SOLAR PV CURRICULUM DEVELOPMENT WORKSHOP REPORT

09th to 13th July 2012

Elsmere Conservation Center, Naivasha

Report Prepared by Kenya Renewable Energy Association (KEREA) Secretariat

Contents

1 INTRODUCTION

The Solar PV training curriculum development retreat was held in Naivasha, Kenya from 9th to 13th July at the Elsamere Conservation Center. It brought together 12 participants from local and international institutions including the academia and regulatory institutions.

Administrative and logistical support was provided by the Kenya Renewable Energy Association secretariat.

The participants list is as follows:

	Name	**Institution**
1	Samson Tsegaye	Solar Energy Foundation, Ethiopia
2	Dwipen Boruah	IT Power Group, India
3	Raphael Lechner	Institute of Energy Technics Amberg University, Germany
4	Robert Pavel Oimeke	Energy Regulatory Commission
5	Kimani Muhoro	Energy Regulatory Commission
6	Francis Njoka	Institute of Energy and Environmental Technology (IEET) Jomo Kenyatta University of Agriculture and Technology (JKUAT)
7	Maina Nguku Kinyua	Senior Industrial Training Officer National Industrial Training Authority(NITA)
8	Patrick King'oina	Mombasa Technical Training Institute
9	Dr. Sebastian Waita	University of Nairobi
10	Dr. Justus Simiyu	University of Nairobi
11	Dr. Alex Ogacho	University of Nairobi
12	Charles Muchunku	Kenya Renewable Energy Association (KEREA)
13	Cliff Owiti	Kenya Renewable Energy Association (KEREA)
14	Aisha Abdulaziz	Kenya Renewable Energy Association (KEREA)

This document is the full report and is comprised of two parts. The first part focuses on the workshop information, its background and design, processes and deliberations. Part one aims to provide insight into the reflections and emerging ideas which contributed towards the first draft of the training curriculum.

The second part is the first draft of the solar PV training curriculum itself; as per the consensus reached in regards to each aspect of the development process.

The Curriculum development workshop program is included for reference as Appendix 1.

2 PART I

2.1 CONTEXT

The Energy Regulatory Commission plans to gazette solar PV regulations in 2012. The regulations have been developed with the intention of improving the delivery of products and services within the solar PV sector.

The regulations shall require that only licensed technicians are allowed to design and install solar PV systems; and to be licensed, technicians shall be required to have undertaken a solar training course allowing them to practice within the following parameters:

a) Class T1, which shall entitle the holder to carry out solar PV system installation work for single PV module or single battery DC system of up to 100 Wp.

b) Class T2, which shall entitle the holder to carry out solar PV system installation work for medium size PV systems i.e. multiple modules of up to 300 Wp or multiple batteries which may include an inverter.

c) Class T3, which shall entitle the holder to carry out solar PV system installation work for advanced, including grid connected and hybrid solar PV systems.

It is on the foundation of this upcoming change in the solar PV sector; that the Kenya Renewable Energy Association (KEREA) entered into collaboration with UNDP to implement joint activities under UNDP's 'Access to Clean Energy Services Programme in Kenya'. The solar PV training curriculum was drafted under this collaboration framework, as part of a series of activities being implemented by KEREA toward harmonization of existing curricula.

The broader objective of the activities is to catalyze institutionalization of solar PV training in public technical training institutions and standardization of private sector based solar training programs in the future.

KEREA's approach to the activity was to bring experts together to review, adapt and consolidate locally and internationally available curricula and develop a comprehensive solar PV training curriculum for the Kenyan market. The draft curriculum developed by the expert group meeting is part II of this report.

The draft will be presented in a stakeholder's consultative workshop to be held before the end of August 2012. A final training package will be prepared that consolidates the feedback and inputs collected.

2.2 SITUATIONAL ANALYSIS

There are approximately 800-1000 solar PV technicians working in the Kenyan market since the sector was established in the 1980s. Majority of them skilled but untrained; these practitioners provide a necessary service to end-users as the demand for solar PV systems is high especially in rural areas of the country. However, the quality of such services is lacking as there is little or no oversight of the sector and expertise. The ERC regulations are therefore timely and welcome; and are envisioned to be successful if adequate emphasis is placed on compliance and adherence.

Licensing regulations will significantly impact the solar PV sector. In addition to licensing of technicians, the ERC regulations propose measures targeting supply and/or sale of solar PV equipment; to ensure reasonable effort is made to guarantee the quality of individual and integrated system components. The trend in the sales market is that urban based importers sell their products to vendors in the rural areas who then provide direct sales to end users. Vendors are accessed directly or through importer depots/branches. Importers also sell directly to end-users. Under this distribution model end-users rely on freelance technicians to provide system installation services. As per the proposed regulations, to be licensed as a solar PV vendor one will need to employ licensed technicians.

The current solar home systems sales are estimated at 20,000 to 30,000 per year with the average system size in the range of 20-30W. In addition, following the success of the IFC/WB Lighting Africa program it is estimated that 80,000 solar lanterns were sold in 2010-2011. A large number of institutional systems (schools, dispensaries and health centers) are also implemented through bulk government tenders. Isolated off grid systems such as diesel- solar PV hybrids and specialized private systems such as electric fencing, base telecommunications transmission stations also form a significant part of the market, with future market expansion into grid connected solar PV systems expected.

The actors that will play a key role in capacity building, certification and licensing of solar technicians are outlined below:

	Institution	**Current Role/Status**
1	Energy Regulatory Commission (ERC)	▪ Licensing technicians and vendors
2	National Industrial Training Authority (NITA)	▪ Trade Tests (Skills testing) ▪ Accreditation before licensing ▪ Curriculum Development
3	Kenya Institute of Education (KIE)	▪ Curriculum Development

	Institution	Current Role/Status
4	University of Nairobi (UoN)	▪ Developing bachelors and postgraduate degree courses in RE ▪ Postgraduate and doctoral projects in RE already ongoing ▪ Offering short courses in solar PV through the solar academy ▪ Development of a Solar testing laboratory (currently equipped to test solar lanterns and to be developed to test larger solar PV system components)
5	Jomo Kenyatta University of Agriculture and Technology (JKUAT)	▪ Offering short courses in solar PV, postgraduate and doctoral courses in energy technology and systems; and undergraduate courses in electrical and mechanical engineering which include units on solar PV ▪ JICA and JKUAT are also collaborating on a project targeting the training of trainers in RE technologies including solar PV and hybrid systems
6	Kenya Renewable Energy Association (KEREA)	▪ Facilitating the curriculum development process ▪ Supporting the institutionalization of solar PV training in public technical training institutions ▪ Facilitating the standardization of private sector based solar training programs
7	German Solar Academy	▪ Private Public Partnership between GIZ and 3 German Companies (Energiebau Solarstromsysteme GmbH, SCHOTT Solar AG and SMA Solar Technology AG) targeting the promotion of grid connected solar PV and quality standards for components
8	Polytechnics and technical training institutes	▪ Providing theoretical and practical training in a number of technical subjects including solar PV; using relevant curricula

With consideration of the roles of these main industry stakeholders the approach utilized for the development of the curriculum was to invite representatives from these institutions to an expert group meeting where their inputs would be consolidated to develop a comprehensive draft curriculum covering T1, T2 and T3.

It was also acknowledged that the Kenya Institute of Education (KIE) has provided a training curriculum which is intended for use by over 40 training institutions in the country. However, there was a view that in addition to providing curricula and training manuals to trainers (at both youth polytechnic level and technical training institution levels) it was important to include a component of training of instructors on solar PV to induct instructors and to adequately equip these institutions to ensure that they had sufficient solar PV equipment and materials for the training course.

Other areas of discussion therefore included training manuals, training of trainers and equipping of training institutions to enable them to roll out the training program. Trade test guidelines were also discussed with the view to creating the path to licensing i.e. trained technicians would be required to undergo accreditation by National Industrial Training Authority (NITA) before apply

for a license from the Energy Regulatory Commission (ERC). For each cluster of technicians, skills assessment/trade test guidelines are therefore included in the curriculum.

The overall strategy of the workshop was therefore to address both immediate and short-term issues; developing a comprehensive curriculum additionally covering both hybrid and grid connected solar PV systems in light of the anticipated policies and technologies that would promote the uptake of grid-connected solar PV systems.

2.3 EMERGING ISSUES AND CONSIDERATIONS

It was noted at the workshop that youth polytechnics are currently shifting their focus from offering courses to post-primary students and targeting post-secondary trainees because of free primary education and upcoming plans for free secondary education. It is estimated that there are a total of 600 youth polytechnics countrywide, with about 300 approved by the government and an equal number being private. About 40 of these youth polytechnics have been selected for ongoing piloting of the KIE training curriculum in a number of subjects not limited to solar PV.

At the polytechnic and technical training institution level, it is estimated that there are over 40 institutions. At these institutions a curriculum for solar PV has been developed by KIE, which is offered at both certificate and diploma level. In these institutions, general electrical courses are offered under which solar PV is taught as one of the units as per the KIE curriculum.

Ideally, review of the curriculum used by all these institutions should be undertaken every 5 years; however due to financial constraints standard practice has been after 10-15 years.

2.4 LESSONS LEARNT FROM OTHER COUNTRIES[1]

A number of lessons were derived and shared from experiences in other countries; and evaluated as part of the curriculum development process. Brief summaries are as follows:

Ethiopia: The experience of the International Solar Energy Institute for Rural Development – Developing a National Solar PV curriculum and a Private Solar Training Institute in Ethiopia

Participating students are nominated from vocational training schools and are required to undertake an entrance exam. The Ministry of Education recommended the Australian curriculum and standards as the benchmark for the national curriculum. It was used as a general reference tool; as a number of components were found to be inapplicable to the Ethiopian context and were disregarded.

Occupational standards and units of competency were derived from the Australian curriculum; with testing being standardized in classroom situations for both theory and practical examinations. An information sheet was prepared separately from the curriculum; with the

[1] Complete copies of the presentations can be provided to members of KEREA upon request.

curriculum indicating titles and time frames while the information sheet provided detailed content.

The curriculum covers 5 levels from Basic Renewable Energy Support (Level 1) to Renewable Energy Technology Management (Level 5). There was a focus on renewable energy in general rather than solar PV, with the aim of meeting the requirements of government instutitutions whose mandate covers other RE technologies other than solar PV. The national occupational standards were prepared for approval by the Ministry of Education and the Ministry of Water and Energy.

In terms of materials; the Solar Energy Foundation has published a book on rural electrification with Solar PV and uses imported standard kits (LEX solar training) for technician training. The training institute has laboratories and there are future plans to set up local assembly of some solar PV system components.

Grid connected PV is already included in the curriculum but it is not being offered extensively because the lessons cover up to about 100W. Policy for grid connected solar PV is yet to be developed in Ethiopia.

Pakistan: The experience of Institute for Energy Technics, Amberg University – Capacity building of the Solar PV industry in Pakistan

The stakeholders of the curriculum development and implementation project included the Alternative Energy Development Board (Government Agency for implementation of RE technologies - Ministry of Water and Power), Renewable Energy Association, GIZ renewable energies and energy efficiency program, INTEGRATION (consultants for facilitation and management) and Amberg University (Technical contribution).

Preliminary situational analysis indicated that poorly designed and installed solar systems and loss of trust in the technology were issues of increasing concern. This was the case and therefore starting point of the project, especially in regards to solar water heaters. Additional issues included lack of formal education in the country on solar technologies and that current practitioners were self-taught.

Short solar training courses were developed and implemented under a GIZ funded program. Trainees were derived from members of the Pakistan renewable energy association. The training process begun with basic solar water heating, solar PV training was subsequently introduced.

The challenge in offering the training was having mixed groups where qualifications and experiences were varied; with majority of the participants being distributors rather than installers.

An open source excel solar PV system design tool developed by the trainers was provided which incorporated irradiation data for different parts of the country. During the course, at the request of the participants, advanced design aspects were incorporated make the tool more detailed.

Demonstration systems were set up rather than offering training with individual systems or kits. Locally available system components were used rather than those from the trainers' institutions and technical data sheets, quality standards and certificates provided as part of the training through group work.

There was also a clear preference by the participants to have a seminar rather than a classroom learning environment.

India: The experience of IT Power Group (Intermittent Technology Development Group)

In the context of India, there are a number of policy and financial challenges related to solar PV sector; including lack of linkages between policies and local regulations, lack of a single window clearance system (existence of a one-stop shop) and insufficient financing options.

The training offered focuses on three main areas/standards: practitioner, hardware and training with management standards being complimentary to all. It is targeted at post-primary education trainees and performing rather than knowing. Short courses are offered on demand-driven basis and the duration is flexible; being dependent on trainees' level of experience. Certification of technicians is specific and includes installers, designers, maintenance technicians and inspectors.

To ensure that training is of good quality, the institution recommends that third party verification and a national/international training framework to be provided together.

2.5 ACKNOWLEDGEMENTS

The Kenya Renewable Energy Association extends its appreciation to the UNDP Energy Access Program for its support. We would also like to thank the local and international experts for their time and contribution, with which the curriculum development process was a success.

We would like to welcome stakeholders in providing feedback and other inputs into the curriculum to ensure the best possible outcome is derived for the benefit of the solar PV market in Kenya.

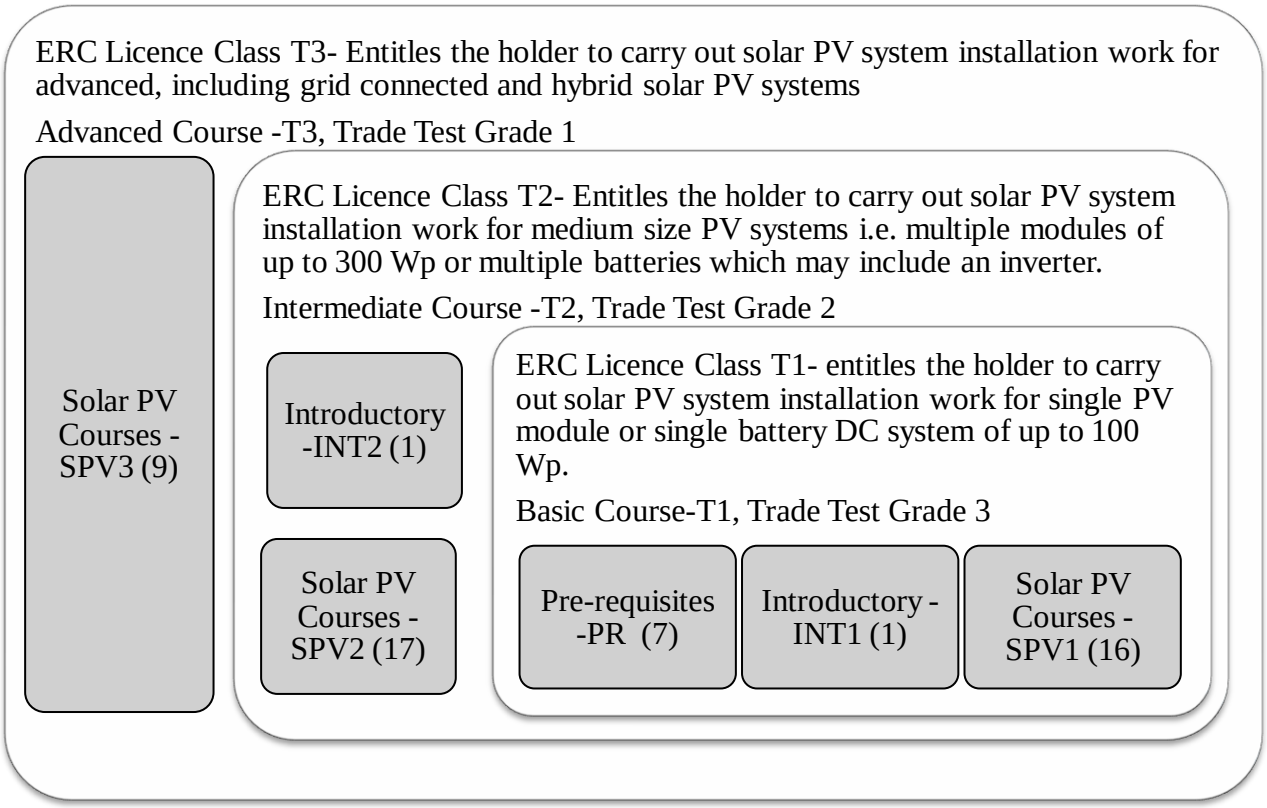
These and any other queries can be addressed by post or email to:

The Kenya Renewable Energy Association
P.O. Box: 42040 – 00100 Nairobi
Kenya
E-mail: chairman@kerea.org and administrator@kerea.org

3 PART II- CURRICULUM

The solar PV training curriculum has been developed and structured to meet the Energy Regulatory Commission's licensing requirements for the classifications (T1, T2 and T3). It has also taken into consideration the National Industrial Training Authority's trade test guidelines and structure.

The summary of the testing and licensing aspects of each class is as illustrated below:



The basic course T1 is built on the premise that the trainee has some foundational understanding of electrical concepts. It therefore introduces technical considerations, selection and application of components and correct procedures to be followed when designing (basic), installing, testing and commissioning, troubleshooting and maintaining basic solar PV systems. This is therefore the first section of the curriculum.

The intermediate course T2 expounds on the courses offered at the T1 level; introducing and expounding on concepts related to installation of multiple modules and batteries and the use of inverters in solar PV systems. It additionally goes into the relevant Kenyan policy, legal and regulatory frameworks for electrical installations; as a point of stepping up to T3. The second section of the curriculum therefore highlights the additions to T1; leading up to the T2 course curriculum. The advanced T3 curriculum appears in the third and final section.

3.1 T1 COURSE

Objective: Provide competence in carrying out solar PV system installation work for single PV module or single battery DC system of up to 100 Wp.

Lesson	Targeted outcome/competence
INT 1-Introduction to Energy	▪ To understand the general sources of energy and the differences between the renewable and non-renewable energy technologies. ▪ To understand the energy situation in Kenya including electrification rates, and the contribution of the different energy resources to the energy mix. ▪ To have a basic knowledge of the policy and regulatory frameworks for solar PV ▪ To know the advantages and disadvantages/limitations of RE
PR1-Solar Resource Introduction	▪ To understand the solar energy resource
PR2-Solar Energy Conversion	▪ To have a basic knowledge of common solar energy conversion devices ▪ To understand the differences between solar PV and solar thermal.
PR3-Solar PV Applications and Limitations	▪ To know where solar PV can be applied ▪ To understand the limitations of the technology
PR4-Solar Configurations	▪ To understand the different configurations and components of solar PV relevant to DC solar PV systems only
PR5-Basics of Solar PV	▪ To know key solar PV terms e.g. solar cell, module, array and IV curve
PR6-DC Basics	▪ To understand and apply Ohms law and power law.
PR7-Tools and Measuring Instruments	▪ To know the various types and proper use of basic tools and equipment for solar PV installations. ▪ To know how to use a multimeter.
SPV101-Solar PV system	▪ To know all the components of the system and their functions
SPV102-Solar PV Modules	▪ To understand the performance of different types of modules under different conditions (heat, shade, orientation etc.) and the implications of module mounting on the performance. ▪ To know how to measure Isc, Voc and charging current and voltage. ▪ To know the modules that have passed the relevant local quality standards. ▪ To know the module connection accessories including connectors and junction boxes. ▪ To know how to read and understand the module specifications. ▪ To understand the use of bypass and blocking diodes in a solar module. ▪ To understand safety requirements when working with modules.

Lesson	Targeted outcome/competence
SPV103-Batteries	▪ To understand the basic parts of a lead acid battery. ▪ To understand the difference between starting lighting and ignition and deep cycle and know why deep cycle batteries are preferred for solar PV systems. ▪ To understand the difference between sealed and flooded batteries. ▪ To know how to read and understand battery specifications ▪ To understand the safety requirements when working with batteries. ▪ To know how to install a battery (filling a flooded lead acid batteries, initial charging), use of battery terminals and storing batteries. ▪ To know how to measure the state of charge using voltmeter and hydrometer. ▪ To know how to maintain a battery. ▪ To understand battery replacement requirements. ▪ To know how to safely and environmentally dispose a battery.
SPV104-Charge Regulators	▪ To understand the functions of a charge controller. ▪ To understand the connection sequence for installation. ▪ To know how to read and understand charge controller specifications. ▪ To understand the safety requirements when working with CC. ▪ To know the CCs that have passed local standards.
SPV105-Wiring	▪ To know the different specifications of DC cables and their applications (single core, twin core, single strand, multiple strand, UV protected etc.). ▪ To know the different types of connectors and their applications (lugs, strip-connectors etc.). ▪ To know local and international cables standards. ▪ To understand the voltage drop and its relationship to cable length and size (diameter). ▪ To understand how to size cables. ▪ To know how to use basic cable sizing tables. ▪ To know how to measure the wire diameter. ▪ To know how to identify a good quality cable (familiarity with products in the market, visual tests and resistance tests). ▪ To know how to size and position fuses or circuit breakers in a solar PV system. ▪ To know how to install light fixtures, switches, sockets and junction boxes. ▪ To know how to do surface wiring, use conduits and use trunking. ▪ To know the different colour codes used in cables. ▪ To understand the 1 switch, 1 light principle.
SPV106-Lighting	▪ To know the pros and cons of different lighting technologies, their costs, efficiency and life (CFL, incandescent, tube FL, LED, Halogen). ▪ To know how to differentiate DC and AC lights. ▪ To understand positioning of lights and use of reflectors to maximize light intensity at the point of application.

Lesson	Targeted outcome/competence
SPV107-Appliances	▪ To understand the size of appliances (watt/power rating) that can be used for different sizes of solar systems. ▪ To know the difference between DC & AC appliances and the pros and cons of DC & AC appliances. ▪ To know the energy efficient DC appliances in the market commonly used in solar PV systems. ▪ To know how and when to use a DC-DC converter
SPV108-Module Mounting	▪ To understand how module performance is affected by module mounting. ▪ To understand module mounting, orientation and inclination requirements. ▪ To know the different module mounting structures (roof, pole, wall and ground) and know how to select the most suitable for a given site. ▪ To know how to select the proper materials and use protective coating to prevent corrosion and maximize module mount life. ▪ To know how to design the different module mounting structures for a single module.
SPV109-System Sizing	▪ To know how to determine the daily energy demand. ▪ To know how to use basic ERC approved sizing tools and tables. ▪ To know how to match the system components as per the voltage of available modules.
SPV110-System Design and Site Planning	▪ To know how to appropriately position the solar PV system components and appliances based on the site layout. ▪ To know how to determine the appropriate cable length and wire gauge for 1) Module/Array to charge controller 2) CC to main junction box 3) Main junction box to other junction boxes, switches, lights and sockets. ▪ To know how to prepare a check list of all the solar PV equipment, installation materials and accessories. ▪ To know how to prepare a schematic and wiring diagram for accurate determination on installation materials and accessories. ▪ To know the system protection guidelines and requirements (earthing, short circuit and lightning arrester) and select appropriately
SPV111-System Installation	▪ To know how to verify that the appropriate equipment, materials, accessories and tools are tested and provided prior to installation (as per the checklist and in good working conditions). ▪ To know how to use the right tool for the right job. ▪ To know the solar PV system installation steps and sequences ▪ To know guidelines for proper handling of solar PV equipment and installation materials.

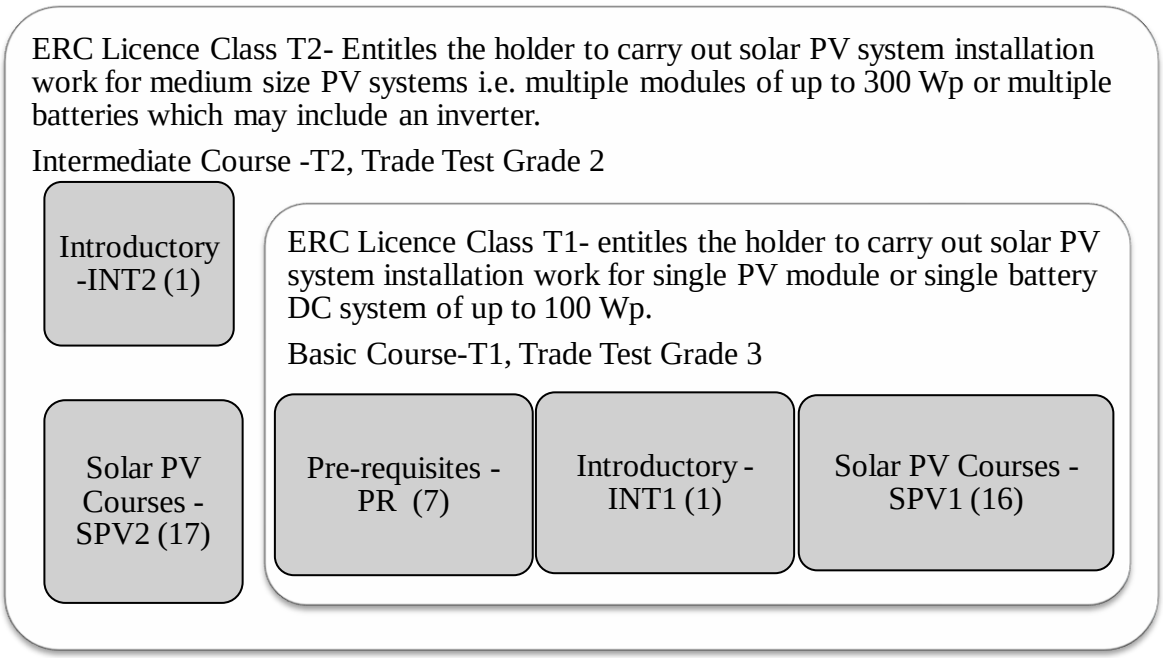
Lesson	Targeted outcome/competence
SPV112-Commissioning	▪ To know the testing and commissioning procedures and requirements for solar PV systems including: 1) Continuity 2) Polarity 3) Insulation 4) Visual inspection 5) Voltage drop 6) Voc and Isc cross check 7) Completion of commissioning certificate
SPV113-End User Education	▪ To know how to train the users on 1) Understanding PV system limitations and balancing energy use 2) How to monitor the performance of the system using the charge controller 3) Do's and don'ts 4) Basic maintenance (cleaning module and battery, topping up of the battery, replacing lights and batteries, battery disposal) 5) Safety 6) Record keeping
SPV114-Troubleshooting and Maintenance	▪ To know how to carry out all routine maintenance requirements. ▪ To know all the types of faults that can occur in a solar PV system and know how to diagnose and rectify them, excluding inverter faults. ▪ To know common solar PV installation mistakes and how to rectify them
SPV115-Policy. legal and regulatory frameworks for solar PV in Kenya	▪ To understand the requirements of the solar PV regulations in so far as licensing and warranties are concerned.
SPV116-Solar Lanterns	▪ To know how to disassemble and assemble and maintain different types of solar lanterns. ▪ To know local and international standards for solar lanterns ▪ To know the solar lanterns in the local market that meet the local and international standards and guidelines ▪ To understand the life cycle cost benefit analysis of solar lanterns as compared to kerosene use.

3.1.1 TRADE TEST 3 – PRACTICAL SKILLS EXAM GUIDELINES FOR T1 TECHNICIAN

Practical Exam	Practical skills to be tested
PR-1A	▪ To test knowledge of how to determine the daily energy demand ▪ To test knowledge of how to use basic ERC approved sizing tools/tables
PR-1B	▪ To test knowledge of how to appropriately position the solar PV system components and appliances based on the site layout as determined by a site visit ▪ To test knowledge of how to determine the appropriate cable length and wire gauge for module/array to charge controller, charge controller to battery, charge controller to main junction box and main junction to other junction boxes, switches, lights and sockets ▪ To test knowledge of how to prepare a schematic and wiring diagram for accurate determination of installation materials and accessories ▪ To test knowledge of the system protection guidelines (earthing, short circuiting and lightning arrester) and requirements and select appropriately
PR-1C	▪ To test knowledge of the solar PV system installation steps and sequences ▪ To test knowledge of the safety guidelines for solar PV installations (end user and installer) ▪ To test understanding of how module performance is affected by module mounting ▪ To test understanding of module mounting, orientation and inclination requirements ▪ To test knowledge of how to install a battery (filing a flooded lead acid batteries, initial charging), use of battery terminals. ▪ To test knowledge of how to install light fixtures, switches, sockets and junction boxes ▪ To test knowledge of how to read and understand charge controller specifications ▪ To test understanding of the connection sequences for connecting a charge controller and knowledge of how to install a charge controller ▪ To test knowledge of the testing and commissioning procedures and requirements for solar PV systems i.e. continuity, polarity, insulation, visual inspection, voltage drop, Voc and Isc and completion of commissioner certificate
PR-1D	▪ To test knowledge of how to maintain a battery
PR-1E	▪ To test knowledge of the common solar PV installation mistakes and how to rectify them ▪ To test knowledge of how to troubleshoot
PR-1F	▪ To test knowledge of how to assemble, disassemble and maintain different types of solar lanterns

3.2 T2 COURSE

Objective: To provide competence in carrying out installation work for medium size PV systems i.e. multiple modules of up to 300Wp or multiple batteries, which may include an inverter.



The T2 course builds on the foundational understanding, knowledge and skills gained through the T1 course. The main objective of the lessons in the T2 course is to provide the learner with an expanded view of solar PV systems; by introducing the concept of multiple system components, inverters and corresponding technical and policy dynamics.

While in many instances there are similarities between the expected outcomes of the two courses; the main focus is the specific content provided and the approach of the trainer. This is one of the key justifications for training of trainers.

T2 Course highlighting the additions to the T1 course:

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
Introductory Course		
INT1-Introduction to energy	▪ To understand the general sources of energy and the differences between the renewable and non-renewable energy technologies. ▪ To understand the energy situation in Kenya including electrification rates, and the contribution of the different energy resources to the energy mix. ▪ To have a basic knowledge of the policy and regulatory frameworks for solar PV ▪ To know the advantages and disadvantages/limitations of RE	
Pre-requisite Courses		
PR1-Solar Resource Introduction	▪ To understand the solar energy resources	
PR2-Solar Energy Conversion	▪ To have a basic knowledge of common solar energy conversion devices ▪ To understand the differences between solar PV and solar thermal.	
PR3-Solar PV Applications and Limitations	▪ To know where solar PV can be applied ▪ To understand the limitations of the technology	
PR24-Solar Configurations	▪ To understand the different configurations and components of solar PV relevant to DC solar PV systems only	▪ To understand the different configurations and components of solar PV relevant to AC
PR25-Basics of Solar PV	▪ To know key solar PV terms e.g. solar cell, module, array and IV curve	▪ To understand how the solar cell works.
PR26-DC Basics	▪ To understand and apply Ohms law and power law.	▪ To understand the concept of energy efficiency, conversion and appliance efficiencies. ▪ To differentiate between energy and power.
PR7-Tools and Measuring Instruments	▪ To know the various types and proper use of tools and equipment for solar PV installations. ▪ To know how to use a multimeter.	
Solar PV Courses		
SPV101-Solar PV system	▪ To know all the components of the system and their functions	

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
SPV202-Solar PV Modules	▪ To understand the performance of different types of modules under different conditions (heat, shade, orientation etc.) and the implications of module mounting on the performance. ▪ To know how to measure Isc, Voc and charging current and voltage. ▪ To know the modules that have passed the relevant local quality standards. ▪ To know the module connection accessories including connectors and junction boxes. ▪ To know how to read and understand the module specifications. ▪ To understand the use of bypass and blocking diodes in a solar module. ▪ To understand safety requirements when working with modules.	▪ To understand the IV curve. ▪ To know how to measure and plot an IV curve and identify the Maximum Power Point. ▪ To know how to connect modules in series and parallel and the effects on voltage and current. ▪ To know how to read and cross check the module certification. ▪ To know the relevant local and international standards for solar PV modules.

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
SPV303-Batteries	▪ To understand the basic parts of a lead acid battery. ▪ To understand the difference between starting lighting and ignition and deep cycle and know why deep cycle batteries are preferred for solar PV systems. ▪ To understand the difference between sealed and flooded batteries. ▪ To know how to read and understand battery specifications ▪ To understand the safety requirements when working with batteries. ▪ To know how to install a battery (filling a flooded lead acid batteries, initial charging), use of battery terminals and storing batteries. ▪ To know how to measure the state of charge using voltmeter and hydrometer. ▪ To know how to maintain a battery. ▪ To understand battery replacement requirements. ▪ To know how to safely and environmentally dispose a battery. ▪ To know the solar batteries that have passed local standards	▪ To understand how lead acid batteries work. ▪ To know the different battery terminologies and characteristics including voltage, capacity, specific gravity, cycle and cycle life, c rating, sulphation, SOC, self-discharge and DOD. ▪ To understand the battery energy curve. ▪ To know how to connect batteries in series and parallel and the effect on voltage and capacity. ▪ To know how to store batteries. ▪ To know relevant local and international standards for batteries
SPV204-Charge Regulators	▪ To understand the functions of a charge controller (CC). ▪ To understand the connection sequence for installation. ▪ To know how to read and understand charge controller specifications. ▪ To understand the safety requirements when working with CCs. ▪ To know the CCs that have passed local standards.	▪ To know the different types of charge controllers (MPPT, SHUNT, SERIES). ▪ To know relevant local and international standards for CCs.

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
SPV205-Wiring	▪ To know the different specifications of DC cables and their applications (single core, twin core, single strand, multiple strand, UV protected etc.). ▪ To know the different types of connectors and their applications (lugs, strip-connectors etc.). ▪ To know local and international cables standards. ▪ To understand the voltage drop and its relationship to cable length and size (diameter). ▪ To understand how to size cables. ▪ To know how to use basic cable sizing tables. ▪ To know how to measure the wire diameter. ▪ To know how to identify a good quality cable (familiarity with products in the market, visual tests and resistance tests). ▪ To know how to size and position fuses or circuit breakers in a solar PV system. ▪ To know how to install light fixtures, switches, sockets and junction boxes. ▪ To know how to do surface wiring, use conduits and use trunking. ▪ To know the different colour codes used in cables. ▪ To understand the 1 switch, 1 light principle.	▪ To know how to use the AWG and British standards for cable sizing.

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
SPV206-Lighting	▪ To know the pros and cons of different lighting technologies, their costs, efficiency and life (CFL, incandescent, tube FL, LED, Halogen). ▪ To know how to differentiate DC and AC lights. ▪ To understand positioning of lights and use of reflectors to maximize light intensity at the point of application.	▪ To know the recommended light intensity/lux levels for different applications (e.g. general lighting, reading, schools, institutional and industrial) and know how to determine the number of light fixtures required. ▪ To understand the life cycle cost analysis for different lighting technologies i.e. as based on efficiency and typical operating life of the light technology.
SP207-Appliances	▪ To understand the size of appliances (watt/power rating) that can be used for different sizes of solar systems. ▪ To know the difference between DC & AC appliances and the pros and cons of DC & AC appliances. ▪ To know the energy efficient DC appliances in the market commonly used in solar PV systems. ▪ To know how and when to use a DC to DC converter	▪ To know the energy efficient AC appliances in the market commonly used in solar PV systems.
SPV217-Inverters	Not offered in T1	▪ To understand how an inverter works. ▪ To know the different types of inverters (pure, modified and square wave inverters) and their suitable applications. ▪ To know the different inverter terminologies and characteristics e.g. efficiency, surge and continuous rating, interference, standby consumption, input and output voltage, self-consumption and idle loads. ▪ To know how to read and understand inverter specifications. ▪ To know the relevant local and international standards for inverters. ▪ To know the inverters that have passed related local standards. To know how to connect an inverter. ▪ To understand the safety requirements when working with inverters.

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
SPV208-Module mounting	▪ To understand how module performance is affected by module mounting. ▪ To understand module mounting, orientation and inclination requirements. ▪ To know the different module mounting structures (roof, pole, wall and ground) and know how to select the most suitable for a given site. ▪ To know how to select the proper materials and use protective coating to prevent corrosion and maximize module mount life. ▪ To know how to design the different module mounting structures for a single module.	▪ To know the relevant local and international standards for module mounting and module mounting structures. ▪ To know how to design the different module mounting structures for arrays
SPV209-System sizing	▪ To know how to determine the daily energy demand. ▪ To know how to use basic ERC approved sizing tools and tables. ▪ To know how to match the system components as per the voltage of available modules.	▪ To know how to select the appropriate system voltage ▪ To know how to use the calculated daily energy demand, system losses, power demand and solar energy resource data to size the 1) Module/Array 2) Battery 3) Charge Controller 4) Inverter
SPV110-System design and site planning	▪ To know how to appropriately position the solar PV system components and appliances based on the site layout. ▪ To know how to determine the appropriate cable length and wire gauge for 1) Module/Array to charge controller 2) CC to main junction box 3) Main junction box to other junction boxes, switches, lights and sockets. ▪ To know how to prepare a check list of all the solar PV equipment, installation materials and accessories. ▪ To know how to prepare a schematic and wiring diagram for accurate determination on installation materials and accessories. To know the system protection guidelines and requirements (earthing, short circuit and lightning arrester) and select appropriately	
SPV111-System Installation	▪ To know how to verify that the appropriate equipment, materials, accessories and tools are tested and provided prior to installation (as per the checklist and in good working conditions). ▪ To know how to use the right tool for the right job. ▪ To know the solar PV system installation steps and sequences ▪ To know guidelines for proper handling of solar PV equipment and installation materials.	

Lesson	Targeted outcome/competence	
	T1	**T2 Additional Outcomes**
SPV112-Commissioning	▪ To know the testing and commissioning procedures and requirements for solar PV systems including: 1) Continuity 2) Polarity 3) Insulation 4) Visual inspection 5) Voltage drop 6) Voc and Isc cross check 7) Completion of commissioning certificate	
SPV113-End User Education	▪ To know how to train the users on: 1) Understanding PV system limitations and balancing energy use 2) How to monitor the performance of the system using the charge controller 3) Do's and don'ts 4) Basic maintenance (cleaning module and battery, topping up of the battery, replacing lights and batteries, battery disposal) 5) Safety 6) Record keeping	
SPV114-Troubleshooting and maintenance	▪ To know how to carry out all routine maintenance requirements. ▪ To know all the types of faults that can occur in a solar PV system and know how to diagnose and rectify them, excluding inverter faults. ▪ To know common solar PV installation mistakes and how to rectify them	
SPV215-Policy. Legal and Regulatory Framework for Solar PV in Kenya	▪ To understand the requirements of the solar PV regulations in so far as licensing and warranties are concerned.	▪ To know the energy (electrical installation works) regulations
SPV116-Solar Lanterns	▪ To know how to disassemble and assemble and maintain different types of solar lanterns. ▪ To know local and international standards for solar lanterns ▪ To know the solar lanterns in the local market that meet the local and international standards and guidelines ▪ To understand the life cycle cost benefit analysis of solar lanterns as compared to kerosene use.	

3.2.1 TRADE TEST 2 – PRACTICAL SKILLS EXAM GUIDELINES FOR T2 TECHNICIAN

Practical Exam	Practical skills to be tested
PR-2A	▪ To test knowledge of how to use the calculated daily energy demand, system losses, power demand and solar energy resource data to size the module/array, battery, charge controller and inverter ▪ To test knowledge of how to select the appropriate system voltage ▪ To test knowledge of how to match the system components as per the voltage of available modules
PR-2B	▪ To test knowledge of how to appropriately position the solar PV system components and appliances based on the site layout as determined by a site visit ▪ To test knowledge of how to determine the appropriate cable length and wire gauge for module/array to charge controller, charge controller to battery, charge controller to main junction box and main junction to other junction boxes, switches, lights and sockets ▪ To test knowledge of how to prepare a schematic and wiring diagram for accurate determination of installation materials and accessories ▪ To test knowledge of the system protection guidelines (earthing, short circuiting and lightning arrester) and requirements and select appropriately
PR-2C	▪ To test knowledge of how to connect modules in series and parallel and know the effect on charging current
PR-2D	▪ To test knowledge of how to connect batteries in series and parallel ▪ To test knowledge of how to measure state of charge using voltmeter and hydrometer

PR-2E	▪ To test knowledge of the solar PV system installation steps and sequences ▪ To test knowledge of the safety guidelines for solar PV installations (end user and installer) ▪ To test understanding of how module performance is affected by module mounting ▪ To test understanding of module mounting, orientation and inclination requirements ▪ To test knowledge of how to install a battery (filing a flooded lead acid batteries, initial charging), use of battery terminals ▪ To test knowledge of how to connect batteries in series and parallel ▪ To test knowledge of how to install light fixtures, switches, sockets and junction boxes ▪ To test knowledge of how to do surface wiring, use conduits and use trunking ▪ To test understanding of the connection sequences for connecting a charge controller and know how to install a charge controller ▪ To test knowledge of how to read and understand charge controller specifications ▪ To test knowledge of how to read and understand inverter specifications ▪ To test knowledge of how to connect an inverter ▪ To test knowledge of the testing and commissioning procedures and requirements for solar PV systems i.e. continuity, polarity, insulation, visual inspection, voltage drop, Voc and Isc and completion of commissioning certificate
PR-2F	▪ To test knowledge of the common solar PV installation mistakes and how to rectify them ▪ To test knowledge of how to troubleshoot
PR-2G	▪ To test knowledge of how to assemble, disassemble and maintain different types of solar lanterns

3.3 T3 COURSE

Objective: Provide competence in carrying out solar PV system installation work for advanced, including grid connected and hybrid solar PV systems.

The advanced course T3 therefore aims to provide a trainee who has already acquired solid technical expertise with the necessary skills to design, plan and install more complex systems.

Lesson	Objective of the lesson/trainee outcomes
SPV301-Grid Connection	▪ To understand the principles of synchronization (voltage, power factor, frequency) ▪ To know about single phase and 3 phase connections and power balancing on the phases ▪ To understand the grid code and its implications on solar PV/hybrid connections ▪ To know the installation and equipment safety requirements when connecting to the grid ▪ To understand the basic principles of transformers and switch gear ▪ To understand the different types of grid-tie inverters and the working principles ▪ To understand specifications for grid tie inverters ▪ To know how to program and install at least common one type of grid-tie inverter ▪ To know how to integrate multiple inverters in a system
SPV302-Batteries	▪ To understand the principles of high capacity batteries (VRLA, Tubular) ▪ To know how to configure large battery banks (combining series and parallel connections to reach required voltage and capacity) ▪ To understand installation requirements for large battery banks (ventilation, stacking, structures, temperatures, temperature control, safety and handling) ▪ To know Energy (electricity licensing) regulations ▪ To know Energy (electrical installation works) regulations
SPV303-Module Mounting	▪ To understand the structural design requirements for large arrays above 300Wp (roof and ground mounting) and know how to interpret structural diagrams
SPV304-System Design and Site Planning	▪ To know the site issues to consider when selecting an appropriate site for module mounting (area requirement, topography, soil condition, connectivity to load, grid, water availability (for cleaning) etc.) ▪ To know how to prepare a system layout (positioning of system components, array configuration), i.e. laying out modules to simplify series and parallel connections ▪ To know how to prepare single line/electrical diagrams for the system ▪ To know how to determine appropriate cable lengths and wire gauge 1) Between arrays and junction boxes 2) Between junction boxes 3) Between junction boxes of power conditioning unit
SPV305 Wiring	▪ To know cable specifications for underground armoured DC cables up to 1000 VDC and medium voltage AC cables.

SPV306 Solar PV Hybrid Configurations	▪ To know the common solar PV hybrid configurations (solar-wind, solar-diesel, solar-wind-diesel, solar-grid (solar PV back up or grid back up) ▪ To understand the optimization, design and control implications of the various solar PV hybrid configurations ▪ To know the AC and DC bus configurations
SPV307 Integration and control systems for hybrid systems	▪ To understand different system integration techniques (manual, automated and intelligent) integrating multiple power conditioning systems ▪ To understand the different system control strategies for hybrid systems ▪ To know how to program and install at least one type of control system
SPV308 System Sizing	▪ To know how to use advanced solar PV system design tools (HOMER, RETSCREEN, NSOL, PVSYST, PVSOL etc.) ▪ To know how to use available solar resource databases (PVGIS, NASA, METEONORM etc.)
SPV309 Tools and Measuring Instruments	To know how to use advanced tools and measuring equipment (PATHFINDER, SOLARIMETER, Data loggers etc.)

3.3.1 TRADE TEST 1 – PRACTICAL SKILLS EXAM GUIDELINES FOR T3 TECHNICIAN

1. Simulate situation to apply design skills (40%)
2. Installation practice based on available/provided system components (60%)

APPENDIX 1 – Curriculum Development Workshop Timetable

Day 1	Day 2	Day 3	**Day 4**	**Day 5**
9:00 - 10:30	**9:00 - 10:30**	**9:00 - 10:30**	**9:00 - 10:30**	**9:00 - 10:30**
Kenya Solar PV sector background Workshop overview and objectives	Discussing methodology for identifying training content for the 3 categories of technicians	Consolidating content for **Class T2** (i.e. lesson, objectives, content/main points & resource materials)	Consolidating content for **Class T2** (i.e. lesson, objectives, content/main points & resource materials)	Review and update of content of KEREA Solar PV manuals for use as training resource material
The Role of the **National Industrial Training Authority** in the Development and Implementation of Technical Training programs in Kenya – *Nguku* (National Industrial Training Authority)	Consolidating content for **Class T1** (i.e. lesson, objectives, content/main points & resource materials)		Consolidating content for **Class T3**(i.e. lesson, objectives, content/main points & resource materials)	
11:00 – 1.00	**11:00 – 1.00**	**11:00 – 1.00**	**11:00 – 1.00**	**11:00 – 1.00**
Overview of Solar **PV training approach in Public Technical Training Institutions**: Experience of the solar PV training program at the Machakos Technical Training Institute, overview of the program approach and training materials – *Patrick*	Consolidating content for **Class T1** (i.e. lesson, objectives, content/main points & resource materials)	Consolidating content for **Class T2** (i.e. lesson, objectives, content/main points & resource materials)	Consolidating content for **Class T3** (i.e. lesson, objectives, content/main points & resource materials)	Review and update of content of KEREA Solar PV manuals for use as training resource material
Overview of Solar **PV training approach in the Private Sector** and an overview of the training approach and materials – *Charles*				
Overview of the process of development and implementation of the Solar PV Curriculum in **Ethiopia** and an overview of the curriculum and training and resource materials – *Samson*				**Workshop close**
2:00 – 4.30	**2:00 – 4.30**	**2:00 – 4.30**	**2:00 – 4.30**	**2:00 – 4.30**
Overview of the process of development and implementation of the Solar PV Curriculum in **Pakistan** and an overview of the curriculum and training and resource materials – *Raphael*	Consolidating content for **Class T1** (i.e. lesson, objectives, content/main points & resource materials)	**Field visit to Ubbink Solar Module Assembly Plant** in Naivasha	Consolidating content for **Class T3** (i.e. lesson, objectives, content/main points & resource materials)	**Field trip to Hells Gate National Park** in Naivasha
Institutionalization of the solar PV curriculum in **India** and an overview of the curriculum and training and resource materials – *Dwipen*				