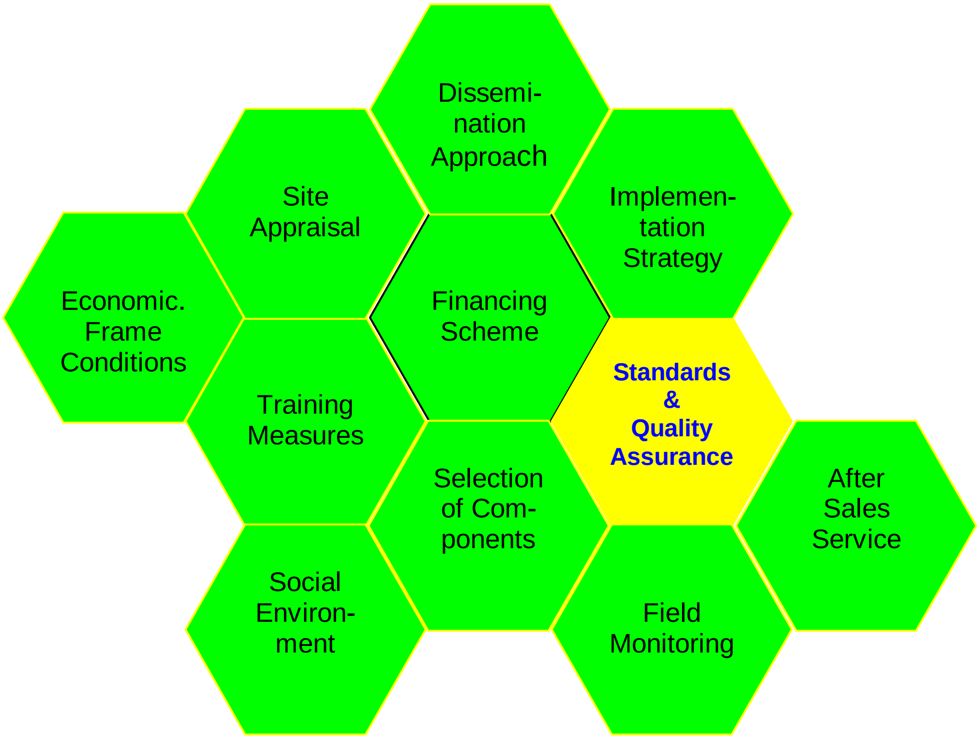
Environmental Management, Water, Energy, Transport
Division 44



QUALITY STANDARDS FOR SOLAR HOME SYSTEMS AND RURAL HEALTH POWER SUPPLY

PHOTOVOLTAIC SYSTEMS IN DEVELOPING COUNTRIES

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1. Introduction

PV systems for applications in developing countries have been tested, optimised and disseminated throughout the world over the last 20 years. A wide variety of demands have been made of the components and systems, partly for reasons due to country-specific characteristics or regional availability, but also because there were no binding standards, or if there were, they were often not known.

The project activities in technical and financial co-operation at bilateral and multilateral level have moved away from the pilot phase and towards the dissemination of PV systems. Yet, secure technical standards are required for dissemination in order to minimise the need for adjustments after the fact and the related costs in the case of large unit numbers.

An international survey carried out in preparation for this publication showed that several different standardisation activities are in progress. Probably the most interesting international project is the so-called “Global Approval Program for Photovoltaics (PV GAP)”, but also technical specifications such as those that have been proposed by the World Bank or the University of Madrid have already been elaborated in great detail.

The publication provides an overview of standards that are relevant for Solar Home Systems (SHS) and in Rural Health Power Supply Systems (RHS). It is intended to facilitate the selection of PV systems and components, especially in tenders, and to provide the impetus for a standardisation of PV systems on a scale that is as broad as possible. Moreover, it also identifies those components for which there is still a need for technical specifications.

This should lead, in the long term or better yet in the medium term, to binding, internationally recognised technical standards, especially for the use of photovoltaic systems in developing countries.

In preparing this publication, all of the well-known national and international institutions concerned with standardisation activities in the field of photovoltaics were contacted in writing. The existing photovoltaics projects of GTZ were also included in the survey.

In the course of the survey, information and documentation obtained from the World Bank, the World Health Organization (WHO), the international standardisation institution IEC, the European standardisation institution CENELEC, the U.S. standardisation office IEEE, as well as a series of projects, firms and experts, were compiled and evaluated.

The available PV-relevant standards were evaluated and summarised in the form of a table with a breakdown by components.

The list of standard specifications for tenders for SHS and RHS forms the largest part of the publication. Eleven different documents with specifications for PV systems and their components were evaluated for this purpose and summarised in a table. These documents varied widely in terms of quality and scope; some of them were intended for the specification of individual components, others as tender documents for whole systems.

Based on these documents, standard specifications were prepared that can be used directly as text modules for international tenders. The minimum requirements were chosen in such a way that a reliably functioning Solar Home System can be set up according to the current state-of-the-art.

Systems and components that are used for power supply to rural health stations (RHS) have to meet higher standards as a matter of principle. The available experience with PV systems in this area of application to date as well as a series of documents, especially from WHO, were evaluated and condensed. A separate list of specifications was compiled for the RHS sector.

A separate set of standard texts for tenders for Photovoltaic Pumping Systems (PVP) entitled "Proposal for Tender Documents for the Procurement of Photovoltaic Pumping Systems (PVP)" is also available from GTZ, Div. 44, Sustainable Energy Systems.

2. National and International Standardisation Institutions

With the steadily growing international trade, short product lives and world-wide distribution of production sites and consumer markets in recent decades, internationally recognised standards have become increasingly important in the field of electrical engineering. Similarly, the standardisation activities in the field of photovoltaics are being pursued almost exclusively at international level by the International Electrotechnical Commission (IEC) and adopted by the national (and regional) standardisation institutions.

However, there are a number of national standards for PV components that were developed independently of IEC, such as the French solar battery standard NF-C 58-510, the German DIN 40025 (type labelling data) or a few American IEEE standards.

Here is a brief description of the various institutions.[1]

The Deutsche Elektrotechnische Kommission (DKE) in the DIN and VDE
The DKE actively represents the German interests in the international and/or European standardisation organisations IEC, CENELEC and ETSI. About 700 DKE staff are working on an honorary basis in the IEC committees, about 500 DKE staff in those of CENELEC. The results of the standardisation work in IEC, CENELEC and ETSI are transposed into national standards and published by DKE.

The European Committee for Electrotechnical Standardisation (CENELEC)
is responsible for harmonising the electrical engineering standards in the framework of European Union and in the European economic area as a whole. About 90% of the CENELEC standards are taken over directly or with joint European amendments from the results of the IEC's work. The standards ratified by CENELEC are recognised by the 18 member countries as the only valid national standards.

The International Electrotechnical Commission (IEC)
elaborates and passes electrical engineering standards at international level. Today the 49 National Committees of the IEC represent over 80% of the world's population and over 95% of the world's consumption of electrical energy. The IEC standards are applied in over 100 countries and especially in international trade.

[1] The addresses of national and international standardization organizations are listed in Annex 1.

2.1. Structure of Photovoltaics Standardisation

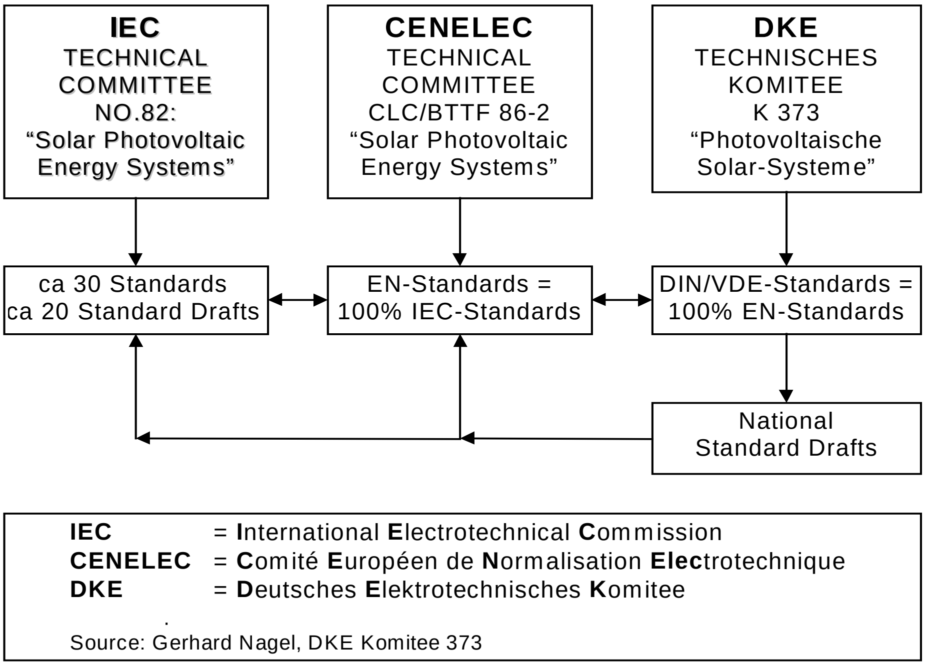

Fig.1: Structure of photovoltaics standardisation

Up to now, work on standardisation in the field of photovoltaic components and systems has primarily been done in the Technical Committee TC No. 82 of IEC, and the IEC standards that have been passed have been taken over in identical form in the European (EN) and German (DIN) standards. TC No. 82 is divided into three working groups:

- WG 1 "Glossary"
- WG 2 "Modules"
- WG 3 "Systems"

There is also a joint TC 21 (Batteries) and TC 82 working group on the subject of batteries in photovoltaic solar systems.
Up to now, most of the existing standards are IEC standards on PV modules and their measuring methods. Draft standards for PV systems and other PV components are currently being discussed and are to be finalised by the end of the year 2000.

At CENELEC, there has been a technical committee called "Solar Photovoltaic Energy Systems" (CLC/BTTF 86-2) since 1996. Denmark, Belgium, Germany, UK, Italy and the Netherlands, as well as the EPIA (European Photovoltaic Industry Association) as observer are represented on the committee.

The following firms, companies and institutions are represented at DKE: A.S.E., ANTEC, BEWAG, BG d. Feinmechaniker & Elektrotechniker, FHG-ISE, Geosolar, ISET, PTB, RWE, Siemens, TÜV-Rhld., Varta, ZSW.

2.2. Current Status of Standardisation Activities for Solar Home Systems

As already mentioned, the standardisation activities of IEC in the past have mainly concentrated on PV modules. The other components, such as batteries, charge regulators, loads, inverter and the system configuration as a whole have only been described very generally so far, or with standards from other fields of application.

Due to large-scale internationally and bilaterally financed rural energy supply projects with Solar Home Systems (World Bank, KfW, GTZ, ADB, etc.), however, as well as the international initiative of the PV industry (PV GAP, see 2.2.2), there is a growing need for standards for qualified components and system installations.

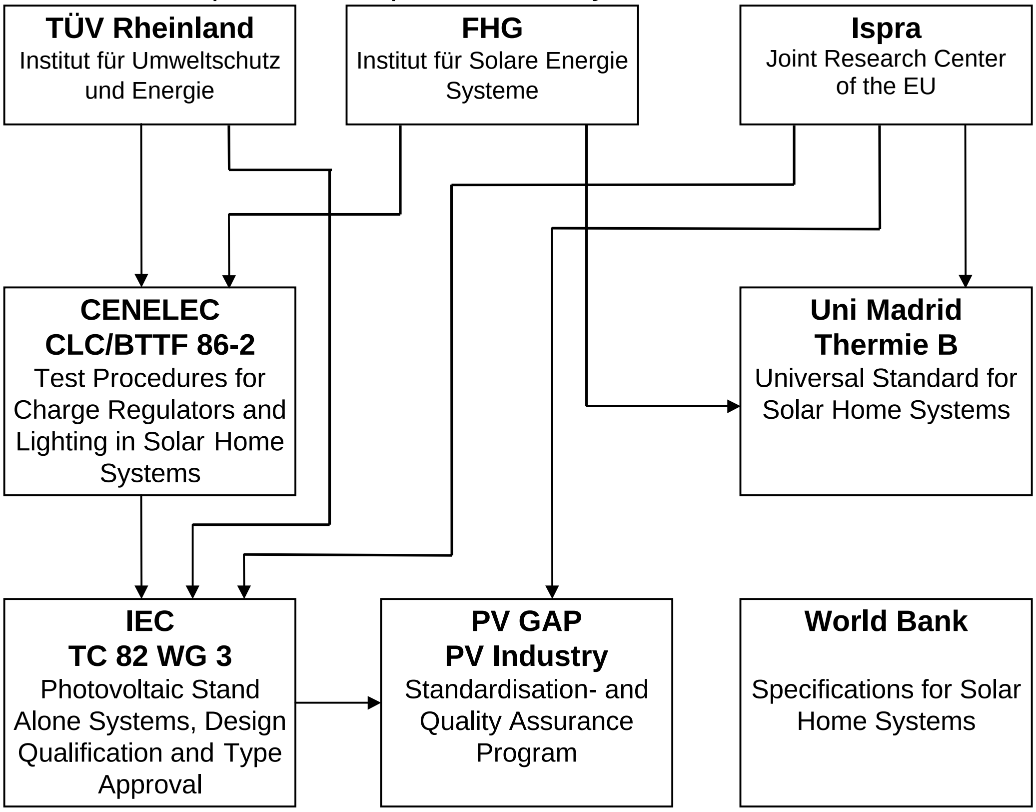

Fig.2 Current standardisation activities on Solar Home Systems at international and regional level with participation by German representatives

The diagram (Fig. 2) provides a selected overview of the current standardisation activities related to SHS systems. It also outlines the role of the German representatives (TÜV-Rheinland[2] and FHG-ISE) on the international and regional projects.

2.2.1. IEC Draft Standard for Small-Scale PV Systems

[2] Technischer Überwachungsverein, the German technical inspectorate, Rhineland

In June 1997, the Technical Committee TC 82 WG 3 of IEC drafted its first standard with the title “PV Stand-Alone Systems - Design Qualification and Type Approval”. This draft refers to individual home application with a solar generator with a maximum of 1000 W_{peak} and electrical loads like lamps, radio, TV, refrigerator and telecommunication facilities. In this draft test procedures are described that can be used to determine the electrical and technical operating characteristics of PV systems and their components.

The current draft, however, is more or less a loose collection of individual documents, and is by far not yet complete for an international standard. Important information such as minimum requirements, system layout, installation, etc., are still missing or are extremely incomplete. In the meantime, there are indications that this draft will be replaced by a new proposal of a European group of experts with representatives of the French GENEC, the Spanish CIAMAT, the German TÜV-Rheinland and the European joint research institute ISPRA.

2.2.2. The Global Approval Program for Photovoltaics (PV GAP)

In the interest of world-wide quality assurance and as a reaction to the lack of standards up to now, various PV producers, lending institutions (e.g. the World Bank) and governmental as well as private organisations came out in favour of a world-wide programme for quality assurance of small-scale PV systems. At the 14th PV Conference in Barcelona, Spain in July 1997, the “Global Approval Program for PV (PV GAP)” was launched. The founding members established the following mission as the goal of PV GAP:

PV GAP is a global, PV industry-driven organisation that strives to promote and maintain a set of quality standards and certification procedures for the performance of PV products and systems, to ensure high quality, reliability and durability.

PV GAP is domiciled at the Central Office of the IEC in Geneva, Switzerland, and works closely together with the IEC and its suborganisation, IEC’s Quality Assessment System for Electronic Components (IECQ). Existing IEC standards for quality approval and certification of components and systems are the basis of its work, and progress is being made on the development of new standards that are still lacking. As long as there are no binding standards for certain components, recommendations are made (Recommended Standards) for the interim, which are generally based on national or regional standards.

Furthermore, test laboratories are identified world-wide, also in the developing countries, which can carry out the type tests on the components described in the standards, reliably and reproducibly.

A Reference Manual was put together, which came out in the first edition in January 1998, and can be purchased from PV GAP for 175 US$. The manual first describes in detail the ideas, the organisation and the planned procedures for a quality assurance of PV components in the framework of PV GAP. The technical part essentially consists of a list of standards that may be relevant for PV components. A comprehensive training manual entitled "Quality Management in Photovoltaics" was published in August 1999 which contains specific quality assurance standards for PV components as well as an updated list of relevant IEC standards. It also comprises proposed standards that are currently in progress (IEC TC 82 Work in Progress) [3].

Moreover, a quality seal of approval is given for PV components that were tested under PV GAP conditions. This quality seal of approval is to become established if at all possible in international tenders as the prerequisite for the approval of components and systems. Qualified and recognised producers, sales and installation companies or system integrators have the right to display the quality seal of approval for PV components and systems.

The organisational structure of PV GAP provides for the following working groups:

Organization Working Group:
To develop a permanent legal entity for PV GAP and a "Seal of Quality." This group will develop a PV GAP organizational structure. This group will work on an interface with the Switzerland-based International Electrotechnical Commission Quality Assurance Program (IECQ), along with the criteria for awarding the "GAP Seal."

Standardization Working Group:
PV GAP will not write standards, but will accept and promote globally the IEC standards. If no IEC standard is available, then, based on peer review, PV GAP will accept existing or future standards of other bodies as "GAP Temporary Standards (GAP TS)," and promote their use globally. These GAP TS will then be submitted to IEC TC 82 to develop them into permanent IEC standards, which, when completed, will replace the GAP TS.

Handbook Working Group:
A PV GAP Handbook will be established, combining inputs from the many other organizations that already have developed a handbook or parts thereof. This PV GAP Handbook then will be promoted globally. The Handbook will incorporate all of the PV GAP-approved standards.

Testing Laboratories Working Group:
This group will establish criteria and compile a list of testing laboratories to be qualified to test PV components and systems according to IEC and PV GAP Temporary Standards. Reciprocity of test results from PV GAP-qualified Testing Laboratories will be established.

PV GAP Membership:
PV-related industrial and commercial organisations, their representatives, producers, system suppliers, traders/retailers, installation companies as well as supporting organisations and individuals can become members of PV GAP. They must abide by the principles of PV GAP, especially in regard to the established quality standards.

The advantages of membership are primarily the better marketing of products that have the PV GAP quality seal. As far as governmental and internationally financed projects

[3] A list of IEC standards recommended by PV GAP, Work Proposals and recommended standards is provided in Annex 4.

are concerned, especially in development co-operation, preference will in all likelihood be given to the use of products that meet the PV GAP specifications. Moreover, members benefit from diverse information services and discounts on purchases of IEC and PV GAP publications and standards as well as the PV Reference Manual.

Sponsors and Partnerships of PV GAP (as at 10/98):
Chairman: Dr. P. Varadi, P/V Enterprises, USA
Secretary: Mr. R. Kay (acting) - IECQ - Switzerland
Treasurer: Mr. M. Real - Alpha Real - Switzerland

Organisations represented on the PV GAP Executive Board:

Board Members:
JEMA – Japan; EPIA – Belgium; NREL – USA; SEIA – USA; Newcastle Photovoltaic Applications Centre – UK; UNDP – USA; JRC, Ispra – Italy; JQAO – Japan.

Advisory Board Members:
PowerMark – USA; WIP – Germany; Fraunhofer Institute – Germany; NOVEM - The Netherlands; EDF – France; ISPMA – India; National Technical University, Athens – Greece.

It remains to be seen how PV GAP develops in the future and whether offices issuing tenders and international donor organisations refer to the quality standards made by PV GAP. As the example of the Training Manual prepared for the World Bank in 1999 shows, however, the PV GAP's quality assurance function has already met with international interest. If these standards become established in future tender procedures, tests according to PV GAP standards will be binding on the suppliers.

2.2.3. The Universal Technical Standard for Solar Home Systems

The Instituto de Energía Solar at the University of Madrid has drawn up a proposal for SHS systems in co-operation with the Joint Research Centre, Ispra, the German WIP-Consult and LTV-Genec within the framework of the European THERMIE-B research programme (SUP-995-96).

On the basis of 15 different documents, tenders, specifications, project reports, test requirements, etc., a set of criteria was developed for all SHS components as well as for the SHS system as a whole. Corresponding explanations that are plausible and easy to understand are provided on all of the specifications. The proposal for a new layout and sizing approach, however, does not seem very practicable.

Some of the formulations of specifications in this document have been taken over from the World Bank tenders for Sri Lanka and Indonesia.

Various PV experts commented on the draft of this standardisation proposal (it does not make any claim to being an international standard), which was distributed in June 1997, and the suggested revisions were incorporated in the final version which was released in Spring 1998. A detailed commentary by the author in behalf of GTZ on the draft study was sent to the Instituto de Energía Solar in early November 1997 and the revisions suggested in the commentary were largely taken into account in the final version. The current, revised version of this GTZ publication now contains the proposed specifications, if they did not conflict with statements from other sources or the opinion of the author.

2.2.4. CENELEC Draft Standards: Test Procedures for Charge Regulators and Lighting Systems in Solar Home Systems

The TÜV-Rheinland, the Fraunhofer Institut für Solare Energiesysteme and the Energy Technology Laboratory of BBPT in Indonesia have elaborated two detailed proposals for standards for charge regulators and lamps (with electronic ballasts) which have been brought into the CENELEC and IEC working groups and are currently under discussion. A panel of experts with representatives of the French GENEC, the Spanish CIAMAT, the German TÜV-Rheinland and the European joint research centre in ISPRA (Italy) is pursuing further work on these draft standards and is also commissioned to develop test procedures for both laboratory and field tests on the other system components and on the SHS system as a whole. These drafts are to be completed by the end of the year 2000 if at all possible.

In the draft standards for charge regulators and lighting systems, minimum requirements and test procedures for type tests of these two components are outlined in detail and subdivided into Part 1: Safety Tests, Part 2: EMC Tests and Part 3: Performance Tests. The revised criteria (as of 07/98) have been included in the specifications in Chapter 5 over other specifications, since it can be assumed that these draft standards are essentially accepted by the standardisation institutions (IEC, EN and DIN).

Three further draft standards of this CENELEC group (PV modules, batteries and Solar Home Systems) are still in the early draft stage and still have to be properly completed and elaborated. They were incorporated in chapter 5 as a supplement to the more detailed specifications from other sources.

Initial concerns that these comprehensive type tests (a total of 30 individual tests and 13 function tests for charge regulators) could be too high of a cost factor for most producers of an electronic device in the price range of 40 to 100 Euro have been put to rest in the meantime by statements of various experts and representatives of the producers. After consulting with PV companies at an information event of GTZ and DFS, in early December 1997, most of them seem prepared to meet the high quality standards and to allow their products to be tested accordingly.

In the opinion of a leading producer of charge regulators, the high quality standards are justified, because these units have to operate reliably under the widest variety of climatic, environmental and application conditions world-wide. Comprehensive climate tests, for example, are indispensable and the widest variety of tests on electromagnetic compatibility (EMC) do not just prevent the device's interference with radio reception but also enhance the operating safety in the event of outside disturbances like surge voltages from lightning, for example.

Aside from the costs for the tests, which necessarily have to be taken into account in the product price, the process has nothing but advantages for the users, because the operating safety of the whole system is improved.

Fears that only a small number of highly qualified and best-equipped laboratories in industrialised countries will be able to carry out these tests should be dispelled by qualifying and accrediting smaller laboratories in developing countries, for example in the framework of PV GAP. The world-wide networking should make it possible for every producer to have his products tested and certified in any accredited laboratory anywhere on the world.

3. Existing Standards for PV Systems and Components

In the framework of an international survey on relevant standards for small-scale PV systems and their components, the following institutions, organisations, projects and individuals were contacted in writing:

Organisation / Institution	Cou ntry	Contact person	Function / Department
International Electrotechnical Commission (IEC)	CH	Dona-Lane Nelson	Customer Service,
PV-Global Approval Program	CH	Dr. Peter Varadi	Chairman PV GAP
Deutsches Institut für Normung (DIN)	D	www/din.de	Internet Investigation
Geosolar, Energie u. Umweltsysteme GmbH	D	Gerhard Nagel	Obman DKE K373
Siemens Energieübertragung u. -verteilung	D	Peter Kremer	German rep. IEC-TC 82
TÜV-Rheinland, Inst. f. Umweltschutz u. Energie	D	W. Vaaßen	German rep. CENELEC
Joint Research Centre, Ispra	I	Dr. H.Ossenbrink	Project Leader IEC Standard
National Renewable Energy Laboratory	USA	Richard de Blasio	Chairman IEEE-SCC 21
Institute of Electrical and Electronics Eng.(IEEE)	USA	Danielle Kunitsky	Customer Service
New ERA	USA	Dr.Charles F. Gay	PV GAP Board Member
Solar Energy Industries Association	USA	A. Jerry Anderson	Secretary IEC TC 82
World Bank	USA	Anil Cabraal	Project Leader PV-Projects
World Health Organization (WHO)	CH	Michel Zaffran	Director General, EPI/GPV
Universidad Politécnica de Madrid,	E	Prof. Miguel A. Egido	Instituto de Energía Solar
Asian Institute of Technology (AIT)	THA	Herbert Wade	Consultant Professor for PV
Energy & Development Group	ZA	Glynn Morris	Consultant for PV
Dep. of Mineral and Energy Affairs	ZA	André Otto	Alternative Energy Specialist
GTZ Project Energie Solaire, Senegal	SN	Massourou Assani	Project leader
GTZ-Project SEP-Niger	RN	Dr. Christian Hempel	Project leader
GTZ-Project Renewable Energies, Namibia	NAM	Hans-Jörg Müller	Project leader
GTZ-Project SEP Philippines	RP	W. Müller-Klingh.	Project leader (Consultant)
GTZ-Project Appropriate Use of Energy. , Brazil	BR	Rainer Schröer	Project leader (Consultant)
GTZ-Project PROPER, Bolivia	BOL	Dr.Pablo Rosenthal	Project leader
GTZ-Project SEP Morocco	MA	Philippe Simonis	Project leader
Universidad de Tarapacá, Arica, Chile	RCH	Reinhold Schmidt	CIM Expert

In addition, a study commissioned by GTZ and carried out by the Fraunhofer Institut für Solare Energiesysteme on quality control of PV components in Senegal, which contains a number of relevant standards, was also included in the list of standards.

The table below provides an overview of the existing international and national standards.

To the extent that such exist, the standards were listed with their English title. If identical DIN or EN standards of the IEC standards exist, these were indicated in the “Equivalent” column. If a German (DIN) or other national standard does not have an official English translation, the original title was taken in the "Description" column.
It should be noted that all IEC standards now have five-digit numbers, which always start with the number 6 as a rule and are filled out with zeroes up to the old number (e.g.: old: IEC 68-2-29, new: 60068-2-29). This means that the IEC numbers are also generally identical with the national and European standards (e.g.: DIN-EN 61215 is the German translation of IEC 61215).

Exceptions are the French solar battery standard NF-C 58-510, the U.S. standards IEEE and the South African standards SABS.

The database program "PERINORM" is available in Germany on CD-ROM (Beuth-Verlag) for general standards research; in the meantime, it can be used to query all major standardisation institutions world-wide. In German college and university libraries with a German standards (DIN) reference facility, access to this PERINORM is generally also available.

The table is sorted by **“Components”**; various standards apply to more than one component. The **“Application”** column is intended to indicate to which field of application the standard refers. A subjective rating of the relevance in small-scale PV systems for every standard is indicated in the **"Relevance"** column. The aim was to rank the importance of a standard with regard to Solar Home Systems and Rural Health Power Supply according to the following scheme:

1 = Basic specification of the component/of the system for applications in SHS and/or RHS
2 = Basic specification of the component/of the system derived from other (non- PV) applications
3 = Supporting standard with partial reference to PV or similar (DC) applications
4 = General standard for components without direct reference to PV
5 = Special PV standard for applications and test procedures under extraordinary conditions (generally not relevant for SHS and RHS)
6 = Special PV standard for components/systems without relevance to SHS or RHS

3.1. List of Existing Standards

List of Relevant Standards for Photovoltaic Solar-Systems								
Standard	**Number**	**Amend.**	**Status**	**Equival.**	**Description**	**Component**	**Application**	**Relevance**
					PV-Modules, -Generators, -Measuring Equipment	**PV-Mod**		
IEC	61215		04/93	DIN EN	Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval	PV-Mod	Type test	1
DIN	40025		05/97		Data sheet and nameplate information for photovoltaic modules; Datenblatt- und Typschildangaben für Photovoltaik-Module (Norm-Entwurf)	PV-Mod	Type test	1
IEC	61646		11/96		Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval	PV-Mod	Type test	1
IEC	60891		04/87	DIN EN	Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices	PV-Mod	Field test	5
IEC	60904-1		12/87	DIN EN	Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics	PV-Mod	Field test	5
IEC	60904-2	A1	05/89	DIN EN	Photovoltaic devices. Part 2: Requirements for reference solar cells	PV-Mod	Measuring	5
IEC	60904-3		02/89	DIN EN	Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	PV-Mod	Field test	5
IEC	60904-5		10/93	DIN EN	Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method	PV-Mod	Measuring	5

List of Relevant Standards for Photovoltaic Solar-Systems

Standard	Number	Amend.	Status	Equival.	Description	Component	Application	Relevance
IEC	60904-6	A1	09/94	DIN EN	Photovoltaic devices - Part 6: Requirements for reference solar modules	PV-Mod	Measuring	5
IEC	60904-7		09/95		Photovoltaic devices - Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device	PV-Mod	Measuring	5
IEC	60904-8		09/95	DIN EN	Photovoltaic devices - Part 8: Guidance for the measurement of spectral response of a photovoltaic (PV) device	PV-Mod	Measuring	5
IEC	60904-9		09/95		Photovoltaic devices - Part 9: Solar simulator performance requirements	PV-Mod	Measuring	5
IEC	60904-10		02/98		Photovoltaic devices - Part 10: Methods of linearity measurement	PV-Mod	Measuring	5
IEC	61701		03/95	DIN IEC	Salt mist corrosion testing of photovoltaic (PV) modules	PV-Mod	Type test	5
IEC	61721		03/95	DIN IEC	Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test)	PV-Mod	Type test	5
IEC	61829		03/95	DIN IEC	Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics	PV-Mod	Field test	5
IEC	61345		02/98		UV test for photovoltaic (PV) modules	PV-Mod	Type test	5
					Batteries	**Bat**		
NF-C	58-510		01/92		Lead-acid secondary batteries for storing photovoltaically generated electrical energy	Bat	Type test	1
IEEE	937		01/93		Practice for Installation and Maintenance of Lead Acid Batteries for Photovoltaic Systems	Bat	Operation	1
IEEE	1013		10/97		Practice for Sizing Lead Acid Batteries for Photovoltaic Systems	Bat	Design	1
IEC	60896-1	A2	01/87	DIN EN	Stationary lead-acid batteries - General requirements	Bat	Type test	2

List of Relevant Standards for Photovoltaic Solar-Systems

Standard	Number	Amend.	Status	Equival.	Description	Component	Application	Relevance
					and methods of test. Part 1: Vented types			
IEC	60896-2		11/95	DIN EN	Stationary lead-acid batteries - General requirements and test methods - Part 2: Valve regulated types	Bat	Type test	2
DIN	40734		04/92		Blei-Akkumulatoren; Ortsfeste Zellen mit positiven Gitterplatten; Zellen in Kunststoff-Gefäßen; Kapazitäten, Hauptmaße, Gewichte(Norm-Entwurf)	Bat	Type test	2
DIN	43530-1		10/87		Akkumulatoren; Elektrolyt und Nachfüllwasser; Allgemeines	Bat	Operation	3
DIN	43530-2		10/87		Akkumulatoren; Elektrolyt und Nachfüllwasser; Elektrolyt für Blei-Akkumulatoren	Bat	Operation	3
DIN	43530-4		10/87		Akkumulatoren; Elektrolyt und Nachfüllwasser; Wasser und Nachfüllwasser für Blei-Akkumulatoren und alkalische Akkumulatoren	Bat	Operation	3
DIN	40729		05/85		Akkumulatoren; Galvanische Sekundärelemente; Grundbegriffe	Bat	Basics	4
DIN	40736-1		06/92		Blei-Akkumulatoren; Ortsfeste Zellen mit positiven Panzerplatten; Zellen in Kunststoff-Gefäßen; Kapazitäten, Hauptmaße, Gewichte	Bat	Type test	4
DIN	40737-2		09/75		Blei-Akkumulatoren; Ortsfeste Batterien mit positiven Panzerplatten, Batterien in Kunststoff-Blockkästen, Kapazitäten, Hauptmaße, Gewichte	Bat	Type test	4
IEC	60095-1	A2,A11, AB	01/95	DIN EN	Blei-Starterbatterien - Teil 1: Allgemeine Anforderungen und Prüfungen	Bat	Basics	4
IEC	60130-3		01/65		Connectors for frequencies below 3 MHz. Part 3: Battery connectors	Bat	Type test	4
IEEE	1361		12/93		Practice for Determining Performance Characteristics and Suitability of Batteries in Photovoltaic Systems	Bat	Field test	5

List of Relevant Standards for Photovoltaic Solar-Systems

Standard	Number	Amend.	Status	Equival.	Description	Component	Application	Relevance
					Battery Charge Regulators, -Charging Methods	**LR**		
IEC	60335-1		06/91	DIN EN	Safety of household and similar electrical appliances - Part 1: General requirements (Third edition)	LR	Type test	2
IEC	60335-2-29		11/94		Safety of household and similar electrical appliances - Part 2: Particular requirements for battery chargers	LR	Type test	2
IEC CISPR	55011		12/97	DIN EN	Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics - Limits and methods of measurement	LR	Type test	2
IEC CISPR	55013	A12,A13,A14	08/98	DIN EN	Limits and method of measurement of radio interference characteristic of sound and television broadcast receivers and associated equipment	LR, Lamp	Type test	2
IEC CISPR	55022	A1+A2+A3	11/97	DIN EN	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement	LR, Lamp	Type test	2
IEC	61000-4-2		01/95	DIN EN	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 2: Electrostatic discharge immunity test. Basic EMC Publication	LR, Lamp	Type test	2
IEC	61000-4-3		03/95	DIN EN	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques -Section 3: Radiated, radio-frequency, electromagnetic field immunity test	LR, Lamp	Type test	2
IEC	61000-4-4		01/95	DIN EN	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 4: Electrical fast transient/burst immunity test. Basic EMC Publication	LR, Lamp	Type test	2
IEC	61000-4-5		03/95	DIN EN	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 5: Surge immunity test	LR, Lamp	Type test	2

List of Relevant Standards for Photovoltaic Solar-Systems								
Stan-dard	**Number**	**Amend.**	**Status**	**Equival.**	**Description**	**Compo nent**	**Applica-tion**	**Rele-vance**
IEC	60068-2-6		03/95	DIN EN	Environmental testing - Part 2: Tests - Test Fc: Vibration (sinusoidal)	LR, Lamp	Type test	2
IEC	60068-2-21		01/83	DIN EN	Environmental testing. Part 2: Tests. Test U: Robustness of terminations and integral mounting devices	LR	Type test	2
IEC	60068-2-27		06/87	DIN EN	Environmental testing. Part 2: Tests. Test Ea and guidance: Shock	LR, Lamp	Type test	2
IEC	60068-2-30		01/80		Environmental testing - Part 2: Tests. Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)	LR, Lamp	Type test	2
IEC	60529		11/89		Degrees of protection provided by enclosures (IP Code)	LR, Lamp	Type test	2
IEC	60695-2-1	sheets 0-3	03/94	DIN EN	Fire hazard testing - Part 2: Test methods - Section 1/sheet 0: Glow-wire test methods	LR, Lamp	Type test	2
IEC	60695-2-2		05/91	DIN EN	Fire hazard testing - Part 2: Test methods - Section 2: Needle-flame test	LR, Lamp	Type test	2
IEC	60439-1	A1+A2+ A11	12/92	DIN EN	Low-voltage switchgear and controlgear assemblies - Part 1: Type-tested and partially type-tested assemblies	LR	Installation	3
IEC	60439-2		11/87	DIN EN	Low-voltage switchgear and controlgear assemblies. Part 2: Particular requirements for busbar trunking systems (busways)	LR	Installation	3

List of Relevant Standards for Photovoltaic Solar-Systems

Standard	Number	Amend.	Status	Equival.	Description	Component	Application	Relevance
IEC	60439-3	A1	12/90	DIN EN	Low-voltage switchgear and controlgear assemblies. Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use - Distribution boards	LR	Installation	3
DIN	41772		02/79		Stromrichter; Halbleiter-Gleichrichtergeräte, Formen und Kurzzeichen der Kennlinien	LR	Basics	3
DIN	41774		11/87		Stromrichter; Halbleiter-Gleichrichtergeräte mit W-Kennlinie für das Laden von Bleibatterien; Anforderungen	LR	Basics	3
IEC	60068-1		06/88	DIN EN	Environmental testing. Part 1: General and guidance	LR, Lamp	Type test	4
DIN EN	50178		11/94		Ausrüstung von Starkstromanlagen mit elektronischen Betriebsmitteln; (Norm-Entwurf)	LR	Type test	4
IEC	60065		01/85		Safety requirements for mains operated electronic and related apparatus for household and similar general use	LR	Type test	4
DIN	41773-1		02/79		Stromrichter; Halbleiter-Gleichrichtergeräte mit IU-Kennlinie für das Laden von Bleibatterien, Richtlinien	LR	Basics	4
					Lamps, Lights, Ballasts	**Lamp**		
IEC	60924		07/90	DIN EN	D.C. supplied electronic ballasts for tubular fluorescent lamps - General and safety requirements	Lamp	Type test	2
IEC	60925	A1	06/89	DIN EN	D.C. supplied electronic ballasts for tubular fluorescent lamps - Performance requirements	Lamp	Type test	2

List of Relevant Standards for Photovoltaic Solar-Systems

Standard	Number	Amend.	Status	Equival.	Description	Component	Application	Relevance
DIN EN	55015	A1	01/98		Grenzwerte und Meßverfahren für Funkstörungen von elektrischen Beleuchtungseinrichtungen und ähnlichen Elektrogeräten	Lamp	Type test	2
IEC	60598-2-25		80/94	DIN EN	Luminaries - Part 2: Particular requirements - Section 25: Luminaries for use in clinical areas of hospitals and health care buildings	Lamp	Health	2
IEC	60598-1	11,14-18,AA	12/96	DIN EN	Luminaries - Part 1: General requirements and tests	Lamp	Basics	3
DIN	5032-2		01/92		Lichtmessung; Betrieb elektrischer Lampen und Messung der zugehörigen Größen	Lamp	Basics	4
DIN	5039		09/95		Licht, Lampen, Leuchten - Begriffe, Einteilung	Lamp	Basics	4
IEC	60400	A1	06/96	DIN EN	Lampholders for tubular fluorescent lamps and starterholders	Lamp	Type test	4
IEC	60921	A2	07/88	DIN EN	Ballasts for tubular fluorescent lamps. Performance requirements	Lamp	Type test	4
IEC	60061-1		12/96	DIN EN	Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 1: Lamp caps	Lamp	Type test	4
IEC	60061-2		12/96	DIN EN	Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 2: Lampholders	Lamp	Type test	4
IEC	60061-3		12/96	DIN EN	Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 3: Gauges	Lamp	Type test	4
IEC	60061-4		12/96	DIN EN	Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 4: Guidelines and general information	Lamp	Basics	4
IEC	60081	A4+A5	12/97	DIN EN	Double-capped fluorescent lamps - Performance	Lamp	Type test	4

List of Relevant Standards for Photovoltaic Solar-Systems

Stan-dard	Number	Amend.	Status	Equival.	Description	Compo nent	Applica-tion	Rele-vance
					specifications			
IEC	60901		03/96	DIN EN	Single-capped fluorescent lamps - Performance specifications	Lamp	Type test	4
					System Requirements, Installation, Lightning Protection, etc.	**Syst**		
IEC	61194		12/92	DIN EN	Characteristic parameters of stand-alone photovoltaic (PV) systems	Syst	Basics	1
IEC	61277		03/95		Terrestrial photovoltaic (PV) power generating systems - General and guide	Syst	Basics	1
IEC	61173		09/92	DIN EN	Overvoltage protection for photovoltaic (PV) power generating systems - Guide	Syst	Lightning Prot.	1
IEC	61724		04/98		Photovoltaic system performance monitoring- Guidelines for measurement, data exchange and analysis	Syst	Measure ment	1
IEC	61836		10/97		Solar photovoltaic energy systems- Terms and symbols	Syst	Basics	1
IEEE	928		01/91		Criteria for Terrestrial Photovoltaic Power Systems	Syst	Basics	1
IEEE	1374		02/96		Guide for Terrestrial Photovoltaic Power System Safety	Syst	Installatio n	1
IEC	61204		02/93		Low-voltage power supply devices, d.c. output - Performance characteristics and safety requirements	Syst	Basics	2
IEC	60998-1		05/90	DIN EN	Connecting devices for low voltage circuits for household and similar purposes. Part 1: General requirements	Syst	Installa-tion	3
DIN VDE	0100		05/73		Bestimmungen für das Errichten von Starkstromanlagen mit Nennspannungen bis 1000 V (Technische Regel)	Syst	Installa-tion	3
IEC	60364-1		11/92		Electrical installations of buildings - Part 1: Scope, object and fundamental principles	Syst	Installa-tion	3

List of Relevant Standards for Photovoltaic Solar-Systems

Standard	Number	Amend.	Status	Equival.	Description	Component	Application	Relevance
IEC	60998-2-5		01/96	DIN IEC	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-5: Particular requirements for connecting boxes (junction and/or tapping) for terminals or connecting devices	Syst	Installation	3
SABS	171		12/86		Surge Arresters for Low Voltage Distribution Systems	Syst	Lightning Prot.	3
SABS	0142				Code of Practice for the Wiring of Premises	Syst	Installation	3
SABS	03	A	12/85		The Protection of Structures and Dwelling Houses Against Lightning	Syst	Lightning Prot.	3
SABS	0400		12/87		Code of Practice for the Application of the National Buildings	Syst	Installation	3
IEC	61725		05/97		Analytical expression for daily solar profiles	Syst	Design	5
					Inverter	**Inverter**		
IEC	60146-1-1		04/91	DIN EN	General requirements and line commutated convertors - Part 1-1: Specifications of basic requirements	Inverter	Type test	3
					Others			
IEC	61727		06/95	DIN EN	Photovoltaic (PV) systems - Characteristics of the utility interface	Mains supply	Acceptance	6
IEC	61702		03/95	DIN IEC	Rating of direct coupled photovoltaic (PV) pumping systems	PV-Pump-syst.	Design	6

4. Overview of Specifications for Solar Home Systems and Rural Health Power Supply

In the framework of the international survey, various documents with specifications for Solar Home Systems and their components were evaluated and summarised in the form of a table. The specifications in the table were subdivided into the following categories:

- PV generator
- Support structure
- Battery
- Charge regulator
- Lamp, ballast
- Wiring, installation
- Documentation

The following 11 documents were evaluated. Not all of the documents did include all components.

[1] Madrid	"Universal Technical Standard for Solar Home Systems", Instituto de Energía Solar, Universidad Politécnica de Sdrid, European Commission, Thermie B: SUP-995-96, EC-DGXVII,1998[4]
[2] FHG-ISE ´94	"Ladereglertest", Fraunhofer Institut für Solare Energiesysteme, for GTZ OE 4150, Energie und Transport, 1994
[3] GTZ ´93	"Standards für SHS-Laderegler" und "Vorläufige Grundanforderungen an elektronische Vorschaltgeräte", GTZ, 1993
[4] PSE Tunisia	"Lastenheft Laderegler und elektronische Vorschaltgeräte für Photovoltaische Kleinsysteme", c. 1994
[5] Steca Midi	"Datenblatt, Solarix Midi & Mini", Steca Solarelektronik, c. 1993
[6] SEP Marocco	"Proposition d'un standard technique pour les systémes photovoltaiques familiaux", CDER, Morocco, 1997
[7] Namibia Health	"Tender: Okavango Clinics: Photovoltaic Systems", GTZ, Department of Works, Namibia, 1997
[8] Namibia SHS	"Tender Annex B: Specifications for Solar Home Systems (50Wp)", GTZ, Ministry of Mines and Energy Namibia, 1997
[9] TÜV/CENELEC	Standard Proposals: "Test Procedures for Charge Regulators and Lighting Systems in Solar Home Systems", CENELEC CLC BTTF 86-2, 1998
[10] Philippines '94	"Material Specification for Solar Home Systems", GTZ SEP Philippinen, 1994
[11] World Bank	"Indonesia: Solar Home Systems Project, Specifications", World Bank, 1996

The results of the evaluation are listed in Annex A2. There is a separate table for each component. [5]

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[4] The specifications from Madrid University additionally contain a three-tier classification of the criteria according to compulsory (C), recommended (R) and suggested (S).

[5] The table can be made available by e-mail as an Excel file upon request.

The specifications table can be used to get an initial overview of which criteria and corresponding components are mentioned in the respective documents.

The table for charge regulators is the most comprehensive; charge regulators are included in all 11 documents. Due to the variety of requirements, local conditions, personal preferences and, last but not least, the different purposes for which the documents are used, a total of 91 criteria were identified for charge regulators, some of which complement each other, or also conflict with one another, and in many cases can be summarised into more general criteria.

At the same time, however, this variety of criteria also shows that there is an urgent need for standardisation, especially of the main components charge regulator and lamp/ballast. On the other hand, if one considers the table for PV generators, for example, one finds that many criteria are already covered by the reference “Qualified according to IEC 61215”.

5. Specifications for Tenders of SHS and RHS

The most up-to-date, comprehensive and best elaborated documents from the previous chapter 4 have been used as the basis for the proposed specifications of SHS and RHS. Specifically, these are:

- the tender documents of the World Bank for 200,000 SHS in Indonesia (and similarly 30,000 SHS in Sri Lanka) [11]
- two tender documents for SHS [8]and RHS [7] in Namibia (which are partly based on the World Bank specifications)
- the proposal by the University of Madrid for a “Universal Standard” [1]
- the CENELEC draft standards for charge regulators and lamps/ballasts of the TÜV-Rheinland and FHG-ISE [9]

The specifications which, in the author's opinion, gave the best technical description were selected from these documents, revised and compiled according to component and topic. These can be used directly as text modules for international tenders. The minimum requirements in each case were selected in such a way that a reliably functioning system can be set up according to the technical state of the art. [6]

5.1. Tender Specifications for Solar Home Systems and Rural Health Power Supply Systems

Some of the texts proposed for the specifications presented here include additional notes marked “Optional”, “Health” and/or *“Comment”*:

Optional: Optional specifications for higher requirements, alternative equipment or special environmental conditions

Health: Additional or alternative specifications for Rural Health Power Supply Systems (RHS) with stricter requirements

Comment: Explanation of the reason for choosing a certain specification or a personal opinion of the author

[6] A separate compilation of tender documents for photovoltaic pumping systems (PVP) entitled “Proposal for Tender Documents for the Procurement of Photovoltaic Pumping-Systems (PVP)” is available from GTZ, Div. 44.

5.1.1. Photovoltaic Generator (PV Modules)

The PV array shall consist of one or more mono- or polycrystalline photovoltaic solar module(s).

Crystalline PV modules must have been tested for qualification in compliance with IEC 61215, "Crystalline Silicon Terrestrial Photovoltaic Modules; Design Qualification and Type Approval".[7]

The PV module(s) should have a rated peak power output of at least 45 W_{peak} (with an allowable tolerance of -2.5 W_{peak} (-5%), alternatively -5 W_{peak} (-10%)), under Standard Test Conditions (STC) as defined in IEC 61215 and IEC 60904-3.

Comment: To date the efficiency and reliability of "thin-film PV-modules" does not yet measure up to the standards of crystalline PV cells, and the price reduction is also still not convincing. In spite of that fact, this option might be feasible for future applications, especially for low-cost Solar Home Systems.
The World Bank has already allowed the use of thin-film PV modules in their Indonesian SHS project tender, but only one company (Canon, Japan) offered these kinds of modules in their quotation.

Optional: If thin-film photovoltaic modules are used, they must be product-tested and certified in accordance with IEC 61646. The peak power output for thin-film modules should be the value after light soaking.

The minimum acceptable operating voltage at MPP (Maximum Power Point) of the PV module shall be no less than 16 V_{dc} at a cell-operating temperature of 60° Celsius.

Optional: Each module shall comprise not less than 36 series-connected single- or poly-crystalline silicon solar cells.

Comment: In order to allow a full charge of a 12 V battery under "controlled gassing" conditions, a voltage of 14.5 to 15 V must be available at the battery terminals. Including voltage losses via cables (0.5 to 1.0 V) and blocking diodes (0.4 V/Schottky diode), the PV generator voltage should be at least 1.0 to 1.5 V above that maximum battery voltage. Under certain conditions, e.g. with the use of sealed batteries (no gassing allowed), very low system losses or permanently low ambient temperatures, this value might be lower, and even PV modules with less than 36 cells might be used. But a PV-generator voltage of 14 - 14.5 V as recommended in the "Universal Standard" Proposal [1] will definitely be too low for SHS applications in tropical countries.

In a PV array all modules should be of the same type and be interchangeable. The cabling and protection diodes must also be uniform. However, if there are sub-arrays which power separate loads or batteries, then different types of modules may be used in each sub-array if necessary.

[7] This IEC specification supersedes ISPRA specification No 503.

The module(s) shall be equipped with a sealable waterproof (international protection code IP54) terminal (junction) box. The poles inside shall be clearly marked. A strain relief for the cables must be provided.

Optional: The junction box must have outlets that allow for attachment of flexible conduit pipes. If the module does not have a junction box which allows for a direct conduit connection, a weather-resistant junction/combiner box must be attached to the support structure.

Optional, for system voltage greater than 50 V: The PV modules must have bypass diodes to offer protection against hot spots in case of partial shading.

The PV modules shall have a frame of non-corrosive material, e.g. anodized aluminium or stainless steel. The frame shall ensure that the module is resistant to torsion during handling and extreme weather conditions.

Comment: Only solid, framed modules are applied for SHS and RHS. At certain sites and for certain applications flexible, unframed modules may be preferred (e.g. tents of nomadic tribes). However, up to now no experience for this module type under rural conditions is available.

Each module must be clearly and permanently labelled according to DIN 40025 “Data-sheets and Labels of PV Modules”, indicating: Name of Manufacturer, Model Type or Number, Serial Number, IP-Protection Code, Maximum System Voltage, Power (Watt Peak) Rating (P_{max}), ± Manufacturing Tolerances, Short-Circuit Current (I_{SC}), Open Circuit Voltage (U_{OC}), Maximum Power Point Voltage (U_{MPP}), all at Standard Test Conditions.

The PV module manufacturer, or module supplier, shall provide a minimum 10-year warranty for the replacement of any modules which:
- show defects, in terms of the qualification test stipulations of IEC-61215
- show power degradation greater than 10% below the rated power specification

(unless damaged by abuse or extreme conditions like lightning, exceptional hail, etc., which are not covered by the qualification test conditions).

For the purpose of this warranty, the rated power specification shall be a fixed value and not a range, and to effect the warranty any tests of power degradation shall conform to the international procedures for testing and referencing PV module power output.

Health, Optional: Each solar module has to have the individual clinic name sandblasted onto the bottom right-hand corner. The names are to be a minimum of 10 mm in height and are to be positioned so that the marking in no way impairs the functioning of the module or negates the guarantee issued with the module.

5.1.2. Module Support Structure

The module support (array mounting) structure shall hold the PV module(s).

The module(s) shall be mounted either on the rooftop of the house or on a metal pole that can be fixed to the wall of the house or separately in the ground, with the module(s) at least 3 (4) meters off the ground.

Roof-mounting: Minimum clearance between the PV module(s) and the roofing material must be at least 10 cm. It is recommended that the module mounting structure be supported on top of a pole at least 50 cm long or fixed with supporting angles at four positions. The mounting structure must be anchored to the building or to the under-roof beam structure and not to the roofing material.

Wall-mounting: A metal pole must be fixed to the outer wall of a house by appropriate clamps and fixing material (screws and wall plugs in solid walls or screws in wooden beams) in at least two positions at a reasonable distance. If the pole is not higher than the top of the house, the problem of shading from house-walls or roof-parts must be taken into consideration.

Ground-mounting: A metal pole at least 2“ (50 mm) in diameter must be used with the modules attached at the top of the pole. The pole must be anchored in concrete at least one meter deep in the ground.

The pole and mounting structure shall be sufficiently rigid to prevent twisting in the wind or if large birds alight on the array. The support structure shall be able to withstand winds up to 120 km/h (150 km/h in windy areas).

All metal parts shall be made of non-corroding materials (aluminium, stainless steel) or adequately protected against corrosion by galvanisation (layer approx. 30µm). The support structure should be able to withstand at least 10 years of outdoor exposure without appreciable corrosion or fatigue.

The structure shall incorporate galvanised steel or stainless steel hardware (bolts, nuts, washers, etc.) for all external connections. These include the modules-to-structure, structure-to-pole and pole-to-building attachments. Particular attention shall be given to protection against galvanic corrosion if different metals are in contact. Different kinds of metal have to be kept separate. Under corrosive environmental conditions (high humidity, high salt content), only stainless steel hardware is allowed.

Optional: The use of rivets or tamper-proof (non-removable) screws for theft protection is recommended.

No objects (trees, buildings, etc.) shall shade any part of the PV modules at any time of the year between 90 minutes after sunrise and 90 minutes before sunset. It should be noted that shading of even a small part of a module or array could cause a considerable reduction in power output. In situations where partial shading is unavoidable, this must be compensated in the system sizing calculations.

The PV modules shall be mounted in a position which allows safe, controlled access for inspection and cleaning. However, security from possible theft and damage may also be important considerations. Where necessary, suitable measures shall be taken to reduce the risk of theft or damage (e.g. from flying stones). It should be possible, however, to remove modules for service, using appropriate tools.

The module(s) shall be installed facing towards the equator (south in the northern hemisphere and north in the southern hemisphere).

The tilt angle should be selected by computer simulation to optimise the energy collection during the month with the lowest mean daily irradiation. To guarantee a self-cleaning effect of the modules by rainwater, the modules shall not be installed at a flatter angle than a minimum tilt angle of 15°.

Optional: If computerised calculation is not available, as a general rule (in areas up to a latitude of 40° around the equator), a tilt angle to the horizontal plane equal to the latitude +10° can be assumed as a good approximation.

Optional: Where necessary, deviations ±5° from the orientation to the equator shall be acceptable, unless otherwise specified. Where necessary, deviations of ±5° from the optimum tilt angle shall be acceptable.

Optional: Facilities for users to adjust the tilt angle in different seasons or to perform a manual tracking throughout the course of the day shall be acceptable, provided the users are well informed and wish to do so. In this case, the strength of mounting (e.g. resistance to wind-loading) shall remain sufficient.

Optional: Passive tracking systems for the PV generator shall be acceptable, if the additional gain of energy justifies the additional cost, provided that the tracking system can withstand wind-loading requirements and is of proven reliability. As the advantage of a tracking system is only valid during direct sunshine periods, the energy gained by the tracker can only be considered for system calculations if detailed irradiation statistics, including measurement of direct and diffuse insolation, are available for the site. Active trackers (requiring electrical power) are not allowed.

5.1.3. Battery

Comment: The storage batteries are still the weakest, most vulnerable component in a photovoltaic power supply system. This might also be the reason why different types of batteries, ranging from automotive starter batteries and so-called "Solar Batteries", all the way to high-quality industrial tubular plate (OPZS) batteries, and also sealed maintenance-free batteries, are used in PV systems.

The "Universal Standard for SHS" [1] gives a brief overview of the various aspects, advantages and disadvantages of the different battery types and their useful application in SHS. Some of the following observations may serve as an introduction for planners of subsequent specifications:

The most important feature of battery operation in SHSs is cycling. During the ***daily cycle,*** *the battery is charged over the day and discharged by the night-time load. Superimposed onto the daily cycle is the* ***seasonal cycle***, *which is associated with periods of reduced radiation availability. This, together with other operating parameters* *(ambient temperature, current, voltage, etc.), affects the battery life and maintenance requirements. In order to maximise the lifetime of lead-acid batteries, the following operating conditions must be avoided:*

- *High voltage during charging (to prevent corrosion and loss of water)*
- *Low voltage during discharge (corrosion)*
- *Deep discharge (sulphation, growth of dentrites)*
- *Extended periods without full charging (sulphation)*
- *High battery temperature (all aging processes are accelerated)*
- *Stratification of the electrolyte (sulphation)*
- *Very low charge current (sulphation)*

These rules lead to specifications for sizing (both battery and PV generator) and for battery protection procedures (charge regulator). However, it must be pointed out that some of the rules generally contradict each other (e.g. full charging requires high voltages but high voltages accelerate corrosion), so compromises must be found that take the particular local conditions into account: solar radiation, PV module and battery prices, duties and taxes, local manufacturing, recycling infrastructure, etc. Perhaps this explains the lack of consensus on this issue among the various sources of information (standards, experts, etc.) that have been consulted during the preparation of this standard; therefore, the requirements given below should be adapted to suit the local circumstances.

The need to prevent excessive discharge leads to the need to limit the maximum depth of discharge to a certain value, PD_{MAX}, which usually ranges from 0.3 to 0.6, but can approach 0.8, depending on the type of battery. The supply to the load must be cut off when this limit is reached. The available or useful capacity, C_U, is therefore less than the nominal capacity, C_B (which refers to the whole charge that could be extracted from the battery if no particular limitations were imposed) and equal to the product $C_B * PD_{MAX}$, such that:

$$C_U = C_B * PD_{MAX}$$

A good compromise between cost and reliability is typically obtained with a battery whose useful capacity ranges from three (in regions where extended cloudy periods are not expected) to five (in regions where cloudy periods are expected) times the total daily energy consumption in the house, so that the depth of discharge in the daily cycle, PD_d ranges from 0.06 to 0.2. The selection of a particular capacity mainly depends on the battery type. High-quality batteries are better able to resist deeper cycling than low-quality batteries. Hence, for the same application, high-quality batteries can be smaller than low-quality batteries, in terms of nominal capacity.

The highest-quality PV batteries are made with tubular plates and grids with low Sb-Se content. More than 8 years life, with $PD_d = 0.2$ and a maintenance period of 1 or 2 times per year, are attainable with such batteries. A particular disadvantage of tubular batteries for SHSs is that they do not readily accept low rates of charge. They are also expensive and are rarely available in the current markets in developing countries. Nevertheless, they should not be excluded from SHS programmes. On the contrary, it is recommended *that large rural electrification programmes consider encouraging manufacturers to put these products on the market.*

In contrast, automotive batteries, usually referred to as SLI, have a number of advantages. They are usually the cheapest batteries when compared in terms of nominal capacity (the difference in cost can be 4 or 5 fold), they are often locally produced and are widely available. Local production is not only convenient for economic and social reasons, but also because it represents the best means of recycling old batteries and avoiding environmental damage. Their main drawback lies in their relatively short lifetime. Because their cell design is optimised to deliver heavy currents during short periods of time, they have large areas of thin plates, and are poorly suited to supplying smaller currents for many hours before being recharged, as is required by SHS. It is therefore necessary to use larger battery capacities leading to $PD_d \leq 0.1$*, and a density of electrolyte which is lower than would normally be used in this type of battery (for example, 1.24 instead of 1.28 g/cl). This is necessary to reduce grid corrosion and hence to lengthen battery life. The associated increase in internal resistance in the battery does not pose any problems in SHS, because the charge and discharge currents are relatively low by comparison to conventional battery charge and discharge regimes. Classical SLI batteries use lead grids alloyed with antimony and require periodic topping up with water.*

The short lifetimes of automotive batteries can also be compensated to some extent by introducing relatively simple modifications to the battery design but not to its technology. The most common modifications are thicker electrode plates and a larger quantity of acid solution in the space above the plates. Such modified SLI batteries are sometimes marketed as "solar" batteries and represent a promising alternative for the future of SHSs. Wherever possible, modified SLI batteries should be selected (and local manufacturers should be encouraged to make them) in preference to conventional SLI batteries. Certain conditions must be met in order for a battery to be categorised as "modified SLI", as follows:

- *The thickness of each plate must exceed 2 mm.*
- *The amount of electrolyte must exceed 1.15 l per 100 Ah of 20-hour nominal capacity and per cell.*
- *The separator must be made of microporous polyethylene.*
- *The density of electrolyte must not exceed 1.25 g/cl.*

"Low-Maintenance" SLI batteries, sometimes marketed as maintenance-free batteries, often employ grids containing calcium alloys. The calcium increases the voltage at which gassing begins but reduces the cohesion of the active material to the grids. Hence, it cuts down the loss of water but also reduces the cycle life. Such batteries are particularly vulnerable to damage from deep discharge. In addition, they are also liable to be damaged by high temperature variations. Hence, many PV system designers strongly recommend that they not be used in PV applications in hot countries. However, the maintenance-free feature is still attractive, and extensive use has been made of these batteries in some countries like Brazil.

"No-maintenance" batteries of various kinds are also made for professional applications by using a semi-solid electrolyte (gel or malting). Such batteries, referred to as VRLA (valve-regulated lead acid), are more often resistant to deep discharges, but they are

usually very expensive for SHSs, and they require specific recycling facilities. They are not considered in the present standard although they represent a legitimate technology choice in some cases. The same is valid for NiCd batteries.

The 20-hour nominal battery capacity in amp-hours (measured at 20 W and up to a voltage of 1.8 V/cell) should not exceed CR times the PV generator short-circuit current in amps (measured at Standard Test Conditions). CR values are proposed for each type of battery in the table below:

Battery type	**CR**
Tubular	15-20
SLI (automotive):	
- Classical	30-40
- Modified	35-40
- Low-Maintenance	30-40

The maximum depth of discharge, PD_{MAX}, (referred to as the 20-hour nominal battery capacity) should not exceed the values proposed in the table below:

Battery type	**PD_{MAX}**
Tubular	70-80
SLI:	
- Classical	30-50
- Modified	40-60
- Low-maintenance	20-30

The useful capacity of the battery, C_U (20 hours nominal capacity, as defined above, multiplied by the maximum depth of discharge) should allow for a three to five-day period of autonomy.

The cycle life of the battery (i.e., before its residual life drops below 80% of the nominal capacity) at 25^0C must exceed NOC cycles when discharged down to a depth of discharge of 50%. A NOC value is given for each type of battery in the table below.

Battery type	**NOC**
Tubular	600
SLI:	
- Classical	200
- Modified	200
- Low-maintenance	300

<u>Comment</u>: As the discussion of the "Universal Standard" above already shows, selecting the “right” battery type for PV systems is a difficult task, considering all of the different aspects of cost, lifetime, local availability, maintenance, recycling, etc. Another fact is, that no international standards for type-testing of batteries for PV applications are available as yet.

The IEC standards 60896 Part 1 and 2 “Stationary lead-acid batteries - General requirements and methods of test. Part 1: Vented types, Part 2: Valve-regulated types” give the general test methods for stationary batteries, but also include the comment that special test procedures for PV applications will be worked out by IEC group TC 21/TC

82. As confirmed by IEC, Geneva, a new standard on solar batteries is still being written and will have the number IEC 61147.

Up to now, the only standard available on solar batteries is the French standard NF C58-510 "Lead-acid secondary batteries for storing photovoltaically generated electrical energy", which will be used temporarily by PV GAP and the IEC SHS standardisation group. Therefore, the type-test procedures described in this standard will be the basis of the following battery specifications:

In addition to the above-mentioned standardisation activities of IEC, the CENELEC committee BTTF 86-2 has also drafted a standard proposal entitled "Accumulators for Use in Photovoltaic Systems, Safety-Test Requirements and Procedures", which was kindly made available by TÜV-Rheinland. As this proposal is not yet complete (no cycle tests, etc.) and all tests described here are also included in the French NF C58-510 standard, this standard-proposal is not considered in the following specifications.

The rechargeable battery shall consist of one 12 V_{DC} vented type lead-acid "solar" battery.

Optional: The rechargeable battery shall consist of one 12 V_{DC} valve-regulated type maintenance-free lead-acid battery.

Health: The rechargeable battery shall consist of a 12 V_{DC} (24 V_{DC}) vented-type "heavy-duty" tubular lead-acid battery.

The battery must be type-tested and certified in accordance with NF C 58-510 "Lead acid secondary batteries for storing photovoltaically generated electrical energy", and/or IEC 60896-1 or -2 "Stationary lead-acid batteries - General requirements and methods of test. Part 1: Vented types, Part 2: Valve-regulated types" (will be replaced by IEC 61147).

The following tests must be performed, documented and certified as described in NF C58-510:

- Nominal capacity C_n in Ah (generally C_{10})
- Rated capacity C_t. (10-hour capacity C_{10} , 20-hour capacity C_{20} or 100-hour capacity C_{100} given by the supplier
- Number of cycles in a constant average state of charge (DOD=40%) Minimum requirement: 400 cycles
- Number of cycles in a changing average state of charge (DOD=20%) Minimum requirements: 1500 cycles for vented tubular plates, 900 cycles for sealed and vented flat plates
- Suitability for operation under increasing and decreasing "state of charge" conditions. Minimum requirements: 95% of C_{10} after 60 cycles

- Suitability for overcharging for 400 days at 2.35 V/cell. Minimum requirements: Vented cells - no dangerous gases escape from the cells; valve-regulated cells: recombination of oxygen and hydrogen > 95%
- Ampere-hour efficiency at discharge until 0.75 C_{100} Minimum requirement: not given.
- Enclosure test: 4 hours at 65° C and alternating temperature 30° C without any deformation
- Cell-sealing test. Minimum requirement: No seepage of electrolyte at an inclination of 30° and under a pressure of 0.1 bar
- Vent plug efficiency test. Minimum requirement: During the overcharge test no sulphuric acid and no explosive concentration of hydrogen escapes from the cells.
- Drop resistance test. Minimum requirement: 10 cm drop with all edges on concrete

Optional (World Bank specification): Cycle life of the battery (i.e., before its residual life drops below 80% of the rated Ah capacity), at 25° C must exceed 200 cycles when discharged down to an average depth of discharge (DOD) of 75%.

The minimum rated battery capacity C_t shall be calculated with the following formula:

$$C_t = (E_d / V_s) * (DOA / DOD)$$

with:
- C_t = Rated Capacity [Ah]
- E_d = Daily Energy Consumption [Wh]
- V_s = Nominal System Voltage [V]
- DOA = Days of Autonomy
- DOD = Depth of Discharge (maximum)
- t = Discharge Time = DOA * 24 h

For a Solar Home System, the following values might be assumed:
- E_d = 180 Wh
- V_s = 12 V
- DOA = 3
- DOD = 0.5 (50%)
- t = 3 * 24 h = 72 h

$$\Rightarrow \quad C_{72} = (180\ \text{Wh} / 12\ \text{V}) * (3 / 0.5) = 90\ \text{Ah}$$

In order to calculate the nominal capacity C_{10} from the rated capacity, the supplier must submit a capacity curve related to the discharge current.

The minimum nominal capacity C_{10} should not be less than 55 Ah.

Optional (World Bank specification): The battery capacity shall be at least 1.4 times the rated Ah per W_{peak} of the PV array power, but not less than 70 Ah. The rated Ampere-hour capacity is measured at 25° C at the C_{20} discharge rate down to a voltage of 1.75 V per cell.

The maximum permissible self-discharge rate is 6% of rated capacity per month (30% per 6 months) at 25° C.

Battery connections in parallel shall be avoided, if possible. It is definitely not allowed to connect batteries of different type, size or age in the same battery bank. Where parallel connections are unavoidable, no more than two identical 12 V_{DC} lead-acid batteries shall be connected in parallel. Batteries of larger capacity shall preferably be selected, rather than a combination of batteries in parallel.

The amount of electrolyte must exceed 1.15 l per 100 Ah of 20-hour nominal capacity and per cell. The electrolyte reserve in the battery must be sufficient for 100 days of operation under overcharging conditions without addition of distilled water.

The density of electrolyte must not exceed 1.25 g/cl.

The following information and specifications must be available from the battery manufacturer, supplier or recognised test laboratory:

- Make, type, nominal voltage and nominal capacity
- Capacity at 10-hour discharge rate (at specified temperatures)
- Electrode type and type of electrolyte
- Specific gravity ranges for the electrolyte (for flooded batteries)
- Graphical information on charge and discharge characteristics, at different current rates and specified temperatures
- Graphical information on cycle life versus depth of discharge (at specified temperatures)
- Information on any particular regulation requirements for optimal cycling in a PV environment

In general, the data must be sufficient to establish the suitable method of battery regulation and suitable set points.

Additionally, the tenderer shall submit information in respect of:

- battery safety requirements
- battery maintenance requirements
- battery replacement requirements

Optional: Batteries shall be protected from the weather and installed in boxes or suitable enclosures which fulfil the following requirements:

- Access to the terminals and electrolyte shall be restricted to authorised and responsible persons only. Batteries shall be protected from access by children. However, the batteries shall be accessible for inspection by authorised persons.
- The terminals shall be protected from accidental short-circuiting from a tool being dropped across the terminals, for example.
- There shall be sufficient ventilation for hydrogen to escape. Hydrogen shall not be routed to any location where there is a danger of sparks or flames.
- There shall be at least 20 mm free space between the batteries and the walls and top of the battery box.
- The battery box or enclosure shall be made of suitable, durable and acid-resistant materials.

- A permanent notice shall be fixed to a battery box or suitably placed at a battery enclosure as a warning of the hazard from a release of gases, the danger of explosion, and that smoking or flames should be prohibited.

Health: Provision shall be made for the storage of distilled water. Further supplies for routine maintenance shall include rubber gloves, goggles and bicarbonate of soda solution. Clear maintenance instructions shall be provided.

Health: Small batteries or battery banks, up to a couple of hundred Ah at 12V or 24V, are normally not considered an undue hazard in large, well-ventilated rooms, provided the above precautions are observed. Larger battery banks should preferably be installed in separate battery rooms on insulated racks (safe for loading), with good ventilation at the highest point in the ceiling, a sloping floor with drain and a raised door threshold.

Optional: In general, moderate temperatures are desirable, between 15° and 30°C, and precautions shall be taken to protect batteries from extreme temperatures. In installations where temperature extremes cannot be avoided, manufacturers' data must be consulted to ensure that the type of battery is suitable for the conditions.

The batteries can be supplied in either a wet-charged or dry-charged condition. If dry-charged, all chemicals and electrolyte must be supplied in accordance with the battery suppliers' specifications.

Installed batteries shall receive an initial conditioning charge, either by using an external (properly regulated) charger, or by charging the batteries from the PV array for at least two days with no loads connected.

The battery and associated containers should be packaged to withstand transport over rough dirt roads.

The supplier guarantees that it will take back and professionally recycle or dispose of old batteries and their toxic chemicals.

The warranty period for batteries shall be at least six months. Longer warranty periods granted by the manufacturer shall be passed on to the user.

5.1.4. Charge Regulator

The charge regulator (or Battery Control Unit, BCU) shall primarily serve to protect the battery against both deep discharging and overcharging.

Comment: To date, there is no generally accepted international or national standard available for charge regulators in PV power supply systems. As mentioned before, the most critical and delicate component in a stand-alone PV system is the battery, and given the variety of battery types and charging characteristics (and philosophies of planners), the requirements for the charge regulators also have to cover a wide range of applications.

Comment: The main requirement for a charge regulator should be that the unit itself will not become the weakest or most vulnerable component in the whole system (which unfortunately was the case in several projects in the past). From all of the experience over the last 15 years, some quite reliable equipment has been developed by various companies. The optimisation of charging characteristics and safety precautions is an ongoing development process, as highly integrated electronic components nowadays allow very complex regulation features in a minimum of space and with low production-cost requirements.

Comment see [1]: Basically, there are two kinds of charge regulators; the main difference lies in the position of the switching device. The "Series" type interrupts the connection between the solar generator and the battery, while the "Shunt" type short-circuits the solar generator. In addition, there are two main types of control strategies. In a "Two-step" control arrangement, the charging current is completely interrupted when the end-of-charge voltage is reached. With a "Pulse-Width Modulation" control, on the other hand, the charging current is gradually reduced to the end-of-charge voltage level, thus keeping the voltage constant. In SHSs, both types of regulators and both control strategies serve the purpose equally well. In fact, recent systematic and independent testing experience does not suggest that there is any real advantage associated with either type of regulator or control strategy in terms of improvements to battery lifetime.

Comment: During the preparation of large-scale projects (WB Indonesia 200,000 SHSs, WB Sri Lanka 30,000 SHSs) and the worldwide PV GAP program an international standard for charge regulators is required, with specifications that can be objectively checked and tested by any qualified test laboratory. The CENELEC CLC/BTTF 86-2 committee has actually drafted a standard for charge regulators in Solar Home Systems, which was also accepted by the IEC TC 82 and is currently circulating among the committee members for discussion and correction. A copy of the current draft version (as of 07/98) was kindly made available by TÜV-Rheinland, a member of the standards committee. The final version of this standard will probably be released by the end of 2000 and will not differ much from this draft. The draft will be the basis for the following specifications:

“Scope of the Standard"
The scope of this standard comprises charge regulators for lead-acid accumulators with liquid electrolyte (vented and gas-tight). The tests described in this standard are valid for charge regulators which use the accumulator terminal voltage as the criterion for operation as well as modern control procedures (e.g. "State of Charge Algorithms"). The following standard governs the requirements placed on charge regulators permanently installed in photovoltaic systems, especially for small domestic power supplies (SHS). Here we assume that the photovoltaic generators' power classification does not exceed 1 kW_p, to which the charge regulators intended for examination have been adapted."

As soon as this standard is released, the tender specification for charge regulators might be formulated as follows:

Charge regulators should have been type-tested and certified for qualification in compliance with IEC 6xxxx (number not yet available by November 1999) "Photovoltaic Systems, Charge Regulators, Part 1: Safety Test - Requirements and Procedures, Part 2: EMC - Test Requirements and Procedures and Part 3: Performance - Test Requirements and Procedures".

The following tests must be performed and documented as described in the standard-proposal Part 1, 2 and 3. After a visual inspection of the charge regulator, the documentation and labelling, the following electrical, mechanical, abnormal-operation and EMC parameters will be determined according to the described procedures.

<u>Electrical Parameters, Performance and Requirements</u>

- The nominal voltage of the charge regulator should be 12 V (24 V) DC.
- The charge regulator must function in accordance with one of the following working principles:
  - Voltage-controlled thresholds with:
    - Pulse-width modulation (PWM)
    - Two-point parallel (shunt) or series regulator
  - State-of-charge (SOC) algorithm with:
    - Pulse-width modulation (PWM)
    - Two-point parallel (shunt) or series regulator
- The following thresholds are required at an ambient temperature of 20°C and an acid concentration of 1.24 kg/l:
  - High-charge-disconnect: 2.30 V/cell
  - High-charge-reconnect with 2-point regulation: 2.25 V/cell
  - Low-charge-disconnect: 1.90 V/cell
  - Low-charge-reconnect: 2.10 V/cell

  At other acid concentrations, the required thresholds must be adjusted according to the manufacturer's specifications.
- A service life of at least ten (10) years of operation should be assumed.
- The charge regulator must have a clear and reliable display. It should signal the actual operating state of the charge regulator. The display can be constructed using LEDs or an LCD display.
- The thresholds for the low-charge-disconnect must be stable (± 0.3 V) across the entire temperature range (-10°C to 55°C).
- Overcharge protection and gassing functions must be temperature-compensated for high-charge-disconnect and high-charge-reconnect thresholds in two-point regulation, whereas the hysteresis must be constant (temperature range: -10°C to 55°C). The temperature compensation must be in the range of -3 to -5 mV/K/cell.
- Own power consumption should not amount to more than 10 mA under all operating states.
- The voltage drop at the terminals of the charge regulator between battery- and load-terminals (discharging) and between PV-generator terminals and battery terminals (charging) may only amount to a maximum of 0.5 V (12 V systems) or 1 V (24 V systems) at maximum load.
- The voltage drop on the battery-lines shall be compensated by either battery sensing lines, electronic compensation or appropriate wire selection (cross-section, length). If

electronic compensation is applied, the difference between battery terminal voltage and demanded thresholds of the charge regulator should not exceed 100 mV.

Mechanical Parameters, Performance and Requirements

- Mechanical stability of all components shall be tested by vibrations test (acc. to IEC 60068-2-6, stringency, see proposed standard) and
- Shock test (acc. to IEC 60068-2-27, stringency, see proposed standard) when specimens are not packaged and not live.
- Temperature and humidity resistance shall be defined and tested in accordance with the climatic conditions of the target region (IEC 60068-1).
- For application in tropical climates, a “cyclical damp heat test” (acc. to IEC 60068-2-30) will be performed with temperatures up to 55°C (not live) and 40°C (at nominal voltage and maximum input and output current).
- Corrosion resistance and long-term stability will be evaluated after this damp heat test.
- Safety requirements shall be evaluated according to IEC 60335-1.
- Insulation resistance shall be tested according to EN 50178 or IEC 60335-1 (section 13.3) with a test voltage of 500 V_{DC}.
- Heat development under maximum power conditions shall not exceed the limits stated in IEC 60335-1.
- Resistance to heat and fire shall be tested according to IEC 60695-2-1 (glow-wire test) and EN 60742, section 26 (ball-pressure test).
- Mechanical sturdiness of the case shall be tested according to IEC 60068-2-75 (stringency, see proposed standard) with a dead stroke hammer of 250 g from certain directions.
- The protection of the case against access to dangerous parts, penetration of foreign bodies and the entry of water (IP code) shall be tested according to IEC 60529. The minimum requirements are IP 20 for solid-built indoor applications and IP 54 for outdoor and other applications.

Comment: This draft standard proposes a protection code of IP 20, which means "no protection against water intrusion". This does not seem to provide for adequate protection in developing countries, even in solidly built houses, as the roofs of these buildings are often not as water-tight as they are expected to be in industrialised countries. The author recommends a minimum protection code of IP 32.

- The robustness of terminations and mounting devices shall be tested according to IEC 61215, test 10.14, for expansion, thrust, bending, pressure, torsion and twisting.

Abnormal Operation Precautions

- At operation without a battery, the charge regulator will limit the output voltage at the load terminals to the maximum permissible output voltage during battery operation. If relays are included in the circuit, they must stay in a stable condition.
- At operation with an extremely exhausted battery (U_{batt} < 9V), a further discharge of the battery must be avoided.
- If voltage-measuring (sensor) lines are used, the stability of all thresholds must be guaranteed with open-circuited and shorted measuring lines.
- If temperature sensor lines are used, the stability of all thresholds must be guaranteed with open circuited and shorted measuring lines.

- The charge regulator must be protected against reverse polarity at the PV generator (up to maximum open circuit voltage) and the battery terminals (up to maximum battery voltage).
- Overload protection by fuses or electronic circuits shall be tested with 125% of the maximum load current.
- If the charge regulator has a separate radio outlet, its overload protection shall also be checked.

Electromagnetic Compatibility (EMC)

- Line-conducted interference emission shall be tested at least on the output (load) line in the radio-frequency range from 150 kHz to 30 MHz (acc. to EN 50081-1, limit value class B).
- Irradiated interference emission at a distance of 3 meters shall be tested in accordance with EN 55013, limit values acc. to IEC CISPR 22.
- Resistance to interference from fast, low-energy pulses (pulse group), coming from the load-side (e.g. energy-saving lamps), will be tested according to IEC 61000-4-4 (0.5 kV).
- Resistance to interference from single high-energy impulses, like atmospheric discharges (lightning), will be measured on the PV generator-to-regulator and on the load-to-regulator line according to IEC 61000-4-5 with 0.5 kV to 1 kV. Additionally, the pulse influence on the connecting lines between solar generator, battery and load should be determined.
- Optional: Resistance to interference due to electromagnetic fields shall be tested in reference to IEC 61000-4-3 (required field strength 3 V/m), only if portable or non-portable transmitters are expected to influence the operation of the charge regulator.
- Optional: Resistance to interference from electrostatic discharge measurements are only required if touching the equipment by operators or other persons is expected to influence the operation of the charge regulator (IEC 61000-4-2, stringency: 8 kV air discharge).

Test Report

All test results must be documented and summarised in a test report, which can be requested from the supplier or manufacturer by the tendering institution.

Marking, Labels:

The charge regulator must be clearly labelled, displaying the following information:

- Original signs (trademark, name of manufacturer or name of responsible dealer)
- Model number or type designation of the manufacturer
- Serial number
- Nominal voltage (V)
- Maximum PV generator (input) current (A)
- Maximum load (output) current (A)
- All connecting terminals must be clearly labelled with function and polarity.
- All displays must be clearly labelled with the meaning of the indication.
- Characteristic type and value of fuses must be written near the fuse holder.

Documentation:

The documentation delivered with the charge regulator must contain the following information and data:

- Installation instructions
- Operating instructions
- Technical data
- Troubleshooting instructions
- Safety warnings
- Information on spare parts
- Warranty

In particular, the documentation must indicate the following data:

Environmental Conditions:

- Range of operating temperature
- Range of storage temperature
- Maximum relative humidity

Physical properties of the charge regulator:

- Case dimensions
- Weight
- Case properties (material)
- Degree of protection (IP Code)
- Fasteners, fixing material
- Connecting terminals, maximum cable size
- Cables (inlet, strain relief, cross-sections)
- Spare parts

Electrical properties of the charge regulator:

- Nominal voltage (V)
- Maximum PV-generator current (A)
- Maximum load current (A)
- Type of regulator (series regulator, shunt regulator)
- Working principle (PWM, two-point-regulation, state of charge algorithm)
- All used thresholds (V)
- Temperature compensation for the thresholds (mV/°C/cell)
- Service life
- Own consumption
- Losses
- Overload protection
- Reverse-polarity protection
- Capability of switching to accommodate different nominal voltages
- Warning before load disconnect
- Delayed load disconnection
- Displays (LED's, display, accuracy)
- Additional functions (MPP tracking, etc.)

All data must be verified in the course of the type-test procedures. Data which are missing or do not conform to the measurements shall be conscientiously recorded.

Sampling: Four charge regulators for qualification testing shall be taken at random from a production batch, in accordance with the procedure given in IEC 60410. The charge regulators 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. If the charge regulators to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report.

Testing / Pass Criteria: All specimens are subjected to the visual inspection, examination of the electrical parameters and a function test. Two specimens are subjected to various tests. The other two serve as replacements: Should one charge regulator fail any test, another two charge regulators shall be subjected to the whole of the relevant test sequence from the beginning. If one or both of these also fail, the design shall be deemed not to have met the qualification requirements. If, however, both charge regulators pass the test sequence, the design shall be judged to have met the qualification requirements.

Comment: As the specifications described in the above proposal version of the standard are not yet final and binding for suppliers, the following specifications were selected from various other sources. Additionally or alternatively to the above standard-proposal, the following specifications can be selected individually to meet the local requirements in a tender for SHS and RHS:

Electrical Parameters, Performance and Requirements

The minimum rated input (PV-generator) current shall be 8 A (WB: 6 A).

The minimum rated output (load) current shall be 10 A (20 A).

The charge regulator must resist without damage the operating condition defined by: ambient temperature of 45°C, charging current 25% greater than the short-circuit current of the PV generator at Standard Test Conditions, and discharging current 25% greater than that corresponding to the full load "on" at the nominal operating voltage.

The charge regulator set points must be factory-preset with the set points applicable to the specified battery characteristics.

The voltage thresholds can only be readjusted by trained service personnel with suitable tools and measurement equipment.

Health, Optional: Two types of load will be connected: Essential and non-essential load. The regulator shall preferably have a facility to disconnect and re-connect the loads at separate settings.

Since the ambient indoor temperature is not expected to vary significantly in the specific locations where the SHS will be installed, battery temperature compensation circuitry is generally not required. The charge regulator voltage set points must be set to match the average ambient daytime indoor temperature for the battery location.

Comment: The following specification should be applied if ambient (indoor) temperatures around the battery and the charge regulator are expected to vary significantly during the year, say, by more than ±10°C. In RHS application, a temperature compensation is generally recommended.

Health, Optional: A temperature correction of -4 to -5 mV/°C/cell should be applied to the end-of-charge and reposition voltage.

Internal voltage drops between the battery and the input and output terminals of the charge regulator must be less than 4% of the nominal voltage (≅ 0.5 V for 12 V in the worst operating conditions, i.e., with all of the loads "off" and the maximum current from the PV generator or when all of the loads are "on" and no current from the PV-generator is flowing.

Health, Optional: The charge regulator shall be equipped with a “voltage sensing line" by means of which the battery voltage can be measured at “zero current" and independently of the charge/discharge cable. If the regulator is positioned “electrically" close to the battery, this voltage sensing line can be omitted.

Comment: Due to charge/discharge cycling, batteries with liquid electrolyte can develop different acid-density zones in their electrolyte. This detrimental phenomenon can be avoided by keeping the electrolyte well mixed. The charge regulator will be able to raise the final charge voltage for one hour every two weeks or when the discharge voltage falls below a set value.

Optional: Controlled overcharging should be done at a constant voltage of 2.5 V/cell. Overcharging should occur after each deep-discharge and/or at 14-day intervals. Overcharging should last between 1 and 5 hours. It should be possible for controlled overcharging to be manually switched off.

Optional for valve-regulated maintenance-free batteries:
The charge regulator set points shall be factory-preset with the set points applicable to the specified maintenance-free battery characteristics. A controlled gassing or boost-charging of the valve-regulated lead-acid battery is NOT allowed, as gassing activates the release of hydrogen and oxygen through the valve, which cannot be refilled anymore.

Optional: Current compensation for the exhaustive discharge protection threshold is recommended (for larger PV systems).

Some form of state-of-charge indicator for the battery must be provided on or near the charge regulator. This device must at least indicate the battery conditions:

- suitable to operate loads (e.g. voltage greater than 12.5 V_{DC})
- when energy conservation is required (e.g., battery voltage less than 11.8 V_{DC})
- when the load is disconnected.

These indicators may be LED's, or analogue or digital meters. The chosen device must come appropriately labelled such that the user does not have to refer to a manual to understand the current battery condition.

Optional: When the battery is within approximately 0.1V above disconnect (30 minutes before disconnect), a visual (and audible) warning must be given.

Health, Optional: The charge regulator shall display at least the following parameters:

- Terminal voltage
- Load connected/disconnected
- Regulator status (example: normal charge or equalisation)
- Charging current
- Load current
- State of charge (example: 60 %)
- Errors: Over-Temperature, Over Voltage, Under Voltage, Overload Current

Mechanical Parameters, Performance and Requirements

Fixing material (screws and wall plugs) for wall mounting shall be included.

The charge regulator shall have a strain relief for the installed cables. If no strain relief is provided inside the case of the charge regulator, an external strain relief must be delivered with the unit.

If certain inlets of the casing are not used for cables (temperature and voltage sense lines), appropriate blind caps must be installed to guarantee the IP protection specified.

The PV-generator, battery and load terminals must be able to accommodate a cross-section of 2,5 mm^2 of each conductor.

Access to the terminals must be from outside (inside) the case only with suitable tools.

The charge regulator case must provide protection of at least IP32 (optional: IP43, IP54 depending on environmental conditions), according to IEC 60529.

Comment: Independently of the specified IP protection code of the case, a certain amount of protection against insects is needed for some projects. This requirement might be useful especially in tropical regions, as insects in connection with humidity can cause short circuits on print-boards and electronics. On the other hand, a protection of IP 54 (or even IP 41) will not allow any insects to enter the case.

The case of the charge regulator should be constructed to keep out insects and dust and should be corrosion-resistant. Encapsulation of the charge regulator is recommended. In tropical areas, the electronic circuit boards have to be coated with water-resistant material.

Optional: A certain amount of air ventilation of the charge regulator should be guaranteed in humid areas to avoid a condensation of water inside the case.

The ambient temperature range for operation of the charge regulator is ....°C to ....°C (normal: -10°C to +40°C, in tropical climates: +5°C to 50°C, in extremely hot desert climates (e.g. Tunisia): -10°C to 70°C).

The maximum relative humidity can be ... % (95% in tropical climates).

Abnormal Operation Precautions:

The charge regulator must be protected against damage caused by short circuit of the input and output terminals, and reverse polarity of any connections.

The charge regulator must be able to resist any possible "non-battery" operating condition when the PV generator is connected and/or with any allowed loads. The charge regulator must also protect the load in any possible "non-battery" condition by limiting the output voltage to a maximum of 1.3 times the nominal value. (Full interruption of output voltage is also allowed.)

The charge regulator should allow battery charging from the PV generator for any battery voltage greater than 1.5 V/cell.

The charge regulator must resist without damage the operating condition defined by: ambient temperature of 45°C, charging current 25% greater than the short circuit current of the PV generator at Standard Test Conditions, and discharging current 25% greater than that corresponding to the full load "on" at the nominal operating voltage.

The charge regulator should be protected against induced over-voltages (caused by lightning) by means of appropriate Metal Oxide Varistors (MOVs), or Transient Voltage Suppressors (TVSs) inserted between both (+ and -) poles, at the PV-generator input and the load output.

The charge regulator must not produce radio frequency interference (AM and FM) under any operating conditions.

Optional: Some means must be provided to safely disconnect the battery and the PV-modules during servicing or repair by a technician.

Warranty:

The warranty period is at least 1 year. Longer warranty periods of the manufacturer will be passed on to the user.

5.1.5. Loads

Comment: In the meantime, radios, TV sets, etc. are directly acquired by the users in the conventional appliances market; the associated energy consumption tends to be modest and they are highly standardised products. For these reasons, only light fixtures are reviewed in these specifications, while features of radios and TV sets are entrusted to training and general information activities.

Lighting Fixtures with Fluorescent Lamps and Ballasts

Comment: The standardisation of lighting fixtures with energy-saving fluorescent lamps and electronic DC ballasts is quite well described in IEC 60924 and 60925 "DC supplied electronic ballasts for tubular fluorescent lamps - General and safety requirements and - Performance requirements". As these kinds of lights are utilised in public transport vehicles, aircraft and emergency lights, as well as in consumer applications like caravans and private cars, there is a much wider market for these products than just for PV solar systems. But there is still a need for standardisation of the special features; such lights must be compatible with PV applications, especially for the operation in Solar Home Systems in developing countries. Therefore, a new standard-proposal was drafted by the CENELEC CLC/BTTF 86-2 committee for "Photovoltaic Lighting Systems, Part 1, 2 and 3", which was also accepted by the IEC TC 82 and is currently circulating among the committee members for discussion and correction. A copy of the current draft version (as of 07/98) was kindly made available by TÜV-Rheinland, a member of the standards committee. The final version of this standard will probably be released by the end of 2000 and will not differ much from this draft. The draft will be the basis for the following specifications :

Scope of the Standard:

The scope of this standard comprises electronic ballasts and fluorescent lamps for use in photovoltaic systems. The electronic ballast and the lamp should be a matching pair, as recommended by the manufacturer or the supplier. If there is no recommendation available, the operation of the fluorescent lamp should at least be in line with the appropriate data sheet of IEC 60081 or IEC 60901.

Definitions:

Lighting systems in PV stand-alone systems serve to illuminate dwellings and working areas. They are DC-supplied and thus consist of an electronic ballast, a fluorescent lamp and some kind of fixtures. The rated voltage range (V_R), at which the ballast may be operated and at which the proper and correct start, and operation, respectively, of the fluorescent lamp is safeguarded (IEC 60924) will be 10 V < V_R < 16 V for a 12 V system and 20 V < V_R < 32 V for a 24 V system.

The following technical data have to be submitted by the manufacturer and will be verified during the tests:

- Casing of electronic ballast: material, IP-protection, type of assembly
- Type of lamp, certified according to IEC 60081 (tubular lamps) or IEC 60901 (single capped lamps)
- Terminals (marking, type, for which cable)
- Fuses (type, where is what protected by the fuse)
- Rated voltage range at which the ballast safely starts and operates (10 to 16 V for 12 V system, 20 to 32 V for 24 V system), see IEC 60924
- Design voltage according to IEC 60924 (about 85% of maximum rated voltage)
- Product identification and labels according to IEC 60924 and 60925

Documentation must include:

- Technical data

- Operating instructions
- Installation instructions
- Personal safety instructions
- Environmentally safe recycling and disposal instructions
- Warranty conditions
- Accessories

The visual inspection will evaluate the quality performance of the light fixture, the electronic ballast and the accessories.

Electrical parameters and performance tests:

- Starting performance test according to IEC 60925, paragraph 5 at ambient temperature of 20 to 25°C, start within 5 seconds, 1 firing failure permitted.
- Preheating condition test (if preheating is applied) according to IEC60925, section 7, electrode voltage range: 6.5 V < V_{el} < 11 V for high-resistance electrodes, 3.05 V < V_{el} < 6.5 V for low-resistance electrodes. Preheating is recommended, but is not imperative.
- Open circuit voltage at lamp terminals as of IEC 60925, section 6.
- Lamp current shall not be 25% higher than in operation with the reference ballast in the voltage range 8.5 V < V_{bau} < 13.6 V for a 12 V system (17 V < V_{bau} < 27.2 V for a 24 V system).
- Input current of the electronic ballast during operation with reference lamps shall only deviate from the data given by the manufacturer by less than 15%. No alternating effective current components may exceed 10% of the direct current.
- Maximum electrode current given in IEC 60081 or IEC 60901 data sheets may not be exceeded.
- Waveform of the lamp operating current shall not exceed the tolerance limits given in IEC 60925, crest factor of the lamp current may not exceed 3, direct current components may not exceed 2% of the RMS value.

- Stability of operation: uninterrupted, flicker-free and stable operation within the rated voltage range.
- Power consumption of the lamp should range between 90 to 110% of the nominal power consumption of the lamp within the rated voltage range.
- Efficiency test is still under consideration.
- Switching durability of the ballast/lamp combination shall be a minimum of 10,000 operating cycles with 60 s ON and 120 s OFF time.

Mechanical parameters and environmental conditions:

- Mechanical stability of all components shall be tested by vibrations test (acc. IEC 60068-2-6, stringency, see proposed standard) and
- shock test (acc. to IEC 60068-2-27, stringency, see proposed standard), while specimens are not packed and not live.
- Temperature and humidity resistance shall be defined and tested in accordance with the climatic conditions of the project (application) region (see IEC 60068-1).

- For application in tropical climates, a “cyclical damp heat test” (acc. to IEC 60068-2-30) will be performed with temperatures up to 55°C (specimen not live, resp. 40°C (specimen run with design voltage).
- Corrosion resistance and long-term stability will be evaluated after this damp-heat test.
- Operation at different temperatures will be tested according to IEC 60925, with five cycles between lowest and highest ambient temperature given by the manufacturer and 200 hours at maximum surface temperature (surface temperature may not exceed 80°C).
- Suitability of construction and sturdiness of casing as of IEC 60068-2-63 or IEC 60335-1, section 21 with a 250 g dead stroke hammer from different directions, operational test of changing fuse and lamp without danger of injury.
- IP protection code according to IEC 60529, IP 20 for solidly built indoor applications, otherwise IP 54.

Safety tests according to IEC 60598 and IEC 60924:

- Insulation resistance as of IEC 60598, section 10 and IEC 60924, sections 12 and 13
- Dielectric strength as of IEC 60598, section 10 and IEC 60924, sections 12 and 13
- Voltage impulses at electronic ballast as of IEC 60924, section 18
- Terminals as of IEC 60598, sections 14 and 15
- Safety earth terminal as of IEC 60924, section 9
- Creepage and clearance distances as of IEC 60924, section 10 for electronic ballast and section 11 for lighting system
- Fault conditions at electronic ballast as of IEC 60924, section 14
- Abnormal operating conditions will be tested as of IEC 60924, section 19:
  - Removal of lamps
  - Non-igniting lamps
  - Reverse polarity of input voltage
  - Surge voltage of 26 V for 12 V system (52 V for 24 V system) as maximum open circuit voltage from PV generator

- Screws, conductive components and connections as of IEC 60598, section 4
- Heat and fire resistance as of IEC 60695-2-1 (glow wire) and –2 (needle flame)
- Protection against accidental contact with live parts as of IEC 60598, section 8, and IEC 60924, section 11

Electromagnetic compatibility (EMC) tests:

- Line-conducted interference emission shall be tested at least on the output (load) line in the radio-frequency range from 10 kHz to 30 MHz (acc. to EN 55015).
- Irradiated interference emission at a distance of 3 meters will be tested in accordance with EN 55015, limit values acc. to EN 55015.
- Resistance to interference from fast, low-energy pulses (pulse group) will be tested according to IEC 61000-4-4 (0.5 kV).
- Resistance to interference from single high-energy impulses like atmospheric discharges (lightning) according to IEC 61000-4-5 with 0.5 kV.
- Optional: Resistance to interference due to electromagnetic fields shall be tested in reference to IEC 61000-4-3 (required field strength 3 V/m), only if broadcasting

transmitters or portable or non-portable transmitters are expected to influence the operation of the charge regulator.

- Optional: Resistance to interference from electrostatic discharge measurements are only required if touching the equipment by operators or other persons is expected to influence the operation of the charge regulator (IEC 61000-4-2, stringency: 8 kV air discharge).

All test results must be documented and summarised in a test report, which can be requested from the supplier or manufacturer by the tendering institution.

Comment: As the specifications described in the above proposal version of the standard are not yet final and binding for suppliers, the following specifications were selected from various other sources. Additionally or alternatively to the standard formulated above, the following specifications can be selected individually in consideration of the local requirements in a tender for SHS and RHS:

A minimum of ....[8] pieces of 12 V_{DC} fluorescent tube or compact lamp light fixtures, each with its own electronic ballast shall be supplied.

Every fluorescent light must have a minimum light output of 200 lm (400, 600, 900 lm) when operated at an ambient temperature of 25° C.

The luminous efficiency of a new light, with any lenses, covers or grids in place, shall be greater than 35 lm/W (50 lm/W), inclusive of power requirements of the ballast when operated at an ambient temperature of 25° C and an input voltage of 12.5 V_{DC}.

Lights should be “daylight white” with a colour temperature >4000 K (“warm-tone” with a colour temperature of approx. 2700 K, similar to incandescent bulbs)

Expected lifetime of the tube in the light fixtures shall exceed 5,000 (8,000) operating hours. The lifetime test procedure should be in accordance with IEC 60081.

Expected lifetime of the electronic ballast should exceed 10,000 (15,000) operating hours.

Ballasts must ensure soft and regulated ignition and operation in the voltage range from -15% to +25% of the nominal voltage (10.3 V to 15 V for a 12 V battery).

The ambient temperature range for operation of the lamp and the ballast is ....°C to ....°C (normal: -10°C to +40°C, in tropical climates: +5°C to 50°C, in extremely hot desert climates (e.g. Tunisia): -10°C to 70°C).

The maximum relative humidity can be ... % (95% in tropical climates).

Ballasts must be protected against destruction when:

- the lamp is removed during operation or the ballast is operated without the lamp.
- the lamp does not ignite.

[8] Fill in according to requirements; typically 3 - 4.

- the polarity of the supply voltage is reversed.
- the output terminals of the electronic ballast are short-circuited.

The minimum operating frequency should be 20 kHz.

The ballast must not produce any radio frequency interference. The wiring length from the ballast to the fluorescent lamp must be kept short to avoid radio interference.

Measures to preheat the electrodes are recommended. The filaments on the fluorescent tube shall not be heated during normal operation.

The minimum electrical efficiency of the ballast must be 70% in the entire range of operating voltage (-15% to +25% of the nominal voltage).

The waveform of the current through the fluorescent lamp must be symmetrical in time to within 10% (i.e., 60%/40% waveform maximum difference in symmetry) over the voltage range of 11 to 12.5 V at an ambient temperature of 25°C.

The maximum crest-factor (ratio of maximum peak to RMS voltage of the waveform applied to the fluorescent tube) should be less than 2 over the voltage range from 11 to 12.5 V at an ambient temperature of 25°C.

The light fixture should be covered by a diffuser or other enclosure (or can be open, i.e. the tube can be bare). If the tube is covered, the cover should be resistant to insect ingress. Lenses, covers, grids, etc. (if used) shall be easily removable without special tools and without the fixture being taken from its mounting by the user for bulb replacement or for cleaning. Reflectors are recommended to maximise lighting effectiveness.

A fuse or similar device should be used to prevent more than double the rated current from being drawn for longer than 100 seconds.

Each light shall be individually switched and the switch shall be rated for DC operation (and shall be of the toggle or rocker variety). The switch should be clearly marked with the international **I/0** to indicate the position.

The light fixtures should be installed approximately 2.4 m (8 ft) above the floor, but not lower than 2.0 m (7 ft) and not higher than 2.8 m (9 ft).

Fixing material (screws and wall plugs) for ceiling or wall-mounting shall be included.

The light fixture shall have a strain relief for the supply cable. If no strain relief is provided in the casing, an external strain relief must be delivered with the light fixture.

The input terminals must be able to accommodate a cross-section of 2.5 mm^2 of each conductor.

No part of the fixture should be flammable and any plastic parts should be of self-extinguishing material.

Light fittings must be labelled with the manufacturer's name, model number, rated operating voltage range, rated current and date of manufacture or batch number.

The warranty period is at least 1 year. Longer warranty periods granted by the manufacturer shall be passed on to the user.

5.1.6. System installation and wiring

<u>Comment</u>: The CENELEC committee CLC BTTF 86-2 recently (06/98) drafted a standard-proposal entitled "Photovoltaic Systems–Solar Home Systems, Safety and Performance Test Requirements and Procedures", which was kindly made available by TÜV-Rheinland. This proposal mainly provides recommendations for system installation, wiring, earthing/grounding and system documentation. The technical specifications given in this proposal are not very precise yet; therefore, most of the following text proposals are taken from other sources.

Stranded and flexible insulated copper wires and cables must be used for all outdoor and indoor installations. Indoor installation of the lighting distribution system might be performed with solid wires, if appropriate and common practice.

External cables should be specifically adapted to outdoor exposure (see IEC 60811). Especially the outer insulation must be sunlight (UV)-resistant, weatherproof and designed for underground installation. Preferably rubber-coated and PE-coated cables shall be used. (H07 R-NF, NYCWY, RV 0.6/1kV, DV 0.6/1kV, VV-K 0.6/1kV, RV-kO.6/lkV, according to VDE 0281, 0282 and CENELEC HD-361). US-American standard cable types are USE (Underground Service Entrance), SE (Service Entrance) and UF (Underground Feeder). The following types are recommended in IEEE P 1374 "Draft guide for terrestrial PV power system safety": USE-2, USE, RHW, RHH, SE, RHW-2, XHHW-2.

The temperature resistance of all interconnecting wires and cables should be > 85° C.

The minimum acceptable cross-section of the wire in each of the following sub-circuits is as follows:

- From PV generator to charge regulator: 2.5 mm^2 (American AWG 13)
- From charge regulator to battery: 4 mm^2 (American AWG 11)
- From charge regulator to loads: 1.5 mm^2 (American AWG 15)

Notwithstanding the above minimum wire-size requirements, all wiring must be sized to keep line voltage losses to less than 3% between PV generator and battery, less than 1% between battery and charge regulator, and less than 5% between battery and load, all of them at the maximum current conditions. The minimum cross-section must also allow the circuit to operate within the ampacity rating of the wire.

For copper cables and 12 V of nominal voltage, the following formula can be used:

$$A[mm^2] = 0.3 * l * I_{Max}[A] / \Delta V [\%]$$

where A is the minimum cross-section of the cable, l the single (one-way) length of the cable, I_{Max} the maximum current and ΔV the allowable voltage loss.

<u>Comment</u>: Alternatively, the following formula can be used to calculate the voltage-loss on a given cable:

$$\Delta V\,[V] = 2 * l\,[m] * I_{Max}[A] \,/\, (56\ m / \Omega\, mm^2 * A[mm^2])$$

For example, the maximum length of a 2.5 mm^2 cable connecting one 50 W_{peak} PV-module (I_{Max} = 3 A) with the battery is approx. 8 m at a tolerable voltage loss of 3%. For a 4 mm^2 cable, the maximum length is 13 m, and for a 6 mm^2 cable, it is 20 m.

All wiring shall be colour-coded and/or labelled. The following conventions shall be followed for two-conductor DC wiring in PV power systems:

Positive	:	Red or brown
Negative	:	Black or blue

Earth conductors, either separate or as a third wire in 3-core cables, if present, must be green-yellow.

All exposed wiring must be in UV-resistant conduits or be firmly fastened to the building and/or support structure. Cable binders, clamps and other fixing material must also be UV-resistant, preferably made of polyethylene. *(<u>Comment</u>: Polyvinyl Chloride (PVC) is definitely not UV-resistant and will become brittle within less than one year in direct sunlight).*

Wiring through roofing, walls and other structures must be protected through the use of bushings. Wiring through roofing must be sealed (waterproof).

Holes through roofing materials should be avoided wherever possible. Cables through roofing shall be contained in purpose-made roof-entry boxes, or proper UV-resistant glands, which shall form a weatherproof seal to prevent leakages. In corrugated roofs, holes for cables are to be drilled at the top of corrugations. All holes in roofing shall be thoroughly sealed and made waterproof with UV-resistant silicone sealant or an equivalent method.

Where wires or cables are fixed to or passed through particularly flammable materials (thatch, etc.), they shall either be flame-retarding cables or shielded in non-flammable conduits. Fittings need to be fastened to suitable supports, which may need to be provided if not already present. No conduit or fitting shall be attached directly to thatch or any other non-supportive surface.

Holes that penetrate external walls shall slope slightly to prevent the ingress of water and be suitably sealed.

Conduits to battery boxes or battery enclosures shall not provide a route through which hydrogen gas may escape, leading to any area or device (relays, etc.) where there is a danger of sparks.

Cables must be joined by the use of junction boxes, screw-connectors, block-connectors or by crimping ferrules (with insulated heat-shrink sleeves). All stranded wires must be terminated with proper end-sleeves. Soldering in the field and the use of wire nuts are not allowed. The rated current-carrying capacity of each joint must not be less than the circuit current rating.

Junction boxes or enclosures must be dust- and waterproof, non-corrosive and electrically insulated (no metal boxes). Interior junction boxes shall have an IP protection of at least IP 32, and external junction boxes a minimum of IP 55 according to IEC 60529.

Fittings for lights, switches and socket outlets may be used as junction boxes where practical.

Careful attention shall be given to entries into enclosures and junction boxes, to provide good sealing, proper strain relief to ensure that the wiring connections themselves are not under tension and to prevent chafing and damage to the insulation.

Surface-mounted cabling shall be installed using appropriate fasteners at suitable intervals (15 to 20 cm) to prevent sagging.

Visible interior cabling or conduits shall be aesthetically tidy, and should not slant from the vertical or horizontal unless essential.

Underground cables shall be buried at least 0.5 m below the surface, mechanically protected either by a conduit or laid in a sand-bed without any sharp rocks or stones.

Health, Optional: Underground cables shall be a minimum of 1 m below the surface and be indicated with markers (coloured plastic tape, minimum 50 mm wide, or lining with bricks or slates, 0.3 m above the cable). Underground cables shall be used across all areas with vehicular traffic, in preference to overhead cables.

Suspended cables shall be mounted so that the lowest point is at least 2.8 m above ground level. The cable shall be held in position by suitable brackets and strain relief to prevent mechanical wear and any strain on the electrical connections.

Fuses and circuit-breakers shall
- be rated for DC service
- have voltage ratings greater than the maximum circuit voltage
- have current ratings between 125% and 150% of the maximum design current for the circuit
- be marked with the rated capacity and circuit voltage.

For circuits where normal transient surges are expected (e.g. when starting motors, refrigerator-compressors, etc.), the fuses or circuit breakers should have an appropriate time-delay before activation.

Health: Every circuit connected to a battery shall have a circuit breaker for protection against high fault currents or overloading. In a two-conductor grounded system these shall be installed in the ungrounded (positive) conductors. They shall be installed as close to the energy source as possible, to minimise the risks of electrical shock.

Health: Required fuses and/or circuit breakers may be integrated into the regulator-box or installed separately in a fuse or distribution box located near the regulator and battery. Each fuse or circuit-breaker shall be clearly marked with rated capacity and the circuit for which it is used.

Health: Distribution boards shall be weatherproof (hot-dipped galvanised). The boards shall be surface-mounted with front panel/door complete with neutral and earth bar, labelling rails, labels, nameplate and legend.

However, fuses or any other components which can cause sparking shall not be installed in a battery enclosure where there is a chance of explosion of hydrogen. No fuses or circuit breakers shall be installed in a grounded conductor.

Light switches shall be installed next to the entrance door of each room at approximately 1.2 m above finished floor level.

Only special DC switches are allowed. They shall be rated for the current and voltage of the circuit they disconnect. AC switches may only be used if their DC switching performance is known (and certified) and satisfies the current and voltage ratings of the circuit. AC ratings are not adequate, due to arcing.

Health: The switch outlet will be of industrial type, watertight and surface-mounted, 5 A rating.

All switches should include a clear visual indication of their state (ON/0FF or I/O). However, suitable pull switches may be acceptable for overhead light fittings.

Health: All appliances that are not hard-wired shall be connected to the wiring through socket outlets unless otherwise specified. AC sockets shall not be used. Only sockets designed for DC shall be used, and it shall not be possible to reverse the polarity. Sockets shall be clearly labelled DC and show the voltage, to inform unfamiliar users about the nature of the power supply. The larger diameter pin in a DC plug shall always be positive.

Warning: Mains sockets and plugs are not to be used under any circumstances. Any 12 V appliance with a mains-type plug attached constitutes an unacceptable safety risk to the user if the appliance is used in a 110 or 230 V outlet.

The warranty for wiring, installation and the performance of the entire system shall be one year (World Bank: 6 months) from the date of commissioning (or date of acceptance test).

5.1.7. Grounding, Lightning Protection

Comment: Grounding (or earthing) refers to the provision of a low-resistance conduction path from points in the PV power system to the earth ground, and can be divided into two aspects:

- *Grounding of equipment casings (e.g. the PV array frames and support structure)*

- *Grounding of the electrical circuits*

Grounding can reduce the risks of damage from lightning-induced surges, may reduce the hazards to people, fix the maximum system voltages relative to the earth ground, and improve radio /TV reception. Complete protection from lightning cannot be guaranteed, and the extent (and the cost) of technical lightning-protection measures should depend on the nature of the installation. In all cases, the primary concern should be people's safety.

The installation of a complete lightning conductor system is far from being acceptable in SHSs for economic reasons. For example, under the Bolivian High Plateau conditions, where lightning storms are frequent, the annual losses of PV modules and regulators due to lightning damage are about 0.2%, while the cost of a lightning conductor system would represent an increase of at least 35% in the costs of a SHS. Moreover, other much cheaper protection options exist:

Exposed metal surfaces and frames of equipment (normally not live) may be grounded for safety. In low-voltage DC power systems (less than 50 V) this is optional, but may be of particular importance in lightning-prone areas, where grounding the PV array frame and structure can provide a safer conduction path. For this purpose, the array frame and structure should be connected by the shortest practical route to an adequate earth contact, using an uninterrupted conductor of at least 16 mm² cross-section.

Optional: In regions with frequent thunderstorms, manual disconnection (switch) of both the positive and negative poles should be installed between the PV generator and the charge regulator, so that the PV generator can be isolated when there is a risk of lightning strikes.

Optional: For improved protection of equipment, an earth electrode system should be installed as close as possible to the PV array, to provide a short conducting path to earth. This earth electrode must then be bonded to any other earth electrode installed.

Optional: If an array source circuit runs for more than 20 m in lightning-prone areas, it is recommended to guide the conductors in a well-grounded metal conduit or use shielded cables.

Ground electrodes may be provided by an earth spike (galvanised T-shaped 30 x 15 mm or round ∅ 15 mm iron-bars), driven at least 1.5 m deep into the ground. In rocky locations a ring or stripe earth-conductor of galvanised flat or round iron can be laid out and buried in a trench. Metal water pipes providing sufficient ground contact for a low-resistance path to earth or reinforcement bars of the concrete foundations may also be suitable.

If other equipment is grounded, it shall either be grounded to the same earth contact ("earth electrode") used for the array, or otherwise to another earth electrode which is bonded to the earth electrode used for the array.

Optional: In a two-conductor DC wiring system, one of the current-carrying conductors shall be grounded by direct connection to a good earth contact. If so, the negative conductor shall normally be the grounded conductor, unless otherwise specified. The connection to earth shall not contain any fuses or switches. There should be a direct connection between its negative input and output terminals of the charge regulator. Conversely, if a regulator is used which has switching in the negative rail, the negative conductor should not be grounded.

Reliable, durable surge arresters are recommended on the input and output of the charge regulator, to reduce the risk of damage from lightning-induced surges. A cheaper, but not as save, alternative is the use of Metal Oxide Varistors (MOVs).

5.1.8. Documentation

The system documentation shall include, in addition to the data sheets of all main components, a user's manual and a technician's manual with the following contents:

The User's Manual should include:
- warranty conditions for all major components
- battery safety requirements
- battery maintenance requirements
- battery replacement requirements
- description of all user-interactive hardware
- requirements for proper system operation, including load limitations, critical loads, load conservation, weather dependence, shading problems, etc.
- system maintenance
- emergency shut-down procedures
- simplified operating instructions for the charge regulator
- functional block diagram

The Technician's Manual should include:
- a copy of the user manual
- a list of all system components, data sheets, warranty conditions, etc.
- installation instructions
- acceptance test procedures verifying all electrical set points for PV generator, charge regulator, load operation, battery capacity, voltage drops, etc.
- the recommended maintenance schedule and maintenance instructions
- trouble-shooting guide, including all repairs and diagnostic procedures that can be performed by the supplier
- functional block diagram
- emergency shut-down procedures

6. Rural Health Power Supply

For some 2 billion people in developing countries, rural health stations are the only form of medical care. The services provided by these clinics range from basic health care and (birth) deliveries to vaccination programmes and general health education. The energy consumption of the health stations depends on the range of services provided and the target area and/or the number of patients.

The care provided by health stations with photovoltaically generated electrical energy ranges from simple station illumination and functional lighting (operating room, laboratory, etc.) to the operation of refrigeration units for the storage of vaccines and medication (sometimes also blood) and the operation of laboratory equipment, VHF and short-wave transmitter radios, fans, radios and TV sets.

The reliability of the supply system is a decisive factor, especially for the operation of refrigerators and other - to some extent life-saving - equipment. A failure or malfunction of a refrigerator jeopardises the effectiveness of vaccines and medicine.

The conscientious layout of a PV system, professional installation as well as regular care and maintenance by skilled personnel, but also understandable instructions, clear-cut signs and labelling, sufficient spare parts and tools contribute a great deal to system reliability.

6.1. Weak Points of Installed PV Systems in the Past

In the past, the widest variety of factors in PV installations for the supply to health stations have led to lower performance and often to outages of the installations. Large-scale WHO studies in the framework of the Extended Programme on Immunization (EPI) in Papua New Guinea, The Gambia, Uganda, Kenya, Zaire and Sudan, as well as experience from GTZ health and energy projects, among others, have shown the following deficits in the layout, installation, care and maintenance of the systems [19], [20], [21]:

<u>Planning, Layout:</u>

- inadequate determination of demand in the planning stage (standard options preferred)
- poor communication between planners and users
- PV generator outputs too low
- battery capacities too low
- energy consumption too high, especially of refrigerators
- cable diameter too small
- deficient lighting capacities

<u>Installation:</u>

- wrong tilt angle and orientation of the solar modules
- shading of the solar modules
- unprofessional execution of the installation work
- overly long cable connections (line losses)
- switches and batteries in completely run-down corners of the buildings

Components:

- use of refrigerators that have not been tested or are not WHO-approved
- exceeding/dropping below the cooling temperatures (frozen vaccines)
- leaky refrigerators
- failure and malfunction of charge regulators (especially at high outside temperatures)
- threshold settings of the charge regulator are not adapted to the battery types used
- use of automotive batteries as replacements for stationary batteries
- use of loads (e.g. lamps) that are not energy-saving

Operation, Maintenance:

- lack of sensitisation and training of personnel (energy management)
- inadequate operating instructions
- no documentation, poor documentation or documentation that is hard to understand
- no financial reserves or income for repairs and procurement of spare parts
- high maintenance costs due to long distances that need to be covered by qualified service personnel
- failures of measuring devices
- no spare parts, no distilled water, no tools, or inadequate tools

The problems with the planning, installation and operation of PV units may be very diverse in nature, but are by far not just to be found at technical level and can therefore hardly be solved by purely technical means. However, the technical planning and execution of a whole system and its components should be carried out as reliably as possible in order to withstand as many outside imponderables as possible without being damaged.

6.2. System Layout

The daily achievable energy yield and the amount of energy that can be stored are limited by the number and output power of PV modules and the installed battery capacity. Both components represent a major cost factor in the configuration of a PV system. On the other side is the energy demand of the health station and the supply security of the individual loads.

In the case of larger installations with various loads, the loads have to be subdivided into "essential" and "unessential" loads with different energy-supply priorities. The availability of components, such as refrigerators or radio transmitters, for example, has to be guaranteed, whereas station illumination, not to mention the lighting of private quarters (living areas), play a subordinate role. A sensitisation of the personnel in dealing with electrical loads, moreover, is indispensable.

The loads can be separated with a charge regulator that has two separate load outlets that are switched with different priorities. This requires two different threshold settings for the load disconnect when the battery is in a low state of charge. Up to now, the measuring size for the state of charge is the terminal voltage of the battery. The temperature differences and ageing processes, however, alter the charge and/or discharge behaviour of a battery and can cause the charge regulator to malfunction.

A temperature compensation in cases of sharply fluctuating ambient temperatures and a regular post-installation adjustment of the charge and discharge thresholds can help to alleviate this problem. Newer developments of charge regulators with intelligent (self learning) logic can adapt their behaviour to the ageing process of the battery.

Better protection against excessive consumption is provided by completely separating the systems, i.e. the refrigerating unit and possibly other important loads are supplied by an independent PV system. Uncritical loads like station lighting, radio, TV, etc., whose energy demand is usually difficult to calculate, are installed as completely separate systems. This makes it possible to avoid jeopardising the vaccines to be refrigerated because of a lamp that has not been turned off. This also offers the possibility of spatial separation, i.e. accommodating the various health services in different buildings.

The PV system also has to ensure the operation of refrigerator and freezer (including medicines and freezing icepacks) during periods of the lowest irradiation. It should be possible for the refrigerator to continue to be operated with a charged battery for at least five days on its own and separated from the solar module.

Some examples of small and medium-sized health stations are summarised in Annex 5.

A precise sizing of a PV system is generally done with a computer program. A high supply security and long autonomy periods should be set for health stations. Examples of simplified manual layout procedures are given in the “gate” publication “Electricity from Sunlight” [16]. A more complicated analytical layout method for stand-alone PV systems, which takes the supply security and outage probability of a system into account, was proposed by M. Egido and E. Lorenzo, University of Madrid [15].

6.3. Components

In the planning of a PV system for health stations, the right selection of components is of critical importance for the reliability, acceptance and permanence of the energy supply. In the framework of the “Expanded Programme on Immunization (EPI)” of the World Health Organization (WHO), about 3,200 PV-supplied refrigeration systems for vaccine refrigeration were installed world-wide in more than 10 years. The actual number of installed systems is probably quite a bit higher, since many installations that were financed by private or non-governmental organisations (NGOs) are not registered with governmental health services.

To date, these refrigeration systems have also been the main application for PV systems in rural health care in developing countries. Other applications like station and function lighting, laboratory equipment, fans, communication facilities as well as electricity supply to non-medical areas like staff quarters, training rooms, workshops, etc., however, are becoming increasingly important.

It is only worthwhile to use special PV systems like drinking water supply (PVP) and water purification, power supply to X-ray units or a complete alternating-current supply via DC/AC inverters as of a certain unit size, depending on technical and financial expense; for this reason, they tend to be reserved for district hospitals with at least 50-100 beds. These systems will not be dealt with any further in the following. Applications like air-conditioning units or any form of electrical heating-up for sterilisation, laundering, kitchen, etc., are prohibitive for PV supply purely for economic reasons, as the energy demand of these applications is much too high.

6.3.1. Refrigerators/Freezers

A comprehensive overview of solar-operated refrigeration and freezing devices and their technical data, as well as other accessories and recommendations for the installation and operation of a reliable cooling chain can be found in the "Product Information Sheets, Edition 1997“ of WHO/EPI [17], which can be obtained free of charge from WHO in Geneva (address see Annex 1). The devices and systems listed in this publication have been tested and approved for WHO standard requirements by independent test laboratories. These standard requirements and test procedures (“EPI Equipment Performance Specifications and Test Procedures” [18] can also be obtained from WHO, free of charge. They are more or less accepted as the standard for refrigeration units in the health-care sector in developing countries.

According to WHO, a system supplier for solar refrigeration units has to meet the following requirements:

- He has to supply a coherent, well sized system in which all components have been set to provide optimum performance of the system.
- He has to be responsible for the installation of at least 10 PV systems over a period of more than two years in developing countries (precise reference list).
- He has to have the capacity and financial resources to provide long-term support of the systems in the country of destination.
- He has to offer a refrigerator/freezer that has passed the test by an independent, WHO-qualified test laboratory in accordance with EPI test requirements.
- He has to be willing to meet all conditions stipulated in the EPI Equipment Performance Specifications and Test Procedures and the current requirements and delivery conditions that are valid between WHO and UNICEF.

If a refrigeration unit is operated to store vaccines, its operating safety has to be guaranteed. Most vaccines have to be stored at a temperature in the range of 0° and 8° C. Freezing and also higher temperatures can ruin the vaccination effect. Precise data regarding cooling temperatures for the various vaccines are indicated in the EPI Product Information Sheets.

In the planning and layout of a refrigeration system, a decision should first be made regarding the selection of the most worthwhile form of energy (and thus of the system as a whole) based on the flow chart (see Annex 6) for every single site. WHO's experience shows that solar refrigeration units are not always the best option, since in addition to the high investment costs, high maintenance and repair costs may also be incurred. For this reason, gas-operated refrigeration units are often the better option.

If the vaccine is to be transported further over longer distances, the possibility of freezing and storing icepacks should be provided for. This naturally increases the unit's energy consumption. Typical values for a 51 litre refrigerator with a 34 litre freezing compartment are [6]:

- 300-380 Wh per 24 hours operation with icepack-freezing
- 440-540 Wh per 24 hours operation with icepack-freezing

The capacity of the refrigeration unit and freezing compartment, the freezing performance and the energy consumption when fully loaded, depending on the outside temperature, are decisive criteria.

The energy consumption, when full but without icepacks and at outside temperatures of 43°C, must be less than 0.7 kWh/day for a volume of less than 50 litres and less than 0.1 kWh for additional 10 litres volume. The quantity of water-filled icepacks required by WHO (2 kg without packaging material, Type E5/IP.1) shall be frozen in less than 24 hours. The freezer capacity shall be sized for at least 16 frozen icepacks (8 kg).

Energy consumption can increase considerably if the refrigeration unit is frequently opened or left open for a relatively long time, more so in the case of refrigerators with a vertical door than in the case of iceboxes with a lid on top. It is critical for reliable operation to initiate the staff in dealing with the refrigeration unit and sensitising them to this problem.

Distinct warning signals have to be installed which point to a low state of charge of the battery or to the separation of the refrigeration unit from the energy supply. If the battery capacity drops below a pre-warning threshold, a warning signal has to light up with the written notice: "Do not freeze icepacks".

A thermometer that can be read from the outside should be provided for. The refrigerator should have a thermostat or a defrost switch that can be operated by the staff without the need to use other tools. However, an additional switch should not be installed.

The inside and outside walls, the lid and frame must be made of non-corroding material and should be easy to clean.

6.3.2. Lighting

The importance of having electric light in a health station is often underestimated. The greater light intensity and better focussing of electric lamps, as compared with oil lamps and gas lamps, is a major improvement in concentrated activity like operations and examinations as well as when working at night-time.

A well-planned illumination of all functional rooms, stations, storage rooms and outside areas that is adapted to the demand of the health station serves the general safety and enhances the quality of work and life. As a matter of principle, only energy-saving lamps like fluorescentlights and compact fluorescent lamps with electronic ballasts should be used.

In operating rooms as well as delivery rooms, OP lights with halogen lamps that are commonly commercially available should be used, which generally run on low voltage (24 V).. If the purchase price of such lamps is too high, one can resort to automotive halogen headlights or domestic halogen beamers; however, this has the critical disadvantage that these types of lamp develop a tremendous amount of heat, which can be extremely unpleasant for both the patient and the operator in open operations.

If a fixed lighting installation for the whole station is too costly, portable battery-operated lamps can be used, which are charged at a PV charging station during the day.

Experience shows that the illumination of the service staff's private rooms increases the consumption of energy, but that it makes a significant contribution to the smooth operation of the health station and also to the PV system, because the staff has a more direct interest in having a functioning unit. If the illumination of the private rooms is connected to the same installation as essential loads of the health station, the non-essential loads have to be switched off separately and early in any case in the event that the battery deep-discharges. A risk to important loads from a lamp that has been left on by mistake or a TV that is operated for 24 hours has to be excluded.

A single 11W energy-saving lamp (about 13 W consumption) consumes 312 Wh in 24 hours, as much as two 50 W_{peak} solar modules with a mean insolation of 5 kWh/m^2d generate. If only for this reason, central (or decentralised) time clocks and/or dimmers should be used with large installations.

All lamps have to be sufficiently fastened and easy to clean. The use of disinfectants and strong cleansers should not do damage to casings, covers or lenses, or reduce their transparency.

Otherwise, the specifications and minimum requirements for lamps and lights in Chapter 5 apply.

6.3.3. Charge regulator

The charge regulator shall primarily protect the battery from overcharging and deep discharge and has to fit the battery type used. It shall monitor the battery's state of charge and the charging process, and also regulate the connect/disconnect of the charge in such a way that as long a battery life as possible is achieved.

The specifications and minimum requirements for charge regulators as indicated in Chapter 5 apply as a matter of principle. The higher standards marked "Health" should be applied for RHS. The specifications marked "Optional" also describe requirements that are higher than those necessary for Solar Home Systems in most cases. All of the technical specifications should be reviewed for their applicability at the planned project site, since requirements that are too high can make the system unnecessarily more expensive, but requirements that are too low (especially for the charge regulator) can have much more tragic consequences for the reliability and safety of the system.

Only a few exemplary specifications are given here, which the texts in Chapter 5 describe in more detail.

The ambient temperature of the battery can vary significantly, depending on the site in the annual and/or daily cycle. To adjust the end-of-charge voltage, a temperature compensation with -4 to -5 mV/K per battery cell has to be provided for, which has to be self-guided via a temperature sensor on the battery or (at the same ambient temperature) by a sensor in the charge regulator.

Due to the charge and discharge processes in the battery, concentration differences in the electrolyte may occur, which can reduce the capacity and lifetime of the battery. This effect can be eliminated by occasional controlled gassing, causing a mixture of the electrolyte. The charge regulator has to raise the end-of-charge voltage for about one hour for this to happen, and repeat this process every two weeks or after a certain deep-discharge battery voltage has been exceeded.

Note! Sealed batteries should not be gassed in any case. (Early ageing and danger of explosion!)

Own consumption by the battery charger should be minimised (< 10 mA).

If high currents flow through the battery wiring, this leads to voltage drops which are not taken into account when the battery voltage is measured at the charge regulator. This measuring error can be eliminated by a separate voltage sensor line. In the case of smaller systems up to 200 W_{peak} and cable cross-sections of at least 4 mm^2, however, this sensing line is not required for cable lengths of up to 3 m.

The display for the function of the charge regulator and of the battery's state of charge should give the trained operating personnel enough information to take any necessary measures (manual switch-off of certain loads, advance warning to the users if load is shut off, etc.).

The charge regulator should be equipped with the following displays; a digital LCD display with alphanumeric measurements is only preferable if the operating personnel is properly trained for this and knows how to interpret the measurement data:

- charge or discharge operation
- load shut off
- system voltage
- battery state of charge
- charging current
- load current
- error notices: battery voltage too high/too low (over voltage/under voltage), battery temperature too high/too low (over temperature/under temperature), load current too high

6.3.4. Batteries

Only high-quality batteries should be used in PV health stations.

The expected life of the batteries is a decisive cost factor in the calculation of a PV system. The 1,000 charging cycles with 50% discharge required by WHO or the 1,500 charging cycles with 20% discharge required in the GTZ RE Project in Namibia, can be used as guidelines for this. This corresponds to a life expectancy of about 3 to 5 years.

Lead-acid batteries with grid plates or tubular plates or closed maintenance-free batteries are used. In any case, the charge regulator has to fit with the battery performance. In the case of closed batteries, it is absolutely necessary to avoid gassing. (Danger of destroying the battery or even explosion.)

To control the acid level, open lead-acid batteries should have a case made of semi-transparent material or an electrolyte display. Distilled water always has to be available in sufficient quantities and the electrolyte level has to be controlled regularly.

Automotive starter batteries should not be used in any case.

If possible, parallel switching of batteries should be avoided, since this can lead to an uneven state of charge in the cells, to compensation currents between the batteries and to premature ageing of the batteries. Batteries of greater capacity are preferable to parallel switching.

The place where batteries are set up should meet the following conditions:

- Batteries have to be protected against weather influences.
- They should be put in a room that can be closed off or should at least be enclosed in a battery case.
- Access must be restricted to authorised and properly trained operating personnel.
- In no case must the batteries be accessible for children.
- The connections have to be secured against an unintentional short circuit, e.g. due to a tool falling on top of the battery.
- Sufficient ventilation must be provided for at the highest point of the room to allow hydrogen gas to escape.
- The hydrogen must not be allowed to float through rooms where there is a danger of sparking or open flames.
- There should be at least 20 mm free space between the battery and the walls and top of the battery box.
- The battery container has to be sufficiently sturdy and acid-resistant.
- A readily visible warning sign (fixed to the battery box or placed at the battery enclosure) should call attention to gases and acids escaping, danger of explosion and that no smoking and no fires are permitted.

If possible, the room temperature should be in the range of about 15° to 30°C. Extreme temperatures and temperature differences should be avoided. If extreme ambient temperatures are expected, only those batteries may be used which are designed for such conditions.

If at all possible, the batteries should be transported in an unfilled state. The acid should be transported in separate containers.

Furthermore, the specifications and minimum requirements for batteries as stated in Chapter 5 shall apply.

6.3.5. PV modules

Mono- and polycrystalline modules with a rated capacity of at least 45 W_{peak} (STC), an MPP voltage of no less than 16 V at 60° cell temperature, which generally means consisting of at least 36 cells in series, should be used for health stations. These requirements correspond to the specifications in Chapter 5, but should be observed even more strictly for RHS than for SHS systems.

PV modules have to be tested as a matter of principle according to IEC 61215, and are thus sufficiently specified.

6.3.6. Support structure, setting up and fastening the PV modules

- The orientation and tilt angle of the module should be optimised to the month with the lowest mean insolation sum.
- Shading should be avoided the whole year round during the period from 90 minutes after sunrise to 90 minutes before sunset.
- To allow for regular cleaning of the solar modules, they should be accessible for personnel, i.e., the proper ladders and safety precautions should be provided for. In many areas with regular precipitation, however, manual cleaning is only very rarely necessary as long as a minimum tilt angle of 15° is maintained in order to ensure self-cleaning of the modules.
- The installation has to be protected against theft and vandalism.
- The connections and cable have to be protected against corrosion and unintentional damages.
- If mounted on the ground, the pole should be anchored sufficiently deep (1 m) in a concrete foundation. The connecting cable should be laid under the ground and the installation should be protected with a fence against unauthorised access.
- If mounted on the roof, care should be taken to ensure that there is sufficient circulation of air between the roof and the modules (minimum space: 10 cm).
- Wiring that leads into the building must be protected (insulated or in a conduit) against dampness.
- The PV module and the support structure must be able to withstand windloads of up to 120 km/h.
- It may be worthwhile and acceptable to use passive tracking systems if they are reliable and have been tested, can withstand the required windloads and result in an appreciable gain in energy. This gain in energy, however, must not be taken into account when the system is sized, because in the design month, in other words, the month with the lowest solar irradiation, strong cloudiness and thus a high diffuse irradiation usually has to be expected. Under these conditions, tracking systems usually have no gain in energy compared with fixed installed PV modules; under certain circumstances, they can even reduce the energy yield due to a completely wrong orientation.

- It is not worthwhile in technical or economic terms to use active (motoric) tracking systems unless the systems are large (as of a few 10 kW_{peak}) and in regions with a very high percentage of direct irradiation.

6.4. Installation

The following elaborations are taken for the most part from the tender documents for health stations in northern Namibia (Okavango).[7]

The work must be done professionally, in a neat and tidy manner, not just to support the optically clean and hygienic impression of a health station, but also for safety reasons, to guard against accidents (no loose cables or components that are not sufficiently fastened) and maintain an overview of system operation as well as for maintenance of the system.

Cable/Wiring and junction boxes:

- Cables have to be clearly colour-coded.
- Reliable cable connections have to be laid out with screw-connectors or crimping-ferrules with appropriate cable end sleeves (no soldered connections in the field, no “twisted connections”).
- All cable connections have to be protected against dust and moisture by being enclosed in junction boxes.
- Interior junction boxes shall have an IP protection code of IP 43 and external junction boxes, IP 55.
- Cables passed through battery cases or junction boxes shall be sealed in accordance with the respective IP protection code.
- Wiring and the insulation have to be protected against damage from strain and twisting.
- Light switches can be used as junction boxes if they are in line with the stated requirements and are designed for that purpose.

Grounding, Earthing:

Grounding takes place from different points, if at all possible forming a star, via conductors with a low resistance to the earth. This reduces the risk of damage in the event of surge-voltage induced by lightning, fixes the maximum potential of the system to the earth and improves radio and TV reception.

In a two-conductor DC system, one of the two conductors, normally the negative conductor, shall be grounded. The conductor connecting the grounded conductor to earth must not contain any fuses or switches. It should have a cross-section of at least 16 mm^2 and should in no case be less than the largest cross-section in the grid.

In a grounded system, no fuses, switches or circuit breakers should be installed anywhere in the grounded conductor. All fuses, switches or circuit breakers should be installed in the non-grounded conductor. Every grounded conductor shall have only one ground connection in order to avoid ground faults and circuit currents.

In a grounded system, no charge regulators with signal processing should be used in the grounded branch. A direct connection must exist between the inlet and outlet of the grounded conductor in the charge regulator. Otherwise, the other conductor shall be grounded or the system should not be grounded at all.

Metal surfaces of cases and frames can also be grounded. This is not absolutely necessary with voltages under 50 V, but may be advisable in lightning-prone areas. In this case, a connection should be created by means of a conductor with a cross-section of at least 16 mm² by the shortest practical route to an earthing electrode. If the electrical system is also grounded, then the same grounder should be used or both grounders should be connected.

Ground electrodes may be provided in the form of an earth spike at least 15 mm in diameter, driven at least 1.2 m into the ground. In rocky locations, an earthing loop made of galvanised band iron can be laid. Metal water pipes with good ground contact can also be used for grounding.

<u>Fuses:</u>

Every current circuit connected to the battery shall be equipped with a melting fuse or a circuit breaker to protect it against short circuit and overload.

In a grounded two-conductor system, the fuses should be installed in the not-grounded path as close as possible to the battery. However, they must not be installed in places where hydrogen escapes, due to the risk of arcing or sparking.

Fuses have to be suitable for direct current and must be designed for the maximum occurring operating voltage; they shall trigger between 125% and 150% of the maximum operating current that occurs.

For circuits with transient effects, e.g. when starting an engine or refrigerator-compressor, the fuses must have a sufficiently slow reaction. The necessary melting fuses or circuit breakers should be included in the charge regulator or in a special fusebox. Every fuse should be clearly marked with its value and the electric circuit it is used for.

DC switches should be used whose current and voltage correspond to those of the circuit that they have to switch. AC switches are to be avoided. If AC switches have to be used, their DC switching performance must be known and sized sufficiently for the application. Values for AC switching behaviour are not relevant for DC applications.
All switches shall be marked indicating the switching positions (ON/OFF, I/O).

It must be possible to disconnect every load from the power sources (PV module and battery) by a switch.

<u>Plugs and socket outlets:</u>

All devices that are not connected permanently to the system can be connected via socket outlets. Sockets have to be designed for DC and have to be safe against reverse polarity. The direct current (DC) and the voltage should be clearly indicated in writing on the device.

Note! *AC plugs and sockets that are commonly available on the market (over the counter) should be avoided in any case. A 12V device with a conventional plug can lead to fatal accidents in the 230V grid.*

Installation of cables:

All cables shall be laid in an orderly manner and sufficiently fixed. They should be laid at a right angle with "aesthetic" considerations in mind. Suspended cables should be avoided.

Underground cables must be laid deep enough (at least 1 m below the surface) and sufficiently marked with stones or bands laid on top. If cables cross a road or street, then an underground cable lay is preferable to overhead cables.

Suspended cables should be mounted so that the lowest point is at least 2.8 m above ground level. They should be secured with suitable brackets and strain reliefs.

Cables through rooftops should be avoided if at all possible. All wiring and insulation material must be made of UV-resistant material and must not be allowed to impair the watertightness of the roof.

In places with easily flammable materials, the cables used should be insulated with extremely flame-retardant material or laid in metal conduit pipes. No cable connections or junction boxes should be installed directly on thatch or similar materials.

Holes that penetrate outside walls shall slope slightly to prevent the ingress of water and must be well sealed.

All outdoor cables have to have a UV-resistant insulation or coating.

Labelling:

All units have to be clearly marked indicating the:
- function
- technical data
- operating instructions
- safety instructions

Special safety instructions shall be provided close to the batteries.

Moreover, the written notices/labels for the individual components have to be taken into account in accordance with Chapter 5.

Inspection and acceptance test:

The entire installation has to be inspected for its functional performance. All units have to comply with the tender documents regarding their technical data.

6.5. Operation and Maintenance

Experience has shown that the reliability of photovoltaic installations depends to a great extent on the quality of handling and maintenance. Therefore, the training of personnel and technicians must be an integral part of the programme as a whole.

Maintenance by the operating personnel:

The responsible personnel should be familiarised with its maintenance tasks both in writing and verbally. All of the tools and equipment that are needed for routine maintenance should be included[9].

All users of the installation/system should be familiarised with the safety requirements.

Operating instructions:

Manuals with technical data and maintenance information that are easy to understand should be included with the system. Special attention should be given to the operation of the batteries, routine maintenance and safety requirements during the maintenance of the batteries.

Every refrigerator should include a set of operating instructions with clear descriptions for users and technicians, with the following contents:
- simple daily, weekly and monthly maintenance
- regular preventive maintenance checks
- diagnostic and repair procedures
- installation procedures

The use of pictures and drawings in comics style to illustrate the technical connections have proved effective, not just for children or illiterate users.

Logbook:

A logbook should be provided to enter all maintenance work and inspections.

Maintenance by technicians:

A maintenance agreement must be part of the order. All work to be carried out and the related anticipated costs should be established verbally and in writing. If a third party is commissioned to perform the maintenance, the client and the user(s) should be informed accordingly.

The name, address and phone number of the maintenance firm should be included in the user manual and posted on signs on the unit.

Inspections should be carried out after three months, six months and at the end of the warranty period.

Warranty:

[9] See list in Annex 7

A one-year warranty shall be provided for the energy yield achievable according to the specifications. Defects during the warranty period that were not caused by improper handling or extreme weather conditions have to be eliminated by the supplier through repair, adjustment or replacement. Deviations of more than 10% from the design layout according to the values indicated in the specifications within the first six months have to be corrected by the supplier.

The minimum warranty period shall be 10 years for solar modules, two (one) years for other components.

Spare parts

Spare parts shall be itemised in a list[10] and shall include fuses as well as spare lamps.

The user has to be informed about the type and price of the batteries and where they could be purchased, as well as about the nearest possible sources to purchase spare lamps and similar items.

No devices may be installed for which spare parts are not sufficiently available or cannot be procured within a reasonable amount of time.

6.6. Income-Generating Services

In the WHO conference working papers of the World Solar Summit, Paris 1993 [19] the possibility of creating sources of income by using surplus energy or expanding the PV system is discussed. Such income could be used to partly cover running costs for repairs and maintenance, but especially to purchase replacement batteries after their service lifetime.

Commercial services of this type could be the charging of batteries, lending out rechargeable storage batteries and portable lamps as well as a supply of TV and video programs. Providing TV and video programs can make a contribution to the health station's popularity as well as to the information and health education of the population.

Experience has shown that the financial gain from such services, but also the installation of electric light in the private rooms of doctors and nurses, as well as the possibility to connect radios and TV sets, contribute to the care and maintenance of the technical facilities and give qualified personnel an added incentive to work in a health station that is away from the developed infrastructure.

The safe supply of energy to the health station, however, must not be jeopardised by such measures. As soon as money is taken in from the charging of automotive batteries, for example, the operator's priorities may soon shift to the detriment of the loads that are important for the health station.

[10] See Annex 7

To charge a completely discharged 60 Ah automotive battery, approximately the daily energy output of four 50 W_{peak} modules (at 5 kWh/m^2d) is required. The experience of several GTZ projects has shown that in general, it is not possible to operate a battery-charging station of this type economically.

Therefore, in any case, the systems should be kept as independent as possible, with precisely set priorities of operation for the essential loads.

7. Glossary

AC	=	Alternating Current
BCU	=	Battery Control Unit
CENELEC	=	Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardization)
CR	=	Charge Rating
DC	=	Direct Current
DFS	=	Deutscher Fachverband Solarenergie (German Expert Association Solar Energy)
DIN	=	Deutsches Institut für Normung (German Institute for Standardisation)
DKE	=	Deutsches Elektrotechnisches Komitee (German Electrotechnical Committee)
DOD	=	Depth of Discharge
EMC	=	Electromagnetic Compatibility
EN	=	Europäische Norm (European Standard)
EPI	=	Extended Program for Immunization
ETSI	=	European Telecommunications Standards Institute
GTZ	=	Deutsche Gesellschaft für Technische Zusammenarbeit (German Development Co-operation)
IEC	=	International Electrotechnical Commission
IEEE	=	Institute of Electrical and Electronics Engineers
IP	=	International Protection Classification
KfW	=	Kreditanstalt für Wiederaufbau
MPP	=	Maximum Power Point
NOC	=	Number of Cycles
PV	=	Photovoltaics
PV-GAP	=	Global Approval Program for Photovoltaics
RHS	=	Rural Health Power Supply System
SHS	=	Solar Home System
SLI	=	Automotive Starter Batteries
STC	=	Standard Test Conditions
UV	=	Ultra-Violet
VDE	=	Verband Deutscher Elektriker (Association of German Electricians)
WB	=	Worldbank
WHO	=	World Health Organization

8. List of References

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9. Annexes:

List of Annexes on “Standards and Specifications for Solar Home Systems and PV Power Supply for Rural Health Stations”

A1 List of E-Mail Addresses on Standards and Specifications for SHS und RHS

A2 Comparative Specification Tables on PV Components

A3 IEC List of Standards for PV Systems (Capsule Descriptions)

A4 PV GAP List of Standards and Standard Proposals

A5 Table of Various Health Station Configurations

A6 Choosing a Refrigerator or Freezer for Vaccine Cooling (WHO/EPI)

A7 Spare Parts and Tools for Rural Health Power Supply Systems (RHS)

List of E-Mail Addresses on Standards and Specifications for Solar Home Systems and PV Supply of Health Stations

Organization / Institution	Country	Contacts	E-Mail Address	Function / Department
International Electrotechnical Commission (IEC)	CH	Dona-Lane Nelson	Nelson_Donna-Lane/CO@IEC.iec.ch	Customer Service,
PV Global Approval Program	CH	Dr. Peter Varadi Richard Kay	pvaradi@aol.com rk@iec.ch	Chairman PV-GAP
Deutsches Institut für Normung (DIN)	D	www.din.de		Internet Investigation
Geosolar, Energie u. Umweltsysteme GmbH	D	Gerhard Nagel		Obmann DKE K373
Siemens Energieübertragung u. -verteilung	D	Peter Kremer	peter.kremer@erls04.siemens.de	German representative IEC-TC 82
TÜV-Rheinland, Inst. f. Umweltschutz u. Energie	D	W. Vaaßen		German representative CENELEC
Joint Research Center, Ispra	I	Dr. H.Ossenbrink	heinz.ossenbrink@jrc.it	Project Leader IEC Standard
National Renewable Energy Laboratory	USA	Richard de Blasio Webmaster	DeBlasiD@tcplink.nrel.gov webmaster@nrel.gov	Chairman IEEE-SCC 21
Institute of Electrical and Electronics Eng.(IEEE)	USA	Danielle Kunitsky Customer Service	dkunitsk@pop.ieee.org customer.service@ieee.org	Customer Service
New ERA	USA	Dr.Charles F. Gay	cgay123@ibm.net	PV-GAP Board Member
Solar Energy Industries Association	USA	A. Jerry Anderson	hhwb72a@prodigy.com	Secretary IEC TC 82
World Bank	USA	Anil Cabraal	acabraal@worldbank.org	Project Leader PV Projects
World Health Organization (WHO)	CH	Michel Zaffran	zaffranm@who.ch	Director General, EPI/GPV
Universidad Politécnica de Madrid,	E	Prof. Miguel A. Egido	egido@ies-def.upm.es	Instituto de Energía Solar
Asian Institute of Technology (AIT)	THA	Herbert Wade	etc57187@ait.ac.th	Consultant Professor for PV
Energy & Development Group	ZA	Glynn Morris	glynn@edg.co.za edg@aztec.co.za	Consultant for PV
Dept. of Mineral and Energy Affairs	ZA	André Otto	andre_o@mepta.pwv.gov.za	Alternative Energy Specialist
GTZ Project Energie Solaire, Senegal	SN	M. Assani Dahouenon	esolgtz@telecomplus.sn	Project Manager(AP)
GTZ-Project SEP-Niger	RN	Dr. Christian Hempel		Project Manager(AP)
GTZ-Project Renewable Energies, Namibia	NAM	Hans-Jörg Müller	ENERGY@IWWN.COM.NA	Project Manager(AP)
GTZ-Project SEP Philippines	RP	Müller-Klinghammer Thomas Scheutzlich	sepwmk@i-manila.com.ph Projekt-Consult@t-online.de	Project Manager(Consultant) Contact in Germany
GTZ-Project Angep. Energienutzung, Brasilien	BR	Rainer Schröer Thomas Scheutzlich	rainer@bis.com.br Projekt-Consult@t-online.de	Project Manager(Consultant) Contact in Germany
GTZ-ProjectPROPER, Bolivia	BOL	Dr.Pablo Rosenthal	proper@albatros.cnb.net	Project Manager(AP)
GTZ-ProjectSEP Marokko	MA	Philippe Simonis	psemaroc@mtds.net.ma	Project Manager(AP)
Universidad de Tarapacá, Arica, Chile	RCH	Reinhold Schmidt	rschmidt@lluta.mecan.uta.ci	CIM Expert
GTZ, OE 415, Energy & Transport	D	Dr. Rolf Posorski	ROLF.POSORSKI@GTZ.DE,	SFP Renewable Energy
Ingenieurbüro f.regenerative Energiequellen	D	Klaus Haars	HAARS@t-online.de,	Consultant
Steca Solarelektronik	D	P. Adelmann	Stecasolar@aol.com,	Manufacturer (Charge regulators, electronics)
Consultant for PV Solar Systems	D	Bernd Fahlenbock	B.Fahlenbock@t-online.de	Consultant

Internet Pages on Standards and Specifications for Solar Home Systems and PV Supply of Health Stations

International Electrotechnical Commission (IEC)	http://www.iec.ch
Global Approval Program for Photovoltaics (PV-GAP)	http://www.pvgap.org
CENELEC (European Committee for Electrotechnical Standardization)	http://www.cenelec.be
Deutsches Institut für Normung (DIN)	http://www.din.de
Verband deutscher Elektrotechniker (VDE)	http://www.vde.de
Institute for Electrical and Electronic Engineering	http://www.ieee.org
Association Francaise de Normalisation (AFNOR)	http://www.afnor.fr
International Solar Energy Society	http://www.ises.org
Eurosolar	http://www.eurosolar.org
FhG Institut für Solare Energiesysteme (ISE)	http://www.ise.fhg.de
TÜV-Rheinland, Umwelt und Energie	http://www.tuev-rheinland.de
Institut für Solare Energietechnik (ISET)	http://www.iset.uni-kassel.de
National Renewable Energy Laboratories (NREL)	http://nrelinfo.nrel.gov/pv
Asean Institute of Technology (AIT)	http://www.ait.ac.th
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)	http://www.gtz.de
Deutsches Zentrum für Entwicklungstechnologien (GATE)	http://www.gate.gtz.de
World Health Organization (WHO)	http://www.who.ch

PV Generator

Criteria	*Madrid*	*Class*	*SPF Morocco*	*Namibia Health*	*Namibia SHS*	*Philippines ´94*	*World Bank*
Qualified According to IEC 1215	yes	C	yes	yes	yes	yes	yes
Nominal Power at STC			min. 50 Wp	min. 50 Wp	50 Wp	50 Wp	50 Wp (-5%)
MPP-Voltage at Tmax	14 -14.5	R			15 V	16 V	
Cell Material			crystal silicon	mono-crystalline	mono/polychryst.	crystalline	crystalline, thin-film
Number of Cells per Module			36		36		36
Embedding of Cells				EVA plastic			
Material of Frames			aluminum	non-corrosive		non-corrosive	allow secure connection
Bypass Diodes				yes			
Terminal Box				waterproof box	moisture resistant	IP 65	sealable, moisture res.
Strain Relief						yes	
Allow Conduit Attachment					yes		yes
Warranty				10 yrs. 15%	10 yrs. 10 %	10 yrs.	10 yrs. (10%)
Identification Marks				yes			

Support Structure

Criteria	*Madrid*	*Class*	*Namibia Health*	*Namibia SHS*	*World Bank*
Structure	robust enough		permanent materials	roof/wall/pole	roof or pole
Corrosion Protection	withstand 10 years	C	non-corros.material or protection	alluminum or galv.	alu or galv. steel
Windload			>120 km/h	> 100 km/h	> 100 km/h
Screws (Bolts), Nuts, etc.)	inox (stainless)	C	modules riveted	galv.or stainless	galv. or stainless
Tilt Angle	latitude +10°+/-3°	R	latitude +10°+/-5°	latitude +0°to15°	fixed, worst month
Minimum Tilt Angle	15°	R			
Seasonal Adjustment of Tilt Angle			accepted if desired		
Orientation			north +/- 5°	north	optimized, adjustable
Tracking	manual 2-3 pos/day	S	passive accepted		
Shading			sunrise/set +/- 90´	minimal shading	
Accessibility			for inspection&cleaning		
Height			min. 3 m above ground	min 2 m above ground	0.2 m roof, 4m ground
Base, Foundation			concrete (0.6x0.6x1m)	concrete 1m deep	concrete 1 m deep

Battery								
Criteria	***Madrid***	***Class***	***SPF Marocco***	***Namibia Health***	***Namibia SHS***	***Philippines ´94***	***NF C 58-510***	***World Bank***
General								
Nominal Voltage			12 V		12 V	12 V	2 V /cell	12 V
Type of Batteries			automotive	flat plate / tubular	sealed, low mainten		open/closed lead ac	lead acid
Parallel Connection of Batteries	not allowed	C		minimised				max. 2 batteries
Material of Casing			Polyprop-ylene	semi-transp. eg PP				
Electrolyte			1st quality				100 days overcharging	for 8 weeks
Condition at Delivery			dry, precharged	cond. charge on site	fully charged			dry- or wet-charged
Recycling						refund on return		
Warranty						1 year		6 months
Capacity								
Discharge Reference Capacity	C20		C 20	C 5 or C 10			C10	C 20
Capacity C20 at 25°C:					90 Ah	> 100 Ah		>70 Ah, 1.4*Wp
- Tubular Batteries	6 Days of Autonomy	C						
- Solar Batteries	8 Days of Autonomy	C						
- Automotive Batteries	12 Days of Autonomy	C						
- Sealed Batteries	12 Days of Autonomy	C			90 Ah			
Cycle Lifetime:	Number of Cycles:						400 @ 40% const.	200 cycl, 75%DOD
- Tubular Batteries	600 @ 75% DOD	R		1500 at 20% DOD			1500 @ 20% var.	
- Solar Batteries	200 @ 75% DOD	R					900 @ 20% var.	

Battery								
Criteria	***Madrid***	***Class***	***SPF Marocco***	***Namibia Health***	***Namibia SHS***	***Philippines ´94***	***NF C 58-510***	***World Bank***
- Automotive Batteries	200 @ 75% DOD	R						
- Sealed Batteries	300 @ 75% DOD	R					900 @ 20% var.	
Minimum Residual Capacity							0,8 * C10	
Self Discharge	10%/month	C			< 10% of rated chrg		25% per 6 months	10% per month
Thickness of Positive Plates	1.7 mm	S						1.7 mm
Thickness of Negative Plates	1.4 mm	S						1.4 mm
Typ Tests								
Nominal Capacity Cn							with I=0,1*Cn	
Rated Capacity Ct							with 1/t*Ct	
Cycling in Constant Avg. State of Charge							yes	
Cycling in Changing Avg. State of Charge							yes	
Oper. with Increasing and Decreasing SOC							yes	
Suitability for Overcharging							400 h @ 2,35V/cell	
Ah-Efficiency between 0% and 75% SOC							yes	
Container Test							temperature resistant	
Cell Sealing Test							30°inclin., 0,1bar	
Vent Plug Efficiency Test							acid- ,explosion- proof	
Drop Resistance Test							10 cm, over all edges	
Location Conditions of Batteries:								

Battery								
Criteria	***Madrid***	***Class***	***SPF Marocco***	***Namibia Health***	***Namibia SHS***	***Philippines ´94***	***NF C 58-510***	***World Bank***
Ventilation	yes	C		yes				vented compartment
Access Restricted	yes	C		yes				no access for children
Close to PV Generator	yes	R						
Close to Loads	yes	R						
Comfortable Place	yes	R						
Accessories:								
Plugs			yes					
Handles for Transport			yes					
Battery Box				durable, acid-resist.	acid resistant			durable, acid proof
Distilled Water				yes		for 1 year		
Rubber Gloves				yes				
Goggles				yes				
Soda Solution				yes				

Charge Regulator												
Criteria	***Madrid***	***Class***	***FHG-ISE´94***	***GTZ '93***	***PSE Tunisia***	***Steca Midi***	***SPF Marocco***	***Namibia Health ´97***	***Namibia SHS ´97***	***TÜV CENELEC ´97***	***Philippines ´94***	***World Bank***
General												
Working Principle									5 different types	PWM, shunt, SOC		const V, PWM, linear
Overcharge Protection										yes		yes
Deep Discharge Protection	should be	C				yes		yes	yes	yes		yes
Operating Temperature Range					-10 - 70° C	-25 - 40°C	-10 - 50°C	-5 to +45°C	+5 to +50°C	+40°C/+55 °C		+10°C to +40°C
Relative Humidity Range								5 - 95%	up to 90%			> 90%
Nominal Voltage										12 V/ 24 V		12 V
Rated Input Current				3,5-7,0 A	8 A	8 A	7 A		125% of PV Isc		> 8 A	> 6 A, 125%of Isc
Rated Output Current				10/20 A	20 A	10 A	10 A				> 16 A	150% of Imax
Expected Lifetime				5-10 years				> 10 yrs.		min 10 years		
Radio Outlet				6/9/12 V		no	4,5 - 9 V					
Warranty											3 years	1 year
Casing												
Material:						hard plastic			corrosion resistant			
- Impact Proof			yes	yes			yes	yes		IEC 68-2-63		
- Acid Proof				yes			yes					
- UV Resistant							yes					
IP Protection Class	> IP 32; IP54	C; R	IP 54	closed	IP 65		IP 54	IP 54	dustproof	IP 41 to IP 54		
Air Ventilation			yes			yes		yes				
Protection Against Insects							yes	yes	yes		yes	

Charge Regulator												
Criteria	***Madrid***	***Class***	***FHG-ISE´94***	***GTZ '93***	***PSE Tunisia***	***Steca Midi***	***SPF Marocco***	***Namibia Health ´97***	***Namibia SHS ´97***	***TÜV CENELEC ´97***	***Philippines ´94***	***World Bank***
Tropical Climate Proof										IEC 68-2-30	yes	
Fixing Material	provided	C	wall mounting				wall mounting	wall mounting (rails)				
Strain Relieve			yes	yes	yes	no		yes			yes	
Transport Damage Protection										Vibrations, Shocks		
Insulation Resistance										500 V DC		
Heat Protection										IEC 335-1 (11)		
Heat and Fire Resistance										IEC 695-2-1/2		
Terminals												
Terminal Sizes:						?						
- PV Generator	min 4mm²	C	min 2.5mm²				4 mm²	16 mm²	4 mm²		4 mm²	
- Battery	min 4mm²	C	min 4 mm²				4 mm²	16 mm²	4 mm²		4 mm²	
- Load	min 4mm²	C	min 4 mm²				4 mm²	4 mm²	2.5 mm²		4 mm²	
- Temperature Sensor												
- Voltage Sensor												
Access to Terminals	easy	C	inside casing	inside casing		from outside		inside, not accessible				
Access to Fuses	easy	C		no		yes						
Robustness of Terminals										IEC 68-2-21		
Protection Measures												
Reverse Polarity Protection PV Generator			yes		yes	yes	yes	yes	yes	yes	yes	yes

Charge Regulator

Criteria	*Madrid*	*Class*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Marocco*	*Namibia Health ´97*	*Namibia SHS ´97*	*TÜV CENELEC ´97*	*Philippines ´94*	*World Bank*
Reverse Polarity Protection Battery	yes	R	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Reverse Leakage-Current Protection	should be	C				Schottky Diode	blocking diode		not necessary			yes, diode or logic
Resist Non-Battery Operation	yes	C	yes			yes	yes	yes	yes	yes		
Protect Load at Non-Battery Operation	limit Vout to 16V	C	yes	yes	yes	yes	yes			max battery voltage		
Short Circuit Protection							yes	yes	yes		yes	yes
Output Overload Protection	yes	C	yes	yes	yes	yes	yes		circuit breakers, no fuses	fuse or electronic	yes	yes (4*Icont)
Operation with Open/Shorted Temp.Sensor										yes		
Operation with Open/Shorted Voltage Sense										yes		
Maximum Charging Current at Tmax	ISC+25%	C				8 A			125% of rated current			125% of Isc
Maximum Discharge Current at Tmax	ILmax+25 %	C				10 A						150% of IL
Overvoltage Protection PV-Input	varistor	R	yes		yes	Varistor	yes	yes	yes			yes
Overvoltage Protection Load Output	varistor	R	yes		yes	no	yes	yes	yes			yes
EMC Tests												
Line Conducted Interference Emission										10kHz to 30 MHz		

Charge Regulator

Criteria	*Madrid*	*Class*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Marocco*	*Namibia Health ´97*	*Namibia SHS ´97*	*TÜV CENELEC ´97*	*Philippines ´94*	*World Bank*
Irradiated Interference Emission										EN 55013		
Resistance to Electromagnetic Fields										optional		
Resistance to Low Energy Pulses										0.5 kV		
Resistance to Electrostatic Discharge										8 kV		
Resistance to Single High-Energy Pulses										0.5 to 1 kV		
Radio Frequency Interference Suppression				yes	yes	?		yes				
Power Consumption/Losses												
Own Power Consumption	10 mA; 5 mA	C; S	max 5 mA	ca. 50mA	< 20 mA	< 3 mA	< 10 mA	< 5 mA	< 2.5 mA	< 10 mA		< 10 mA (LEDs off)
Voltage Drop Battery-Load Terminals	< 0.5 V	C	< 0.5 V					< 5%		max 0.5 V		
Voltage Drop Generator-Battery Terminals	< 0.5 V	R										
Charging Efficiency					>94%		>90%					
Discharge Efficiency					>96%		>95%					
Thresholds												
End of Charge Voltage	2.3 -2.4 V/cell	C	2.3 V/cell	2,4 V/cell	14-15V adjustable	13.7 / 14.1	adjustable		acc. to battery specs.	2.3 V/cell	14,5 V	

Charge Regulator

Criteria	*Madrid*	*Class*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Marocco*	*Namibia Health ´97*	*Namibia SHS ´97*	*TÜV CENELEC ´97*	*Philippines ´94*	*World Bank*
Reconnection Voltage	2.2 - 2.25 V/cell	C	2.25 V/cell			?			acc. to battery specs.	2.25 V/cell		
Low Voltage Cut-off:	V/cell		1.9 V/cell	adjustable	10.5-11.5V adjustable	11.1 V	adjustable			1.90 V/cell	11,5 V	
- Tubular Batteries	1.90	R										
- Solar Batteries	1.95	R										
- Automotive Batteries	2.00	R										11.6 V (+0,1 V)
- Sealed Batteries	2.00	R										
Low Voltage Reconnect (Cut-in)	2,1 V/cell		2.15 V/cell		Uco+1.5 V	12.6 V	Uco+1,5 V			2,10 V/cell		12,6 V (+0,2 V)
Accuracy of Voltage Settings	+/-2%	R				+/-2%						
Cut-off Pre-Warning			1.98 V/cell			no						
Current Compensation of Cut-off Voltage	allowed	R	allowed			no		yes (essential)				
Manual Reset of Deep Discharge Protection	not allowed	C	not allowed			no		no	acc. to battery specs.			
Time Delay for Disconnection	> 1 sec	R	> 1-2 sec			yes		yes (1-2 sec)		yes	>1 s	
Possibility to Adjust Thresholds			no	no		no		no	by technicians only			
Resetable Pre-Disconnection	yes	S				no			yes			
Controlled Gassing												
Controlled Overcharging (except sealed bat.)	allowed	C	yes			yes	yes	yes	no	optional		recommended
Controlled Overcharging Voltage	2.5 V/cell	S	2.5 V/cell			14.5 V						

Charge Regulator

Criteria	*Madrid*	*Class*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Marocco*	*Namibia Health ´97*	*Namibia SHS ´97*	*TÜV CENELEC ´97*	*Philippines ´94*	*World Bank*
Controlled Overcharging Lower Limit	2.1 V/cell	S				?						
Controlled Overcharging after deep discharge	yes	S	yes			yes	yes	yes				
Controlled Overcharging after Time Interval	14 days	S	14 days			no		14 days				
Controlled Overcharging Manual Switch Off	yes	S	yes			yes		yes				
Voltage-/Temperature-Compensation									generally not required	yes		generally not required
Temperature Compensation Overcharge	-4 - -5 mV/°C	R	-4 - -5 mV/°C			-4/-3mV/K/cell		-4 to -5 mV/K/cell	-5 mV/K/cell	-4 to -5 mV/K/cell		
Temperature Compensation Deep-Discharge			no			no		no	no	no		
Voltage Sensing Line								yes, if necessary		optional		
Indications												
Normal Operation	green	C		yes		yes	yes	yes	yes	yes	yes	yes
Battery Fully Charged			yes			yes		yes	yes			
Load Disconnected	red	C	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Pre-Warning of Disconnection	yellow	R	yes	yes		no		yes	visual and audible		yes	yes

Charge Regulator												
Criteria	***Madrid***	***Clas s***	***FHG-ISE´94***	***GTZ '93***	***PSE Tunisia***	***Steca Midi***	***SPF Marocco***	***Namibia Health ´97***	***Namibia SHS ´97***	***TÜV CENELEC ´97***	***Philippi nes ´94***	***World Bank***
Fuse blown				yes	yes	no						
Manual activation of Indication Signals	yes	S				no						
Battery Charge Status			yes			optional LCD			if desired			
LCD Display										yes		optional

Lamp, Ballast											
Criteria	***Madrid***	***Class***	***TÜV-Rhld.***	***PSE Tunesia***	***GTZ '93***	***SPF Marocco***	***Namibia Health***	***Namibia SHS***	***Philippines ´94***	***TÜV CENELEC ´97***	***World Bank***
General											
Nominal Voltage										12 V / 24 V	12 V
Ballast Operating Range	10 - 15 V	C	10 - 16 V	10.5-14.4V	10.5-15 V	10 - 16 V		10 - 15 V	9 - 18 V	10 - 16 V, 20 -32 V	10.2 - 15 V
Maximum Input Voltage										26 V, 52 V	
Lamp Ignition	safe and regulated	C	reliable			preheating				no great delay,flickering	
Electrode Preheating	yes	S			> 0.5 sec	yes					
Operating Temperature Range			10°-55° C	-10°-50° C		-10°-50° C		5°- 50° C			
Operating Frequency				20-40 kHz	20-40 kHz	20-40 kHz		min 20 kHz			min. 20 kHz
Minimum Lifetime of Ballast			>10000 h	>15000 Cycles	>50000 Cycles						
Minimum Lifetime of Lamp			5000 h	>6000 h			long service life	> 8000 h			
Procedure for Lifetime Test			EN 60081								
Warranty									1 year		
Power, Electrical Characteristics											
Luminous Yield of Ballast + Lamp	min 35 lum/W	R						70 lum/W	50 lum/W		200 lum,<35 lum/W
Input Power				20-22 W	< 22 W						
Output Power				18-20 W	< 18 W	70-100% of lamp rating					
Power Losses					< 5 W				<10 %		
Efficiency					> 75 %	> 75%	high				

Lamp, Ballast											
Criteria	***Madrid***	***Class***	***TÜV-Rhld.***	***PSE Tunesia***	***GTZ '93***	***SPF Marocco***	***Namibia Health***	***Namibia SHS***	***Philippines ´94***	***TÜV CENELEC ´97***	***World Bank***
Waveform Symmetry	10% at 11 - 12.5V	R						10% at 11 - 12.5V			10% at 11 - 12.5V
Crest Factor	< 2 at 11 - 12.5 V	R			< 1,7	< 1,7		< 2			< 2
Protection at Unnormal Operation											
Removed Lamp	yes	C	yes	yes	yes	yes	yes	yes	yes	yes	yes
Not Ignited Lamp	yes	C	yes	yes	yes	yes	yes	yes		yes	yes
Reversed Polarity of Supply Voltage	yes	C	yes	yes	yes	yes	yes	yes	yes	yes	yes
Shortcircuit of Output	yes	C	yes	yes		yes	yes		yes		
Overvoltage Protection			2.2*UNom				yes				
Undervoltage Protection								yes			
Casing, Mechanical Characteristics											
IP Protection Code										IP 54	
Fixing Material	yes	C									
Access of Fuses and Terminals	easy	C									
Lenses and Grids Removable	easy	C						easily			easily removable
Standard Package for Transport			drop 1m					yes			
Protection: Environmental Conditions											
Maximum Rel. Humidity for Operation			93%					90%			
Protection Against Humidity						yes		yes	yes	yes	yes

Lamp, Ballast

Criteria	*Madrid*	*Class*	*TÜV-Rhld.*	*PSE Tunesia*	*GTZ '93*	*SPF Marocco*	*Namibia Health*	*Namibia SHS*	*Philippines ´94*	*TÜV CENELEC ´97*	*World Bank*
Protection Against Corrosion											yes
Protection Against Unintended Touch			yes								
Protection Against Insects						yes		yes			yes
Protection of Electronics								encapsulated, coated			
Vibration Tested										acc.to IEC 68-2-6	
Shock Tested										acc. to IEC 68-2-27	
Damp Heat Tested										55°C acc. IEC 68-2-30	
Electromagnetic Compatibility											
Radio Frequency Interference Suppression	yes	C	yes	yes			yes	minimal interf.(AM)			
Line Conducted Interference Emission										acc. EN 55015, class B	
Irradiated Interference Emission										acc. EN 55013, 55022	
Resistance to Electromagnetic Fields										acc. IEC 1000-4-3	
Resistance to Low Energy Pulses										acc. IEC 1000-4-4	
Resistance to Electrostatic Discharge										optional IEC 1000-4-2	

Lamp, Ballast											
Criteria	***Madrid***	***Class***	***TÜV-Rhld.***	***PSE Tunesia***	***GTZ '93***	***SPF Marocco***	***Namibia Health***	***Namibia SHS***	***Philippines ´94***	***TÜV CENELEC ´97***	***World Bank***
Resistance to Single High-Energy Pulses										acc. IEC 1000-4-5	
Safety Tests											
Insulation Resistance										acc. IEC 598, IEC 924	
Dielectric Strength										acc. IEC 598, IEC 924	
Terminals										acc. IEC 598	
Safety Earth Terminal										acc. IEC 924	
Creepage and Clearance Distances										acc. IEC 598, IEC 924	
Accidental Contact with Active Parts										acc. IEC 598, IEC 924	
Fault Conditions										acc. IEC 924	
Screws, Conductive Components										acc. IEC 598	
Heat and Fire Resistance										acc. IEC 695-2-1and-2	
Voltage Impulses										acc. IEC 924	

Wiring, Installation

Criteria	*Madrid*	*Class*	*Namibia Health*	*Namibia SHS*	*Philippines ´94*	*World Bank*
General						
Cable Types			stranded recommended	stranded & flexible	stranded twin wire	stranded, flexible copper
External Cable Specifications	for outdoor exposure	C	fully UV-resistant	sunlight resistant	humidity, UV, ozon	
Internal Cable Specifications			acc. to SABS 0142			
Cable Identification	color coded or labelled	R	color-coded or marked	color coded or labled		color coded or labelled
Warranty			1 year		3 years	6 months
Cable Losses				total < 3%		
Cable Losses: PV-Generator - Battery	< 3%	R				< 5%
Cable Losses: Battery - Charge Regulator	< 1%	R				< 5%
Cable Losses: Battery - Load	< 5%	R				< 5%
Minimum Cable Cross-Sections	2.5 mm²	C		2.5 mm²		2.5; 2.5; 1.5 mm²
Cable Ends	appropriate fitting	C		no soldering		
Cable Lays						
Cable Lays	vertical and horizontal	R	aesthetic appearance			in conduits or firmly fastened
Cable Fixing	every 25 cm	C	at suitable intervals	conduit or firmly fastened		firmly fastened to building
Children Protection	keep out of reach	C				
Wiring Through Roofing			waterproof, UV-resistant	waterproof seal		waterproof sealed
Wiring Through Walls			slightly sloped	with bushings		with bushings
Wiring Through Flammable Materials			flame retard./conduits	in metal conduit		metal conduit
Underground Cables			1m deep, indicated			
Suspended Cables			2.8m above ground			
Cable Connections			junc.box, block connector	in junction boxes		connectors, no soldering

Wiring, Installation

Criteria	*Madrid*	*Class*	*Namibia Health*	*Namibia SHS*	*Philippines ´94*	*World Bank*
Internal Junction Boxes			insulated, IP 43			yes
External Junction Boxes			insulated IP 55			yes
Entries to Enclosures			sealing, strain relief			
Protection, Fuses						
Fuse Types	widely available	R	rated for DC, delayed			
Fuse Protection at Maximum Current	80% of rated capacity	C	125 - 150% of Imax			
Fuse Location	positive line	R	all positive lines			
Switches, Outlets, Plugs, etc.						
Switches Specifications	DC or >10 A AC	R	DC characteristics	only DC switches		
Outlets Reverse Polarity Protection	yes	C	yes, only DC outlets			yes
Cable Terminals and Plugs from Vehicles	can be used	S				
PV-Generator Disconnect	manual switch	R	yes	yes		
Battery Disconnect			yes			
Load Switches			all equipment, 1.2m above floor			
Grounding, Earthing						
Grounding of Electrical Circuits			negative grounded			
Min. Cross Section of Ground Wire			6 mm²			
Grounded Conductor			no fuses, switches,etc.			
Grounding of Casings			optional < 50V DC			
Ground Electrodes			15mm diam., 1.2 m deep			

Documentation

Criteria	*Madrid*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Morocco*	*Namibia Health*	*Namibia SHS*	*TÜV/CENELEC*	*Philippines ´94*
PV Generator										
Nominal Power at STC		yes								
Open Circuit Voltage		yes								
Short Circuit Current		yes								
NOCT		yes								
Temperture Coefficients		yes								
IV-Curves at Different Temperatures		yes								
Mechanical Characteristics		yes								
Description of Junction Box		yes								
Battery										
Percentage of Antimon		yes								
Thickness of Plates		yes								
Discharge Curves		yes								
Charge curves										
Capacity										
Specific Acid Gravity										
Cycle Life vs. DOD										
Electrode Type										
Special Requirements for PV-Application										
Safety Requirments										
Maintenance Requirements										
Replacement Requirements										
Charge Regulator										
Technical Data				yes	yes		yes		yes	
Wiring Diagram				yes	yes	on casing	yes			
Principle of Charge Regulation					yes	yes			yes	
Threshold Settings									yes	
Installation instructions						yes	yes		yes	yes
Operating instructions						yes	yes		yes	yes
Troubleshooting instructions									yes	

Documentation

Criteria	*Madrid*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Morocco*	*Namibia Health*	*Namibia SHS*	*TÜV/CENELEC*	*Philippines ´94*
Safety warnings									yes	
Information on spare parts									yes	
Warranty									yes	
Range of operating temperature									yes	
Range of storage temperature									yes	
Maximum relative humidity									yes	
Case dimensions									yes	
Weight									yes	
Case properties (material)									yes	
Fasteners									yes	
Degree of protection (IP Code)									yes	
Connecting terminals									yes	
Cables (inlet, strain relief, cross-sections)									yes	
Nominal voltage (V)									yes	
Maximum module current (A)									yes	
Maximum load current (A)									yes	
Type of regulator (series, shunt)									yes	
Working principle (PWM, SOC algorithm, etc.)									yes	
Thresholds (V)									yes	
Temperature compensation (mV/°C/cell)									yes	
Service life									yes	
Own consumption									yes	
Losses									yes	
Overload protection									yes	
Reverse-connect protection									yes	
Different Operation Voltages									yes	
Warning before load disconnect									yes	

Documentation										
Criteria	***Madrid***	***FHG-ISE´94***	***GTZ '93***	***PSE Tunisia***	***Steca Midi***	***SPF Morocco***	***Namibia Health***	***Namibia SHS***	***TÜV/CENELEC***	***Philippines ´94***
Delayed load disconnection									yes	
Displays (LEDs, LCD-display, accuracy)									yes	
Additional functions (MPP tracking, etc)									yes	
Lamp, Ballast										
Technical Data		complete	yes		yes				yes	
Wiring Diagram			yes						yes	
Operation Instructions									yes	
Installation Instructions									yes	
Safety Instructions									yes	
Disposal/Recycling Instructions									yes	
Warranty Conditions									yes	
Accessories									yes	

Labels

Criteria	***Madrid***	***FHG-ISE´94***	***GTZ '93***	***PSE Tunisia***	***Steca Midi***	***SPF Morocco***	***Namibia Health***	***Namibia SHS***	***TÜV Cenelec***	***World Bank***
PV Generator										
Manufacturer										yes
Model & Serial No										yes
Rated Power at STC										yes
MPP Current										yes
MPP Voltage										yes
Short Circuit Current										yes
Open Circuit Voltage										yes
Battery										
Nominal Capacity		yes								
Date of Production		yes								
Min./Max. Levels of Electrolyte		yes								
Polarity of Terminals		yes								
Charge Regulator										
Original Signs, Trade Mark									yes	
Model Number, Designation									yes	yes
Serial Number									yes	yes
Nominal Voltage [V]									yes	yes
Maximum PV-Current [A]									yes	yes
Maximum Load Current [A]									yes	yes
Polarity of Terminals									yes	
Displays									yes	yes
Characteristic Fuse Rating									yes	
Lamp, Ballast										
Technical Data		yes			polarity					

Labels

Criteria	*Madrid*	*FHG-ISE´94*	*GTZ '93*	*PSE Tunisia*	*Steca Midi*	*SPF Morocco*	*Namibia Health*	*Namibia SHS*	*TÜV Cenelec*	*World Bank*
Switch							ON/OFF			
Original Signs, Trade Mark										yes
Model Number, Designation										yes
Serial Number										yes
Nominal Voltage [V]										yes
Rated Current [A]										yes

IEC List and Brief Description of Standards for Photovoltaic Systems

PV Modules

IEC 61215 (1993-04)
Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
Lays down requirements for the design qualification and type approval of terrestrial photovoltaic modules suitable for long-term operation in general open-air climates, as defined in IEC 721-2-1. Applies only to crystalline silicon types.
77 pp. CHF 121

IEC 61646 (1996-11)
Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval
Lays down requirements for the design qualification and type approval of terrestrial thin-film photovoltaic modules suitable for long-term operation in moderate open-air climates.
85 pp. CHF 133

IEC 60891 (1987-04)
Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
Gives procedures that should be followed for temperature and irradiance corrections to the measured I-V characteristics of only crystalline silicon photovoltaic devices.
14 pp. CHF 32

IEC 60904-1 (1987-12)
Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics
Describes measurement procedures for current-voltage characteristics of crystalline silicon photovoltaic devices in natural or simulated sunlight. These procedures are applicable to a single solar cell, a sub-assembly of solar cells or a flat module.
10 pp. CHF 27

IEC 60904-2 (1989-05)
Photovoltaic devices. Part 2: Requirements for reference solar cells
16 pp. CHF 36

IEC 60904-3 (1989-02)
Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
Applies to the following crystalline silicon photovoltaic devices for terrestrial applications: single solar cells with or without protective cover, sub-assemblies at solar cells and flat modules.
25 pp. CHF 49

IEC 60904-5 (1993-10)
Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method
Describes the preferred method for determining the equivalent cell temperature of PV devices for the purposes of comparing their thermal characteristics, determining NOCT (nominal operating cell temperature) and translating measured I-V characteristics.
11 pp. CHF 29

IEC 60904-6 (1994-09)
Photovoltaic devices - Part 6: Requirements for reference solar modules
Gives requirements for the selection, packaging, calibration, marking and care of reference solar modules. It is intended to supplement IEC 904-2.
13 pp. CHF 32

IEC 60904-7 (1995-09)

Photovoltaic devices - Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device
Describes the procedure for determining the error introduced in the testing of a photovoltaic device caused by the interaction of the mismatch between the spectral responses of the test specimen and the reference device, and the mismatch between the test spectrum and the reference spectrum.
5 pp. *CHF 23*

IEC 60904-8 (1995-09)
Photovoltaic devices - Part 8: Guidance for the measurement of spectral response of a photovoltaic (PV) device
Gives guidance for the measurement of the relative spectral response of both linear and non-linear photovoltaic devices.
9 pp. *CHF 27*

IEC 60904-9 (1995-09)
Photovoltaic devices - Part 9: Solar simulator performance requirements
Gives requirements for solar simulators used for indoor testing of terrestrial flat plate (non-concentrating) photovoltaic devices in c onjunction with a spectrally matched reference device.
6 pp. *CHF 23.*

IEC 61701 (1995-03)
Salt mist corrosion testing of photovoltaic (PV) modules
Determines the resistance of the module to corrosion from salt mist.
7 pp. *CHF 26*

IEC 61721 (1995-03)
Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test)
Determines the susceptibility of a module to accidental impact damage.
7 pp. *CHF 26*

IEC 61829 (1995-03)
Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics
Describes procedures for on-site measurement of crystalline silicon photovoltaic (PV) array characteristics and for extrapolating these data to Standard Test Conditions (STC) or other selected temperatures and irradiance values.
19 pp. *CHF 43*

<u>Batteries</u>

IEC 60896-1 (1987-01)
Stationary lead-acid batteries - General requirements and methods of test. Part 1: Vented types
Applies to lead-acid cells and batteries which are designed for service in a fixed location (i.e. not habitually to be moved from place to place) and which are permanently connected to the load and to the DC power supply.
21 pp. *CHF 46*

IEC 60896-2 (1995-11)
Stationary lead-acid batteries - General requirements and test methods - Part 2: Valve regulated types
Applies to valve-regulated stationary lead-acid cells and batteries for service in a fixed location (i.e. not habitually to be moved from place to place) and permanently connected to a load and to a DC power supply.
51 pp. *CHF 96*

IEC 60130-3 (1965-01)
Connectors for frequencies below 3 MHz. Part 3: Battery connectors

Gives dimensions and gauges for plug-in pin connectors and snap-fastener connectors for dry batteries. Specifies requirements and a schedule for type tests.
25 pp. CHF 49

Charge Regulators

IEC 60335-1 (1991-06)
Safety of household and similar electrical appliances - Part 1: General requirements (Third edition)
This third edition of IEC 335-1 will replace the second edition (1976) and its six amendments as soon as the different Part 2s are aligned with this edition. A reprint of this third edition, incorporating some editorial changes, has been published in 1993.
239 pp. CHF 225

IEC 60335-2-29 (1994-11)
Safety of household and similar electrical appliances - Part 2: Particular requirements for battery chargers
This standard deals with the safety of battery chargers for household and similar use having an output at safety extra-low voltage, their rated voltage being not more than 250 V. Is to be used in conjunction with IEC 335-1 (third edition).
29 pp. CHF 55

CISPR 11 (1997-12)
Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics - Limits and methods of measurement
Electromagnetic radiation disturbance limits are developed for the purpose of protecting radiocommunication services and signal levels, as well as for taking frequency bands, signal levels, separation distances between the interfering and interfered equipment, desired signal ratio, etc. into account.
69 pp. CHF 108

CISPR 22 (1997-11)
Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
The intention of this standard is to establish uniform requirements for the radio disturbance level of the equipment contained in the scope, to fix limits of disturbance, to describe methods of measurement and to standardize operating conditions and interpretation of results.
107 pp. CHF 153

IEC 61000-4-2 (1995-01)
Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 2: Electrostatic discharge immunity test. Basic EMC Publication
This publication is based on IEC 801-2 (second edition: 1991). It relates to the immunity requirements and test methods for electrical and electronic equipment subjected to static electricity discharges, from operators directly, and to adjacent objects. It additionally defines ranges of test levels which relate to different environmental and installation conditions and establishes test procedures. The object of this standard is to establish a common and reproducible basis for evaluating the performance of electrical and electronic equipment when subjected to electrostatic discharges. In additijon, it includes electrostatic discharges which may occur from personnel to objects near vital equipment.
58 pp. CHF 96

IEC 61000-4-3 (1995-03)
Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 3: Radiated, radio-frequency, electromagnetic field immunity test
Applies to the immunity of electrical and electronic equipment to radiated electromagnetic energy. Establishes test levels and the required test procedures. Establishes a common reference for evaluating the performance of electrical and electronic equipment when subjected to radio-frequency electromagnetic fields.
55 pp. *CHF 96*

IEC 61000-4-4 (1995-01)
Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 4: Electrical fast transient/burst immunity test. Basic EMC Publication
Relates to the immunity requirements and test methods for electrical and electronic equipment to repetitive electrical fast transients. Additionally defines ranges of test levels and establishes test procedures. The object of this standard is to establish a common and reproducible basis for evaluating the performance of electrical and electronic equipment when subjected to repetitive fast transients (bursts), on supply, signal and control ports. The test is intended to demonstrate the immunity of electrical and electronic equipment when subjected to types of transient disturbances such as those originating from switching transients (interruption of inductive loads, relay contact bounce, etc.). The standard defines:
- test voltage waveform;
- range of test levels;
- test equipment;
- test set-up;
- test procedure.

59 pp. *CHF 96*

IEC 61000-4-5 (1995-03)
Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 5: Surge immunity test
Relates to the immunity requirements, test methods, and range of recommended test levels for equipment to unidirectional surges caused by overvoltages from switching and lightning transients. Several test levels are defined which relate to different environment and installation conditions. These requirements are developed for and are applicable to electrical and electronic equipment. Establishes a common reference for evaluating the performance of equipment when subjected to high-energy disturbances on the power and inter-connection lines.
77 pp. *CHF 121*

IEC 60068-2-6 (1995-03)
Environmental testing - Part 2: Tests - Test Fc: Vibration (sinusoidal)
Gives a method of test which provides a standard procedure to determine the ability of components, equipment and other articles to withstand specified severities of sinusoidal vibration. Has the status of a basic safety publication in accordance with IEC Guide 104.
87 pp. *CHF 133*

IEC 60068-2-21 (1983-01)
Environmental testing. Part 2: Tests. Test U: Robustness of terminations and integral mounting devices
Applies to all electrical and electronic components whose terminations or integral mounting devices are liable to be subjected to stress during normal assembly or handling.
36 pp. *CHF 75*

IEC 60068-2-27 (1987-06)
Environmental testing. Part 2: Tests. Test Ea and guidance: Shock
Applies to components, equipment and other electrotechnical products which, during transportation or in use, may be subjected to relatively infrequent non-repetitive shocks. Provides a procedure for determining the ability of a specimen to withstand specified severities of shock. Has the status of a basic safety publication in accordance with IEC Guide 104.
49 pp. *CHF 92*

IEC 60068-2-30 (1980-01)

Environmental testing - Part 2: Tests. Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)

Determines the suitability of components, equipment and other articles for use and/or storage under conditions of high humidity when combined with cyclic temperature changes.

19 pp. CHF 43

IEC 60529 (1989-11)

Degrees of protection provided by enclosures (IP Code)

Applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV. Has the status of a basic safety publication in accordance with IEC Guide 104.

73 pp. CHF 121

IEC 60695-2-1/0 (1994-03)

Fire hazard testing - Part 2: Test methods - Section 1/sheet 0: Glow-wire test methods - General

Specifies a glow-wire test to simulate the effect of thermal stresses which may be produced by heat sources such as glowing elements or overloaded resistors, for short periods, in order to assess the fire hazard by a simulation technique. The test described in this standard is applicable, in the first place, to electrotechnical equipment, its sub-assemblies and components, but may also be applied to solid electrical insulating materials or other solid combustible materials. Replaces IEC 695-2-1. Has the status of a basic safety publication in accordance with IEC Guide 104.

23 pp. CHF 46

IEC 60695-2-1/1 (1994-03)

Fire hazard testing - Part 2: Test methods - Section 1/sheet 1: Glow-wire end-product test and guidance

Specifies the details of the glow-wire test when applied to end products for fire hazard testing. Replaces IEC 695-2-1. Has the status of a basic safety publication in accordance with IEC Guide 104.

17 pp. CHF 38

IEC 60695-2-1/2 (1994-03)

Fire hazard testing - Part 2: Test methods - Section 1/sheet 2: Glow-wire flammability test on materials

Specifies the details of the glow-wire test when applied to specimens of solid electrical insulating materials or other solid combustible materials for flammability testing. Replaces IEC 695-2-1. Has the status of a basic safety publication in accordance with IEC Guide 104.

15 pp. CHF 36

IEC 60695-2-1/3 (1994-03)

Fire hazard testing - Part 2: Test methods - Section 1/sheet 3: Glow-wire ignitability test on materials

Specifies the details of the glow-wire test when applied to specimens of solid electrical insulating materials or other solid combustible materials for ignitability testing. Replaces partially IEC 829. Has the status of a basic safety publication in accordance with IEC Guide 104.

15 pp. CHF 36

IEC 60695-2-2 (1991-05)

Fire hazard testing - Part 2: Test methods - Section 2: Needle-flame test

Specifies a needle-flame test to stimulate the effect of small flames which may result from fault conditions within the equipment, in order to assess by a simulation technique the fire hazard. This edition supersedes the first edition of IEC 695-2-2 (1980). Has the status of a basic safety publication in accordance with IEC Guide 104.

18 pp. CHF 38

IEC 60439-1 (1992-12)

Low-voltage switchgear and controlgear assemblies - Part 1: Type-tested and partially type-tested assemblies
Applies to low-voltage switchgear and controlgear assemblies (type-tested assemblies (TTA) and partially type-tested assemblies (PTTA)), the rated voltage of which does not exceed 1000 V AC at frequencies not exceeding 1 000 Hz, or 1 500 V DC.
194 pp. *CHF 218*

IEC 60439-2 (1987-11)
Low-voltage switchgear and controlgear assemblies. Part 2: Particular requirements for busbar trunking systems (busways)
Applies to busbar trunking systems intended to supply luminaires through tap-off units but does not apply to supply track systems in accordance with IEC Publication 570.
29 pp. *CHF 55*

IEC 60439-3 (1990-12)
Low-voltage switchgear and controlgear assemblies. Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use - Distribution boards
This standard gives supplementary requirements for enclosed distribution boards (DBU), which are stationary, type-tested assemblies (TTA) for indoor use, containing protective devices and intended for use either in domestic (household) applications or in other places where unskilled persons have access for their use.
31 pp. *CHF 62*

IEC 60068-1 (1988-06)
Environmental testing. Part 1: General and guidance
Enumerates a series of environmental tests and appropriate severities, and prescribes various atmospheric conditions for measurements for the ability of specimens to perform under normal conditions of transportation, storage and operational use.
53 pp. *CHF 96*

IEC 60065 (1985-01)
Safety requirements for mains operated electronic and related apparatus for household and similar general use
Applies to receiving apparatus for sound or vision, amplifiers, load and source transducers, motor-driven apparatus (radio-grammophones, tape recorders and sound-film projectors, etc.) which are to be connected to the mains, directly or indirectly, and which are intended for domestic and similar indoor use. Gives a safety and classification terminology based on IEC 536. Specifies requirements for marking, insulation, components, electrical connections and fixings, protection against ionizing radiation, resistance to heating, mechanical strength and stability, etc., as well as a requirement for splash-proof mains operated electronic equipment. Does not apply to apparatus designed for rated supply voltage exceeding 433 V (r.m.s.) between phases in the case of three-phase supply and 250 V (r.m.s.) in all other cases. Has the status of a group safety publication in accordance with IEC Guide 104.
137 pp. CHF 180.

<u>Lamps</u>

IEC 60924 (1990-07)
D.C. supplied electronic ballasts for tubular fluorescent lamps - General and safety requirements
This standard specifies general and safety requirements for electronic ballasts for use on DC supplies, having rated voltages not exceeding 250 V, associated with fluorescent lamps complying with IEC 81. This standard also specifies electronic ballasts for lamps which are not yet standardized. It does not specify independent ballasts. Supersedes IEC 458.
92 pp. *CHF 133*

IEC 60925 (1989-06)
D.C. supplied electronic ballasts for tubular fluorescent lamps - Performance requirements

Specifies general performance requirements for electronic ballasts for use on DC supplies having rated voltages not exceeding 250 V associated with tubular fluorescent lamps. Specifies also particular performance requirements for d.c. electronic ballasts for public transport lighting, general lighting and aircraft lighting. Supersedes IEC 458.
36 pp. *CHF 75*

IEC 60598-1 (1996-12)
Luminaires - Part 1: General requirements and tests
Covers general requirements for the classification and marking of luminaires and for their mechanical and electrical construction, together with related tests. Is applicable to luminaires for use with tungsten filaments, tubular fluorescent and other discharge lamps on supply voltages not exceeding 1 000 V. This publication supersedes IEC 162 (1972).
317 pp. *CHF 238*

IEC 60400 (1996-06)
Lampholders for tubular fluorescent lamps and starterholders
States the technical and dimensional requirements for lampholders for tubular fluorescent lamps and for starter-holders, and the methods of test to be used in determining the safety and the fit of the lamps in the lampholders and the starters in the starterholders.
111 pp. *CHF 153*

IEC 60061-1 (1969-01)
Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 1: Lamp caps
Consolidated edition incorporating the sheets of the third edition (1969) plus supplements A, B, C, D, E, F, G, H, J, K, L, M, N, P, Q R, S, T and U valid on 1996-12-31.
242 pp. *CHF 231*

IEC 60061-2 (1969-01)
Lamp caps and holders together with gauges for the control of interchangeability andsafety. Part 2: Lampholders
Consolidated edition incorporating the sheets of the third edition (1969), plus supplements A, B, C, D, E, F, G, H, J, K, L, M, N, P, Q, and R valid on 1996-12-31.
191 pp. *CHF 218*

IEC 60061-3 (1969-01)
Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 3: Gauges
Consolidated edition incorporating the sheets of the third edition (1969), plus supplements A, B, C, D, E, F, G, H, J, K, L, M, N, P, Q, R, S and T valid on 1996-12-31.
534 pp. *CHF 265*

IEC 60061-4 (1990-02)
Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 4: Guidelines and general information
Consolidated edition incorporating the sheets of the first edition (1990) plus supplements A, B, C and D valid on 1996-12-31.
34 pp. *CHF 69*

IEC 60081 (1997-12)
Double-capped fluorescent lamps - Performance specifications
Gives technical requirements for tubular fluorescent lamps with preheated cathodes for general lighting service, operated with or without a starter from a.c. mains, also describes tests for the lamps with non-preheated cathodes operated without the use of a starter. Gives testing methods to be used for checking quality and interchangeability for type testing, for individual lamp batches or for a manufacturer's entire production. Consists of a series of standard data sheets, each giving the characteristics of a specific lamp type. Introduces new co-ordinates for the standard colours together with a new standard 'white' colour.
316 pp. *CHF 238*

IEC 60901 (1996-03)
Single-capped fluorescent lamps - Performance specifications
Specifies the performance requirements for single-capped fluorescent lamps for general lighting service. The requirements of this standard relate only to type testing. Conditions of compliance, including methods of statistical assessment, are under consideration.
367 pp. *CHF 250*

System, Installation

IEC 61194 (1992-12)
Characteristic parameters of stand-alone photovoltaic (PV) systems
Defines the major electrical, mechanical and environmental parameters for the description and performance analysis of stand-alone photovoltaic systems.
27 pp. *CHF 55*

IEC 61277 (1995-03)
Terrestrial photovoltaic (PV) power generating systems - General and guide
Gives an overview of terrestrial PV power generating systems and the functional elements of such systems.
41 pp. *CHF 84*

EC 61173 (1992-09)
Overvoltage protection for photovoltaic (PV) power generating systems - Guide
Gives guidance on the protection of overvoltage issues for both stand-alone and grid-connected photovoltaic power generating systems.
19 pp. *CHF 43*

IEC 61204 (1993-02)
Low-voltage power supply devices, d.c. output - Performance characteristics and safety requirements
Describes a method of specifying requirements for low-voltage power supply devices (including switching types) providing d.c. output(s) up to 200 V d.c. at a power level up to 30 kW, operating from AC or DC source voltages of up to 600 V. The devices are for use within class I equipment or for free-standing operation when used with adequate electrical and mechanical protection, except for medical applications and toys, where special considerations apply.
55 pp *CHF 96*

IEC 60998-1 (1990-05)
Connecting devices for low voltage circuits for household and similar purposes. Part 1: General requirements
Applies to connecting devices as separate entities for the connection of two or more electrical copper conductors, rigid or flexible, having a cross-sectional area of 0.5 mm2 up to and including 35 mm2 with a rated voltage not exceeding 1 000 V AC up to and including 1 000 Hz and 1 500 V DC where electrical energy is used for household and similar purposes. This publication supersedes IEC 685-1. Has the status of a group safety publication in accordance with IEC Guide 104.
50 pp. *CHF 92*

IEC 60364-1 (1992-11)
Electrical installations of buildings - Part 1: Scope, object and fundamental principles
Applies to electrical installations such as those of: (a) residential premises; (b) commercial premises; (c) public premises; (d) industrial premises; (e) agricultural and horticultural premises;

(f) prefabricated buildings; (g) caravans, caravan sites and similar sites; (h) construction sites, exhibitions, fairs and other temporary installations; (i) marinas and pleasure craft. Covers: (a) circuits supplied at nominal voltages up to and including 1000 V AC or 1500 V DC; (b) circuits, other than the internal wiring of apparatus, operating at voltages exceeding 1000 V and derived from an installation having a voltage not exceeding 1 000 V AC, e.g. discharge lighting, electrostatic precipitators; (c) any wiring not specifically covered by the standards for appliances d)all consumers' installations external to buildings; e)fixed wiring for telecommunication, signalling, control and the like (excluding internal wiring of apparatus); (f) the extension or alteration of the installation and also parts of the existing installation affected by the extension or alteration. Does not apply to: (a) electric traction equipment; (b) electrical equipment of motor vehicles; (c) electrical installations on board ships; (d) electrical installations in aircraft; (e) public street-lighting installations; (f) installations in mines; (g) radio interference suppression equipment, except in so far as it affects the installation's safety; (h) electric fences; (i) lightning protection of buildings Note: - Atmospheric phenomena are, however, covered, in so far as effects on the electrical installations are concerned (e.g. with respect to selection of lightning arresters). Contains the rules for the design and erection of electrical installations so as to ensure safety and proper functioning for the use intended. Note: For identification of insulated and bare conductors by colours, see IEC 446.
31 pp. CHF 62

IEC 60998-2-5 (1996-01)
Connecting devices for low-voltage circuits for household and similar purposes - Part 2-5: Particular requirements for connecting boxes (junction and/or tapping) for terminals or connecting devices
has the status of a group safety publication in accordance with IEC guide 104. Applies to connecting boxes (junction and/or tapping): with fixed (integrated or incorporated) terminals or connecting devices; intended to be used with fixed terminals or connecting devices; intended to be used with floating terminals or connecting devices.
75 pp. CHF 121

IEC 61725 (1997-05)
Analytical expression for daily solar profiles
Provides a normative equation for analytically deriving a set of data points or a curve of irradiance versus time of day for a synthetic solar day.
13 pp. CHF 32

<u>Inverter, Others</u>

IEC 60146-1-1 (1991-04)
General requirements and line commutated converters - Part 1-1: Specifications of basic requirements
Part 1-1: Specifications of basic requirements. Specifies the requirements for the performance of all electronic power converters and electronic power switches using controllable and/or non-controllable electronic valves. Specifies the requirements applicable to line commutated converters for conversion of AC power to DC power or vice versa including tests and service conditions which influence the basis of rating.
135 pp. CHF 180

IEC 61727 (1995-06)
Photovoltaic (PV) systems - Characteristics of the utility interface
Addresses the interface requirements between the PV system and the utility, and provides technical recommendations.
25 pp. CHF 49

IEC 61702 (1995-03)
Rating of direct coupled photovoltaic (PV) pumping systems
Defines predicted short-term characteristics (instantaneous and for a typical daily period) of direct coupled photovoltaic (PV) water pumping systems.
9 pp. CHF 27

Appendices of PV-GAP "Quality Management in Photovoltaics"

Appendix II: Publications Issued by IEC TC 82

IEC 60891 Ed. 1.0 (1987-04)
Procedures for temperature and irradiance corrections to measured I-V Characteristics of crystalline silicon photovoltaic devices

IEC 60891 Amd.l Ed. 1.0 (1992-06)
Amendment No.1

IEC 60904-I Ed. 1.0 (1987-12)
Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics

EC 60904-2 Ed. 1.0 (1989-05)
Photovoltaic devices. Part 2: Requirements for reference solar cells

IEC 60904-2 Amd.1 Ed. 1.0 (1998-02)
Amendment l

IEC 60904-3 Ed. 1.0 (1989-02)
Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

IEC 60904-5 Ed.. 1.0 (1993-10)
Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method

IEC 60904-6 Ed. 1.0 (1994-09)
Photovoltaic devices - Part 6: Requirements for reference solar modules

IEC 60904-6 Amd.l Ed. 1.0 (1998-02)
Amendment 1

IEC 60904-7 Ed. 2.0 (1998-03)
Photovoltaic devices - Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device

IEC 60904-9 Ed. 2.0 (1998-02)
Photovoltaic devices - Part 8: Measurement of spectral response of a photovoltaic (PV) device

IEC 60904-9 Ed. 1.0 (~995-09)
Photovoltaic devices - Part 9: Solar simulator performance requirements

IEC 60904-10 Ed. 1.0 (1998-02)
Photovoltaic devices - Part 10: Methods of linearity measurement

IEC 61173 Ed. 1.0 (1992-09)
Overvoltage protection for photovoltaic (PV) power-generating systems - Guide

IEC 61194Ed. 1.0 (1992-12) .
Characteristic parameters of stand-alone photovoltaic (PV) systems

IEC 61215 Ed. 1.0 (1993-04)
Crystalline silicon terrestrial photovoltaic (PV) modules –
Design qualification and type approval

IEC 61277 Ed. 1.0 (1995-03)
Terrestrial photovoltaic (PV) power-generating systems - General and guide

IEC 61345 Ed. 1.0 (1998-02)
UV test for photovoltaic (PV) modules

IEC 61646 Ed. 1.0(1996-11)
Thin-film terrestrial photovoltaic (PV) modules - Design
qualification and type approval

IEC 61701 Ed. 1.0 (1995-03)
Salt mist corrosion testing of photovoltaic (PV) modules

IEC 61702 Ed 1.0 (1995-03)
Rating of direct coupled photovoltaic (PV) pumping systems

IEC 61721 Ed. 1.0 (1995-03)
Susceptibility of a photovoltaic (PV) module to accidental impact
damage (resistance to impact test)

IEC 61724 Ed 1.0 (1998-04)
Photovoltaic system performance monitoring - Guidelines for
measurement, data exchange and analysis

IEC 61725 Ed. 1.0 (1997-05)
Analytical expression for daily solar profiles

IEC 61727 Ed. 1.0 (1995-06)
Photovoltaic (PV) systems - Characteristics of the utility interface

IEC 61829 Ed. 1.0 (1995-03)
Crystalline silicon photovoltaic (PV) array - On-site measurement of IV characteristics

IEC 61836 TR2 Ed. 1.0~(1997-10)
Solar photovoltaic energy systems - Terms and symbols

IEC TC 82 Work in Progress

IEC 60904-9 Ed. 2.0
Amendment to IEC 60904-9 (1995) to take into account thin-film silicon

IEC 61683 Ed. 1:0
Photovoltaic systems - Power conditioners - Procedure for measuring efficiency

IEC 61723 Ed. 1.0
Safety guidelines for grid connected photovoltaic (PV) systems mounted on buildings

IEC 61728 Ed. 1.0
Safety test procedures for utility grid connected photovoltaic inverters

IEC 61729Ed. 1.0
Equipment and safety specifications for direct coupled PV pumping systems

IEC 61730 Ed. 1.0
Safety testing requirements for PV modules

IEC 61836-2 Ed 1.0
Solar photovoltaic energy systems - Terms and symbols - Part 2

IEC 61849 Ed 1.0
Design qualification and type approval of photovoltaic (PV) modules for marine environments

IEC 6I8S3 Ed.1.0
Power and energy rating of photovoltaic (PV) modules

IEC 62078 Ed. 1.0
Certification and accreditation program for photovoltaic (PV) components and systems - Guidelines for a total quality system

IEC 62093 Ed. 1.0
BOS components - Environmental reliability testing
- Design qualification and type approval

IEC 62IO8 Ed 1.0
Concentrator photovoltaic (PV) receivers and modules
Design qualification and type approval

IEC 621Q9 Ed. 1.0
Electrical safety of static inverters and charge controllers for use
in photovoltaic (PV) power systems

IEC 62116 Ed. 1.0
Testing procedure - Islanding prevention measures for power conditioners used in grid-connected photovoltaic (PV) power generation systems

IEC 62124 Ed. 1.0
Photovoltaic stand-alone systems - Design qualification and type approval

IEC/PAS 62111 Ed. 1.0
Specification for the use of renewable energies in rural decentralized electrification

- ❖ PNW 82-225 Ed. 1.0
  Crystalline silicon terrestrial (PV) modules - Blank detail specification – Qualification approval

- ❖ PNW 82-226 Ed. 1.0
  Thin-film terrestrial PV modules - Blank detail specification –
  Qualification approval

- ❖ PWI 82-1 Ed. 1.0
  Photovoltaic electricity storage systems

- ❖ PV GAP “PVRS” introduced as New Work Item

Appendix III: IEC Standards Possibly Useful for PV[1]

BATTERIES

IEC 1044 Ed. 1.0	Opportunity-charging of lead-acid traction batteries
IEC 1056-1 Ed. 1.0	Portable lead-acid cells and batteries (Valve-regulated types) - Part 1: General requirements, functional characteristics - Methods of test
IEC 1056-2 Ed. 1.0	Portable lead-acid cells and batteries (Valve-regulated types) - Part 2: Dimensions, terminals and marking
IEC 1056-3 Ed. 1.0	Portable lead-acid cells and batteries (Valve-regulated types) - Part 3: Safety recommendations for use in electric appliances
IEC 254-1 Ed. 3.0	Lead-acid traction batteries - Part 1: General requirements and methods of test
IEC 254-2 Ed. 3.0	Lead-acid traction batteries - Part 2: Dimensions of cells and terminals and marking of polarity on cells
IEC 896-1 (1987-01)	Stationary lead-acid batteries - General requirements and methods of test. Part 1: Vented types.
IEC 896-1 Amd.1 Ed. 1.0	Amendment No. 1
IEC 896-1 Amd.2 Ed. 1.0	Amendment No. 2
IEC 896-1 Ed. 1.0	Stationary lead-acid batteries - General requirements and methods of test. Part 1: Vented types
IEC 896-1-am1 (1988-01)	Amendment No. 1
IEC 896-1-am2 (1990-12)	Amendment No. 2
IEC 896-2 (1995-11)	Stationary lead-acid batteries - General requirements and test methods - Part 2: Valve-regulated types.
IEC 896-2 Ed. 1.0	Stationary lead-acid batteries - General requirements and test methods - Part 2: Valve-regulated types
IEC 95-1 Ed. 5.0	Lead-acid starter batteries. Part 1: General requirements and methods of test
IEC 95-2 Amd.1 Ed. 3.0	Amendment No. 1
IEC 95-2 Amd.2 Ed. 3.0	Amendment No. 2
IEC 95-2 Ed. 3.0	Lead-acid starter batteries. Part 2: Dimensions of batteries and dimensions and marking of terminals
IEC 95-4 Amd.1 Ed. 1.0	Amendment No. 1
IEC 95-4 Ed. 1.0	Lead-acid starter batteries. Part 4: Dimensions of batteries for heavy trucks
IEC 952-1 (1988-07)	Aircraft batteries. Part 1: General test requirements and performance levels.

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IEC 952-1 Ed. 1.0	Aircraft batteries. Part 1: General test requirements and performance levels
IEC 952-2 (1991-03)	Aircraft batteries - Part 2: Design and construction requirements.
IEC 952-2 Ed. 1.0	Aircraft batteries - Part 2: Design and construction requirements
IEC 952-3 (1993-07)	Aircraft batteries - Part 3: External electrical connectors.
IEC 952-3 Ed. 1.0	Aircraft batteries - Part 3: External electrical connectors

CABLING / WIRING

IEC 610 (1978-01)	Principal aspects of functional evaluation of electrical insulation systems: Aging mechanisms and diagnostic procedures.
IEC 611 (1978-01)	Guide for the preparation of test procedures for evaluating the thermal endurance of electrical insulation systems.
IEC 614-1 (1994-03)	Conduits for electrical installations - Specification - Part 1: General requirements.
IEC 614-1-am1 (1995-09)	Amendment No. 1
IEC 614-2-1 (1982-01)	Specification for conduits for electrical installations. Part 2: Particular specifications for conduits. Section One: Metal conduits.
IEC 614-2-1-am1 (1993-10)	Amendment No. 1
IEC 614-2-5 (1992-11)	Specifications for conduits for electrical installations - Part 2: Particular specifications for conduits - Section 5: Flexible conduits.
IEC 811-1-1 (1993-10)	Common test methods for insulating and sheathing materials of electric cables - Part 1: Methods for general application - Section 1: Measurement of thickness and overall dimensions - Tests for determining the mechanical properties.
IEC 811-1-2 (1985-07)	Common test methods for insulating and sheathing materials of electric cables - Part 1: Methods for general application - Section Two: Thermal aging methods.
IEC 811-1-2-am1 (1989-11)	Amendment No. 1
IEC 811-1-4 (1985-07)	Common test methods for insulating and sheathing materials of electric cables - Part 1: Methods for general application - Section Four: Test at low temperature.
IEC 811-1-4-am1 (1993-08)	Amendment No. 1
EC 811-4-1 (1985-10)	Common test methods for insulating and sheathing materials of electric cables - Part 4: Methods specific to polyethylene and polypropylene compounds - Section One - Resistance to environmental stress cracking - Wrapping test after thermal aging in air - M
IEC 811-4-1-am2 (1993-08)	Amendment No. 2

IEC 812 (1985-07)	Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA).
IEC 998-1 (1990-05)	Connecting devices for low-voltage circuits for household and similar purposes. Part 1: General requirements.
IEC 998-2-1 (1990-05)	Connecting devices for low-voltage circuits for household and similar purposes. Part 2-1: Particular requirements for connecting devices as separate entities with screw-type clamping units.
IEC 998-2-2 (1991-11)	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units.
IEC 998-2-3 (1991-11)	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-3: Particular requirements for connecting devices as separate entities with insulation piercing clamping units.
IEC 998-2-4 (1993-05)	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-4: Particular requirements for twist-on connecting devices.
IEC 998-2-5 (1996-01)	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-5: Particular requirements for connecting boxes (junction and/or tapping) for terminals or connecting devices.

CHARGE CONTROLLER

IEC 439-1 (1992-12)	Low-voltage switchgear and controlgear assemblies - Part 1: Type-tested and partially type-tested assemblies.
IEC 439-1-am1 (1995-11)	Amendment No. 1
IEC 439-1-am2 (1996-12)	Amendment No. 2
IEC 439-2 (1987-11)	Low-voltage switchgear and controlgear assemblies. Part 2: Particular requirements for busbar trunking systems (busways).
IEC 439-2-am1 (1991-09)	Amendment No. 1
IEC 439-3 (1990-12)	Low-voltage switchgear and controlgear assemblies. Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use - Distribution boards.
IEC 439-3-am1 (1993-10)	Amendment No. 1
IEC 439-4 (1990-12)	Low-voltage switchgear and controlgear assemblies. Part 4: Particular requirements for assemblies for construction sites (ACS).
IEC 439-4-am1 (1995-12)	Amendment No. 1
IEC 439-5 (1996-03)	Low-voltage switchgear and controlgear assemblies - Part 5: Particular requirements for assemblies intended to be installed outdoors in public places - Cable distribution cabinets (CDCs) for power distribution in networks.

IEC 529 (1989-11)	Degrees of protection provided by enclosures (IP Code). Applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72.5 kV. Has the status of a basic safety publication.

DC SAFETY

IEC 1204 (1993-02)	Low-voltage power supply devices, d.c. output - Performance characteristics and safety requirements.

INVERTER

IEC 146-1-1 (1991-04)	General requirements and line commutated convertors - Part 1-1: Specifications of basic requirements.
IEC 146-1-1-am1 (1996-07)	Amendment No. 1 to IEC 146-1-1.
IEC 146-1-2 (1991-04)	General requirements and line commutated convertors - Part 1-2: Application guide.
IEC 146-1-3 (1991-04)	General requirements and line commutated convertors - Part 1-3: Transformers and reactors.

LAMPS

IEC 400 (1996-06)	Lampholders for tubular fluorescent lamps and starterholders.
IEC 400-am1 (1997-04)	Amendment No. 1
IEC 598-1 (1996-12)	Luminaires - Part 1: General requirements and tests
IEC 598-2-1 (1979-01)	Luminaires. Part 2: Particular requirements. Section One: Fixed general purpose luminaires.
IEC 598-2-1-am1 (1987-01)	Amendment No. 1
IEC 598-2-23 (1996-04)	Luminaires - Part 2: Particular requirements - Section 23: Extra low voltage lighting systems for filament lamps.
IEC 598-2-3 (1993-04)	Luminaires - Part 2: Particular requirements - Section 3: Luminaires for road and street lighting.
IEC 598-2-3-am1 (1997-04)	Amendment No. 1
IEC 598-2-4 (1997-04)	Luminaires - Part 2: Particular requirements - Section 4: Portable general purpose luminaires
IEC 598-2-5 (1979-01)	Luminaires. Part 2: Particular requirements. Section Five: Floodlights.
IEC 598-2-5-am1 (1987-01)	Amendment No. 1
IEC 598-2-5-am2 (1993-04)	Amendment No. 2
IEC 598-2-7 (1982-01)	Luminaires. Part 2: Particular requirements. Section Seven: Portable luminaires for garden use.
IEC 598-2-7-am1 (1987-01)	Amendment No. 1
IEC 598-2-7-am2 (1994-08)	Amendment No. 2
IEC 598-2-8 (1996-07)	Luminaires- Part 2: Particular requirements - Section 8: Handlamps.

IEC 81 (1984-01)	Tubular fluorescent lamps for general lighting service.
IEC 81-am1 (1987-01)	Amendment No. 1
IEC 81-am2 (1988-01)	Amendment No. 2
IEC 81-am3 (1992-07)	Amendment No. 3
IEC 81-am4 (1993-09)	Amendment No. 4
IEC 81-am5 (1994-12)	Amendment No. 5
IEC 810 (1993-10)	Lamps for road vehicles - Performance requirements.
IEC 810-am1 (1994-07)	Amendment No. 1
IEC 924 (1990-07)	D.C. supplied electronic ballasts for tubular fluorescent lamps - General and safety requirements.
IEC 924-am1 (1993-03)	Amendment No. 1
IEC 925 (1989-06)	D.C. supplied electronic ballasts for tubular fluorescent lamps - Performance requirements.
IEC 925-am1 (1996-05)	Amendment No.1
IEC 95-1 Amd.1 Ed. 5.0	Amendment No. 1
IEC 95-1 Amd.2 Ed. 5.0	Amendment No. 2
IEC 1162-1 (1995-‘11)	Maritime navigation and radio communication equipment and systems - Digital interfaces - Part 1: Single talker and multiple listeners. Contains the requirements for data communication between maritime electronic instruments, navigation and radio communication.

Appendix IV: PV GAP Recommended Standards*

PVRS 1 (Version 1.1)

Photovoltaic Stand-alone Systems

Design Qualification and Type Approval

PVRS 2

Crystalline silicon terrestrial photovoltaic (PV) modules. Blank detail specification – Qualification Approval under the IEC Quality Assessment System for Electronic Components (IECQ)

PVRS 3

Thin-film terrestrial photovoltaic (PV) modules. Blank detail specification – Qualification Approval under the IEC Quality Assessment System for Electronic Components (IECQ)

* As of July 25, 1999

Configurations at Health Stations			
Devices used	**Number**	**Output**	**Energy / 12 V=**
Lighting	4-7	18 W	-
Fan	1	12 W	-
Panels	3	55 Wp	-
Battery	1	-	200 Ah/day
Daily requirement	-	-	*50 Ah/day*
[1]			
Lighting	up to 10	18 W	-
Fan	1	12 W	-
Refrigerator	1	-	30-40 Ah/day
Panels	8	55 Wp	-
Battery	2	-	200 Ah/day
Daily requirement	-	-	*120 Ah/day*
[2]			
Lighting	4	8 W	27 Ah/day
Lighting	2	16 W	11 Ah/day
CB radio	1	-	15 Ah/day
Panels	3	50-60W	-
Battery	1	-	200 Ah/day
Daily requirement	-	-	*53 Ah/day*
[3]			
Lighting	3	20 W	13 Ah/day
Refrigerator	1	100 W	20 Ah/day
Laboratory	-	-	3 Ah/day
Panels	3	50 Wp	-
Battery	1	2-	200 Ah/day
Daily requirement	-	-	*36 Ah/day*
[4]			
Lighting	7	9 W	-
Radio terminal	-	-	-
TV terminal	-	-	-
Refrigerator	1	-	50 Ah/day
Fans	-	-	-
Panels	7	55 Wp	-
Battery	6	-	544 Ah/day
Daily requirement	-	-	*230 Ah/day*
[5]			
Refrigerator	1	-	30-40 Ah/day
Panels	2-3	50 W	-
Battery	1	-	300-400 Ah/day
[6]			

Medical Requirement - District Hospital (up to 50 Beds)			
Devices	**Number**	**Specifications**	**Remark**
Light	12 2	8W, 10h (fluorescent tubes) 40W, 8h (fluorescent tubes)	80 Ah/day 53 Ah/day
Water pump	-	1000 litres	-
Warm-water heater	-	40/65°C,500 litres	-
Sterilisation	-	120°C, 3 h	-
CB radio	-	24 h stand-by 2 h operation	max. 32 Ah/day
Oxygen acquisition	-	24 h	max. 0.2 kWh/day
Laboratory	-	8 h small loads	0,6 kWh/day (Zentrifuge)
Cooling: Food	-	200 litres	1.2 kWh/day
X-ray unit	-	30 min.	-
Cooling: Blood	-	Blood: 2-8°C Blood plasma (frozen)	0.3 kWh/day
Cooling: Vaccines	-	0-8°C, 100 Liter	0.7 kWh/day
Tools	-	-	0.3 kWh/day

[1] GTZ, SEP-Niger, Dispensaire, small, [2] GTZ, SEP-Niger, Dispensaire, large, [3] WHO, World-Solar-Summit, health-center, up to 10 beds, [4] Klaus Haars, Electricity from Sunlight, health-center, [5] GTZ, SEP-Namibia, clinic [6] WHO, World-Solar-Summit, refrigerator

1. Choosing a refrigerator or freezer for vaccine cooling

1.1 Points to consider:

1) Vaccine storage capacity: How much vaccine must be stored:
   (a) at +4^{0}C; (b) at -20^{0}C?
   As a guide to calculating storage capacity, see the information on vaccine storage volumes on page 5.

2) Icepack freezing capacity: How many icepacks should be frozen per 24 hours?
   The freezers in these sheets are recommended when large quantities of frozen icepacks are needed and/or when the appliance is also used for vaccines. If the program requires only icepack freezing, and capacity is not a major concern, any locally available, low-power consumption freezer can be used.

3) External temperatures: Performance of the refrigerator/freezer at 32°C or 43°C:
   (a) internal minimum and maximum temperatures; and
   (b) high day-time and low night-time temperatures.
   For vaccine storage, select refrigerators which remain in the +0^{0}C to +8^{0}C range and freezers in the -15^{0}C to -25^{0}C range. Outside these ranges there is a risk for some of the vaccines

4) Power source: Which power sources are available (see flowchart next page)?
   (a) Electricity: what is the voltage; 50 or 60Hz; is supply continuous or not?
   (b) Kerosene or bottled gas?
   Continuous refrigeration is required for vaccine storage. It is often difflcult to ensure this in areas where power sources are intermittent or fuel is of poor quality. Ice-lined refrigerators or equipment with permanent tanks of frozen “eutectic” can provide stable refrigeration even in areas of intermittent power. The longer the “holdover time" of the refrigerator, the better the security for the vaccine.

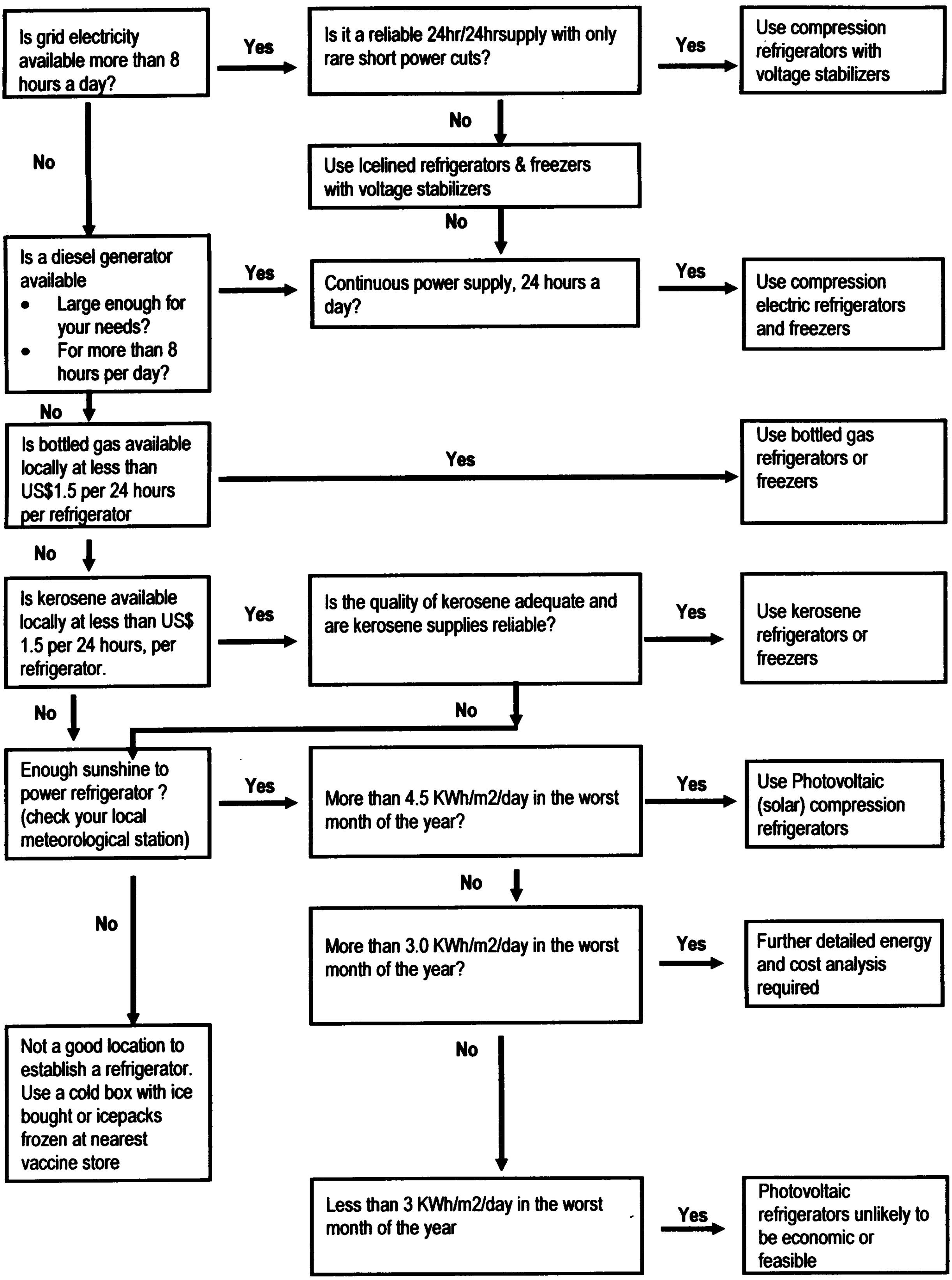
5) Holdover time: What holdover time is needed in case of power failure? How many hours will the vaccine remain below 10°C?

6) Reliability: Repair facilities and spare parts available for which types?
   *Spare parts and repairs account for 40-50% of the whole-life cost of a refrigerator. Each of the models in this section is listed with essential spare parts which will be needed within the first seven years of the equipment’s use. To avoid shortages later, purchase these **spares** at the time the equipment is purchased.*

7) Price: Which refrigerator meets requirements 1-6 at the lowest cost? Remember to consider shipping costs!
   *When placing your order for a refrigerator or a freezer, indude a request for a thermometer; order a voltage stabilizer for electrical equipment if local conditions require one and remember to specify the language for **user’s** and service manuals.*

8) Training: Are the users and those in charge of maintenance of the equipment properly trained?
   The importance of users’ and technicians’ training is often underestimated and therefore under- budgeted. A cold chain with good equipment, but insufficiently trained staff may seriously hamper an immunization programme. Users’ handbooks for training on electric, kerosene, gas and solar refrigerators are available from WHO Regional Offices or WHO / EPI, Geneva.

1.2 Selecting an appropriate energy source



Spare Parts and Tools for PV Rural Health Power Supply Stations

The WHO/EPI “Product Information Sheets" propose holding the following spare parts in reserve for every 10 cooling systems:

- 1 PV module
- 2 charge regulators
- 1 battery set
- 1 cable
- 1 compressor or complete cooling unit
- 3 compressor electronic control cards
- 3 thermostats or temperature control cards
- 1 condenser fan

For the “Okavango Clinics” tender in Namibia, a basic maintenance kit is to be provided comprising:

- End-user operating manual (Maintenance guidelines and procedures)
- Maintenance logbook
- Distilled water for battery (10 litres)
- Hydrometer
- Spanner for battery connections
- 6 meter ladder
- 10 litre PVC (plastic) bucket
- 2 sponges
- Squeegee with extension pole
- Eye protection (Goggles or eye shield)
- 2 fluorescent light lamps (PL 9)