SYLLABUS AND
TEACHERS' REFERENCE

MINI-GRID DESIGN

Focus on Solar Photovoltaic and Micro Hydro

European Union

german cooperation
DEUTSCHE ZUSAMMENARBEIT

USAID
FROM THE AMERICAN PEOPLE

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Mini-Grid Design – Focus on Solar PV and Micro Hydro

Syllabus & Teacher's Reference for a 35-day training course for engineers
2nd Edition • March 2017
Developed in pursuit of conformity with the Nigerian Competency Standards for Clean Energy | Released 2016 in the domain "Designing Rural Mini-Grid Renewable Energy Systems with Focus on Solar PV and Micro Hydropower"

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Content

ABOUT

This document seeks to guide trainers on the delivery of the training course Mini-Grid Designer – Focus on Solar PV and Micro-hydro. The topics and subjects contained are a result of the needs expressed by the clean energy private sector in Nigeria conducted 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 electrical engineers to plan, design, analyse and commission renewable energy systems, supervise construction and provide related advisory services – in conformity with the requirements of the **Nigerian Competency Standards for Clean Energy**	Release 2016 in the domain "*Designing Rural Mini-Grid Renewable Energy Systems with Focus on Solar PV and Micro Hydropower*".
Target group	**Engineers**
Recommended entry criteria	Minimum Higher National Diploma (HND) or university degree in electrical or mechanical engineering or comparable or university degree in physics or comparable.
Duration	280 hours recommended (equivalent to 35 days at 8 hours per day)
Classroom size	15-20 trainees recommended
Expected tasks and duties	▪ Plan, design, analyse and commission renewable energy systems ▪ Supervise construction ▪ Provide related advisory services on solar photovoltaics and micro hydropower
Teaching methods	▪ Lectures (presentations & videos) ▪ Practical work ▪ Simulations ▪ Group work (homework, role play, presentation) ▪ Pop-quiz ▪ Laboratory-experiments & workshops ▪ Field trips ▪ Demonstration ▪ Discussion
Assessment methods	▪ Written examination ▪ Oral examination ▪ Practical 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** that 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 exceed that of the Course Handbook.

1.2. COURSE DURATION

The recommended contact hours for delivery of this course are **280 hours**. This would translate into 35 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 practical time.

1.3. 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 ***teaching 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 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:

- Multimeters
- Rig labs
- Inverters
- Charge controllers
- Batteries
- PV modules
- HOMER software
- Access to sites with hydropower potential
- Theodolite or dumpy level
- Altimeters
- Conductivity meter
- Hand-held GPS
- Weighing scale
- Common salt
- Measurement tape
- Stopwatch
- Topographical maps
- Water level tube
- Internet

Minimum requirements for a class of 20 students	*Quantity*	*Estimated unit cost (NGN)*	*Estimated cost (NGN)*
Cardboard strips	Lot		
Pin board (Metaplan)	4		
Laptop for trainer	1		
Projector	1		
Whiteboard	1		
Whiteboard markers	Lot		
Coloured pins	Lot		
Loudspeaker	1		
AC/DC digital multimeter with clamp	4	10,000	40,000
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
45 A charge controller	2	53,000	106,000
100 Ah battery	8	35,000	280,000
63 A MCCB	2	8,000	16,000
32 A MCCB	2	5,000	10,000
Spirit level	4	2,000	8,000
Compass	4	10,000	40,000
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
HOMER software			
Glass prism	10		
Light source	2		
Access to site with hydropower potential	Lot		
Internet access			
Water level tube (8 m length)	4		
Altimeter – Hand Held Barometer Huger EB 833 H	4		
Hand held GPS – Garmin GPSMAP64	4		
Dumpy level or theodolite	1		
Measuring tape– 30 m	4		
Conductivity meter (Lutron, CD-4301)	4		
Weighing scale – kitchen top model	4		
Common salt (2 kg)	1		
Stopwatch	4		

Prices are as at March 2016

1.5. TRAINING COURSE OVERVIEW

Module 1. Renewable energy overview	***18 hours***
Content	1.1 Global energy resources 1.2 Renewable energy resources and energy efficiency 1.3 Renewable energy in Nigeria 1.4 Energy access and poverty alleviation
Recommended time allocation	16 hours Classroom 0 hours Lab/workshop, field trip 2 hours Spare time + 2 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Understand the global challenge of fossil fuel reserves and climate change ▪ Outline and describe different renewable energy technologies ▪ Appreciate potential applications of renewable energy technologies ▪ Understand issues and barriers of achieving energy access in rural areas ▪ Appreciate the electricity supply and distribution challenges in Nigeria

Module 2. Electrical consumers and load assessment	***28 hours***
Content	2.1 Appliances 2.2 Load analysis
Recommended time allocation	18 hours Classroom 8 hours Lab/workshop, field trip and home work 2 hours Spare time +4 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Explain the characteristics of the most common loads ▪ Explain the typical load patterns and their properties in Nigerian rural areas ▪ Estimate and calculate energy demand on the base of number of inhabitants and activities

Module 3. Generation technologies	***114 hours***
Content	3.1 Solar power (focus topic) 3.2 Micro hydropower (focus topic) 3.3 Wind power (non-focus topic) 3.4 Biomass (non-focus topic)
Recommended time allocation	80 hours Classroom 28 hours Lab/workshop, field trip 6 hours Spare time +24 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Explain the different sources of renewable energy ▪ Explain under which conditions RE sources can be applied ▪ Estimate the costs of energy from renewable sources under consideration of climatic and technical conditions ▪ To design technical solutions for the installation of small grids

Module 4. Electric power distribution	*52 hours*
Content	4.1 The national grid 4.2 Mini-grids 4.3 Mini-grid hybrid systems 4.4 Protective measures 4.5 Metering 4.6 Commissioning 4.7 Operation and maintenance
Recommended time allocation	32 hours Classroom 16 hours Lab/workshop, field trip 4 hours Spare time +2 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Explain the basics of power distribution ▪ Explain the basics of setting up small grids of power supply ▪ Calculate system losses of a given small grid ▪ Commission mini-grid systems ▪ Identify and correct system faults

Module 5. Social, economic and legal framework	*12 hours*
Content	5.1 Policies, permits and key institutions 5.2 Non-financial appraisal 5.3 Community mobilisation 5.4 Ownership models and funding 5.5 Productive end uses
Recommended time allocation	11 hours Classroom and exercises 0 hours Lab/workshop, field trip 1 hours Spare time +4 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Know the different political and economic models of power supply ▪ Know the basics how to calculate tariffs and prices ▪ Appreciate the role of the local community in RE projects

Module 6. Project development	*40 hours*
Content	6.1 Project planning and management 6.2 Financial analysis
Recommended time allocation	16 hours Classroom with exercise and presentations 24 hours Lab/workshop, field trip 0 hours Spare time +4 hours Additional self-study
Learning outcomes	At the end of the module the learner is able to: ▪ Outline the procedures involved in planning RE systems ▪ Carry out basic financial analysis of RE projects

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 "Designing Rural Mini-Grid Renewable Energy Systems with Focus on Solar PV and Micro Hydropower".

Recommended duration and weightage

Duration	Examination type	Weightage
2 hours	Written examination	30%
6 hours	Oral examination	35%
8 hours	Practical examination	35%

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: RENEWABLE ENERGY OVERVIEW

Content	Topics	Methods & materials	Key resources
1.1 Global energy resources (4 hours classroom)			Competency level: To know
Classes of energy	- Primary vs. secondary - Commercial vs. non-commercial - Renewable vs. non-renewable	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards **Activities** ⌘Video 1.1-1: At the beginning of the class, the teacher should show video on general problems related to carbon dioxide and global warming. Interactive session 1.1-1: Teacher should encourage discourse in the class by asking students to give their opinions on the following topics: 1. Carbon dioxide 2. Global warming 3. Effect of mining on their immediate environment etc. 4. Nuclear energy 5. Dependency and economic impact of utilisation of fossil fuels 6. Post combustion carbon capture.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir 2. ♦*World energy outlook 2016: Executive summary* • IEA 3. ♦*African energy outlook 2014: A focus on energy prospects in Sub-Saharan Africa* • IEA
Energy and environment	- Global warming and climatic change impact - Impact of coal mining - Crude oil and natural gas mining - Global primary energy reserves and commercial energy production		
1.2 Renewable energy resources and energy efficiency (4 hours classroom)			Competency level: To know
Renewable energy (RE) sources	- Solar energy - Hydropower - Wind power - Biomass and biofuels - Geothermal energy	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards **Activities** ⌘Video 1.2-1: The combined power plant; 100% from RE.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir 2. ♦ *Renewable and efficient power systems* • Gilbert M. Masters
Energy efficiency	- in industry - in buildings - for appliances - for transport		

Content	Topics	Methods & materials	Key resources
1.3 Renewable energy in Nigeria (4 hours classroom)			Competency level: To know
Sources of renewable energy in Nigeria	- Solar - Wind - Hydro - Biomass energy	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards **Activities** Interactive session 1.3-1: Discussions between students and teacher of barriers to RE adoption in Nigeria.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir 2. ♦*National renewable energy action plan* • Nigeria Federal Ministry of Power, Works and Housing 3. ♦*The Nigerian energy sector* • German Agency for International Cooperation (GIZ) 4. ♦*Training needs assessment for RE in Nigeria* • Nigerian Energy Support Programme (NESP)
1.4. Energy access and poverty alleviation (4 hours classroom)			Competency level: To know
Definitions	- Domestic energy poverty	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards **Activities** Exercise 1.4-1: Teacher divides the class into groups and assigns topics for internet research (30 minutes) on SE4ALL, MDG, SDG, followed by short presentation by each group (approx. 5 minutes). Interactive session 1.4-1: Teacher discusses the current situation of SDG's with students. Focus should be on the approaches and what has been achieved. Exercise 1.4-1: Teacher divides the class into groups and assigns topics for internet research on various international programmes to support RE implementation.	1. ♦*SDG factsheet* • UN 2. ♦*The Sustainable Development Goals Report* • UN, New York 3. ♦*The 2030 agenda for sustainable development* • H.E.S. Kutesa 4. ♦*Sustainable Energy for All* • UN 5. ♦*SE4All - A frame work for action* • UN 6. ♦*Millennium Development Goals* • OECD 7. ♦*The MDGs report* • UN 8. ♦*The MDGs report summary* • UN 9. ♦*Nigeria's path to sustainable development through green economy* • UNDP
Millennium Development Goals (MDGs)	- Overview		
Sustainable Development Goals (SDGs)	- Challenges facing SDGs in Nigeria		
Sustainable Energy for All (SE4ALL)	- Introduction - Challenges		

MODULE 2: LOAD ASSESSMENT

Content	Topics	Methods & materials	Key resources
2.1 Appliances (2 hours classroom + 4 hours laboratory)			Competency level: To understand
Lighting	- Basic parameters and terms - Lamp types - Other lamps	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards, Mobile training toolkit **Activities** Experiment 2.1-1: Energy consumption of different lamp types. Experiment 2.1-2: Effect of efficient lighting on power.	1. ♦*The lighting handbook* • Zumtobel 2. ♦*Grundfos motorbook* • Grundfos 3. ♦*Electric motors and drives* • Austin Huges 4. ♦*Pumps and motors* • Technical learning college 5. ♦*Refrigeration – an introduction to the basics* • Danfoss 6. ♦*Refrigeration and air-conditioning handbook* • UNEP
Motors	- Motor types and function - Motor characteristics		
Refrigeration equipment	- Compression systems - Absorption systems - Air conditioning		
Other load types	- Electric heating equipment - Electronics - Power consumption of electronics		
2.2. Load analysis (16 hours classroom + 4 hours homework)			Competency level: To apply
Basic concepts	- Peak power - Total energy demand - Power supply by inverters - Load profile - Load optimisation	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards **Activities** Exercise 2.2-1: Students collect data on energy consumption of typical Nigerian villages (N, S, E, W). ⌘Exercise 2.2-2: Calculation of various load consumption data for any of 3 building types 1. Single family home 2. Multi-building community	1. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • Earthscan 2. ♦*Renewable energy resources* • John Tidwell and Tony Weir 3. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel 4. ♦*Renewable and efficient electric power systems* • Gilbert M. Masters 5. ♦ *Hybrid energy systems* • Renewable Energy Centre, Brisbane Institute of TAFE

MODULE 3: GENERATION TECHNOLOGIES

Content	Topics	Methods & materials	Key resources
3.1 Solar power (focus topic)			
The sun, sunlight and its properties (2 hours classroom + 4 hours laboratory)			Competency level: To use
Describing the solar resource	- Basic properties of light - Light spectrum	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards, Light source, Glass prism, Suneye, Irradiance sensor, Pyranometer **Activities** ⌘Video 3.1.1-1: How light travels in space and reaches Earth. Experiment 3.1.1-1: The teacher shows the students the spectrum of light using a simple experiment. Experiment 3.1.1-2: The students conduct laboratory experiments to explain the concept of direct and diffuse irradiance.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir 2. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel 3. ♦*Renewable and efficient electric power systems* • Gilbert M. Masters 4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • Earthscan 5. ♦*Applied photovoltaics* • Wenham et al 6. *Solar energy - renewable energy and the environment* • Robert Foster et al
Terminology and units	- Radiation - Solar power – irradiance - Solar constant - Air mass - Solar energy – irradiation - Peak sun hours		
Weather and meteorology	- Measurement of solar resource (common measurement instruments) - Meteorological data		
Physics of photovoltaics (2 hours classroom)			Competency level: To understand
Physics of photovoltaics	- Semiconductors materials - Electrical characteristics of semiconductors - Intrinsic semiconductors - The P-N junction - The solar cell: Photovoltaic effect Losses in solar PV cells	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Video 3.1.2-1: Film showing the manufacture of solar cells.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir 2. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel 3. ♦*Renewable and efficient electric power systems* • Gilbert M. Masters 4. ♦*Planning and installing PV systems: A guide for installers, engineers and architects* • Earthscan
PV cell design and materials	- PV cell design and structure - PV cell materials - Electrical characteristics of PV cells		

Content	Topics	Methods & materials	Key resources
Components of PV systems (2 hours classroom + 8 hours laboratory)			Competency level: To understand
Solar cell and module characteristics	- Equivalent circuit - Cell parameters (cell co-efficient, I-V curves, P-V curves) - Maximum power point - Efficiency and losses (effect of temperature and irradiance)	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Experiment 3.1.3-1: Characteristic curve of solar cells. Experiment 3.1.3-2: I-V measurement at different irradiance. Experiment 3.1.3-3: I-V measurement at different temperatures. Experiment 3.1.3-4: MPP and fill factor of solar cells. Experiment 3.1.3-5: Temperature effect on power. Experiment 3.1.3-6: Irradiance effect on PV module output.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir 2. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel 3. ♦*Renewable and efficient electric power systems* • Gilbert M. Masters 4. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects*• Earthscan
PV modules	- Primary PV module component		
Performance of PV modules and STC	- Shading - Hotspot effect - Shading caused by dust - Lifetime - Solar array		
Mounting	- Pole mount - Ground mount - Roof mount - Factors to consider (wind loading), theft protection - Tracking - Shading - Inter-row spacing		
Batteries	- Classification of batteries - Types of secondary batteries - Discharge process - Charge process - Flooded battery - Valve – regulated lead – acid (VRLA) battery - Application of lead – acid batteries - Battery specification - Charge efficiency in batteries - Battery banks - Lead – acid batteries in operation - Battery storage and maintenance		

Content	*Topics*	*Methods & materials*	*Key resources*
Charge controller	- Function of charge controller - Types of charge controllers - Specification of charge controllers - Features of charge controllers - Charge controllers in operation		
Inverter	- Function - Classification of inverter - Types (PV and battery) - Battery inverter - Connecting inverters - Output waveforms (square, modified sine, pure) - Specification and ratings - Efficiency - Interconnecting multiple inverters - Features		
Cables	- Types		
Electrical protection of PV systems	- DC circuit breakers and fused - Surge protection devices (SPD) - DC main disconnect - Enclosures - Shield cable - Protective measures on the DC side - Protective measures on the AC side - Measures to protect against lightning – induced surge voltages		
Application configuration	- On-grid and off-grid systems		
Grounding	- Equipment grounding - System grounding - When to ground solar systems		

Content	Topics	Methods & materials	Key resources
Stand-alone system sizing (8 hours classroom +8 hours laboratory)			Competency level: To apply
Sizing a PV system	- Terminology, yield, performance ratio - Decision making algorithm - Sizing the battery bank - Choosing system voltage - Sizing the PV array - Choosing the correct type and number of PV panels - Sizing the charge controller - Sizing the inverter - Cable sizing and selection - Software for sizing	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Exercise 3.1.4-1: Using load consumption data and results from the load assessments in exercise 2.2-2, students size a PV system. Students make presentation of results to the class. Exercise 3.1.4-2: Students design a stand-alone PV system and produce a single line diagram showing the system. Exercise 3.1.4-3: Students create a BoQ for a predesigned stand-alone PV system.	1. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • Earthscan 2. ♦*Renewable energy resources* • John Tidwell and Tony Weir 3. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel 4. ♦*Renewable and efficient electric power systems* • Gilbert M. Masters
System design	- Orientation of solar panels - Shade analysis and sun path chart - Inter – row shading		
PV system costing	- Cost estimation		
Commissioning	- Checklist for commissioning		
Solar thermal technologies (2 hours classroom)			Competency level: To understand
Solar water heating (SWH)	- Solar flat plate collector - Evacuated tube collector	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Video 3.1.5-1: To explain the application CSP, the teacher shows a video on DESERTEC project or other CSP plant.	1. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • Earthscan 2. ♦*Renewable energy resources* • John Tidwell and Tony Weir 3. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel ♦*Renewable and efficient electric power systems* • Gilbert M. Masters
Concentrated solar power (CSP)	- Power towers - Parabolic trough collectors		

Content	*Topics*	*Methods & materials*	*Key resources*
Current technologies and trends (4 hours research + 4 hours presentation)			Competency level: To know
	- Amorphous Si, CdTe, CIGS, high efficiency PV modules) - BIPV (windows, roofing sheets, facades	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Exercise 3.1.6-1: The class is divided into groups to conduct internet research on topics defined by the teacher. The groups make presentations on their findings to the rest of the class thereafter.	Requires periodic reviews by teacher to stay up to date with latest information
3.2 Micro hydropower (focus topic)			
Introduction (2 hour classroom)			Competency level: To know
What is small hydropower?	- Definition - Sub classification of small hydro - How does it work?	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Video 3.2.1-1: Teacher shows video introducing micro hydropower. The video should focus on the opportunities it creates (approx. 10 minutes).	1. ♦*Layman's handbook on 'How to develop a small hydro site'* • European Small Hydropower Association (ESHA) 2. *Micro hydro design manual* • ITDG (presently Practical Action)
General characteristics of SHP	- Strength - Weakness - Opportunity - Threat		
Types of hydropower schemes (2 hours classroom)			Competency level: To understand
Power calculations for SHP	- Flow - Head	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. ♦*Layman's handbook on 'How to develop a small hydro site'* • European Small Hydropower Association (ESHA) 2. *Micro hydro design manual* • ITDG (presently Practical Action)

Content	Topics	Methods & materials	Key resources
Based on flow condition	- Run-of-the-river - With dam storage - Pumped storage	**Activities** ⌘Exercise 3.2.2-1: Students are given numerical exercises to calculate the theoretical power output on different hydropower schemes. The students use these results to classify the schemes.	
Based on head	- Low - Medium - High		
Based on load and interconnection	- Base load - Peak load - Grid connected - Isolated		
System components (4 hours classroom)			Competency level: To apply
General layout	- Reservoir - Diversion/intake - Spillways & desilting - Headrace - Flume - Power intake - Penstock - Powerhouse - Tailrace	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Interactive session 3.2.3-1: Teacher discusses with students the importance of appropriate sizing of each component.	1. ♦*Manuals and guidelines for micro hydropower development in rural electrification – Volume 1* • Japan International Cooperation Agency (JICA)
Turbine selection (4 hours classroom)			Competency level: To apply
Specific speed	- Definition - Choosing a turbine - Transmission/isolated grids	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Exercise 3.2.4-1: Students are given numerical exercises where they have to select turbines for hydropower schemes using the examples in exercise 3.2.3-1.	1. ♦*Pumps as turbines* • Arthur Williams
Impulse and reaction turbines	- Characteristics - Types		

Content	Topics	Methods & materials	Key resources
Load control and protective devices (2 hours classroom)			
Electric load controllers	- Mode of operation	**Methods** Instruction, Discussion, Laboratory experiments **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	
Protective devices in micro hydropower systems	- Vibration detection - Grounding/earthing - Fuses - Miniature circuit breaker (MCB) - Residual current device (RCD) - Lightning arrestors		
Planning a hydropower scheme (8 hours classroom + 8 hours site visit)			Competency level: To apply
Resource measurement	- National and regional levels - Regional flow duration models - Remote sensing data for catchment analysis - Digital terrain models	**Methods** Instruction, Discussion, Site visit **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Site visit 3.2.6-1: Class visits an incomplete/potential SHP site to take readings and measurements. Exercise 3.2.6-1: The class is divided into groups and each group prepares a DPR using recorded data from the site visit.	1. *Hydro-electric handbook* • William P Creager and Joel D Justin 2. *Water power engineering* • M.M. Dandeker & K.N. Sharma 3. ♦*Feasibility studies for small scale hydro power additions: A guide manual* • US Army Corps of Engineers
Resource estimation at local levels (site specific)	- Measuring head - Measuring flow - Measuring area - Measuring velocity		
Pre-feasibility	- Planning - Desk work - Site visit - Quick assessment		
Detailed project report (DPR)	- Detailed analysis - Complete design - Economic analysis		
Environmental and social considerations (6 hours classroom)			Competency level: To apply
Environmental aspects	- Quality of water - Flood mitigation - Aquatic life - Greenhouse emissions	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. *Civil engineering guidelines for planning and designing hydroelectric developments* • American Society of Civil Engineers (ASCE)
Social aspects	- Rehabilitation - Loss of agricultural lands		

Content	Topics	Methods & materials	Key resources
		Activities Role play 3.2.7-1: The students are divided into groups representing stakeholders to discuss contentious issues on water usage and their priorities. Groups are ▪ Farmers ▪ Local industries for power ▪ Local government ▪ NGOs representing affected communities.	
Potential risks and issues (2 hours classroom)			Competency level: To use
Risks	- Hydrology failure - Geology evacuation - Power evacuation - Delayed payment by state utility - Natural calamities - Economic failure	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. *Civil engineering guidelines for planning and designing hydroelectric developments* • American Society of Civil Engineers (ASCE)
Issues	- Land clearances from different departments - Long project period - Skilled labour - Resistance from local population		
3.3 Wind power (non-focus topic)			
Wind resources and assessment (4 hours classroom)			Competency level: To know
How is wind created?	- What is wind? - Local and atmospheric wind conditions - Boundary layer and free atmosphere - Roughness length - Topographic conditions - Turbulences	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Video 3.3.1-1: Introducing wind energy formation and resources.	1. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel
Measurement instruments	- Wind vane - Anemometer - LIDAR - SODAR		
Wind resource estimation and assessment	- Wind speed measurement - Atmospheric remote sensing - Wind direction		

Content	Topics	Methods & materials	Key resources
	measurement - Temperature and pressure measurement - Wind speed estimation - Variable nature of wind - Frequency distribution of wind speed - Weibull distribution - Rayleigh distribution - Wind rose - Estimating long term wind speed - Statistical methods: measure, correlate, predict (MCP) - Physical methods		
Technological history (2 hour classroom)			Competency level: To know
History of wind energy conversion	- Development history - Electricity from wind - Early wind turbines - Modern wind turbines	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Interactive session 3.3.2-1: Students discuss the traditional uses of wind energy in Nigeria from their personal experiences and perspectives.	1. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel 2. www.telosnet.com/wind/future.html
Application history	- Onshore wind turbines - Wind turbines		
Design, components and control (4 hours classroom)			Competency level: To know
Wind turbine design	- HAWT vs. VAWT - Main features and components	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel
Horizontal axis wind turbines	- Solidity - Operating characteristics of wind turbine - Power available from the wind turbine - Capacity factor		

Content	Topics	Methods & materials	Key resources
Small wind turbines (4 hours classroom)			Competency level: To apply
Characteristics and design concepts	- Classification of small wind turbines (SWT) - Size and categorisation - Rotor types - Tower types - Upwind versus downwind	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Exercise 3.3.4-1: Students are given numerical exercises to calculate energy yield of SWT's.	1. ♦*Wind and solar power systems: Design, analysis and operations* • Mukund R. Patel
Applications of small wind turbines	- Grid-connected wind turbines - Stand-alone wind turbines (Water pumping, rural electrification, battery charging)		
Planning to install a wind turbine	- Siting - Visual influences - Noise - Power in the wind - Energy yield estimation - Small wind certification council		
3.4 Biomass (non-focus topic)			
Carbon cycle, climate change and biomass (2 hours classroom)			Competency level: To know
Carbon cycle and the atmosphere	- The carbon cycle - The atmosphere - The terrestrial biosphere - Oceans - Geological carbon cycle - Sediments	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Video 3.4.1-1: Explaining the carbon cycle. Video 3.4.1-2: Explaining photosynthesis.	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir
Plants and biomass	- The cell as the basis of biomass - Photosynthesis, generation of biomass - Definition of biomass		

Content	Topics	Methods & materials	Key resources
Biomass conversion technologies (6 hours classroom)			Competency level: To understand
Combustion	- Fixed bed combustion - Dust combustion Fluidised bed combustion	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. ♦*Renewable energy resources* • John Tidwell and Tony Weir
Gasification of biomass	- Raw material - Techniques (catalytic, non-catalytic) - Products - Effects of temperature		
Anaerobic digestion	- Basics - Raw materials - Products of anaerobic digestion - Types of digesters - Uses of biogas		
Energy farming for biomass production	- Energy farming - Advantages and dangers - World distribution - Crop yield - Worked example: Estimating yield and land requirements		
Biomass energy in Nigeria (4 hours classroom)			Competency level: To apply
Historical use of biomass	- Historical use in different cultures and climates.	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Exercise 3.4.3-1: The teacher divides the class into groups. Each group makes a research on topics defined by the teacher (3 hours) and makes presentations of findings to the rest of the class (1 hour).	

Content	Topics	Methods & materials	Key resources
Barriers to the development of biomass energy production and benefits	- Economic and policy barriers - Technological barriers - Social and environmental barriers - Reducing barriers - Environmental benefits	Exercise 3.4.3-2: The teacher divides the class into groups. Each group makes a research on topics defined by the teacher (3 hours) and makes presentations of findings to the rest of the class (1 hour). Topics could include: ▪ Biomass and CDM ▪ Utilisation of bio-energy in rural areas ▪ Opportunities for utilization of biomass in Nigeria.	

MODULE 4: ELECTRIC POWER DISTRIBUTION

Content	Topics	Methods & materials	Key resources
4.1 The national grid (2 hours classroom)			Competency level: To know
Overview	- Historical overview - Structure - Current status of the national grid - Standards and regulation - Extension plans	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. ♦*The Nigerian energy sector* • German Agency for International Cooperation (GIZ)
4.2 Mini-grids (1 hours classroom + 4 hours site visit)			Competency level: To understand
Introduction	- Design considerations - Load assessment	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Site visit 4.2-1: Students visit a local utility where they are able to see distribution and metering equipment. Exercise 4.2-1: Students size electrical distribution systems as designed by the teacher.	1. *Electrical systems installation: Work and practice* • Peter O. Ewesor 2. *Electrical systems installation: Practice and maintenance* • Peter O. Ewesor
Mini-grid distribution	- Voltage selection - Cables and conductors - Low voltage systems (single and 3-phase) - Transformers - Poles - Grid layouts - Interconnection with the main grid		
System design	- System configurations		
4.3 Mini-grid hybrid systems (24 hours classroom)			Competency level: To understand
Topologies	- Solar mini-grids - Diesel mini-grids - Hydro mini-grids - Wind mini-grids - Biomass mini-grids - O&M implications	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Interactive session 4.3-1: At the beginning of the class, the teacher asks the students to briefly explain their understanding of hybrid systems (max. 30 minutes).	1. *Hybrid energy systems resource book* • Renewable Energy Centre, Brisbane Institute of TAFE 2. ♦*Photovoltaic standalone systems* • US Department of Energy 3. ♦*Applied photovoltaics* • Wenham et al

Content	Topics	Methods & materials	Key resources
Hybrid system sizing and optimization	- Economic factors - System control - Sizing calculations - Software tools (HOMER)	⌘Video 4.3-1: Hybrid systems (SMA). Demo 4.3-1: Teacher shows students how to obtain data from online sources. Exercise 4.3-1: Students obtain data from online sources themselves for locations defined by teacher. Exercise 4.3-2: Students design a hybrid system and produce a single line diagram showing the system. Exercise 4.3-3: Students create a BoQ for a predesigned hybrid system. Exercise 4.3-4: Group exercise to optimise a hybrid system (optional).	
4.4 Protective measures (2 hours classroom)			Competency level: To apply
Functions of electrical protective devices	- Insulation - Enclosures - Spacing - RCD protection - Automatic disconnect of power supply - Double insulation - Protection by non-conductive spaces	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. ♦ *Electrical wiring: Domestic* • Brian Scaddan 2. ♦*SPD electrical protection handbook* • Bussman by Eaton 3. *Sizing conductors and selecting protection devices* • Legrand 4. *Electrical installation handbook (protection, control and electrical devices)* • ABB
Application	- Protection of conductors and electrical equipment - Protection of people		
4.5 Metering (1 hours classroom + 2 Hours Workshop)			Competency level: To use
Metering	- Meter standards - Types of meters - Smart metering techniques - Load limiters	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	

Content	Topics	Methods & materials	Key resources
		Activities Site Visit 4.5-1: Students visit a local utility where they are able to see distribution and metering equipment. Demo 4.5-1: Students are shown different types of meters available on the local market.	
4.6 Commissioning (4 hours workshop)			Competency level: To apply
Commissioning	- Checklist for commissioning - PV commissioning and testing - Battery testing - Power conditioning unit functional tests	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Workshop 4.6-1: Students carry out commissioning activities on various system components.	1. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • Earthscan 2. ♦*Applied photovoltaics* • Wenham et al 3. *Solar energy* • Robert Foster
4.7 Operation and maintenance (2 hours classroom + 6 hours workshop)			Competency level: To apply
Steps, procedures and consideration	- Mini-grid sustenance	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. ♦*Planning and installing photovoltaic systems: A guide for installers, engineers and architects* • Earthscan 2. ♦*Applied photovoltaics* • Wenham et al 3. *Solar energy* • Robert Foster

MODULE 5: SOCIAL, ECONOMIC AND LEGAL FRAMEWORK

Content	Topics	Methods & materials	Key resources
5.1 Policies, permits and key institutions (4 hours classroom)			Competency level: To know
Key institutions	- Public sector institutions - Private sector institutions	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pin boards **Activities** Interactive session 5.1-1: Students compare Nigerian policies and plans with international best practices. Interactive session 5.1-1: Discussing ownership of electricity production and nets, statal or private, Tariff structure. **Recommendation** 2 hours lecture from professionals in the Nigerian Electricity Supply Industry (NESI).	1. ♦*The Nigerian energy sector* • German Agency for International Cooperation (GIZ) 2. ♦*National Renewable energy and energy efficiency policy* • Nigeria Federal Ministry of Power, Works and Housing 3. www.nercng.org 4. ♦*National Energy Policy* • ECN 5. ♦*The Renewable Energy Master Plan* • A.S. Sambo 6. ♦*Rural Electrification Strategy and Implementation Plan* • econ ONE Research, Inc. 7. ♦*Policy brief - feed-in-tariff regulation for RE in Nigeria* • Gender and Energy Policy 8. *Draft feed-in-tariff regulations for RE in Nigeria* • NERC
Regulatory guidelines for licences	- NERC licensing requirements - Licencing requirements for embedded generation - NERC licensing process		
Acts and policies	- Approved documents - Draft documents - Global and regional policies		
5.2 Non-financial appraisal (4 hours classroom)			Competency level: To use
Environmental impact assessment (EIA)	- Technology-specific environmental impacts - Nigerian EIA procedure - Environmental ethics - Best practices in EIA	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Interactive session 5.2-1: Teacher explains the best practice for EI.	1. ♦*Dealing with social aspects of hydropower development* • German Agency for International Cooperation (GIZ) 2. ♦*Environmental impact assessment in Nigeria: regulatory background and procedural framework* • N. Echefu and E. Akpofure 3. *Energypedia* https://energypedia.info/wiki/Portal:Financing_and_Funding
Socio impact assessment (SIA)	- Social norms - Economic impacts		

5.3 Community mobilisation (1 hour classroom)		Competency level: To apply	
Community mobilisation	- Project objectives - Baseline economic analysis of Roguwa community	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards Role play 5.3-1: Students are divided into groups representing the different stakeholders in a rural electrification project. Teacher is the mediator. ▪ Community ▪ Government ▪ Project developers ▪ Non-governmental organisation (NGO).	1. https://www.globalgiving.org/projects/community-mobilization-for-solar-energy-in-gaza/ 2. www.globalcommunities.org/node/38087 3. ♦*Community Mobilisation in Nepal* • UN
5.4 Ownership models and funding (1 hour classroom)		Competency level: To understand	
Ownership and operating models	- Private company ownership - Community ownership - Government ownership - Mixed ownership - Types of funding - Access to project funding	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards	1. *Energypedia* https://energypedia.info/wiki/Portal:Financing_and_Funding
5.5 Productive end uses (1 hour classroom)		Competency level: To understand	
Productive end use assessment	- Categories of productive activities - Project impact on productive activities	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Interactive session 5.5-1: Teacher discusses opportunities of productive end use from renewable energy.	1. *Energypedia* https://energypedia.info/wiki/Portal:Productive_Use

MODULE 6: PROJECT DEVELOPMENT

Content	Topics	Methods & materials	Key resources
6.1 Project planning and management (8 hours classroom)			Competency level: To understand
Introduction to project planning	- Pre-development - Project development - Project implementation - Project commencement - Challenges - Success factors	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** Interactive session 6.1-1: At the beginning of the class, the teacher asks students to suggest project planning activities and tasks for: ▪ A stand-alone system ▪ Hybrid system ▪ Mini-grid system ⌘Interactive session 6.1-2: After the lectures, the students are divided into groups. Each group is given a sample project and they are to list out the project planning activities. [*The project planning worksheet will be made available by the teacher*].	1. ♦*ZOPP Objectives oriented planning* • German Agency for Technical Cooperation (GTZ)
6.2 Financial analysis (8 hours classroom)			Competency level: To apply
Financial forecasting tools	- Net present value (NPV) - Internal rate of return (IRR) - Lifecycle cost analysis (LCCA) - Cost-benefit analysis (CBA) - Payback period (PP) - Levellised cost of energy (LCoE) - Considerations when making a financial analysis	**Methods** Instruction, Discussion **Materials** Laptop, Projector, Loud speakers, Whiteboard, Whiteboard markers, Metaplan cards, Metaplan pinboards **Activities** ⌘Exercise 6.2-1: Students are to conduct financial analyses for sample projects. [*Financial worksheet will be made available by the teacher*].	

Content	*Topics*	*Methods & materials*	*Key resources*
Financial statements	- Profit & loss account - Cash flow statement - Balance sheet		

End of course project (24 hours)

Students are divided into three groups to work on one narrative for a hybrid system mini-grid. The teacher shall be available to provide answers to student's questions during this period. At the end of the exercise (16 hours), each group makes a presentation to the rest of the class and answers questions on their design process and assumptions (8 hours).