, Discussion | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc. |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| Types of hybrid systems | - System connected via a DC bus to supply DC load<br>- System connected via a DC bus through an inverter to supply an AC load<br>- Connected via an AC bus to supply an AC load (charge controller option) | **Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards | 2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories.<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

# MODULE 5: BASIC SYSTEM SIZING

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **5.1. Electrical loads (2 hours workshop)** | | | Competency level: To apply |
| Types | - AC loads<br>- DC loads | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>⌘Workshop 5.1-1: Students investigate the effect of efficient lighting on power<br><br>Video 5.1-1: Short video introducing application of energy efficiency in solar PV systems | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **5.2. Step-by-step calculations (12 hours classroom)** | | | Competency level: To apply |
| Step-by-step | - Evaluating the energy demand<br>- Sizing the battery bank<br>- Estimate the available solar resource<br>- Sizing the solar panel array<br>- Sizing the charge controller<br>- Sizing the inverter<br>- System optimisation<br>- Cable sizing | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards<br><br>**Activities**<br>Demo 5.2-1: Teacher solves some sizing calculations in classroom<br><br>⌘Exercise 5.2-1: Students are given various system sizing exercises to complete | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

# MODULE 6: INSTALLING A 1KW$_P$ SOLAR SYSTEM

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **6.1. Required tools (2 hour workshop)** | | | Competency level: To apply |
| Types of tools | - Measurement instruments<br>- Installation tools<br>- Other tools | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Demo 6.1-1: Teacher shows as many of the installation tools as possible<br><br>Exercise 6.1-1: Students familiarize themselves with the measurement instruments by taking readings | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **6.2. Suitable surfaces (2 hours workshop)** | | | Competency level: To apply |
| Installation surfaces | - On poles<br>- On roof tops<br>- On flat surface or ground | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Interactive session 6.2-1: Students discuss any other surfaces that they may have seen | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **6.3. Working with batteries (2 hours workshop)** | | | Competency level: To apply |
| Important information | - Precautions<br>- Battery installation considerations | **Methods**<br>Instruction, Discussion | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc. |

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|---|---|---|---|
| | | **Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards, Deep cycle batteries<br><br>**Activities**<br>Exercise 6.3-1: Students practice working with batteries | 2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **6.4. Working with solar panels (2 hours workshop)** | | | Competency level: To apply |
| Shading | - Effect of shading | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Workshop 6.4-1: Students practice working with solar panels such as handling<br><br>Workshop 6.4-2: Students practice mounting solar panels on various surfaces | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| Handling solar panels | - Based on usage/application<br>- Based on cell type | | |
| Mounting solar panels | - Installing the solar panel | | |
| **6.5. Installing solar panels on a roof (2 hours workshop)** | | | Competency level: To apply |
| Procedures | - Preparing for shingle installation<br>- Installing on a pitched roof | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>⌘Workshop 6.5-1: Students investigate the effect of shading on a solar panel | 1. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

| **6.6. Connecting system components (2 hours workshop)** | | | Competency level: To apply |
|---|---|---|---|
| Solar system circuits | - Solar source circuit<br>- Solar output circuit<br>- Charge controller input circuit<br>- Charge controller output circuit<br>- Inverter output circuit | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>⌘Workshop 6.6-1: Students investigate the effect of voltage drops in cables | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| Cabling and wiring | - Types of cables and wires<br>- Rules for wiring solar systems | | |
| **6.7. Step-by-step installation (40 hours workshop)** | | | Competency level: To apply |
| Practical installation of the system components | - Installing the solar panel<br>- Installing the battery<br>- Installing the inverter<br>- Installing the charge controller<br>- Installing cables | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>⌘Exercise 6.7-1: Students connect a system by themselves<br><br>Exercise 6.7-2: Students carry out commissioning tasks | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |

# MODULE 7: MAINTENANCE AND TROUBLESHOOTING

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| **7.1. Maintenance (2 hours classroom + 8 hours workshop)** | | | Competency level: To apply |
| Tasks | - Battery maintenance<br>- Solar panel maintenance<br>- Inverter and charge controller maintenance<br>- Maintenance of cables and connections<br>- Maintenance schedule | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards<br><br>**Activities**<br>Interactive sessions 7.1-1: Teacher asks students to share experiences they have had in maintenance of electrical equipment<br><br>Interactive session 7.1-2: Teacher discusses various maintenance tasks with students<br><br>Exercise 7.1-1: Students carry out maintenance activities on system components<br><br>⌘Workshop 7.1-1: Students investigate the effect of soiling on a PV array<br><br>⌘Workshop 7.1-2: Students define preventive maintenance tasks | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO<br>4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |
| **7.2. Troubleshooting (2 hours classroom + 8 hours workshop)** | | | Competency level: To apply |
| Faults | - Common Solar system faults<br>- Fault finding<br>- Troubleshooting steps | **Methods**<br>Instruction, Discussion<br><br>**Materials**<br>Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards | 1. ♦*Photovoltaic design and installation for dummies* • Wiley Publishing Inc.<br>2. ♦ *Stand-alone photovoltaic systems – A handbook of recommended design practices* • Sandia National Laboratories<br>3. ♦*Solar photovoltaic systems technical training manual* • UNESCO |

| Content | Topics | Methods & materials | Key resources |
|---|---|---|---|
| | | **Activities**<br>⌘Workshop 7.2-1: Students analyse a given failure and define troubleshooting steps<br><br>Exercise 7.2-2<br>Teacher explains various scenarios of failed or faulty systems to students who shall carry out troubleshooting on faulty equipment | 4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • The German Energy Society |