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Solar Hot Water Standards and Certifications – Pathways to 2030

IEA SHC TASK 69 | SOLAR HOT WATER FOR 2030

Technology Collaboration Programme
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Solar Hot Water Standards and Certifications – Pathways to 2030

A SHC Task 69: Solar Hot Water for 2030 Report

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Solar Heating & Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is: *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56,
- 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

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1 Executive Summary

In the past, solar hot water (SHW) systems were mainly designed using traditional solar thermal collectors, specifically thermosyphon collectors. However, new technologies, for example PV to heat systems (PV2heat) and smart components, are promising to enhance the overall performance and decrease the system capital cost. This creates the need to develop new standards, add new technologies/configurations, and revise the current standards.

This report focuses on the current international series of standards for SHW systems, ISO 9459, and how to improve and revise the standards to cover all existing and new technologies for reliability, durability, and performance, focusing on thermosiphon and PV2heat solar water heaters (SWH). Further, the status of selected Quality Certification networks is included in this report.

The investigation shows that the existing international Standards for SHW systems, ISO 9459, cover thermosyphon systems, but not yet PV2heat systems.

2 Solar Water Heaters in focus

Below, examples of the solar water heaters (SWH) in focus are displayed. Other system configurations than the ones shown here for the system types in focus may exist.

a. *Thermosyphon SWH with evacuated tubular and flat plate solar collector*

b. *SWH with immersed electrical heating element(s) and PV panels*

c. *SWH with split air source heat pump and PV panels. Heat pump and hot water tank in one unit*

d. *SWH with PVT panels. Heat pump and hot water tank in one unit. Thermal part of PVT connected to the heat pump evaporator*

3 Certification basics

The importance of standards must be understood together with the word “certification”. When a product is mentioned as “certified”, it means that some agency or company can guarantee that the product fits one or more requirements given by a standard. In most cases, products are certified only when the client demands them to be. The client can be a particular person, company, or the government itself by means of public policy or regulation.

In most cases, there are no barriers to trading solar water heaters when there is no certification demand. The need arises when a certificated solar hot water system is required, either by public policy or by a particular person or company.

When solar water heaters are included in a public policy or promotion or benefit schemes, they are usually required to be "certified", that is, to fit a specific series of requirements given in a standard. So, to be certified, several basic things are needed as described below:

- **Standards**. Two types of standards are needed. First, ones that specify the requirements that must be met. Second, the methods to test the product's fitness to those Standards.
- **Laboratories (public or private)**. The laboratories perform tests according to the test standards and issue a test report with the results.
- **Certification bodies, companies, or agencies**. A private or governmental agency that uses the standards and the test reports to check if the product fits the requirements, also known as "conformity assessment". If everything goes fine, they issue the final "Certificate," and hence, the product is certified.

When a product is required to fit several standards, it is usual to find the word "label". The famous energy efficiency label means that a product complies with several standards. In the same way, the "Solar Keymark" label, for example, implies that a solar water heater has been tested under several standards and has been successfully approved to meet all of them.

In this way, it is usual that Europe allows only "Solar Keymark" certified equipment in their benefit schemes or SRCC certification in the case of the USA Other labels or similar schemes are in place in different countries.

The problem or barrier arises when a solar water heater that is already certified under one of the systems is required to be certified under another system to be included in a public benefit scheme. For example, a benefit scheme in a Latin American country (LAC) demands local certification of national standards and does not recognize other certificates or certified labels such as "Solar Keymark" or "SRCC," thus imposing the need for a new certification for the supplier, doubling certification costs.

Regarding testing, one may ask what is the guarantee that the laboratory is performing the test in agreement with the standards, with calibrated instruments and professional staff? Furthermore, how can one be sure the certifying agency effectively checks true compliance with standards? The answer is that both need to be "accredited", meaning that they must be checked annually by a national accreditation agency, which in turn is required to be accredited under the international accreditation entity. This is called "Quality Infrastructure", meaning that all parties involved in the certification scheme are checked or verified by third parties, allowing transparency in the value chain.

Any country may use the scheme mentioned or any other equivalent system. Instead of accredited laboratories or certifying agencies, a university laboratory and national government dependencies may be used. Nevertheless, national systems where one agency performs more than one of the tasks, such as being a laboratory and certifying agency at the same time, or being the normalization, testing, and certification agency, are usually not impartial. The entire quality system is based on different tasks performed by individual checked third parties. If one agency is responsible for the three things, there is no control over them, and thus, all results can be invalid.

Personal competencies or capacities can also be certified under the same scheme, provided the existence of a standard, a testing body, and a certification body.

Finally, until public policy or a specific customer requirement demands it, standards certification is voluntary. Nevertheless, certified products can differentiate from the rest of the products in the market, highlighting their certified durability, reliability, and performance.

In this way, solar water heater certification can be voluntary or mandatory, depending on the context of each country.

A basic scheme for product certification is shown in Figure 1.

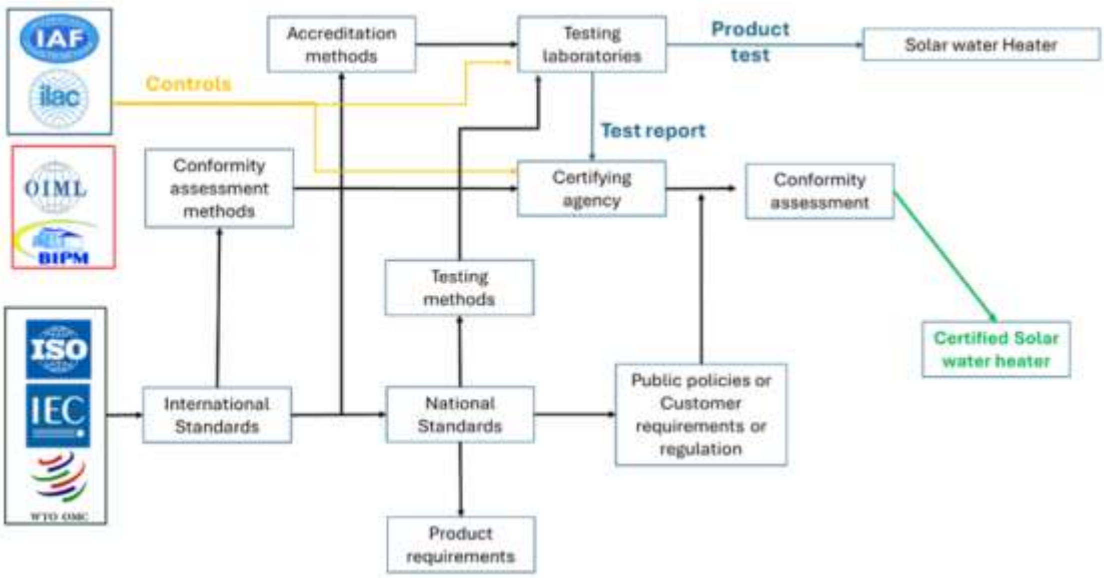

Figure 1: Basic scheme solar water heater certification scheme.

4 Standards for Solar Water Heaters

4.1 About National and International Standards

National standards are specific to the needs of a particular country or industry [1]. They are usually developed by a single organization, often a government agency [2]. For example, in the United States, many diverse types of organizations can develop national standards, with the American National Standards Institute (ANSI) serving as the designated administrator [2].

International standards are developed to ensure consistency, safety, and quality across countries and industries [1]. They are developed by international standards organizations like the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) [3]. Any ISO member country can propose a new standards development project, which can move forward if supported by enough additional ISO member countries [2]. International standards are the reference for national standards.

International standards are needed even if national standards exist for several reasons:

- Ensure that products, services, and systems work together seamlessly, which is particularly important in a globalized world [3].
- Overcome technical barriers in international commerce caused by differences among technical regulations and standards developed independently by each nation, national standards organization, or business [3].
- Consumers can have confidence that their products are safe, reliable, and of good quality [4].

After the ISO standards development process, a country may choose to adopt the ISO standard as its national standard, and the ISO standard obtains a prefix to associate it with that region. For example, when the European Union adopts an ISO standard, it becomes EN ISO. A country may also make country-specific amendments to the ISO standard to provide sufficient specificity for implementation or to reflect the unique needs of its government, industries, and economy [2]. This allows for a balance between global consistency and local relevance.

4.2 International Standards

The ISO 9459 standards were developed under the ISO Technical Committee 180 (ISO/TC 180). The work of ISO/TC 180 is undertaken in subcommittees and working groups utilizing the skills of experts from participating countries and input from observing countries [5].

The standards were developed to facilitate international comparison of solar water heaters. Since a universal performance model that applies to all systems has not been established, achieving international agreement on a single test method and a standard set of test conditions has been challenging. As a result, the decision has been made to disseminate the currently available simple test methods while efforts are ongoing to complete the broader applicability procedures.

There are five standards in the ISO 9459 series for solar water heaters, of which four are valid today. The third standard in the series, Part 3: Performance test for solar plus supplementary systems, has been withdrawn.

ISO 9459-1:1993 – Domestic water heating systems – Part 1: Performance rating procedure using indoor test methods

The test performed according to this standard is characterized as a rating test that allows for comparing different systems using a test period of one day, a standard day where systems are compared under identical solar, ambient, and load conditions. The test is performed indoors with a solar simulator.

The advantage of this approach is that every system is tested under the exact same conditions, making comparing one system's performance to another very easy. The disadvantage of this approach is that the test must be conducted on every system design configuration and under every set of weather and load conditions that the comparison desires [5].

The standard does not apply to systems of more than 0.6 m^3 of solar storage capacity, integral collector storage (ICS) systems, thermosyphon systems, systems employing a collector heat transfer fluid combination that cannot be tested following the collector test, systems operated in freeze protection mode, individual component test and the standard is not generally applicable to concentrating or evacuated tube systems, mainly because of difficulties producing a uniform irradiance level across the solar collector area at different incidence angles using a solar simulator.

ISO 9459-2:1995 – Domestic water heating systems – Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems

The test performed according to this standard is characterized as black box correlation procedures, with no assumptions about the system type, for performance rating for a range of system loads and operation conditions, but only for an evening draw-off. The test produces a family of input-output characteristics for the system that may be used directly with daily mean values of local solar irradiance and ambient air and cold-water temperatures to predict annual system performances.

Although the test offers the ability to predict system annual performance based on daily mean data for ambient air temperature, solar radiation, and water mains temperature through a correlation procedure used to simulate the performance of all system configurations, specific details of a system's configuration cannot be simulated to determine their impact on overall system performance [5].

The standard applies to thermosyphon systems. However, as prescribed by the standard, pressurized cold water injection into the system is not suitable for unpressurized systems.

The standard does not apply to systems of more than 0.6 m^3 of solar storage capacity, systems operated with auxiliary boosting or individual component tests, and the standard does not generally apply to concentrating or evacuated tube systems. Further, the energy consumed or lost by a system while operated in freezing mode is not determined following this standard.

ISO 9459-4:2013 – Domestic water heating systems – Part 4: System performance characterization by means of component tests and computer simulation

The test performed according to this standard prescribes a system performance characterization employing individual component tests and computer simulations. This approach allows for determining the annual performance of a differently sized but identical system configuration with limited effort. The standard does not prescribe a specific computer simulation software but states that the selected simulation program should be flexible and capable of modelling the diverse array of renewable energy water heaters utilized globally. One option for such a flexible simulation program is TRNSYS.

Currently, standard TRNSYS Deck templates are available, but only in Australia.

The Australian and New Zealand "standards" AS/NZS 4234:2021 "Heated water systems — Calculation of energy consumption" and its companion document SA/SNZ MP 104:2021 "Modelling of heated water systems in accordance with AS/NZS 4234:2021, using TRNSYS" includes template TRNSYS Decks that cover a range of solar and heat pump water heaters that could be used with the ISO 9459-4:2013 methodology.

Supplementary durability tests might be necessary to guarantee the smooth functioning of the entire system. These tests would assess the system's operation under extreme conditions like freezing or overheating, following relevant standards.

The standard also outlines a method for assessing the performance of traditional electric and gas domestic water heaters. This allows for the energy efficiency of solar and heat pump water heaters to be compared to conventional water heaters operating under identical annual load tasks.

The standard applies to custom-built and most factory-made systems but is unsuitable for a few factory-made systems where the key components, such as the solar collector and the tank, cannot be tested individually.

ISO 9459-5:2007 – Domestic water heating systems – Part 5: System performance characterization by means of whole-system tests and computer simulation

The testing performed according to this standard prescribes dynamic testing of a complete system to determine the system parameters to be used in a special parameter identification and yearly performance simulation software package that has been validated for a defined set of system configurations.

The software requires an operating system not higher than Windows XP and specific training to use it. The software cannot be modified by the user for other system design configurations. The software is calibrated with data from a Dynamic System Testing Program (DST) in which the system's thermal performance is measured. For those system designs where it has been validated, hourly weather and water mains temperature data for any climate can be used to predict annual system performance [5]. The limitations of the software have been recognized for many years. However, the resources to upgrade it haven't been available.

The standard aims to minimize experimental effort and uses a "black box" approach without measurements inside the storage and solar collector loop and no requirements for steady-state operation conditions. Given the limited experimental data, the simulation tool is used to maximize the extraction of information from the test data through a parameter identification process. The simulation tool must also be robust enough to prevent distortion by unimportant transient effects.

The system tested must be driven into as many operational stages as occurs in the actual operation in a minimum time, and the system must "forget" the conditions from one stage to the next. Consequently, testing may take a long time, especially in-situ testing.

The standard applies to systems with forced circulation of fluid in the solar collector loop, thermosiphon systems, and integral collector storage (ICS) systems. The draw-off volumes depend on the storage volume (Vs) and the ratio between the storage volume and the solar collector area (Vs/Ac). The solar collector area must be between 1 and 10 m^2. If larger, additional validation tests are prescribed. The storage capacity must be between 0.5 and 1 m^3, and the specific volume between 0.01 and 0.2 m^3 per m^2 solar collector aperture area.

The standard does not apply to

- Individual component tests. However, it is permitted to obtain test data of components in combination with a test according to the procedure described in the standard.
- Systems containing more than one storage tank. This does not exclude preheat systems with a second tank in series. Here, only the first tank is part of the system tested
- Integral auxiliary solar systems with a proportion of the auxiliary heated volume > 0.75 of the tank volume
- External load-side heat exchanger in combination with a temperature-dependent pump

In summary, the ISO 9459 series of standards are very old and only partly cover today's technologies on solar water heaters. Meanwhile, some national standards have been designed to cover today's technologies. Therefore, reviewing national standards may provide the perfect foundation for updating the ISO 9459 standards.

ISO 9806:2017 – Solar thermal collectors - Test methods

ISO 9806:2017 specifies test methods for assessing the durability, reliability, and safety and for measuring the thermal performance of liquid and air-heating solar collectors. The test methods are applicable for laboratory and on-site tests. The standard applies to all types of liquid-heating solar collectors, air-heating solar collectors, hybrid solar collectors that simultaneously generate heat and electricity (only the thermal part is covered, but not for all thermal operation modes like ice, condensation, and indirect ambient heat gains), and to solar collectors that use external power sources for normal operation and/or safety purposes. This standard is, therefore, applicable to practically all known solar thermal collector types. If the heat storage is an integral part of the collector to such an extent that the collection process cannot be separated from the storage process when measuring the thermal performance of the collector, the collector must be tested as a system, normally to one of the ISO 9459 standards.

The standard deals exclusively with test methods and the presentation of the results of these tests. No pass/fail criteria or thresholds are defined. Such pass/fail criteria shall be defined in supplementary standards, in certification programs, or in other similar documents that refer to the test methods of ISO 9806.

The ISO 9806 is in revision, and it is expected that the next version (2024/2025) will include also a mandatory assessment of the materials used and of the product repairability.

4.3 European Standards

The European Committee for Standardization CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at the European level [6].

The European standards for solar water heaters are:

- Solar energy – Vocabulary (**EN ISO 9488**). The standard specifies basic terms for solar energy utilization in different solar thermal products, including solar water heaters. The solar thermal products specified here are eligible for testing according to the EN standards.
- Solar thermal collectors (**EN 12975)**. The standard defines the European requirements for solar collectors based on testing according to ISO 9806.
- Factory-made (prefabricated) solar thermal systems (**EN 12976-1 and EN 12976-2**). These standards specify factory-made solar heating systems' durability, reliability, and safety requirements. They also include test methods for validating these requirements. The performance rating is based on testing according to ISO 9459-4 or ISO 9459-5.
- Custom-built systems (**EN 12977-1 and EN 12977-2**). These standards specify the durability, reliability, and safety requirements for custom-built solar heating and cooling systems. They also provide test methods for performance characterization.
- Solar water heater stores (**EN 12977-3**). This standard specifies test methods for the performance characterization of stores used in small custom-built solar heating systems. It applies to stores with a nominal volume of between 50 and 3,000 l.
- Solar combistores (**EN 12977-4**). This standard specifies test methods for the performance characterization of combistores used in small custom-built solar heating systems. It applies to combistores with a nominal volume of up to 3,000 l without an integrated burner.
- Control equipment (**EN 12977-5**). This standard specifies performance test methods for control equipment. It contains requirements on control equipment's accuracy, durability, and reliability.

The thermosyphon solar water heaters can be tested according to the EN Standards. PV2heat systems can, in principle, be tested according to the EN Standards if they are defined as solar heating systems in EN ISO 9488 Vocabulary and that the performance parameters of PV and other auxiliary components are evaluated by other test standards.

4.4 Chinese Standards

4.4.1 The SAC Standards

The standard body in China is the Standardization Administration of the P.R.C. (SAC). Technical Committee on Solar Energy Standardization of SAC (SAC/TC 402) is the Chinese Mirror Committee of ISO/TC 180. It is responsible for the standardization of solar thermal products such as：

- Solar thermal collectors,
- Collector components and materials
- Domestic water heating systems
- Solar cookers

Main standards published by SAC/TC 402:

For solar thermal collectors:

- **GB/T 4271-2021** *Test methods for the performance of solar collectors*. This standard specifies the test methods of solar collectors for pressure resistance, standard stagnation temperature, exposure, external thermal shock, internal thermal shock, rain, freezing resistance, mechanical load, impact resistance, thermal performance, and pressure drop. This standard applies to the laboratory and field tests of liquid mass collectors and PVT solar collectors (thermal part). This standard does not apply to thermal storage solar collectors where the storage heater and the collector are integrated, nor does it apply to solar collectors without transparent cover.
- **GB/T 6424-2021** *Flat plate solar collectors*. This standard specifies the symbols and units, product classification and labelling, technical requirements, test methods, inspection rules, signs, packaging, transportation, storage, and inspection reports of flat-plate solar collectors. This standard applies to flat-plate solar collectors that utilize solar radiation for heating and with liquid heat transfer mass.
- **GB/T 17581-2021** *Evacuated tube solar collectors*. This standard specifies the evacuated tube solar collector product symbols and units, product classification and labelling, technical requirements, test methods, inspection rules, signs, packaging, transportation, storage, and inspection reports. This standard applies to all-glass evacuated tube solar collector, glass-metal structure of evacuated tube solar collector and heat pipe evacuated tube solar collector that utilize solar radiation for heating with liquid heat transfer mass.

For collector components and materials:

- **GB/T 17049-2005** *All-glass evacuated solar collector tubes*. This standard specifies the all-glass evacuated solar collector product definition, classification, technical requirements, testing methods, inspection rules and signs, packaging, transportation and storage. This standard applies to all-glass evacuated solar collector that receive solar radiation and convert thermal energy.
- **GB/T 26975-2011** *All-glass heat pipe evacuated solar collector tube*. This standard specifies the all-glass heat pipe evacuated solar collector tube product definition, naming, technical requirements, testing methods, inspection rules, as well as signs, packaging, transportation and storage. This standard applies to all-glass heat pipe evacuated solar collector that receive solar radiation and convert and transmit thermal energy.
- **GB/T 40517-2021** *Solar thermal storage system for low and medium temperature applications*. This standard specifies the solar thermal storage system for low and medium temperature terminology and definitions, classification and labelling, general requirements, technical requirements, test methods, inspection rules, signs, manuals and certificates of conformity, packaging, transportation, and storage. This standard applies to heat storage devices that are mainly heated by solar radiation and have an operating temperature of less than or equal to 150℃ (302 ℉).

For domestic water heating systems:

- **GB/T 35606-2017** *Green product assessment- Solar water heating system*. This standard specifies the green solar water heating system assessment of terms and definitions, product classification and components, evaluation requirements, and evaluation methods. This standard applies to close-coupled, remote-storage, and integral collector-storage domestic solar water heating system green product assessment.
- **GB/T 18708-2002** *Test methods for thermal performance of domestic solar water heating systems*. This standard has been developed with reference to the international standard ISO 9459-2:1995 *Solar heating - Domestic water heating systems - Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems*. This standard specifies the procedure for testing the thermal performance of domestic solar water heating systems without auxiliary heating. This standard applies to domestic hot water systems with a hot water storage tank volume of 0.6 m^3 or less that only use solar energy. This standard is not applicable to the test of solar water heating systems with auxiliary heating.

- **GB/T 19141-2011** *Specification of domestic solar water heating systems*. This standard specifies the domestic solar water heating system terms and definitions, symbols and units, product classification and marking, design and installation requirements, technical requirements, test methods, inspection rules, documentation, packaging, transportation, and storage. This standard applies to domestic solar water heating systems with a hot water storage tank volume of 0.6 m^3 or less.
- **GB/T 25966-2010** *Specification of domestic solar water heating systems with electrical auxiliary heat source*. This standard is formulated with reference to the European standards EN 12976-1:2006 *Thermal solar systems and components - Factory made systems - Part 1: General Requirements* and EN 12976-2:2006 *Thermal solar systems and components - Factory made systems - Part 2: Test Methods*. This standard specifies the terms and definitions, product classification and labelling, technical requirements, test methods, inspection criteria, marking, packaging, transportation, and storage of domestic solar water heating systems with electrical auxiliary heat sources with a hot water storage tank volume of 0.6 m^3 or less.
- **GB/T 25967-2010** *Test methods for thermal performance of domestic solar-plus-supplementary water heating systems*. This standard is formulated with reference to the European standards EN 12976-1:2006 *Thermal solar systems and components - Factory made systems - Part 1: General Requirements* and EN 12976-2:2006 *Thermal solar systems and components - Factory made systems - Part 2: Test Methods*. This standard specifies the test methods for the thermal performance of domestic solar-plus-supplementary water heating systems under outdoor conditions. This standard applies to domestic solar-plus-supplementary water heating systems with hot water storage tank volume below 0.6 m^3.

4.4.2 The MOHURD Standards

The Technical Committee on Building Environment and Energy Efficiency Standardization of the Ministry of Housing and Urban-Rural Development of the P.R.C. (MOHURD) is responsible for the standardization of the design and construction of building HVAC and other service systems.

There are several standards related to solar thermal systems applied in buildings, such as solar water heating systems, solar heating systems, solar cooling systems, etc.

Main standards published:

- **GB 55015-2021** *General code for energy efficiency and renewable energy application in buildings*. This standard is a full-text mandatory specification, which contains relevant provisions for the design of renewable energy building application systems. The design, construction, acceptance and operation management of building energy efficiency and renewable energy building application systems for new construction, expansion and alteration of buildings as well as energy-saving renovation projects for existing buildings must implement this specification. This standard puts forward requirements for solar energy system installation, design, basic requirements, monitoring and measurement of relevant parameters, protective measures, design service life, collector efficiency and so on.
- **GB 50364-2018** *Technical standard for solar water heating system of civil buildings*. The development of this standard is to regulate the design, installation, project acceptance and routine maintenance of solar water heating system, so that the civil construction of solar water heating system is safe, reliable and stable, energy efficient, and building coordination and unity. This standard applies to new construction, expansion and alteration of civil buildings, as well as existing buildings and renovation of solar water heating system design, installation, acceptance and operation and maintenance.
- **GB 50495-2019** *Technical standard for solar heating system*. This standard is used to standardize solar heating and heating engineering design, construction, acceptance and evaluation, so that the solar heating and heating project is safe and suitable, economically rational, technologically advanced and reliable, and improve the quality of the project. This standard applies to the use of solar heating and heating in new buildings, expansion and alteration of buildings, as well as in existing buildings to add or remodeling of solar heating and heating facilities, systems of engineering design, construction, acceptance and evaluation.
- **GB 50787-2012** *Technical code for solar air conditioning system of civil buildings*. This standard is used to standardize the design, construction, acceptance and operation management of solar energy air-conditioning system, to achieve safe and applicable, economically rational, technologically advanced, and to ensure the quality of the project. This standard applies to the use of thermal refrigeration-based solar air-conditioning systems in new buildings, expansion and alteration of civil buildings, as well as in existing buildings on the renovation or addition of thermal refrigeration-based solar air-conditioning system projects.
- **GB/T 50604-2010** *Evaluation standard for solar water heating system of civil buildings*. This standard is used to standardize the evaluation of solar water heating systems for civil buildings. This standard applies to the evaluation of new construction, alteration and expansion of civil buildings on the use of solar water heating system, as well as in the existing civil buildings on the addition, remodeling of solar water heating system. Evaluation of solar water heating systems should be based on the principle of local conditions,

combined with the type of building and its geographical solar energy resources, natural environment, level of economic development, social customs and other characteristics of the evaluation.

- **GB/T 50801-2013** *Evaluation standard for application of renewable energy in buildings*. This standard is used to promote the healthy development of China's renewable energy building application cause, to guide the testing and evaluation of renewable energy building application project, the development. This standard applies to the application of solar thermal utilization system, solar photovoltaic system, ground source heat pump system of new construction, expansion and alteration of energy efficiency, environmental benefits, economic benefits of testing and evaluation.

GB 55015 is a technical code for buildings published in 2021. It is required that all new buildings must install Solar Energy Systems.

Not all the system types in focus, thermosyphon solar water heaters and PV2heat solar water heaters (i.e., heat pump, PVT collectors), can be tested according to the listed standards. Since many of the above standards were developed a decade ago, when there were relatively few types of solar water heaters on the market, and some types of water heaters (e.g., PV water heaters) were not yet available, there was a lack of relevant standards. According to the current development of solar water heating system products in China, some new standards are being prepared, such as:

NB/T XXXXX—20XX *Domestic photovoltaic water heater*. This standard specifies the classification and coding, technical requirements, test methods, inspection rules, marking and accompanying documents, packaging, transportation, and storage of domestic photovoltaic water heaters. It applies to photovoltaic water heaters with a single hot water storage tank and a water capacity of not more than 0.6 m^3.

This standard has not yet been published. Unlike ISO standards, Chinese standards only get a number when they are published. The standard is expected to be published in June 2025.

4.5 Australian Standards

Australian and New Zealand Standards Committee CS-028 *Solar Heating and Cooling* develops and maintains several standards relevant to the performance measurement and durability of solar and heat pump water heaters.

AS/NZS 2535.1:2007 "*Test methods for solar collectors, Part 1: Thermal performance of glazed liquid heating collectors including pressure drop (ISO 9806-1:1994, MOD)"* is a national standard that uses the method in the now revised ISO 9806 to characterise the performance of solar collectors. Whilst it has been superseded internationally, the method of performance testing and characterisation is still consistent with most other standards. Committee CS028 is planning to update this standard to the current version of ISO 9806

AS/NZS 4234:2021 "*Heated water systems — Calculation of energy consumption*" and its companion document **SA/SNZ MP 104**:2021 "*Modelling of heated water systems in accordance with AS/NZS 4234:2021 using TRNSYS*", are used to model the performance of solar, heat pump and PV2heat water heaters for a number of federal and state market support mechanisms that provide financial incentives based on the energy saved compared to conventionally fuelled (electric or gas) water heaters. The method is also used as a benchmark exempting solar and heat pump water heaters from Minimum Energy Performance Standards (MEPS) requirements that apply to conventional gas and electric water heaters. The method is a Component Test System Simulation (CTSS) that uses performance characteristics of components – Collectors AS 2535.1, heat pump units AS/NZS 5125, and tanks AS4692 together with controller, pump, and connecting pipework data to build a computer model that can be used to predict energy consumption performance of the system with different loads in different climatic conditions. An earlier version of this standard was the basis for ISO 9459 part 4. However, standard AS/NZS 4234 has been revised a number of times since the ISO standards were published, so it could be a basis for a future revision of ISO 9459 part 4.

SA/SNZ MP 104 includes template TRNSYS decks that cover a range of solar and heat pump water heaters that could be used with the ISO 9459-4:2013 methodology. An Australian extension to TRNSYS "**TRNAUS"** is required to run these templates.

AS 2984-1987 *Solar water heaters — Test for thermal performance — Outdoor test* is now Obsolescent[1]. It sets out a method of determining the thermal performance of a solar water heater under outdoor conditions and

[1] This indicates that the publication is no longer recommended for current practice, but it is retained to provide information on existing requirements.

prescribes a method of transforming the results into a performance characteristic capable of predicting performance at other loads and solar conditions. It is useful to provide a performance test of systems that can't be modelled or tested by other standardized methodologies. This is similar to the now withdrawn ISO 9459 part 3, which was based on AS 2984.

AS/NZS 2712-2007 *Solar and heat pump water heaters - Design and construction* specifies performance-based requirements for the design and construction of both components of solar and heat pump hot water supply systems, and complete systems, for household water heaters up to 700 litres of storage. This includes some tests that are like those in ISO 9806 so when ISO 9806 is taken up as an Australian standard the overlapping tests will likely be removed from AS/NZS 2712 to avoid duplication of test requirements for collectors.

System types covered. The system types in focus in this report are covered completely or to a large extent by these Australian Standards. Thermosyphon water heaters have been one of the main technologies primarily considered in developing all the standards, so they are comprehensively covered in design & construction as well as the performance of components and systems. PV powered water heaters are included in the system performance calculations undertaken in AS/NZS 4234, although the PV performance parameters and other auxiliary components need to be evaluated by other test standards. Heat pump performance is covered by AS/NZS 4234 using HP performance parameters derived by testing to AS/NZS 5125.1, and using PV to power heat pumps can be calculated in TRNSYS models.

4.6 Latin American Standards

There is no regional standard valid for all the countries in Latin America (LAC). It is rather a country-by-country policy application. In all cases or countries, the equipment that is sold in the private sector does not have the need to be certified. In some countries, the need for certification arises when solar thermal equipment is included in a public support or incentive program. The situation for technology is very different amongst all the LAC countries. Brazil and Mexico concentrate up to 50% of the region's population and have local SWH manufacturers and supply chains. The rest of the countries rely mainly on imported technology and supplies, except for a few isolated and distributed small-scale local factories, such as Argentina and Barbados.

Given this diverse coexistence of the region, standards, certification, and promotion rates or benefits are variable across the entire region.

4.6.1 Argentina

The National Normalization and Certification Institute (IRAM) oversees elaborating national technical standards in all technical issues. They are voluntary both for equipment manufacturers and importers and are based in a mixture of ASHRAE and ISO standards. The Argentina Accreditation Organism (OAA) oversees the accreditation of laboratories and certification organisms.

The current existing standards are:

- IRAM 210001-1: Solar collectors. Part 1 - Definitions.
- IRAM 210002-1: Solar energy. Solar collectors. Part 1 - Test methods to determine the thermal performance of covered solar collectors for heating liquids.
- IRAM 210003: Thermal accumulators. Performance determination methods thermal
- IRAM 210004: Solar energy. Sanitary water heating systems. Outdoor test methods for the characterization and prediction of the annual performance of solar systems
- IRAM 210005: Code of practice for the installation and operation of water heating systems, operating with solar energy.
- IRAM 210005-1-1: Solar energy. Water heating systems. Part 1-1 - Installation, commissioning and maintenance of compact solar thermal water heating systems
- IRAM 210007: Solar energy. Solar thermal collectors. Test methods
- IRAM 210008-5: Covers for solar collectors. Method for determining the solar transmission factor and the reflection factor of sheet materials
- IRAM 210015-1: Compact solar systems. Part 1 - General requirements
- IRAM 210022-1: Solar energy. Solar thermal collectors. Part 1 - General requirements
- IRAM 210023: Solar energy. Prefabricated forced circulation solar thermal systems. General requirements

4.6.2 Barbados

Barbados has voluntary solar water heater standards. Nevertheless, it is worth mentioning that they do not have testing laboratories and no certification obligation. Barbados' population is around 300.000 inhabitants. Quality control is made by the people themselves in a “mouth-to-mouth” manner. The current standards in solar water heating are all based on ASHRAE:

- BNS 147:1983: Specification for Methods of Thermal Testing of Flat Plate Collectors - contents: a. Scope – describes the test methods of thermal performance of flat plate solar water collectors, and in particular, thermal losses, collector time constant and thermal efficiency. b. Definitions c. Theory d. Experimental Conditions e. Experimental Procedure f. Test Results g. Reporting format.
- BNS CP 20:1983: Code of Practice for Solar Heating Systems for Domestic Hot Water. - contents: a. Scope – deals with Solar Heating Systems having a flat plate collector for heating water, for domestic purposes in single family dwellings. b. Basic principles of solar water heaters c. Design Considerations d. Installation e. Thermal performance.

4.6.3 Brazil

The National Metrology Institute of Brazil (INMETRO) oversees the technical standards. In addition to being the metrology entity of Brazil, INMETRO also has legal powers to establish the criteria and guidelines for conformity assessment activities, including requirements and test methods. In most countries, the standardizing entity, the accrediting entity, and the certifying entity are independent, guaranteeing impartiality in their actions. In this case, a single institution operates as all three. A priori, this may be an obstacle, but the case of Brazil has shown the opposite. The Brazilian regulations are essentially based on the EN-12975 regulations for collectors and EN-12976 for systems. The current standards are:

- ISO/DIS 9459-2 ISO 9459-2: Thermal performance test
- ABNT NBR 15747-2 (based in EN 12975): Internal pressure test; High temperature resistance test; Exposure test; Internal and external shock test; Large Exposure test; Ensayo Choque térmico interno y externo II; Rain penetration test; Mechanical load test (positive and negative pressure); Impact resistance test
- ASTM G155, complemented with other acceptance criteria: Accelerated aging test
- Anexo 4 de RTQ of resolution 301: Labelling test; Storage volume test; Hydrostatic pressure test
- NBR NM IEC 335-1, Chapter 16: Electricity resistance test
- ABNT NBR 14016: Current leak test
- ABNT NBR 14013: Absorbed power test
- NBR NM IEC 335-1, Chapter 30: Heat and fire resistance test
- NBR NM IEC 335-1, Chapter 31: Corrosion resistance test

4.6.4 Chile

Although Chile has INN (National Normalization Institute) and Chilean Standards regarding solar thermal technology, all public regimes of promotion and incentive programs use European regulations (EN) regarding certification. The main reason for this exception is the large amount of imported equipment. It is easier to define a policy based on international standards rather than on a country's own norms. According to the work (AETS, 2014), the proportion of nationally manufactured equipment with respect to imported ones was from 5% to 95% in 2014. Nowadays, as of 2024, it is 100% imported. A public promotion or incentive policy requiring compliance with specific national regulations for all imported equipment is equivalent to requiring double certification, generating additional and unnecessary needs in quality infrastructure. So, the basic procedure is to check that the imported goods are properly certified according to EN regulations.

4.6.5 Colombia

The Colombian Institute of Technical Standards and Certification (ICONTEC) has a wide and diverse range of standards referring to solar water heaters based on EN 12975, EN 12976 and ASHRAE standards. Its origin dates to the 80s when the crisis in oil prices generated a boom in solar thermal energy in Colombia. However, there are no regulations or official requirements regarding compliance with them. The current standards are:

- NTC 5434-1: Solar thermal systems and components. Solar collectors. Part 1. General requirements
- NTC 5434-2: Solar thermal systems and components. Solar collectors. Part 2: test methods
- NTC 1736: Solar energy. Definitions and nomenclature
- GTC (Guía técnica colombiana) 108: Solar energy. Specifications for solar water heating systems intended for domestic use
- NTC 4368: Energy efficiency. Solar thermal systems and their components

- NTC 2631: Solar energy. Measurement of photometric transmittance and reflectance in materials subjected to solar radiation
- NTC 2774: Evaluation of thermal insulating materials used in solar collectors
- NTC 3322: Rubber seals used in flat plate solar collectors
- NTC 3507: Installation of solar-powered domestic hot water systems
- NTC 5291: Domestic solar water heating systems (heat transfer from one liquid to another)
- NTC 5709: Analytical expression for daily solar profiles

4.6.6 Mexico

In Mexico, the National Consultative Committee for Standardization for the Preservation and Rational Use of Energy Resources (CCNNPURRE, its acronym in Spanish), dependent on the Ministry of Energy, is the entity in charge of standardizing thermal solar heating. This Committee develops the official mandatory standards of the country, that is, the technical regulations that allow promoting quality by establishing rules, specifications, and product characteristics.

According to its application regime, the Mexican federal law on metrology and standardization distinguishes two types of standards (Campos, 2016):

- Official Mexican Standards (NOM) of mandatory application
- Mexican Standards (NMX) of voluntary application

The law determines the purpose of the official Mexican standards (NOM) to establish the characteristics and/or specifications that products and processes must meet when they may constitute a risk to the safety of people or harm the human, animal, plant, general and work environment, or for the preservation of natural resources.

Since establishing the mandatory nature of a standard requires complex treatment, typically, a regulation is adopted voluntarily (NMX), and then with the experience of this, the NOM is developed once the market is ready.

NMX standards are issued by the Mexican Society for Standardization and Certification (NORMEX) through the National Standardization Technical Committee for Solar Energy (NESO-13).

The Mexican Accreditation Entity (EMA) is the one delegated the power to accredit laboratories, product certification bodies and inspection bodies.

Current mandatory and voluntary standards are:

- NOM-027-ENER/SCFI- 2018: Thermal performance, gas savings and safety requirements for solar water heaters and solar water heaters backed up by a water heater using L.P. gas or natural gas as fuel. Specifications, test methods, and labelling
- NMX-ES-001-NORMEX-2018: Solar energy – Thermal performance and functionality of solar collectors for liquid heating – Testing and labelling methods
- NMX-ES-002-NORMEX-2007: Solar energy – Definitions and Terminology
- NMX-ES-003-NORMEX-2021: Solar energy – Minimum requirements for the installation of solar thermal systems for water heating
- NMX-ES-004-NORMEX-2010: Solar energy – Thermal evaluation of solar systems for water heating – Test method
- NMX-ES-J-005-NORMEX-ANCE-2015: Solar energy – Field pyranometers – Recommended practice of use
- NMX-ES-J-9060-NORMEX-ANCE-2015: Solar energy – Specification and classification of instruments to measure the hemispheric solar radiation and the direct solar radiation
- NMX-ES-J-9845 –1- NORMEX-ANCE-2015: Solar energy – Reference solar spectral irradiance on the earth at different receiving conditions – Part 1: Direct solar normal and hemispheric irradiance for air mass 1.5
- NMX-ES-J-9846-NORMEX-ANCE-2015: Solar energy – Calibration of a pyranometer using a pyrheliometer

4.6.7 Uruguay

Since 2008, Uruguay has developed all the appropriate regulations to correctly develop quality infrastructure. In the ETUs (Uruguayan Technical Specification, from Spanish, Especificaciones Técnicas Uruguayas), the relevant regulations are cited as a reference either for the requirement or for testing. The current standards are:

- UNIT 1185:2009: Solar thermal systems and components. Prefabricated systems. Requirements

- UNIT 705:2009: Solar thermal systems and components. Solar collectors, requirements
- UNIT 1195:2012: Solar thermal systems and their components. Custom installations
- UNIT-ISO 9459-2:1995: Solar heating. Sanitary water heating systems. Part 2: Outdoor test methods for the characterization and prediction of annual performance of solar systems
- UNIT-ISO 9806-1:1994: Test methods for solar collectors. part 1: thermal performance of collectors with liquid heating glass considering pressure drop
- UNIT-ISO 9806-2:1995: Test methods for solar collectors. Part 2: Qualification Test Procedures
- UNIT-ISO 9806-3:1995: Test methods for solar collectors. Part 3: thermal performance of collectors without liquid heating glass considering pressure drop (sensible heat transfer only)
- UNIT-ISO 1184:2010: Solar thermal systems and components. Prefabricated systems. Test methods
- UNIT-ISO 1196:2012: Solar thermal systems and their components. Custom installations. Test methods

Most of the standards for collectors, tanks, and systems are based on EN 12975:1, EN 12975:2, EN 12976:1, EN 12976:2, and ISO 9806 and 9459. The modifications to the rules of origin lie in small differences on which it is necessary to intervene. For example, UNIT 1184 defines the climatic and irradiation conditions under which it is necessary to test the prefabricated system according to the UNIT-ISO 9459:2 method.

4.7 US Standards

The International Code Council (ICC) produces model building codes and standards for building products used in the U.S. and several other countries. ICC is the parent company of the Solar Rating & Certification Corporation (ICC-SRCC), which certifies solar heating and cooling equipment in North America. ICC and SRCC collaborate to develop several American National Standards (ANS) under ICC's ANSI-approved standard development procedures for solar thermal systems and components. These standards are referenced in various building codes, regulations, incentive programs, and other standards in North America.

The ICC/SRCC standards for solar thermal products are:

- Solar thermal collectors (**ICC 901/SRCC 100)**. The standard defines minimum requirements for solar collectors and performance testing according to ISO 9806. It includes all major collector types for heating water and air, including PVTs (Thermal part). Compliance with the standard is required for SRCC OG-100 certification. The latest edition was published in 2020, and it is expected to be updated in 2025.

- Solar water heating systems (**ICC 900/SRCC 300**). The standard specifies minimum requirements for durability, reliability, and safety of solar water heating systems, both field and factory-made types. They also include test methods for validating these requirements. Some information on Uniform Energy Factor (UEF) performance ratings for comparison with gas and electric water heaters is provided in an optional appendix. The standard and optional UEF ratings include definitions and provisions for both thermosyphon and PV water heaters. Compliance with the standard is required for SRCC OG-300 certification. The latest edition was published in 2020, but it is currently under revision and review for publication in late 2024 or early 2025.

- Solar pool heating systems (**ICC 902/PHTA 902/SRCC 400**). The standard sets minimum requirements for the safety, durability, and reliability of solar pool heating systems. It references ICC 901/SRCC 100 requirements for collectors and applies to residential and commercial swimming pools, spas and hot tubs. It does not provide performance ratings. SRCC provides compliance assessments to the standard under its Listing Program.

- Solar tanks (stores) (**ICC 903/SRCC 500**). This standard sets minimum requirements for the durability, reliability, and safety of solar tank components used in solar water heating systems. It applies to pressurized and unpressurized tanks and includes provisions for tanks with integral heat exchangers and supplemental heaters. It provides a method for characterizing the thermal capacity of the tank. Performance test methods are addressed in an optional appendix. It will be the basis of a new certification program for tanks to be offered by SRCC later in 2024 for use with the OG-300 program. The new standard was first published in 2024.

4.8 Canadian Standards

The CSA Group (former Canadian Standards Association, CSA) is the Standard development organization in North America. It is divided into two sub-organizations: Standards and Testing and Inspection and Certification.

Canada developed a comprehensive set of standards for solar thermal systems that were released nationally in 1988. These included durability, safety, and test and rating methods for solar thermal collectors (CAN/CSA F378) and packaged solar thermal systems (CAN/CSA F379.1 and F379.2). Since then, the standards for packaged solar domestic hot water (SDHW) systems have been consolidated into CAN/CSA F379 Series-09 (R2024). In addition, the CAN/CSA-F383-08 (R2024) specifies the installation requirements for systems that meet the requirements of the CSA F379 Series.

Solar thermal standards in Canada have primarily focussed on "Indirect" forced flow systems due to the requirement to operate during freezing winter conditions. Drain-back or drain-down configurations are permitted, although most packaged domestic hot water systems rely on non-toxic anti-freeze solutions in a forced-flow collector circulation loop with a heat exchanger to deliver heat to a thermal storage (e.g., water tank). There are currently no standards covering the thermal performance testing of systems and collectors operating under natural convection circulation (e.g., thermosyphon systems). However, requirements for durability and safety may apply.

Solar Collectors. CAN/CSA-F378 Series-11 (i.e., CSA F378.1-11 and F378.2-11) superseded the previous F378 collector standard to address both *Glazed and Unglazed Liquid Heating Solar Collectors, and Air Heating Solar Collectors, respectively.* CSA F378.1-11 also included provisions for testing glazed vacuum tubes and integral collector-storage (ICS) systems, as well as some concentrating collectors. Testing included thermal performance, high pressure leakage, uniform positive and negative loads, rain penetration, high temperature resistance, thermal shock, and exposure, etc. However, due to the high cost of certification to CSA F378, it was withdrawn in 2016. In its absence, most local jurisdictions usually accepted certification under SRCC OG 100.

Packaged Solar Domestic Hot Water Systems. The CSA F379 standard was introduced for packaged solar thermal systems in 1988. This standard outlined physical tests for performance, durability, and safety. System-level thermal performance tests were specified according to "standard day" irradiance profiles, wind and ambient air temperatures. Hot water draw-off volumes and draw schedules were prescribed based on Canadian conditions. Packaged systems were to be tested under quasi-steady-state conditions in the large-area solar simulator at the Canadian National Solar Test Facility (NSTF). Scaling of solar collector arrays was allowed through the use of slave heaters, allowing large systems to be evaluated. This series included a simple calculation for converting "standard day" results into a prediction of seasonal performance for locations in Canada.

The current CAN/CSA F379 Series-09 (R2024), "Packaged solar domestic hot water systems (liquid to liquid heat Transfer)" consolidated Can/CSA F379.1 and F379.2 into one document and was modified to include year-round (freeze tolerant) and *Seasonal Use* systems (SSDHW) that are not intended to be operated in freezing conditions. This standard was reaffirmed in 2024 and is currently in effect. However, the NSTF was decommissioned in March of 2024 due to its high running cost and reduced demand.

Current Activities. The National Building Code of Canada references the CAN/CSA F379 standard for packaged domestic solar water heating systems and requires that all solar thermal collectors used in these systems comply with CAN/CSA F378. Faced with the closure of the main testing facility capable of performing the standard day ratings described in the F379 series, the CSA F379 Technical Committee has convened to revise the standard. The goal of this activity is to harmonize F379 with other North American and International standards, such as ICC 901/SRCC 100 and 300. Consistent with this approach, the revised CSA standard should allow packaged solar systems to be rated by computer modelling as well as full-scale testing. However, physical testing of solar collectors still be required. Where possible, uniform requirements for durability and safety will be harmonized.

A proposed addition to the new CSA F379 standard is the requirement for pre-engineered, site-constructed solar systems (i.e., not factory prepackaged). Minimum requirements will be included for components, including the solar collectors, but system approval will be primarily based on meeting the requirements of the local jurisdictions, e.g., municipal, provincial, and national, where applicable. It is hoped that this would provide a pathway to certification for site-engineered systems and accommodate differing system designs and load scenarios.

The revised CAN/CSA-F379 document should be issued for public review and approval early in 2025.

4.9 Sub-Saharan Africa Standards

There is no regional standard valid for all the countries in Sub-Saharan Africa region, although they have regional groupings such as Central Africa, East Africa, West Africa, and Southern Africa. It is rather a country-by-country policy application. In all cases or countries, the equipment that is sold in the private sector does not have the need to be certified. In some countries, the need for certification arises when solar thermal equipment is included in a promotion regime or benefit. The situation for technology is very different amongst all the Sub-Saharan African countries. The region does have their own SWH manufacturers and supply chains but rely mainly on imported technology and supplies.

Given this diverse co-existence of the region, standards, certification, and promotion rates or benefits are variable across the entire region.

4.9.1 Zimbabwe

The Standards Association of Zimbabwe (SAZ) is responsible for the standards development through technical committees and adopted for SANS standards in the region. The following are the relevant standards used in Zimbabwe [9,10]:

- ZWS 744:2003 Installation of solar water heaters
- ZWS ISO 9459:1999 Solar heating systems; Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar system
- ZWS 1016 Installation, maintenance, repair and replacement of domestic solar water heating systems
- ZWS 1017 Domestic solar water heaters – Mechanical qualification tests
- ZWS 1032 Part 1 Domestic solar water heaters Part 1: Thermal performance using an outdoor test method
- ZWS 1032 Part 2 Domestic solar water heaters: Part 2: Thermal performance using an indoor method

Most of the systems under consideration are evacuated tube collectors, thermosyphon solar water heaters.

4.9.2 South Africa

The following are the relevant standards used in South Africa [11,12]:

- SANS 6211-1 Thermal performance of domestic solar water heaters by means of an outdoor test method.
- SANS 6211-2 Thermal performance of domestic solar water heaters by means of an indoor test method.
- SANS 10106 The installation, maintenance, repair and replacement of domestic solar water heating systems.

4.9.3 Namibia

The following are the relevant standards used in Namibia [13]:

- NAMS/SANS 1307-4:2013 Domestic solar water heaters.
- NAMS/SANS 10106-3:2016 The installation, maintenance, repair and replacement of domestic solar water heating systems.
- NAMS/ISO 9806:2016 Solar Energy – Solar thermal collectors- Test method

4.9.4 Tanzania

The following are the relevant standards used in Tanzania:

- Tanzania Bureau of Standards (TBS) EDC 5 (1223) CD3 [15,16]

4.9.5 Uganda

The following are the relevant standards used in Uganda [17]:

- US 853:2009, Code of practice for solar water heating systems — Design, installation, testing, repair and maintenance
- US 854-1:2011, Thermal solar systems & components — Solar collectors — Part 1: General requirements
- US 854-2:2011, Thermal solar systems & components — Solar collectors — Part 2: Test methods
- US 855-1:2011, Thermal solar systems & components – Factory made solar systems –Part 1: General requirements
- US 855-2:2011, Thermal solar systems & components – Factory made solar systems – Part 2: Test methods

- US 856:2011, Standard method for on-site inspection and verification of operation of solar hot water systems
- 1353. US 857-1: 2011, Custom built solar systems – Part 1: General requirements
- 1354. US 857-2: 2011, Custom built systems – Part 2: Test methods
- US 857-3: 2011, Custom built solar systems – Part 3: Performance characterization of stores for solar heating systems
- US 858: 2011, Method of test for exposure of solar collector cover materials to natural weathering under conditions simulating stagnation mode
- US 859: 2011, Standard practice for exposure of cover materials for solar collectors to natural weathering under conditions simulating operational mode
- US 860: 2011, Standard practice for non-operational exposure and inspection of a solar collector
- US 861: 2011, Method of test for evaluating absorptive solar receiver material when exposed to conditions simulating stagnation in solar collectors with cover plates
- US 885:2011, Standard practice for generating all-day thermal performance data for solar collectors
- US 888:2011, Code of practice – Solar heating systems for swimming pools
- US ISO 9553:1997, Solar energy – Methods of testing preformed rubber seals and sealing compounds used in collectors
- US ISO 9808:1990, Solar water heaters – Elastomeric materials for absorbers, connecting pipes and fittings – Method of assessment
- US ISO TR 10217:1989, Solar energy – Water heating systems – Guide to material selection with regard to internal corrosion

4.9.6 Ghana

The following are the relevant standards used in Ghana [18]:

- GS ISO 9459-1: 2007Ψ 27.160; 91.140.20 Published by ISO in 1993 Solar Heating - Domestic Water Heating Systems Part 1: Performance Rating Procedure using Indoor Test Methods
- GS ISO 9459-2: 2007Ψ 27.160; 91.140.20 Published by ISO in 1995 Solar Heating - Domestic Water Heating Systems - Part 2: Outdoor Test Methods for System Performance Characterization and Yearly Performance Prediction of Solar -
- GS ISO 9553: 2007Ψ 27.160; 83.140.50 Published by ISO in 1997 Solar Energy - methods of Testing Preformed Rubber Seals and Sealing Compounds used in Collectors
- GS ISO 9808: 2007Ψ 27.160 Published by ISO in 1990 Solar Water Heaters - Elastometric Materials for Absorbers, Connecting Pipes and Fittings - Method of Assessment
- GS ISO/TR 10217: 2007Ψ 27.160 Published by ISO in 1989 Solar Energy - Water Heating Systems - Guide to Material Selection with Regard to Internal Corrosion
- GS ISO 9806-1: 2006Ψ Test Methods for Solar Collectors Part 1: Thermal Performance of Glazed Liquid Heating Collectors including Pressure Drop
- GS ISO 9806-2: 2006Ψ Test Methods for Solar Collectors Part 2: Qualification Test Procedures
- GS ISO 9806-3: 2006Ψ Test Methods for Solar Collectors Part 3: Thermal Performance of Unglazed Liquid Heating Collectors (Sensible Heat Transfer Only) including Pressure Drop

These standards focus on thermosyphon systems, solar water heaters, and pumped systems. These do not apply to PV2heat solar water heaters (heat pump, PVT collectors) because of the Electrical measurements needed on the PV2Heat systems.

4.10 Status for Standards for SWH

International and national standards are well established for solar thermal technologies, but not for PV2heat systems, mainly because the standards do not cover PV panel testing. Table 1 highlights the current situation for standards for solar thermal and PV2heat systems.

Table 1: Current situation for standards for SWHs and PV2heat systems

Type of system	Testing standard	Comments
Thermosyphon	ISO-9459 or national equivalent	Testing procedures widespread
PV off-grid to tank	No ISO standard available	Needs PV testing and component simulation
PV on grid to tank	No ISO standard available	Needs PV testing and component simulation
PV off-grid to heat pump-tank	No ISO standard available	Needs PV testing and component simulation
PV on grid to heat pump-tank	No ISO standard available	Needs PV testing and component simulation
PVT to heat pump-tank	No ISO standard available Thermal part of PVT, according to ISO 9806	Needs PV testing and component simulation

5 Quality Certification Programs

Quality Certification programs provide benefits for both manufacturers and consumers. Manufacturers can freely choose among the accredited test labs and thereby gain access to markets that rely on the specific programs, and consumers are assured a high-quality product, and the product may be eligible for subsidies, providing financial benefits to the consumers.

5.1 Quality Certification Programs accredited to ISO/IEC 17065

The following Quality Certification programs are accredited according to ISI/IEC 17065:

- Solar Keymark
- Solar Rating and Certification Initiative (ICC-SRCC)

5.1.1 Solar Keymark

The Solar Keymark was developed by the European Solar Thermal Industry Federation (ESTIF/SHE) and CEN (European Committee for Standardisation) in close cooperation with leading European test labs and with the support of the European Commission. The Solar Keymark is one of the schemes of the general Keymark certification system, which generally aims at demonstrating the conformity of a product with its European standard. It is the main quality label for solar thermal products and is widely spread across the European market and beyond.

The Solar Keymark was created to certify high-quality solar thermal products at the European level. The aim is to reduce trade barriers and promote the use of high-quality solar thermal products in the European market and beyond.

Governments recognize the certification as a useful tool to ensure end-consumers get qualitative products; as such, it is required by several public authorities as an eligibility criterion for public support schemes.

Under the Solar Keymark, several working groups perform network activities to ensure confidence in the Solar Keymark, for example, maintaining and improving the Solar Keymark scheme rules and procedures, exchanging information and experience, and ensuring uniform testing quality between different test labs.

Solar Keymark covers the following product main types within the work program of CEN/TC 312 “Thermal solar systems and components,” always referring to the latest version of the European standards:

- Solar energy – Vocabulary as defined in EN ISO 9488
- Solar thermal collectors as defined in EN 12975
- Factory-made (prefabricated) solar thermal systems as defined in EN 12976-1 and EN 12976-2
- Custom-built systems as defined in EN 12977-1 and EN 12977-2
- Solar water heater stores as defined in EN 12977-3
- Solar combistores as defined in EN 12977-4
- Control equipment as defined in EN 12977-5

5.1.2 Solar Rating and Certification Corporation (ICC-SRCC)

The Solar Rating and Certification Corporation (ICC-SRCC) is a non-profit organization that provides certifications and ratings for solar thermal products and systems. It was founded in 1980 and became part of the International Code Council (ICC) in 2015. ICC-SRCC has become a trusted authority in the solar industry, ensuring that solar thermal technologies meet stringent performance and quality standards.

The certifications are designed to help manufacturers comply with building codes and regulatory and incentive program requirements in the United States, Canada, Mexico, and the Caribbean Region.

ICC-SRCC provides several certification and rating programs that evaluate the performance and durability of solar thermal components and systems. These include:

- SRCC OG-100 for solar thermal collectors’ certification
- SRCC OG-300 for solar water heating systems certification
- ENERGY STAR certification for residential solar water heaters
- SRCC OG-500 for solar tank certification

SRCC also operates a listing program to assess compliance of solar thermal products (without performance ratings) to a range of building codes and standards used in North America. This includes plumbing codes, building codes, mechanical codes, low-lead regulations and laws, and standards like NSF 50, ICC 902/SRCC 400 and others. Listings are used by manufacturers and installers to demonstrate compliance with the laws and regulations for safety and durability at the federal, state, and local levels. SRCC listings do not, however, include electrical safety listing to the National Electrical Code (NEC). For PV water heaters, the ICC 900/SRCC 300 standard specifies that PV water heaters use listed components like PV modules, inverters, power conditioners and resistive heating elements. Separate electrical safety listings to the NEC may be needed for some manufacturers from a Nationally Recognized Test Lab (NRTL). NRTL’s are accredited by the U.S. Occupational Safety and Health Administration (OSHA) to perform electrical safety testing and listings. At the time of writing, SRCC is not accredited as a NRTL for electrical safety listings.

All SRCC certification and listing programs support both thermosyphon and PV water heaters. And SRCC currently certifies numerous models of each type. At the time of writing, SRCC certified 151 thermosyphon and 6 PV water heaters under its OG-300 program.

Note that Federal tax credits in the US for residential water heaters require that to qualify, they “must be certified for performance by the nonprofit Solar Rating Certification Corporation or a comparable entity endorsed by the government of the state in which the property is installed.” (IRA § 25D(b)(2)

Another specification for solar water heater system performance is provided by the U.S. Federal Government under the ENERGY STAR program. It provides specifications for rating and labeling residential water heaters, including solar water heaters. It is published by the U.S. Environmental Protection Agency (EPA). To qualify, solar water heaters must be OG-300 certified, meet minimum performance standards based on UEF (uniform energy factor), and meet minimum warranty requirements. SRCC is approved by the ENERGY STAR program to certify qualifying solar water heaters to the standard. The program references the Solar UEF specification (SUEF) for solar water heaters in an appendix of the ICC 900/SRCC 300 standard. It allows for both solar thermal and PV water heating systems. Certification to the ENERGY STAR Residential Water Heating Specification is optional and is not required by regulations, but it is required to qualify for some regional financial incentives and rebates. The ENERGY STAR program requires certified manufacturers to report their annual sales of ENERGY STAR certified products to the EPA.

5.2 Quality Certification Programs accredited to National Standardization Bodies/Benefit Programs

The Quality Certification programs are:

- Solar Heating Arab Mark and Certification Initiative (SHAMCI)
- China Green Product (CGP)
- Quality Certification Schemes in Argentina
- Promotion and Benefit Schemes in Barbados
- Quality Certification Schemes in Brazil
- Quality Certification Schemes in Chile
- Promotion and Benefit Schemes in Colombia
- Quality Certification in Mexico
- Promotion and Benefit Schemes in Uruguay
- Australian programs required for subsidies
- Other Quality Certification programs

5.2.1 Solar Heating Arab Mark and Certification Initiative (SHAMCI)

SHAMCI is the first Arab certification scheme for solar thermal products. It is built around specific characteristics and needs of Arab states in the Middle East and North Africa. SHAMCI is inspired by Solar Keymark, the European certification scheme.

SHAMCI was initiated by the Regional Center for Renewable Energy and Renewable Energy with the support of the Arabian Industrial Development and Mining Organization (AIDMO) based on the Arab Ministerial Council of Electricity (AMEC) of the League of Arab States request.

SHAMCI provides certification of solar collectors and solar water heaters for the Arab States [22]. These include

- ISO 9806 “Solar energy — Solar thermal collectors — Test methods
- ISO 9459-2 - Solar heating -- Domestic water heating systems -- Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems
- ISO 9459-5 - Solar heating -- Domestic water heating systems -- Part 5: System performance characterization by means of whole-system tests and computer simulation
- EN 12976-2 - Thermal solar systems and components - Factory made systems - Part 2: Test methods

5.2.2 China Green Product (CGP)

According to GB/T33761-2017 *General principles for green product assessment*, green products refer to products that meet the requirements of environmental protection, are harmless or less harmful to the ecological environment and human health, consume less resources and energy, and are of high quality throughout their life cycle.

Green product assessment is a voluntary product assessment system being implemented by the State Administration of Market Regulation, aiming to integrate existing environmental protection, energy-saving, water-saving, recycling and low-carbon products into green products and evaluate them uniformly in accordance with the guidelines of unified catalogue, unified standards, unified evaluation and unified labelling. The targets are mainly end-user consumer products, selected for their high consumer concern, urgent need for consumption upgrading, and high impact on the ecological environment and human health.

The certification of green products for solar water heating systems is based on GB/T 35606-2017 *Green product assessment - Solar water heating systems*. Main certification modes include:

- Type inspection (sampling)

- Initial factory inspection
- Supervision after certification

The CGP certification is valid for 5 years and is a voluntary program.

In addition to national-level green product certification, some certification bodies conduct different voluntary certification programs, which are usually valid for 3 years. Organizations that can carry out this certification include:

- **China Academy of Building Research Certification Centre (CABRCC):** CABRCC mainly focuses on construction engineering and products as the main research object, with applied research and technology development as the main focus and is committed to solving key technical problems in China's engineering construction and carrying out research on common, basic and public welfare technologies required by the industry. And is responsible for the preparation and management of China's major engineering construction and product standards, while assuming the national construction engineering, air-conditioning equipment, solar water heaters, elevators, chemical building materials, quality supervision, inspection and testing tasks.
- **China Quality Certification Centre (CQC):** CQC is a national certification body in China. CQC's product certification business mainly includes national mandatory product certification, CQC logo certification, national implementation of voluntary product certification, and other certification businesses, and is also a third-party certification body authorized by the state to carry out energy-saving, water-saving, and environmental protection product certification work.
- **China General Certification Center (CGC):** Founded in 2003, CGC is a third-party technical service organization specializing in standard development, testing, inspection, certification, and technical and industry research services. We provide services in the areas of renewable energy, climate change and sustainable development, industrial equipment and intelligent manufacturing, rail transit, consumer goods, and other industries. CGC established China's solar water heater certification system and carried out the "Golden Sun" certification for solar water heaters.
- **China Environmental United Certification Centre (CEC):** CEC, approved by the Ministry of Ecology and Environment of the People's Republic of China (MEE) and accredited by the Certification and Accreditation Administration Committee of PRC, is a comprehensive certification and service institution leading in environmental protection, energy saving and low carbon areas. Business areas include products certification, management systems certification, services certification, addressing climate change, energy-saving and energy efficiency certification, green supply chain assessment, environmental stewardship, green credit assessment and green manufacturing system evaluation. CEC also carries out standard establishment and research projects, and international cooperation and exchanges, etc.

5.2.3 Quality Certification Schemes in Argentina

Technical Resolution issued by the Ministry of Production 720/2020 states that the solar thermosyphon equipment must withstand a working pressure of 750 mbar, and the testing procedure should agree with IRAM standards. However, there is no need for a certified laboratory to perform that test. The presentation of a test report of any lab Is sufficient until the first local testing laboratory is accredited under ISO 17.025. Given that there is no such facility nowadays and no plans for such a laboratory to exist in the near future, any manufacturer or importer may sell their product by simply presenting to the customs a test report from any laboratory in the world (certified or not) at the moment of importation.

The use of solar thermal systems in social housing is mandatory at a national level, provided it is certified according to the stated procedure. Furthermore, in national government social houses, it is mandatory to use locally manufactured technology, with the exception of the Patagonia region, where the use of solar collectors requires selective surface to be used all year round, and that technology is not locally manufactured. Nevertheless, each province may choose to use the imported system and comply with provincial rather than national laws. So, there is a coexistence of imported with locally produced goods that are included in social housing.

5.2.4 Promotion and Benefit Schemes in Barbados

The incentives for consumption and manufacturing, created from pilot experiences, were added over the years and are still in force today:

- **Tax Incentives**. In 1974, a 30% tax was imposed on electric and gas heaters, increasing their prices, to make SWH prices more competitive, and a tax exemption was also introduced for the import of inputs for the local production of SWH that helped reduce product cost by 20%.
- **Mandatory SWH in public constructions**. In 1977, the obligation to install SWH in new public constructions was imposed.
- **Tax benefits for homeowners** (Homeowner tax benefit). From 1980 to 1992, another benefit was installed where the total cost of installing a SWH was tax deductible up to a maximum of U$1,750. This incentive was stopped in 1992 as part of a process of government restructuring and economic recession.
- **Homeowner tax benefit improved**. In 1996 the benefit was reinstated with some modifications. The homeowner can deduct up to $1,750 in annual taxes on any home improvements, repairs, renovations, energy efficiency measures, and SWH installation.

5.2.5 Quality Certification Schemes in Brazil

The growth of the market in its beginnings was characterized by installations of non-certified systems due to the difference in prices and quality between national and imported products. For this reason, the manufacturers grouped in ABRAVA (Brazilian Association of Refrigeration, Air Conditioning, Ventilation, and Heating), currently the company ABRASOL, took the initiative to develop quality standards and associated regulations to define conformity evaluation criteria and demand a voluntary certification of standards. Although some manufacturers chose to differentiate themselves through certification after its voluntary implementation in 1996, the market did not immediately react to this fact, and the practice of installing non-certified systems prevailed due to the price difference. However, the number of manufacturers that decided to differentiate themselves by certifying their products was growing, and as this trend consolidated, manufacturers began to mobilize to demand mandatory certification of all products (imported and domestic) and national policies to promote those products. Since then, the certification scheme that operates in Brazil has managed to bring together 33 certified manufacturers and 284 types of SWH (GIZ, 2016).

In Brazil, there are two laboratories accredited under the ABNT NBR ISO/IEC 17025 standard to carry out SWH tests:

- Institute of Energy Research (Laboratorio de Instalações Prediais e Saneamento - LIP), of the Technological Center of the Built Environment (CETAC) of the Institute of Technological Research (IPT) located in Sao Paulo.
- Energy Studies Group (POLYTECHNICAL INSTITUTE – PONTIFÍCIA UNIVERSIDADE CATÓLICA DE MINAS GERAIS), located in Minas Gerais.

Until 2015, all imports had to be tested in laboratories located in Brazil under the country's regulations. This practice allowed a sufficient market for solar testing laboratories, which, by having a constant demand, could strengthen their capacities. However, it also had negative repercussions. Brazil is a mature market that has more than 100 SWH-producing companies and only 2 testing laboratories, a disproportion that generated an obstacle to certification. Starting in January 2015, INMETRO opened the door to reports from laboratories located outside Brazil, if they are accredited under the standards of the ILAC (International Laboratory Accreditation Cooperation) or the IAF (International Accreditation Forum).

One of the pioneers in promoting the use of solar energy was the federal state of São Paulo, which, since July 2008, made using solar thermal energy mandatory to heat water in new buildings (residential and non-residential) and those subject to renewal by law. However, until then, there was no national promotion strategy for using solar thermal energy, nor were there demonstration projects in the different potential sectors.

On the other hand, in 2008, on behalf of the Federal Ministry of the Environment, Nature Protection, Construction and Nuclear Safety of Germany (BMU), the German Agency for Technical Cooperation (GIZ) implemented the "1,000 Solar Roofs" Project, executed between in 2009 and 2013, with the aim that in certain regions of Brazil and various industries and fields of application, SWHs are used as an environmentally friendly and energy efficient alternative for water heating (INFONAVIT-GIZ, 2015). The project concluded in 2013 and can be recognized as an extremely successful project. Through it, the first 496 social housing units with solar water heaters were built in Rio de Janeiro through the "Mangueira" demonstration project, which was financed by the Brazilian development bank CAIXA with the cooperation of the GIZ. (INFONAVIT-GIZ, 2015).

Based on the positive technical and institutional experiences of the "1000 solar roofs" pilot project, the basis for financing the "Minha Casa Minha Vida - MCMV" program was formed, which is still in force today. This program was and is the first to promote the use of solar thermal energy in social housing. From 2009 to 2014, 1.7 million homes were delivered within the framework of this plan, with the incorporation of SWH (Solar Water heaters) being mandatory since 2012.

The "Minha Casa Minha Vida - MCMV" is a national housing credit program for families with up to 1,600 Reales (U$ 588) of gross income. Since 2012, the use of solar thermal has been mandatory for single-family units and optional for multi-family units. The covered costs are limited to 2,000 reais (approx. U$610), including equipment and installation. Financing is provided by CAIXA (State Bank).

The financed equipment must comply with the conformity assessment requirements demanded by INMETRO (the responsibilities of INMETRO in the certification processes are explained below) and be installed according to the recommendations of ABRASOL, preferably by a company or professional accredited with the "QUALISOL" label.

The rest of the incentive programs in Brazil are based on local, municipal, or state regulations, but in all of them, the same requirements are required as in the MCMV program.

5.2.6 Quality Certification Schemes in Chile

Supreme Decree 331/2009 and Exempt Resolution 1150/2016, 1392/2011, and others of the Superintendency of Energy and Fuels (SEC) establish the requirements of the certifying organizations, the testing protocols for collectors, tanks, prefabricated systems, and the requirements of solar hot water (SHW) inspection and certification bodies. The SEC is the authority of SHW application and is responsible for demanding compliance with the conformity assessment requirements. It also keeps track of certified products and suppliers. The SEC demands that all products to be implemented in public policies should be certified according to European regulations for integrated or prefabricated systems, i.e., implies compliance with the requirements through test methods or by demonstrating that the equipment is properly certified under "Solar Keymark" or equivalent.

Equipment certification is not mandatory for those collectors sold in the private market. It is only mandatory for those that are included in public policies.

From 2015 to 2020, Law 20.365 and then Law 20.897 established a tax benefit for those constructing companies that implemented solar thermal energy in their new buildings. This benefit was not further implemented.

Since 2011, social housing developed by the Housing Ministry (MINVU) includes mandatory use of solar thermal systems, and there is also a subsidy to integrate solar thermal in the reconstruction of the houses after a natural catastrophe such as an earthquake.

5.2.7 Promotion and Benefit Schemes in Colombia

Colombia has law 1.715, which promotes using renewable energy and energy efficiency. Solar thermal recently was included in the benefits of renewable energy. In addition, it is included in the energy efficiency benefits, replacing gas or electric water heaters. The law defines three incentives to incorporate renewables and energy efficiency:

- Income tax deduction. The investment in solar thermal is tax deductible, up to 50% of the cost
- Imported solar water heaters are exempt from VAT and import fees. (This needs clearance and certification from the energy agency)
- The cost of SWH can be used for accelerated depreciation

To access the benefits of law 1715, it is only necessary to present adequate documents that demonstrate the quality of the solar thermal equipment, as well as project design and document that describes the goal for which it will be used.

There is no mandatory certification needed to access law 1.715 benefits. It is only necessary to present adequate documents that demonstrate the quality of the solar thermal equipment, as well as project design and document that describes the goal for which it will be used. Typically, product brochures with technical characteristics will suffice.

5.2.8 Quality Certification in Mexico

In 2010, the Institute of the National Housing Fund for Workers (INFONAVIT) launched the “Green Mortgage” program, in compliance with the national housing policy, which has the objectives to promote environmentally sustainable housing, territorial planning, and urban development through the granting of an additional credit so that the beneficiaries include in their homes green technologies that generate savings in the consumption of gas, electricity, and water. Including technologies is mandatory and the additional amount of credit is set according to the acquirer's salary. The technologies that participate in the Green Mortgage program must meet quality, safety, efficiency and guarantee criteria that ensure their useful life in relation to their performance to guarantee that they really help reduce energy and water consumption in the home. With this program, the user pays the additional credit fee with the savings generated by efficient technologies. Starting in 2011, the use of the requirements was generalized in all INFONAVIT credits, and the program is still valid today.

To be financed by the Green Mortgage, solar water heating equipment must be certified by the DTESTV (Dictamen Técnico de Energía Solar Térmica en la Vivienda). In this way, the DTESTV can be understood as the opinion of an expert entity under certain requirements instead of attempting to compare it to a conformity assessment system with independent third parties formally accredited by the national accreditation body.

Additionally, in 2015, the Mexican Ministry of Energy started executing a support project to implement a pilot financial mechanism in the Yucatan Peninsula, with a national replication factor, to promote the use of solar water heating systems within the hotel sector. This mechanism provides technical and economic advice on the savings generated by reducing fuel consumption, favours the technical guarantee through mandatory compliance with NMX standards or the DTESTV, and performs the monthly evaluation of CO_2 reductions and fuel savings.

Other cities and provinces of Mexico, such as Mexico City, have their promotion regime by complying with either NMX-ES-004-NORMEX-2010, NMX-ES-001-NORMEX-2018, NOM-027ENER/SCFI-2018 or the DTESTV.

Currently, the Mexican Accreditation Entity accredits three testing laboratories according to the NOM standard, and three certification bodies and five testing laboratories support the quality infrastructure necessary for compliance with the NMX standards and the DTESTV. Therefore, the certification system for solar equipment is based on extending the scope of the certification organisms to solar products and supervising these to the testing laboratories through a scheme like that of ISO 17025.

5.2.9 Promotion and Benefit Schemes in Uruguay

In September 2009, Law No. 18,585 “Solar Thermal Energy” was approved, which requires the installation of Solar Thermal Energy systems in new works and comprehensive renovations in the sectors with the highest consumption of hot water: Health Centres, Hotels, Clubs, Heated Swimming Pools and Public Organizations (at least 50% of the energy to heat the water in these facilities must come from the sun). This law was regulated through decree 451/011 and later modified by decree 325/12.

Law No. 18,585 and its regulatory decrees establish an exemption from VAT, customs taxes, and specific internal tax (IMESI) for the manufacture of solar thermal collectors with a minimum national component of 35%, covering direct labor, components, inputs, and utilities. To obtain the benefit, they must present the plans and have the national manufacturing certificate to the National Directorate of Industry of the Ministry of Energy and Mining (MIEM).

In addition to this, it has defined as mandatory the requirements for sanitary and construction pre-installations in social housing. In the resolution of the Ministry of Housing, Territorial Planning and Environment (MVOTMA) that regulates the promotion of social housing, it establishes in article 8 - Pre-installation for water heating through solar energy, that: "*The projects must provide for the sanitary and construction facilities necessary so that homes can receive, in the future, equipment for heating water using solar energy”*. This last component, strongly supported in small pilot projects developed previously.

The “Solar Plan” (Decree 50/2012) is a program to facilitate access to a solar thermal energy system at the residential level. The solar plan targets only the solar thermal system. It does not include the acquisition of an efficient support system, but rather, the user continues using the pre-existing support system, which could be a water heater, a hot water tank, or a boiler. In this way, the real savings of the solar thermal system will depend on the type of support system on which it is coupled.

The National Energy Directorate (DNE) coordinated the Solar Plan with all public and private institutions that were considered able to contribute to it.

The "Solar Plan" had financing from the Mortgage Bank of Uruguay (BHU) in up to 60 instalments (5 years) for the purchase of solar thermal systems. This financing time allows the fee paid by the user to be of a value like the electricity/gas savings obtained by using the solar thermal equipment.

For the first 2,000 users who acquire a solar thermal system within the framework of the solar plan, the Electrical Energy Company of Uruguay (UTE) provides an efficiency bonus to each family of 700 pesos per month (approximately U$25) for 24 months. The user can use this bonus as credit when paying their electricity bill.

The equipment marketed in the solar plan requires certification and additionally, installations can only be carried out by registered professionals (RTI: technical installation managers, translated from Spanish as Responsible Técnico Instalación).

As an additional requirement for the equipment purchased, each facility is required to have insurance issued by the State Insurance Bank (BSE) or any other insurer for a period of 5 years against theft, weather (hail, winds, etc.), and vandalism. and against third parties for 50,000 U$.

5.2.10 Australian Certification Schemes required for subsidies

In Australia there are three Green and White certificate schemes operating at a national level and in some of the States that support the market for Solar and Heat Pump water heaters. These schemes use the modelled performance calculated from **AS/NZS 4234:2021** "*Heated water systems — Calculation of energy consumption*" and its companion document **SA/SNZ MP 104**:2021 "*Modelling of heated water systems in accordance with AS/NZS 4234:2021 using TRNSYS*" to provide a market subsidy based on the expected performance of the products. That is products that will provide more savings will receive more subsidy. Product eligibility for rebates in all instances mandate a minimum energy saving requirement (when compared reference electric and gas storage water heaters) and in some instances user controls such as timers are mandated to allow consumers to maximise PV self-consumption from rooftop PV.

The National Government operates a Renewable Energy Target [19] scheme that requires electricity suppliers to purchase tradeable certificates relating to the installation of renewable energy technologies. When installed, solar and heat pump water heaters are eligible for Small Technology Certificates (STCs), which are traded to provide a point-of-sale discount.

The States of Victoria and New South Wales [20] operate similar schemes that reward purchasers of energy-saving appliances based on the expected amount of carbon savings when installed and operated.

Various other programs are delivered by state and local governments, providing rebates and discounts to residents via bulk procurement and low-/zero—interest loan schemes [21].

5.2.11 Other Quality Certification Programs

In Sub-Saharan Africa, the governments are trying to push for Solar Keymark.

In the United Kingdom, two programs exist: the Microgeneration Certification Scheme (MCS) and Insurance Backed Guarantees (IBG). The MCS in the UK provides certification for registered installers of microgeneration technologies, including solar thermal technologies with heat outputs up to 45 kW. The scheme places a legal requirement for guarantees, free to the customer, on both equipment and installation. Manufacturers typically provide guarantees for major pieces of equipment. In addition, it is a legal requirement for the installation contractor to provide guarantees for the installation work for at least two years. The installer guarantee must additionally be insured to ensure cover continues in the event of the contractor going out of business. This insurance must be transferable in the event of the property changing ownership. These Insurance Backed Guarantees provide additional assurance to the customer that the contractor is suitably qualified and experienced to install systems that are still relatively new. The purpose is to raise consumer confidence, as well as increase the requirement of installers to ensure appropriate levels of expertise and quality of work. The MCS provides a list of approved IBG providers and includes a streamlined IBG purchase to help contractors navigate the process.

ENERGY STAR is a wide certification program used for almost all appliances and energy related products in North America. Its use is extended to solar water systems, including water tanks.

5.2.12 Summary of Quality Certification Programs

The map (Figure 2) includes the known existing Quality Certification Programs. Quality Certification Programs may change from one year to another. This report shows those in place up to September 2024. Other countries may have Quality Certification Programs, even if they are not colored on the map. The map only shows the Quality Certification Programs the project group could get information about.

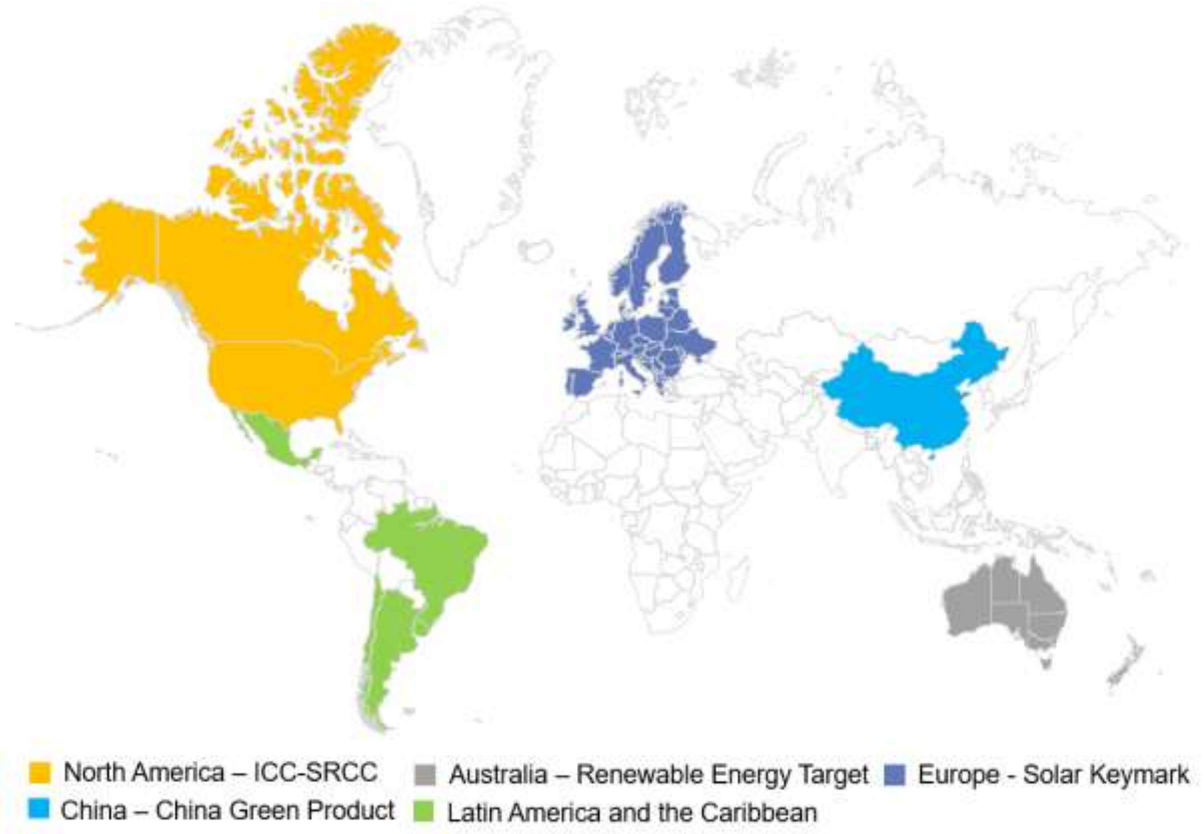

Figure 2: Quality Certification Programs of the participating countries.

6 Summary, Conclusions, and Recommendations

Task 69 has identified NO need for completely NEW Standards because there are many national Standards covering all possible aspects of component and system performance, legionella control, etc.

Regarding solar thermal technologies and particularly thermosyphon systems, there is a large availability of standards, regulations, and certification schemes across the different regions. Trade barriers occur in those places where national certifications are demanded on top of international certifications and not in general. If only national or international certifications are demanded, no trade barriers are in place. On the other hand, other system options, such as PV2heat systems, do not have international testing standards. Some countries have advanced in this sense such as New Zealand with standard AS/NZS4234 *Heated water systems – Calculation of energy consumption* and US with OG-300 *Solar water heating systems*. In this way, there is no international standard reference to compare solar thermal systems with PV2heat systems.

As opposed to solar thermal systems, there is no single combination in PV2heat systems that works without electricity either generated from the PV panels or the grid. This fact is a difficult starting point for a comparison of both systems. Nevertheless, both systems can be compared in terms of total energy efficiency, either as heat or electricity. But to establish a fair comparison between both technologies, new international standards are needed among PV2heat systems.

Given that the components of PV2heat systems, such as PV panels, heat pumps, and heating elements, are manufactured at a much larger scale than solar thermal systems, they are usually factory certified. That is, there is an accredited laboratory that tests the product in-house. In this way, most components of a PV2heat system are certified individually under different standards, and given the possible multiple configurations of these systems, a new testing and certification scheme would constitute an escalating obstacle for trading and commercialization. Solar thermal systems, manufactured at a much lower scale, have gone through this experience. Thermosyphon systems, solar collectors, and tanks are usually certified. Given the multiple options of configuration of forced circulation solar thermal systems, there are not many examples of on-site tested systems. For the same reason, it would not be convenient to develop a single standard for each combination of PV2heat systems. Perhaps a modelling approach would be more suitable. A possible solution would be to develop a model that can be customized for each combination, such as that developed in the case of New Zealand and the US. An alternative operational reference could be the approach of solar thermal forced circulation systems from *ISO 9459, Part 4: System performance characterization by means of component tests and computer simulation*. Each component is parametrized into the model with its certified operational characteristics. Then, several simulations on solar radiation, weather, and use conditions are simulated, and overall energy balance and efficiency are obtained.

Task 69 recommends that the Standards for PV2HEAT and solar thermal systems should be more harmonized globally, similar to the method for AS/NZS4234 (or OG-300 of the ICC-SRCC), which can also be used by manufacturers as a product development tool to reduce development time. Consumers and *large* manufacturers would benefit from a uniform, widely adopted process across jurisdictions (but it should be noted that this may come at the expense of larger manufacturers dominating over smaller local/regional manufacturers).

A possible harmonization starting point would be to accept a minimum requirement for all manufacturers and not raise the bar too high. For example, there is no need for freezing resistance in the Caribbean and hence, a certification in this issue for a Caribbean manufacturer makes no sense. So, a minimum harmonization at the international level may be good, with the local modifications on top of it for each case.

The procedure defined in AS/NZS 4234 overcomes the time and cost limitations of direct outdoor testing by using component performance data determined through standards, as inputs to an annual simulation model of hot water systems. Standard AS/NZS 4234 defines how to quantify the annual energy consumption of water heaters under various operating conditions using computational time series software such as TRNSYS. The simulated energy consumed can then be compared to reference gas and electric water heaters under the same thermal load, and hence energy savings can be calculated.

A starting point for global harmonization could be:

- Replace the use of TRNSYS and define the necessary equations to be used by anyone willing to implement or possibly develop a calculation sheet available for everybody, for example a google sheet. (Sort of EnergyPLus, which can be downloaded by everybody)
- Define local load profiles for each country or region: Europe, LAC, US, China, Africa, etc. Load profiles are very different among regions and climates.

Harmonization can be achieved by defining this common method. Small local modifications will always exist due to differences in hot water and electricity use. Nevertheless, a common ground for calculating system performance will exist.

Standard harmonization for solar collectors, systems, and component performance is another subject and need to consider other macroeconomic variables such as local manufacturing and local energy policies. Nevertheless, the suggestion is the same: Keep harmonization requirements as low as possible to guarantee essential quality and leave space for local modifications that arise from local policies or incentives. (For example, low efficiency and direct solar water may be preferred over high efficiency due to excess sunshine, i.e., desert areas).

All in all, full harmonization of standards and systems is almost impossible due to differences in load profiles of end users and climate conditions. The best solution may be a reference method and system that is general to all and allows or expects local deviations associated with local policies or other specific requirements.

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