

***The United Nations Development
Programme- PV Mwanza Project***

Report on the

**Evaluation of the Photovoltaic
Training Programme at VETA-
Mwanza Centre**

Final Report

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Acknowledgement

Monitoring and evaluation of the Solar PV training programme at VETA-Mwanza Centre forms part of the project on the Transformation of Rural PV Market in Tanzania in an attempt to contribute to tackle barriers to secure PV promotion in rural areas of the country. UNDP Mwanza PV Project has requested an expert familiar with Solar PV curriculum to evaluate the PV training programme after it has been introduced at the Centre in Jan 2006.

The expert appreciates the co-operation and guidance received from the UNDP Mwanza PV Project, the VETA-Mwanza Centre staff, whose contributions brought about valuable inputs to the evaluation. Specifically, the team would like to acknowledge the inputs of the Mwanza Centre Manager, Mr. John B. Mshanga and the staff of the Electrical Installation department as well as some the graduates of the programme, who provided additional information so as to enrich the evaluation. The cooperation and logistical support from Mr. Mzumbe Musa of the PV Project in Mwanza, is highly appreciated.

I am also obliged to express my gratitude to my employer, the University of Dar es Salaam for granting permission and encouragement to take up this assignment.

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1. Background

1.1 Introduction

Training for technicians on photovoltaic technologies in Tanzania has not been well institutionalised within the accredited vocational training institutions. There are a few 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.

It is has been reported [1] that a number of problems have been experienced with regards to PV system designs, installation as well as operation of PV systems. Lack of knowledge and skills on the production and installation of modern PV technologies to harness the wealthy resource 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 such energy services have been hampered by lack of skilled personnel among others to maintain and operate such technologies.

Thus the Government of Tanzania through MEM/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 address especially in Mwanza region and, where appropriate, institute a well-established PV training programme(s) for trainees in a number of vocational training institutions.

For smooth running of PV systems, it is imperative that training of technical personnel at various levels is made available and on a scalable

size. As an initial strategy, a curriculum was designed and integrated into an existing VETA programme for artisans. In this way one could expect a multiplying effect depending on the demand as the PV market grows. VETA Mwanza Centre was chosen on the basis of its 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. The pilot programme in Mwanza is expected to be replicated in other parts of the country.

1.2 Terms of Reference (ToR)

The PV Project in Mwanza has invited an expert familiar with solar PV curriculum for technicians to make an evaluation of the Solar PV training programme after it has been introduced at VETA, Mwanza Centre since Jan 2006. The curriculum had been incorporated into the domestic electrical installation trade course for VETA trainees. Therefore the objective of the present evaluation is to assess the technical capabilities gained by the students especially the practical aspects of PV systems design, sizing, installation, maintenance and repair. The adequacy of the facilities including time allotted for the whole course or to different components, training materials, methodologies and/or Training of Trainers courses be examined and means of improvement recommended.

The expert was given as his Terms of Reference (TOR) the task of evaluating the solar PV training programme. Subsequently the expert re-interpreted the TOR into the following tasks:

- To review the time schedule of the course and the relative time allotted to different components and staff members,
- To determine adequacy of the various components of the programme for effective delivery of teaching and learning process,
- To review the examination papers and assess suitability and coverage of the curriculum,

- To review and assess the results of the theoretical and practical examinations,
- To interview some selected students, to identify the strengths and weaknesses of the training process and discuss the results with the respective instructors,
- To prepare a draft report including the evaluation of the results of the training process and the recommendations for its further improvement and perfection.
- To present the main findings in a meeting with PIU, VETA management and the course instructors.
- To finalize the report and submit an electronic copy to the project.

It was also important for the consultant to review the programme as a whole with a view to assess its future sustainability.

1.3. Methodology

In line with the terms of reference, the assignment was divided into three parts:

- (a) Review of various documents pertaining to the assignment, including the Solar PV curriculum, examination papers, work-plan etc. The Curriculum and the work plan for implementation of the programme at VETA, Mwanza Centre served as benchmark for the evaluation.
- (b) The fieldwork to complement the aforementioned tasks involved visiting the relevant institution i.e. VETA Mwanza Centre. The study visit in Mwanza was focused to examine and assess field situation regarding the implementation of the Solar PV training programme, as well as interviewing the first graduates of the programme.

- (c) Subsequent to the study visit phase, the Solar PV expert employed both structured and unstructured questionnaires and interviews that were guided by the expert to obtain more information on the programme. The pertinent Data Collection Instruments (DCIs), which included both closed and opened-ended questions, were tailored for three main target groups. The target groups in question included:
- (i) *Instructors* of the programme in which information was sought on a number of issues patterning to the implementation of the teaching syllabus; coverage of the course contents in relation to the time allocation, adequacy of mode of delivery of both theoretical and practical sessions, human and infrastructure support to the programme, staff competencies, students assessments, problems encountered in the course of implementing the programme, etc.
 - (ii) The *graduates* of the programme were consulted with a view to gather their reactions about the overall conduct of the training programme. The expert wanted to know how the programme was overall rated in terms of administration, whether it met their expectations, the scope of the course materials, duration of the course in relation to the course contents, the media of communication, teaching and learning environment, whether the course objectives were achieved, etc.
 - (iii) Communication was also made with the *administration* of the Mwanza Centre where the expert wanted to learn the extent at which the Centre management supported the training programme, whether the examinations were set and administered according to the plan, whether the graduates have been issued with their certificates and determine what type of certificate that VETA will issue to capture the professional content of the programme and future sustainability of the programme.

The evaluation exercise took place on August 11, 2006 and lasted for five days. During this period the graduates had already left the Centre but the consultant was able to contact 5 out of 13 graduates for the interview.

1.4 Structure of the Document

The following chapter give a brief description of the design of the Solar PV training programme by outlining the major components of the programme; including the structure of the training programme, syllabus, human resource and infrastructure capacity development, teaching and learning environment, objectives of the programme, assessment and certification. Chapter three provides findings of the implementation of the programme since its inception in January 2006, assessing each individual element of the PV training programme, thereby identifying weaknesses and strengths of the programme. The report concludes with recommendations on measures to be taken to improve the performance of the programme.

2. Design of the Photovoltaic Training Programme

2.1 Structure of the PV Training Programme

The PV training programme was initially targeted at vocational training institution, VETA Mwanza Centre aiming at creating a quality standard leading to more confidence of the customer in PV technologies and therefore consequently support the potential PV market in Tanzania and elsewhere. The entry point qualification for the PV training programme was that the trainees must have successfully completed level one of the electrical installation trade course, which encompasses an introductory course on solar energy or its equivalent. This approach would allow an enabling learning environment for the trainees in the new PV programme. In this way the trainees would have the opportunity to be exposed to the subject and therefore be in a position to adjust smoothly with specialized PV topics at level II of their study. The basic principles of solar energy and solar energy conversion formed a good starting point.

The duration of the course was estimated to be about six months with an initial enrolment of about 15 trainees. The chart in Figure 1 shows the distribution of the trainees at various levels of study.

The delivery of the PV training programme was divided into two main parts, namely, theory and workshop training. Each course module was treated separately in such a way that it was self-contained. The theory part was mostly 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 were provided. For each workshop task, the instructor provided the trainees with all the necessary steps required to complete the assignment.

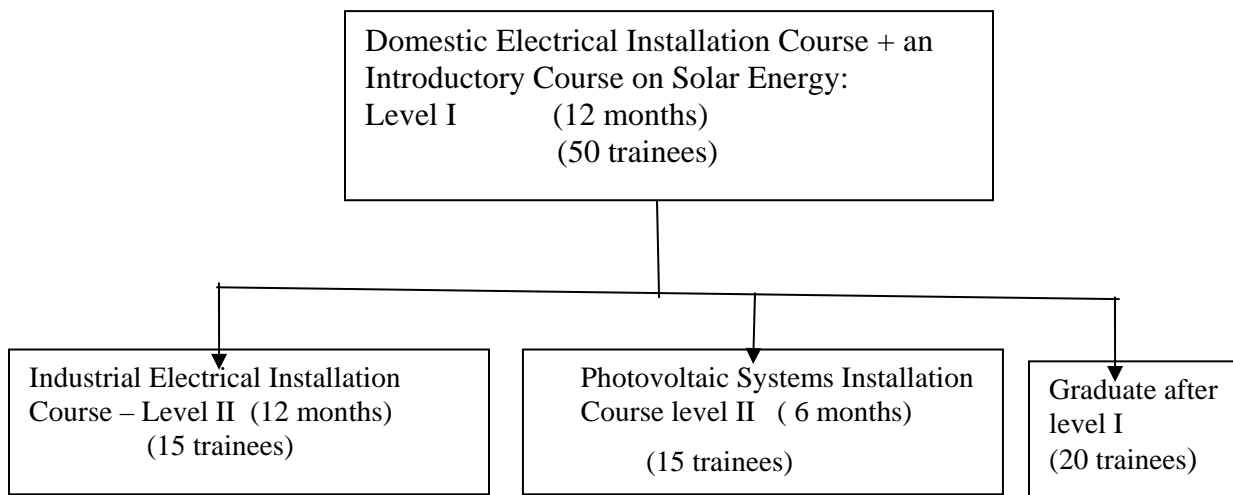


Figure 1. Layout of the proposed integration of the PV course-module into the Electrical Installation Course.

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

2.2 Human Resource Capacity Development

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

In order to start implementing the training programme, the Centre through the assistance of the UNDP Mwanza PV Project embarked on an enhancement capacity building programme aiming at equipping three instructors with the necessary PV skills so as to be able to train trainees under the PV programme. A PV course, tailored according to the curriculum coupled with sufficient teaching, learning and workshop materials was implemented for effective implementation of the programme.

2.3 Infrastructure Capacity Development

It was envisaged that the introduction of the PV training programme would lead to an expansion in student enrolment. As a conservative estimate, it was anticipated that the enrolment would increase from the current 15 to at least 30 trainees in year two of their study. To cater for such an expansion the UNDP PV Mwanza PV Project assisted the centre in the acquisition of additional workshop equipment, materials, PV components and tools. This was particularly important since the goal of the PV training programme was to offer more workshop practice than theory. Furthermore UNDP Mwanza PV Project assisted the Centre in the renovation of the existing pump house, which was not being utilized to cater for additional space for the PV training programme.

2.4 Objective of PV Training Programme

The overall objective of the PV training programme was 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.

2.5 Teaching and Learning Materials

Teaching and learning materials for the PV training programme were based on three main textbooks, manuals and several references. Due to the rapid growth of the PV technology, the instructors were encouraged

to make use of the internet for additional teaching materials. Below is a short-list of relevant teaching materials:

Books and manuals

- (i) R.T. Kivaisi (2005), PV training manual compiled for the PV training programme (168 pg),
- (ii) RT Kivaisi (2005), PV training workshop manual,
- (iii) Mark Hankins (1995) Small Solar Electric Systems in Africa, Commonwealth Science Council, Marlborough House, United Kingdom,
- (iv) Steven J. Strong and William G. Scheller (1993), the Solar Electric House, Sustainability Press, Still River, Massachusetts, USA,
- (v) Fraunhofer Institute for Solar Energy Systems (1995), Photovoltaic Systems, Freiburg, Germany.

2.6 Assessment and Certification

The continuous assessment for the trainees followed the VETA assessment procedure, which is on the competence based approach. However, unlike the other vocational training programmes, VETA had to appoint a team of experts for setting examination questions as well as moderation of the examination papers before they are administered to the trainees at the end of the programme. Furthermore VETA headquarters are responsible for the design and issuing certificates to the graduates of the programme.

3 Evaluation

The evaluation of the PV training programme was focused mainly on the review of the implementation of programme design and assess the adequacy of the various components of the programme to achieving the intended goal and output.

3.1 Structure of the Syllabus

Initially it was planned that the PV training programme would be integrated into the VETA-domestic electrical installation courses in such a way that the course would be taught to trainees after successful completion of level I of the electrical installation course. This element was well and smoothly incorporated into the existing domestic electrical installation trade course.

It was anticipated that most applicants would have basic secondary school education qualification although this pre-condition was not necessary. However, the selection of the candidates was limited to those who showed interest to take up the course on solar photovoltaic. The number of applicants was only 15 out of 50 trainees who graduated at level I of the electrical installation trade course. They were all enrolled into the programme, as this was just the optimum number of trainees required for the program. In the course of the implementation of the programme, two trainees dropped from the course after they had secured jobs in town.

The mode of delivery of the programme was based on class-instructions (theory) and workshop training. Each topic of the syllabus was assigned a specific time to complete but at the implementation phase it was realized that some topics needed more time than others. The following topics were identified and recommended to be allotted more time:

- Fundamentals of solar radiation,
- Solar cells, modules, array and application,
- Solar cells module characterisation,
- Storage batteries,
- Appliances,
- Photovoltaic system sizing,
- Planning and PV system installation.

However when some of the graduates of the programme were asked to indicate areas of the syllabus that they found particularly useful and interesting, most of them centred on the following topics:

- PV system sizing,
- PV system Installation,
- Storage batteries,
- Solar cells modules and array,
- Energy management.
- Maintenance and commissioning.

When the instructors were asked if all the topics were covered in the syllabus, they responded that all topics were covered except pumping. This topic was not taught mainly due to lack of a demonstration kit.

Apparently looking at the topics that required more time for the instructor to deliver in class, most of them were the ones in which the graduates have indicated as their most favourable topics. This clearly indicates the need to revisit the syllabus in order to allow more time for the identified topics. When asked what should be done to improve the programme, all the interviewees showed concern on the complete absence of field practical training. It was recognised that since the programme was designed to produce professionals in the field of solar photovoltaic, it was felt necessary for trainees to be exposed to field environment. This component would have added value to the programme and consequently be able to attract more applicants in subsequent years.

It would also expose the trainees for opportunities that exist in the employment market.

As for the workshop training, it was also noted that some topics needed more time and in particular to topics such as:

- PV system design and installation and
- PV system diagnosis and testing.

It was observed that the number of applicants to the programme was quite small, i.e. 15. The reason for this could not be established although we are aware that there were many level I domestic electrical and installation graduates out in town and one would have expected more applicants to the programme. A larger number of applicants would have assisted the Centre to select from a wide range of candidates for the programme. In order to address this situation in future, it is important for the Centre to market the programme more vigorously through various means and more important to sensitise prospective trainees on the challenges and opportunities on the PV- technology to serve the rural communities as well as job-opportunities in this field.

The overall assessment of the course syllabus, enrolment level, course delivery and programme integration was adequate to yield the intended output. However, further adjustments are needed to improve the structure of the syllabus in order to address some of the weaknesses observed during the implementation of the programme. It is therefore recommended that:

- (i) Additional time be allocated to the identified theoretical topics as well as workshop training modules. This move will however have an implication on the duration of the course itself,
- (ii) There is need for the Centre to vigorously market the PV programme including sensitizing prospective trainees with a view to attract more applicants,

- (iii) There is need to design and incorporate field practical training in the programme. However, the practical aspect of this component should as far as possible involve the private sector who are dealing with the PV technology and in particular those stationed in Mwanza Region,
- (iv) There is need to provide additional workshop training materials commensurate to the theoretical topics in the syllabus (see the attached list in appendix 4).

3.2 Human Resource Capacity

The instructors of the PV-Programme are also responsible for offering the other trade courses on domestic electrical installation at levels I & II. In designing the PV- programme it was recommended that additional staff would be required to shoulder the anticipated additional teaching load as a result of the integration of the PV-Programme in the current domestic electrical installation course.

In preparation to the implementation of the PV training programme, VETA- Mwanza Centre earmarked all the three instructors of the department of Domestic Electrical Installation¹ to be trained for the programme. This was done through the generous assistance of the Mwanza- PV Project where the identified instructors were given a crash training of trainers (TOT) programme lasting for two weeks. The titles of the training modules are given in Appendix 2. The TOT programme was later followed by a one day planning meeting where all the elements of the PV-training programme were reviewed and allocation of topics distributed to the respective instructors as shown in Appendix 1.

The programme started as planned in January 2006. In the course of implementing the PV training programme, one of the trained instructors declined to participate in the programme and therefore only two instructors were available for the training. This had serious implication on the teaching load of the instructors given the fact that they had to

participate in the other trade courses. The reason for declining could not be established.

VETA Mwanza Centre having realized the magnitude of the problem as narrated in the previous paragraph, it hired an additional staff to shoulder workload for the other programmes in electrical installation levels I & II. This arrangement made it possible for the remaining two trained instructors to devote more time to the PV- training programme.

The intervention made by the VETA Mwanza-Centre by hiring an additional staff to strengthen the Department of Electrical Installation has enabled the programme to run smoothly although with less flexibility as earlier planned. This situation poses a risk on the continuity of the programme and therefore the centre should develop strategic intervention to avoid this kind of situation to happen again.

The assessment of the adequacy of human resource for the programme was of the right level, thanks to the Management of the Centre for providing an additional staff to strengthen the Department. In view of the above it is recommended that:

- (i) The trained instructors be given an advanced course on PV technology and be exposed to field environment. This will give them additional competence in some topics of the syllabus as well as field-working environment.
- (ii) There is need to train more staff on PV technology in other VETA centres so as to allow a bigger pool of trained staff from which instructors can draw from.

3.3 Teaching and Learning Environment

To implement the PV training Programme effectively, it was important to provide a conducive learning environment for which the trainees could

tape for successful implementation of the programme. Apparently only few titles of teaching materials were available for the instructors and therefore the trainee depended on lesson-notes and laboratory instructions written on slip charts. A few titles were made available for instructors and these included:

- Mark Hankins, Small Solar Electric Systems in Africa, Commonwealth Science Council, Marlborough House, United Kingdom, 1995.
- PV Training manual: Compiled by R.T. Kivaisi, 2005.
- C.Z.M. Kimambo and R.M. Magembe; Umeme wa Jua na Matumizi yake, 2005.

Although an overhead projector was provided by the Mwanza PV project, it was not extensively used as expected due to unavailability of a white screen. Since most instructions were given in the PV – laboratory, the environment was not appropriate for overhead projection. The laboratory was constructed in such a way that it has no walls and therefore allowing too much light into the PV laboratory that interferes with the overhead projection.

Furthermore with assistance of UNDP – Mwanza PV project, the Centre had acquired about 90% of the recommended training materials and equipment. However, it was also found that a few items have not yet been procured and delivered (appendix 4)

The medium of instruction used in the classroom as well as in the laboratory was a mixed mode of English and Kiswahili. This was the mode that was highly preferred by the graduates. As the trainees had secondary or primary school education, the mixed mode ensured that both groups comprehended adequately the course contents. However it was important to stress on English writing because they were required to answer the examination papers in English.

With respect to teaching and learning environment, there was evidence that the programme lacked a number of learning tools, including:

- (i) relevant books for the trainees,
- (ii) relevant learning materials in the library,
- (iii) Inadequate demonstration kits (e.g. mini water pump, electric fan, small ac and dc motors, etc),
- (iv) a photocopier to duplicate training materials for the students,
- (v) a computer and a printer,
- (vi) outdoor PV demonstrations.

The overall assessment of this component reveals that despite the inadequacy of teaching and learning tools for the trainees, the programme was able to achieve its objective. However, there is need to improve the conduct of the programme by availing the necessary and sufficient learning materials as well as out door demonstration kits.

In view of the above it is recommended that:

- (i) There is need to improve the teaching and learning environment by providing enough learning and demonstration materials.
- (ii) There is need to provide duplication equipment for mass production of relevant course notes for the trainees.
- (iii) There is need to provide a computer for word – processing as well as surfing for up-to date teaching and learning materials from the Internet.

3.4 Infrastructure Capacity

The most important needed infrastructure for the implementation of the programme was to provide adequate training space for about 15 trainees. This was achieved by having a pump house, which was no longer in use, renovated and converted to a PV laboratory. Furthermore, an open shed for outdoor experiments was constructed adjacent to the previous pump house. This was achieved with funds from UNDP – Mwanza PV – Project. The PV laboratory is located at a place appropriate for carrying out solar electricity experiments. It is adequate for the intended size of the group (i.e. 15 students) and has adequate space for storing all the training materials, components and equipment.

The teaching and learning materials for the PV programme was based on three main textbooks and manuals. However, due to the rapid growth of the PV technology, it was proposed that the instructors would make use of the internet for additional teaching materials.

In terms of physical facilities, the Centre has sufficient infrastructure capacity to run the programme effectively. However, further improvement could be made in the following areas:

- (i) Internet connectivity,
- (ii) Mounting structures and demonstration PV – systems be put in place.

3.5 Objective of the Programme

The question here is whether the objective of the programme was achieved. In the initial design the programme intended to provide sufficient knowledge and trade skills on PV technology and application to vocational trainees. Specific objectives for each taught course module were provided and strategies developed to achieve the objectives were designed through the program structure. All the graduates that were

interviewed responded that over 75% of the objectives for each course – module were achieved. When asked whether the programme met their expectations, all of the respondents indicated that to a large extent the programme has achieved their expectation. However, the issue of field practical training was again raised as one of the weaknesses of the programme.

Assessments of this component indicate that the objective of the programme has to a high degree been achieved. However for further improvement of the programme field practical training component would add value to the programme.

3.6 Assessment and Certification

The trainees were examined to test the understanding of the theoretical component as well as skills acquired through the workshop training sessions. Initially there were problems with examination arrangements starting from setting examination papers, moderation and marking the answer scripts. The practice for other trade courses is that an independent panel of experts sets questions papers while another panel of experts conducts moderation. In both cases, VETA headquarters appoints the panels. In addition VETA headquarters also appoints an invigilator. In the case of the PV training programme, probably due to lack of independent competent personnel to set the question papers, the instructors at Mwanza Centre were asked to set examination questions as well as preparation of the model solutions. Moderation, invigilation, marking, and subsequent release of examination results were the responsibility of the VETA headquarters.

At the time the consultant visited VETA, Mwanza Centre, he was unable to scrutinise examination scripts because they were at the VETA headquarters in Dar es Salaam. However, he had a chance to look at the theoretical examination paper as well as questions 3, 4 and 5 of the

practical paper. A complete practical examination paper covering questions 1- 5 was not available and therefore unable to comment on them. Likewise it was not possible to assess the practical exercise performed by the trainees because most of the components had already been dismantled and kept safely in the store.

The theoretical question paper consists of 10 short objective questions covering about 60% of the topics of the syllabus. Regarding the type of questions, most of them carried descriptive type of questions. The spread of questions could have been improved if the examiner or moderator were to set one question per topic. This was however not the case. It was found that for example, questions 3 and 5 came from the same topic of the syllabus while questions 7 and 8 came from the same topic on Solar Radiation. Similarly the same applied to questions 1 & 10.

The format of setting the question papers was such that candidates were required to answer all the 10 questions. Although this format allows testing the candidates on a wider spectrum of the syllabus, it was not clear whether the distribution of marks for the different questions was the same. The questions could also be split into parts thereby covering more module materials of the syllabus but with an increased duration, say two hours instead of the one-hour and half.

At the time when the evaluation was conducted, the graduates had not yet been given their examination results nor issued with their certificates. Furthermore it was not clear as what kind of certificates the graduates would be issued. The Centre management informed that the responsibility of preparing certificates for the graduates lies with the VETA headquarters in Dar es Salaam.

3.7 Sustainability

Some elements of sustainability of the programme activities are vivid. The Centre is optimistic that the number of applicants will grow after

addressing major weaknesses observed during the implementation of the programme. Furthermore, there are various initiatives being taken by the government as well as development partners aiming at improving energy services in the rural areas using renewable energy sources and in particular photovoltaic. As a result, this will attract both the business community and the civil societies to engage themselves more in photovoltaic thereby increasing demand for more trained artisans in the field of photovoltaic technology.

The PV training programme is now well integrated into the regular trade courses and therefore will have an annual budget and treated like the other trade courses.

Three instructors have received training on photovoltaic technologies and are most likely going to participate in the programme. However if one of the staff members is transferred to another VETA centre or elsewhere, then this move will pose a high risk to the continuity of the programme.

PV components, materials, equipment and books were purchased to facilitate the programme. The teaching equipment as well as the PV laboratory acquired through the assistance of the Mwanza PV Project will facilitate sustainability of PV training programme. The relationship and contact made between the Centre, PV business community in Mwanza region and UNDP Mwanza PV project will be maintained to enhance support and delivery of the PV training programme.

4. Conclusion

In general the findings of the evaluation have shown the extent at which the programme has achieved its objective. The findings have also identified specific strengths for which the programme was able to build upon to achieve the intended output. However, several weaknesses were also recognized and measures to address them have been proposed. The sustainability of the programme is unquestionable because all the basic elements that constitute the foundation of the programme are firm and strong. What is needed is to nurture and build on the good groundwork that was laid through the assistance of the UNDP Mwanza PV Project.

5 Recommendations

Based on the synthesis of the interviewer's opinions and experiences of the consultant on various aspects of the programme, it was possible to identify strengths and weaknesses of programme. Specific recommendations have been given for each aspect of the programme and therefore the following are broad recommendations for improving the curriculum and hence achieving more and effective teaching, learning and assessment while maintaining acceptable quality output:

- (i) For effective implementation of the PV training programme there is need to **conduct a review of the curriculum** in order to allow more time needed to accomplish some of the identified useful and relevant topics as well as to incorporate essential elements that seem to be missing in the curriculum,
- (ii) Code of practice for photovoltaic technology is one such field that ensures that common guidelines are being followed when designing and installing photovoltaic systems, hence providing quality assurance for products and workmanship. Tanzania Bureau of Standards in collaboration with National Standards

Bodies of the partners' states of the East African Community has recently completed a task of developing code of practice for PV technology practitioners relevant for East African Countries. In order to disseminate the outcome of this development, it therefore recommended that **code of practice be incorporated as one of the priority topics** in the PV training programme for VETA trainees,

- (iii) Regarding human resource capacity, there is need for VETA to **embark on a short and medium term training programme** for capacity enhancement in the discipline of Photovoltaic in order to sustain the programme. A long term solution would be for VETA to open up a discussion with relevant technical colleges offering Full Technician Certificate course with a view to introduce a comprehensive PV module course either as core or option in their curricular,
- (iv) On the infrastructure capacity, the Centre should **strive to acquire internet** connectivity,
- (v) Although teaching and learning environment was adequate for achieving the goal of the programme, this aspect can further be improved by **providing additional learning tools** to enhance the performance of the programme,
- (vi) Assessment and certification of the programme is not yet clear and therefore there is **need for VETA to mainstream the assessment and certification process** for the PV training programme in the same way as for the other trade courses.

References

1. RT Kivaisi, G. John and G. Mbise (2001). *Feasibility study on the Development of PV Standards and Norms-UNDP Project.*
2. R.T. Kivaisi (2004). *Development of PV Curriculum for Vocational Education and Training Authority (VETA)*
3. R.T. Kivaisi (2005). *Planning Meeting for the Implementation of the PV Training Programme at VETA Centre –Mwanza,*
4. *East African PV Standards (2006). Solar photovoltaic power systems — Design, installation, operation, monitoring and maintenance — Code of practice.*

Appendices

(1) Work-load distribution and time allocation for the various course modules:

Topic	Instructor	Week No	Time (hours)	Remarks
1. Introduction of Solar Energy	<i>J. Mwanda</i>	01	10	
2. Fundamentals of solar radiation	<i>J. Mwanda</i>	01/02	24	
3. Solar cells, modules and arrays and applications	<i>J. Mwanda</i>	02/03/04	60	
4. Solar cells and module characteristics	<i>J. Mwanda</i>	05	24	
5. Storage batteries and accumulators	<i>F. Nkwabi</i>	06	24	
6. Charge controllers and load management	<i>F. Nkwabi</i>	07	27	
7. Inverters and converters	<i>F. Nkwabi</i>	08	27	
8. Appliances	<i>F. Nkwabi</i>	09/10	72	
9. PV system configurations	<i>F. Nkwabi</i>	11	24	
10. Planning for PV installation	<i>F. Nkwabi</i>	11/12	32	
11. Photovoltaic system sizing	<i>J. Mwanda</i>	13/14	60	
12. Field Work	<i>All</i>	15	40	
13. Cable sizing, wiring and fittings	<i>A. Makore</i>	16/17	60	
14. Water pumping	<i>A. Makore</i>	18	24	
15. Cost consideration	<i>A. Makore</i>	19	24	
16. Practical Assessment	<i>F. Nkwabi</i>	20	24	
17. Lightning protection in photovoltaic systems	<i>A. Makore</i>	21	24	
18. Maintenance and service of PV systems	<i>A. Makore</i>	22	24	
19. Commissioning and customer care	<i>A. Makore</i>	22	24	
20. Revisions	<i>All</i>	23	30	
21. Assessments, Examination and Certification	<i>All</i>	24	30	

(2) **The outline of the modules:**

1. ***Fundamentals of solar Radiation***

This component provides principles of solar radiation and its measurements. The theory of direct as well as diffuse radiation and insolation was 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 were treated.

2. ***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 were discussed.

3. ***Solar cells and module characteristics***

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

4. ***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 introduces the instructors on the working principle of a battery and provides 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 were dealt with in detail.

5. ***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 covered devices used to manage the energy flow in solar electric systems. It also introduces the instructors 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 was also treated.

6. ***Inverters and converters***

This course unit dealt 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 covered a wide range of advantages for using AC power against DC in PV systems and hence the integration of inverters in PV systems.

7. *Appliances*

This course module focused 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) was 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 were presented.

8. *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 explored 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 were covered.

9. *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 covered designing a small solar electric system. It combined information already covered earlier enabling the trainee to tailor a PV system to ones' needs depending on the resources available. The trainee were able to choose cost effective PV components, mount or assemble them and install the PV system as per recommended guidelines.

10. *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 were 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, could be estimated. As more appliances are added to the system the size of the components can be worked out proportionate to the ultimate load.

11. *Wiring and fittings*

This unit emphasized 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 was 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.

12. Photovoltaic 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 introduced basic pumping technology, including motor and pump technologies, power conditioning, water requirement, array sizing, etc.

13. Cost consideration

This training module introduced the instructors 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 were reviewed.

14. 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 surveyed 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.

15. 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 surveyed a number of couplings that are responsible for overvoltages in typical PV installations and proposes counter measures to the effect.

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.

17. Commissioning and customer care

Under this course unit, instructors were 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) A sample of the examination question paper

THE UNITED REPUBLIC OF TANZANIA

VOCATIONAL EDUCATION AND TRAINING AUTHORITY

**PROFESSIONAL EXAMINATION
SOLAR (PV) SYSTEM**

THEORY PAPER

TIME: 1½ hrs.

DATE: 31/07/2006

INSTRUCTIONS:

1. This paper consists of TEN (10) questions
2. Answer all questions
3. Write your answers in the answer booklet provided.
4. Write your examination number on every page of the answer booklet provided.

ANSWER ALL QUESTIONS

1. Explain why in PV system Installation we use bigger size of cables than in a.c. supply installations.
2. State the I.E.E. Regulation regarding to solar system installations.
3. Explain briefly the difference between solar module and solar array.
4. With regard to maintenance of battery, explain briefly what is equalizing charge.
5. Mention at least three applications of photo voltaic d.c. supply.
6. List down three functions of the charge controller.
7. In regard to solar radiation, differentiate direct radiation, diffuse radiation.
8. Mention two factors, which affect solar radiation.
9. When designing a small solar system, what should be considered? Mention at least four items.
10. Calculate the voltage drop produced by a current of 40A in 24m of a single core 10mm² Copper cable (Resistivity of copper = $1.78 \times 10^{-8} \Omega \text{ m}$).

(4) A list of materials, equipment and tools

	Item	Qty	Remarks
1	Switch socket	20	local
2	Watt-meter	1	external
3	Oscilloscope	1	external
4	Banking powder (packets)	5	local
5	Switch over relay	5	local
6	Lux meter	1	external
7	Mini water pumps	1	External/local
8	Black mat paint (litres)	5	local
9	Metal plate 50x50cm.	10	local
10	Vaseline (50 gm)	100	local
11	RMS meter	1	external
12	DC power supply (0 -18 V- 5amp	5	external
13	Calculator	20	local
14	DC/DC converter	20	local
15	Diodes 5, 10, 15, 20, 30 amp-rating	25	local
16	Drawing instruments	20	local
17	Drill machine	5	local
18	Fuses-5, 10, 15, 20, 30 Amps	200	local
19	Inclinometer and compass	10	local