ESMAP TECHNICAL PAPER
078

Portable Solar Photovoltaic Lanterns: Performance and Certification Specification, and Type Approval

August 2005

JOINT UNDP / WORLD BANK
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) is a special global technical assistance partnership sponsored by the UNDP, the World Bank and bi-lateral official donors. Established with the support of UNDP and bilateral official donors in 1983, ESMAP is managed by the World Bank. ESMAP's mission is to promote the role of energy in poverty reduction and economic growth in an environmentally responsible manner. Its work applies to low-income, emerging, and transition economies and contributes to the achievement of internationally agreed development goals. ESMAP interventions are knowledge products including free technical assistance, specific studies, advisory services, pilot projects, knowledge generation and dissemination, trainings, workshops and seminars, conferences and roundtables, and publications. ESMAP work is focused on three priority areas: access to modern energy for the poorest, the development of sustainable energy markets, and the promotion of environmentally sustainable energy practices.

GOVERNANCE AND OPERATIONS

ESMAP is governed by a Consultative Group (the ESMAP CG) composed of representatives of the UNDP and World Bank, other donors, and development experts from regions which benefit from ESMAP's assistance. The ESMAP CG is chaired by a World Bank Vice President, and advised by a Technical Advisory Group (TAG) of independent energy experts that reviews the Programme's strategic agenda, its work plan, and its achievements. ESMAP relies on a cadre of engineers, energy planners, and economists from the World Bank, and from the energy and development community at large, to conduct its activities under the guidance of the Manager of ESMAP.

FUNDING

ESMAP is a knowledge partnership supported by the World Bank, the UNDP and official donors from Belgium, Canada, Denmark, Finland, France, Germany, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom. ESMAP has also enjoyed the support of private donors as well as in-kind support from a number of partners in the energy and development community.

FURTHER INFORMATION

For further information on a copy of the ESMAP Annual Report or copies of project reports, please visit the ESMAP website: **www.esmap.org**. ESMAP can also be reached by email at **esmap@worldbank.org** or by mail at:

ESMAP
c/o Energy and Water Department
The World Bank Group
1818 H Street, NW
Washington, D.C. 20433, U.S.A.
Tel.: 202.458.2321
Fax: 202.522.3018

Portable Solar Photovoltaic Lanterns: Performance and Certification Specification, and Type Approval

August 2005

Peter F. Varadi
Markus Real
Frank Wouters

Energy Sector Management Assistance Program
(ESMAP)

First printing August 2005

ESMAP reports are published to communicate the results of ESMAP's work to the development community with the least possible delay. The typescript of the paper therefore has not been prepared in accordance with the procedures appropriate to formal documents. Some sources cited in this paper may be informal documents that are not readily available.

The findings, interpretations, and conclusions expressed in this paper are entirely those of the author(s) and should not be attributed in any manner to the World Bank or its affiliated organizations, or to members of its Board of Executive Directors or the countries they represent. The World Bank does not guarantee the accuracy of the data included in this publication and accepts no responsibility whatsoever for any consequences of their use. The boundaries, colors, denominations, and other information shown on any map in this volume do not imply on the part of the World Bank Group any judgment on the legal status of any territory or the endorsement or acceptance of such boundaries.

Reference to any name brand products is only for illustrative purposes and does not imply any endorsement whatsoever.

Papers in the ESMAP Technical Series are discussion documents, not final project reports. They are subject to the same copyright as other ESMAP publications.

Table of Contents

Acknowledgments

This work is part of the work program of the Energy Sector Management Assistance Programme (ESMAP) on renewable energy. It recognizes the critical role of good-quality, reliable, and safe lighting sources in improving rural people's quality of life. The establishment of a performance specification and certification process for photovoltaic (PV)-powered Solar Lanterns was initiated by Anil Cabraal of the Energy and Water Department of the World Bank, who served as the task manager for this assignment. The Global Approval Program for Photovoltaics (PV GAP), a nonprofit organization based in Geneva, Switzerland was contracted to undertake the work. The project manager for PV GAP was Dr. Peter F. Varadi, also the program's chairman.

The authors of the technical performance test specification, "Portable Solar Photovoltaic (PV) Lanterns—Design Qualification and Type Approval," in the form of the PV GAP Recommended Specification (PVRS 11A) were Dr. Markus Real of Alpha Real, Switzerland and Mr. Frank Wouters MSc of Ecofys, Germany.

The author of the specification, "Portable Solar Photovoltaic (PV) Lanterns—Blank Detail Specification," (PVRS 11) was Mr. Richard Kay of the International Electrotechnical Commission (IEC) of Geneva, Switzerland. He was assisted by Dr. Real. This report was formatted by Mrs. Nidhi Sachdeva and Mrs. Marjorie K. Araya (ESMAP) coordinated the publication process.

We thank the following peer reviewers for their reviews and suggestions for improvements:

Dr. Gobind Atmaram, FSEC, Florida, USA

Dr. Anil Cabraal, The World Bank, Washington, DC, USA

Mr. Frans Nieuwenhout, ECN, The Netherlands

Dr. Adolfo Perujo, JRC Ispra, Italy

Mr. Norbert Pfanner, Fraunhofer Institute, Germany

Mr. Felix Garcia Rosillo, CIEMAT, Spain

Mr. Hidenori Shimizu, Japan

Special thanks are due photovoltaic-powered solar lantern (PVSL) manufacturers who offered constructive comments. It was also encouraging that the manufacturers were not reluctant to have their product tested according to the requirements. We thank the following for their comments and cooperation:

Mr. Manhal Allos, Sollatek Ltd, UK

Mr. Stefan Erbacher, Solux E.v., Germany

Mr. Siegfried Popp, Solaris Lantern from Light Corporation, Germany

Mr. Pavankumar Siddhi, Sungrace Energy Solutions, India

We thank the following for their cooperation (these individuals and organizations did not provide comments):

Mr. K.G. Madhu Ammini Energy Systems, India

Mr. Jan Nijland, Logic Electronics B.V., Netherlands

Maharishi Solar Technology, India

Acronyms and Abbreviations

AC	Alternating current
Ah	Ampere-hours
BDS	Blank Detail Specification (Specification used for certification)
BC	Battery Charging
BOS	Balance of system
CAC	Conformity Assessment Certificate
CAR	Conformity Assessment Report
CFL	Compact fluorescent lamp
DC	Direct current
DRT	Daily Run Time (of the solar lantern)
ECT	Equivalent cell temperature
ESMAP	Energy Sector Management Assistance Programme (UNDP/World Bank)
FS	Full Screen
FT	Functional Test
HVD	High Voltage Disconnect (of the charge controller)
HVR	High Voltage Reconnect
IEC	International Electrotechnical Commission (www.iec.ch)
IEC TC 82	IEC's Technical Committee 82, responsible for standardization of PV components and systems
IECEE	IEC System for Conformity Testing and Certification of Electrical Equipment (www.iecee.org)
ISO	International Organization for Standardization
LCD	Liquid crystal display
LED	Light-emitting diode
LVD	Low Voltage Disconnect (of the charge controller)
LVR	Low Voltage Reconnect
NCB	National Certification Body
NERDC	National Engineering Research and Development Center
NiMH	Nickel metal hydride
NOCT	Nominal Operating Cell Temperature
PAS	Publicly Available Specification
PTOC	Performance Test under Operation Conditions
PV GAP	Global Approval Program for Photovoltaics (www.pvgap.org)
PV	Photovoltaic(s)
PVRS	PV GAP Recommended Specification
PVSL	PV-powered solar lantern
QMS	Quality Management System
RT	Recovery Test
SHS	Solar Home Systems
STC	Standard testing conditions (Reference testing value of cell temperature (25 °C), in-plane irradiance (1000 W/m²), air mass solar reference spectrum (AM = 1.5) for a PV module or PV cell testing)
TC	Technical Committee
TL	Tubular fluorescent lamp
UBC	Usable battery capacity
VI	Visual inspection

Executive Summary

1. A photovoltaic-powered solar lantern is a consumer product that is—and will continue to be—used in quantities of hundreds of thousands in many countries by people who have no other source of electricity to provide light. These lanterns constitute a substantial investment for such people, who in most cases have no recourse if the product fails. Unfortunately it is documented that failures are not infrequent. Often the construction of the unit or its enclosure is not robust enough to withstand the transport and day-to-day handling, the components are not properly sized or do not meet the specifications, the cable junctions are not durable, and the battery charging regime is not suitable for the application, to name but a few. Such concerns prompted the World Bank to support the establishment of performance test specifications, and a certification process for PV-powered solar lanterns (PVSLs). It is expected that the adoption of these specifications and the manufacturing of products that are in compliance will result in more reliable, efficient, and cost-effective products and enhance consumer satisfaction.

2. This project aimed to establish a performance test specification to ensure that when a PVSL successfully completed the tests, it would be expected to have an extended period of life without failure at the specified performance level. The project also aimed to establish a specification that could be used for the certification of PVSL performance. Since PVSLs are shipped worldwide, obviously the result should be global in scope so that all manufacturers in every country can use the specifications.

3. The ultimate goal is to provide consumers with an easy visual recognition that the PVSL they intend to buy is a quality product and can be clearly distinguished from products of unknown quality. This work outlines the way this can be achieved.

4. The cost of producing quality products is the same as, or maybe marginally more expensive than, the cost of producing a bad quality product. One would think that testing and certification might be expensive and would handicap small manufacturers; however, it has been shown[1] that the requirement to test and certify a PV product does not create a financial burden for even for the smallest manufacturer; and it may even reduce the manufacturing cost.

5. It is also important that the developed specification and certification be globally acceptable—by technical experts as well as by PVSL manufacturers.

6. The two main outputs of the evaluation process described here are as follows:

   1. Portable photovoltaic solar lantern—blank detail specification
   2. Portable solar lantern—design qualification and type approval

7. The main features incorporated into the specifications are as follows:

- Addresses the main design issues that have led to lantern failures or inadequate performance in the field, including general construction robustness, module cable junction, module rating, battery, battery charging regime, and overall system sizing
- Builds on technical standards issued by Sri Lanka and India used for procuring solar lanterns

[1] P. F. Varadi and A. Bergmann. 2002. "PV GAP: Is Quality Expensive?" *Renewable Energy World*. Vol. 5 No. 5, Sept-Oct 2002.

- Adopts component specifications for batteries, PV modules, controllers and direct current (DC) fluorescent lamps issued by PV GAP and IEC
- Prescribes tests to assess the performance and reliability of the lantern as an integrated product and gives a method for classifying its performance depending on environmental conditions
- Includes tests to verify the product's robustness of components, its construction, and its ability to withstand rough handling
- Balances cost and quality aspects
- Ensures that testing can be done in developing-country laboratories or testing institutions

8. As PV GAP is a liaison agency of the IEC, it has begun a process for having the lantern technical specifications be considered and adopted by the IEC as an international standard.

1

Introduction

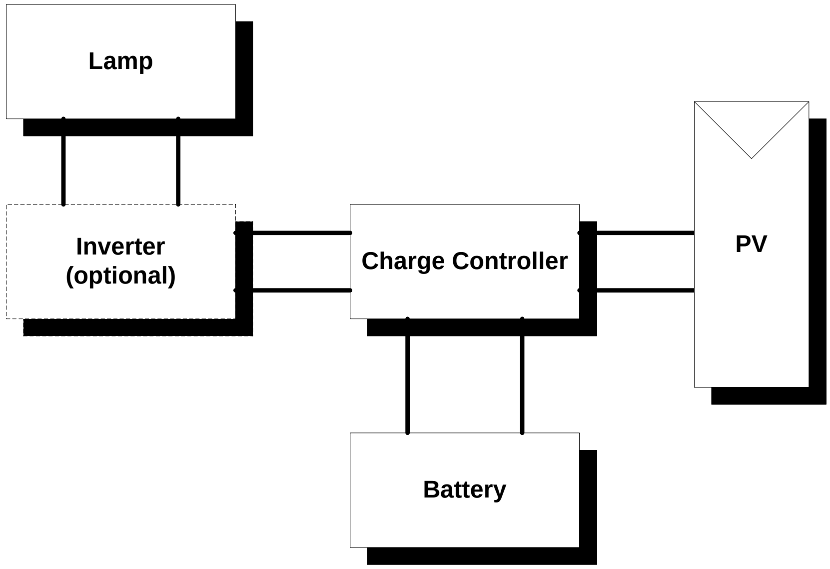
1.1 A photovoltaic-powered solar lantern (PVSL) is a small integrated, portable solar power lighting device that is widely utilized in many developing countries. It comprises a solar PV module, a fluorescent lamp, battery, and electronics, all packaged in a suitable housing.[2] Solar lanterns could be regarded as the first step up the modern lighting ladder: Even the simplest units will provide superior lighting compared with those offered by candles, kerosene lamps, and electric lamps operated by car batteries.

1.2 An ESMAP-supported market test for solar lanterns in Kenya found that while customers appreciated the service the lantern provided, most solar lanterns were unacceptable from a technical point of view. They lacked low-voltage disconnects and had poor quality light bulbs or electronic ballasts. Many lamp tubes showed blackening early on. The main reason given for returning lanterns (18 percent) was technical failure, resulting in unsatisfactory performance. Mr. Van der Plas, the principal investigator noted, "The ESMAP surveys showed that the perceived ideal solar lantern is durable, has a high luminous flux that is fairly evenly distributed, gives a good quality spectrum light, is able to operate for more than three hours every night, and has readily available spare parts. The light output desired is relatively high: The 200–300 lumen from a 5 watt compact fluorescent lamp (CFL) or a 6 watt tubular fluorescent lamp (TL) is acceptable, whereas the 160–200 lumen from a 4 watt TL is not; a lantern with a 6 watt TL and a modified ballast to reduce electricity consumption (it only consumes 3 watts) was not appreciated because it compromised the light output and quality."

1.3 Figure 1.1 shows a schematic of the components of a solar lantern and Annex 1 provides a few illustrative examples.

[2] In the last few years, PVSLs using low power white light emitting diodes instead fluorescent lamps with Nickel-Cadmium batteries have entered the market. These test procedures do not directly apply to these products.

Figure 1.1: Solar Lantern Components



Source: Authors

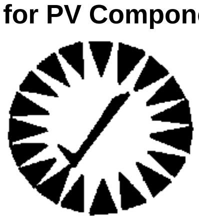
1.4 Over 500,000 solar lanterns are reportedly deployed in the developing world, with the majority in India. Because of the popularity of the solar lantern, several countries (including India and Sri Lanka) have developed procurement specifications describing the requirements to protect the customers, but none of these specifications identify or describe proper testing procedures to evaluate and certify lantern performance. The performance certification is applicable to lanterns used in developing countries as well as a large number of lamps used in developed countries sold as consumer goods. Failures are not crucial for consumers in developed countries (since the loss for them is a small one), but in developing countries the loss for individual consumers is severe, because it is not small compared to their income and they usually do not have any recourse for replacement if the product is faulty.

Product quality verification requirements: The certification process in practice

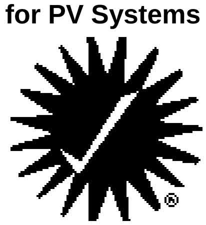
1.5 To enable consumers to easily distinguish between quality PV products and products of unknown quality the Global Approval Program for Photovoltaics (PV GAP) was initiated. PV GAP established a PV Quality Mark for PV components and a PV Quality Seal for PV systems. The utilization of this mark/seal is licensed to PV Manufacturers when their product's quality meets the criteria established by PV GAP (figure 1.2).

Figure 1.2: PV GAP Quality Seal and Quality Mark

PV Quality Mark for PV Components



PV Quality Seal ® for PV Systems



1.6 The four main criteria established by PV GAP to certify the quality of PV components and systems are as follows:[3]

- The manufacturer must have current quality certification for the manufacturing site, with relevant scope. This certification should adhere to a Quality Management System (QMS) standard such as ISO 9001:2000.
- The product must be tested according to a global standard/specification—such as the IEC Standard, an IEC Publicly Available Specification, or a PV GAP–Recommended Specification (PVRS)—and prove this with an acceptable test certificate from an accredited testing laboratory.
- The manufacturer has to complete a blank detail specification (BDS), which specifies the product's characteristics and requirements when retesting of the product is needed.
- Finally, auditing and factory inspection should be carried out according to a harmonized factory audit procedure.

1.7 Based on this, the products receive an IECEE Conformity Assessment Certificate (CAC), which entitles the manufacturer to obtain from PV GAP a license to display the PV GAP Quality Mark (for components) and PV Quality Seal (for systems, such as PVSLs) on the approved product.

Objectives

1.8 To provide the users with quality PVSLs, global specifications are required, which include proper test procedures and procedures concerning retesting of the product. Therefore the objective of this assignment is twofold

- Establish a performance and certification specification to verify the system design and performance of a solar lantern and develop test procedures so that the product can be tested and its performance certified. The specification will cover PVSL lantern testing both for outdoors in prevailing conditions and indoors under simulated conditions. The testing conditions are intended to represent the majority of climatic zones for which these solar lanterns are designed. The assignment developed the global PVRS, which will be submitted, based on the established liaison between the IEC Technical Committee (TC) 82 and PV GAP, to IEC TC 82 for adoption as an international standard.[4]
- Establish a BDS to which the PVSL can be certified.

1.9 The solar lantern specification goes beyond the component specifications that PV GAP has developed for use in solar home systems. While individual components have to be qualified to a performance standard (set for solar home systems), the assembled solar lantern needs further verification to ensure that the components operate properly together as specified by the PVSL manufacturer. The performance test must comprise a check of functionality, autonomy, ability to recover after periods of low battery charge, and ruggedness, and hence give reasonable assurance that the lantern will not fail prematurely. This requires evaluating the required metrics to be tested, including pass/fail criteria, to ensure that future solar lanterns on the market meet customer expectations with regard to quality and performance.

---

[3] M. Real, P. de Ruvo, R. Kay, and P. F. Varadi. 2004. "PV GAP Global Quality Label Based on IECEE Certification." *Renewable Energy World*, November/December, p. 44. IECEE stands for "IEC System for Conformity Testing and Certification of Electrical Equipment."

[4] M. Azzam, C, Jacquemart, R. Kay, H. Ossenbrink, A. Perujo, and P. F. Varadi. 2004. "Global PV Standardization and Specification." *Renewable Energy World*, July-August, p. 138.

PV GAP's methodology for developing a PVSL design qualification and type approval specification

1.10 In the preparation of the solar lantern PVRS, the following steps were taken:

Step 1: Preparation of a technical specification and a blank detail specification

Step 2: Peer review of the technical specification and the BDS

1.11 The drafts were sent to peer reviewers for comments. The comments of the peer reviewers were analyzed, and a number of changes were made in the PVRS drafts as a result of these comments. Each peer reviewer received a letter stating which of their recommendations had been accepted and why the others had not been accepted. The peer reviewers had the opportunity to review the changed drafts.

Step 3: Review by the lantern manufacturers

1.12 The draft with the revisions suggested by the peer reviewers was sent to seven solar lantern manufacturers in developing and developing countries. The comments of the manufacturers were analyzed, and changes were made in the PVRS drafts as a result of these comments. Each manufacturer received a letter stating which of their recommendations had been accepted and why the others had not been accepted.

Step 4: Final revision and review

1.13 The technical specification and the BDS were edited and arranged in the PVRS format and sent to all of the peer reviewers and all of the PVSL manufacturers for further comments.

Step 5

1.14 No additional comments were received. The technical specification and the BDS were formatted in the PVRS format for the PV GAP approval process.

2

Status

Solar lantern status

2.1 The project conducted an extensive literature survey, complemented by interviews of experts, industry, users and test labs on a range of topics. The purpose of the survey was to acquire most of the available information and knowledge on real-life quality issues with solar lanterns. Table 2.1 shows some of the people consulted.

Table 2.1: List of Consultants

Person	Organization	Country	Type of organization/Position
Reinhard Eckert	Würth Solergy	Germany	Manufacturer/Manager
Norbert Pfanner	Fraunhofer Gesellschaft–ISE	Germany	Research lab/Expert
Willi Vaassen	TÜV-Rheinland	Germany	Test lab/ Expert
Joachim Gaube	GTZ	Afghanistan	Development organization/User
Prof. W. Wiesner	University of Applied Science Cologne	Germany	University/Expert
Mr. Sattor	APWO	Afghanistan	Manufacturer/Chief technician
Prof. P. Adelmann	Phocos AG	Germany	Manufacturer/Manager
K. Radhakrishna Rao	SFCBA Cell Bharathiya Vikas Trust	India	Consultants
Frank van der Vleuten	Free Energy Europe	Netherlands	Distributor/Manager
Working Group 3	IEC TC82	International	Experts

2.2 The feedback from extremely qualified manufacturers such as Sollatek (manufacturer of the Glowstar lantern) on the draft PVRS documents also proved to be very useful to validate our assumptions on failure modes. It is worth in this context that the Glowstar project itself evolved from a thorough analysis of the performance of existing lanterns and consumer needs. Sollatek noted that the poor construction, inadequate quality of light, and limited battery life of many solar lanterns then on the market has led users to experience sharp drop-offs in performance after only a few months of use.

2.3 These observations, which were partly based on a World Bank survey in Africa, indicate the importance of general construction, the quality of the individual components such as the battery and the light, and a good design.

2.4 Frans van den Nieuwenhout from the Netherlands Energy Research Centre did a survey on the quality of solar home systems and also describes technical problems with solar lanterns.[5] Mark Hankins did an extensive field survey in Kenya in the framework of a World Bank market test (of seven lanterns);[6] the results included the following:

- Sealed lead-acid batteries were used, which are not suited for lantern use without specially adjusted low voltage disconnect.
- Several of the fluorescent lamps had unacceptably low light output. Lamp diffusers and reflectors can be improved.
- All modules produced substantially less than rated power during normal operating conditions at noon, where cell temperatures were higher than 45 °C. Average measured power of the four crystalline modules was 66 percent of rated output, compared to 77 percent for the amorphous modules.

2.5 After 12 months, a survey was conducted by Polak[7] to study the failure rates in this World Bank project. Information about 47 lanterns was obtained through dealers and interviews of owners. Of four different lantern types the actual failure rate is estimated to be 50 percent or higher.

2.6 There are many manufacturers of PV solar lanterns. The survey's overall assessment included a representative mix of products manufactured in Europe, the United States, and developing economies such as China, India, Kenya, and Afghanistan. The main quality issues represented here apply to all solar lanterns manufactured worldwide.

2.7 The main quality issues identified by the survey were as follows:

- General construction robustness—Many users and distributors reported frequent problems with the housing and the construction during transport and during day-to-day use, especially cracks and loose or faulty connections/components.
- Module cable junction—In many lanterns this seems to be a weak point in the design. Often a type of plug/socket combination is used that is not intended for frequent connection/disconnection (for example, a connector designed for audio equipment)
- The module itself—A major concern is the fact that many modules do not meet their nameplate specification and are generally poor in construction (frame, cell soldering joints, materials, and if relevant, diodes/junctions box).
- *Battery*—Many batteries are of inferior quality. Several manufacturers even use batteries of different manufacturers in one lantern.

---

[5] F. D. J. Nieuwenhout et al. 2000. "Monitoring and Evaluation of Solar Home Systems: Experiences with Applications of Solar PV for Households in Developing Countries." ECN report no. ECN-C-00-089.
[6] Mark Hankins et al. 1997. "Solar Lantern Market Review." Report prepared for Intermediate Technology Consultants by Energy Alternatives Africa.
[7] Paul Polak. 1997. "Study of Failure Rate of Solar Lanterns 12 Months after Sale to Consumers in Kenya," International Development Enterprise.

- *Battery charging regime*—The charging set-points do not always match the type of battery, leading to short battery life.
- *Overall system sizing*—For example, the undersizing of the module capacity leads to very short battery life.

Status of technical standards for off-grid PV use including for PV solar lanterns

2.8 Two documents that were found to be appropriate and available were evaluated: a testing document produced by National Engineering Research and Development Center [NERDC] in Sri Lanka ("Test Methods for Solar Lantern Testing," NERDC document no. TM-10-03, version April 2004) and the IEC document no. 62124, Ed.1, titled "Photovoltaic (PV) Stand Alone Systems—Design Verification," which was developed under the leadership of the authors.

NERDC document TM-10-03: Test methods for solar lantern testing

2.9 The document proved to be a good start since it had been developed by experts in testing. However, for a full technical standard several issues needed to be addressed:

- Missing introduction on scope and application (that is, for what kind of lamps is the test designed?)
- The document contains detailed testing on the components, but the functionality test for the entire lantern is very brief. Basically the functional test is limited to verifying whether a green and red lamp is working.
- There are almost no pass/fail criteria. For example, the elaborate battery test has no indication of whether the test results are acceptable.
- Several definitions are unclear, for example with regard to symmetrical sine wave-forms and quasi-sine waveforms.
- High and low discharge procedures are not complete.

IEC 62124 Ed.1: Photovoltaic (PV) stand alone systems—Design verification

2.10 Although solar lanterns should fall under this standard based on their definition, there are some considerations leading to the necessity for a separate standard:

- IEC 62124 has been developed for standalone PV systems that are usually assembled on site. Each component can usually be identified, accessed, and tested separately. Solar lanterns are often completely integrated units; sometimes certain printed circuit boards cannot be accessed or tested separately.
- IEC 62124 deals with larger and more expensive systems and aims at guaranteeing a lifetime well over 5 years--typically more than 10 years. For a portable solar lantern a lifetime of 5 years is more in line with the user expectancy and its price. This leads to some fundamentally different requirements, for example concerning certificates of components such as modules.

2.11 As a result, this document was combined with the NERDC report, taking the performance/ failure modes in the markets into account in preparing the PVSL specifications.

3

Solar Lantern Specification

Major metrics for solar lantern testing

3.1 The critical design issues to be tested can be summarized as follows:

- General construction robustness
- Module cable junction
- The module
- The battery
- The battery charging regime
- The overall system sizing

3.2 The purpose of the specification is to verify the design, performance, and durability of portable solar PV lanterns. While individual components must be qualified to environmental, performance, and safety specifications, the assembled system needs further qualification to ensure that the components operate properly together as specified by the system manufacturer. The performance test consists of a check of the product's functionality, autonomy, and ability to recover after periods of low battery charge, and hence gives reasonable assurance that the solar lantern will not fail prematurely.

3.3 Accordingly, this solar lantern certification procedure is based on two series of tests. The first group evaluates the *components* such as the PV module, the lead-acid battery, the lamps, the manual on-off switch and the module connecting device, while the second, called a "type approval," examines the solar lantern as an *entire unit*, specifically, whether it is optimized to provide the lighting services it is specified for.

3.4 A positive test result is a very strong indication that the potential lifetime is at least five years.

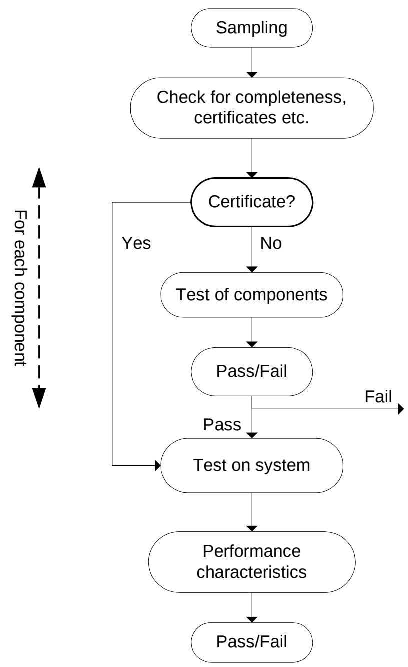
3.5 These two tests are independent and essential steps for evaluating the quality of solar lanterns. Components previously tested according to the procedure in this specification and already certified do not need retesting.

3.6 An important overall quality specification is the robustness of the overall assembly. An extensive switch test, a connector test, and a shipping vibration test were introduced to evaluate robustness.

Overview of technical specifications and test protocol

3.7 Figure 3.1 outlines the qualification process.

Figure 3.1: Photovoltaic Solar Lantern Qualification Process



3.8 Table 3.1 presents an overview of the tests used for this technical specification:

Table 3.1: Overview of Tests

Test	Conditions	Criteria
PV module	The PV module as specified by the manufacturer and included in the set shall bear a type approval certificate from an internationally recognized PV quality system.	The PV module shall be certified according to IEC 61215 and PVRS 2 in the case of crystalline PV modules and according to IEC 61646 and PVRS 3 in case of thin film PV modules.
PV module	The PV Module does not have a certificate but the criteria to the right are met.	The module manufacturer has already structurally similar larger modules certified according to IEC 61215 and PVRS 2 in the case of crystalline PV modules and according to IEC 61646 and PVRS 3 in case of thin film PV modules. The module for the solar lantern applies the same materials (including but not limited to solar cells, interconnecting material, encapsulants, junction box connections, and so on) and is made in the same factory using the same manufacturing

Test	Conditions	Criteria
		installation as for the module(s) for which the manufacturer received certification.
PV module	The PV module does not have a certificate and the criteria above right are not met.	The modules shall be qualified for solar lantern application if they pass the tests described in Clause 11.
The battery	Certificate required	PVRS 5A
The lamp	Certificate required	PVRS 7A
Switching and solar module connector durability test	1,000 cycles	No signs of wear that endangers the functionality or cause potential safety hazards Resistance connector <20 mΩ
Open circuit test of the inverter	Input voltage 1.2 times the nominal battery voltage, repeat twice.	The lantern shall function.
Open circuit test of the charge controller	Remove the battery. Apply 1.25 times open-circuit voltage to the PV module input terminals of the charge controller.	The charge controller shall withstand the condition without any damage.
Reverse polarity of the PV module	Apply a reverse polarity voltage equal to 1.5 times the nominal open-circuit voltage of the PV module to the PV module input terminals of the charge controller.	The charge controller shall withstand the condition without any damage.
Reverse polarity of the battery	Apply a reverse polarity voltage equal to 1.2 times the nominal battery voltage to the battery input terminals of the charge controller.	The charge controller shall withstand the condition without any damage.
Fuses	The battery shall be protected against short-circuit by a fuse or fuses, as close as possible to the battery terminal(s).	Overcurrent devices shall be rated for at least 156% of the short circuit current (at standard testing conditions) and shall have a voltage rating of at least 125% of the open-circuit voltage.
Shipping vibration test	10 Hz to 11,8 Hz; 11,9 Hz to 150 Hz Amplitude: 3,5 mm Acceleration: 2 *g* Cycling: 1 octave/minute Duration on each axis: 2 hour; overall: 6 hour	The lantern shall function.
System performance	Functional test	The lamp shall function at all stages of the test unless the charge controller has disconnected the

Test	Conditions	Criteria
tests	Autonomy test Recovery test	lamp because of a low battery charge. The battery capacity shall not decrease over the testing period more than 10%, expressed by $(C_0-C_2)/C_0 < 10\%$; C_o is the initial battery capacity, C_1 is the battery capacity after recovery test, and C_2 is the final battery capacity. The recovery test should exhibit an upward trend in the system voltage. During the test, the total net Ah into the battery should be >=50% of C_1. After capacity test C_1, the load shall begin operating again on or before the third recovery test cycle. The system balance point (see the heading for system characterization plot in box 1) shall match or stay below the defined minimum irradiation class. The measured days of autonomy shall match or end up more than the defined minimum days of autonomy as indicated by the manufacturer. The lamp shall operate undamaged according to the manufacturer's specification at the maximum battery voltage occurring during periods of high irradiance and at high state of charge. No sample shall exhibit any abnormal open-circuit or short-circuit during the tests.

3.9 The tests in PVRS11A are structured as follows.

3.10 First, two of each of the components shall be tested. If the components bear a relevant type approval certificate, such as the PV GAP Quality Mark, no testing is necessary. If the components do not bear a type approval certificate, they shall be subjected to the test sequences in the specification, carried out in the order prescribed. If both components fail any test, the design shall be deemed not to have met the qualification requirements. If one of the two components fails any test, the third component shall be subjected to the whole of the relevant test sequence from the beginning. If this component also fails, the design shall be deemed not to have met the qualification requirements.

3.11 Once all the components have passed the component tests, the solar lanterns shall be subjected to the Shipping Vibration Test and the System Performance Test. The procedures of the latter are subdivided into three tests: the Functional Test, the Autonomy Test, and the Recovery Test.

3.12 The system shall be subjected to the test sequences in the specification, carried out in the order described.

3.13 If both sample lanterns fail any test, the design shall be deemed not to have met the qualification requirements. If one of the two samples fails any test, the third lantern shall be subjected to the whole of the relevant test sequence from the beginning. If this lantern also fails, the design shall be deemed not to have met the qualification requirements.

3.14 Volume I presents the design qualification and type approval document for PVSLs.

Development of a blank detail specification (PVRS 11) for PVSLs

3.15 A blank detail specification (BDS) relates to a performance standard or specification (in this case PVRS 11A, possibly to become IEC 62xxx, for a product—in this case a PVSL). It is a framework agreed for use in a certification program (in this case the IECEE PV Scheme), under which the manufacturer obtains an IECEE Conformity Assessment Certificate (CAC), which is recognized by PV GAP for issuing its PV Quality Seal. The BDS permits a manufacturer to integrate its product data sheet information (product characteristics, outline drawing, and so on) in a standard manner (which facilitates the comparison of products from different manufacturers) and to agree to precise requirements in respect of the approval procedure (including registration/certification to ISO 9001:2000), quality conformance inspection (periodic testing), possible retesting following changes, and so on. The completed BDS, as a Detailed Specification, is publicly available and certification can be made and maintained using it as a reference. It is “harmonized” in that all the National Certification Bodies (NCBs) concerned can work according to it instead of following their own requirements—for instance for periodic testing and testing following changes. The BDS PVRS 11 was made according to the well-established model that was used for the PV module BDSs and which resulted in a series of Detailed Specifications for the first module certifications in 2002 and 2003.

3.16 In PVRS 11, the periodic testing requirement is very simple for all of the performance tests in clauses 15 and 16 of PVRS 11A, which are repeated every two years.

3.17 Portable photovoltaic solar lanterns—Blank detail specification is given in Volume II.

Next steps

Subsequent actions to establish global standard/specification

3.18 First, PVRS 11 and PVRS 11A are being sent to the Secretary of PV GAP’s Technical Committee for distribution to the TC members to obtain their comments. (This step was initiated on December 20, 2004). After the PV GAP TC approval process is completed, PVRS 11 and PVRS 11A will be submitted to the PV GAP Board. After the Board has approved them, they are going to be published by PV GAP.

3.19 Second, because PV GAP is a liaison organization of IEC TC 82, PVRS 11 and PVRS 11A will be submitted to IEC TC 82 for action. They could become an IEC Standard or an IEC Publicly Available Specification (PAS); if IEC does not take action, the documents will remain PV GAP–Recommended Specifications.

Testing laboratories

3.20 It has been established that the National Engineering Research and Development Center (NERDC) of Sri Lanka has all capabilities (except the vibration test) to perform the tests required by PVRS 11A. NERDC has accreditation as well. PVGAP will send PVRS 11A to other testing laboratories to find out whether they have the capability to perform all of the tests required. Similar information is being sought from test laboratories in China, India, Germany and the USA.

Certification of PVSLs

3.21 IECEE was contacted to enable the proper National Certification Bodies to be contacted by the manufacturers to receive certification.

Annex

Examples of Photovoltaic Solar Lanterns

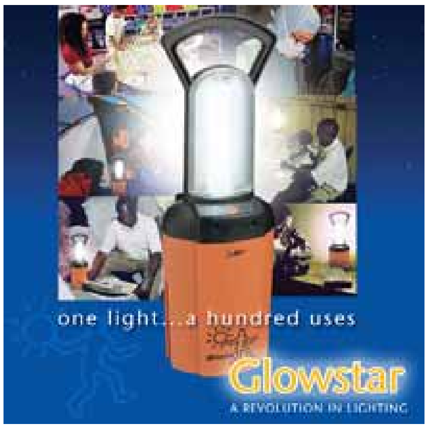
This annex shows a selection of solar lanterns from manufacturers all over the world. The selection was done at random and without any quality criteria, other than to demonstrate the variety, especially with regard to regional origin. The information given herein is mainly derived from manufacturers' specifications.

This inclusion in no way constitutes an endorsement of the products by the World Bank Group or ESMAP.

Glowstar (UK, Kenya and other countries)

The Glowstar lantern is the brainchild of a British nonprofit consultancy called Intermediate Technology Consultants.

After trials in Kenyan homes, the lamp was launched commercially in 2000. The hope was that it would provide a cheap, reliable, and ecologically friendly product that does not require mains power, expensive batteries, or kerosene.



The Glowstar Lantern

Contact:

Sollatek (UK) Limited
Unit 10, Poyle 14, Newlands Drive, Poyle, Slough, SL3 0AX. UNITED KINGDOM
Tel : +44 1753 688300
Fax : +44 1753 685306
Email: sales@sollatek.com

Afgan Public Welfare Organization (Pakistan/Afghanistan)

APWO is a small-scale manufacturer of solar lanterns in Afghanistan and was visited in May 2004. The chief technician and some users were interviewed. The following pictures show assembled lanterns in the workshop, the used batteries, and some PCBs (components ordered from Germany, Printed Circuit Board manufactured in Pakistan).

The design consists of a Chinese-made kerosene storm lantern, which is subsequently modified by Kabul craftsmen to accommodate the modern electronics. The solar panel is purchased in China.

Manufacturing of solar lanterns by Afgan Public Welfare Organization in Kabul, Afghanistan

Contact:

Afgan Public Welfare Organization
Eng.Sayed Rahim Sattar, Director
Main Office: G.P.O. Box: 288, House No. 3, Opposite Secondary Board, Khalid Town, Peshawar Pakistan
Telephone: 840386)
Fax: 43476
Website: www.pcpafg.org/Organizations/APWO/

Würth Solergy (Germany)

Using a 30 x 15 cm CIS (Copper Indium di-Selenide) module with 3.5 W of power, the Würth Solergy lantern takes about eight hours to charge a nickel metal hydride battery, integrated into the lantern's base for extra stability. The charge capacity of 2.2 Ah is enough for three hours of illumination. A 4.5 Ah model is also available. The 3.6 W lamp, filled with inert krypton gas, functions like a halogen lamp. According to specifications provided by Würth Solergy, the luminous flux is about 180 lumens, comparable to a 5 W energy-saving lamp.

Würth Solergy PV lantern

Contact:

Würth Solergy
Ludwigsburger Strasse 100
71672 Marbach am Neckar
Germany
Telephone: +49/7142/941-420, fax -074
Email: ws.vk@we-online.de
Website: www.wuerth-elektronik.de

Solux (Germany)

The SOLUX program from the Ludwig Bölkow Foundation was founded together with numerous national and international religious and charitable organizations. Its aim was to design a low-cost, high quality solar lantern with special attention to ensure that the lanterns could be easily assembled by trained personnel using the simple tools available in developing countries. For the initiators, job creation and the transfer of know-how were as important as providing efficient solar lanterns.

SOLUX lanterns are equipped with nickel-cadmium accumulators that are protected against damage from high current and deep discharge. All parts of SOLUX are designed for a minimum lifetime of 10 years (please note that a set of accumulators will last through 5 years of operation).

Solux-I PV lantern

Contact:

SOLUX e.V.
Daimlerstr.15
D-85521 Ottobrunn
Germany
Tel : +0049 (0) 89 60811026
Fax: +0049 (0) 89 6099 731
Email: info@solux.org
Website: www.solux.org

Maharishi Solar Technology (India)

	Mini solar lantern		Solar lantern			
Model	I	II	I	II	III	IV
PV module	3WP	5WP	5WP	8WP	10WP	12WP
Lamp	5W CFL		5W CFL		5W/7W CFL	
Battery	6V 4AH sealed maintenance free		12V 7AH sealed maintenance free			
Electronics	Sine/Quasi-sine wave 20-35 Hz.					
Luminaire	Acrylic					
Application	Portable lighting					
Installation and replacement	Solder free					

Maharishi Solar Lantern

Contact:

Maharishi Solar Technology (Pvt) Ltd.
A-14, Mohan Co-op, Industrial Estate,
Mathura Road, New Delhi 110044
India
Tel. : +91-11-26959800/26959701
Fax : +91-11-26836682/26959669
Email : solar@maharishi.net
Website : www.maharishisolar.com

Ammini (India)

Technical specifications

	Sunny 3W	Sunny 5W
General		
Solar PV module	4Wp	
Battery	6V, 4.5AH VRLA (SMF) lead-acid battery	
Application	Portable emergency indoor light source	
Lamp type	Compact fluorescent lamp (CFL), 4-pin, single U	
Lamp wattage	3W	5W
Rated light output (lumens)	150 ± 5%	250 ± 5%
Light coverage	360 degrees	
Daily hours of operation	3 - 4 Hrs	2 - 3 Hrs
Number of days of autonomy	2 days	
Night lamp	Super bright LED (2 numbers)	
Electrical		
Inverter type	Quasi-sine wave, free running	
Inverter frequency	24-28 kHz	
Inverter efficiency	> 82%	
Charging method	Series pulsed, two-step	

	Sunny 3W	Sunny 5W
Indications	Charging and low battery	
Reverse polarity protection	Provided with glass cartridge fuse	
Mechanical		
Lamp fixing	CF lamp in base-up or base-down configuration	
Case	Injection-molded engineering plastic (ABS)	
Light diffuser	UV-stabilized, nonyellowing acrylic	
Size (Shipping) (mm)	280 X 175 X 150	
Weight , without SPV module (Shipping)	1.3 kg	
Note: Specifications subject to change without notice. Check for latest update.		

Ammini solar lantern “Sunny”

Contact:

Ammini Solar (Pvt) Ltd.
Plot No. 33-37,
KINFRA Small Industries Park
St. Xaviers College PO,
Trivandrum 695 582
India
Telephone: +91-471-2705588
Fax: +91-471-2705599
Email: solar@ammini.com
Website: www.ammini.com/corporate.php

Solaris solar lantern (United States)

- Total weight (including lamp, battery, and solar panel): Approximately 1 kg
- Charge time (from dead battery): 13 hours
- Run time: 4.5 to 6 hours per charge
- Height: 8.9" (226 mm)
- Diameter: 6.0" (152 mm)
- Bulb: Energy-efficient compact fluorescent
- Solar panel: 8.2" x 11.25" (210 mm x 287 mm)

Solaris PV lantern

Contact:

Light Corporation
14800 - 172nd Avenue
Grand Haven, MI 49417-9401
USA
Telephone: 800.544.4899 toll-free
Telephone: 616.842.5100 phone
Fax; 616.846.2144
Email: patc@lightcorp.com, jimk@lightcorp.com
Website: www.lightcorp.com

MPGVM (India)

One of the countries with a high penetration of solar lanterns is India. The following pictures show a set-up of a solar lantern hiring scheme to small-scale marketers in Bhopal by the organization MPGVM from Balaghat. The organization mentions technical problems with the lanterns when transported on a bicycle on a daily basis,[8] highlighting the necessity for a mechanically robust set-up.


A solar lantern hiring scheme by Madhya Pradesh Gramin Vikas Mandal (MPGVM)

Contact:

Mr. Ram Chandra Prasad
Madhya Pradesh Gramin Vikas Mandal
AT/PO Khurmundi
Balaghat District
Madhya Pradesh
India

Logic Green Energy (The Netherlands)

The charging of the logic lantern is controlled by a microcomputer that automatically selects the battery float or boost level according to ambient temperature and battery use. When the solar panel is capable of charging the battery, the light is automatically turned off. Depending on the user's light requirements, two light levels can be selected.

The Logic Lantern

[8] See http://www.ashdenawards.org/winners_03_06.html.

Contact:

Logic Green Energy Bv
Mr. Jan Nijland
Patinastraat 56A, 8211 AR,
Lelystad
Netherlands
Telephone +31 320 268 091
Fax +31 320 268 092
Email: sales@le.nl
Website: www.le.nl

Seasun Green Lighting Industries Ltd. (China)

The key specifications and special features of this company's lanterns are summarized below:

- Solar panel: 3W sharp multi-crystalline silicon solar module
- Battery: 6V, 4Ah rechargeable lead-acid battery (Unikor Korea)
- 7W fluorescent lamp, with a lifetime of 6,000 hours
- Charging time: 12 hours by AC power, 16 to 20 hours by solar panel
- Lighting time: 5.5 to 6.5 hours
- Warranty: 1 year
- Lifetime: 4 years
- Inner packing: 1 piece/box
- Box dimensions: 22.5 x 19.5 x 30cm
- Outer packing: 12 boxes/carton
- Carton dimensions: 68 x 40 x 61cm

Seasun Lantern Model SCL-601

Contact:

Seasun Green Lighting Industries Ltd
21 Haier Road, Qingdao
Shandong, 266101
China
Tel:+86 532 8912007
Fax: +86 532 8912005
Email: sales@solarseasun.com
Websites:www.globalsources.com/seasunsolar.co,www.solarseasun.com

Portable Solar Photovoltaic (PV) Lanterns–Design Qualification and Type Approval

Volume I

PV GAP RECOMMENDED SPECIFICATION

PVRS 11A

2005-03

Reference number
PVRS 11A : 2005

PV GAP Secretariat c/o IEC Central Office
3 rue de Varembé - PO Box 131 - 1211 Geneva 20 – Switzerland
www.pvgap.org Fax: 41 22 919 03 00 E-mail: rk@iec.ch

Contents

PORTABLE SOLAR PHOTOVOLTAIC (PV) LANTERNS
DESIGN QUALIFICATION AND TYPE APPROVAL

1 Scope

The specifications, test methods and procedures for indoor tests included in this document cover portable solar photovoltaic lanterns, which are lighting systems consisting of a lamp, a lead-acid battery and electronics, all placed in a suitable housing made of durable material such as metal or plastic and an integrated or separate PV module. The battery is charged by electricity generated through the solar photovoltaic module. The lantern is basically a portable lighting device suitable for indoor lighting. For the purpose of this standard the service environment of the lantern (without the PV module) can be described as being fully covered by a building or enclosure to protect it from direct rain, sun, wind-blown dust, fungus, and radiation to the cold night sky, and the like, but the building or enclosure is not conditioned in terms of temperature, humidity or air filtration.

A lighting device (such as typical flashlights), which provides only unidirectional lighting, will not be classified as a solar lantern in the present context.

The focus of the test methods and procedures in this document is on solar lantern performance and durability evaluation and therefore includes the lantern components.

The results of this test are applicable to the exact components and the entire lantern configuration that are tested, as specified in the Blank Detail Specification (BDS) sheet or Conformity Assessment Report (CAR).

The chosen testing condition is intended to represent the majority of climatic zones for which these solar lanterns are designed.

Note 1:The test procedure is composed to ensure a lifetime expectancy under conditions of normal use and in moderate climatic conditions of five years and beyond, without major need for maintenance such as change/replacement of modules, charge controller, batteries, lamps or switches.

Note 2: The test logic is similar to that defined in IEC 62124 for Solar Home Systems (SHS). Testing laboratories qualified to test SHS against IEC 62124 have therefore both test equipment and expertise in performing the tests.

Note 3: For solar lanterns, some of the regular functions of the modern charge controller in other standalone PV systems may not be available because of the more simple nature of the solar lantern. On the other hand, electronic ballast of the lamp may already be included in the electronic circuit.

Note 4: The scope of this standard is limited to lead-acid batteries and to fluorescent lamps, since the majority of available lanterns incorporate these technologies. Newer technologies such as NiMH batteries and Light Emitting Diodes (LED) lamps are under consideration for future editions.

Note 5: Annex D contains design recommendations, which are not normative. However, experience has shown that many of these design aspects are positively correlated to the solar lantern’s performance.

2 Purpose

The purpose of this specification is to verify design, performance and durability of portable solar PV lanterns. While individual components must be qualified to environmental, performance and safety specifications, the assembled lantern needs further qualification, to ensure that the components operate properly together as specified by the lantern manufacturer. The performance test consists of a check of the functionality, the autonomy and the ability to recover after periods of low state-of-charge of the battery, and hence gives reasonable assurance that the solar lantern will not fail prematurely.

3 Normative references

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this International Specification. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and International Standards Organization (ISO) maintain registers of currently valid International Standards. PV GAP Recommended Specifications can be obtained from PV GAP.

IEC 60068-2-6: 1995, *Environmental testing – Part 2 : Tests – Test Fc: Vibration (sinusoidal)*

IEC 60529: 1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60904-1: 1987, *Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-2: 1989, *Photovoltaic devices. Part 2: Requirements for reference solar cells*

IEC 60904-5 :1993, *Photovoltaic devices. Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

IEC 60904-9: 1995, *Photovoltaic devices - Part 9: Solar simulator performance requirements*

IEC 61215: 1993, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval.*

IEC 61646: 1996, *Thin-film silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval.*

IEC 61724:1998, *Photovoltaic system performance monitoring. Guidelines for measurement, data exchange and analysis.*

IEC 61725: 1997, *Analytical expression for daily solar profiles*

IEC 61730-1:2004, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2: 2004, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

IEC 61853*, Performance testing and energy rating of terrestrial photovoltaic (PV) modules (under consideration)*

IEC 62093, *Balance-of-system components for photovoltaic systems – Design Qualification (under consideration)*

IEC 62124: 2004, *Photovoltaic (PV) stand-alone systems - Design Verification*

ISO/IEC 17025: 1999, *General requirements for the competence of testing laboratories and calibration laboratories*

PVRS 2: 2003 *Crystalline silicon terrestrial photovoltaic (PV) modules – Blank detail specification*

PVRS 3: 2002 *Thin-film terrestrial photovoltaic (PV) modules – Blank detail specification*

PVRS 5A: 2003 *Lead-acid batteries for solar photovoltaic energy systems – General requirements and methods of test for modified automotive batteries*

PVRS 6A: 2000 *Charge controllers for photovoltaic (PV) stand-alone systems with a nominal system voltage below 50V*

PVRS 7: 2005*, DC supplied systems. Blank detail specification*

PVRS 7A: 2003 *DC supplied lighting systems with fluorescent lamps for photovoltaic (PV) stand-alone systems*, Annex – Specification and testing procedure to PVRS 7

4 Abbreviations

AC: Alternating Current

Ah: Ampere-hours

CAR: Conformity Assessment Report

CFL: Compact Fluorescent Lamp

DC: Direct Current

DRT: Daily Run Time (of the solar lantern)

FS: Full Screen

HVD: High Voltage Disconnect (of the charge controller)

LVD: Low Voltage Disconnect (of the charge controller)

MPP: Maximum Power Point

NOCT: Nominal Operating Cell Temperature

PV: Photovoltaic(s)

STC: Standard Testing Conditions (Reference testing value of cell temperature (25°C), in-plane irradiance (1000W/m²), air mass solar reference spectrum (AM = 1.5) for PV module or PV cell electrical performance testing)

TMP: Typical Mean Daily

UBC: Usable Battery Capacity

VI: Visual Inspection

5 Testing methods

The tests in this specification are conducted to gauge the performance under conditions of irradiance and temperature that cover a large part of the world where these solar lanterns are being used. However these tests can be adapted to meet other specific climatic conditions, if those are significantly different from the testing conditions in this specification.

This solar lantern qualification procedure is based on two series of tests:

- To test the solar lantern components such as the PV module, the lead-acid battery, the light bulbs, the manual on-off switch and the module connecting device, and
- To test the solar lantern as the entire unit.

The first series of tests are component tests, to determine whether the module, the lead-acid battery and the lamp are appropriate for use in a solar lantern application. The second test procedure then is a type approval, to verify whether or not the component configuration in the solar lantern is well optimized to provide the lighting services for which the solar lantern is specified.

These two tests are independent and essential steps for evaluating the quality of solar lanterns. Components previously tested according to the procedure in this specification and already certified do not need retesting.

The battery test (PVRS 5) and the fluorescent lamps test (PVRS 7A) have been developed under the leadership of PV GAP, and are available through PV GAP.

Usually, solar lanterns powered by photovoltaic modules having a maximum STC power output less than 10 Watts under standard testing conditions, can be subjected to a reduced test sequence, which is based on either IEC 61215 or IEC 61646, as described in clause 11 of this specification. However, if these modules are from a family of modules, that has either an IEC 61215 or 61646 certificate, this small module is considered to be certified for the solar lantern application without any further tests.

5.1 Sampling

Three complete solar lanterns for qualification testing (plus spares as specified by the supplier) shall be taken at random from a production batch or batches. The systems shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer’s normal inspection, quality control and production acceptance procedures. The solar lanterns shall be complete in every detail and shall be accompanied by the manufacturer’s handling, mounting and connecting instructions, including safety instructions.

A copy of the relevant test certificate for the PV-module, battery (or batteries) and lamp(s) shall be included, if present. Otherwise these tests must be performed independently.

When the solar lanterns to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (clause 20). In this case, certificates will not be eligible for type approval certification.

If the lamps are sealed or components are not accessible (potted) and the configuration is based on an inverter/electronic ballast between battery and fluorescent lamps, the solar lantern has to be provided in a nonsealed/nonpotted version, with the components accessible for measuring current/voltage characteristics to perform the tests. If DC CFL units with integrated inverter are used, this is not necessary, even when the lantern is potted. The lamp current will then be measured with an interface between the lamp socket and the lamp.

If the solar lantern is designed for different lamps with different run times for each lamp, the configuration with the largest power consumption shall by default be tested. The manufacturer may, however, deviate from this procedure and select the configuration for which he wants to get the certification.

5.2 Testing sequence

In carrying out the tests, the test operator shall strictly follow the manufacturer's handling, mounting and connection instructions.

First two of each of the components shall be tested. If the components bear a relevant type approval certificate such as the PV GAP "PV Quality Mark" no testing is necessary. If the components do not bear a type approval certificate, they shall be subjected to the test sequences in this specification, carried out in the order laid down. If both components fail any test, the design shall be deemed not to have met the qualification requirements. If one of the two components fails any test, the third component shall be subjected to the whole of the relevant test sequence from the beginning. If this component also fails, the design shall be deemed not to have met the qualification requirements.

Once all the components have passed the component tests, the solar lanterns shall be subjected to the shipping vibration test and the lantern performance test. The procedures of the lantern performance test are subdivided into three different tests: the functional test, the autonomy test and the recovery test.

The lantern shall be subjected to the test sequences in this specification, carried out in the order described.

If both lantern samples fail any test, the design shall be deemed not to have met the qualification requirements. If one of the two lantern samples fails any test, a third lantern shall be subjected to the entire relevant test sequence from the beginning. If this lantern also fails, the design shall be deemed not to have met the qualification requirements. Figure 1 represents the qualification process.

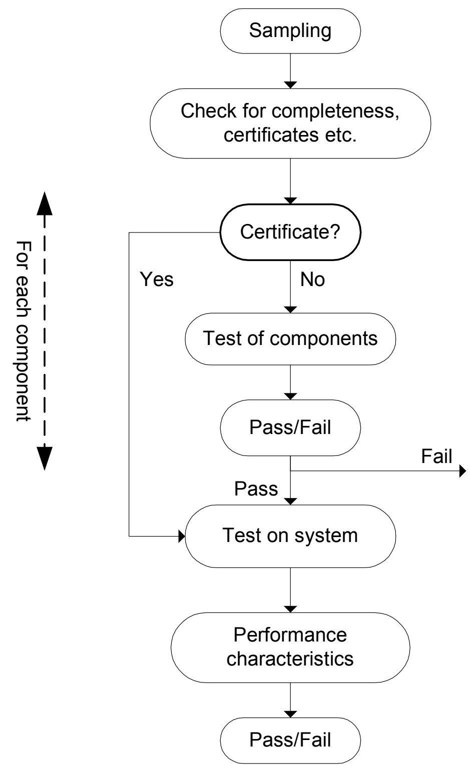


Figure 1: Flow diagram representing the qualification process

5.3 Testing levels and criteria

The Table 1 contains an overview of the tests, testing conditions and criteria.

Table 1: Test Overview

Test	Conditions	Criteria
PV module	The PV module as specified by the manufacturer and included in the set shall bear a type approval certificate from an internationally recognized PV quality system (constitutes acceptability).	IEC 61215 or PVRS 2, or IEC 61646 or PVRS 3
PV module	The PV module does not have a certificate but the criteria to the right are met (constitutes acceptability).	The manufacturer manufactures certified modules of a similar type and the module power is lower than 10 W.
PV module	The PV module does not have a certificate, the module power is lower than 10 W and the manufacturer does not manufacture certified modules of	A standard module test is passed, limited to • Outdoor exposure test • Damp-heat test • Robustness of terminations test.

Test	Conditions	Criteria
	a similar type.	
Battery	Certificate required (constitutes acceptability)	PVRS 5A
Lamp	Certificate required (constitutes acceptability)	PVRS 7A
Switching and PV module connector durability test	1,000 cycles	• Functionality and safety evaluated • Resistance of connector <20 mΩ
Open circuit test of the ballast	Input voltage 1.2 times the nominal battery voltage, repeat twice.	The lantern shall function.
Open circuit test of the charge controller	Remove the battery. Apply 1,25 times open-circuit voltage to the PV module input terminals of the charge controller.	The charge controller must withstand the condition without any damage.
Reverse polarity of the PV module	Apply a reverse polarity voltage equal to 1.5 times the nominal open-circuit voltage of the PV module to the PV module input terminals of the charge controller.	The charge controller must withstand the condition without any damage.
Reverse polarity of the battery	Apply a reverse polarity voltage equal to 1.2 times the nominal battery voltage to the battery input terminals of the charge controller.	The charge controller must withstand the condition without any damage.
Fuses	The battery shall be protected against short-circuit by (a) fuse or fuses, as close as possible to the battery terminals.	Overcurrent devices shall be rated for at least 156% of the short circuit current (at STC) and shall have a voltage rating of at least 125% Voc.
Shipping vibration test	10 Hz to 11,8 Hz; 11,9 Hz to 150 Hz • Amplitude: 3,5 mm, • Acceleration: 2 g • Cycling: 1 octave/min, • Duration on each axis: 2 h; overall: 6 h.	The lantern shall function.
System performance tests	• Functional test • Autonomy test • Recovery test	1. The lamp must function at all stages of the test unless the charge controller has disconnected the lamp due to a low battery state of charge. 2. The battery capacity shall not decrease over the testing period more than 10%, expressed

Test	Conditions	Criteria
		by $(C_0-C_2)/C_0 < 10\%$; C_o is the initial battery capacity and C_2 is the final battery capacity. 3. The 'recovery test' should exhibit an upward trend in the system voltage. During the recovery test, the total net Ah into the battery should be >=50% of C_1 where C_1 is the battery capacity after recovery test. 4. After capacity test C_1, the load shall begin operating again on or before the third 'recovery test' cycle. 5. The System Balance Point (see System Characterization Plot) shall match or stay below the defined minimum irradiation class. 6. The measured days of autonomy shall match or exceed the defined minimum days of autonomy as indicated by the manufacturer. 7. The lamp shall operate undamaged according to the manufacturer's specification at the maximum battery voltage occurring during periods of high irradiance and at high state of charge. 8. No sample shall exhibit any abnormal open-circuit or short-circuit conditions during the tests.

6 Marking

The manufacturer shall provide the solar lantern and the PV module (if not integrated) with the following clear and indelible markings:

- Name, monogram or symbol of the manufacturer/supplier
- Type or model number
- Nominal module and battery voltage
- Serial or batch number
- Polarity of terminals or leads
- Precautionary warning concerning special requirements for storage or handling

The date and place of manufacture shall be marked on the component or be traceable from the serial number.

All components must be provided with relevant documents concerning their rating, certificates and specifications in the language of the user and/or technician. Instead of a written user's manual, illustrations may be used where appropriate.

Labeling on equipment shall be in accordance with good ergonomic principles so that warning notices, controls, indications, testing facilities, fuses and the like, are sensibly placed and logically grouped to facilitate correct and unambiguous identification.

7 Pass criteria

A solar lantern design shall be judged to have passed the qualification test if each test sample meets all the following criteria:

7.1 Solar lantern completeness

The lantern shall be complete and contain the following elements:

- All the necessary hardware
- Specification by the manufacturer of Daily Run Time (DRT) under testing conditions. For the purpose of this test, DRT is based on the irradiation class III, as shown in Annex A;
- Specification by the manufacturer concerning the design load (Watt-hour), the irradiation level for which this design load can be energized by the solar lantern, the autonomy and the classification under design conditions (see Annex A). These specifications enable the test lab to verify the manufacturer’s calculations
- Specification by the manufacturer concerning the days of autonomy under testing conditions
- Certificates
- Manual, including list of spare parts and tools, as described in clause 8.

7.2 The PV Module

The PV module as specified by the manufacturer and included in the set shall bear a type approval certificate from an internationally recognized PV quality system.

The PV module shall be certified according to IEC 61215 or PVRS 2 in case of crystalline silicon PV modules and according to IEC 61646 or PVRS 3 in case of thin film PV modules.

In case the module does not bear a certificate, the following three requirements shall be met:

(i) The module manufacturer already has larger module(s) certified against IEC 61215 or PVRS 2 in case of crystalline silicon PV modules and according to IEC 61646 or PVRS 3 in case of thin-film PV modules.

(ii) The peak power rating of the solar lantern module is less than 10 Watts.

(iii) The module for the solar lantern applies the same materials (including but not limited to solar cells, interconnecting material, encapsulants, and junction box connections) and is made in the same factory using the same manufacturing installation as for the module(s) for which the manufacturer has received certification.

In case the module does not bear a certificate and one or more of the above three criteria do not apply, the module shall be qualified for solar lantern application following the tests described in clause 11.

Note: The reason for simplifying some of the requirements for modules of solar lantern is based on the following: Solar lanterns are designed for a minimal lifetime of five years, and normally their price reflects the lower life expectancy compared to larger systems. In view of the different lifetime expectation and the smaller sizes, reducing some of the severe tests of IEC 61215 or IEC 61646 is justified. The retesting of the complete module is unnecessary if the module manufacturer already has in the same module family larger modules certified.

7.3 The battery

The battery as specified by the manufacturer and included in the set shall bear a type approval certificate from an internationally recognized PV quality system.

The battery shall be certified according to PVRS 5.

7.4 The lamp(s)

The lamp(s) as specified by the manufacturer and included in the set shall bear a type approval certificate from an internationally recognized PV quality system.

The lamps shall be certified according to PVRS 7.

7.5 Protection against open-circuit, short-circuit and reverse polarity

The inverter shall be protected against damage from voltage under open-circuit conditions (for example, when the lamp is removed or has failed).

The charge controller shall be protected against damage from voltage under open-circuit conditions when the battery is removed or has failed and from short-circuit conditions when the PV module terminals are short-circuited.

The charge controller shall be protected against damage from reverse polarity conditions of the battery and the PV module.

7.6 Fuses and circuit breakers

The battery shall be protected against short-circuit by a fuse or fuses, as close as possible to the battery terminals.

Soldered fuses on the printed circuit board are also allowed. Where fuses of different capacity are installed, they shall have clear color coding or labeling or be of different physical size.

Fuses shall meet the following conditions:

- Be sized per the conductor size and per the component they are protecting as specified by the manufacturer
- Be marked with rated current, voltage and use (AC or DC)
- Be rated for DC service in DC applications
- Have appropriate voltage ratings for the circuit they are protecting.

Overcurrent devices protecting PV source and output circuits and carrying currents from the PV modules shall be rated for at least 156% of the short circuit current (at Standard Test Conditions) and shall have a voltage rating of at least 125% Voc.

7.7 Switch and module connectors

Switches suitable for DC use are to be provided on the lantern. The switch shall be able to withstand a minimum of 1000 cycles under load.

The PV module connector shall be able to withstand a minimum of 1000 connections cycles.

A test sequence is provided in clause 12.

7.8 System performance tests

The system shall pass the system performance tests described in clause 15

The following pass-fail-criteria apply:

1. The lamp must function at all stages of the test unless the charge controller has disconnected the lamp due to a low battery state of charge (LVD).
2. The battery capacity shall not decrease over the testing period more than 10 percent, expressed by $(C_0-C_2)/C_0$ < 10 percent; C_o is the initial battery capacity and C_2 is the final battery capacity.
3. Recovery: the 'recovery test' should exhibit an upward trend in the system voltage. During the recovery test, the total net Ah into the battery should be >=50 percent of C_1 where, C_1 is the battery capacity after recovery test.
4. After capacity test C_1, the load shall begin operating again on or before the third 'recovery test' cycle.
5. The System Balance Point (see System Characterization Plot) shall match or not exceed the defined minimum irradiation class.
6. The measured days of autonomy shall match or exceed the defined minimum days of autonomy as indicated by the manufacturer.
7. The lamp shall operate undamaged according to the manufacturer's specification at the maximum battery voltage occurring during periods of high irradiance and at high state of charge.
8. No sample shall exhibit any abnormal open-circuit or short-circuit conditions during the tests.

7.9 Visual evidence of a major defect

There shall be no visual evidence of a major defect, as defined in clause 9, both before and after the components tests as well as the system performance test as described in clause 14.

8 Manual

The manual shall be written in English and the user's language and shall include the following:

- A complete list of all system components and spare parts, with associated manufacturers literature, specifications and warranties.
- A complete set of electrical schematic, mechanical composition, functional block diagram and layout.
- Battery safety requirements including maintenance/replacement procedures.

- Lamp maintenance/replacement procedures.
- Installation instructions that ensure proper placement of the PV module and lamp assembly. The lamp must be installed in a protected environment to be consistent with the scope of this specification.
- Procedures for proper system operation, including load conservation during periods of inclement weather, and/or a low voltage disconnect event. A checklist that contains what to do in case of a system failure shall be included. The procedures for checking that the PV module is not shaded and how to prevent shading must be explained.
- Maintenance items.
- A troubleshooting guide referencing all the system components. This must include repairs and diagnostic procedures that can be done by the supplier.

Lantern performance must be specified in the following terms:

- Rated average energy supply (Wh/day)
- Autonomy (number of days without sunshine the lantern can service the load)
- Hours of use of lamp
- Test conditions.

9 Major defects

For the purpose of design qualification, the following are considered to be major defects:

- Failure of any system component, including the on/off switch
- Broken, cracked, bent, misaligned or torn external surface of any component (PV module, battery, charge controller, or other balance of system (BOS) component)
- Browning of any printed circuit board
- Loss of mechanical integrity, to the extent that the installation and/or operation of the system would be impaired
- Deterioration of wiring insulation
- Electrolyte leakage from the batteries
- Signs of overheating or corrosion.

10 Load specification

Many solar lanterns have multiple lighting modes, which may be activated by incorporating two lamps or via electronic controls.

For the purpose of this test the lamp shall be operated at maximum power.

The manufacturer shall specify the daily number of hours the system can service the load under the test conditions described in this specification (DRT). This number shall be derived using the irradiation class III, specified in Annex A.

For the purpose of the test and while the PV modules are connected, the load is never operated during daylight or at times when the solar irradiance is above 50 W/m².

11 Solar PV modules test

The purpose of this test sequence is to determine the electrical characteristics of the module and to show, as far as possible within reasonable cost and time constraints that the module is capable of matching the expected lifetime that a solar lantern is expected to have.

The test is a simplified version of the IEC module test according to IEC 61215 in the case of crystalline silicon PV modules or according to IEC 61646 in the case of thin-film PV modules.

For the purpose of this standard the testing procedure under clause 10 of IEC 61215 or IEC 61646 is limited to the following three tests:

- Outdoor exposure test
- Damp-heat test
- Robustness of terminations test.

12 Switching and solar module connector durability test

12.1 Purpose

The purpose of this test is to ensure that the switch and the module connector are able to withstand normal use and do not fail prematurely.

12.2 Procedure

Subject the switch to an initial electrical resistance measurement test. In case the switch has a resistance of more than 20mΩ, the switch has failed the test.

Make sure the lantern is fully charged and ready for use.

1) Switch on the light; in case there is more than one switch, use all the switches.
2) Switch off the light.
3) Connect the module to the lantern housing.
4) Flex the module cable at the connector and disconnect the module from the lantern.

Repeat the procedure 1000 times.

Measure the electrical resistance over the module connection.

12.3 Requirements

None of the components must show signs of wear that endanger the functionality or cause potential safety hazards.

The switch must function and the module connector must not exhibit an electrical resistance value more than 20 mΩ.

13 Protection against open-circuit, short-circuit and reverse polarity tests

13.1 Open-circuit test of the ballast

13.1.1 Procedure

A. Connect the lamp with the electronic ballast to a regulated power supply. Adjust the input voltage to 1.2 times the nominal battery voltage. Remove the lamp, turn the switch on and off twice, leave the set-up for 1 hour and put the lamp back. Wait at least 1 minute. Repeat this test twice without waiting for 1 hour.

Requirement: The lantern shall function.

B. Connect the electronic ballast to the regulated power supply. Do not connect the lamp. Adjust the input voltage to 1.2 times the nominal battery voltage, wait at least 1 minute and measure the input current.

Requirement: The ballast shall function properly. This is normally the case when the input current is not more than 10 mA.

Note: Not all lanterns incorporate electronically controlled ballasts.

13.2 Open-circuit test of the charge controller

13.2.1 Procedure

Apply a voltage equal to 1.25 times the open-circuit voltage of the PV module to the PV module input terminals of the charge controller using a regulated power supply. Remove the battery. Wait at least 1 minute.

Requirement: The charge controller must withstand the condition without any damage.

Requirement: When the battery is removed, the PV voltage must not “snap through” to the load terminals! Otherwise the load can be destroyed. This means that the charge controller must cut down the PV-voltage in case of a removed battery.

13.3 Reverse polarity test of the charge controller

13.3.1 Procedure for reverse polarity of the PV module

Apply a voltage equal to 1.5 times the nominal open-circuit voltage of the PV module to the PV module input terminals of the charge controller using a regulated power supply connected with reverse polarity. Wait at least 1 minute.

Requirement: The charge controller must withstand the condition without any damage.

13.3.2 Procedure for reverse polarity of the battery

Apply a voltage equal to 1.2 times the nominal battery voltage to the battery input terminals of the charge controller using a regulated power supply connected with reverse polarity. Wait at least 1 minute. Observe any irregularities (excessive heat, smoke, fire, damaged components, etc) with the charge controller.

Requirement: The charge controller must withstand the condition without any damage.

Note: Battery protection fuses may blow, which is a normal outcome and should not be interpreted as a failure of this test.

14 Shipping vibration test

14.1 Purpose

The purpose of this test is to identify mechanical weak points and/or to ascertain any deterioration of the specified performance. According to IEC 60068-2-6, it must be conducted on structural elements or devices that are exposed to harmonic vibrations during shipment, such as occur on ships, in aircraft and land vehicles.

14.2 Requirements

Frequency range:	10 Hz to 11,8 Hz; 11,9 Hz to 150 Hz
Constant amplitude:	3,5 mm
Constant acceleration:	2 g
Cycling:	1 octave/min
Duration on each axis:	2 h
Total test duration:	6 h

14.3 Apparatus

See IEC 60068-2-6.

14.4 Procedure

See IEC 60068-2-6.

The specimens are neither packaged nor energized during the test.

15 Solar lantern performance tests

15.1 Instrumentation and equipment

Annex B contains a description of the instrumentation and equipment for the solar lantern tests.

15.2 Test documentation

In addition to recording all the relevant system data, the test operator shall keep relevant test data, calculations, and appropriate comments. An electronic copy of the system data shall be kept for future reference.

15.3 Installation

Operate the solar lantern according to the manufacturer’s instructions.

For indoor testing, a '"class C", as defined in IEC 60904-9, or better solar simulator shall be used.

15.3.1 Solar lantern preconditioning

Follow the manufacturer's instructions for adding electrolyte (in case of flooded batteries) and preconditioning the battery for system operation.

If battery preconditioning is not called for in the solar lantern documentation, the battery shall be subjected to:

- At least five cycles from High Voltage Disconnect (HVD) to Low Voltage Disconnect (LVD) in an outdoor test, or
- At least five cycles at C_{10} for an indoor test.

> *Note:* Certain advanced charge controllers need a few days/cycles to find the optimum settings matching the system design. The manufacturer shall state this and the performance test shall be preceded by the prescribed number of cycles.

PV modules exhibiting light-induced degradation (for example. amorphous silicon) shall be subjected to initial light soaking according to IEC 61646.

15.3.2 Verify load operation

The lamp is an integral part of the solar lantern and the size of the lamp is an important design parameter. Lanterns may contain more than one lamp or can be varied in brightness. For the purpose of this test, always use the maximum light output as specified by the manufacturer.

Verify that the lamp starts and operates properly.

In systems with multiple lamps, verify that each individual lamp can start and run while all other lamps are operating.

For this test, it is only necessary to operate the lamp(s) long enough to determine whether they function correctly.

Turn off all lamps after verifying they operate properly.

15.3.3 Data acquisition system installation

Install the plane of the module irradiance sensor (reference device). The irradiance sensor shall be as close as possible to the PV module without shading the module and shall be mounted in the same plane and within +/- 5° of the module tilt angle.

Program the data acquisition system to monitor the measurement parameters and store as 5-minute averages.

Install the temperature sensors:

- The ambient temperature sensor must be mounted in an aspirated or double-shaded shield.
- The temperature sensor on the back of the module must be mounted in the middle of a solar cell within the center of a module, utilizing thermal paste and covering the sensor with insulation material and foil.
- The battery temperature sensor must be mounted as close as possible to the temperature compensation sensor. If temperature compensation is internal to the charge controller, a

temperature sensor in addition to the battery temperature sensor shall be mounted to sense the controller temperature.

Install voltage sensors for the PV module and loads.

Install the voltage sensor for the battery at the battery terminals.

Maximum and minimum values of the signals specified in Annex Table B-1 shall also be collected and stored.

Install current sensors for the PV module, battery and lamp.

Calculate module and load DC Power. DC power may be computed by multiplying average DC voltage and average DC current.

Install a sensor to detect proper load operation, for example a light sensor in front of a lamp.

> *Note:* In case of a fluorescent lamp, it would not be adequate to only look at the current load as an indicator of load operation because the lamp could malfunction yet the ballast may continue to draw current.

Note the load operation method.

Modify a copy of the schematic to show the data acquisition system sensor locations.

This modified schematic shall be included in the report of clause 20.

15.3.4 Lantern photographs

Photograph the lantern after the lantern has been instrumented. Include the photos with the documentation.

15.4 Visual inspection

The lantern and its components must be checked for damage and workmanship (for example, suitability of structural elements)

After each test, flex all conductors along their entire length, noting any discoloration or brittleness of the insulation. Undersized conductors and poor connections will tend to overheat, leading to brittle and discolored insulation.

Any peculiarities observed must be carefully documented in the report (clause 20) and if necessary by means of photography.

Verify that all parts listed on the parts list are present. Note any missing system parts that should have been included. If essential parts, that is, parts without which the system cannot go through the testing procedure, are missing, the system shall be deemed to have failed the test and shall be sent back to the manufacturer.

15.5 Test sequences

The Figure 2 indicates the steps of the system performance test, as described in more detail in clause 16:

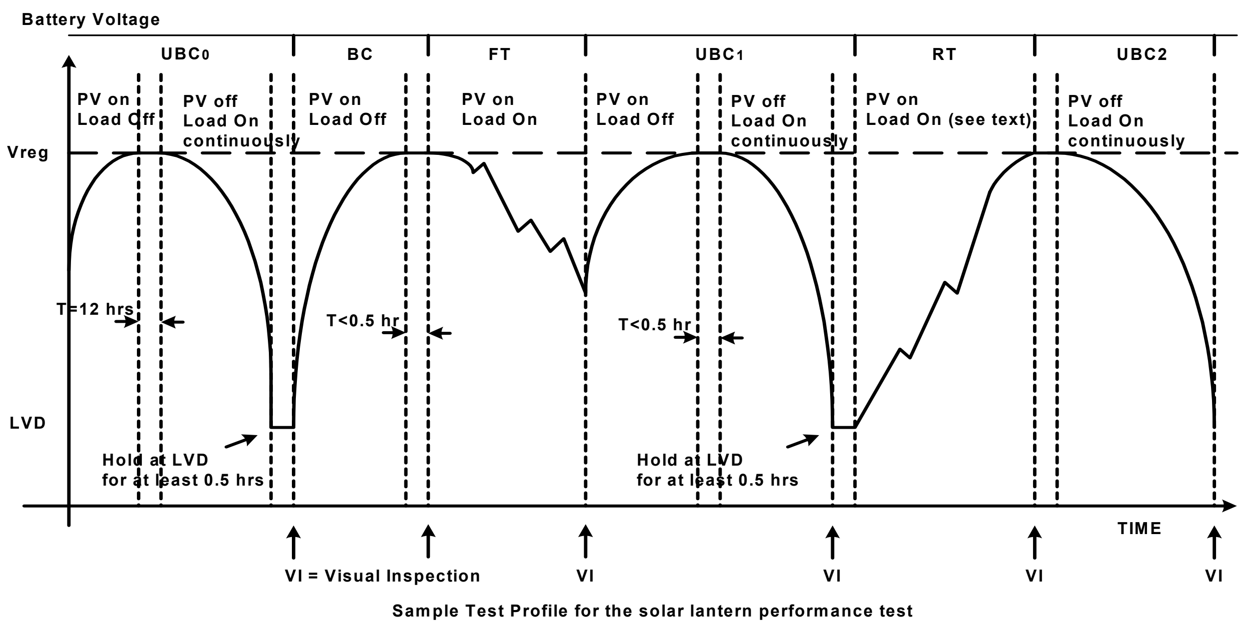


Figure 2: Steps in the System Performance Test

Various test sequences are applied during the test to verify performance for low discharge, battery recovery, functionality operation and ability to reach HVD under normal operation in sunny weather, even after having been completely discharged. These tests are outlined below.

UBC_0 = Initial Usable Battery Capacity Test: Initial capacity test – After installing the system, charge and discharge the battery, and measure the usable battery capacity (UBC).

Vreg = voltage level at which the controller determines a “full battery level”

BC = Battery Charging: Recharge the battery before running the Functional Test.

FT = Functional Test: Run the Functional Test to verify that the system and load operate properly.

UBC_1 = First Usable Battery Capacity Test: Capacity test and autonomy test – Charge and discharge the battery. Measure the usable battery capacity. Determine the system autonomy.

RT = Recovery Test: Determine the ability of the PV System to recharge the discharged battery.

UBC_2 = Second Usable Battery Capacity: Final capacity test – Charge and discharge the battery. Measure the usable battery capacity.

15.6 System characterization graph

Plot the values found in the tests and construct the system characterization graph as described in clause 17.

Determine the System Balance Point.

16 Lantern Testing Sequence

16.1 Lantern testing conditions

The temperature of the batteries shall be kept at 27 °C ± 3 °C.

The general ambient temperature during testing shall be within 27 °C ± 3 °C

The test is valid both for using a solar simulator or a solar module simulator. Both shall have the ability to simulate the Reference Solar Day using the Daily Irradiance Profiles as described in this specification.

The solar simulator shall be Class C or better. However, for days with a high solar irradiation a three-step profile is allowed. For days with a low solar irradiation, a constant value of the irradiance is allowed. This specification may be amended to allow the use of non-solar simulators upon the publication of IEC 61853: Performance testing and energy rating of terrestrial photovoltaic (PV) modules (under consideration).

The requirements for the solar module simulator are described in annex C.

16.2 Initial capacity test

Make sure the system has been properly preconditioned in accordance with clause 15.3.1.

With PV on and load off allow the lantern to charge the battery by imposing at least 700 W/m². Once the lantern reaches a state of regulation, keep the lantern at this state for 12 hours. The battery will then be regarded as charged.

With PV off and load on continuously, allow the lantern to fully discharge the battery. The battery is fully discharged when it reaches LVD. Allow the battery to remain at LVD for 5 hours. Record the number of Ah discharged from the battery. This is the Initial Usable Battery Capacity (UBC_0).

Perform a visual inspection as described in the section in accordance with clause 15.4.

16.3 Battery charge cycle

Switch off the light. Set the simulator at 700 W/m² ± 50 W/m². With PV on and load off let the module recharge the battery until it has reached regulation (HVD). Allow the lantern to stay there for a maximum of 0.5 hours. Record the number of Ah recharged into the battery.

16.4 Lantern functional test

This test verifies that the lantern can service the load as intended.

With PV on and light on as specified by the manufacturer in accordance with clause 10, allow the lantern to operate “normally” for 10 days. Figure 3 gives an overview of the recommended irradiance profiles to be used in the test.

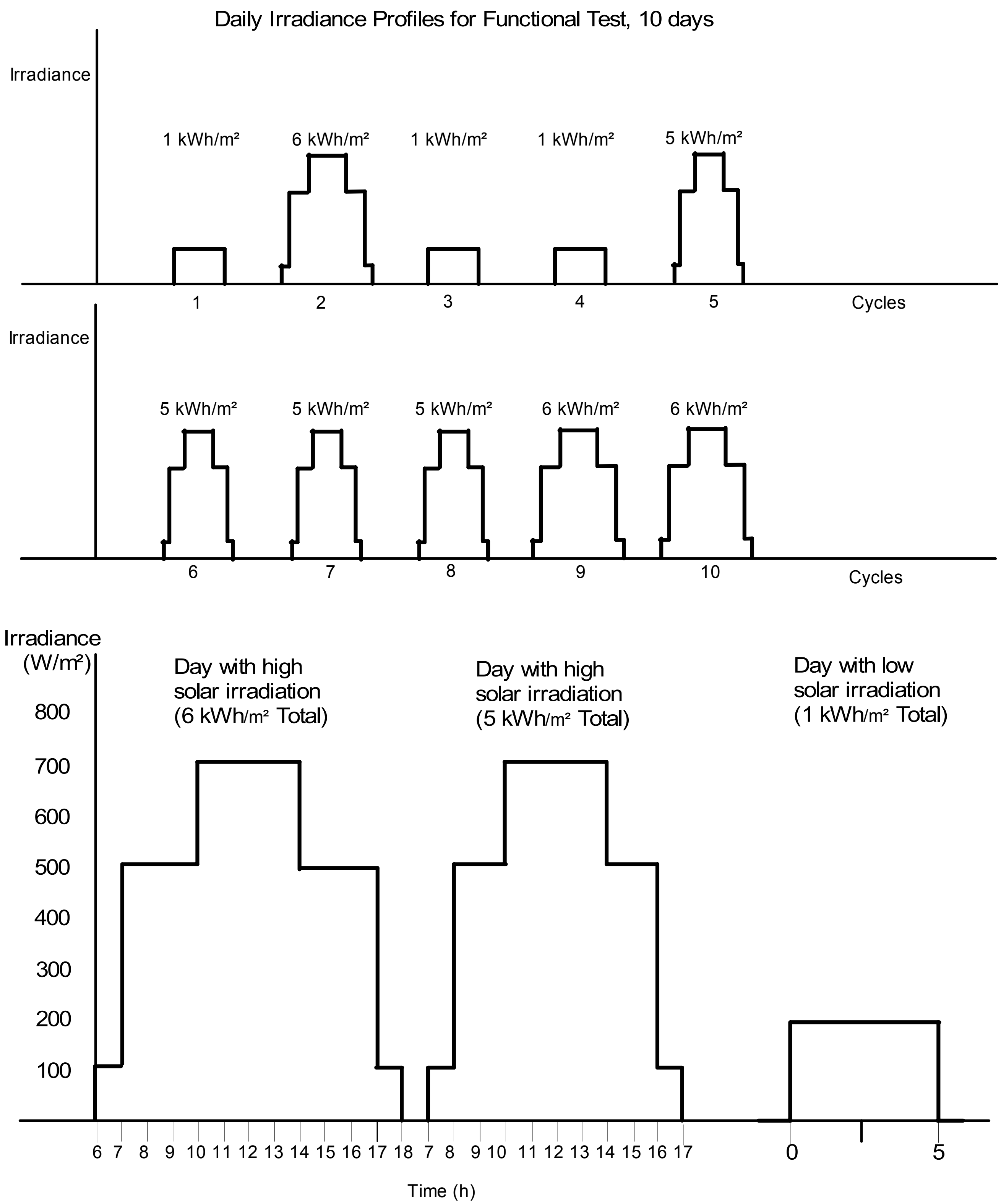


Figure 3: Recommended Irradiance Profile to be Used in Test

Table 2: Cycles of the performance test

Cycle #	Irradiance profile
Cycle 1:	Day with low irradiation (1 kWh/m²), operate load
Cycle 2:	Day with high irradiation (6 kWh/m²), operate load
Cycle 3:	Day with low irradiation (1 kWh/m²), operate load
Cycle 4:	Day with low irradiation (1 kWh/m²), operate load
Cycle 5:	Day with high irradiation (5 kWh/m²), operate load
Cycle 6:	Day with high irradiation (5 kWh/m²), operate load
Cycle 7:	Day with high irradiation (5 kWh/m²), operate load
Cycle 8:	Day with high irradiation (5 kWh/m²), operate load
Cycle 9:	Day with high irradiation (6 kWh/m²), operate load
Cycle 10:	Day with high irradiation (6 kWh/m²), operate load

The cycles do not necessarily have to cover 24 hours, since no rest time between operation of the load and the PV charging is required.

The irradiation profiles in Table 3 are minimum requirements that must be applied, better (smoother) profiles leading to a similar daily sum are also allowed:

Table 3: Irradiance profiles

Day with high solar irradiation (6 kWh/m²day +/- 0.3 kWh/m²)
1 hour at 100 W/m²
3 hours at 500 W/m²
4 hours at 700 W/m²
3 hours at 500 W/m²
1 hour at 100 W/m²

Day with high solar irradiation (5 kWh/m²day +/- 0.3 kWh/m²)
1 hour at 100 W/m²
2 hours at 500 W/m²
4 hours at 700 W/m²
2 hours at 500 W/m²
1 hour at 100 W/m²

Day with low solar irradiation (1 kWh/m²day +/- 0.3 kWh/m²)
5 hours at 200 W/m²

Perform a visual inspection in accordance with clause 15.4.

16.5 Second capacity test plus autonomy test

Disconnect the load after the functional test. Set the simulator at 700 W/m² ± 50 W/m². With PV on and light off recharge the battery until it has reached regulation (HVD) and stays there for a maximum of 0.5 hours. Disconnect the PV module and switch on the light. Allow the lantern to discharge the battery until it reaches LVD.

Determine the lantern autonomy.

Determine the number of Ah discharged from the battery and the total time to discharge. This is the Second Usable Battery Capacity (UBC_2).

Allow the battery to remain at LVD for at least 5 hours but not more than 72 hours.

Perform a visual inspection in accordance with clause 15.4.

16.6 Recovery test

Connect the PV module and switch off the light. Operate the solar simulator with an irradiance profile of a day with high solar irradiation (5 kWh/m²) in accordance with clause 16.4. Then connect the load as specified by the manufacturer in accordance with clause 10.

> *Note:* The lantern may still have low-voltage protection at this time. If that is the case, disconnect the load again and operate the solar simulator with an irradiance profile of a day with high solar irradiation (5 kWh/m²) in accordance with clause 16.4. Then connect the load as specified by the manufacturer in accordance with clause 10.

Once the load comes on, wait until the lantern reaches LVD or the Daily Run Time has passed.

Repeat this test until the lantern has gone through seven recovery test cycles. The lantern has then been exposed to an overall irradiation of 3.5 kWh/m². If the lantern reaches HVD, record after how many recovery test cycles HVD was reached.

Record at which "recovery test cycle" the load started to operate.

Measure the net Ah into the battery and to the load during seven recovery test cycles.

After these recovery test cycles switch off the light, set the simulator at 700W/m² ± 50W/m² and wait until the lantern reaches a state of regulation. Once the lantern reaches a state of regulation, keep it at this state for 12 hours. The battery can then be regarded as fully charged.

Perform a visual inspection in accordance with clause 15.4.

16.7 Final capacity test

With PV off and light on continuously, allow the lantern to fully discharge the battery. The battery is fully discharged when it reaches LVD. Allow the battery to remain at LVD for 5 hours. Record the number of Ah discharged from the battery. This is the Final Usable Battery Capacity (UBC_2).

16.8 Operation at maximum voltage

Verify the suitability of the light operated at the maximum battery voltage occurring during periods of high irradiance (between 800 and 1000 kWh/m²) and at high state of charge. The light shall be operated for a period of 1 hour under these conditions. The light shall operate undamaged.

> *Note:* there are lanterns on the markets that have a built-in automatic protection mechanism, preventing simultaneous charging of the battery and use of the lamp. For such lanterns this test cannot be carried out.

16.9 Visual inspection

Perform a visual inspection in accordance with clause 15.4.

16.10 Unusual occurrences

Note any unusual occurrences during the test period. These may include unplanned short or open circuits, data acquisition system malfunctions, and so on.

17 Determination of the System Balance Point

The lantern characterization plot gives a graphical representation of the minimum average irradiation that the intended location must have for the lantern to function properly.

Sum the Ah into the battery and the irradiation for each day during the functional and recovery tests. Plot the battery Ah along the Y-axis vs. irradiation along the X-axis.

The data should tend to fall along and in between two lines similar to those shown in example in Figure 4.

A horizontal line is drawn through the point with the minimum value of Ah for days when the charge controller limits the module current flowing into the battery. A sloped line is drawn through origin and the point with the highest value on days the controller does not limit the current flowing into the battery at any time. The System Balance Point is defined by the intersection of these lines.

The System Balance Point can be determined by calculation or by using graphical means.

The system as shown in Figure 4 will, for example, be suitable for locations that have at least 2.5 kWh/m²·day as a yearly average. Therefore the lantern would be qualified for irradiation class I (Annex A) and the specified daily load profile (Daily Run Time) which must be stated in the final test report and should correspond with the manufacturer's lantern performance declaration.

Note: A different load profile results in different characterization chart.

18 Indoor testing using a PV module simulator

18.1 Testing conditions

An electronic power supply simulating the module characteristics shall be used, which has the ability to simulate the Reference Solar Day in accordance with clause 16.4.

Annex C describes the calculations leading to current and voltage characteristics simulating the PV module under conditions prescribed in this specification.

The temperature of the batteries shall be kept at 27°C ± 3°C.

The general ambient temperature during testing shall be within 27°C ± 3°C.

18.2 Initial capacity test

Perform this test in accordance with clause 16.2.

18.3 Battery charge cycle

Perform this test in accordance with clause 16.3.

18.4 Lantern functional test

Perform the functional test in accordance with clause 16.4.

18.5 Second capacity test

Perform this test in accordance with clause 16.5.

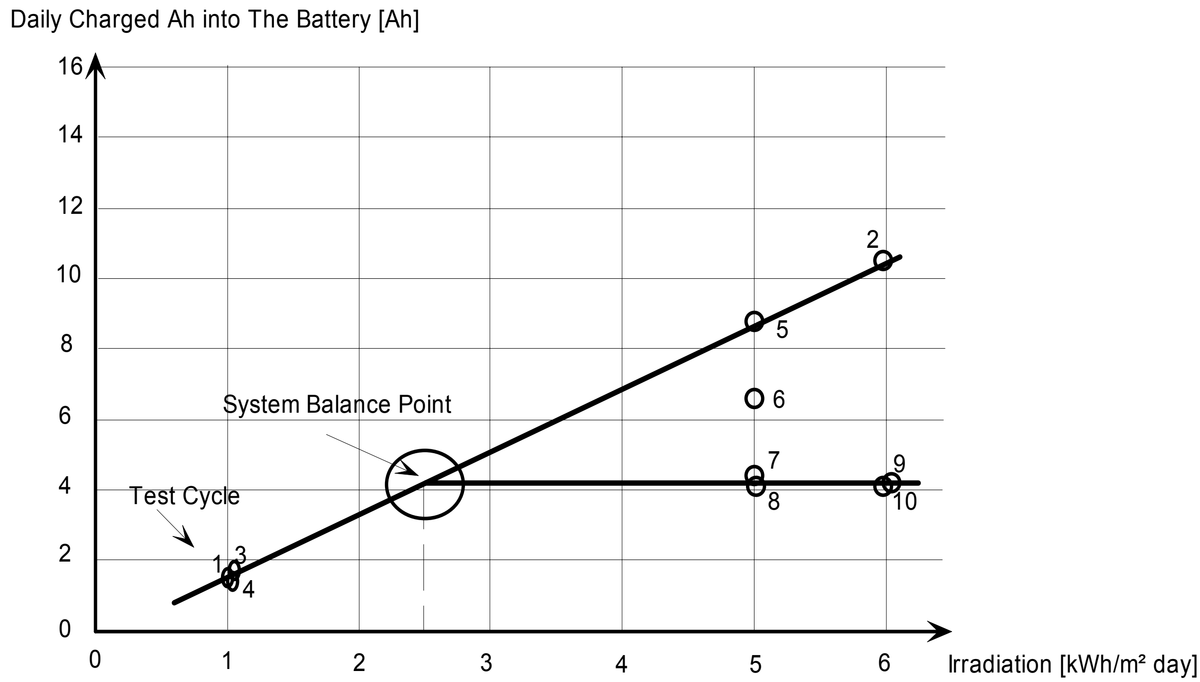


Figure 4: Lantern characterization chart, charge sequence example with three irradiation profiles and 10 cycles. Discharge: constant load profile.

18.6 Recovery test

Perform this test in accordance with clause 16.6.

18.7 Final capacity test

Perform this test in accordance with clause 16.7.

18.8 Operation at maximum voltage

Perform this test in accordance with clause 16.8

18.9 Visual inspection

Perform a visual inspection in accordance with clause 15.4.

18.10 Unusual occurrences

Note any unusual occurrences during the test period. These may include unplanned short or open circuits, data acquisition system malfunctions, and so on.

19 Modifications

Any change in the design, materials, components or processing of the lantern may require a repetition of some or all of the qualification tests to maintain design qualification.

20 Report

A report of the qualification tests, with measured performance characteristics and details of any failures and retests, shall be prepared by the testing laboratory. The manufacturer shall keep a copy of this report for reference purposes.

Annex A (Normative)

Classification of Irradiation and Systems

A.1 Determination of the irradiation class and design irradiation

Derive the *Yearly Average Daily Horizontal Irradiation* and the *Irradiation Range* from a meteorological station near the location of intended use.

The *Irradiation Range* (H_{range}) is the difference between the *Monthly Average Daily Horizontal Irradiation* of the months with the highest and lowest irradiation (in kWh/m²·day).

Table A-1 contains a classification system for locations with different irradiation patterns.

Every location can thus be allocated to an *Irradiation Class*.

Table A-1: Irradiation Classes

Irradiation Class	I	II	III	IV	V	VI
Yearly average daily horizontal irradiation [kWh/m²·day]	<4.5	<4.5	4.5 - 5.5	4.5 - 5.5	>5.5	>5.5
Range [kWh/m²·day]	>1.5	<1.5	>1.5	<1.5	>1.5	<1.5

Note: The calculation of the DRT is based on Irradiation class III.

A.2 Rating systems

For a given system at a specific location, the *Effective Daily Energy Available to the Load* can be calculated. This will then be expressed as the *Effective Daily Energy Available to the Load* for a system of make X at location Y and shall be expressed in Wh. The same system may be classified differently in another country, or even at another location in the same country.

Annex B (Normative)

Instrumentation and equipment for the system test.

The following instrumentation and equipment is necessary for conducting the system tests:

- DC voltage and DC current measuring instruments
- DC amp-hour meter or some other means of monitoring
- Elapsed time meter or some other means of monitoring
- A PV reference device that has been selected and calibrated in accordance with IEC 60904-2 to match the test modules regarding the spectral response
- Suitable instrumentation to check that the reference device and the module are co-planar to within ± 5°
- Temperature sensors
- A means to identify orientation
- Automated data acquisition system to facilitate system monitoring during the test

Data acquisition system specifications

The datalogger shall use at least a 12 bit analog-to-digital converter and have an input range that exceeds the expected positive and negative maximum voltages. The data acquisition system must be reliable: if more than 4 hours of data is lost or if any critical data is lost owing to a power failure during any test, then that test shall be restarted.

The sample rate of the datalogger is dependent on the type of charge controller. For on-off controllers, the datalogger sample rate shall be at least two times as fast as the switching period of the controller. For example, if the operation of the regulation voltage circuitry is every 10 seconds, the sample rate shall be once every 5 seconds, or faster.

For charge controllers using constant-voltage or pulse-width-modulation circuitry, the switching period may be milliseconds, not seconds. The sampling rate of the datalogger should be at least twice the switching frequency of the charge controller. If the sample rate of the used datalogger is not fast enough, one method is to sample once per second with an integrator/filter circuit added to the data acquisition system input. The time constant of the integrator/filter will need to be at least two times the sample period.

An oscilloscope may be required to determine the controller type and its switching frequency.

Data shall be stored as 5 minute averages as appropriate for each test.

The parameters shown in Table B-1 shall be measured or determined:

Table B-1: Parameters to be Measured/Determined

Measured parameter	Recorded Values	Comments
Module voltage	Minimum, average and maximum	Voltage at the module, before blocking diodes
Load voltage	Minimum, average and maximum	Measured at the load
Battery voltage	Minimum, average and maximum	Measured at the battery
Module current	Minimum, average and maximum	
Load current	Minimum, average and maximum	
Battery current	Battery amp-hours in and out	
Air temperature	Average	
Module temperature	Average	Use IEC 60904-5
Battery temperature	Average	At temperature compensation sensor or negative battery terminal
Solar irradiance	Average	Reference device, short circuit current and temperature of device
Load operation	Load run time	

Sensor specifications

The voltage sensors shall have a range exceeding the maximum expected voltage and the measurement shall have a resolution of 0.01 V or better. The current sensors shall have a range exceeding the expected maximum positive and negative current and the measurements shall have a resolution of 0.01 A or better.

DC voltage and DC current measuring instruments shall comply with IEC Publication 60904-1, except that the accuracy shall be within ± 1% Full Screen (FS).

The temperature sensors shall have a range exceeding the expected maximum positive and negative system and ambient temperatures and measurement resolution of 1° C or better. The temperature measurement accuracy shall be ±2° C or better.

The irradiance sensor shall have a suitable range and an accuracy of at least ±5 percent of the reading.

Annex C (Normative)

Determination of the module output for the indoor testing using a PV module simulator.

> *Note:* Please be aware that certain PV module simulators may not be compatible with all types of charge controllers owing to the internal switching frequencies.

C.1 Constant current source simulation

The flow diagram (Figure C-1) explains the steps to be taken to arrive at appropriate settings for a constant current source simulating the PV module:

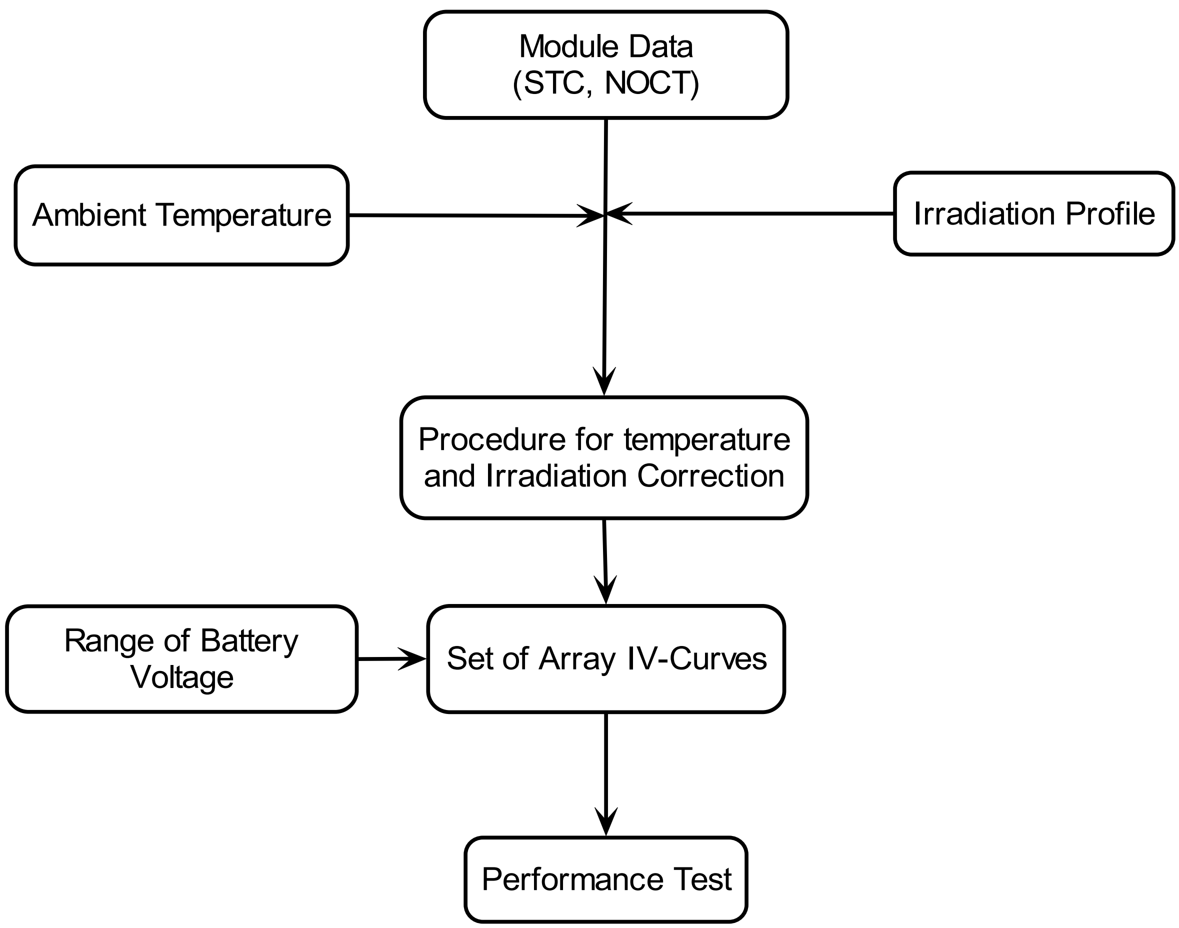


Figure C-1: Flow Diagram

Assuming the NOCT of the module is determined, only the performance of the module under STC shall be measured (refer to module performance data).

The output corresponding to the conditions at the defined reference solar day has to be calculated according to the following formula:

Translation factors

$$I_{SC,2} = I_{SC,1} \cdot \left[1 + \alpha \cdot (T_2 - T_1)\right] \cdot \frac{G_2}{G_1}$$

$$V_{OC,2} = V_{OC,1} \cdot \left[1 + a \cdot \ln \frac{G_2}{G_1} + b \cdot (T_2 - T_1)\right]$$

Translation equations for the IV data points

Current: $I_2 = I_1 \cdot \left(\frac{I_{SC,2}}{I_{SC,1}}\right)$

Voltage: $V_2 = V_1 + (V_{OC,2} - V_{OC,1}) + R_S \cdot (I_1 - I_2)$

Module parameters

α	: dimensionless temperature coefficient of I_{SC}	(default =0.0005 /°C)
b	: dimensionless temperature coefficient of V_{OC}	(default=-0.004 /°C)
a	: dimensionless radiation correction factor of V_{OC}	(default=0.06)
R_S	: serial resistance of the module, PV array	(default=0)

C.2 Temperature and irradiance correction of current-voltage characteristics

As a result of the procedure for temperature and irradiance correction a set of IV-curves is defined according to the specified reference solar day. One curve for each step of the day profile is estimated. This procedure must be repeated for every profile which is used in the test sequence of the performance test. See Figure C-2.

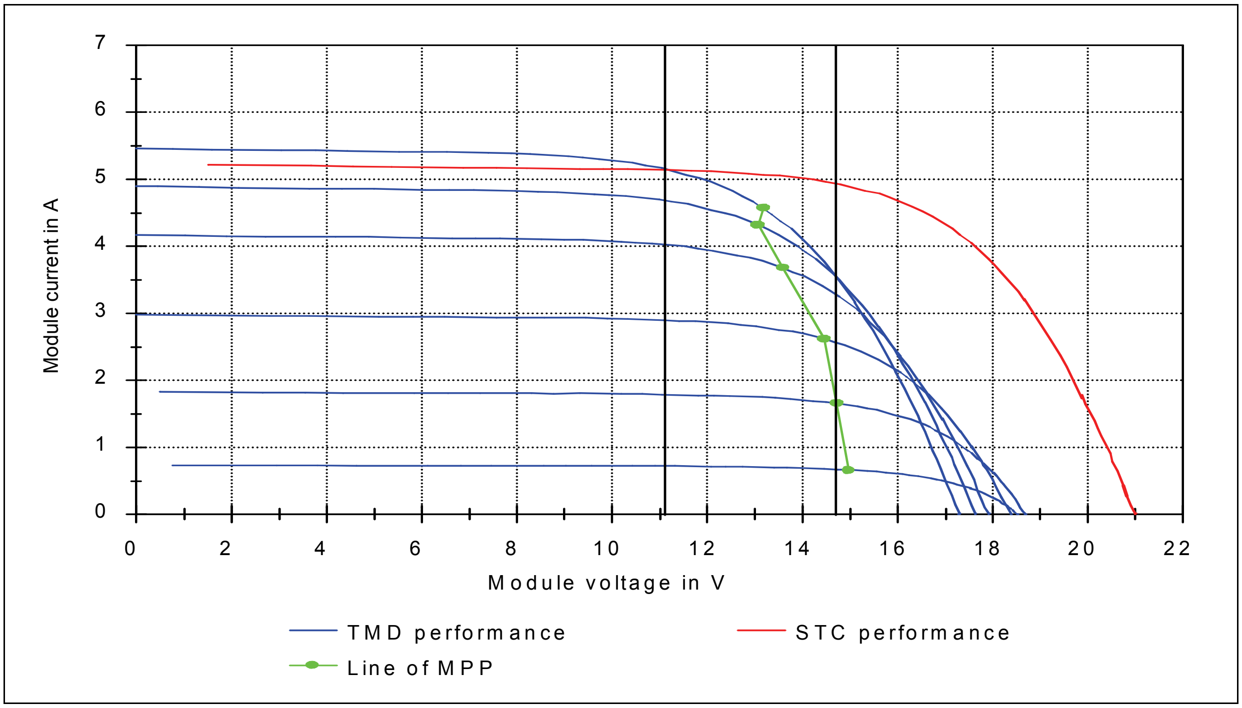


Figure C-2: Set of IV characteristics for a daily irradiance profile (example) [TMD – typical mean daily; MPP – maximum power point]

The solar lantern voltage is dominated by the battery voltage and therefore the module operates in the range of the battery voltage. The window is limited by two significant thresholds. The upper limit is the High Voltage Disconnect (HVD) set-point which disconnects the module at a certain voltage. The lower limit is the Low Voltage Disconnect point (LVD) which protects the battery and cannot be exceeded by normal system operation.

The IV-curves within the window can be estimated linearly. These estimated linear lines are called operation lines. Each IV curve within the battery voltage range is defined by means of two operation lines to achieve a good estimation. The operation lines are defined by three points on the IV-curve. The point of intersection between the module IV-curve and the lower voltage limit is the first point (Lx). The second point (Mx) is at the middle of the defined voltage range. The point of intersection between the module IV-curve and the higher voltage limit is the third point (Hx). See Figure C-3.

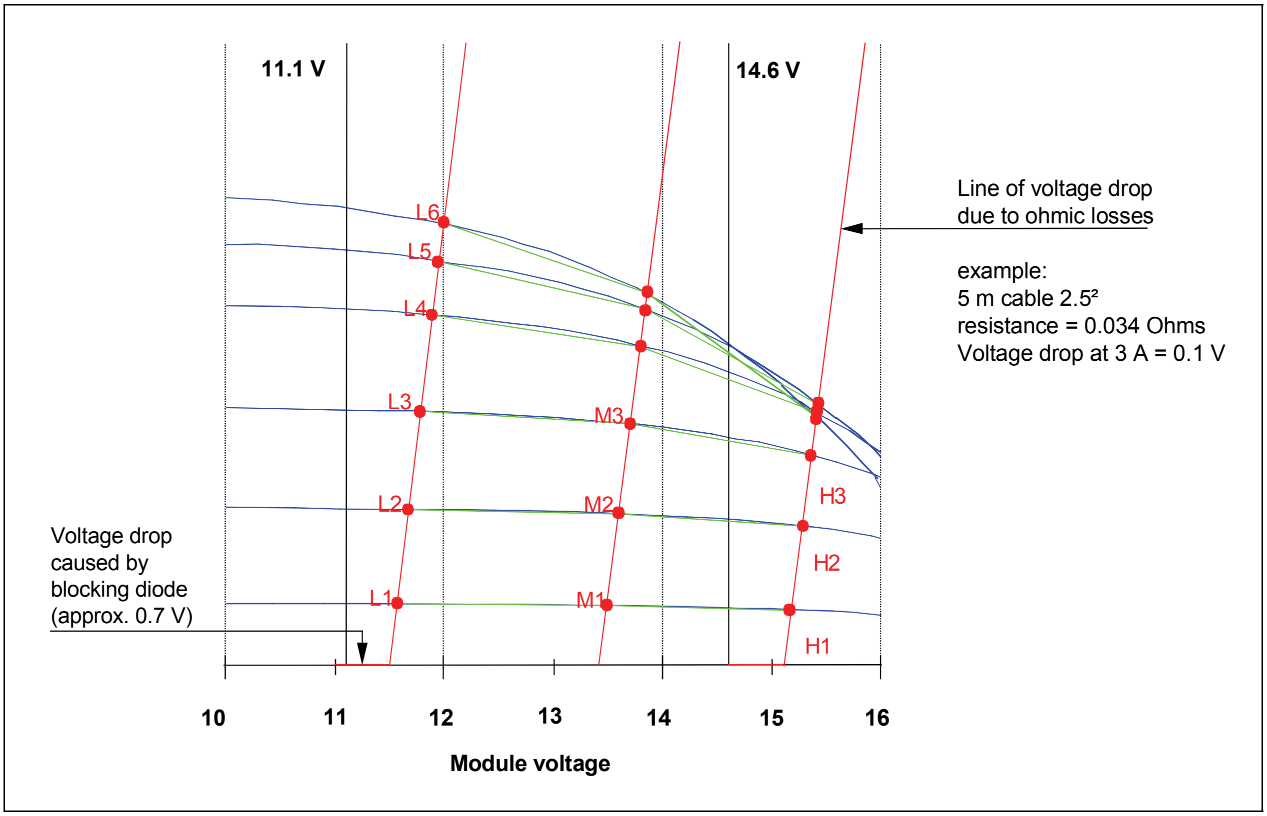


Figure C-3: Approximation of module characteristics by a set of module operation lines

Note: The vertical line at 11.1 V is the Low Voltage Disconnect (LVD) and the vertical line at 14.6 V is the High Voltage Disconnect (HVD) set-point of the charge controller. Different charge controllers have different set-points.

C.3 Module simulation procedure

The electrical behavior of the module can be simulated by means of a programmable constant current source.

Charging of the battery is controlled by the processing unit. The inputs are the- current-voltage co-ordinates for the linear approximation of the module characteristics and the battery voltage and the output is the module current.

Depending on the measured battery voltage, the current is changed continuously by successive approximation steps until the current-voltage operation point fits with the module operation line. See Figure C-4.

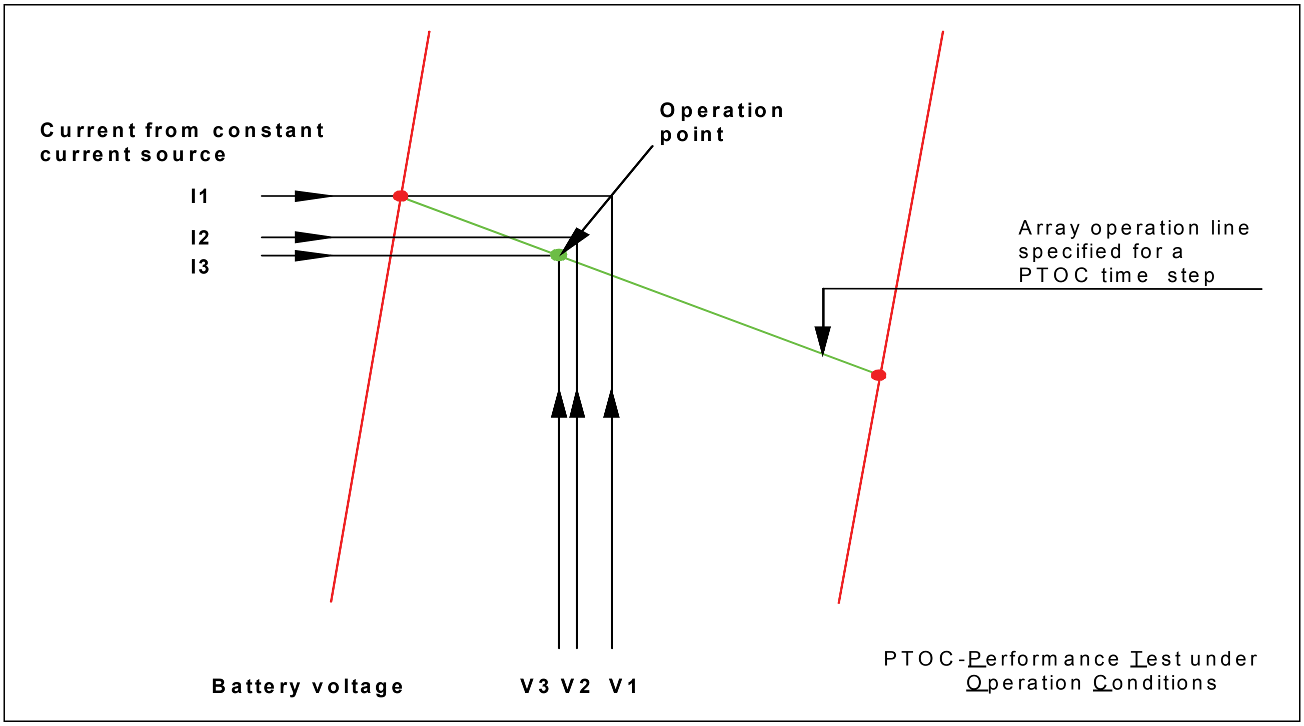


Figure C-4: Iteration process for current adjustment

C.4 Set-up for testing

The lantern without module(s) shall be installed in a climatic chamber (in case the charge controller uses a separate temperature sensor, it is possible to place only the battery in a climatic chamber or a bath). See Figure C-5.

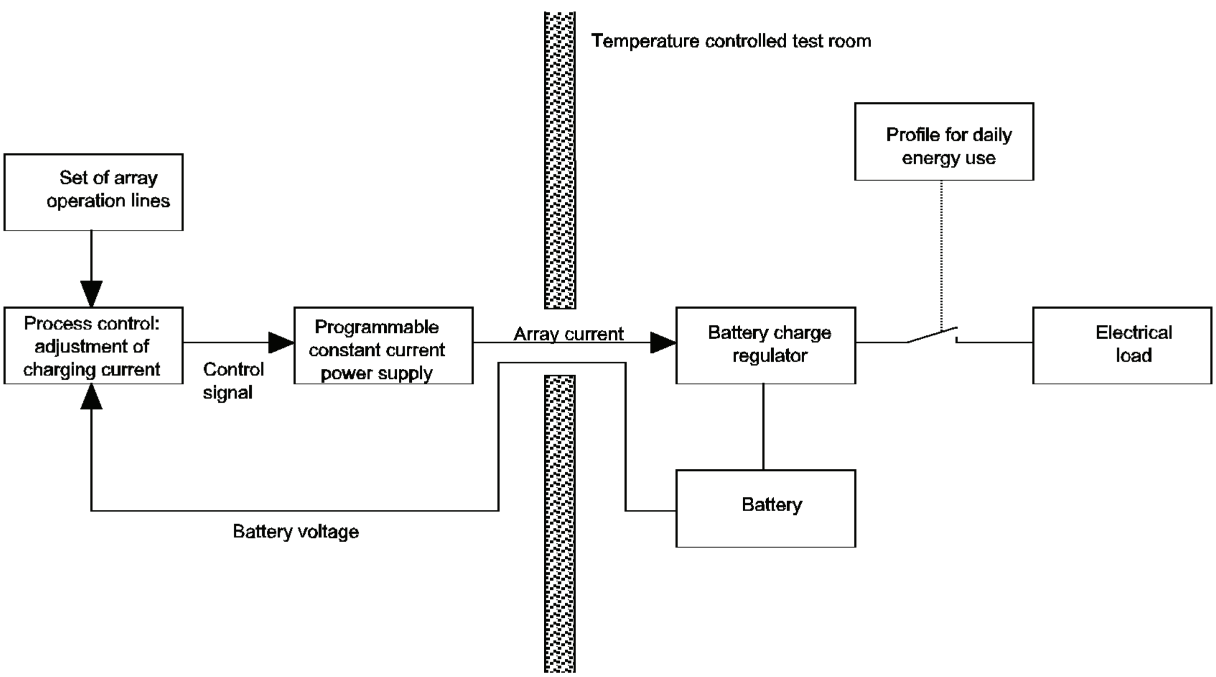


Figure C-5: Experimental set-up for PV system performance testing

C.5 Algorithm for simulation of the module performance

Flow chart for simulation of the module performance presented for one time step of the PTOC profile. See Figure C-6.

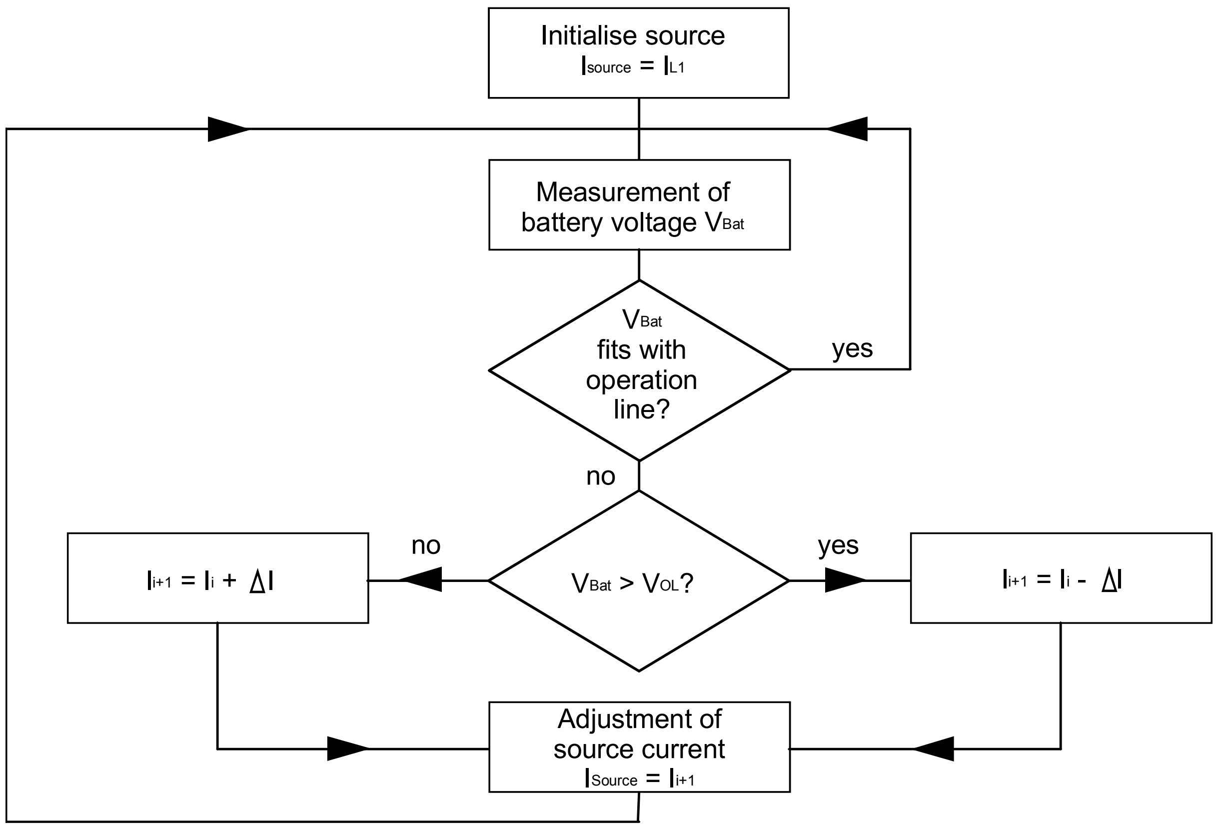


Figure C-6: Flow chart for simulation of the module performance

Annex D (Informative)

Design Recommendations

The following recommendations represent current best-practice design recommendations for portable solar PV lanterns are summarized below.

D.1 Reverse current

Reverse current, that is, the battery discharge into the module(s), should be minimized. The means by which this is achieved should be documented. If blocking diodes are used, the current capacity should be 50 percent higher than the short circuit current (at STC). The peak inverse voltage of the diode should be at least double the open circuit battery voltage.

D.2 Quiescent current

The quiescent current, that is, the self-consumption when no lamp is lit, should not exceed 2.0 mA.

D.3 Protection against dust, water and foreign bodies (IP-code)

Since the solar lanterns are predominantly used indoors, but may be taken outdoors occasionally and hence may be subjected to occasional rainfall, a minimum IP class of IP23 (see IEC 60529) is recommended. This also ensures a desired level of safety with regard to accidental accessibility of live parts.

D.4 Cable

A water resistant, mechanically robust and UV resistant cable should be used between the solar PV module and the charge controller. A cable at least 5 meter long should be provided for inter-connection between the module and the lantern

The continuous maximum current rating of the conductors (after any deratings for temperature or installation conditions) in the PV source and output circuits should be at least 156 percent of the short circuit current (at STC) and should not be less than the rating of any overcurrent device protecting those conductors.

All wiring should be color coded and/or labeled.

D.5 Connectors

All connectors should be polarized and be able to withstand 156 percent of the short circuit current at STC.

The rated current-carrying capacity of the connectors should not be less than the circuit current rating.

D.6 Indicators

The lantern should provide an indication of charging state, and an indication of load-disconnect state. The indicator may consist of LEDs or an LCD display.

D.7 Switching thresholds for charge controllers for lead-acid batteries

The following thresholds are recommended for using the battery voltage as the main parameter for the switching algorithm, at a surrounding temperature of 20 °C and an acid concentration of 1.24 kg/l:

- High Voltage Disconnect (HVD): > 2.35 V/cell
- High Voltage Reconnect by two-point regulation (HVR): 2.15-2.35 V/cell
- Low Voltage Disconnect (LVD): ≥ 1.90 V/cell
- Low Voltage Reconnect (LVR): ≥ 2.15 V/cell

At other acid concentrations, the required thresholds must be adjusted according to the manufacturer's specifications.

Note 1: The lower limit of the Low Voltage Disconnect is an absolute minimum.

Note 2: These values are primarily intended for charge controllers that use the battery voltage as the main parameter for the switching algorithm. Some manufacturers use other parameters, such as state of charge.

Portable Solar Photovoltaic (PV) Lanterns Blank Detail Specification

Approval under the IEC System for Conformity Testing and Certification of Electrical Equipment (IECEE).

Volume II

PV GAP
RECOMMENDED
SPECIFICATION

PVRS 11

2005-03

Reference number
PVRS 11 : 2005

PV GAP Secretariat c/o IEC Central Office
3 rue de Varembé - PO Box 131 - 1211 Geneva 20 – Switzerland
www.pvgap.org Tel: 41 22 919 02 16 Fax: 41 22 919 03 00 E-mail: rk@iec.ch

Contents

FOREWORD

1) PV GAP (Global Approval Program for Photovoltaics) is a not-for-profit international organization; dedicated to the sustained growth of global photovoltaics (PV) markets to meet energy needs world-wide in an environmentally sound manner. Its mission is to promote and encourage the use of internationally accepted standards, quality management processes and organizational training in the design, fabrication, installation, sales and services of PV systems. To this end, it joins with PV related industries, international organizations, testing laboratories, government agencies, financing institutions, non-governmental organizations, and private foundations, in developing and developed countries.

2) PV GAP co-operates closely with the International Electrotechnical Commission (IEC) in respect of standardization (principally with IEC Technical Committee N° 82, Solar Photovoltaic Energy Systems) and certification (with the IEC System for Conformity Testing and Certification of Electrical Equipment, IECEE).

   PV GAP publishes specifications that have been developed and recommended by experts from the PV industry and other organizations, to be used as interim, recommended specifications until the corresponding IEC standards can be completed. The acceptance of these PV GAP "Recommended Specifications" is voluntary. PV GAP only recommends these specifications but disclaims any liability for their utilization.

   It should be noted that, as soon as a corresponding IEC standard is issued, the PV GAP "Recommended Specification" is withdrawn. This is announced on the PV GAP website www.pvgap.org, together with information about the new IEC standard.

3) The present PV GAP Recommended Specification has been endorsed by the PV GAP Technical Committee and approved by the PV GAP Executive Board. Members of the Technical Committee and the Executive Board are listed on the website www.pvgap.org).

4) General enquiries about PV GAP may be addressed to the publisher, which is the PV GAP Secretariat, c/o IEC Central Office, 3 rue de Varembé, Box 31, CH 1211 Geneva 20, Switzerland, E-mail rk@iec.ch, TP +41 22 919 02 16, TF +41 22 919 03 01.

   The publisher will be pleased to receive any comments from users of this PV GAP Recommended Specification. All comments will be acknowledged.

   While every effort has been made to ensure the accuracy of the contents of this PV GAP Recommended Specification, the publisher can accept no responsibility for any errors that may have occurred.

PORTABLE SOLAR PHOTOVOLTAIC (PV) LANTERNS

Blank detail specification

For approval under the IEC System for Conformity Testing and Certification of Electrical Equipment (IECEE)

1 General

1.1 Scope

This PV GAP Recommended Specification is a blank detail specification applicable to portable solar photovoltaic (PV) lanterns, of assessed quality.

This specification references PVRS 11A requirements and testing methods to be used in detail specifications derived from this specification, and lists the technical criteria that are necessary and sufficient to assess the quality of the portable solar PV lanterns in accordance with the IECEE approval procedure described in IECEE 03.

1.2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this PV GAP Recommended Specification.

1. PVRS 11A: 2005, *Portable solar photovoltaic (PV) lanterns—Design qualification and type approval*

2. IECEE 03: 1995-12, *Rules and Procedures of the Scheme of the IECEE for Mutual Recognition of Conformity Assessment Certificates according to Standards for Safety of Electrical Equipment (CB-FCS) (currently under revision by IECEE with the title "Rules and Procedures of the Scheme of the IECEE for Mutual Recognition of Conformity Assessment Certificates according to Standards for Electrical Equipment and Components (CB-FCS)").*

1.3 Informative reference

Operating Guide of the CB-FCS Scheme, see http://www.iecee.org

1.4 Front page of detail specification

The layout of the front page of detail specification shall be as follows (see key below)

<table>
<tr><td>(1)</td><td>IECEE PVRS 11 AAxxxx (2)
Edition: 200x
Page 1 of x</td></tr>
<tr><td>Portable solar photovoltaic (PV) lantern, of assessed quality, in accordance with :

IECEE PVRS 11A : month, 2005 (3)</td><td>(4)</td></tr>
<tr><td colspan="2">Irradiation classification (5)</td></tr>
<tr><td colspan="2">Electrical characteristics (see 2.2) (6)</td></tr>
<tr><td>Drawing or photograph (7)</td><td>Applications : (8)</td></tr>
<tr><td colspan="2">Constructional characteristics (see 2.3) (9)</td></tr>
<tr><td colspan="2">Documentation (see 2.4)</td></tr>
</table>

User information included Technical manual available		
Principal components	(see 2.5)	(10)
Information about manufacturers who have lanterns approved according to this detail specification is available on the IECEE website www.iecee.org.		

Key to the front page:

The numbers between brackets on the front page correspond to the following.

Identification of the detail specification

(1) The name of the National Standards Organization under whose authority the detail specification is published and, if applicable, the organization from which the detail specification is available.

(2) The IECEE logo and the number allotted to the completed detail specification by the National Standards Organization or the IECEE Member Body (IECEE PVRS 11 is the IECEE provisional document reference allocated by the IECEE Secretariat to the blank detail specification PVRS 11 published by PV GAP. AA is the country identifier, for example, CN for China, FR for France, DE for Germany, IN for India, US for USA).

(3) The number and the year of availability of the IEC standard or provisional document accepted for use by the IECEE concerning test and measurement procedures for the lantern; also national reference, if different.

Identification of the lantern

(4) If different from the IECEE number, the national number of the detail specification, date of issue and any further information required by the national system, together with any amendment numbers.

(5) Irradiation classification: according to annex A, table A-1, of normative reference 1.

(6) Electrical characteristics.

(7) An outline drawing or photograph. Alternatively, this may be given in an annex to the detail specification, but (7) should always contain an illustration of the general appearance of the lantern.

(8) Applications: For example, general lighting in any environment, lighting for specific task, or as portable emergency indoor light source.

(9) Constructional characteristics.

(10) Documentation and principal components.

2 Technical specifications

2.1 General

Solar PV module	Wp
Battery	V, AH, type, system (for example. Lead Acid)
Application	
Lamp type	
Lamp wattage	W
Luminous efficacy of the lamp	lumens/watt
Light coverage of the lantern	degrees, for example. 360 degrees
Daily Run Time (DRT) under testing conditions	h
Irradiation classification under testing conditions	(see Annex A)
Manufacturer’s specified design load	Wh
Days of autonomy under testing conditions	days
Operating temperature, design figure	degrees C

2.2 Electrical characteristics

Inverter type	quasi-sine wave or sine wave
Lamp current crest factor	
Inverter frequency	in the range 20-35 kHz
Inverter efficiency	Percent
Inverter idle current	mA
Charging method	for example. series pulsed, two step
Indication of charging state	
Indication of load disconnect state	
Protection against open-circuit	
Protection against short-circuit	
Protection against reverse polarity	
System voltage	V
Maximum load current	A
Storage capacity	Ah
Daily Run Time under testing conditions	h
Autonomy under testing conditions	days
Consumption when power turned off (maximum self-consumption)	mA
Cable to module, type	
Cable to module, length	m
Cable connectors, type	
Switch, type	

2.3 Mechanical characteristics

Lamp fixing position	
Case material	
Light diffuser	
Size (shipping) without solar PV module	mm x mm x mm
Weight (shipping) without solar PV module	kg
Size (shipping) with stated solar PV module	mm x mm x mm
Weight (shipping) with stated solar PV module	kg

2.4 Documentation

See clause 7 of this specification.

2.5 Principal components

Component	Quantity	Nominal rating specified by the component manufacturer	Type approval organization or testing laboratory	Type approval number or test report number
Solar PV module				
Charge controller				
Battery				
Lamp				

2.6 Additional information (not for inspection purposes)

- Design lifetime for each of the principal system components (including number of switching cycles for lamps, with the on and off periods specification)
- Electromagnetic compatibility (transient and emission disturbance)
- Pre-assembled cable (cable lengths (m))
- Mounting set (including module support (wooden pole, steel pipe, etc.))

- Maintenance (battery topping-up, cleaning of solar modules in dusty areas, or maintenance free)
- Number of connections
- Level indicator (of electrical energy available)
- Accessories, for example. mains charger, vehicle charge cable
- Rain proof (when vertical), dust proof, insect proof
- Ability to stand in water of a stated depth
- Ability to operate in any orientation
- Temperature compensated charging
- Shutdown warning
- Socket output for for example: mobile phone charging
- Automatic switch-on function at loss of ambient light

3 Approval procedure

3.1 General

The approval procedure shall be in accordance with IECEE 03

Note: Approval includes current registration/certification to ISO 9001 (see 5.1 h of IECEE 03)

3.2 Primary stage of manufacture

The primary stage of manufacture is that stage (or those stages) of the manufacturing operation at which, and beyond which, the manufacturer shall demonstrate that he has control over all aspects of the processes that affect the quality of the finished product.

Note: A manufacturer, does not necessarily have direct control of all aspects of any preceding processes, although he does have the responsibility for accepting the quality achieved by them.

This may be that stage of the manufacturing operation at which partly manufactured components can be evaluated economically without precise knowledge of the preceding processes.

The primary stage of manufacture is the interconnection of the components to form the complete lantern.

The principal component manufacturers of the, on which the overall quality and reliability of the lantern is strongly dependent, shall each have a quality system that meets the requirements of ISO 9001 for the component manufacturing site.

If the manufacturer builds complete lanterns except for the batteries, and then obtains the batteries in the country of use, these lanterns shall be tested and approved with the batteries the manufacturer intends to use.

3.3 Subcontracting

Where an organization chooses to subcontract any process that affects product conformity with requirements, the organization shall ensure control over such processes. Control of such subcontracted processes shall be identified within the quality management system, (as specified in 4.1, General Requirements, of ISO 9001:2000, with reference to outsourcing).

Subcontracting of the primary and subsequent stages of manufacture (not including installation) is not permitted.

3.4 Technical requirements

Sampling, testing, pass criteria and classification of major defects shall be in accordance with normative reference 1.

Note: This blank detail specification cannot add requirements that do not exist in normative reference 1.

Reporting, and issuing of the Conformity Assessment Certificate, shall be in accordance with IECEE 03 (see in particular clauses 7, 8 and 9) and clause 20 of normative reference 1.

3.5 Increased severity

Detail specifications derived from this blank detail specification may make the severities of test, the end-of-test requirements, or the sampling levels, more severe. These severities, or requirements, can never be made less stringent.

3.6 Preparation of the detail specifications

An individual manufacturer may prepare a detail specification from this blank detail specification and submit it to the responsible national organization for verification of compliance to the IECEE rules and the allocation of a number. After completion of the testing in accordance with IECEE 03 and in agreement with the chosen National Certification Body of the CB-FCS, the manufacturer or the responsible national organization shall publish the detail specification.

Alternatively, a group of manufacturers may act together to produce a common detail specification with one of them accepting the responsibility for the submission for verification and the allocation of a number, the procedure being the same as above.

The above actions may be in co-operation with one or more customers.

Detail specifications may also be prepared by a responsible national organization or by an IEC technical committee (in this case, IEC TC 82, Solar photovoltaic energy systems).

3.7 Product identification and traceability

The minimum period for maintenance of records shall be as prescribed by the National Certification Body referred to in 3.6 above.

4 Quality conformance inspection

Qualify conformance inspection comprises the tests stated in Table 1, broken down as follows:

- Group A: lot-by-lot (100% inspection) tests;
- Group C: periodic tests.

All tests shown in the table are mandatory. Where a subgroup contains cumulative tests, the order of the tests is mandatory. Specimens subjected to tests denoted as destructive (D) shall not be released for delivery.

Table 1 — Test schedule for quality conformance inspection

Clause number and test of Normative reference 1	Destructive or non-destructive	Conditions of test	Performance requirements
GROUP A INSPECTION (100%) **Subgroup A1** 15.4 Check for completeness	ND		As in clause 15.4 of normative reference 1
GROUP B INSPECTION covering additional important characteristics None			

Clause number and test (see Note 1) of Normative reference 1	D or ND	Conditions of test	Sample size and acceptance criterion (see Note 1)			Performance requirements
			p	n	c	
GROUP C INSPECTION (periodic)						
Subgroup C1						
15 and 16 Performance	ND	Clauses 15 and 16 of normative reference 1	24	3	1	As in clauses 15 and 16 of normative reference 1
			See 5.1 of reference 1			

Note 1 - In this table:
p = periodicity (in months)
n = sample size
c = acceptance criterion (permitted number or non-conforming items)

5 Modifications

Any change in the design, materials, components or processing of the system may require a repetition of some or all of the qualification tests to maintain approval.

Principal system components may be changed if they are of equivalent size and performance and if the component has equivalent certification. Example: 50W crystalline silicon PV module (with IECEE approval) from Supplier A with 50W crystalline silicon module (with IECEE approval) from Supplier B.

6 Marking

Marking of each component of the lantern shall be in accordance with clause 6 of normative reference 1. The detail specification may also require that, in addition, the following be marked:

PV module(s) if not integrated

- Maximum power (W);
- Maximum power current (A);
- Maximum power voltage (V);
- Maximum permissible system voltage (V);
- Open-circuit voltage (V);
- Short-circuit current (A);
- NOCT (°C).

Marking of the system package may also be required, for example

- Manufacturer’s name, monogram or symbol,
- Type or model number,
- Serial or batch number,
- Precautionary warning concerning special requirements for storage or handling.

7 Documentation

A detailed manual in accordance with clause 9 of normative reference 1 shall be available.

User information shall be supplied with each lantern.

8 Annexes

Annexes may be included if necessary, to show more details of the lantern.

Joint UNDP/World Bank

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF TECHNICAL PAPER SERIES

SUB-SAHARAN AFRICA (AFR)

Region/Country	***Activity/Report Title***	***Date***	***Number***
Africa	Power Trade in Nile Basin Initiative Phase II (CD Only): *Part I: Minutes of the High-level Power Experts Meeting; and Part II: Minutes of the First Meeting of the Nile Basin Ministers Responsible for Electricity*	04/05	067/05
Chad	Revenue Management Seminar. Oslo, June 25-26, 2003. (CD Only)	06/05	075/05
Côte d'Ivoire	Workshop on Rural Energy and Sustainable Development, January 30-31, 2002. (French Only)	04/05	068/05
Ethiopia	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Ethiopia - Action Plan.	12/03	038/03
	Sub-Saharan Petroleum Products Transportation Corridor: Analysis And Case Studies	03/03	033/03
	Phase-Out of Leaded Gasoline in Sub-Saharan Africa	04/02	028/02
	Energy and Poverty: How can Modern Energy Services Contribute to Poverty Reduction	03/03	032/03
East Africa	Sub-Regional Conference on the Phase-out Leaded Gasoline in East Africa. June 5-7, 2002.	11/03	044/03
Kenya	Field Performance Evaluation of Amorphous Silicon (a-Si) Photovoltaic Systems in Kenya: Methods and Measurement in Support of a Sustainable Commercial Solar Energy Industry	08/00	005/00
	The Kenya Portable Battery Pack Experience: Test Marketing an Alternative for Low-Income Rural Household Electrification	12/01	05/01
Malawi	Rural Energy and Institutional Development	04/05	069/05
Mali	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Mali - Action Plan. (French)	12/03	041/03
Mauritania	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Mauritania - Action Plan. (French)	12/03	040/03
Nigeria	Phase-Out of Leaded Gasoline in Nigeria	11/02	029/02
	Nigerian LP Gas Sector Improvement Study	03/04	056/04
	Taxation and State Participation in Nigeria's Oil and Gas Sector	08/04	057/04
Regional	Second Steering Committee: The Road Ahead. Clean Air Initiative In Sub-Saharan African Cities. Paris, March 13-14, 2003.	12/03	045/03
	Lead Elimination from Gasoline in Sub-Saharan Africa. Sub-regional Conference of the West-Africa group. Dakar, Senegal March 26-27, 2002 (French only)	12/03	046/03
	1998-2002 Progress Report. The World Bank Clean Air Initiative in Sub-Saharan African Cities. Working Paper #10 (Clean Air Initiative/ESMAP)	02/02	048/04
	Landfill Gas Capture Opportunity in Sub Saharan Africa	06/05	074/05
Senegal	Regional Conference on the Phase-Out of Leaded Gasoline in Sub-Saharan Africa	03/02	022/02
	Elimination du Plomb dans I'Essence en Afrique Sub-Saharienne Conference Sous Regionales du Groupe Afrique de I'Quest. Dakar, Senegal. March 26-27, 2002.	12/03	046/03
South Africa	South Africa Workshop: People's Power Workshop.	12/04	064/04
Swaziland	Solar Electrification Program 2001—2010: Phase 1: 2001—2002 (Solar Energy in the Pilot Area)	12/01	019/01

Region/Country	*Activity/Report Title*	*Date*	*Number*
Tanzania	Mini Hydropower Development Case Studies on the Malagarasi, Muhuwesi, and Kikuletwa Rivers Volumes I, II, and III	04/02	024/02
	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Tanzania - Action Plan.	12/03	039/03
Uganda	Report on the Uganda Power Sector Reform and Regulation Strategy Workshop	08/00	004/00

WEST AFRICA (AFR)

Regional	Market Development	12/01	017/01

EAST ASIA AND PACIFIC (EAP)

Cambodia	Efficiency Improvement for Commercialization of the Power Sector	10/02	031/02
China	Assessing Markets for Renewable Energy in Rural Areas of Northwestern China	08/00	003/00
	Technology Assessment of Clean Coal Technologies for China Volume I—Electric Power Production	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume II—Environmental and Energy Efficiency Improvements for Non-power Uses of Coal	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume III—Environmental Compliance in the Energy Sector: Methodological Approach and Least-Cost Strategies	12/01	011/01
Thailand	DSM in Thailand: A Case Study	10/00	008/00
	Development of a Regional Power Market in the Greater Mekong Sub-Region (GMS)	12/01	015/01
Vietnam	Options for Renewable Energy in Vietnam	07/00	001/00
	Renewable Energy Action Plan	03/02	021/02
	Vietnam's Petroleum Sector: Technical Assistance for the Revision of the Existing Legal and Regulatory Framework	03/04	053/04

SOUTH ASIA (SAS)

Bangladesh	Workshop on Bangladesh Power Sector Reform	12/01	018/01
	Integrating Gender in Energy Provision: The Case of Bangladesh	04/04	054/04
	Opportunities for Women in Renewable Energy Technology Use In Bangladesh, Phase I	04/04	055/04

EUROPE AND CENTRAL ASIA (ECA)

Russia	Russia Pipeline Oil Spill Study	03/03	034/03

Region/Country	Activity/Report Title	Date	Number

MIDDLE EASTERN AND NORTH AFRICA REGION (MENA)

Regional	Roundtable on Opportunities and Challenges in the Water, Sanitation And Power Sectors in the Middle East and North Africa Region. Summary Proceedings. May 26-28, 2003. Beit Mary, Lebanon. (CD)	02/04	049/04

LATIN AMERICA AND THE CARIBBEAN REGION (LCR)

Brazil	Background Study for a National Rural Electrification Strategy: Aiming for Universal Access	03/05	066/05
Bolivia	Country Program Phase II: Rural Energy and Energy Efficiency Report on Operational Activities	05/05	072/05
Ecuador	Programa de Entrenamiento a Representantes de Nacionalidades Amazónicas en Temas Hidrocarburíferos	08/02	025/02
Guatemala	Evaluation of Improved Stove Programs: Final Report of Project Case Studies	12/04	060/04
Mexico	Energy Policies and the Mexican Economy	01/04	047/04
Nicaragua	Aid-Memoir from the Rural Electrification Workshop (Spanish only)	03/03	030/04
	Sustainable Charcoal Production in the Chinandega Region	04/05	071/05
Regional	Regional Electricity Markets Interconnections — Phase I Identification of Issues for the Development of Regional Power Markets in South America	12/01	016/01
	Regional Electricity Markets Interconnections — Phase II Proposals to Facilitate Increased Energy Exchanges in South America	04/02	016/01
	Population, Energy and Environment Program (PEA) Comparative Analysis on the Distribution of Oil Rents (English and Spanish)	02/02	020/02
	Estudio Comparativo sobre la Distribución de la Renta Petrolera Estudio de Casos: Bolivia, Colombia, Ecuador y Perú	03/02	023/02
	Latin American and Caribbean Refinery Sector Development Report – Volumes I and II	08/02	026/02
	The Population, Energy and Environmental Program (EAP) (English and Spanish)	08/02	027/02
	Bank Experience in Non-energy Projects with Rural Electrification Components: A Review of Integration Issues in LCR	02/04	052/04
	Supporting Gender and Sustainable Energy Initiatives in Central America	12/04	061/04
	Energy from Landfill Gas for the LCR Region: Best Practice and Social Issues (CD Only)	01/05	065/05

GLOBAL

	Impact of Power Sector Reform on the Poor: A Review of Issues and the Literature	07/00	002/00
	Best Practices for Sustainable Development of Micro Hydro Power in Developing Countries	08/00	006/00
	Mini-Grid Design Manual	09/00	007/00
	Photovoltaic Applications in Rural Areas of the Developing World	11/00	009/00

Region/Country	***Activity/Report Title***	***Date***	***Number***
	Subsidies and Sustainable Rural Energy Services: Can we Create Incentives Without Distorting Markets?	12/00	010/00
	Sustainable Woodfuel Supplies from the Dry Tropical Woodlands	06/01	013/01
	Key Factors for Private Sector Investment in Power Distribution	08/01	014/01
	Cross-Border Oil and Gas Pipelines: Problems and Prospects	06/03	035/03
	Monitoring and Evaluation in Rural Electrification Projects: A Demand-Oriented Approach	07/03	037/03
	Household Energy Use in Developing Countries: A Multicountry Study	10/03	042/03
	Knowledge Exchange: Online Consultation and Project Profile from South Asia Practitioners Workshop. Colombo, Sri Lanka, June 2-4, 2003	12/03	043/03
	Energy & Environmental Health: A Literature Review and Recommendations.	03/04	050/04
	Petroleum Revenue Management Workshop	03/04	051/04
	Developing Financial Intermediation Mechanisms for Energy Efficiency Projects – Focus on Banking Windows for Energy Efficiency	08/04	058/04
	Evaluation of ESMAP Regional Power Trade Portfolio (TAG Report)	12/04	059/04
	Gender in Sustainable Energy Regional Workshop Series: Mesoamerican Network on Gender in Sustainable Energy (GENES) Winrock and ESMAP	12/04	062/04
	Women in Mining Voices for a Change Conference (CD Only)	12/04	063/04
	Renewable Energy Potential in Selected Countries: Volume I: North Africa, Central Europe, and the Former Soviet Union, Volume II: Latin America	04/05	070/05
	Energy Efficiency Operational Exchange Program (CD Only)	06/05	076/05
	Renewable Energy Toolkit Needs Assessment	08/05	077/05
	Portable Solar Photovoltaic Lanterns: Performance and Certification Specification and Type Approval	08/05	078/05

Last report added to this list: ESMAP Technical Paper 078/05.