**UNITED NATIONS DEVELOPMENT PROGRAMME**

# Proposal for the Development of PV Curriculum for Vocational Education and Training Authority (VETA)

**Final Report**

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# Acknowledgements

The idea of preparing a PV curriculum for VETA institutions originated from UNDP during the implementation of the project, 'Transformation of Rural PV Market in Tanzania' in an attempt to tackle barriers to secure PV promotion in rural areas of Tanzania. UNDP requested a team of experts to prepare a relevant curriculum proposal to be submitted to VETA for approval and subsequently for adoption as one of the main lines of their courses. The assignment is based on literature survey, a study visit to Mwanza and a stakeholder's seminar held on December 19, 2004.

The team appreciates the co-operation and guidance received from the UNDP, the Regional Vocational Training Centre Mwanza staff, and the seminar participants whose contributions brought about valuable inputs to this proposal. Specifically, the team would like to acknowledge the inputs of the Mwanza Centre Manager, Mr. John B. Mshanga and the head of Electrical Installation department, Mr. Joseph Mwanda who provided additional information so as to enrich the proposal. The cooperation and logistical support from Mr. S. Kesy of UNDP and the coordinator of the PV Project in Mwanza, Mr. Mzumbe Musa is highly appreciated.

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# Abbreviation

| | |
|---|---|
| Ah | Ampere hour |
| BOS | Balance of System |
| CD | Compact Disc |
| $CO_2$ | Carbon Dioxide |
| DC | Direct Current |
| DoD | Depth of Discharge |
| EAA | Energy Alternatives Africa |
| ELCT | Evangelical Lutheran Church of Tanzania |
| GEF | Global Environment Facility |
| GREET | Global Renewable Energy Education and Training |
| HVD | High Voltage Disconnect |
| ICT | Information and Communication Technology |
| KARADEA | Karagwe Rural Development Association |
| KSTF | Karadea Solar Training Facility |
| kW | Kilowatt |
| kWp | Kilowatt – peak |
| LED | Light Emitting Diode |
| LVD | Low Voltage Disconnect |
| MEM | Ministry of Energy and Minerals |
| MLVTC | Mafinga Lutheran Vocational Training Centre |
| MWp | Megawatt- peak |
| NGO | Non - Governmental Organization |
| PV | Photovaltaic |
| PVC | Polyvinly Chloride |
| QA | Quality Assurance |
| RE | Renewable Energy |
| RET | Renewable Energy Technology |
| SHS | Solar Home System |
| Sida | Swedish International Development Authority |
| SOIT | Solar Innovation of Tanzania |
| SoC | State of Charge |
| TaTEDO | Tanzania Traditional Energy Development and Environment Organisation |
| TAZARA | Tanzania and Zambia Railways Authority |
| TFT | Thin Film Technology |
| ToR | Terms of Reference |
| ToT | Training of Trainers |
| TRC | Tanzania Railways Corporation |
| TTCL | Tanzania Telecommunications Company Limited |
| TV | Television |
| U.H.F | Ultra High Frequency |
| UNDP | United Nations Development Programme |
| UNESCO | United Nations Education, Science and Cultural Organisation |

| | |
|---|---|
| UNIDO | United Nations Industrial Development Organisation |
| USA | United States of America |
| USD | United States Dollar |
| V | Volt |
| VETA | Vocational Education and Training Authority |
| VTC | Vocational Training Centre |
| Wp | Watt - peak |
| WSP | World Solar Programme |

# 1.0 Introduction

## 1.1 Background

Solar energy is among the alternative sources of energy that is particularly attractive in proving energy needs to the rural populations as well as remote areas. Photovoltaic (PV) energy is a promising component of solar energy that has witnessed significant growth in application, as a result of advances in materials science and related fields. PV is used worldwide for lighting and power supply for rural and remote areas, pumping, refrigeration, water desalination and purification, communications, fencing, etc. There are many potential advantages of photovoltaic systems for decentralised applications and these include but not limited to:

- PV technology is a modular system, which can be enlarged in size as demand increases.
- PV modules have a high degree of reliability (life span of 20 – 25 years) and ease of maintenance when compared with conventional diesel generators.
- Solar electric systems consume no fuel. The PV modules convert the freely available sunlight into electricity.
- PV systems make no noise, no moving parts and do give off minimal exhaust gases or pollutants.
- Risk of electric shock is small because of the low system voltage. Fire risks are also lower in homes and schools powered by solar electricity than in those with kerosene lanterns.
- PV systems offer better quality service, availability, rapid start up, etc. The quality of PV lights is by far superior to that of ordinary kerosene lamps.

In view of the urgent concerns of the environmental costs of conventional energy sources and urgent need to ensure that all human beings can enjoy a decent quality life, it has been advocated that PV technology should be put into widespread use. In particular, it can help meet the basic electricity needs of about 85% of Tanzania rural poor population for whom this is the main hope towards social and economic development.

Photovoltaic technology has made significant progress to date, but there is still a long way to go before it can contribute significantly to the welfare of the rural communities in Tanzania. One of the major obstacles to wide dissemination of photovoltaic systems is their high capital cost, which has been estimated to be three to five times higher than that of conventional energy sources. A drastic reduction in the cost of photovoltaic systems will be necessary, if they are to have widespread application. Other factors that tend to hinder wide spread of the technology, especially in rural communities include, lack of awareness, lack of financing schemes, institutional structure to support PV technologies, technical back up support at local level, conducive policies, marketing channels, etc.

Currently there is no uniform way or common procedure for component selection, pricing and installation of PV systems in Tanzania. For example, it is common to find PV modules installed to face in all directions, i.e. south, east, north, west, or intermediate these directions. In this way, many systems have failed, as a consequence, and the credibility of PV technology has eventually become questionable. Other factors that have contributed to the failure/non optimal performance of PV systems include under sizing of some of the PV systems, use of poor-quality components, improperly installed PV systems and improper system configuration. The failure rate is significant and this is partly due to lack of well trained personnel in the PV industry resulting in poorly designed systems, reflecting badly on the use of PV technology especially in rural areas. Likewise, inadequate knowledge/education among vendors as well as consumers has also contributed to undermining the PV technology application in Tanzania. Furthermore lack of locally available PV components, even in regional towns is a big challenge to wide dissemination of PV technology.

It is in this context that the Government of Tanzania through UNDP/GEF has embarked on the Project ‘’Transformation of Rural PV Market in Tanzania’ in an effort to address barriers to secure PV market penetration in rural areas. Lack of technical and related supports is one such barrier that the project needs to evaluate in Tanzania and especially in Mwanza region and, where appropriate, institute a well-established training PV programme(s) for trainee in a number of vocational training institutions.

## 1.2 Terms of Reference (ToRs)

At its initial stage, the PV Project in Mwanza has invited a team of two experts on PV technology and curriculum development, respectively to work on the development of PV curriculum to be incorporated in the domestic electrical installation certificate course for VETA trainees. The two experts were given as their Terms of Reference the task of preparing a proposal for the Development of PV Curriculum for Vocational Education and Training Authority (VETA). The team subsequently re-interpreted the TOR into the following tasks:

- Collect data on the most appropriate PV systems for household, community based and productive applications, both locally, regionally and world wide, especially in the developing countries;
- Analyze and assess PV curriculum available and the training experiences on PV systems and applications in the country and the region, both formal and informal training undertaken by training institutions, NGOs and the private sector;
- Assess the current domestic electrical installation curriculum in the VETA institutions and recommend, in consultation with the VETA authorities, any additions and/or modifications, deemed necessary to assist in the proper integration of the proposed PV curriculum;
- Develop an appropriate set of course modules on PV systems applications, PV components, planning, pricing, system design configuration, installation, commissioning, service and maintenance for the VTC trainees to be integrated into the electrical installation curriculum.
- Recommend size and scope of the course modules in consultation with the VETA;
- Propose a training manual and reference learning materials for the developed PV course modules;
- Design and develop a number of workshop tasks for the practical training on PV systems and prepare a list of PV components, instruments and tools needed to conduct the practical training.
- Prepare a draft report to be presented in a seminar;
- Finalize the report taking into account the seminar recommendations;

## 1.3 Methodology

### 1.3.1 Debriefing Meetings

There were two debriefing meetings with the client (PV Project in Mwanza) at the following stages in the course of pursuing the proposed assignment.

(i) Before the study commenced, the team met the Mwanza PV Project management to discuss the objectives and tasks, approach and expected outputs of the assignment. Relevant observations made during the discussion by the client were taken into account by the team as long as they were within the TORs and the agreed upon budget.

(ii) After field data collection and preliminary analyses, there was another de-briefing meeting with the client to share the precursory impressions. This part was important for the team to have the client's perspectives before a draft report is presented and discussed at a seminar.

### 1.3.2 Desk Study/Field Visit

The Desk Study included collection of literature, and other relevant materials, for information on the overall process of curriculum development in VETA institutions and the status of PV technology in Tanzania and elsewhere in the sub-Region. The team made a physical visit to VETA institution in Mwanza to gather additional information on the available capacity in terms of human resource and workshop facilities. The team interviewed both the centre manager and the head of the electrical installation department. After the field data have been collected the team embarked on the development of the photovoltaic curriculum, recommended a number of workshop assignments and compiled a list of equipment and materials for implementation of a pilot project at Mwanza Centre.

# 2.0 Situational Analysis

## 2.1 Introduction

This chapter discusses on the status of PV systems in general. First, we look at the common PV application areas, the user categories, common solar PV systems installed, technical problems associated with the installed systems, training facilities as well as the scope of the training courses available in the country and elsewhere in the sub-region. Finally we provide justification for the proposed training programme to support the growing PV industry in Tanzania. The information gathered in this chapter will provide the necessary inputs to the formulation of the proposed curriculum.

## 2.2 PV Application Areas

Considering the advantageous geographical location of Tanzania it is not difficult to conclude that solar energy could easily be a good and reliable source of power supply provided that the right steps are taken for its adoption, application and diffusion. Solar irradiance which is freely available in abundance in the tropics could be put to use in areas such as:

- household - lighting, television, cassette players and radios;
- small industries - sewing machines, light tools and computers;
- health centres - vaccine and blood refrigeration, laboratory equipment (microscope, centrifuges, calorimeters) and dental clinics ;
- communications - power radio, telephone repeaters, weather stations, internet, etc;
- pumping - water pumping for drinking, washing, irrigation and livestock purposes;
- electric fencing - to keep wild animals inside game parks and out of farmland.
- village centres - street lighting and security systems;

- education - Possibilities for distant education by radio, television, e-learning, etc.

## 2.3 Institutional Based Installations

In Tanzania, photovoltaic technology was introduced several years ago mainly for lighting and communication purposes. Most of the systems were installed at missionary centres, health centres, public places like guesthouses, offices, railway stations, schools, telecommunication sites, etc. The major institutions that have adopted PV technology in place of the grid electricity are briefly discussed in the following sections:

### 2.3.1 Tanzania Zambia Railways Authority (TAZARA)

Before the idea of installing solar modules came in 1988, TAZARA used imported dry batteries at its remote carrier repeater stations and these had to be regularly because their life span was only a few months.

The procurement of dry charged batteries sometimes met delays, which affected the TAZARA's telecommunication system. The project started in 1985 by a feasibility study to analyse different electricity supply options to the remote TAZARA stations. Among the three alternatives i.e. solar PV, mains power and generator charging of batteries, solar PV proved to be the best alternative.

To date, there are more than 82 stations supplied with solar PV electricity with more than 180 kW peak along the railway track running from Dar es Salaam to Kapirimposhi in Zambia. At each station the solar modules have been installed on house roofs for security reasons. While the solar modules are Arco M75, imported from USA, the electronic control units (regulators) were bought from Canada and batteries from Norway. The power produced is enough to cater for both telecommunication and lighting purposes at carrier repeater stations and railway stations.

TAZARA is quite happy with the technology and the Authority has recently upgraded 14 of its installed PV stations.

### 2.3.2 Tanzania Railways Corporation (TRC)

Since 1988, TRC has installed solar photovoltaic systems along the Central Line (Dar es Salaam – Tabora – Kigoma) to power its telecommunication systems. With exception of Dar es Salaam, Tabora and Kigoma, solar generators power the lines' stations and so far the performance of units is good. TRC has more than 30 PV installations of about 100 Wp each at various stations along the central line.

### 2.3.3 Tanzania Telecommunications Company Limited (TTCL)

TTCL launched the PV project in about 1981 after facing power problems with diesel engine generators, which were used to power the carrier repeater stations in remote areas. The problems included; too much fuel consumption, frequent mechanical breakdowns, noise and air pollution and the need for monthly routine maintenance and annual major repairs for generators.

Thus, the solar energy technology was introduced to replace the said diesel genets used to power microwave radios, U.H.F. radios and multiplex equipment at stations located far from the national electricity grid.

Currently, TTCL has more than 1500 solar panels installed providing a total power of 60 kW, powering carrier repeater stations and other telecommunication applications.

## 2.4 Community Based Installations

The Government of Tanzania had submitted five project proposals to UNESCO, and subsequently, to the World Solar Commission which held the World Solar Summit in Harare in September, 1996.

The Proposals were:

(1) Village Solar Power Supply in Tanzania;
(2) Small Island Solar Power Supply in Tanzania;
(3) Isolated Townships Solar Power Supply in Tanzania;
(4) Solar Power Supply for Dedicated Systems in Tanzania;
(5) Research and Development on Bio-Fuel in Tanzania.

Apparently, out of the five project proposals, the Government has identified projects (1)&(2) above as being of high national priority. Within the village level implementation at least 50 villages would benefit from the World Solar Energy Programme (1996-2005) by having a number of demonstration sites so as to sensitise villagers and other stakeholders on potential use of the PV technology. A typical solar power installation in a village in the rural areas would serve the following community based units:

**(i) Village School**

Solar power will be provided for lighting, for a science laboratory and/or a computer system, etc. Also, a small solar powered demonstration pump will be used for irrigating the school farm. Typical load will be 1.52 KW.

**(ii) Village Dispensary/Health Centre**

The village dispensary will be illuminated for obstetrics, administering first aid, powering small vaccine cooler, for heating and boiling water for sterilisation, etc. Typical load will be 3.65 KW.

**(iii) Village Community Centre**

The village community centre will be provided with solar power for lighting, audio visual equipment (TV, video deck, overhead projector, slide projector, radio, etc.). Typical load will be 2.45 KW.

**(iv) Village Household**

To demonstrate the use of solar power at household level, a typical village household, say the houses for school and health centre staff will be powered using solar energy. Provision will be made for lighting, radio, refrigerator and a small TV. Typical load will be 0.67 KW.

Through the World Solar Energy Programme, UNESCO has supported three demonstration and promotional solar energy projects on electrification of villages in Tanzania. One of them is in Umbuji Village in the island of Zanzibar, which serves a secondary school, mosques, a community centre, a health centre and residential houses for school staff and a doctor. The second one is in Mangaka village, Mtwara region, in the mainland Tanzania and serves a secondary school, a village clinic, a police post and residential houses for school staff. The third success story is the installation of a solar energy system on the island of Kilwa Kisiwani that powers communication facilities, lighting at the German House (guest house) and health centre with a view to support the management system of the site in order to promote tourist activities in the area. In addition, the presence of solar PV electricity in the island will ultimately lead to an improved quality of life of the island population through improvement of community services and healthcare facilities.

The above facilities have now been in operation for a number of years and the influence of the technology can be vividly seen. School children can now extend study periods beyond daylight and evening classes have been arranged for adult education. Villagers can now view TV programmes of which it would have been impossible without the facility.

So far, there are more than 19 solar water-pumping installations in the country but experience has shown that most communal owned pumps have problems, which are attributed to the following factors:

(a) Technically, it seems most projects were imposed on the beneficiaries such that literally no body was given proper training to look after the installations.

(b) Socially, the non-involvement of locals (beneficiaries) have led to poor ownership for the installed units, leading to vandalism.

(c) On the Government side there has been poor follow-up on solar projects i.e. failure to put answerable people at some of the Governments/donor's investments.

Besides telecommunications and water pumping, solar electricity has been used for lighting and to a minor extent, refrigeration. The following section provides a brief overview on the most commonly used PV systems in the sub-Region.

## 2.5 Domestic PV Systems Installations

"Solar home systems" (SHS) are one of the most common forms of PV application in rural areas. An SHS usually provides electricity for two or three fluorescent lights, a radio or cassette player, television, and perhaps small fans or other small appliances. Electricity is drawn from rechargeable batteries recharged through an electronic controller by PV modules mounted on a pole beside the house or on the rooftop. The total capacity of the unit is usually in the range of 30 Wp to 100 Wp but can be smaller or larger.

Solar home systems can eliminate or reduce the need for candles, kerosene, liquid propane gas (LPG), and/ or battery charging. Direct economics benefits include avoided costs of battery charging and LPG or kerosene purchases; other significant benefits include increased convenience and safety, improved indoor air quality, a higher quality of light than kerosene lamps for reading, and reduced carbon dioxide emissions. Improved lighting quality can assist reading and provide additional educational benefits, especially to children, or allow income-generating activities to occur at night. PV systems can also power lights and vaccine refrigerators in medical clinics, run water pumps, and assist other applications.

The price of a solar module has fallen from about USD 100 per peak watt in 1974 to less than USD 5 per peak watt in 1995. The decrease in price has caused a rapid expansion of the rural market in the 90's especially in Kenya, Zimbabwe, Botswana, and South Africa.

To date it is estimated that there are about 2500 – 3000 PV installations all over Tanzania mainland and it is expected that the number will increase because of its proven reliability and the growing individual interest in the technology.

Although there has not been any detailed survey to ascertain the status of the systems before the study, it is true that a number had problems and required design modification. A survey that was conducted in three regions of Tanzania mainland in 1997 showed that some of the PV systems had not worked well as expected. Both private and public users of PV technology tended to use the systems to the limit, leading to the eventual failure of the system. Under sizing of some of the systems was thought to be the main cause of the problems.

By the year 2000, more than 120,000 rural homes in Kenya were using solar electric power for household appliances. Solar home systems account for about 1.4 MWp of the total 2 MWp of PV installed in Kenya. A systematic survey of 400 PV users was conducted for the World Bank in 1996/1997. The study showed that 60% of users were satisfied with their PV systems and 94% would recommend them to a friend. Dissatisfaction over battery problems accounted for 19%, insufficient electricity (13%) and poor quality fluorescent lights (8%). On the other hand, Zimbabwe had more than 15,000 while South Africa alone had an installed capacity of more than 150,000 domestic lighting units by 2001.

The use of photovoltaic systems in Uganda began in the early 1980's through donor agencies, non-governmental groups and government (for communication, isolated government and military outposts, schools and health services). Today the government is encouraging PV based rural electrification to be market driven, commercially based and private sector led.

PV systems generally serve two distinct groups of consumers in Uganda, namely; donor-funded public sector institutions (hospitals, clinics, schools, telecom, military, etc) and private households. It is estimated that there are over several thousands in both categories. There are presently about 30 companies in Uganda that are marketing and installing solar PV systems.

Ugandan PV industry sources indicate that over the past one year, there has been an upsurge in the purchase of small (24 $W_P$) kits by consumers. The kit generates electricity to power three 8 Watt-lights and a radio.

## 2.6 Solar Lantern

For the very low-income groups a typical solar house system discussed in section 2.5 would be too expensive even if credit facilities were available. Families may prefer a simple PV solar lantern with an 8 W lamp powered from a sealed lead-acid battery and charged by a built-in 8 Wp PV module. Such lanterns are commercially available on the market. The cost of purchasing one is about US $ 70. The Evangelical Lutheran Church of Tanzania (ELCT) has implemented programmes in Dodoma region and Zanzibar for assembling the solar PV lanterns.

## 2.7 Battery Charging Stations

Battery charging stations offer similar service to central grid charging stations. Typical 0.5 – 1 Kwp systems can be operated and managed by local entrepreneurs or by village operators. Five to ten 100 Ah automobile batteries which have discharged by 20-30% can be charged per day. Battery-charging stations have the advantage over the alternative charging systems because they require low investment on the part of the consumer but they are less convenient. It is probably the best hope of reaching consumers in the lowest income bracket.

Experience from the Philippines, shows that people charge batteries twice a month. This has the effect of reducing the life span of the batteries because in most cases people come for charging their batteries when they have gone into deep discharge. The service life time for most batteries is less than 3-4 years, so some kind of protection against deep discharge is needed. It has been reported that the charging stations are not economically attractive to power utilities unless the community contributes buildings and labour. Nevertheless, those stations that are operated by co-operatives have been successful, especially where women have been involved in operation and management.

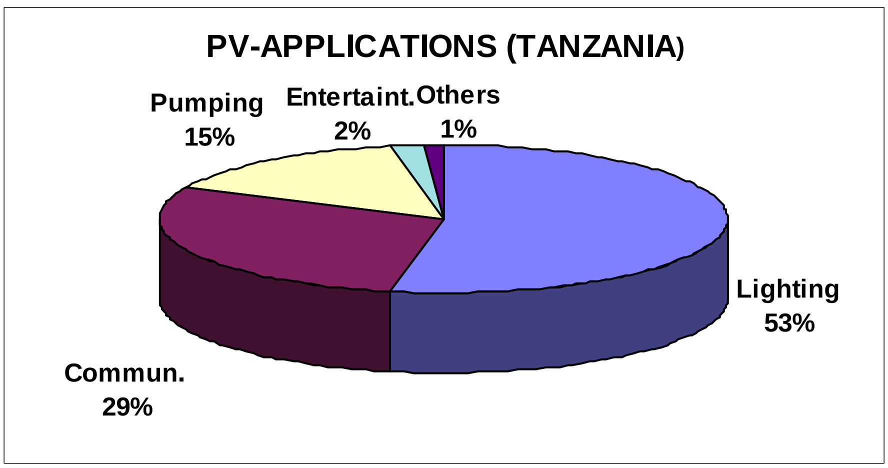
A similar assessment made by the Battery World of Zimbabwe (Ministry of Energy, Water Resources and Development, 1992) showed that a solar powered battery charging facility is less attractive because of the high capital cost involved. A five-50 Wp array charging system, for example, can charge five 14 Ah batteries a day, giving a reasonable return on investment. The design features, however, assume that the station will be fully occupied and does not allow for any labour costs and infrastructure. For users who have the option of purchasing a domestic lighting PV kit, centralised battery charging is not an economically attractive option unless energy use is very low.

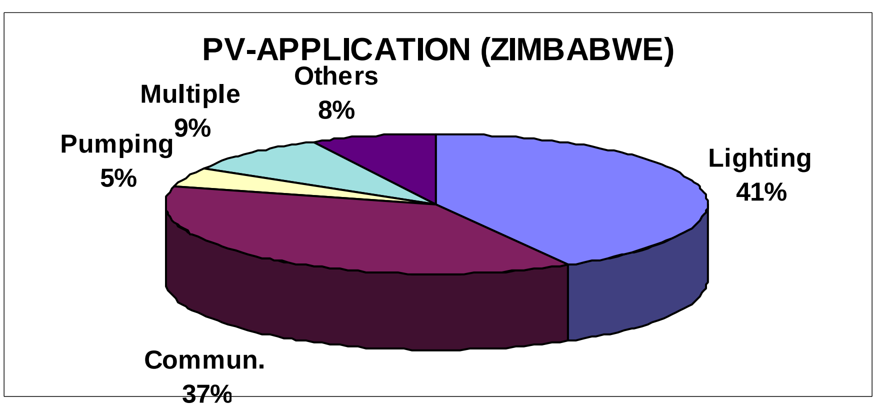
On the other hand, there is a growing market for battery charging in Kagera Region, Tanzania. A survey of existing battery charging centres revealed that there are 6 grid connected battery charging centres in Omurushaka and Kayanga towns and 1 solar powered centre in Kaisho. At least 40 batteries are charged per day at all centres at a cost ranging from Tsh. 800-1000 per battery. More than 100 batteries are charged per day in April and December during the days approaching Easter and Christmas celebrations.

More than 95 percent of customers come from rural areas of up to 100 km far from the centre and all these areas are not connected to the national grid. There are no any other means for charging customers' batteries, which are used mainly for powering radios. As these people incur transport costs of up to Tsh. 500 for batteries from their homes, there is a need for solar powered battery charging station in the vicinity.

## 2.8 Application and User Category of PV Technologies

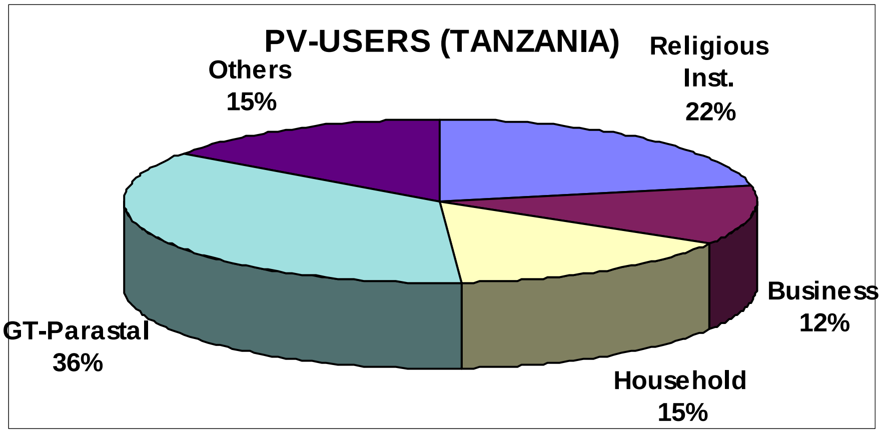
The installed power for various PV applications for Tanzania and Zimbabwe are summarised in figure 1. One can clearly see that lighting and communication dominate the use of the PV system in both countries. We also note that water pumps are also important. Figure 2 shows PV user category. The main users of PV are government institutions and parastatal organisations such as telecommunication companies, railways and national parks. It is true that the trend for user category and applications is the same for most countries in sub-Saharan Africa.




***Multiple uses include various applications such as entertainment, lighting refrigeration, etc***

Figure 1. PV applications for Tanzania and Zimbabwe



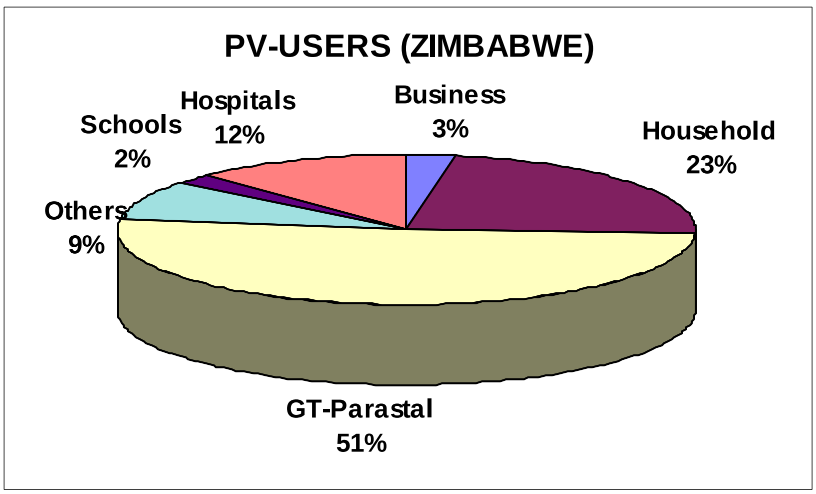




Figure 2. PV users by category for Tanzania and Zimbabwe

## 2.9 Commercialisation of PV Technology

Solar PV is now a fully commercial technology and several companies and organisations are involved in its marketing in Tanzania (appendix 1). Most of PV components, including PV modules, batteries, controllers, inverters, light fixtures and lights, etc, are imported from abroad making it difficult to have the necessary technical support readily available within a short notice. Secondly, most of the personnel employed in these companies have had no formal PV training programmes apart from short training courses (of at most two weeks duration) often offered to them through NGO's dealing with renewable energies. Most of them lack basic skills in terms of the technology, service and maintenance.

Another major hindrance for wider dissemination of PV systems in Tanzania is the lack of suppliers in regional and district towns, and the relatively limited marketing effort put in by the existing actors. Although there are positive indicators showing that this is beginning to change, PV components and systems are still not easily accessible to the majority of the rural people because they are not aware of the technology and its potential for social economic development. There is need to have as many demonstration plants as possible and people that have the requisite skills and knowledge to advocate the use of PV technology.

Despite the moderate growth rate of PV industry in Tanzania, the lack of skilled technicians or artisans in the rural areas will further jeopardise the wide dissemination and use of PV technology, if the issue is not addressed as quickly as possible. There should be someone to call when the system breaks down, and someone to advice on the choice of PV system(s) to buy. If one should go to regional towns to acquire the technical support, then PV development will not be sustainable. Experience has shown that without sustainable technical service in many developing countries, dissemination of PV technology can create a very bad reputation for the technology and hence its growth.

## 2.10 PV Experience in Mwanza – (a case study)

A field survey was conducted in Mwanza region in 2001 to determine the technical status of PV systems regarding installations, technical support including service and maintenance, availability of technical staff as well dealers of PV equipment. A number of stakeholders were interviewed including policy makers/planners, PV dealers as well as consumers. In the latter case, a physical inspection of the installed systems/components was made and, where possible, a random measurement was made to ascertain the design and the installation procedures.

The surveyed population was divided into three categories, as shown below. This was made so in order to tailor the appropriate Data Collection Instruments for each category. Thus, for Mwanza the surveyed population was grouped as follows:

(a) Dealers of PV systems and components
(b) PV end-users. This category was further sub-divided into:
- Private Users (mostly households); and
- Institutions

(c) Local PV technicians

The following sub-sections provide a summary of the status of the PV systems inspected during the survey.

### 2.10.1 PV-System Supply Situation

In Mwanza region, the number of suppliers of PV equipment is growing, although photovoltaic business is a minor part of their activities. Most of them are involved in hardware sales of goods such as electrical appliances, music systems (radio and television, etc), batteries and miscellaneous items. Most of the salesmen or shop owners have little experience in PV systems and in many cases they rely on freelance technicians who have little knowledge in PV electrical installation. In one shop, however, the owner was found to have basic knowledge of PV systems and therefore could provide leaflets to would-be customers of PV systems. The leaflets provide basic information on various PV components that the shop stocks. These include inverters, PV panels, light and light fittings, etc.

### 2.10.2 Conditions of the Installed Systems

#### *2.10.2.1 Household*

The motivation to purchase PV for all the households visited was to provide lighting, often to enable children to study at night. A few households wanted to power radios and television. Some users were keen to use electricity from the system for other purposes such as cooking, refrigeration, ironing and the like but were disappointed to be told that this was not possible. During the survey, both DC and AC operated systems were found installed. Most users had purchased standard single or double panelled system ranging from 20 Wp to 90 Wp. One user had three panels for a 24-V DC system. During the survey, all three types of PV modules i.e., monocrystalline, polycrystalline and amorphous were seen in the field. It was also common to see a combination of them and varying sizes installed in one system.

Most owners reported that they carried out some maintenance of their systems, mainly adding distilled water to the battery. Most of the battery terminal had corroded and nearly all PV systems surveyed were very dusty. The survey team noted that none of the users had been given maintenance instruction or even hands-on training during the installations.

The most commonly used battery in solar home systems is a lead-acid battery of the type used in automobiles. The capacity of the batteries ranged from 40 Ah to as high as 200 Ah. The team was informed that automotive batteries were used because they are relatively inexpensive and readily available locally. Solar batteries were found installed in a few houses.

The solar batteries were available in two brands:

(1) the lead-acid batteries that demanded the user to check and add distilled water to the appropriate levels frequently; and
(2) the "maintenance free" type batteries. These are gel-type lead acid batteries, which do not require users to add-in distilled water as for the previous type.

Some astonishing observations were made, where the batteries were located in the bedroom or the living room. It should be noted that batteries emit gaseous matter, as a by-product during their operation and that can be harmful if inhaled for prolonged duration of time. That can be the case, when the battery is placed in the bedroom or living room. Some batteries were also located in rather dark places, in which cases it was difficulty to record electrolyte level or/and other information of the battery.

The survey revealed that whenever a system failed to function, often owners of the systems had to call a technician from Mwanza town to repair them. Unfortunately, repair took time before it was made, and this is because of lack of knowledgeable technicians nearby. Secondly, the repair exercise seemed expensive because of the replacement of the components as well as travel costs of the technician from town to the villages.

The failure of a system may be due to a dead battery, but sometimes the failure of one component may cause a failure of another. In addition, the failure attributed to charge controller could cause a premature failure in the battery by allowing it to overcharge or undercharge. A controller that does not isolate the battery at low voltage can cause the battery to fail by undercharging. It can cause failure in fluorescent light as the low voltage below 11.5V stops the inverter from striking and can cause mercury deposition at the end of the tube. Low voltage also causes an inverter to overheat, which can cause failure if this condition is left to continue for a long time.

#### *2.10.2.2 Institutions*

The PV systems surveyed were installed at religious and public institutions as well as private companies/institutions. The PV systems installed in both of these categories of institutions have larger capacity (from about 300 W to 1.5 kWp or so) than for household systems and were installed about 3 to 10 years ago. The status of installed PV systems in these institutions, by category, is hereunder summarized:

##### *2.10.2.2.1 Religious Institutions*

Most of religious institutions were found to own schools, churches, training centres and (a few cases) telecommunication facilities. In most cases the donors would have initiated the purchase of the PV systems. The reasons given for the purchase of these systems were predominantly for lighting in church or classroom buildings. The other reasons given were for telecommunication systems and refrigerators. One telecommunication system was dedicated to this end use, but mostly the systems were used for lights and powering a radio.

Of the four institutions visited, only two PV systems were found working. The systems in the other two institutions were abandoned mainly because of poor performance and secondly, the institution had already been connected to the national grid.

The survey noted that the poor performance was attributed mainly to a number of causes. First, there were more problems with the installations, as the systems had panels incorrectly installed, and had poor quality controllers. In one institution (Nyegezi Seminary), it was noted that although it had a person resident and responsible for maintenance, there was almost no maintenance at all to the system. The survey team found that the battery electrolyte had completely dried up and therefore the batteries were permanently damaged. Secondly, there were indications that the energy supply was sometimes inadequate (e.g. at the Formation Centre, Mwanza), and typically this was attributed to the fact that the systems were under sized. There were reports that the lights were dim or did not start at all.

The quality of installation observed during the field survey varied widely depending on the technician who installed the PV system. Some used well-sized cables run in PVC conduits and some used wall surface wiring. In some installations, the purchasers tended to use undersized cable slung loosely hanging along the walls.

Cable connections in the system are important because bad connections will increase resistance in the circuit dramatically resulting in high power losses. The connection to the battery are particularly important because the battery needs to be disconnected by user from time to time for recharging after a long period of extensive use or in the occurrence of a problem in the system or replacement. It should be possible to disconnect the battery without using tools, for instance, by using wing nuts.

Many of the connection seen during the survey were poorly done, especially at the battery terminals. In some cases, cables were connected to components by wrapping the cable end around a nut and tightening the wire into the terminal. This is unreliable way of getting a good contact since nuts are chamfered and do not give a good compression surface.

Most (over 95%) of the PV systems visited had mounted the solar panels on the rooftops. Only 50% (or less) of the PV owners had their PV modules installed to face north, which is the recommended orientation if the installation site is south of equator. Moreover, there was no uniformity in terms of tilt angle of the panels, which was found to vary from as high as 25° to as low as 0°, with reference to the horizontal.

Regarding the mounting of the PV panels, a variety of mounting were used. Generally, the brackets worked well when mounted facing North on a North-facing roof. Many roofs did not face due north, resulting in panels, which did not face north.

#### *2.10.2.2.2 Public and Private Institutions*

Most of the public institutions surveyed had large part of their activities centred on telecommunication or transportation services. In most (not all) cases the idea of purchasing the PV system(s) was initiated within the institution(s), although the purchase of the systems would usually involve the donor community. The systems in these institutions are much larger compared to ones installed in household or religious institutions. PV systems generating electricity well beyond 1.5 kWp are not uncommon in the public institutions, and most systems were installed about two decades ago. Several of the systems are polar mounted, although most of them are roof-mounted. The orientation and tilt angles of the modules were professionally done in most of the cases.

Very seldom lighting was cited as reason for purchasing the system(s), although a number of lighting fixtures were included in the actual installations. But the primary objective for purchase of these systems was to run telecommunication and other signalling equipment.

### *2.10.2.3 Maintenance and Service*

Maintenance of power conditioning equipment, such as inverters and controllers is not for the layman. The components that make modern inverters and controllers are relatively trouble free. It would require a skilled-trained technician to diagnose problems when they occur and make repairs that may be necessary. As for the present case in Mwanza, the best policy for the villagers was to adopt preventive maintenance by not overloading the systems.

At present, there are few well-trained technicians in Tanzania to handle the advanced power conditioning equipment. Therefore, an engineer from the supplier, University of Dar es Salaam or other competent companies should be consulted for any serious problem. Most of the electronics components for the PV system are not available in Tanzania and therefore have to be imported from abroad.

The battery storage bank is the only photovoltaic system component requiring regular schedule of inspection and maintenance. As batteries are charged the electrolyte solution is diminished. This can be viewed through the holes of the cells. Typically, the cells will require additional distilled water once a year and this will depend on the electrical capacity of the battery. Cells have to be checked regularly, especially after the first year of service. Electrolyte level and battery terminal inspection is the only major areas in battery maintenance. An old toothbrush can be used to wipe off any corrosive white/blue powders around the battery terminals and coat the terminals with grease or petroleum jelly.

## 2.11 Technical situation related to suppliers of PV components and system installations

From the previous discussions it is apparent that most of the installed systems have experienced a number of multiple problems. Some of them are as listed below:

(i) Most shop owners of PV components have little or no knowledge on PV systems and rely on freelance technicians;

(ii) Failed PV systems take a long time before they are repaired;

(iii) Most of the PV systems are not properly installed;

(iv) Placement of PV components in some places is wrongly located or incorrectly installed;

(v) Most of the systems are undersized;

(vi) Most systems receive little or no maintenance;

(vii) The quality of installations vary widely depending on the technician who installed the system;

(viii) Undersized cables are used for most DC operated systems

(ix) There is lack of adequate skilled technicians to undertake maintenance of power conditioning equipment such as inverters and controllers

## 2.12 Training and Training Institutions

Training for technicians on photovoltaic technologies has not been well institutionalised within the accredited vocational training institutions. There are a number of institutions within and outside the country, which have been providing training on PV technologies on an ad-hoc basis mainly on installation and to some extent service and maintenance. One of the major problems in dissemination process of the PV technology has been lack of people with appropriate knowledge and skills capable of giving the right service to potential dealers and customers. This is an area that requires as a matter of urgency, a well-coordinated effort to ensure high technical quality is available when required and especially in the rural areas where it is mostly needed.

A survey conducted in 2001 in Mwanza and Dar es Salaam indicated that there is a lot of variations among the technicians, in terms of morale, skills, field experience, basic education, etc. Generally speaking, however, lack of adequate training in PV technology was a common problem to almost all of them. Some were quite confident with their field experience, but the study apparently revealed that most of them were not knowledgeable enough.

Although a few technicians had a two-week training workshop in Mwanza a few years back, majority of them had no prior knowledge on PV systems. A similar scenario was revealed for those who attended training elsewhere (e.g. at KARADEA, SOIT-Msasani; or on-job training at Ultimate Energy, etc). Most of these training provided basic concepts of PV technology mainly on the operation of PV systems. From discussions held with the local technicians in Mwanza it was apparent that more training was required for maintenance, troubleshooting and repair of PV systems. Furthermore, an understanding of the energy management of stand-alone PV systems is another component of training that is lacking among many local technicians.

In Kenya most customers buy PV components, assemble together and install their own systems. The resulting systems are inferior and therefore anticipated increasing numbers of failures due to lack of technical skills in the field. The PV infrastructure is developing fast in Kenya and there is high demand for PV technical training. There are no formal institutions offering these specialised training but several dedicated professionals and leading PV companies are dealing with the problem.

In Tanzania a few institutions including NGO's, have been involved in providing one form or another of basic PV training courses to various groups. These are described below:

### 2.12.1 KARADEA

The KARADEA Solar Training Facility (KSTF) in Kagera Region was constructed in 1993 with financial support from the Swedish International Development Authority (SIDA). In November 1993 KSTF held its first Solar Photovoltaic (PV) course with financial support from the Commonwealth Science Council. This course was held in collaboration with Energy Alternatives Africa (EAA) of Nairobi, Kenya. The course attracted 16 participants from Uganda, Kenya and Tanzania. Ever since then KSTF has held at least one basic PV course each year, except in 1994 and 1995 when two courses were held per year.

Since 1993, KARADEA has Organised and held 13 basic training solar electric installation courses benefiting about 159 technicians from Tanzania, Kenya, Uganda, Ethiopia, Zimbabwe, Zambia, Togo, Cameroon, Nigeria and Sweden. Other related PV activities conducted by the Facility include:

- Conducting apprenticeship course for 15 technicians from East Africa;
- Training of Trainers (TOT) PV course for 8 instructors from Kenya, Uganda and Tanzania;
- Developing capacity to assemble some of the solar electric components including lights, voltage droppers, battery boxes and module mount.

Topics covered in the training varied from one to another but basically encompass the following:

- Low voltage DC electric review

- Basic PV theory
- Data gathering for system design
- Trouble-shooting and support networks
- PV system installation practice
- PV system user training
- PV system marketing and evaluation

### 2.12.2 TaTEDO

Since 1999 TaTEDO started short training PV courses for technicians alongside with promotion activities and awareness campaigns for solar PV. A number of activities related to PV training that have been accomplished include;

- Dar es Salaam Training on Solar PV systems, 2000
- Kilimanjaro Training on Solar PV systems, TaTEDO, 2001
- Mwanza Training on Solar PV systems, TaTEDO, 2000
- Mwanza Training on Solar PV systems, TaTEDO, 2001

The training was of duration between one week and two weeks and covers basically the following topics:

- Theory of solar energy
- PV systems and components
- Planning and sizing of PV systems
- Installation of small PV systems
- Approaches for setting up a solar business and guidelines for training
- Elements of PV systems, basic designs, installation procedures servicing and maintenance.

### 2.12.3 Mafinga Lutheran Vocational Training Centre

Mafinga Lutheran Vocational Training Centre (MLVTC) in Mafinga has introduced and conducts a two-year vocational training programme dedicated to Renewable energy (RE) including Photovoltaic technologies.

The programme provides detailed knowledge on various Renewable Energy Technologies) RETs in terms of theoretical underpinnings and practical craftsmanship. MLTVC submitted the curriculum of this RE course to the Vocational Education and Training Authority (VETA) and it was expected that vocational training centres operated under VETA would adopt the curriculum. However VETA has not been able to take up the training programme mainly due to lack of back-up resources.

#### 2.12.4 University of Dar es Salaam

Since 1990, the Physics Department, University of Dar es Salaam has been conducting Colleges on Thin Film Technology (TFT), which include a comprehensive dose on Photovoltaic. Since the first College, over 140 participants have participated in this programme. Participants from several countries including Kenya, Ethiopia, Uganda, Sudan, Zambia, Malawi, Lesotho, South Africa, Zimbabwe, Mozambique, Republic of Congo and Tanzania have benefited from the programme.

The main objectives of the College include:

- Training young scientists in various disciplines of thin film materials science.
- To stimulate research in solar energy and materials science.
- To promote South-South co-operation in research in solar energy and materials science.
- To develop communication, cooperation network and exchange experience among the participants and stake-holders in the field of solar energy and materials science.

In 2001, the Department of Physics in collaboration with UNESCO Dar Es Salaam Office organised a Training of Trainers workshop which was offered within the framework of the Global Renewable Energy Education and Training (GREET) Programme. The GREET programme is one of the five major projects of universal scope included in the World Solar Programme (1996 – 2005), which is the outcome of the World Solar Energy Summit that was held in Harare, Zimbabwe, in 1996. UNESCO launched the GREET Programme with special attention to the Africa Chapter. During the meeting of Southern

African National Commissions for UNESCO held at the UNESCO Sub-region offices for Southern Africa in Harare in October 2001, an outline of the GREET Programme was submitted as a working document. Among the identified activities to be undertaken were education and training activities in renewable energies including solar photovoltaics. The GREET programme responds to the enormous need for education and training in renewable energies in the developing countries so as to contribute towards sustainable energy development.

### 2.12.5 Weakness of the current PV training

It has been observed that the types of PV training as presented in the previous sections have had several limitations, including;

- The duration of the PV training courses are too short to have an in depth coverage – (2- 3 weeks);
- The mode of delivery of the courses does not provide adequate practical training;
- The courses vary widely and are not accredited by an approved body;
- The mode of training is not scalable;
- Accessibility of the training courses is limited to a few individuals;
- The PV training courses are conducted on ad-hoc basis and therefore there is no continuity;
- The training has relied mostly on donor support and therefore not sustainable.

Thus the present PV curriculum proposal intends to address the above weaknesses.

## 2.13 Justification for the Proposed Curriculum

(i) From the discussions given in the previous sections it is clear that a number of problems have been experienced with regards to PV system designs, installation as well as operation of the systems. Lack of knowledge and skills on the production and installation of modern PV Technologies to harness abundant sunshine available in Tanzania has been observed to be a major constraint to the improvement of rural energy situation. In some few places in rural areas where PV systems have been introduced, continued availability of energy services from such technology have been hampered by lack of skilled personnel among others to maintain and operate such technologies.

It has also been observed that there is no single institution that offers a certified course purely on photovoltaics apart from the short courses offered by a number of NGOs, private companies, some government institutions and projects on an ad-hoc basis. In the absence of any accredited body or institution responsible for training the needed technical cadre in the field of PV technology, dissemination of PV technology as a viable energy option for rural communities would suffer. Relying on the ad hoc type of training would lead to producing technical personnel that are not competent in the field thereby affecting negatively the transformation process of marketing PV technology.

For the smooth running of PV systems, it is imperative that training of technical personnel at various levels is made available and on a scalable size. This can be achieved by designing a curriculum and integrate it into an existing programme for artisans. In this way one could expect a multiplying effect depending on the demand as the PV market grows. VETA institutions have been chosen on the basis of their competence to undertake the responsibility of preparing technical personnel that will feed into the PV market and ensure that the PV industry is technically sustainable.

(ii) A number of studies in Tanzania on renewable energies have shown that the issue of technical training on renewable technologies is critical especially in the rural areas where such technologies including PV are mostly needed for social-economic development.

A survey commissioned by UNDP, UNIDO and the Ministry of Energy and Minerals (MEM) (1998) carefully analysed the renewable energy situation in Tanzania and proposed a framework for national programme to promote renewable energy technologies including PV. The study emphasised on the need for technical training aiming at supporting solar-product companies, provision of community services with electricity, providing information services on photovoltaic to rural population, etc. The study recommended the establishment of vocational courses in Renewable Energy Technologies aiming at equipping artisans with the necessary skills of planning, designing, installing, commissioning, maintaining and repairing PV technology. It concluded by proposing VETA and all other vocational training centres under VETA to spearhead the delivery of courses in this emerging discipline.

Support for training individuals in PV technology is seen as important to the existing institutions which are already undertaking related activities, and therefore be able to integrate some PV course modules in their curricula. In this way, the institutions will be able to expand their enrolment intake and at the same time widen the scope of their training disciplines. The UNDP/GEF PV Project is committed to assist VETA institutions to increase capacity for training in terms of instructors and facilities that will provide the needed ability to facilitate faster growth of energy service enterprises or even energy supply centres, among others.

(iii) In another study sponsored by UNDP/GEF and MEM (2001) on "Removing Barriers to the Transformation of the Rural PV Market in Tanzania" one of the barriers identified to the utilisation of PV to meet the basic electricity needs of rural communities in Mwanza region was limited technical knowledge of proper sizing, installation, operation and maintenance of PV systems. The findings have resulted into a project: "Transformation of the Rural Photovoltaic Market" which is being financed by UNDP/GEF aiming at reducing Tanzania's energy-related $CO_2$ emissions by introducing PV as a substitute for fossil fuel (kerosene) utilised for lighting in the rural areas remote from the electricity grid. This strategy will ultimately slow down the rate of additional diesel-based captive generation or grid extension for providing basic electricity services to the un-electrified rural households. The project has initially targeted Mwanza Region and the best practice learnt will be emulated to other regions in Tanzania.

(iv) UNESCO through the World Solar Summit launched the World Solar Programme (WSP 1996-2005) aiming at enhancing the understanding of the role that renewable energy sources could play in the preservation of the environment, provision of energy services, particularly for the rural and remote areas, creation of employment and improvement of social-economic conditions of the rural people, particularly women in the developing countries.

The programme was conceived as a necessary global commitment and a major co-ordinated effort of the various national and international actors to develop and implement 300+ top-priority renewable energy projects of national, regional and international value within a 10-years period in order to demonstrate the technical feasibility, economic viability and social and political acceptability of solar energy. Tanzania is a participant to the programme and has submitted five top priority proposals mainly on PV technologies, for consideration and adoption. The scope of the planned project was to install at least one demonstration PV system in each district in Tanzania. The implementation of the programme was such that each participating country would set up a process in motion in their respective countries through their annual budgetary allocation and incorporation of renewable energy in their national energy policies with action plans that would attract collaborative partners to support renewable energies especially PV technologies. The implementation and sustainability of such a programme would call for the need to have a comprehensive strategic objective for technical training in Photovoltaics and related fields.

# 3 The Proposed Curriculum

## 3.1 Background

### *3.1.1 The Vocational Education and Training Authority*

Vocational education and training in Tanzania is guided by the Act of parliament No 1 of 1994, which allowed the establishment of an autonomous government entity: The Vocational Education and Training Authority (VETA) vested with the overall responsibility to promote vocational education and training in Tanzania. For proper functioning of the Authority, the act further established the National Board as well as Regional Boards to assist the Authority in implementing its activities at regional level. One of the functions that is relevant to the current proposal is to promote or provide vocational education and training according to needs, within the framework of overall national social-economic development plans and policies. On the advice of the Trade Advisory Committee, the National Board may establish new vocational training and education programmes and at the same time close down existing ones. The organisation structure for the authority is depicted in Appendix 2

### *3.1.2 The Mwanza Regional Vocational Training Centre*

The Mwanza Regional Vocational Training Centre started its training operation in 1997. The centre plays as a role model and nucleus for training needs for the Lake Zone Region. Its vision is to become a highly developed training institution proving vocational skills according to the existing labor market. Thus the training aims at promoting employment both in the formal and informal sectors

The organization structure of the centre is such that it is headed by a manager and assisted by four persons, namely the registrar, the entrepreneurship coordinator, the human resource and administrative manager and the bursar. The registrar is responsible for all matters relating to the training affairs of centre. The centre has established four training departments and a library. The training departments are (1) Civil Trade (2) Mechanical Trade (3) Electrical Trade and (4) Other Trades. Other Trades include catering, driving, food production, business skills, computer application, etc. The organization structure is given in appendix 3.

The centre conducts 4 courses lasting two years and six courses lasting one year as shown below:

- Machinery fitter (24 months), MV Mechanics (24 months), Welding /Fabrication (24 months) and **Electrical Installation (24 months**)
- Carpentry (12 months), Plumbing and pipe fitting (12 months), Masonry and brick laying (12 months), Painting and Sign writing (12 months), Ginnery fitting (12 months) and Catering (12 months)

The electrical installation course is divided into two components, namely domestic electrical installation (offered in year one) and industrial electrical installation (offered in second year). To qualify entry to the second component, a candidate should have passed level one and assessed on his /her competence in the field of study. At present the number of trainees in year one is 50, which are divided into two groups of about 25 each. The groups are trained in sessions in such a way that one group is trained in the morning while the other one is instructed in the afternoon. As for the second year, the department has an enrolment of 16 trainees. The low numbers enrolled in this course is mainly attributed to the available workshop capacity.

Solar electricity is one such field that is closely related to the electrical installation course described above and therefore the skills attained in the course will complement the tasks designed for PV technologies. The proposed PV technology course modules will empower the trainee to learn the specific features of photovoltaic power systems as sources of energy and as a prerequisite for planning, sizing and installation of the systems. The clear matching between the current electrical installation course at VETA institutions and the proposed PV course modules calls for a good integration between the two.

Entry qualifications for the above courses are Standard VII or higher and an admission qualifying test usually conducted once every year. On successful completion of the courses the candidates are awarded a certificate appropriate to the duration of the course, i.e. Level one certificate for a one year of training and Level-two certificate for a two-year training course.

The department of electrical installation is housed in one building where all the classes and workshop training are conducted. It has basic equipment and other facilities for conducting the course effectively but lacks the necessary materials and equipment for mounting a PV training course and therefore external assistance will be required for the acquisition of the required PV components and test equipment. However, the department has basic working tools, which could easily compliment those needed for PV installation.

Currently, there are three instructors in the department of electrical installation. The staff:student ratio stands at 1:22, which is above the recommended ratio of 1:16 in vocational training institutions. By integrating the proposed PV course modules in the current electrical installation course and the expected expanded intake at the centre, there is need to have an additional staff to undertake the anticipated extra training load. Accordingly, for optimum delivery of the courses a total of four staffs will be required.

## 3.2 Organisation of the Curriculum

The proposed training curriculum is targeted formally at vocational training institutions. It will create a quality standard that leads to more confidence of the customer in this new technology and therefore consequently supports the potential PV market in Tanzania and elsewhere. To allow an enabling learning environment for the trainees, it is proposed that the trainees are initially introduced into the subject right from their first year of study (level I). In this way the trainees will have the opportunity to be exposed to the subject and therefore be in a position to continue smoothly with specialized

PV topics at level II of their study. The basic principles of solar energy and solar energy conversion will form a good starting point. The trainees should be aware that the sun is the source of virtually all of our energy, i.e. biomass, fossil fuels, solar electricity, solar thermal, wind and hydropower, etc.

The entry point for the proposed PV course is that the trainees must have successfully completed level one of the electrical installation certificate, which encompasses an introductory course on solar energy or its equivalent. The duration of the course is estimated to be about six months with an initial enrolment of about 15 trainees. The chart in figure 3 shows the distribution of the trainees at various levels of study.

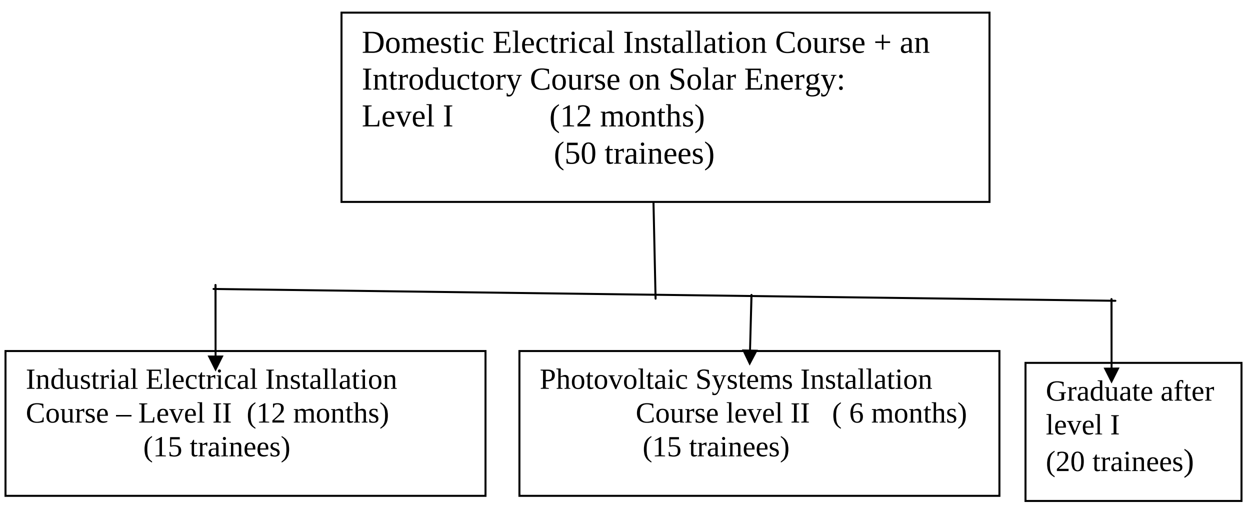



Figure 3. Layout of the proposed integration of the PV course-module into the Electrical Installation Course.

### *3.2.1 Objective*

The overall objective of the proposed curriculum is to instill knowledge and trade skills on PV technologies and applications to trainees in an effort to support wide dissemination of PV technologies in Tanzania and elsewhere.

### *3.2.2 Course Modules*

The training for the PV trainees consists of the following course units/modules:

**Level I:**

1. Introduction of Solar Energy

**Level II**

1. PV system configurations and applications
2. Fundamentals of solar radiation
3. Solar cells, modules and arrays
4. Solar cells and module characteristics
5. Storage batteries and accumulators
6. Charge controllers and load management
7. Inverters and converters
8. Planning for PV installation
9. Photovoltaic system sizing
10. Wiring and fittings
11. Lightning protection in photovoltaic systems
12. Appliances
13. Water pumping
14. Cost consideration
15. Practical Assessment
16. Maintenance and service of PV systems
17. Commissioning and customer care

## 3.3 PV Curriculum in Brief

The outlines of the modules are briefly given below while the details are covered in the subsequent section.

### 1. *PV systems Configurations and applications*

One of the great advantages of photovoltaic generation of electricity is the modular approach it encourages. The degree of complexity of a particular system is closely related to the end use demands that it is designed to meet. This course module will explore a variety of system configurations including, DC stand-alone systems, Basic AC/DC systems, Utility interactive systems and criteria for choosing appropriate PV systems. Common uses of solar electricity and its limitations will be covered.

### 2. *Fundamentals of solar Radiation*

This component will provide principles of solar radiation and its measurements. The theory of direct as well as diffuse radiation and insolation will be covered. Terms such as kilowatt-hours, peak-sun hours, solar tracking, seasonal solar radiation variation and energy available at a given site using meteorological data as well as the solar map will be treated.

### 3. *Solar cells, modules and arrays*

Solar modules are used to convert sunlight to electricity via the photoelectric effect of the solar cell. The PV installer must know, what parts constitute the PV system and how these components must be handled. This part of the training deals with the PV technology in its purest form; this means functionality of PV, cell technology and different types of modules, including mono-crystalline, poly-crystalline and amorphous thin films. Evaluation of important solar cell technologies and their applications will be discussed.

### 4. *Solar cells and module characteristics*

This course module will provide basic concepts of the energy output and characteristics of modules under various temperature, radiation and weather conditions. Module ratings and the I-V curve will be covered. The information in this chapter will help system designers choose, install and estimate module energy output in local conditions.

### 5. *Storage batteries and accumulators*

The most widely known method for storing electric energy is the use of batteries, which chemically store electric energy. The life expectancy is usually an order of magnitude lower than that of most other PV system components. The most common types of accumulators found on the market today are lead acid and nickel cadmium batteries. Thus this course unit will introduce the trainee on the working principle of a battery and provide information on the various types of batteries (application and make). Battery concepts including storage capacity in amp hours, charge and discharge, state of charge (SOC) depth of discharge (DOD), cycle life, and self-discharge. Series and parallel connections and problems associated with deep discharge and overcharging will be dealt with in detail.

### 6. *Charge controllers and load management*

The lifetime of a battery depends on the operating conditions as specified by the manufacturer. A charge controller is used to guarantee that the conditions, which are described, are met by limiting voltage values. Its main function is to protect the battery against overcharging and deep discharging. Thus this unit will cover devices used to manage the energy flow in solar electric systems. It will also introduce the trainees on various aspects of charge controller, including fuses, blocking diodes, LED indicators, low voltage disconnect (LVD) and high voltage disconnect (HVD). Management of small PV systems without a charge controller will also be treated.

### 7. *Inverters and converters*

This course unit will deal with a device that can convert a dc voltage to a lower one than that of the battery for use with appliances such as radio, cassette players, CDs, etc (i.e. If a radio/CD/Cassette draws 6 volts dc when the storage battery is at 12 volts dc, then a voltage converter is required to step the current down to the proper voltage). The course component also covers a wide range of advantages for using AC power against DC in PV systems and hence the integration of inverters in PV systems.

### 8. *Planning for PV installation*

Planning and dimensioning is the first step to a proper working PV-plant. According to the different needs of the user, the system has to be planned. This part of the concept is theoretical and practical. This unit will cover designing a small solar electric system. It will combine information already covered earlier enabling the trainee to tailor a PV system to ones' needs depending on the resources available. The trainee will be able to choose cost effective PV components, mount or assemble them and install the PV system as per recommended guidelines.

### 9. *Photovoltaic system sizing*

One of the great advantages of photovoltaic generation of electricity is the modular approach it encourages. The degree of complexity of a particular system is closely related to the end use demands that it is designed to meet. At the most basic level, a PV system design can be very simple. As loads increase and versatility becomes more important, the system can be made as complex as necessary to meet virtually any requirement. This course unit outlines how to estimate the total daily energy demand of appliances in a PV system. A practical example is used to demonstrate how this is done. The concepts of watt-hours and amp-hours will be explained and how the two quantities are determined at the initial stages of sizing a PV system. Once the energy demands of the appliances and the irradiance are known the size of other components including battery, modules, controller, etc, can be estimated. As more appliances are added to the system the size of the components can be worked out proportionate to the ultimate load.

### *10. Wiring and fittings*

This unit will emphasize on the concept of low voltage at moderate and high currents dc cables and fittings for solar electricity. Choosing cable types and size as well as other fittings will be covered in detail. The concept of voltage drop will be introduced to guide the choice and type of DC cables. Guidelines for wiring a PV system will be emphasized, including, laying cables, mounting solar modules, method of mounting, construction of mounts, wiring modules, battery wiring, mounting other BOS, etc. For the installer it is important to have an overview about wiring instructions and to know their importance in PV technology.

### *11. Lightning protection in photovoltaic systems*

When lightning strikes an exterior conductor of a building installed with a photovoltaic system, overvoltage results due to inductive, capacitive and conductive coupling. The variations in the electric field intensity during a thunderstorm over the solar generator bring about overvoltages even if the lightning does not strike the building itself or its surrounding. This course module will survey a number of couplings that are responsible for overvoltages in typical PV installations and proposes counter measures to the effect.

### *12. Appliances*

This course module will focus on how to choose the best lamps and appliances for solar electric systems. Principles of efficient lighting are explained, including lumen output, efficacy, and reflection. Introduction about incandescent, halogen, and fluorescent lamps (and associated fixtures) is provided. Choice of lamp, depending on the intended purpose, is outlined. Important aspects of low voltage and appliances likely to be used in solar electric systems are presented.

### *13. Phovoltaic water pumping*

Solar pumping can be more appropriate than many other appliances in rural areas. As communities expand, hand or animal driven pumps may not be sufficient to supply all daily needs, even if the well capacity is enough. Diesel pumps tend to be unreliable and require fuel and regular maintenance. This module will introduce basic pumping technology, including motor and pump technologies, power conditioning, water requirement, array sizing, etc.

### *14. Cost consideration*

This training module will introduce the trainee on how to compare cost of solar electricity against other alternatives. Simple cost comparison of PV systems and others such as kerosene for lighting purposes, dry cells for powering radios and cassette players/CDs will be treated. Practices and devices that reduce the cost of PV components and systems including modular and centralized types will be reviewed.

### *15. Practical assessment*

A PV installer needs to know how to determine whether a proposed site for a PV installation will be adequate for proper operation of the system. This training module will survey site assessments including:

- Determining whether the array can operate without being shaded during critical times;
- Determining the location of the array;
- Determining the mounting method for the array;
- Determining where the balance-of-system (BOS) components will be located;
- Label in accordance with recommended procedures;
- Determining how the PV system will interface with the existing electrical system, and

- Undertake operational test for each PV component at the site before installation.

***16. Maintenance and service of PV systems***

The photovoltaic system and the components that make it up are all made of solid-state electronics. The absence of moving parts and of mechanically replenished fuel supply render PV installations virtually maintenance free, or at least reduce most maintenance work to the category of preventive care. When storage batteries are involved, maintenance is some-what more demanding but it is still far from complicated. This unit provides a systematic approach towards handling routine maintenance, tasks involved in the care of batteries, modules, wiring and controls as well as trouble-shooting in the event of problems. (Appendix 5)

***17. Commissioning and customer care***

Under this course unit, trainees will be exposed to a number of issues, including handover procedures, safety precautions while commissioning, awareness of customers for installation services, installation specifications, manufactures data, user instructions and sales and promotion.

## 3.4 Teaching and Learning Materials

Teaching and learning materials for the proposed curriculum will be based on three main textbooks and several references. Due to the rapid growth of the PV technology, it is proposed that the instructors make use of the internet for additional teaching materials. Below is a comprehensive list of teaching materials:

***Textbooks and manuals***

(i) Mark Hankins, Small Solar Electric Systems in Africa, Commonwealth Science Council, Marlborough House, United Kingdom, 1995.

(ii) Steven J. Strong and William G. Scheller, the Solar Electric House, Sustainability Press, Still River, Massachusetts, USA, 1993
(iii) Fraunhofer Institute for Solar Energy Systems, Photovoltaic Systems, Freiburg, Germany, 1995

***Reference Resources and Additional Reading Materials for Instructors***

(i) Study Guide for Phovoltaic System Installers and Sample questions, Prepared for US Department of Energy and Sandia National laboratories, 2003.

(ii) Objectives and Task Analysis for the Solar Photovoltaic System Installer; North American Board of Certified Energy Practitioners Technical Committee Document, Approved 6/4/2002, http://www.nabcep.org/nabcep/www/media/pdf/NABCEPPVInstallerTasksAnalysis.

(iii) A Guide to Photovoltaic System Design and Installation, California Energy Commission Consultant Report 500-01-020, June 2001 http://www.energy.ca.gov/reports/2001-09-04_500-01-020.

(iv) Battery Service Manual, 11th Edition. Battery Council International, 401 North Michigan Avenue, Chicago, IL, 60611 http://www.batterycouncil.org/publications.

(v) Installing Photovoltaic Systems (Course Manual), 2002, Florida Solar Energy Center, 1679 Clearlake Road, Cocoa, FL 32922-5703 http://www.fsec.ucf.edu.

(vi) Working Safely with Photovoltaic Systems, January 1999. Sandia National Laboratories, Photovoltaic Systems Assistance Center, Albuquerque, NM 87185-0753 http://www.sandia.gov/pv

(vii) Maintenance and Operation of Stand-Alone Photovoltaic Systems, December 1991. Sandia National Laboratories, Photovoltaic Systems Assistance Center, Albuquerque, NM 87185-0753 http://www.sandia.gov/pv

(viii) Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices, SAND87-7023. Sandia National Laboratories, Photovoltaic Systems Assistance Center, Albuquerque, NM 87185-0753:http://www.sandia.gov/pv

## 3.5 PV Curriculum Details

The delivery of the proposed PV course is divided into two main parts, namely, theory and workshop training. Each course module will be treated separately in such a way that it is self contained. The theory part will mostly be concerned with the understanding of the basic principles of various components of PV systems, installations, safety measures and regulations so as to enable the trainees perform several assignments in the workshop. For each course module, a number of practical assignments corresponding to the theoretical components have been proposed. For each workshop task (Appendix 6), the instructor will provide the trainees with all the necessary steps required to complete the assignment. This method allows a degree of flexibility in the training where the instructor can adapt new effective methods in the learning process.

The workshop training is an integral part of the theoretical component of the course and as such it is considered to be a vital element of the curriculum. In the workshop, the trainee is able to perform a number of tasks that may verify some of the fundamental principles that have been explained in class. Thus, the aim of the workshop training is to assist the trainees build confidence and familiarize themselves with workshop equipment and at the same time develop trade skills in working with a variety of materials and tools.

The curriculum is designed such that it can be administered by the present number of instructors. However, it is envisaged that the proposed new course will lead to an expansion in student enrolment. As a conservative estimate, it is anticipated that enrolment will increase from the current 16 to at least 30 trainees in year two of their study. To cater for such an expansion it will be necessary for the centre to invest in the acquisition of additional workshop equipment, materials and tools. This is particularly important since the goal of the proposed PV curriculum is to offer more workshop practice than theory. Furthermore the centre should as soon as possible embark on an enhancement capacity building programme aiming at equipping the present electrical installation course instructors with the necessary PV skills so as to be able to train trainees under the proposed curriculum. A PV course, tailored according to the proposed curriculum coupled with sufficient teaching, learning and workshop materials will be necessary for effective implementation of the curriculum.

The layout of the syllabus is arranged such that at the beginning of each course module, an objective(s) is conceived and strategies developed to achieve the objectives are designed through the theoretical part of the course and subsequently tested in the workshop. For each course unit, basic materials, measuring test equipment, PV components and tools have been proposed (Appendix 4). The following tables provide details of the syllabus of the proposed curriculum.

# Level I

| Introduction of Solar Energy | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:<br><br>• Identify various forms of energy<br>• Be aware of the potential applications of solar energy<br>• Be aware of the advantages and disadvantages of solar energy | The sun as a source of other forms of energy:<br>(i) Biomass<br>(ii) Fossil fuel<br>(iii) Solar electricity<br>- applications<br>- advantages<br>- limitations<br>- electricity storage<br>(iv) Solar thermal<br>- -green house effect<br>- concentrating technologies<br>- solar crop driers<br>- solar water heaters<br>- solar cookers<br>- solar distillation<br>- thermal storage<br>(v) Solar wind<br>(vi) Solar hydro-power | | 10 | |

**Level II**

| 1 | **PV system configurations and applications** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Identify various PV systems options<br>• Identify potential uses PV systems<br>• Identify limitation of PV technology<br>• Identify advantages of PV systems | • Basic Photovoltaic system options<br>- DC stand alone systems<br>- Basic AC/DC systems<br>- Utility interactive systems<br>- Choosing PV systems<br>• PV Application areas:<br>- Domestic, industrial and medical<br>- Fencing and security<br>- Refrigeration and fishing<br>- Water pumping<br>- PV powered Calculators<br>- Flashlight battery charger<br>- PV powered emergency telephone<br>- Railway signalling<br>- Corrosion protection<br>- PV powered vending machine for parking<br>- PV powered lighting bus stop shelters<br>- PV powered watches/clocks/<br>• PV systems limitations<br>• Potential advantages of PV technology | | 10 | |

| 2 | **Fundamentals of Solar Radiation** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Understand the concepts of the solar resource<br>• Understand solar radiation principles.<br>• Distinguish between direct, diffuse and global radiation.<br>• Measure solar irradiance. | • The sun as basic source of renewable energy;<br>• Solar radiation principles.<br>• Direct, diffuse and global radiation;<br>• Use meteorological records;<br>• Seasonal solar radiation;<br>• Hourly solar radiation;<br>• Optimum tilt for solar collectors;<br>• Tracking the sun;<br>• Solar energy applications | • To determine solar radiation measurements using simple meteorological instruments<br>• Study visits to meteorological station. | 24 | • Pyranometer<br>• Watt-meter |

| **3** | **Solar Cells, Modules and Arrays** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Recognize a PV cell, module, and string array;<br>• Differentiate among various types of solar cells;<br>• Know the advantages and disadvantages of different types of technologies;<br>• Select appropriate solar cell modules and arrays;<br>• Arrange PV modules in parallel and in series configuration. | • Photoelectric effect.<br>• Solar cell technology<br>• Solar cell<br>• Types of solar cell:<br>- Mono – crystalline<br>- Poly – crystalline<br>- Amorphous<br>- Thin film<br>• Solar module<br>• Solar string<br>• Solar array:<br>- Series connection<br>- Parallel connection<br>• Blocking and shunt (bypass) diodes<br>• PV modules as current limiting devices<br>• Methods of disposing toxic materials | • Determine the Photovoltaic effect;<br>• To determine the effect of arranging PV modules in series on output current (Isc), voltage (Voc), and power;<br>• To determine the effect of arranging PV modules in parallel on output current (Isc), voltage (Voc) and power<br>• To determine the effect of partial shading on the output current and voltage of PV module or array;<br>• To determine the effect of module temperature on output current and voltage. | 60 | • 40 watt and 20 Watt PV modules<br>• PV cable 4 $mm^2$<br>• Wood screws<br>• Lamp holder<br>• Bulb<br>• One way switch<br>• Combination pliers<br>• Screw drivers<br>• Ammeters<br>• Voltmeter<br>• Electrician knife<br>• Cable lugs<br>• Cable lug-tool<br>• Diodes<br>• Solar cell<br>• Black paint<br>• Black cloth or plastic sheet |

| 4 | **Solar Cell and Module Characteristics** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br>• Measure I-V characteristics of a solar cell/module<br>• Determine solar cell/ module maximum power ($w_p$) output;<br>• Test and evaluate performance of solar module under field conditions<br>. | • IV characteristics and Power output<br>- IV curve<br>- Open circuit voltage ($V_{OC}$)<br>- Short circuit current ($I_{SC}$)<br>- Maximum power, ($P_{max}$) current ($I_{max}$) and voltage ($V_{max}$)<br>• Choice of solar cell module(s) | • Measure I-V characteristics of a module in both series and parallel configuration<br>• Determine maximum power output ($P_{max}$ or $W_p$)<br>• Determine short circuit current, Isc and open circuit voltage, Voc | 12 | • Multimeter;<br>• Ammeter;<br>• Watt-meter;<br>• Screw drivers;<br>• Combination pliers;<br>• Side cutting pliers;<br>• Cotton/ woollen cloth;<br>• Connectors;<br>• Calculator.<br>• 40 watt and 20 Watt solar cell modules;<br>• Graph paper. |

| **5** | **Storage Battery and Accumulators** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Know the principles and operation of different storage batteries;<br>• Know the battery concepts such as storage capacity, (state of charge SoC), charge and discharge, life cycle, depth of discharge (DOD), deep discharge and overcharging of batteries;<br>• Measure the state of charge of a battery;<br>• Handling, servicing and maintaining batteries;<br>• Recognize safe practices for handling, moving and storing batteries. | • Battery principle and operation<br>• Terminology:<br>- Liquid electrolyte<br>- Specific gravity<br>- Distilled water<br>- Ionised water<br>- Battery, cell<br>- primary cell<br>- lead acid battery<br>- accumulator cell<br>- Battery terminals<br>- hydrometer<br>• Types of batteries (application)<br>• Types of batteries (make);<br>• Rated storage capacity;<br>• Charge, discharge and state of charge;<br>• Life cycle and depth of discharge, floating voltage<br>• Self – discharge; Overcharging;<br>• Measuring state of charge of batteries;<br>• Efficiency of the battery;<br>• Batteries in series, parallel<br>• Batteries for back-up power supplies<br>• Methods of disposing batteries | • Determine Specific gravity or density of liquid electrolyte;<br>• Fill battery with dilute sulphuric acid;<br>• Add battery with distilled water;<br>• Connect terminals to the battery;<br>• Measure state of charge using hydrometer or multimeter;<br>• Clean and grease battery terminals;<br>• Connect batteries in series and parallel.<br>• Practice on handling batteries with acid (when | 24 | • Battery;<br>• Battery terminals;<br>• Adjustable spanners;<br>• Goggles;<br>• Gloves;<br>• Battery boxes;<br>• Hydrometer;<br>• Battery lead tester.<br>• Multimeters.<br>• Glass /plactic Funnel;<br>• Baking powder (*Chapa-maa-ndazi)*<br>• Petroleum jelly<br>• Tooth brush<br>• distilled water<br>• acid water<br>• goggles<br>• Rubber Gloves<br>• Basins<br>• water |

| | | | | | |
|---|---|---|---|---|---|
| | | • -Safety on batteries to prevent blindness, skin burn, damage to clothing and metal, short circuit and explosions | filling batteries with acid and transport ting them)<br>• Use of protetive gears (goggles, rubber gloves, bicarbonate soda labelling acid bottles) | | |

| **6** | **Charge Controllers and Load Management** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Understand the operation of charge controllers<br>• Choose appropriate charge controllers | • Introduction to charge controller /regulator;<br>• Function of charge controller;<br>• Features of charge controller;<br>• Choosing charge controllers;<br>• Managing systems without charge controllers;<br>• Blocking diodes;<br>• Night mode controllers. | • Identify various parts of charge controller;<br>• Identify battery, module and load terminals;<br>• Characteristics of PV charge controllers/regulators.<br>• Determine Low Voltage Disconnect (LVD), High Voltage Disconnect (HVD) and reconnect voltage of a charge controller | 30 | • Charge controller/<br>• Charger controller.<br>• Multimeters<br>• Screw drivers.<br>• Combination Pliers;<br>• Fuses;<br>• Diodes<br>• Power supply<br>• DC Loads |

| **7 Inverters** | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time** | **Tools, equipments and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>▪ Understand the operation of inverter.<br>▪ Choose appropriate inverters.<br>▪ Understand inverter waveforms | • Introduction to Inverter.<br>• Inverter charger<br>• Efficiency of an inverter and matching an inverter with AC load to optimise its efficiency<br>• Function and features of inverters 12V - 48V systems.<br>• Advantages and Limitations of inverters<br>• RMS values, meters and measurement<br>• Inverter wave forms<br>- square waves<br>- modified square waves<br>- sinusoidal waves | •Connect Inverters to DC source<br>•Use an oscilloscope demonstrate various AC wave forms derived from an inverter<br>•Determine the working voltage range of a converter<br>•Test efficiency of different types of inverters (with and without load)-this will give idea to the users that even without load inverter consumer power and have to be switched off when no loads in use.<br>•Investigate the effect of output power on the type of loads, e.g. inductive, capacitive and resistive leads<br>•Use an ordinary multimenter and RMS multimeter to determine output voltage of an inverter. | 24 | • DC / AC inverter.<br>• Multimeter<br>• Screw drivers;<br>• Oscilloscope<br>• Inverter charger<br>• RMS multimeter<br>• 12V battery<br>• Different AC loads |

| 8 Converters | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:- <br>• Understand the operation of converters. <br>• Choose appropriate converters. | • Introduction to converters <br>• Types of converters i.e. 3V, 4.5V, 6V, 7.5V, 9V converters. <br>• Functions and features of converters. | Connect DC/ DC Converters and measure output voltages and limiting current and efficiency | 12 | • DC / DC converter <br>• Multimeter <br>• 12 V Battery |
| | | | | | |

| 9 Cable Sizing | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to: <br><br>• Size and select appropriate cables, and fuses for PV system | • Cable size calculations <br>- Voltage drop <br>- Voltage allowable drop <br>- Resistance of cable <br>- Length of cable <br>- Cross – section area. | Use worksheet to calculate voltage drop <br>Calculating Voltage drop mathematically | 10 | Calculator |

| 10 | Planning for PV Installation | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Draw a layout-diagram for a PV system<br>• draw and interpret different diagrams used in PV system<br>• Select appropriate PV modules, battery and charge controller.<br>• Survey and compare cost of materials, tools and equipments required<br>• Select appropriate type of mounting.<br>• Install solar PV system. | • Site assessment<br>• Placement of PV components<br>• Draw a wiring circuit diagram for solar PV small system<br>- diagrams used in PV systems (block diagrams, cable diagrams,<br>- circuit diagrams and<br>- wiring diagrams)<br>• Survey and selection of modules.<br>• Selection of cables fuses and switches;<br>• Cable routing<br>• Access to site/roof<br>• Equipment cost<br>• Types of mounting.<br>• Component breakage through poor storage/handling<br>• Labour cost<br>• Commission costs<br>• Switch over relay | • Site inspection assessment<br>• Draw a chart<br>• Selection of PV equipment<br>• To determine the cost of PV components and labour<br>• Prepare diagrams for a mount for the supplied modules<br>• Install a small household PV system | 12 | • Calculator<br>• Pencil.<br>• Rubber.<br>• Ruler.<br>• Hammer,<br>• Screw drivers.<br>• Combination pliers,<br>• Drawing Instruments,<br>• Drawing papers,<br>• Side cutter<br>• Torch<br>• Shovel<br>• File<br>• Extension cord<br>• Switch over relay<br>• Inclinometer and compass |

| **11 PV System Sizing** | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Use metrological data for PV system designing purposes<br>• Design cost effective PV system.<br>• Size and select appropriate cables, fuses and switches | • Prepare appropriate worksheets for the design of the system<br>• Available Metrological data.<br>• Daily system energy requirement and system voltage.<br>- Estimation of number of appliances and their rating;<br>- Daily working durations.<br>• Estimation of number of module required, type of module and configuration (i.e. series or parallel).<br>• Estimation of number of batteries required, size and types of battery<br>• Choice of regulator:<br>- Current under load<br>- Current under charge<br>• Choice of inverter:<br>- Types of inverter and rating:<br>• Additional accessories | Draw a chart<br>• Determine meteorological data at a site<br>• Determine the PV system voltage<br>• Determine the energy requirement of a typical household<br>• Determine optimum number of components as well as the size of cables required for installation of a household PV system. | 60 | • Calculator<br>• Papers<br>• Rulers<br>• Drawing sets |

| **12** | **Wiring and Fittings** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Prepare tools and materials necessary to carry out an installation.<br>• Read and interpret wiring circuit diagram for a given PV system.<br>• Mount and positioning PV modules.<br>• Lay cables.<br>• Inspect the final connections before commissioning the system. | • Wiring the load.<br>• Mounting solar modules, controller, battery, etc<br>• Final connections;<br>• Laying cables<br>• Wiring guidelines<br>• Method of mounting<br>• Instruction of mounts<br>• Wiring modules<br>• Battery wiring<br>• Mounting other BOS | • Install switches.<br>• Install and connect junction boxes.<br>• Install solar light (fluorescent lamps)<br>• Install switch sockets.<br>• Connect other loads. | 90 | • Claw Hammer<br>• Screwdrivers.<br>• Combination pliers.<br>• Side cutting pliers.<br>• Switches, sockets.<br>• Solar light.<br>• Lamp holder.<br>• Wood screws.<br>• Crimping tools.<br>• Adjustable spanner.<br>• Drill machine.<br>• Utility knife.<br>• Tape measure.<br>• Hack saw.<br>• Installation board<br>• Multimeter.<br>• Cables,<br>• Square boxes,<br>• Junction box,<br>• Modules.<br>• Charge controller<br>• 12 V Battery |

| **13** | **Maintenance and Service of Solar PV Systems** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• Undertake routine maintenance of the solar PV system.<br>• Service and repair the installed system<br>• Identify the causes of problems and how to solve them when the system fails to work. | • Routine maintenance.<br>• Battery maintenance.<br>• Module maintenance.<br>• Wiring and control<br>• Lamps and other loads.<br>• Log book<br>• Trouble shooting<br>- -types of system failures<br>- component failure – only one or some of the components are not working<br>- system failure – complete system not working<br>- Procedures of identifying each type of failure in a PV systems<br>• Guidelines of trouble shooting in a PV system ( as shown in appendix) | • Carry out testing e.g. measure SOC using hydrometer/ multimmeter;<br>• Check continuity of the fuses using ohmmeter.<br>• Check the operation of lamps.<br>• Clean dusty from the module using smooth cotton wool.<br>• Check defective wires.<br>• Clean battery terminals.<br>• Tighten terminals<br>• Procedure of Performing general routine maintenance of PV systems<br>• **DISCONNECTION** procedures of solar modules and loads from charge controller<br>• **BATTERY**: measure SOC, check the level of electrolyte in a battery, clean top of a battery and check battery | 24 | • Battery<br>• Module<br>• Hydrometer.<br>• Multimmeter.<br>• Continuity tester.<br>• Cotton cloth.<br>• Fuses.<br>• *Chapa maandazi.*<br>• Inverter, Converter.<br>• Charge controllers.<br>• Line tester meter<br>• Wires, sockets, connectors<br>• Appropriate tools<br>• Vaseline |

| | | | | | |
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| | | | terminals (corrosion and tightness of connections)<br>• **SOLAR MODULE**<br><br>Measure Isc and Voc of solar modules, Clean dusts from the solar module using smooth cotton wool and check connections in junction boxes<br>• **LOAD SIDE WIRING**<br><br>Check connections in switches and Junction boxes<br><br>Clean Light fitting and replace worn out bulb and tubes<br><br>• **RECONNECTION** procedures of solar modules and loads to the charge controllers<br>• **FILLING IN INSPECTION/MAINTE NANCE FORM**<br>• carry out trouble shooting of a system which is completely not working | | |

| **14 PV System Commissioning and Customer Care** | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:-<br><br>• State the completion requirements.<br>• State the testing requirements.<br>• Describe methods of visual inspection.<br>• State basic principles of diagnostic testing commissioning.<br>• Identify appropriate documentation necessary for testing.<br>• Describe handover procedures and customer information requirements<br>• state the safety precaution to be taken when carrying out commissioning. | • Completion requirements.<br>• Cleaning of array.<br>• Operation status of the inverter.<br>• Monitoring system.<br>• Basic principles of diagnostic testing and commissioning.<br>• Testing documentation.<br>• Handover procedures.<br>• Safety precautions while commissioning.<br>• Awareness of customers for installation services.<br>• Installation specifications.<br>• Manufactures data.<br>• User instructions.<br>• Code of practice on<br>– Sales and promotion.<br>– Warranties.<br>– Services and repairs.<br>– Customer complaints | • General visual inspection of the system.<br>• Polarity test<br>• Insulation test<br>• Earthing test<br>• Continuity test<br>**Practice commissioning procedures of a PV system:**<br>• Measure Isc, Voc and polarity of solar module/array<br>• Measure state of charge of a battery bank, its polarity and inline fuse(if intact)<br>• Test wiring of the load side of a PV system (Insulation, continuity, switching, polarity and voltage drop tests)<br>• Final visual Inspection of a PV system | 60 | • Smooth clothes or cotton wool.<br>• Arrays.<br>• Megameter<br>• Multimeter<br>• Technicians toolkit<br>• Completion certificate<br>. |

| | | | | | |
|---|---|---|---|---|---|
| | | | • User training (including the manual)<br>• Documentation i.e. completion certificate ( all tests done above, specifications of installed components, diagrams, warranty ) | | |

**15 Appliances**

| | Objective | Theory | Practical | Time (hrs) | Tools, equipment and materials |
|---|---|---|---|---|---|
| | • At the end of this unit, the trainees should be able to:<br>• Identify various PV appliances<br>• Understand different types of lamps used in a PV system<br>• choose appropriate lamps and other appliances<br>• Understand principles of efficient lighting<br>• Understand | • Types of dc lamps_<br>- Luminance<br>- Efficacy<br>- Reflection<br>- Lumens<br>• Ac and dc lamps<br>- Incandescent lamps<br>- Florescence lamps<br>- LED<br>• Operating voltage of dc appliances | Measure and compare the light intensity of halogen and florescence lamps/tube/PL | 12 | lux meter |

| | | | | | |
|---|---|---|---|---|---|
| | important aspects of low voltage tools and appliances | | | | |

**16 Cost Consideration**

| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
|---|---|---|---|---|---|
| | At the end of this unit, the trainees should be able to:<br>• Compare the cost of energy produced by PV system and other alternatives<br>• Identify and choose cost effective PV components | • Identify alternative energy sources<br>• Energy cost analysis<br>• PV-Energy management<br>• Energy efficient appliances | Calculations | 30 | Calculator |

| **17 Lightening protection in PV systems** | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipment and materials** |
| | At the end of this unit, the trainees should be able to:<br>• Understand earthing requirements<br>• Understand lighting protection system requirements<br>• Describe protection tools for small PV systems | • Array frame earthing<br>• DC conductor earthing<br>• Inverter earthing<br>• Surge protection unit<br>• Over and under voltage<br>• Causes of overvoltages in PV systems<br>• Under and over frequency<br>• Codes of practice on earthing | Installation of earth electrodes | 30 | • Earth electrode<br>• Hammer<br>• Combination pliers |

| **18 Practical Assessment** | | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (hrs)** | **Tools, equipments and materials** |
| | At the end of this unit, the trainees should be able to:<br>• Make the work area safe before work commences<br>• Select and use | • Aspects to consider for safety of work<br>• mounting method for the array,<br>• Location of Balance-of-system (BOS) components and | • Supporting structures eg ladders, sloping roofs, etc<br>• Carry out measurement within modules and arrays | | • Ladder<br>• Ohmmeter<br>• RMS meter |

| | | | | | |
|---|---|---|---|---|---|
| | appropriate access equipment<br>• Carry out basic roofing techniques<br>• Label according to recommended standards<br>• Carry out field test of various PV components | • how the PV system will interface with the existing electrical system. | • Undertake operational testing of inverter and regulator<br>• Label in accordance with recommended guidelines<br>• Carry out basic roofing techniques<br>• Field Test of PV system components to check conformity to components specifications<br>• (solar module, charge controller, battery) | 30 | |

| **19** | **Water pumping** | | | | |
|---|---|---|---|---|---|
| | **Objective** | **Theory** | **Practical** | **Time (Hrs)** | **Tools, Equipment and Materials** |
| | At the end of this unit, the trainees should be able to:<br><br>• understand Economic possibilities and Limitations of different energy sources for water pumping<br>• Understand different types of solar pumps<br>• select appropriate type of water pump for different applications(situatio ns)<br>• determine power of solar modules required for water pumping<br>• install solar water pumping systems | • basic pumping technology,<br>• motor and pump technologies,<br>• Criteria for selection of energy source for water pumping<br>• power conditioning<br>• water requirement,<br>• Array sizing. | • Install various water pumps<br>• Design appropriate array for water pumping | 60 | • Water pumps<br>• Inverter<br>• Solar Modules<br>• Calculator<br>• Wiring<br>• Tools. |

# Bibliography

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3. A Study and Assessment of Energy Projects and Their Effective Utilization in Tanzania, 1994.
4. Promotion of Renewable Energy in Tanzania – A Project Appraisal Report, GTZ, 2003.
5 Dissemination of Photovoltaic in Zimbabwe, Energy Programme Zimbabwe, Ministry of energy and water Resources and Development, 1992

# Appendices

## Appendix 1 Main actors in the PV industry in Tanzania

| | | | |
|---|---|---|---|
| 1. | MONA-MWANZA ELECTRICAL AND ELECTRONICS<br>P.O. Box 110<br>Sheikh Amin Street: Opposite Ijumaa Mosque<br>MWANZA<br><br>Attn: Nizar A. Parpia<br>Tel: 028 2502337/0744 487183<br>Fax: 028 2502910<br>E-mail: totomona@hotmail.com<br><br>Products: Sales of solar PV system components | 2. | F.H. HAJI<br>MWANZA<br><br>Attn: Mama Haji<br><br>Tel: 0282502019<br><br>Products: PV system components |
| 3. | MUKESH KARIA VUNJA BEI SHOP<br>P.O. Box 10119<br>MWANZA<br><br>Attn: Mr. Emmanuel Petro Lusaya/Shop Manager<br><br>Tel: 028 41719<br><br>Products: sales of solar PV (amorphous) system components | 4. | REX INVESTMENT LIMITED<br>P.O. Box 4836<br>BHESCO Building, Kisarawe Street<br>DAR ES SALAAM<br><br>Attn: Francis Kibhisa/Managing Director<br><br>Tel: 022 2180109/0741 607633<br>E-mail: fkibhisa@yahoo.com<br><br>Products: Solar PV Equipment and installation |
| 5. | NYANZA MEDICAL ENGINEERING<br>P.O. Box 905<br>MWANZA<br><br>Attn: Malaki Emmanuel Diason/Zonal Medical Engineer<br><br>Tel: 0741 244551<br><br>Products: Installation and maintenance of solar PV medical equipment for churches in Lake Zone | 6. | CHLORIDE EXIDE TANZANIA LTD<br>P.O. Box 12746<br>DAR ES SALAAM<br><br>Attn: Ismail Indeche<br><br>Tel: 022 2182313<br>E-mail: exide@iconnect.co.ke<br><br>Products: Sales of modules, solar batteries, charge controllers and DC lights |
| 7. | BP Tanzania Ltd<br>P.O. Box 9043, Bandari road, Kurasini<br>DAR ES SALAAM<br><br>Attn: Mr. Boniface Hanga<br><br>Tel: 022 2111269/o741 200998<br>E-mail hangaba@ar1.bp.com<br><br>Products: Solar PV system equipment including refrigerators | 8. | LIKUNGU INVESTMENT (T) LIMITED<br>P.O. Box 972<br>DAR ES SALAAM<br><br>Attn: Einhard D. Haule<br><br>Tel: 022 2864443<br>E-mail: Liku haule@yahoo.com.au<br><br>Products: Sales of solar PV equipment and water pumps. |

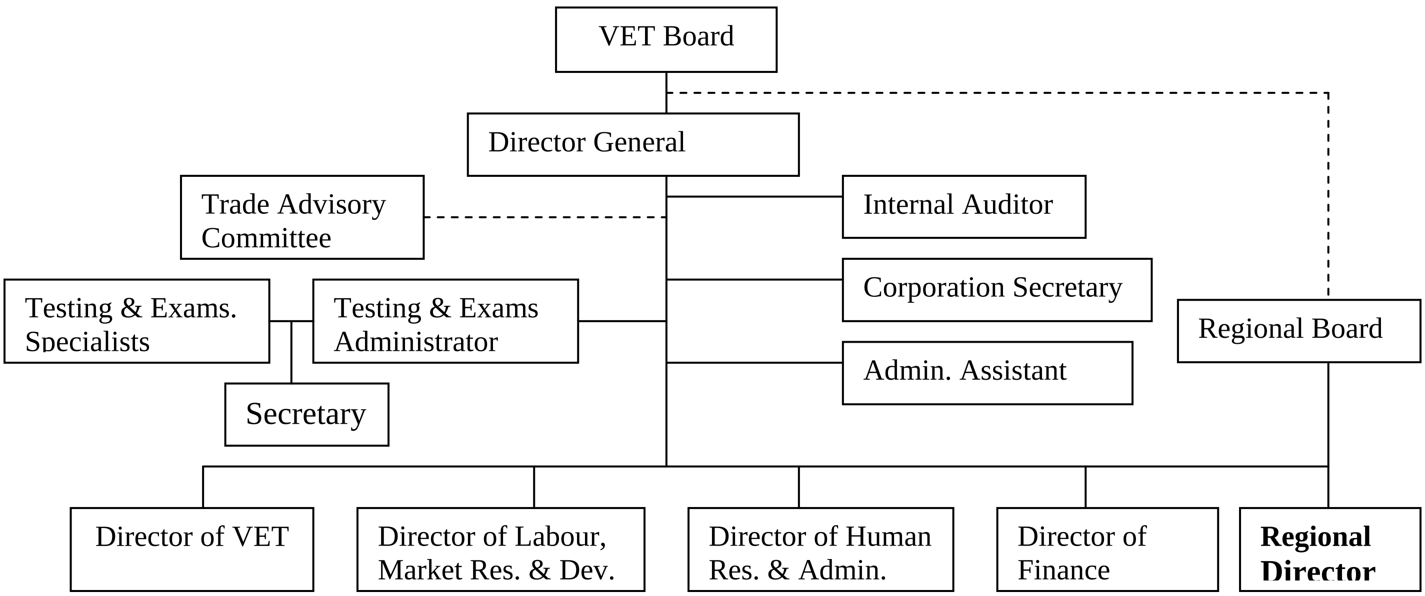
<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>9.</td><td>SIEMENS LTD<br>P.O. Box 14977<br>Patel building, Ground Floor, plot 2071/2<br>DAR ES SALAAM<br><br>Attn: Murtaza Bhaji/Sales Engineer<br><br>Tel: 022 2118898, 2114073<br>E-mail: murtazab@siemens@co.tz.<br>Products/Service PV installation</td><td>10.</td><td>GESCO LTD<br>P.O. Box 71358<br>DAR ES SALAAM<br><br>Attn: Nyamo-Hanga B.G.<br><br>Tel: 022 2421104/0744 364587<br>Fax: 022 2421103<br>E-mail: gesco127@hotmail.com.<br><br>Products: Solar PV equipment, installation and consultancy.</td></tr>
<tr><td>1.1</td><td>KARAGWE DEVELOPMENT ASSOCIATION<br>P.O. Box 299<br>KARAGWE<br><br>Attn: Oswald Kasaizi/Executive Secretary<br><br>Tel: 028 222254/222297/2223389<br>Fax: 028 2222541<br>E-mail: karadea@africaonline.co.tz<br><br>Products: Training in solar PV, sales and installation of solar PV systems</td><td>12.</td><td>DEPARTMENT OF ENERGY ENGINEERING<br>University of Dar es Salaam<br>P.O. Box 35131<br>DAR ES SALAAM<br><br>Attn: Dr. C.Z. Kimambo<br><br>Tel: 2410369/0744 281680<br>E-mail: kimambo@udsm.ac.tz<br><br>Service: demonstration and research programmes in solar energy technology</td></tr>
<tr><td>13.</td><td>FREDKA INTERNATIONAL LTD<br>P.O. Box 8089<br>ASG Building, Gerezani/Nyerere Road<br>DAR ES SALAAM<br><br>Attn: Wilfred Kipondya<br><br>Tel: 0744 282428<br>E-mail:fredka@intafrica.com or wkipondya@hotmail.com<br><br>Products: Energy Consultancy, project development and product marketing (solar systems and energy saving lights).</td><td>14.</td><td>LOCKING CENTRE<br>102 Kinondoni road<br>P.O. Box 78282<br>DAR ES SALAAM<br><br>Attn: Y. Arusi (Executive Director)<br>Tel: 022 2666547/0744 271890<br>Fax: 022 2667912<br>E-mail: mul-t-lock@intafrica.com<br><br>Products: Solar water heaters</td></tr>
<tr><td>15.</td><td>TaTEDO – Tanzania Traditional Energy Development and Environment Organization<br>P.O. Box 32794<br>DAR ES SALAAM<br><br>Attn: E.N. Sawe<br>E-mail: tatedo@raha.com<br>Products: Training and demonstration of solar: PV systems, consultancy and project development</td><td>16.</td><td>TIREWORKS COMPANY LTD<br>ARUSHA<br><br>Attn: Mr. M. Jusuf, Mr. Kitale (Manager)<br><br>Tel: 027 2507389<br><br>Products; Sales of solar PV amorphous modules and solar batteries.</td></tr>
<tr><td>17.</td><td>KALWANDE CHURCH SERVICES AND TRAINING CENTRE<br>P.O. Box 1137<br>MWANZA</td><td>18.</td><td>SWIFT HOLDINGS LTD<br>P.O. Box 2082<br>ARUSHA</td></tr>
</table>

| | | | |
|---|---|---|---|
| | Attn: Father Claudius Mpya or Mr. Damas<br>Tel: 0741 531110<br><br>Products: Installation of solar PV systems. | | Attn: Mr. M.Y. Hassanie<br><br>Tel: 027 2504147/0741 344832/0744 285045<br>E-mail: my hasanie@yahoo.com<br>Products: Installation services, solar PV system packages, solar PV system components: charge controller, solar modules, deep cycle batteries, lights, wind turbine. |
| 19. | TROSS (Tropical Energy Systems Ltd)<br>P.O. Box 1746<br>ARUSHA<br><br>Attn: Mr. Kitutu<br>Tel: 027 2503506/0744 302151<br>E-mail: Trossre@yahoo.com<br><br>Products: Solar cookers. | 20. | COMMISSION OF SCIENCE AND TECHNOLOGY (COSTECH)<br>P.O. Box 4302<br>DAR ES SALAAM<br><br>Attn: Salvatory Mushi<br><br>Tel: 0222700751/022 2700745/6/0744 753245<br>Fax: 022 2775313<br>E-mail: stambjli2002@yahoo.com<br><br>Services: promotion of solar energy technology |
| 21. | SOLAR AND BIOGAS/KEREC<br>P.O. Box 7322<br>Sukari Road<br>ARUSHA<br><br>Attn: Mr. A.E. Mfinanga<br><br>Tel: 027 2752401<br><br>Products: Promotion of solar energy and installation of solar PV systems. | 22. | DEPARTMENT OF PHYSICS<br>University of Dar es Salaam<br>P.O. Box 36063<br>DAR ES SALAAM<br><br>Attn: Prof. R.T. Kivaisi<br><br>Tel: 2410258/0744 767660<br>E-mail: Kivaisi@hotmail.com<br><br>Services: research, training and installation of solar PV technologies |
| 23. | KADETFU<br>BUKOBA<br><br>Attn: Muchuruza<br><br>Products: Promotion of solar cooker technology | 24. | DEPARTMENT OF ENERGY ENGINEERING<br>Faculty of Mechanical and Chemical Engineering<br>University of Dar es Salaam<br>P.O. Box 35131<br>DAR ES SALAAM<br><br>Attn: Prof. Godfrey R. John<br><br>Tel: +255 22 2410754/0744 319945<br>+255 22 2410500-9 ext. 2950<br>Fax: +255 22 2410380/2410112/2410029<br>E-mail: grijohn@uccmail.co. tz.<br>Services: research Energy Systems. |
| 25. | OLKONOREI SOLAR ENERGY PROJECT<br>P.O. Box 12785<br>ARUSHA | 26. | TANZANIA KOLPING SOCIETY<br>P.O. Box 1236<br>BUKOBA |

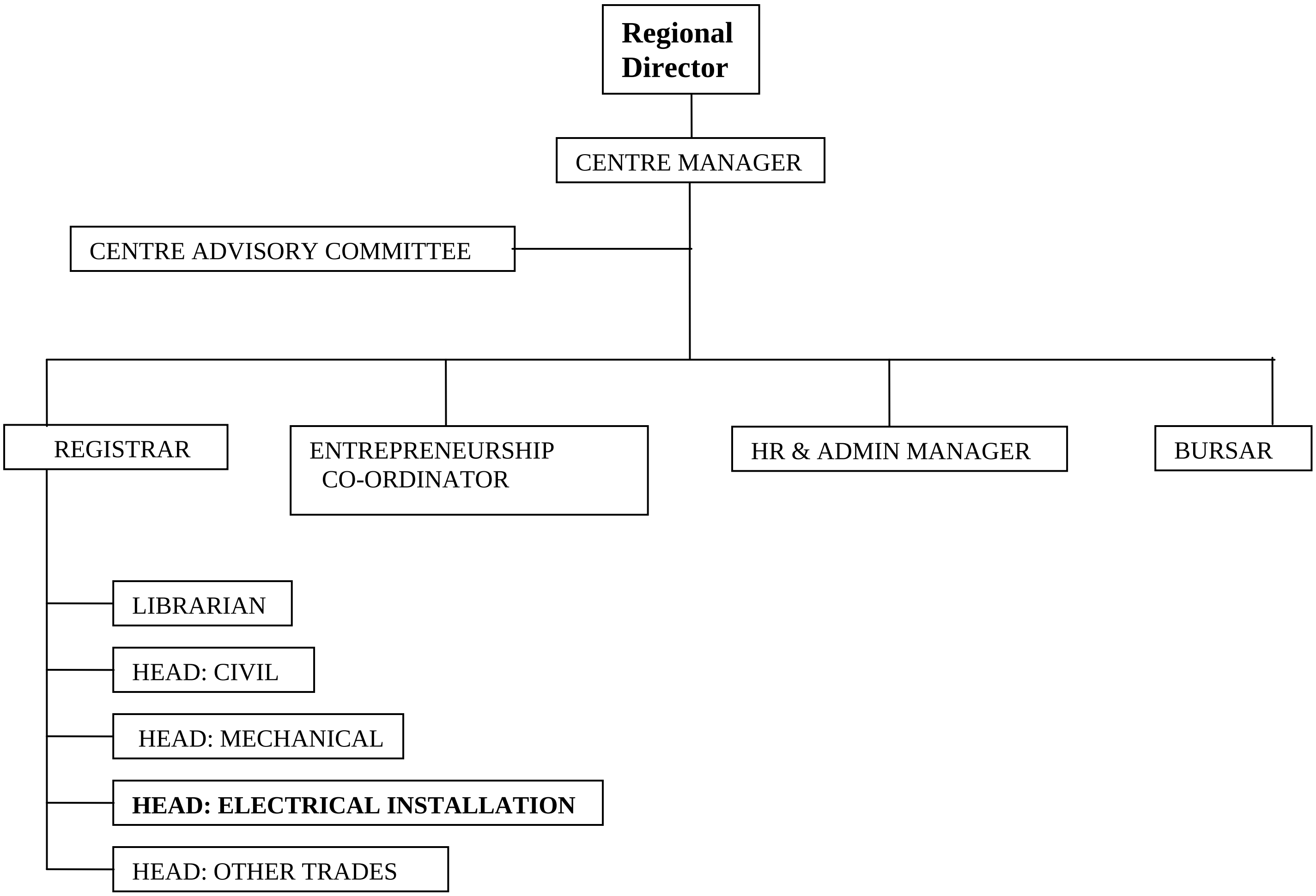
| | | | |
|---|---|---|---|
| | Products/Service: Installation of Solar PV Systems | | Tel:028 21236<br><br>Attn: Prudence Rwejuna<br>Products: Installation of solar PV systems. |
| 27. | KATOKE SOLAR ENERGY<br>Biharamulo<br><br>Attn: Father Bedel<br><br>Tel:<br>Products: Installation of solar PV system. | 28. | MINISTRY OF WATER<br>P.O. Box 9153<br>DAR ES SALAAM<br><br>Attn: Elizabeth Kingu<br><br>Tel: 022 2451451/2450391<br>E-mail: kingu@hotmail.com<br><br>Products: Installation of Solar water pumps |
| 29. | MINISTRY OF ENERGY AND MINERALS<br>P.O. Box 2000<br>Dar es Salaam<br><br>Attn: N. Mwihava<br><br>Tel: 022 2117156<br>E-mail: mem@raha.com<br>Or<br>hoseambise@yahoo.co.uk.<br>Role: Policy formulation, monitoring, data base for PV technology, Projects implementing agency, etc | 30. | DEPARTMENT OF AGRICULTURAL ENGINEERING<br>Sokoine University of Agriculture<br>P.O. Box 3000, Chuo Kikuu<br>MOROGORO<br><br>Attn: Dr. Silay<br><br>Services: Research on solar drying. |
| 31. | SOLAR INNOVATIONS OF TANZANIA (SOIT)<br>P.O. Box 12809<br>DAR ES SALAAM<br><br>Attn: Ms. Ruth Shija<br><br>Tel: 022 2668721<br>E-mail: sonnet@twiga.com<br><br>Products: Dissemination of solar cookers, solar drinking water purification plants and solar home systems. | 32. | GLOBAL ENVIRONMENTAL FACILITY (GEF),<br>UNDP<br>P.O. Box 9182<br>Dar es Salaam<br><br>Atn: Murusuri/ S Kessy<br><br>Tel: 022 21180808/2119088<br><br>Services: Provide grants for RE projects. |
| 33. | LEONARD D. KIPONDYA<br>P.O. Box 8080<br>DAR ES SALAAM<br><br>Products/Services: Installation of solar system | 34. | BUGHE KOLOWAH<br>P.O. Box 15875<br>Dar es Salaam<br><br>Tel: 0744 296071/0741 401928<br>E-mail: abuche@hotmail.com<br>Products: Installation of solar PV and backup power systems. |
| 35. | O.K. SOLAR ENGINEERING AND WORKS<br>P.O. Box 1346<br>Arusha – Tanzania<br><br>Attn: L.T. Kweka | 36. | AIC MEDICAL SERVICES<br>Mkula Hospital<br>P.O. Box 213<br>MAGU<br><br>Attn: SHIGELA MONISA |

| | | | |
|---|---|---|---|
| | Tel: 3446<br>Products: fabrication of solar water heaters. | | Tel: 50302<br>Products: Installation of solar PV systems for A.I.C. health facilities and solar water pumps battery chargin |
| 37. | CENTRE FOR ENERGY, ENVIRONMENT, SCIENCE AND TECHNOLOGY (CEEST)<br>P.O. Box 5511<br>Dar es Salaam<br><br>Attn: Mr. Hubert Meena<br>Tel: 022 667569<br>Product/Service: Consultancy | 38. | RESCO (T)) LTD<br>Shekilango Rd, White Star Invest. Bldg,<br>Opp. Mapambano Pr. School<br>P.O. Box 1517<br>Dar es Salaam<br><br>Attn: Azaria Mulinda<br><br>Tel:/Fax:+255 22 277180/0744 982004<br>E-mail: resco@resco.tz.com<br>Website: www.resco-tz.com<br><br>Products: Solar PV systems and Solar water heating Systems. |
| 39. | AGLEX COMPANY LIMITED<br>Cooperative Building Ground Floor<br>Lumumba Street<br>P.O. Box 9818<br>Dar es Salaam<br><br>Attn: Adroph Rwelamira<br>Finance & Admini. Manager.<br>Tel: 255 22 2185014/0744 268686<br>Fax: 255 22 2185015<br>E-mail: aglex@africaonline.co.tz.<br>Product; Radio communication | 40. | HAGI SYSTEMS CO LTD<br>P.O. Box 34536<br>Dar es Salaam<br><br>Tel: 2772966<br>Fax: 277 2960<br>Cell: 0744 320782<br>E-mail: hagi.tanzania@suntank.com<br>www.suntank.com<br><br>Products: Solar water heaters |
| 41. | DESTINATIONS ALL LIMITED<br>P.O. Box 2635<br>Dar es Salaam<br><br>Tel:/Fax: 213 1220<br>Off: 212 6891 213 5909<br>E-mail: destinations@intafrica.com<br><br>Products: Solar lanterns | 42. | .<br>TANZANIA SOLAR ENERGY ASSOCIATION (TASEA)<br>c/o TaTEDO<br><br>Chairman: Dr. C.Z.M. Kimambo<br><br>Service: Promotion of solar energy technologies |
| 43. | ENSOL (T) Limited<br>Dar es Salaam<br><br>Attn. Hamisi<br><br>Products: Installation services, solar PV system packages and solar PV system components | | |

# Appendix 2 Organisational Structure of VETA



## Appendix 3 Organisational Structure of Mwanza Centre



# Appendix 4 A List of materials, equipment and tools for Students' exercises

| | Item | Qnty | | Item | Qnty |
|---|---|---|---|---|---|
| 1 | Acid water (litres) | 100 | 42 | Junction box | 40 |
| 2 | Adjustable spanner | NA | 43 | Ladder | 20 |
| 3 | Ammeters ( 5 – 10 amps) | 10 | 44 | Lamp holder | 60 |
| 4 | Banking powder (packets) | 10 | 45 | Line tester | NA |
| 5 | Battery 12V/40 Ah | 10 | 46 | Lux meter | 1 |
| 6 | Battery boxes; Bandages (rolls) | 10 | 47 | Metal plate 50x50cm. | 20 |
| 7 | Battery terminals | 20 | 48 | Meter/Clamp | 1 |
| 8 | Black mat paint (litres) | 5 | | | |
| 9 | Energy efficient bulbs DC+AC (5, 8, 11, 15, 18, 22, 25)- watt | 80 | 49 | Modules -amorphous/ 20W | 10 |
| 10 | Burn cream (in tubes - 80 gm) | 5 | 50 | Modules: 40/20 Watt Mono/Poly | 40 |
| 11 | Cable lugs (variable sizes) | 100 | 51 | Multimmeter | 10 |
| 12 | Cable lug-tool | 10 | 52 | Nails, screws | NA |
| 13 | Calculator | 20 | 53 | Ohmmeter | NA |
| 14 | Charge controller (Fused) and non fused | 40 | 54 | One way switch | 40 |
| 15 | Claw Hammer | NA | 55 | Oscilloscope | 1 |
| 16 | Combination pliers | NA | 56 | Pencil | NA |
| 17 | Connectors | 40 | 57 | Pliers | NA |
| 18 | Continuity tester | NA | 58 | Pyranometer -Eppley | 1 |
| 19 | Converter | 20 | 59 | Ruler | NA |
| 20 | Cotton woollen cloth | NA | 60 | Screw drivers | NA |
| 21 | DC Cable various sizes 4 - 25 $mm^2$( various lengths in m) - | 200 | 61 | Shovel | NA |
| 22 | DC/DC converter | 20 | 62 | Side cutting | NA |
| 23 | Diodes 5, 10, 15, 20, 30 amp-rating | 100 | 63 | Solar light - DC | 20 |
| 24 | Distilled water (litres) | 40 | 64 | Soldering gun/iron | 20 |
| 25 | Drawing instruments | 20 | 65 | Soldering wire (25kg) | 10 |
| 26 | Drill machine | 5 | 66 | Sprit level | 10 |
| 27 | Earth electrode | 20 | 67 | Square boxes | 100 |
| 28 | Electrician knife | NA | 68 | Sulphuric acid ( litres) | 60 |
| 29 | Extension cord | NA | 69 | Switch sockets | 60 |
| 30 | Files | NA | 70 | Switch over relay | 20 |
| 31 | Fire extinguisher ($CO_2$) | 1 | 71 | Tape measure | NA |
| 32 | Fuses-5, 10, 15, 20, 30 Amps | 200 | 72 | Tooth brush | 50 |
| 33 | Glass/plastic Funnel | 20 | 73 | Torch | 10 |
| 34 | Gloves | 100 | 74 | Vaseline (50 gm) | 100 |
| 35 | Goggles | 20 | 75 | Water pumps | 1 |
| 36 | Hack saw | NA | 76 | Watt-meter | 10 |
| 37 | Hammer | NA | 77 | RMS meter | 1 |
| 38 | Hydrometer | 10 | 78 | DC power supply | 5 |
| 39 | Inclinometer and compass | 10 | | | |
| 40 | Installation board | 10 | | | |

| | | | | | |
|---|---|---|---|---|---|
| 41 | Inverters | 20 | | | |

# Appendix 4 B

## List of materials, equipment and tools for teaching

| | **Item** | **Qnty** | |
|---|---|---|---|
| | | | |
| | | | |
| 1 | Multimmeters (10 -15 Amp) | 2 | |
| 2 | Lux meter | 1 | |
| 3 | Battery 12V/40 Ah | 2 | |
| 4 | Modules - amorphous/ 20W | 3 | |
| 5 | Battery terminals | 4 | |
| 6 | Modules: 40 & 20 Watt Mono/Poly | 4 | |
| 7 | Energy efficient Bulb DC+AC | 5 | |
| 8 | Charge controller (Fused) and non fused | 2 | |
| 9 | Oscilloscope | 1 | |
| 10 | Pyranometer –Eppley type | 1 | |
| 11 | RMS meter | 1 | |
| 12 | DC Cable various sizes 4 - 50 $mm^2$ | | |
| 13 | DC/DC converter | 2 | |
| 14 | Drawing Instruments | 1 | |
| 15 | Hydrometer | 2 | |
| 16 | Installation board | 1 | |
| 17 | Inverter | 1 | |
| 18 | Sulphuric Acid ( litres) | 5 | |
| 19 | Water pumps | 1 | |
| 20 | Distilled water (litres) | 5 | |

# Appendix 5 Trouble Shooting Guide

| PROBLEM | CAUSE | HOW TO FIX |
|---|---|---|
| Battery state of charge is low<br><br>"Battery low" indicator comes on, low voltage disconnect turns OFF load, or battery state of charge is constantly below 10.5 volts | • There is no solar charge<br>• Battery acid low<br>• Bad connection to control terminal<br>• Defective (bad) battery or cell<br>• Loose or corroded battery terminal<br>• Dusty modules<br>• Overuse of system<br>• Battery will not accept charge<br>• Voltage drop between module and battery too high<br>• Defective controller | • Check and fix connection to module<br>• Add distilled water to cells<br>• Check for broken wires or loose connection<br>• Check state of charge of each cell. If there is a significant difference between cells, replace or repair<br>• Clean and tighten battery terminals<br>• Clean modules<br>• Leave appliances and lamps "OFF" for a week to allow recharging or recharge battery by other means<br>• Find out age and history of battery. Replace if old, or if ruined by careless use.<br>• Check voltage drop. Replace cable with larger diameter if required<br>• Check operation of controller with dealer.<br>• Replace or repair if necessary |
| No solar charge<br><br>Solar charge indicator does not light up during the day.<br>There is no current in the wires from module. | • Short circuit along wires to modules<br>• Loose connection in wires connecting battery to the control<br>• Blown fuse<br>• Thick coating of soot or dust on module<br>• Broken module | • Locate and repair short circuit<br>• Locate and fasten loose connection<br>• Clean module with water and soft cloth<br>• Check for broken cells, broken glass, or poor connection inside module. Replace solar module. |
| **Appliances or lamps do not work**<br><br>One or more appliance fails to come ON when connected. | Lamps<br><br>• Bad tube or globe<br>• Bad ballast inverter<br>• Bad connection in wire<br>• Switch is "OFF"<br>• Tubes or globes have very short lifetimes | Lamps<br><br>• Replace with new tube or globe<br>• Replace ballast inverter with new one<br>• Locate broken or loose wire and repair<br>• Turn switch "ON"<br>• Check voltage of system: too low or too high? (system Voltage is always lower when load is ON than without load) |
| | Appliances<br>• Bad connection in wire<br>• Switch is "OFF"<br>• Bad socket<br>• Broken appliance | Appliances<br>• Locate broken or loose wire and repair<br>• Turn switch "ON"<br>• Check socket. Replace if bad<br>• Check fuse in socket |

| | | |
|---|---|---|
| Blown fuse<br><br>When the fuse is removed,<br><br>the wire inside is found broken. | • Short circuit along wire to solar cell module, battery or load<br>• Fuse was too small<br>• Lightning or power surge | • Locate and repair short circuit<br>• Use fuse 20% larger than combined power of loads<br>• Replace fuse<br>• Determine continuity |

# Appendix 6 Workshop Training Manual

| | Course Module | Tasks |
|---|---|---|
| 1 | ***Fundamentals of solar energy*** | 1) Take the two metal plates ( size 50 cm x 50 cm) supplied to you and describe their appearances<br>2) Expose the plates to the sun for one hour and measure the temperature of plates using a thermocouple. Take the readings.<br>3) Use the black paint provided and paint one of the metal plates and repeat task (2) above. How do you compare the two values?<br>**4)** Place two similar metal pans half filled with the same quantity of water to each metal plate, and observe the temperature rise of both pans. Explain your observation. |
| 2 | ***Solar cells, modules and arrays*** | You are provided with three PV modules for the following tasks: (the instructor should label the modules, A,B & C to distinguish them according to sizes and module types).<br>(i) Use a tape measure to determine the – geometrical sizes of the modules.<br>A [ ] B [ ] C [ ]<br>(ii) Describe the physical appearance of each module.<br>(iii) Identify module type i.e. monocrystalline, polycrystalline and amorphous.<br>A ______________ B _________________ C____________<br>(iv) Identify the cells that constitute the module and determine the number of cells in each module.<br>(v) Draw on a piece of paper the arrangement of the cells in the modules.<br>(vi) Turn the modules upside –down and identify the positive and negative terminals of the modules by opening the junction box. |

| | | |
|---|---|---|
| | | (vii) Use a watt – meter to determine the irradiance at the site of measurements (outside the building). Record the readings at the beginning and after taking measurements in each of the following tasks:<br><br>(viii) Place the modules outside the building, where there is sufficient sunlight and measure the ***open circuit voltage*** for each module and records the values.<br><br>A____________ B____________ C____________<br><br>Comment on the values obtained.<br><br>(ix) Repeat steps (viii), measure the ***short circuit current*** of the modules and record the values :<br><br>A______________ B_____________ C___________<br>Comment on the values obtained<br><br>(x) Connect two modules in parallel and take reading as in (vii) and (viii) above and record the reading:<br>(a) – Short circuit current _______________<br>(b) - Open – circuit voltage ______________<br>Comment on the values obtained and compare with those of (viii) & (ix)<br><br>(xi) Connect all the three modules in parallel and determine the short circuit current and open circuit voltage.<br>(i) Open circuit Voltage _____________<br>(ii) Short circuit current________________<br>Comment on the values and compare with those obtained in x<br><br>(xii) Arrange two modules in series and use multimeter to determine<br>(i) Open circuit Voltage____________ |

| | | |
|---|---|---|
| | | (ii) Short circuit Voltage ___________<br><br>(xiii) Arrange all the three modules in series and determine:<br>(i) Open circuit voltage __________<br>(ii) Short circuit current ___________<br><br>(xiv) Arrange module A or B as in (vii) above and use a piece black cloth or plastic sheet to cover completely one of the module cells. Determine:-<br>(i) Open circuit Voltage ___________<br>(ii) Short circuit current _____________<br><br>xv. Repeat xiv with module C and determine<br>(i) Open circuit voltage ____________<br>(ii) Open circuit current ______________<br>Comment on the values obtained in (xiv) & (xv).<br><br>(xvi) Arrange your modules A & B parallel and determine the<br>(i) Open circuit Voltage _____________<br>(ii) Short circuit current _____________<br>When module A is completely covered with a black plastic sheet or black cloth.<br><br>Repeat the above setting and record your values when module B is covered completely with a black plastic sheet or black cloth. Record:<br>(i) Open circuit voltage _____________<br>(ii) (ii) Short circuit current _______________<br><br>(xvii) Arrange the module A & B in series and determine the:<br>(i) Open circuit voltage ______________<br>(ii) Short circuit current ________________<br>When module A is completely covered with a black plastic sheet or cloth, repeat the above set – up and determine:-<br>(iii) Open circuit voltage ____________<br>(iv) Short circuit current ______________<br>When module B is completely covered with black cloth or |

| | | |
|---|---|---|
| | | black plastic sheet,<br>(xviii)- Repeat (xvii) and determine:-<br>(i) Open circuit voltage ________________<br>(ii) Shot circuit voltage________________ when only one cell of any of the modules is completely covered with black cloth. |
| 3 | ***Solar cells and module characteristics*** | Perfect operation of a solar module is best demonstrated by measured current-voltage characteristics. Equipment is commercially available which allows measurements to be made and subsequently analyzed with a computer. As this equipment is not readily available, a simple method to measure a solar module with simple laboratory tools can be applied. The open circuit voltage Voc and short circuit current measurement, Isc can be directly measured with an appropriate multimeter. To determine the current-voltage characteristics, resistance of different values must be applied to the module. Of course these must be able to dispense the resulting power. As the working point of the solar module is typically near the MPP and partial shading has the greatest effect on the characteristics curve there, several measurements should be made near this point in particular.<br><br>1. Setup a circuit and obtain data for IV characteristics of the given module. Plot your data on a millimeter paper and read the position of MPP. Use the raw data to calculate the maximum power output of the module. How does this figure compare with the rated value displayed by the manufacturer? Comment on your results.<br><br>2. Connect modules in different configurations:<br>(i) Connect 2 similar modules in series<br>(ii) Connect 2 similar modules in parallel<br>3. Determine the IV characteristics in both cases (series and parallel connection) and determine maximum power |

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| | | **4.** Place two similar modules at different temperatures, one module at 60° and the other at near room temperature.<br><br>Determine the module output voltage at the beginning of the task and 15 minutes later. State the effect of high temperature of the modules on the operation of the module. |
| 4 | ***Storage batteries and accumulators*** | You are supplied with one battery,<br><br>1) Describe the physical appearance of the battery. Is the battery housing opaque, transparent or translucent? Put it on a wooden plate<br>2) Identify the two limit levels of the electrolyte. Read the marked levels.<br>3) Open the battery by unscrewing the hole caps and describe what you see through the holes<br>4) Measure the voltage between the terminals and record the reading.<br>5) Count the number of cells in your battery and record your reading.<br>6) (i) Take the hydrometer supplied to you and identify the areas marked red, white and green;<br>(ii) What does the three regions signify<br>(iii) Take reading of the hydrometer in the middle of the three areas, identified earlier<br>7) You are supplied with four glass/plastic containers each half filled with sulphuric acid of different specific gravities/densities. Use the hydrometer provided to slowly suck in enough acid so that the weight inside the hydrometer floats feely;<br><br>(i) Determine the specific gravity of the liquid in the four containers;<br>(ii) Comment on the different values obtained;<br>(iii) Take concentrated sulphuric acid provided and determine its specific gravity;<br>(iv) Mix concentrated sulphuric acid with distilled water |

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| | | until the hydrometer reads 1.25.<br>(v) Half fill plastic/ glass containers with distilled water. Determine its specific gravity.<br><br>8) Use the funnel supplied to you and fill each cell with sulphuric acid of the recommended specific gravity to the level marked Max.<br>9) Feel the housing of the battery with your hands and describe how do you feel<br>10) Leave it to rest for two hours and feel again with your hands. Describe your feeling.<br>11) Use an analogue voltmeter, measure the voltage across the battery terminals. Take down the reading.__________________<br>12) Secure the battery terminals to the battery.<br>13) Identify polarity of the battery.<br>14) Look through the transparent container of the battery and check the level of the electrolyte. Has the level changed from the initial one?<br>15) Look through the transparent housing and describe the colour of the metal plates.<br>16) Battery cable loops:<br>(a) Cut two 6 mm² wire of length 60 cm and strip the two ends to accommodate the two lugs provided.<br>(b) Insert the two ends into the lugs and press them using the tool provided to secure the cable ends fixed tight into the lugs.<br>Make two move cables and use them for your experiment.<br>17) Use the 40-watt – module provided, place it outside where there is enough sunshine. Connect the terminals of the module to the terminals of the battery. Ensure to maintain the correct polarity.<br>18) Take reading of the battery voltage using a multimeter before connecting the module – wires to the battery.<br>19) Take reading after every 15 minutes<br>20) Remove the caps of each cell before charging.<br>21) Look through the electrolyte and describe your observation. |

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| | | 22) After the battery has charged for half a day, perform the following tasks.<br><br>(i) Disconnect the battery from the PV module.<br>(ii) Leave the battery to rest for about 30 – 45 minutes and measure voltage.<br>(iii) Connect two batteries in series and measure the voltage.<br>(iv) Arrange two batteries in parallel and measure the voltage.<br><br>Note: (a) in series connection the voltages are added.<br><br>(b) In parallel connection the currents are added.<br><br>Set up a circuit to light a 12V and 24V bulbs<br>A drawing is required.<br>23) Leave the system to work for 3 hrs while taking the reading after every 15 minutes.<br>24) Plot a graph of voltage versus time<br>25) Use a hydrometer to measure the specific gravity of the electrolyte in the battery. |
| 5 | ***Charge controllers and load management*** | 1) Identify the various parts of a controller<br>2) Identify the polarity of the battery, module and load on the regulator<br>3) Prepare appropriate cables for connecting the battery terminals to the controller<br>4) Prepare appropriate cables for connecting the module terminals to the controller<br>5) Prepare appropriate cables for connecting the lead to the controller<br>6) Make connection to the module, battery and dc loads |

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| | | 7) Allow the system to charge for a few hours and monitor the charging voltage and irradiance. |
| 6 | Inverters | 1) Connect the inverter to a dc source<br>2) Measure the output voltage of the inverter using RMS Multimeter and an ordinary multimeter. Explain any differences in the values measured;<br>3) Connect the output terminals of the inverter to an oscilloscope and observe various ac wave form;<br>4) Connect various loads to inverter and investigate the effect of the lead on the output power;<br>5) Determine the lowest working voltage of the inverter;<br>**6)** Install an inverter charger |
| 7 | Converters | 1) Connect the converter (DC/DC) supplied to you and measure its output voltage.<br>2) Determine the limiting current |
| 8 | Photovoltaic system sizing | 1) Draw a chart<br>2) Determine meteorological data at a site<br>3) Determine the PV system voltage<br>4) Determine the energy requirement of a typical household<br>5) Determine optimum number of components as well as the size of cables required for installation of a household PV system. |
| 9 | Planning for PV installation | You are required to design a small PV system for a shopkeeper living in Mwanza. He has a house measuring 15 m by 20 m, which has four rooms, a corridor, a toilet, kitchen, living room and a store. He would like to have light in his house. In addition he has a colored TV (21"). He has also a radio, which is currently being powered by 6 dry cells.<br>You may use any data or information provided in the lecture notes.<br>1) Make a site visit and identify the direction of the modules for obtaining maximum output |

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| | | 2) Produce sketches and drawings supporting the direction and location for installation of the solar arrays.<br>3) Estimate cost of materials and components and labour charge cost. |
| 10 | Wiring and fittings | Install the PV solar array with all necessary accessories for controlling the loads. |
| 11 | Maintenance and service of PV systems | Clean the battery once every month. Carry the battery outside when cleaning it to avoid spilling acid. Keep plenty of water nearby to rinse spills. For safe and proper cleaning, proceed as follows:<br><br>1. First, switch OFF or disconnect the solar charge.<br>2. Disconnect the battery from the leads, and remove the terminals from the posts.<br>3. Clean the top and outside of the battery with water (do not allow water to enter the cells).<br>4. Clean the terminals and posts until they are shiny. If the terminals are corroded (i.e. if they are covered with white powder), clean them carefully using a solution of baking soda and water. If a terminal has been badly corroded replace with a new one.<br>5. Replace the clean terminals and tighten the bolts. Apply petroleum jelly or grease to connected terminals.<br>6. Once every month, check and top up electrolyte in the battery. Remove the caps of each cell one at a time and check the level of the electrolyte. Acid should be within two centimeters (cm) of the top of the battery. If you can look inside the batteries, check the plates to see their condition. Make sure the acid is well above the level of the plates.<br>7. Since modules do not have moving parts, they require minimum maintenance. Keeping the glass surface clean is the most important task.<br>8. Once every year, inspect the wiring, fuses, indicator lamps and switches. |

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| | | (iii) Check the tightness of screws on all connector strips, controls, switches, etc. Make sure that no bare wire is visible.<br>(iv) Inspect system wire runs for breaks, cracks in the insulation or places where it has been chewed. This is especially important for old or exposed wire.<br>(v) Inspect junction boxes to make sure they have not become homes for insects and if they in an exposed location, to make sure they are still water tight.<br>(vi) Check switches to make sure they are operating properly.<br>(vii) Check the indicator lamps on the control. The solar charge indicator should come ON when the sun is up. If it is not ON; check to see if batteries are being charged. Check whether the other LED indicator lamps are working (i.e. battery full and low voltage).<br>(viii) Check grounding wires to make sure they are still intact. |
| 12 | Appliances | 1) Install the halogen lamp and fluorescent lamp. Then compare the light intensity of the two lamps by using lux meter.<br>2) Install an electric fan |
| 13 | Cost consideration | 3) Identify other alternative sources of energy.<br>4) Compare the cost of energy produced by PV system and the other alternatives<br>5) Identify the cost of PV components and compare the cost manufactured by various manufactures<br>6) Propose the best cost effective combination of components bearing in mind the quality of the components. |
| 14 | Lightning protection in photovoltaic systems | Install the earthing system to the PV system for protection purpose. |

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| 15 | Water pumping | 1) Identify various water pumps and their technical specifications<br>2) Work out the water requirements for a typical village<br>3) Design an appropriate PV system for water pumping<br>4) Install an array for a small pump<br>5) Install a water pump<br>6) Identify and install appropriate power conditioning for water pumping |
| 16 | Commissioning and customer care | Keep all information about the system in a safe place, where it can be referred to when necessary. Update it periodically. Most of the important information can be kept in one ledger or file. Large institutional systems work better when someone is given the job of maintaining the system and keeping records up to date. This information includes:<br><br>• Hand over circuit diagrams and maps showing the location of batteries, loads, wire runs, junction boxes, and buried cables to the client<br><br>• Hand over manuals, warranties and manufacturers' specifications for system components to the client<br>• Prepare a logbook with battery state of charge and history, installation dates, repairs, equipment replacement and system maintenance and let the client fill in the details as instructed. |