SRI LANKA: ENERGY SERVICES DELIVERY PROJECT

SPECIFICATIONS FOR SOLAR HOME SYSTEMS
(Revised on 17 October 2000)

Packaged Solar Home System Hardware Specification

1. The Solar Home System (SHS) is intended to provide the user with a convenient means of supplying power for small electrical loads such as lights, TV and radio/cassette players. A typical SHS will provide power for at least three 12 Vdc fluorescent light fixtures and at least one 12 Vdc outlet for a black and white 14 inch TV or similar appliance for more than three hours a day. Additional 12 Vdc light fixtures, 12 Vdc or lower voltage socket outlets or a dc/AC inverter may be supplied as options. Each SHS will consist of one or more photovoltaic (PV) modules with an output of 20 Wp or more charging a 12 Vdc lead-acid battery along with light fixtures, related electronic and electrical components and mounting hardware. The batteries, charge controller, low voltage disconnect, and associated components, will be located in sturdy enclosure(s). Examples of SHS PV module sizes and typical service levels provided with five peak sunlight hours per day are shown below:

Solar Home System	*Useful energy*	*Operation of three 8 watt fluorescent lights and 12 watt TV*
20 Wp	6 Ah/day	2 hours per day
30 Wp	9 Ah/day	3 hours per day
40 Wp	12 Ah/day	4 hours per day
50 Wp	15 Ah/day	5 hours per day

Note: These are representative levels of service assuming 10% module derating and 20% battery round-trip Wh losses. Actual operating hours per day will vary depending on the wattage of the lights and other appliances, number of lights and other appliances switched on at any given time and peak hours of sunlight available on any given day.

2. The SHS components shall be packaged to provide convenient installation at a remote customer home site by a supplier-trained technician. The system will be constructed such that a user can perform routine maintenance such as adding battery water and replacing light bulbs and fuses, and a technician can easily perform system diagnostics or replace components.

3. The supplier/dealer will provide the most appropriate system integration, components, assembly and packaging that meet all the specifications in Annex 1 - Solar Home System Requirements. The specifications of the SHS should be summarized in Annex 2 - Solar Home System Specification Sheet along with the required test certificates (see para 4). Any exceptions and variations to the specifications must be explicitly stated a section entitled Exceptions and Variations in Annex 2. The scope and reasons for each listed exception and variation must be fully explained with supporting data.

4. Products to be financed in the International Development Agency (IDA) and Global Environmental Facility (GEF)-assisted Energy Services Delivery Project must have a type-test certificate from a testing and certification organization acceptable to the Government of Sri Lanka and the World Bank stating that the Solar Home System meets or exceeds the specifications given in Annex 1. Organizations accredited according to ISO 25 or equivalent standards will be acceptable.

Documentation

5. The solar home system (SHS) supplier must provide two supporting SHS documents. The first is a USERS MANUAL intended for the customers and will be included with each of the packaged systems. The second document, TECHNICIANS INSTALLATION, OPERATIONS AND MAINTENANCE MANUAL, will be for use by the service technicians will include the specific details on installation, operation and maintenance. At a minimum, the documents must be provided in

Sinhalese and/or Tamil. Users manual documentation should be simple and easy to understand. Use of sketches or graphics should be used to make the manual easier to use. The documentation is to include the following:

Users Manual

6. Theory of operation of the SHS which discusses: battery charging by the array; functions, battery low voltage protection, and battery overcharge protection. The relationship between energy available on a daily basis and sunlight conditions should be clearly and simply explained.

7. A description of all user interactive hardware including disconnect switches and status indicators.

8. Procedures for proper system operation, including a list of load limitations and any problem loads. These procedures should include suggested operation, including load conservation, during periods of inclement weather, and/or a low voltage disconnect event. The procedures for checking that the photovoltaic array is not shaded and how to prevent shading must be explained.

9. Any user maintenance items.

10. Emergency shut down procedures and recommendations for extended periods of system non-use.

11. A user trouble shooting guide.

Technicians Manual for Installation, Operations And Maintenance

12. A complete list of all system components, with associated manufacturers literature, specifications, and warranties.

13. A complete copy of the USERS MANUAL.

14. Complete installation instructions.

15. A recommended post-installation acceptance test procedures, including all appropriate set points and test procedures. They will include:

- Verify that the installation of the photovoltaic array with regard to position, direction, inclination and shading avoidance will maximize energy generation.
- Ensure that the battery has received an equalization charge just before installation.
- Use a shunt to measure the current from the array under charging conditions to verify the array charging current. This measurement should be done under clear sky conditions.
- Test all of the loads for proper operation.
- Make system-wide voltage drop measurements in the sub-circuits to verify that connections meet the required maximum allowable voltage drop.
- Note all measurements in the installation log.
- Explain to the user the system operating principles, load management requirements, impact of shading of the array and how to check and avoid it, user maintenance checks and how to conduct them

16. A recommended annual maintenance schedule, with complete maintenance instructions.

17. A detailed trouble shooting guide referencing all the system components. This shall include repairs and diagnostic procedures that can be done by the supplier or a qualified third party. Repairs and procedures not to be attempted by non-electricians and/or electricians unfamiliar with photovoltaic systems shall also be identified.

18. A functional block diagram, electrical single-line drawing showing the placement of all hardware and ratings of all component, and physical layout diagram.

19. Emergency shut down procedures.

Annex 1

SOLAR HOME SYSTEMS REQUIREMENTS

General

1. The supplier/dealer will provide at a minimum a six month warranty against manufacturers defects on all system integrated parts and labor excluding fuses or end-use devices such as light bulbs. On all major individual components, manufacturers warranties will be passed through to the user. Specifically, the PV modules should be warranted against reduction of output of no more than 10 percent of rated capacity over a ten year period. The charge controller, low voltage disconnect, switches, charge indicators, light fixtures, etc. should be warranted for at least one year. The battery should be warranted for at least six months. Battery end-of-life will be determined when the battery capacity down to 1.75 V/cell at 25 degrees centigrade drops to less than 80 percent of the initial rated capacity. In addition, the supplier/dealer will provide a 30-day money back guarantee for users who wish to return the SHS for whatever reason, and the suppler/dealer will refund no less than 75 percent of the selling price of the SHS when the module, controller, battery and light fixtures are returned to the supplier/dealer in good working condition. All warranties will start from the day the system is accepted by the user.

2. Nominal system voltage (rated voltage) shall be 12 Vdc.

3. The entire SHS system must be designed and constructed so that it requires maintenance and inspection by a technician no more frequently than once every six months.

4. The main components shall be integrated in such a way as to allow replacement (in case of failure) with a similarly functioning component of a newer design or a different brand. This will allow for future component evolution or variability of future component availability.

5. With the exception of the PV module(s), the supplier shall deliver the system to the user with as many components pre-assembled and prewired as is feasible prior to shipment.

6. All components must have a proven and documented record of reliable performance in similar applications. All components, including spares, will undergo full bench testing at the supplier factory or the originating source factory with proper documentation supplied. All set point voltages will be verified and documented with the results dated and the records maintained at the suppliers facility.

Operating Environment

7. The entire system shall be designed and built to withstand the environmental conditions found in Sri Lanka. For design purposes, consider that temperature extremes could range from +20 to +40 degrees Centigrade and humidity levels could reach 100 percent. The PV array and support structure must be able to withstand wind gusts up to 100 km/hour without damage. All wiring, enclosures, and fixtures that are mounted indoors must be resistant to high humidity, corrosion and insect and dust intrusion. Use of corrosion resistant terminals is required. Protection of the electronic circuit boards from corrosion by potting or applying a conformal coating is recommended.

Photovoltaic Array

8. The photovoltaic array will consist of one or more flat-plate photovoltaic modules. Each module should comprise of no less than 36 series-connected single or poly-crystalline silicon solar cells. Flat plate thin-film modules could also be used.

9. The photovoltaic array should have at least an average peak power output of at least 20 Wp, under Standard Test Conditions (STC) as defined in IEC (International Electrotechnical Committee)

Specification No. 904-series. The peak power output for thin film modules should be the value after light soaking.

10. The single-crystalline or poly-crystalline modules must be product tested and certified in accordance with IEC Specification No. 1215 or ESTI No. 503 issued by the Joint Research Committee of the European Commission. If thin-film photovoltaic modules are used, they must be product tested and certified in accordance with ESTI Specification No. 701 issued by the JRC, SERI/TR-213-3624 issued by the National Renewable Energy Laboratory, USA, or equivalent specifications.

11. If more than one module is used, identical models shall be used and they shall be connected in parallel.

12. Each module must be clearly marked indicating: Manufacturer, Model Number, Serial Number, Peak Watt Rating, Peak Current, Peak Voltage, Open Circuit Voltage and Short Circuit Current of each module.

13. The module junction box must be sealable and moisture resistant. If the module does not have a junction box which allows for a direct connection, then the structure will have a weather resistant junction/combiner box attached to the support structure. This box will have a terminal strip for connecting the parallel-wired modules.

14. The modules must be framed in such a way as to allow secure connection to the module mounting structure.

PV Array Mounting Structure

15. The array mounting structure will hold the photovoltaic module(s). The module(s) must be mounted to structural angle made of either aluminum or galvanized steel, secured at multiple points in order to assure stable and secure attachment.

16. The structure must be mounted at a fixed angle and oriented to maximize the useful energy supplied to the user during the design month (i.e., the month with the worst average daily insolation). Array orientation must be adjustable in the field.

17. The structure will incorporate galvanized steel, aluminum or stainless steel hardware for all external connections. These include the modules to structure, structure to pole and pole to building attachments.

18. The modules can be roof or ground-mounted: Roof-mounting: Minimum clearance between the PV array and the roofing material must be at least 10 cm above the roofing material. Anchoring of the mounting structure must be to the building and not to the roofing material. Ground-mounting: A metal pole must be used with the modules attached at the top of the pole. The modules must be at least 4 meters off the ground. The pole must be anchored in concrete at least one meter deep in the ground The pole and mounting structure must be sufficiently rigid to prevent twisting in the wind or if large birds alight on the array.

Battery Storage

19. The rechargeable battery will preferably consist of one 12 Vdc lead-acid battery, but no more than two identical 12 Vdc lead-acid batteries connected in parallel.

20. The 20-hour battery amp-hour capacity at 12 Vdc, measured at 25°C should be such that it will permit three days of autonomy where the maximum depth of discharge is limited to 50 percent of rated

capacity, but have a minimum amp-hours capacity at 12 Vdc (measured at the 20-hour rate) as given in the table below. It is recommended that the battery be sized to permit five days of autonomy in regions where extended cloudy periods are expected. For example,

Example: Minimum Lead-acid Battery Capacity Assuming Three Days of Autonomy

Module Rating (Wp)	*Average Daily Ah to Load at 12 Vdc*	*(Daily Ah x 3 days of autonomy)/.5*	*Acceptable Battery Sizes* (Ah at 20-hour rate)*
20	6	36	45
30	9	54	70
40	12	72	90
50	15	90	90

* Acceptable battery size is based on typical batteries sizes available locally in Sri Lanka

21. The maximum permissible self discharge rate is 10 percent of rated capacity per month at 25 degree Centigrade.

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

23. The battery must be production tested and certified in accordance with British Standard 60095-1:1993 or better equivalent standard. In addition, the thickness of each positive plate must exceed 1.7 mm and the thickness of each negative plate must exceed 1.4 mm. Also, for flooded-electrolyte type cells, the electrolyte volume must be sufficient to allow at least eight weeks of continuous operation of the SHS as per specification without the addition of distilled water.

24. The batteries can be supplied either in a wet-charged or dry-charged condition. If dry-charged, all chemicals and electrolyte must be supplied in accordance with battery supplier specifications. The battery and associated containers should be able to handle transport down rough dirt roads without damage.

Charge Regulator and Load Control

25. A solid-state photovoltaic charge controller must be provided. The charge controller must incorporate one of the following charge control algorithms: (a) Constant Voltage, (b) Pulse Width Modulated, (c) On/Off series or shunt linear. Voltage regulation (high voltage disconnect voltage) set points should prevent excessive gassing of the battery. The set points must be factory preset with the set points applicable to the specified battery characteristics. If on/off control algorithm is used, regulation voltage of 14.4 volts and a reconnect voltage of 13.4V is recommended for flooded lead-acid batteries. It is recommended that circuitry to allow boost or equalization charging the battery be provided.

26. The charge controller must have some type of display to indicate when it is in the charging mode.

27. The charge controller must be capable of handling 125% of the array's rated short circuit current, but not less than (a) 6 A when used with modules rated at 30 Wp or more, and (b) 3 A when used with modules rated at less than 30 Wp.

28. The charge controller must be equipped with reverse current leakage protection. Blocking diodes or logic derived methods are both acceptable. If blocking diodes are used they must exhibit a low forward voltage drop.

29. Battery temperature compensation circuitry is not required if flooded lead-acid batteries are used. However, if temperature compensation is not provided, then the set points must correspond to the type of battery and the ambient temperature of the site where the SHS is to be used. Temperature compensation is required if sealed lead-acid batteries are used.

30. The load must be controlled by a low voltage disconnect (LVD) device. The LVD must be capable of handling at least 150 percent of the maximum expected continuous load (e.g., assuming all end use devices are simultaneously on). It should be factory preset to disconnect and reconnect voltages corresponding to the safe operation of the battery under ambient temperature conditions. For example, a disconnect voltage of 11.7 Vdc $\pm$ 0.1 Vdc and reconnect voltage of 12.9 Vdc $\pm$ 0.2 Vdc is suitable for safe operation of lead-acid batteries used in SHS. Discharge of automotive-type lead-acid batteries below a depth of discharge of 75% of rated capacity should not be permitted

31. Maximum current draw of the controller, when no LED's are lit should not exceed 10mA.

32. The charge regulator/controller must be protected against damage caused by short circuit of the input and output terminals, and reverse polarity of connections. The controller shall have electronic or manual circuit breaker capability for load inrush currents up to 10 times rated dc current lasting less than 10 microseconds. Such an inrush current shall not cause the load to be disconnected and shall not cause degradation of the controller. Protective devices should disconnect the load should currents of 10 times rated dc current last longer than 10 microseconds. Lightning induced surge protection must be provided.

33. Some means must be provided to safely disconnect the battery and the module during servicing or repair by a technician.

34. The model number, serial number, rated voltages and currents, set points and indicator settings should be noted on the charge regulator case.

System Monitoring

35. Some form of a Battery State-of-Charge indicator must be provided on or near the controller or load center.

36. This device must, at a minimum, indicate when the battery condition is:

(a) Suitable to operate all loads (e.g. voltage greater than 12.5 Vdc)

(b) Energy conservation required (e.g., battery voltage less than 11.9 Vdc)

37. These indicators may be LED's, or analog or digital meters.

38. The chosen device must come appropriately labeled such that the user does not have to refer to a manual to understand the existing battery condition.

Equipment Enclosure

39. The equipment enclosure(s) will house the batteries, charge controller, charge indicators, low voltage disconnect, and all interconnecting wiring. The enclosure(s) must not be installed in a location that could be subject to flooding or be exposed to rain.

40. The batteries must be housed in a vented compartment. All parts of the compartment subject to battery acid contact must be acid resistant. This compartment must be built strong enough to

accommodate the weight of the battery. This compartment must adequately support and vent wet, lead-acid batteries. Access to the battery compartment by children must be prevented.

41. The remainder of the system components (electronics, switches etc.) must be housed in a separate compartment or enclosures which prevents the system components being affected by battery acid spills or fumes. The compartment or enclosure design must allow the internal electronic equipment to operate within acceptable operating temperature limits. It must be weather, dust, and insect resistant.

42. The enclosure must be constructed of a durable material so as to last 10 years without maintenance.

Wiring

43. Stranded and flexible insulated copper wiring must be used. Minimum acceptable cross-section of the wire in each of the following sub-circuits is as follows:

(a) From PV module to regulator/controller: 2.5 mm^2

(b) From regulator/controller to battery: 2.5 mm^2

(c) From controller to loads: 1.5 mm^2

44. Notwithstanding the above minimum wire size requirements, all wiring must be sized to keep line voltage losses to less than 5% in each sub-circuit and to allow the circuit to operate within the ampacity rating of the wire.

45. All exposed wiring (with the possible exception of the module interconnects) must be in conduits or be firmly fastened to the building structure. Wiring through roofing, walls and other structures must be protected through the use of bushings. Wiring through roofing must form a water-proof seal. Where the wiring is through flammable material (e.g. thatched roofs), they must be in a metal conduit. Adequate fasteners, conduits, bushings and other installation hardware must be supplied.

46. All wiring shall be color coded and/or labeled.

47. Field-installed wiring must be joined using terminal strips or screw connectors. Soldering or crimping in the field must be avoided if at all possible. Wire nuts are not allowed. The rated current carrying capacity of the joint must not be less than the circuit current rating. All connections must be made in junction boxes. Fittings for lights, switches, and socket outlets may be used as junction boxes where practical.

Lighting Fixtures

48. A minimum of three 12 Vdc fluorescent tube light or compact fluorescent light (CFL) fixtures, each with its own inverter (ballast) shall be supplied. Initially, each fluorescent light must have a minimum lumen output of 200 lumens when operated at an ambient temperature of 25°C.

49. Minimum operating voltage when the tube light or CFL will still strike shall be less than 85% of the rated voltage.

50. Maximum continuous operating voltage without damage to the circuit must be at least 125% of the rated voltage.

51. The minimum operating frequency should be 20 kHz and the wiring length from the inverter to the fluorescent light bulb must be kept short to minimize radio interference.

52. The electrical waveform on the fluorescent tube terminals must be symmetrical in time to within 10 percent (i.e., 60%/40% waveform maximum difference in symmetry over the voltage range of 11.0 to 12.5 Vdc at an ambient temperature of 25 degree C).

53. The maximum crest factor (ratio of maximum peak to RMS voltage of the waveform applied to the fluorescent tube light) shall be less than 2.

54. The input connections to the inverter should prevent the application of voltage with reverse polarity, or the inverter should be protected against damage when the rated voltage is applied with reverse polarity.

55. The inverter should be protected against damage by the application of voltage under open circuit conditions (e.g., when the light bulb is removed or has failed).

56. Lenses, covers, grids etc. (if used) must be easily removable by the user for bulb replacement or for cleaning.

57. The luminous efficacy of the light, inclusive of the power requirement of the inverter, must be either: i) greater than 30 lumens/watt with any reflectors, lenses, covers or grids (if used) in place; or ii) greater than 35 lumens/watt without reflectors, lenses, etc in place.

58. Light fittings must be insect proofed and corrosion and weather protected.

59. Light fittings must be marked with the manufacturer, model number, rated operating voltage, rated current and date of manufacture or batch number.

Socket Outlet

60. A 12 Vdc socket outlet for a TV or similar appliance shall be provided. The outlet must be rated to carry the maximum expected dc current. The outlet must be protected from reversing the polarity of the voltage applied to the appliance. An optional 6/9V outlet for use with radio/cassette player is recommended.

Packaging and Delivery

61. The SHS supplier/dealer must obtain the PV system equipment and components, assemble and wire them into integrated packaged SHS in accordance with the proposed design, and deliver the packaged SHS to the user.

62. Each system must be packaged for shipping to prevent any shipping related damage. The supplier/dealer will be responsible for settling any shipping related damaged claims and will be responsible for replacing damaged systems in a timely manner.

63. The modules must be packaged separately (not attached to the module support structure).

Annex 2

Solar Home System Specification Sheet

1. Photovoltaic Module(s)

(a) Model Number _____

(b) Type (a-Si, crystalline Si,.etc.) _____

(c) Number of cells in series _____

(d) Rated peak power (Pmax) _____ Wp

(e) Open circuit voltage _____ V

(f) Short circuit Current _____ A

(g) V max _____ V

(h) I max _____ A

(i) NOCT _____ deg C

(j) Test Certification Standard _____

(k) Test Laboratory _____

(Attach I-V curve and copy of test certificate)

2. Support Structure

(a) Type _____ (roof/pole)

(b) Material _____

3. Battery Storage

(a) Model Number _____

(b) Number of batteries _____

(c) Rated voltage _____ V

(d) Structure and material of positive plate _____

(e) Capacity per battery at C/20 down to 1.75V/cell _____ Ah

(f) Self discharge rate _____ (%/month)

(g) Cycle life down to 75 percent of DOD _____

(h) Positive plate thickness _____ mm

(i) Negative plate thickness _____ mm

(j) Electrolyte volume _____liters

(k) Certified to standard: _____: _____ (Yes/No)

(Attach test certificate)

4. Charge Regulator and Load Control

(a) Model number _____

(b) Rated voltage _____ V

(c) Control algorithm_____

(d) High voltage disconnect

(i) Voltage regulation set point (Vr) _____ V

(ii) Reconnect voltage (Vrr)_____ V

(e) Boost charging method _____

(f) Charge indicator?_____ Yes/No

(g) Maximum current handling capability_____ A

(h) Type of current leakage protection _____

(i) Voltage drop between module and battery terminals at controller/regulator_____ V

(j) Temperature compensation? _____ Yes/No

(k) LVD maximum current handling capability _____ A

(l) LVD set points

(i) Disconnect voltage _____ V

(ii) Reconnect voltage _____ V

(m) Maximum current draw when no LED's are not lit _____mA

(n) Short circuit protection?_____ Yes/No

(o) Reverse polarity protection? _____ Yes/No

(p) Over current protection (inrush current at 10 microseconds)?_____Yes/No, A

(q) Lightning surge protection?_____ Yes/No

(r) Module/battery/loads disconnection method_____

(Attach test certificate)

5. System Monitoring

(a) Battery State-of-Charge meter/indicator? _____ Yes/No

(b) Type of Indicator _____

(c) Indications Settings

Fully Charged Suitable to Use_____ V

Energy Conservation _____ V

Other (explain) _____

6. Equipment Enclosure

(a) Type of battery enclosure _____

(b) Material _____

(c) Type of controller housing_____

(d) Material _____

(e) Protection method against battery acid/fumes etc. _____

7. Wiring

(a) Wire material type _____

Wire cross-sections

(b) PV module to controller _____ mm^2

(c) Controller to battery_____ mm^2

(d) Controller to loads _____ mm^2

Lengths of wiring supplied

(e) PV module to controller _____ m

(f) Controller to battery_____ m

(g) Controller to loads _____ m

(h) Wiring identification method (color coded/labeled) _____ .

8. Lighting Fixtures

(a) Number of fixtures_____

(b) Number of fluorescent lights _____

For fluorescent lights:

(c) Model number(s) _____

(d) Wattage(s) _____ W

(e) Lumen output(s) _____ L

(f) Luminous efficacy _____ L/W

(g) Minimum striking voltage _____ V

(h) Maximum continuous operating voltage _____ V

(i) Operating frequency _____ kHz

(j) Electrical waveform voltage symmetry _____

(k) Maximum crest factor _____

(l) Open circuit voltage protection? _____ (Yes/No)

(Attach test certificate)

9. Socket Outlet

(a) 12 Vdc Socket outlet? _____ (Yes/No)

(b) Reverse polarity protection? _____ (Yes/No)

(c) 6 and/or 9 V outlet? _____ (Yes/No)

10. Other Components/Features

(a) _____

(b) _____

(c) _____

(d) _____

11. Exceptions and Variations to the Specifications Taken and Explanations

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