IIEC
International Institute for Energy Conservation

UNEP

Small Scale Funding Agreement (SSFA)

Solar Water Heating Applications: Evaluation of Product Standards (Draft)

Prepared for

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Partners for Sustainable Energy and Environmental Solutions

CONTENTS

ABBREVIATIONS

ANSI	American National Standards Institute
ASQC	American Society for Quality Control
AST	Asian Institute of Technology
BPS	Bureau of Product Standards
BSTI	Bangladesh Standards and Testing Institute
CMU	Chiang Mai University
DEDE	Department of Alternative Energy Development and Efficiency
GTZ	German Technical Cooperation
IIEC	International Institute for Energy Conservation
ISO	International Organization for Standardization
KM	Knowledge Management
KMUTT	King Mongkut's University of Technology Thonburi
NERD	National Engineering Research and Development
NU	Narasaun University
PNS	Philippine National Standard
QA	Quality Assurance
RERC	Renewable Energy Research Centre
SERT	School of Renewable Energy Technology
SLSI	Sri Lanka Standards Institute
SSFA	Small Scale Funding Agreement
SWH	Solar Water Heater
TIS	Thai Industry Standard
TISI	Thai Industrial Standards Institute
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UPSL	University of the Philippines Solar Laboratory
VSQI	Vietnam Standards and Quality Institution

EXECUTIVE SUMMARY

United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) have initiated *Global Knowledge Management (KM) and Networking* activities within framework of its global project “Solar Water Heating (SWH) Market Transformation and Strengthening Initiative”. International Institute for Energy Conservation (IIEC) as a regional partner to the project is committed to the development of knowledge products and services for SWH applications in five of South Asian and Southeast Asian counties – Bangladesh, Sri Lanka, Thailand, The Philippines and Vietnam.

The report discusses the efforts of the regional countries in adoption of product standards for solar water heaters, third party tests, test procedures, certification of solar water heaters. It also presents efforts of several organizations working it these countries to improve quality of installation and hot water servicing of the installed systems.

1 INTRODUCTION

Solar water heaters are not new; the world's first commercialized solar water heating system was patented in the United States in 1891. Since then, the technology is being improved through continuous innovation and research studies all over the world. The basic principle of Solar Water Heating (SWH) system can be simply explained as "solar radiation (heat) from the sun is absorbed by high-absorbance material and is transferred to cold water, thus water becomes hot". While many parts of the world are experiencing energy shortage and rising concern on environmental degradation caused due to conventional form of energy utilization, during the 1990s and beginning of 2000, the global solar thermal market has undergone a favourable development with a steady annual growth.

"Solar Water Heating (SWH) Market Transformation and Strengthening Initiative", jointly developed by the United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) consists of two components as follows:

- **Component 1 - Global Knowledge Management (KM) and Networking:** Effective initiation and co-ordination of the country specific support needs and improved access of national experts to state of the art information, technical backstopping, training and international experiences and lessons learnt.
- **Component 2 - UNDP Country Programs:** The basic conditions for the development of a SWH market on both the supply and demand side established, conducive to the overall, global market transformation goals of the project.

International Institute for Energy Conservation (IIEC) as a regional partner to the program is committed to generate knowledge products and services to ensure that developmental experiences and benefits of knowledge can be effectively disseminated to other regional countries.

The report was prepared within the framework of "Solar Water Heating Market Transformation and Strengthening Initiative" under UNEP's Small Scale Funding Agreement (SSFA). The objective of the report is to provide overview of solar water heater product standards, accredited test laboratories and certification bodies and accreditation of planners/installers. The countries chosen for the evaluation in the report are – Bangladesh, Sri Lanka, Philippines, Thailand and Vietnam.

1.1 Methodology

The analysis in this report is based on compilation of secondary data readily available from various web sources, product standards developed by the Regional Standard Bureaus in these countries, discussions or email exchanges with industry experts, SWH manufacturers, primary data gathering from questionnaires sent out to SWH manufacturers, organizations endeavouring to promote SWH and local associations through IIEC regional offices. The details and potential sources of information are cited in respective sections of the report. The value of this report lies in its bringing together data from many sources which is extremely difficult to obtain. In cases where sufficient data is unavailable either in the form of secondary data or quick primary data collection; further detailed studies are recommended in Phase II and are not covered under the current SSFA contract.

2 BACKGROUND: NEED FOR QUALITY PRODUCTS

The term *'quality'* as defined by the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) is *"the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs"*. The definition implies that identification of *features and characteristics of products and services* that determine customer satisfaction is essential and forms the basis for measurement and control. The *"ability to satisfy given needs"* reflects the value of product or service to the customer, including the economic value, reliability, and maintainability. A certain quality level in manufacturing of the system components and the system as a whole is essential and acts a pre-condition in order to guarantee an appropriate and optimized function of the system.

Quality assurance (QA) is the systematic monitoring and evaluation of the various aspects of a project, service or facility to maximize the probability that minimum standards of quality are being attained by the production process. Two basic principles of QA are: "Fit for purpose - the product should be suitable for the intended purpose"; and "Right first time - mistakes should be eliminated". QA includes regulation of the quality of raw materials, assemblies, products and components, services related to production, and management, production and inspection processes.

In order to ensure a certain quality level in manufacturing, product standards are developed and the products are tested for compliance to the standards. International Organization for Standardization (ISO) is the world's largest developer and publisher of International Standards. ISO is a network of the national standards institutes of 162 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.

Solar water heaters are typically known for high investment cost, low operating costs and a lifespan of 15-20 years depending upon the type of solar collector. Considering these factors, maintaining high quality in manufacturing is needed in order to deliver uninterrupted services over prolonged life time of the technology. Realizing this, ISO and its members are in process of continuously developing/ revising product standards for Solar water heaters. The products complying with the Standard are ensured a minimum quality (fit for purpose).

3 NATIONAL PRODUCT STANDARDS FOR SOLAR WATER HEATERS

As mentioned in Section 2 of the report, several countries have realized the importance and necessity of quality and performance checks for solar water heaters and are engaged in developing of SWH product standards applicable to their countries. The product standard of a country may have considerable variance compared to the other because of climatic conditions, solar irradiation, hot water requirement pattern etc.

3.1 Details of Product Standards

Details or status of solar water heater product standards for the countries selected for study under the current SSFA, namely – Bangladesh, Philippines, Sri Lanka, Thailand, Vietnam are discussed in the following sub-sections.

3.1.1 Bangladesh

Product standards are not available for SWH systems in Bangladesh, there are no documented measures/initiatives for development of such standards in Bangladesh. However, Bangladesh Standards and Testing Institute (BSTI)[1], the national standards body was established in 1985 for product standardizations in the country.

3.1.2 Philippines

Bureau of Product Standards (BPS)[2] is the national standards body in the Philippines to develop, implement and coordinate standardization activities in the country. It is primarily involved in standards development, product certification, and standards implementation/promotion to raise the quality and global competitiveness of Philippine products at the same time to protect the interests of consumers and businesses.

In 2008, the BPS has adopted SWH standards developed by ISO for the Philippines[3]. The Standard number and equivalent ISO standard of SWH Standards adopted by the BPS are below.

[1] "Bangladesh Standards and Testing Institution." [Online]. Available: http://www.bsti.gov.bd/. [Accessed: 27-Apr-2011].

[2] "Bureau of Product Standards S&C Portal - Home", n.d., http://www.bps.dti.gov.ph/.

[3] Source of Information: Communication from BPS

No.	PNS Standard No.	Title	Reference ISO Standard No.
1	PNS ISO 94-5:2008	Solar heating "Domestic water heating systems" Part 5: System performance characterization by means of whole-system tests and computer simulation	ISO 9459 – 5: 2007
2	PNS ISO 9459-1:2008	Solar heating "Domestic water heating systems" Part 1: Performance rating procedure using indoor test methods	ISO 9459 – 1:1993
3	PNS ISO 9459-2:2008	Solar heating "Domestic water heating systems" Part 2: Outdoor test methods for system performance Characterization and yearly performance prediction of solar-only systems	ISO 9459 – 2: 1995
4	PNS ISO 9808:2008	Solar water heaters Elastomeric materials for absorbers, connecting pipes and fittings - Method of assessment	ISO 9808:1990

Applicability and summary of the first two listed PNS standards above are discussed in the following sub-sections.

3.1.2.1 PNS ISO 94 – 5: 2008 Solar heating "Domestic water heating systems" Part 5: System performance characterization by means of whole-system tests and computer simulation

Scope:

This standard discusses a method of determining the performance of a solar water heating system under natural outdoor conditions and prescribes a method of transforming the test results (using computer simulation) from the particular climate conditions of the test to long-term average conditions for the test location or for other location with similar solar irradiation conditions.

Field of Application:

The tests will be carried out in typical operational conditions; the only restriction on the nature of systems that can be tested is that there can be no long-term energy storage. The total energy storage capacity in the solar pre-heat section of the system must be less than twice the nominal system capacity. The standard applies only to systems with auxiliary heating systems (integrated or remote). Both thermo-siphon and forced circulation systems are covered by the standard.

Test Method:

Name of the test:	**Preliminary Evaluation**
Description: The system will be inspected to determine its basic construction details and verified as being in accordance with the manufacturer's description. The manufacturer shall nominate a daily total load that the particular system is designed to deliver.	
Name of the test:	**No-solar test**
Description: The purpose of the no-solar test is to determine the ability of the system to meet the load specified by the manufacturer, when the solar input is zero (to ensure that the auxiliary heating system is adequate). The system under test is connected to the cold water supply and filled. The supplementary energy source is switched on and the system left until the first thermostat cut-out occurs following which the manufacturer's specified load is applied using the draw-off sequence. The system shall be operated with constant daily energy draw-off for 5 days after the first thermostat cut-out. The delivered temperature for the purpose of assessing energy draw-off shall be not less than 55^{o}C and four no-solar test periods should be evaluated.	
Name of the test:	**Solar test**
Description: For Solar test, the performance of the system shall be evaluated for three different daily loads. The difference between the maximum and minimum loads shall be at least 0.5 times the nominal system capacity. To minimize transient effects associated with outdoor operation the performance is averaged over test periods of 5 or more days. Sample analysis of test results and formats for reporting system performance using all the tests are shown in the standard.	

3.1.2.2 PNS ISO 9459 – 1: 2008 Solar heating "Domestic water heating systems" Part 1: Performance rating procedure using indoor test methods

Scope & Applicability:

This standard specifies a uniform indoor method of testing for rating solar domestic water heating systems for thermal performance under benchmark conditions. And, the standard is not applicable to concentrating or evacuated tube systems. The standard covers testing the performance of three categories of solar domestic hot water systems – Solar-only systems, Solar pre-heater systems, Solar-plus-supplemental systems.

Test can be performed in the following ways:

1) By assembling the complete system and irradiating the collector array by use of a solar irradiance simulator
2) By assembling the complete system and non-irradiating the collector array (by adding a controlled heating device in series)

For either case, the system shall be tested for a test day with no solar input.

Name of the test:	**Solar – Only and Solar – Preheat System Test**
Description: In order to perform this test, the storage device shall be filled with water at a specified temperature, on the morning of the first day. The system shall be energized and shall be allowed to operate in its normal mode during the day and each successive day of the test. Any device which is intended to limit or control the operation of the solar energy collection equipment shall be set as recommended by the manufacturer. On each test day, water shall be withdrawn from the system at times, rates, and duration as specified for the day. The energy content of the water withdrawn shall be determined by installed flow meters and temperature sensors. The delivery temperature shall be measured and recorded at no greater than 4.5 kg intervals throughout the withdrawal period. The test shall be performed until the daily system solar contribution is within three percent of the value on the previous test day.	
Name of the test:	**Solar Hot Water System Test with Integral Supplement Heaters**
Description: The test procedure is same as that of Solar-only and Solar-preheat system except that performance of Solar hot water system with integral supplement heaters is measured for both a test day with solar energy input and a test day with no solar energy input.	
Name of the test:	**Hot water – Continuous Draw Test**
Description: The purpose of this test is to determine the capability of the solar hot water system to deliver hot water with no auxiliary energy source operating and during a continuous draw-down. The solar hot water system shall be installed, adjusted, and operated similar to the two tests procedure described above. Ten minutes after the last draw on the final test day, a special test draw test shall be conducted. All auxiliary energy source thermostats shall be disabled. The cold water supply shall be adjusted to supply water at t_{main}	

± 1°C. Water shall be withdrawn at a uniform flow rate as specified in the test day.

The PNS standards that are adopted from ISO has no relevance to climate conditions (humidity levels, solar irradiation, salt in air etc.) in the Philippines

3.1.3 Sri Lanka

Product standards are not available for SWH systems in Sri Lanka; the efforts are being put in to develop standards and may likely to come out in near future. The Sri Lanka Standards Institute (SLSI)[4] is the premier national body associated with the task of developing product standards.

3.1.4 Thailand

The Thai Industrial Standards Institute (TISI)[5] is an internationally recognized focal point for standardization in Thailand to strengthen capabilities for sustainable competitiveness. There are two product standards applicable to solar water heaters in the country: TIS 899 – 2532 (1989) applicable for industrial solar flat plate collectors and TIS 1507 – 2541 (1998) for domestic solar flat plate collectors.

3.1.4.1 TIS 899 – 2532 (1989) applicable for industrial solar flat plate collectors

This Thai Industrial Standard specifies types, components, required characteristics, label, sampling and judging criteria, and testing of solar collector with exposure area larger than 0.5 m^2.

Types of solar collectors:

The type of solar collectors covered by the Standard are divided into 4 categories based on production processes of absorbing plates.

Type	Manufacturing technique of Absorber plate
Type 1	Electroplating technique
Type 2	Chemical process

[4] "Sri Lanka standards Institution." [Online]. Available: http://www.slsi.lk/index.php. [Accessed: 27-Apr-2011].

[5] "Thai Industrial Standards Institute eng." [Online]. Available: http://www.tisi.go.th/eng/index.php. [Accessed: 26-Apr-2011].

Type	Manufacturing technique of Absorber plate
Type 3	Painting technique
Type 4	Other techniques

Components:

According to the Standard, the solar collector consists of frame, transparent plate, absorber plate, tubes located inside the solar collector, insulator, and container and backing plate.

Required characteristics:

Parameter	Sub-parameters
Solar collector performance	Leak-proof Tolerance of temperature change
Materials for solar collector	Transparent plate • Glass used as a transparent plate should comply with TIS 54 or tempered glass Absorber plate • Optical property: The label must correctly state the solar absorbance and emittance. • Tolerance to the weather: There must be visible crack or flake at the surface of the absorber plate no more than 1% of the whole surface. • Adhesion: The surface of the absorber plate that is peeled off with the glue strip should be no more than 5 mm^2. • Tolerance to corrosion: There must be no corrosion or swelling at the surface of the absorber plate and no rust should be found at the metal base. Container and backing plate • Tolerance to the weather: There must be no visible crack or flake at the surface of the container and the backing plate. • Tolerance to corrosion: There must be no visible corrosion or swelling at the weld. Insulator • Changes of mass and dimensions of the insulator must not be greater 5%

Sampling and judging criteria:

Sampling and judging criteria can be done for one particular lot with no more than 300 plates, and with the same type, materials, production process, and trading period.

Parameter	Criteria
Sampling and acceptance for performance testing of the solar collector	Random Sampling from the same lot for 1 plate. The sample must be identical to solar collector performance in order to qualify.
Sampling and acceptance of the testing of absorber plate, container and backing plate, and insulator	A sample of the absorber plate, container and backing plate, and insulator are cut off from the solar collector that has passed the performance test and absorber plate testing. The sample must comply with the material standard for solar collector.
Judging criteria	Samples must comply with the sampling criteria and the standard of material, which can be chosen as the material for a solar collector. If the samples qualify, that lot of solar collectors can be regarded as the solar collectors approved by the TIS.

Methods of test:

Name of the test:	**Internal Pressure Test of the Absorber**
Description: The absorber shall be pressure-tested to assess the extent to which it can withstand the pressures which it might meet in service. Inorganic absorbers shall be pressure-tested at ambient air temperature within the range of 20℃ to 40℃. The test pressure shall be 1.5 times the maximum collector operating pressure specified by the manufacturer. The test pressure shall be maintained for 15 minutes meanwhile the collector shall be inspected for leakage, swelling and distortion.	
Name of the test:	**Exposure Test**
Description: The exposure test provides a low-cost reliability test sequence, indicating operating conditions which are likely to occur during real service and which also allows the collector to "settle", such that subsequent qualification tests are more likely to give repeatable results. The collector shall be mounted outdoors, but not filled with fluid. All except one of the fluid pipes shall be sealed to prevent cooling by natural circulation of air and one fluid pipe that is left open permit free expansion of air in the absorber. The collector shall be inspected for damage or degradation under the following parameters. Corresponding climate parameter values for testing are: ▪ 30 hours of global solar irradiance on collector plane, $G > 850$ W/m^2 (in sequences with a minimum of 30 minutes or longer) ▪ at least 30 days with a global daily irradiation on collector plane, $H > 14$ MJ/m^2 (interruptions allowed) ▪ surrounding air temperature, $T_{amb} > 15$℃	
Name of the test:	**High Temperature Resistance Test**
Description: This test is intended to assess rapidly whether a collector can withstand high irradiance levels without failures, such as glass	

breakage, collapse of plastic cover, melting of plastic absorber, or significant deposits on the collector cover from outgassing of collector material. The collector shall be mounted outdoors or in a solar simulator, and shall not be filled with fluid. All of the fluid pipes except for one shall be sealed to prevent cooling by natural circulation of air.

A temperature sensor shall be attached to the absorber to monitor its temperature during the test. The sensor shall be positioned at two-thirds of the absorber height and half the absorber width. It shall be fixed firmly in a position to ensure good thermal contact with the absorber. Furthermore the sensor shall be shielded from solar radiation.

Corresponding climate parameter values are:

- global solar irradiance on collector plane, $G \geq 1000$ W/m^2
- surrounding air temperature, T_{amb} 20 – 40 °C
- surrounding air speed < 1 m/s

The test shall be performed for a minimum of 1 hour after steady-state conditions have been established, and the collector shall be subsequently inspected for signs of damage such as degradation, shrinkage, outgassing or distortion.

Name of the test:	**External Thermal Shock Test**

Description: Collectors may be exposed to sudden rainstorms on hot sunny days, especially in the monsoon, causing a severe external thermal shock. This test is intended to assess the capability of a collector to withstand such thermal shocks. The collector shall be mounted either outdoors or in a solar simulator, but shall not be filled with fluid. All except one of the fluid pipes shall be sealed to prevent cooling by natural circulation of air. One shall be left open to permit free expansion of air in the absorber.

A temperature sensor may be optionally attached to the absorber to monitor its temperature during the test. An array of water jets shall be arranged to provide a uniform spray of water over the collector. The collector shall be maintained under a high level of solar irradiance for a period of 1 hour before the water spray is turned on. It is then cooled by the water spray for 15 minutes before being inspected. The collector

shall be subjected to two external thermal shocks. The corresponding solar irradiation level is: ▪ global solar irradiance on collector plane, $G > 850$ W/m^2 The water spray shall have a temperature of less than 25°C and a flow rate in the range of 0.03 kg/s to 0.05 kg/s per square metre of collector aperture. If the temperature of the water which first cools the collector is likely to be greater than 25°C (for example if the water has been sitting in a pipe in the sun for some time), then the water shall be diverted until it has reached a temperature of less than 25°C before being directed over the collector. The collector shall be inspected for any cracking, distortion, condensation, water penetration or loss of vacuum.	
Name of the test:	**Internal Thermal Shock Test**
Description: Collectors may from time to time be exposed to a sudden intake of cold heat transfer fluid on hot sunny days, causing a severe internal thermal shock, for example, after a period of shutdown, when the installation is brought back into operation while the collector is at its stagnation temperature. This test is intended to assess the capability of a collector to withstand such thermal shocks without failure. The collector shall be mounted either outdoors or in a solar simulator, but shall not be filled with fluid. One of its fluid pipes shall be connected via a shutoff valve to the heat transfer fluid source and the other shall be left open initially to permit the free expansion of air in the absorber and also to permit the heat transfer fluid to leave the absorber. If the collector has more than two fluid pipes, the remaining openings shall be sealed in a way that ensures the designed flow pattern within the collector. A temperature sensor may be optionally attached to the absorber to monitor its temperature during the test. The collector shall be maintained under a high level of solar irradiance for a period of 1 hour before it is cooled by supplying it with heat transfer fluid for at least 5 minutes or until the absorber temperature drops below 50°C. The collector shall be subjected to two internal thermal shocks.	

The corresponding solar irradiation level is:

- global solar irradiance on collector plane, $G > 850$ W/m^2

The heat transfer fluid shall have a temperature of less than 25 °C. The recommended fluid flow rate should be minimum 0.02 kg/s per square metre of collector aperture (unless otherwise specified by the manufacturer). The collector shall be inspected for any cracking, distortion, deformation, water penetration or loss of vacuum.

Name of the test:	Rain Penetration Test

Description: This test is applicable only for glazed collectors and is intended to assess the extent to which glazed collectors are substantially resistant to rain penetration. They shall normally not permit the entry of either free-falling rain or driving rain. Collectors may have ventilation holes and drain holes, but these shall not permit the entry of driving rain. The collector shall have its fluid inlet and outlet pipes sealed (unless hot water is circulated through the absorber), and be placed in a test rig at the shallowest angle to the horizontal recommended by the manufacturer. If this angle is not specified, then the collector shall be placed at a tilt of 20° to the horizontal. Collectors designed to be integrated into a roof structure shall be mounted in a simulated roof and have their underside protected. Other collectors shall be mounted in a conventional manner on an open frame or a simulated roof.

The collector shall be sprayed on exposed sides, using spray nozzles or showers. The collector shall be mounted and sprayed while the absorber in the collector is kept warm (minimum 50°C). This can be done either by circulating hot water at about 50°C through the absorber or by exposing the collector to solar radiation. The heating up of the collector should be started before spraying of water in order to ensure that the collector box is dry before testing. In cases of collectors having wood in the backs (or other special cases), the laboratory must take all necessary measures during the conduction of the test so that the final result will not be influenced or altered by the special construction of the collector. The collector shall be sprayed with water at a temperature lower than 30°C and with a flow rate of more than 0.05 kg/s per square metre of sprayed area. The duration of the test shall be 4 hours. The water pressure shall be 300 kPa. The collector shall be inspected for water penetration. The results of the inspection, i.e. the extension of water penetration and the places where water penetrated shall be reported.

The penetration of water into the collector shall be determined by inspection (looking for water droplets, condensation on the glass cover or other visible signs) and by one of the following methods:

- weighing the collector before and after the test: the determined water quantity shall be less than 50 grams/m² collector area;
- measuring the humidity inside the collector (standard uncertainty better than 5%)
- measuring the condensation level, which shall be less than 20 % of the transparent cover and the quantity of the water that come out of the collector when tipping it shall be less than 50 grams/m² collector area.

Due to the heavy monsoon rain and generally high air humidity, it is recommended to locate an adequate number of drain holes at the lowest point of the collector casing, so that ingress of water can be avoided. Thereby the invaded water and humidity can escape more easily.

Name of the test:	**Mechanical Load Test**

Description:

Positive pressure test

This test is intended to assess the extent to which the transparent cover of the collector and the collector box are able to resist the positive pressure load due to the effect of wind.

The collector shall be placed horizontally on an even ground. On the collector a foil shall be laid and on the collector frame a wooden or metallic frame shall be placed, high enough to contain the required amount of gravel or similar material. The gravel, preferably type 2-32 mm, shall be weighed in portions and distributed in the frame so that everywhere the same load is created (pay attention to the bending of the glass), until the desired height is reached. The test can also be carried out loading the cover using other suitable means (e.g. water), or a uniformly distributed set of suction cups. As a further alternative, the necessary load may be created by applying an air pressure on the collector cover. The test pressure shall be increased at maximum steps of 250Pa until a failure occurs or up to the value specified by the manufacturer. The test pressure shall be at least 3200Pa.

Note: The value 3200 Pa corresponds to requirements in areas with high danger of occurrence of tropical cyclones, e.g., like in Caribbean areas. In Europe, recommended values are between 1000 and 2400 Pa.

A failure can be the destruction of the cover and also the permanent deformation of the collector box or the fixings. The pressure at which any failure of the collector cover or the box or fixings occurs shall be reported together with details of the failure. If no failure occurs, then the maximum pressure which the collector sustained shall be reported. The maximum positive pressure is the pressure reached before a failure occurs. The permissible positive pressure is the maximum pressure divided by the safety factor. When the test is done with an on-roof mounting system the test result is also valid for the roof integrated mounting system.

Negative pressure test

This test is intended to assess the extent to which the fixings between the collector cover and collector box are able to resist uplift forces caused by the wind. The collector shall be installed horizontally on a stiff frame by means of its mounting fixtures. The frame which secures the cover to the collector box shall not be restricted in any way. A lifting force which is equivalent to the specified negative pressure load shall be applied evenly over the cover. The load shall be increased in steps up to the final test pressure. If the cover has not been loosened at the final pressure, then the pressure may be stepped up until a failure occurs. The time between each pressure step shall be the time needed for the pressure to stabilise.

Either of two alternative methods may be used to apply pressure to the cover:

- Method 1

The load may be applied to the collector cover by means of a uniformly distributed set of suction cups.

- Method 2

For collectors which have an almost airtight collector box, the following procedure may be used to create a negative pressure on the cover. Two holes are made through the collector box into the air gap between the collector cover and absorber, and an air source and pressure gauge are connected to the collector air gap through these holes. A negative pressure on the cover is created by pressurising the collector box. For safety reasons the collector shall be encased in a transparent box to protect personnel in the event of failure during this test.

During the test, the collector shall be visually inspected and any deformations of the cover and its fixings reported. The collector shall be examined at the end of the test to see if there are any permanent deformations. The test pressure shall be increased in steps of 250Pa until a failure occurs or up the value specified by the manufacturer. The test pressure shall be at least 2400Pa. A failure can be the destruction of the cover and also the permanent deformation of the collector box or the fixings.

A permanent deformation is to be assigned to a load value, while it is completely relieved after every load increment of 250Pa and the distortion is measured compared to the beginning of the test sequence. The value of an inadmissible permanent deformation amounts to max. 0.5 %. (Example: 10 mm distortions at 2 m length of collector frame). The pressure at which any failure of the collector cover or the box or fixings occurs shall be reported together with details of the failure. If no failure occurs, then the maximum pressure which the collector sustained shall be reported. The maximum negative pressure is the pressure reached before a failure occurs. The permissible negative pressure is the maximum pressure divided by the safety factor.

Name of the test:	**Impact Resistance Test**

Description: Collectors shall sustain no significant damage, cracking, breakage or puncture of any glazing, or the absorber in an unglazed collector, when affected by hail. This test is intended to assess the extent to which a collector can withstand the effects of heavy impacts caused by hailstones. Where hail guards are provided, it is recommended that they are located not less than 50 mm from the surface of the glazing of glazed collectors, or the absorber surface for unglazed collectors. The collector shall be mounted either vertically or horizontally on a support. The support may be stiff enough so that there is negligible distortion or deflection at the time of impact. Steel balls (diameter: 25.4 mm) shall be used to simulate a heavy impact. If the collector is mounted horizontally then the steel balls are dropped vertically, or if it is mounted vertically then the impacts are directed horizontally by means of a pendulum. In both cases, the height of the fall is the vertical distance between the point of release and the horizontal plane containing the point of impact.

The point of impact shall be no more than 5 cm from the edge of the collector cover, and no more than 15 cm from the corner of the collector cover, but it shall be moved by several millimetres each time the steel ball is dropped. A steel ball shall be dropped onto the collector 10 times from the first test height (0.2 m), 10 times from the second test height (0.4 m), etc. until the maximum test height (2.0 m) is reached. The test has to be stopped when the collector sustains some damage or when the collector has survived the impact of 10 steel balls at the maximum test height. The collector shall be inspected for damage. The results of the inspection shall be reported, together with the height from which the steel ball was dropped and the number of impacts which caused the damage.

The solar collectors are tested to perform even during instances of high humidity (Rain Penetration Test) and high solar irradiation (High Temperature Resistance Test)

Thailand's Building Energy Code[6] does not include or recommend use of solar water heaters particularly, but use of Renewable energy technologies as a whole is supported.

[6] "New Building Energy Code & Government Policies of Thailand", n.d., http://lcsrnet.org/meetings/2010/11/pdf/D2S9_3_Rakkwamsuk.pdf.

3.1.5 Vietnam

Product standards are not available for SWH systems in Vietnam, there were no documented measures/initiatives for development of such standards for Vietnam. However, Vietnam Standards and Quality Institution (VSQI)[7], the national representative body for product standardizations in Vietnam is operational.

3.2 Accredited Test Laboratories and Certification

Accredited test laboratories are independent laboratories that test the SWH systems for compliance with the national product standards. The manufacturers take a sample from the manufactured lot to these test laboratories to have them certified as conforming to the standards.

National certifying bodies are the organizations which certify the manufacturing facilities for complying quality standards of International Organization for Standardization. Few solar water heater manufacturers in the countries of interest have obtained or are in the process of receiving quality management certification[8].

3.2.1 Bangladesh

Renewable Energy Research Centre (RERC) of Dhaka University initiated its research activities on solar hot water systems in 1990 by manufacturing Thermosyphon solar hot water system at their facility. It continued refining skills in fabrication of SWH from locally available materials in Bangladesh. Understanding the need for testing SWH systems for its performance, 2003 onwards the centre is also involved in outdoor and indoor performance tests for flat plate type solar collectors.

RERC has designed and fabricated a SWH flat plate collector system of 60-400 Litre capacities with all local available materials and successfully tested the performance in July 2009. Bangladesh has a wealth experience in solar water heaters on laboratory scale, which is not commercialized rightly for its promotion.

[7] "GS1 Vietnam - Vietnam Standards and Quality Institute." [Online]. Available: http://www.gs1vn.org.vn/default.aspx?portalid=5. [Accessed: 27-Apr-2011].

[8] "Solar Products in Sri Lanka ~ Green Earth renewables (Pvt) Limited", n.d., http://www.greenearth.lk/products.htm.

Institute of Fuel Research & Development (IFRD)[9] has established a laboratory for conducting research & testing on solar, wind, and micro-hydro equipment to study the applicability for water pumping and generation of electricity in remote and off-shore islands of Bangladesh. The facility can be improved to test solar water heaters in future.

The Centre for Mass Education in Science (CMES)[10] was established in 1978 to create awareness among citizens of Bangladesh towards developments in science and technology. Later on CMES started solar energy related activities through its field offices. It has established its “Solar Lab” in 2000-01 to take up adaptive research on accessories of solar PV systems, solar cookers, solar water heaters and solar dryers. CMES is one of the country’s focal agencies in the “RET in Asia Program” funded by Swedish International Development Cooperation Agency (SIDA).

3.2.2 Sri Lanka

Sri Lanka does not have any approved solar water heaters testing laboratories within the country. However, the National Engineering Research and Development (NERD) [11] is instrumental in fabrication of SWH from locally available materials and also have all the facilities required for testing of the units.

3.2.3 Thailand

Following the development of in-country manufacturing facilities of solar water heating systems, a few testing facilities for testing solar thermal collectors (indoor and outdoor) have been developed at Asian Institute of Technology (AIT), King Mongkut’s University of Technology Thonburi (KMUTT), School of Renewable Energy Technology (SERT) in Phitsanulok province and Chiang Mai University (CMU). The facilities are intermittently operational according to the production level of collectors. It is not mandatory for the manufacturers to conduct performance and reliability tests at national certified test institutes with which some of the manufacturers are taking privilege of skipping the tests for their products.

Asian Institute of Technology (AIT): The test method adopted in AIT is called a ‘transient test method’ which is more suitable to meteorological conditions in Thailand. This outdoor

9 “BCSIR”, n.d. http://www.bcsir.gov.bd/inst_ifrd.php.

10 “Welcome to CMES”, n.d. http://cmesbd.org/.

11 “National Engineering Research and Development Centre of Sri Lanka”, n.d., http://www.nerdc.lk/en/index.html.

collector test method was developed by Prof. Supachart Chungpaibulpatana in 1988. The test requires a simple fixed test rig and focuses on a special evaluation algorithm. Unlike the standard collector performance tests which require continuous high radiation level for days, this test can be performed during overcastted sky days.

A simple one-node heat capacitance model is used to characterize the collector thermal performance. In the experiment, the collector inlet and outlet are connected in a closed circuit by a tube equipped with a circulating pump and the fluid inside the whole system is circulated at a very high flow rate.

King Mongkut's University of Technology Thonburi (KMUTT): Using the Solar Simulator and Outdoor Test, Ms. Sawitri Chuntranulak and Prof. Prida Wibulswas from KMUTT developed testing method for Domestic Solar Water Heating System.

School of Renewable Energy Technology (SERT): The study at SERT is focused on "Suitable Meteorological Condition for Solar Collector Performance Testing for Thailand"

Chiang Mai University (CMU): CMU researchers have studied on the performance of solar collector in the north region of Thailand.

3.2.4 Philippines

The University of the Philippines Solar Laboratory (UPSL) established in 1989 is the major testing facility for solar water heaters in the Philippines. It was established to institutionalise the technical, education, research, policy and market support of renewable energy (RE) in the Philippines. Research activities include primarily the adaptation and localization of renewable energy technologies to suit the Philippine situation. It has been developing and evaluating the techno-economic performance of solar water heaters and market delivery mechanisms of the technology in the Philippines.

3.2.5 Vietnam

There is documented record of research activities and testing facilities for solar water heaters in Vietnam.

Below is the available list of test facilities for SWH systems in the chosen five countries under the project.

Test facility	Type of tests
Bangladesh	
Renewable Energy Research Centre (RERC) - Dhaka University	Indoor and outdoor performance test for flat plate solar collectors (services not available for manufacturers, only research purpose)
Sri Lanka	
National Engineering Research and Development (NERD)	Indoor and outdoor performance test for flat plate solar collectors (services not available for manufacturers on continuous basis, only for research purpose)
Thailand	
Asian Institute of Technology (AIT)	Commercial performance testing of solar flat plate glazed collectors using outdoor transient test method
King Mongkut's University of Technology Thonburi (KMUTT)	Indoor and outdoor tests and solar simulator for solar flat plate glazed collectors
School of Renewable Energy Technology (SERT), Narasaun University (NU)	Outdoor test method for solar flat plate glazed collectors
Chiang Mai University (CMU)	Outdoor test method for solar flat plate glazed collectors
Philippines	
University of the Philippines Solar Laboratory (UPSL)	Indoor and outdoor performance test for flat plate solar collectors & components (services not available for manufacturers, only research purpose)

4 PLANNING, INSTALLATION AND MAINTENANCE

In addition to quality assurance in manufacturing, proper site planning, installation and periodic maintenance are equally important for sustained life of the systems. Uptake of Solar water heaters in Thailand is an example; because of improper planning, installation and maintenance over the years (during 1990-2000), the users have lost faith in the technology which affected the sales of the SWH systems in the country.

4.1 Accreditation /Certification of Planners or Installers

Realizing the need for adoption of best practices for planning and installation of solar water heating systems, countries like Thailand started training and certification program for the workmen.

4.1.1 Thailand – Training of Solar Thermal Systems for Engineers and Technicians

Department of Alternative Energy Development and Efficiency (DEDE) and German Technical Cooperation (GTZ) jointly conducted training course on *"Design, Installation and Maintenance of Solar Thermal Systems for Engineers and Technicians"* in January - February 2011. The program was a Train-the-Trainer program and the participants ultimately will become the trainers to train a cadre of planners and installers in the country.

Except Thailand, rest of the four countries found not to have conducted any such programs.

4.2 Commissioning & Certificate of Installation

Currently none of the five countries – Bangladesh, Philippines, Thailand, Sri Lanka and Thailand have mandate/requirement to get certified before commissioning the solar water heating system. Once the installation is done, the service provider themselves checks the proper working of the system and then is commissioned.

5 SUMMARY

The following table summarises the present condition of SWH product standards in these countries under reference and the recommendations for each.

Parameter		Bangladesh	Sri Lanka	Thailand	Philippines	Vietnam
SWH Standards	Present Condition	Not available	Under Development	Standards available but not mandatory[12]	Standards available but not mandatory[13]	Not available
	Recommendation	First establish Standards borrowing them if necessary from other countries with similar conditions of climate, economy etc., then set up a mechanism to implement the standards.	First establish Standards borrowing them if necessary from other countries with similar conditions of climate, economy etc., then set up a mechanism to implement the standards.	Set up a mechanism to implement the standards.	Set up a mechanism to implement the standards.	First establish Standards borrowing them if necessary from other countries with similar conditions of climate, economy etc., then set up a mechanism to implement the standards.
Accredited test	Present	Not available for	Not available for	Available[14]	Available	Not available

[12] Source: Soltherm Thailand project report funded by EU-Thailand Economic Cooperation Small Project Facility (EU-SPF)

[13] Refer Section 3.1.2 of the report for details & sources of information

[14] Source: Information received from “STA - Solar Thermal Association”, n.d., http://www.stasolar.org/.

laboratories	Condition	testing individual manufacturer's products	testing individual manufacturer's products			
	Recommendation	Upgrade the services at the existing testing facilities for testing individual manufacturer's products on regular basis.	Upgrade the services at the existing testing facilities for testing individual manufacturer's products on regular basis.	Upgrade or expand the testing facilities to ensure completion of testing in short time	Upgrade or expand the testing facilities to ensure completion of testing in short time	Develop testing facilities for product testing in the country
Accreditation of planners/installers	Present Condition	Not available	Not available	2 training programs (2010 & 2011)[15]	Not available	Not available
	Recommendation	Institute a plan to train planners and installers on best practices	Institute a plan to train planners and installers on best practices	Institute a plan to train planners and installers on best practices	Institute a plan to train planners and installers on best practices	Institute a plan to train planners and installers on best practices

[15] Source: Information received from DEDE, Thailand