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SHC STANDARDS: AN INTEGRAL COMPONENT OF QUALITY INFRASTRUCTURE

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Abstract

Quality Infrastructure has been defined as "a system of institutions which jointly ensure that products and processes meet predefined specifications." Ideally, a fully and properly developed Quality Infrastructure (QI) would be fully represented by each of the components: Certification, Standardization, Testing, Metrology, and Accreditation. However, in reality every component may not be fully developed, depending on the history and growth of the industry. Standards are an integral component to any Quality Infrastructure. Compared to other renewable technologies, solar heating and cooling (SHC) standards have been in development for a long time. We discuss how these Standards fit into a complete quality infrastructure. We take a look at examples of SHC standards in the U.S.

1. What is Quality Infrastructure?

The International Renewable Energy Agency (IRENA) promotes the widespread adoption of renewable energies through the sharing of best practices and lessons learned regarding policy frameworks and capacity-building activities. Recently, IRENA's Innovation and Technology Centre (IITC) studied existing Quality Infrastructure (QI) structures in two small scale renewable energy technologies to provide guidance on how QI might be implemented to promote and expand these renewable energy technologies. This paper reflects some of the work done on QI for solar water heating in the U.S., as part of that effort.

Quality Infrastructure is defined as "a system of institutions which jointly ensure that products and processes meet predefined specifications." (Goncalves and Peuckert 2011) Recognizing the importance of the pursuit of quality as a fundamental prerequisite to sustainable growth of any industry including the renewable industry, IRENA has been championing an effort to promote the concept of QI within the renewable community. QI helps ensure that quality products and services are produced by mitigating technology risk, establishing standards for acceptable minimum levels of quality in products and services, and improving performance and function.

Ideally, a properly developed Quality Infrastructure would be fully represented by each of the components:

- Certification
- Standardization
- Testing
- Metrology
- Accreditation

National or regional QI also interacts with the international QI system to increase harmonization, raise the local level of quality, and minimize duplicate effort. Each of the components in the national or regional QI is able to support the end users, or what is described as the "value chain" of consumers, suppliers, vendors, and integrators. Each of the QI components is interrelated to the others in a network, relying on information supplied by one and supporting the effort of another. However, in reality every component may not be fully developed, depending on the history and growth of the industry. One of IRENA's objectives is to encourage sustainable growth of the renewable industry in various regions in part by promoting QI within those regions.

The term Solar Heating and Cooling (SHC) recently has become the term preferred by the solar thermal industry to describe its market, replacing the more traditional term "Solar Water Heating". This reflects the fact that the markets are expanding from domestic hot water and pool heat into space heating and cooling and industrial process heat. "Solar Water Heating" or "SWH" includes those technologies which convert solar energy directly to thermal energy, or heat. Commonly used collector fluids are water, glycol mixes, and air.

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Historically, the market-dominant solar thermal loads have been the heating of water for domestic use at the residential level and the heating of swimming pools. Within the U.S., QI is relatively well-established for these uses. Growth areas include space heating ("combi" systems which provide both hot water and space heat), small commercial heat loads (hot water and space heat for hotels, laundries, restaurants, etc), process heat (for agricultural and industrial processes), and solar cooling (the use of solar energy to cool and dehumidify a conditioned space or process load). In many ways, these loads are natural extensions of the more traditional potable water and pool heat loads. QI, in the form of applicable standards and certifications, is being developed for each of these load types. While they can provide peak shaving or electricity load displacement, and while they typically will interact with an electric or fossil heat source, SWH systems are typically not connected to the electrical grid. Further, concentrating solar thermal technologies for centralized utility-scale electricity generation are not considered in this definition of SWH.

Note that there are parts of QI which cover SHC but which also extend beyond SHC. For example, plumbing and mechanical codes cover all aspects of plumbing in a structure including SHC. The local Authority Having Jurisdiction (AHJ) will adopt portions of the international Code and require permits for all construction work including SHC installations. The local AHJ will also require that various trades carry licenses to perform various types of work including plumbing, roofing, electrical which include SHC work. Some AHJ's have license requirements specifically for various types of SHC work. An SHC system is only one part of a building inspection. Training of building inspectors in SHC technology, like other technologies, may be part of a required continuing education program.

2. Certification

Within the context of QI, certification refers to attestation of performance or competence by a third party regarding an Entity such as a product, process, system or even person. Certification of an entity should be based on consensus standards and protocols. While "accreditation" refers to attestation related to a conformity assessment body or institution such as a certifying entity, standards development organization, or test lab, "certification" refers to attestation related to specific product lines, systems or persons. When a SHC product is certified, a third party has borne witness and confirmed that such product meets or exceeds specific criteria. Thus, the certification must define which specific criteria have been met. In many ways an educational degree or certificate attest that the awarded individual has met certain minimum criteria and/or passed certain tests. While there is no guarantee that the individual will successfully implement those skills or knowledge, there is an increased level of comfort or assurance that the individual is competent in those skills or knowledge. Sometimes there can be misunderstanding of the certification in the general public perception. For example, the UL mark typically means that the product has met certain minimum criteria for safety but the public may also assume incorrectly some attestation of performance or reliability. It is important that the public be informed in straightforward and simple terms the extent and limits of a given certification. The importance of certification by a third party independent of the company producing the product is not to be underestimated. An entity providing certification should be "independent" of the entity it is certifying. The certification body and employees of the certification body should not have any fiduciary interest in the certified entity. To ensure that appropriate and relevant criteria are developed in certification protocols, industry experts should be involved in the development of those protocols but they should regularly sign statements revealing potential conflict of interest, and to maintain impartiality they should not be directly involved in certification decisions regarding specific entities.

3. Testing

Testing of an entity following defined procedures and protocols would be required to accurately assess characteristics of that entity. Certification testing has always been an essential part of a robust and successful SHC industry. Testing can easily be the most costly and time-consuming portion of a certification process. It is important that a test lab meet a minimum threshold of competence. A fundamental aspect is that the lab and its employees not have any fiduciary interest in the type of product being tested. Thus, labs operated by manufacturers which test their own products or those of their competitors may have difficulty in eliminating all conflict of interest, even if the management structure of the test lab is separate from the management structure of the manufacturer. Labs should hire managers and employees who at once have significant experience in SHC but also have no fiduciary interest in a particular product or type of SHC product. While in a small industry such as SHC it can be difficult to find line employees who meet both qualifications and occasionally subcontractors may be used, these subcontractors must not have any existing or ongoing conflict of interest in the product being tested. At no time should decision makers have any fiduciary interest in the type of product being tested, and all employees must sign a statement regarding conflict of interest. At a minimum, a test lab should endeavor to have its procedures and protocols "accreditable" to a recognized standard such as ISO 17025. It can be costly in time and money to develop and maintain the required quality assurance mechanisms and to obtain the accreditation, especially for a new lab, or for one where the certification testing market is very small. However, the lab should foster an environment of continuous quality improvement with the goal of obtaining such an accreditation. A core component is the maintenance of procedures and logs for calibration and competency training. Site inspections are a somewhat costly but important aspect of accreditation. These inspections allow a third party to verify that such procedures are in place and are being followed. Inspections should ultimately include evaluation of error band calculations and procedures to improve the quality of data by reducing or minimizing the error bands. Inter-comparisons and "round-robin" testing of reference specimens between test labs allows further verification of the accuracy of data produced by the labs. "Round-robin" testing is where a reference test specimen is passed from lab to lab and tested to identical protocols. The test labs then compare their test results and resolve discrepancies in the data. While somewhat expensive and time consuming, this effort helps define error bands in the data and can help identify if a test lab is not following a protocol before too many proficiency tests are conducted by that lab.

4. Metrology

In the context of QI for SHC, metrology refers to how test labs can ensure accurate and repeatable test results. During qualification testing, sensors are used to measure system parameters such as fluid flow rate, system (static) pressure, pressure difference, fluid temperature, fluid temperature difference, mass or weight, and length. Sensors are also used to measure relevant ambient parameters such as ambient temperature, global irradiation, direct radiation, diffuse radiation, local wind speed, and local wind direction. Sometimes additional parameters are measured such as ambient relative humidity, infrared radiation, fluid pH, fluid concentration, fluid density, transmissivity, emissivity, etc.

5. Accreditation

When practical, the process or the entity performing the process should be accredited for an added measure of confidence whether the process is certification, testing, or standards promulgation. ISO/IEC 17000:2004 defines accreditation as a "third party attestation related to a conformity assessment body conveying formal demonstration of its competence to carry out a specific conformity assessment tasks." Accreditation should be assessed on a specific process or processes that the entity is implementing. While accreditation is not a guarantee of quality workmanship, its independent third party attestation provides a measure of comfort regarding the entity's ability to implement that specific process. While theoretically the accrediting body itself could also be independently evaluated, many accrediting bodies develop and maintain their reputation by subscribing to rigid rules of conduct to ensure impartiality, accuracy, repeatability and fairness.

6. Standards

The last component of QI and the subject of this paper is the Standard. A standard typically is a document which defines important features and/or requirements for a product or process and is preferably developed in a transparent and open-source type of setting with input from stakeholders of all interests including competing ones. Standards are an integral component to any Quality Infrastructure.

The ISO/IEC Guide 2 defines a Standard as "a document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context." It goes on to note that a Standard should promote "optimum community benefits" and be based on science, technology and experience.

There are several important terms used in this definition. "Consensus" is further defined as "general agreement, characterized by the absence of sustained opposition to substantial issues by any important part of the concerned interests, and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments." While consensus does not imply unanimity, it does imply an agreement has been achieved which is substantially more than a simple majority of voting members. Also, dissenting opinions are reviewed, discussed and responded to in a positive and proactive manner. A consensus decision may require more discussion and debate when compared to a decision by simple majority vote. However, when a consensus decision is finally reached, the statement usually has been thoroughly vetted and there is little if any opposition to it. One potentially negative aspect of a consensus decision is that, occasionally in an effort to hurry the process, a committee may choose to remove contentious aspects of the statement under discussion. This could lead to a decision with which everyone agrees but which has no significant strength or value, i.e. a statement "with no teeth". This should be avoided, even if debate becomes tedious or drawn out. A strong Standard is one which is accurate and fair and which can withstand the test of time. Stakeholders benefit from accurate and fair standards, not those which are hastily crafted. While technical experts should review and debate the language to ensure accuracy, lack of ambiguity, and fairness, a standard should not be heavily influenced by any single opinion or school of thought. Committees should strive to be balanced by representing all affected stakeholders. Committee chairs should not have any undue conflicts of interest with the Standard's intent, and they should encourage and ensure diverse opinion and discussion among competing interests.

Ideally, the "recognized body" promulgating the standard is one which has been accredited by yet another recognized and independent accrediting entity. However, there is an administrative and bureaucratic cost to becoming accredited, which must be weighed against the benefit of accreditation. Regarding development of SHC standards in the U.S., for decades the industry has been too small to justify the cost of developing standards by a body which has been formally recognized by another accrediting entity.

As an example, in the 1990's at the request of solar thermal companies in California where product certification by an entity accredited by International Association of Plumbing and Mechanical Officials (IAPMO) had been written into local law, the Florida Solar Energy Center (FSEC) had its testing labs and certification programs accredited by IAPMO. However, the high cost of obtaining and maintaining this accreditation could not be justified by the tiny market that it served, and neither FSEC nor the solar thermal companies could afford to continue paying the costs so the accreditation was dropped after a couple years. While FSEC's certification programs are not accredited they are mandated by Statute of the State of Florida. FSEC was created and therefore recognized by the State of Florida to promulgate SHC standards within Florida. Standards originally developed by FSEC were developed in collaboration with the industry and other stakeholders, to the extent possible given the very small industry. Futher, in the last decade, FSEC's SHC standards were substantially revised to be based on the relevant consensus standard promulgated by the Solar Rating & Certification Corporation (SRCC). In addition to improving the harmonization between the FSEC and SRCC standards, it allowed the FSEC standards to have a consensus-based level of effort similar to the SRCC standards.

For perhaps a decade SRCC has evaluated getting its standards and certification programs accredited to ISO/IEC 17065 (formerly Guide 65). Since its inception the SRCC has been generally recognized as the national body for promulgating SHC standards in the U.S. Standards promulgated by the SRCC have been developed in an open, transparent, and consensus manner therefore meet the intent of the accrediting process. Further, its policies and procedures of openness, fairness, accuracy and consensus substantially meet the intent of an accredited Standards Development Organization (SDO), so few substantive changes would be required. However, each year the administrative cost associated with documentation, inspection, application fees, etc. could not be justified against the benefit to the tiny SHC industry. Recently, SRCC began the process of collaborating with an established and accredited SDO, the International Code Council (ICC), to review and formally seek ANSI accreditation for the SRCC standards. The projects are titled ICC 900/SRCC 300, Minimum Standards for Solar Water Heating Systems and ICC 901/SRCC 100 Minimum Standards for Solar Thermal Collectors.

IAPMO recently published Standard S1001.1 Design and Installation of Solar Water Heating Systems. IAPMO is a Standards Development Organization so the American National Standards Institute (ANSI) approved S1001.1 as an American National Standard. IAPMO Standard S1001.1 is based on FSEC's Standard 104-10, which is itself almost completely based on SRCC's Standard 300.

Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits. Standards should be developed in an open, consensus process by a committee open to the public.

- Committee members should preferably represent every category of stakeholder, preferably with competing industry interests participating to help ensure fairness.
- All members should commit to be impartial in judgment, to not use their position for personal benefit (including the company they represent), to actively participate, to disclose all potential conflicts of interest, and to recuse oneself from any decision which constitutes a conflict of interest.
- Consensus should be obtained first by full and fair discussion of and agreement on each new issue.
- Public comment should be sought from as wide an interested audience as possible on each new change for a reasonably long period to allow time for studied response, typically 30-90 days.
- All comments must be considered and all dissenting or opposing comments must be addressed, either with a change to the language to accommodate the opposing comment, or with a written argument as to why the opposing comment was not accepted.

- If the new change is considered "substantial", that is, if it is more than a clerical or grammatical change and/or it changes the intent of the language, then the newly revised language must be issued for public comment.
- Once a standard is developed, it should be reviewed and if necessary revised on a pre-determined cycle. Typically in the U.S., the cycle is three years. These procedures make the process slow, but help ensure impartiality and they minimize the potential for individual interests to write language in their favor which may not benefit the stakeholders in general.

Standards have been written to document almost every feasible aspect of QI. With regards to SHC, FSEC promulgates standards for operation of its certification programs, test methods and protocols, and IAPMO promulgates S1001.1. Both these are substantially based on the SRCC standards and protocols. SRCC currently promulgates three consensus Standards.

- Standard 100 "Minimum Standards for Solar Thermal Collectors" specifies test requirements for collectors required to obtain certification. It references other standards for specific test protocols, such as ASHRAE 93 for collector performance testing and the ISO 9806 series for performance and qualification. Collectors meeting the requirements of Standard 100 are certified by SRCC following the OG 100 protocol.

- Standard 600 "Minimum Standard for Solar Thermal Concentrating Collectors" specifies requirements for selection and testing of concentrating collectors which cannot be tested under Standard 100. Like those of Standard 100, collectors meeting the requirements of Standard 600 are certified by SRCC to OG 100.

- Standard 300 "Minimum Standards for Solar Water Heating Systems" defines minimum threshold requirements as well as evaluation criteria for solar thermal systems. One of the requirements is that the collector(s) be certified to OG 100. Systems meeting the requirements of Standard 300 are certified by SRCC to OG 300. This standard originally covered only residential SWH systems, but has recently has been reviewed to include combi-systems, commercial systems, and cooling systems.

7. A brief history of SHC Standards in the U.S.

Although solar cooling was attempted in the 1970's, only recently has it started to gain a legitimate foothold in the market. Until recently, solar thermal has been used almost exclusively for swimming pool heating and domestic hot water. Hence, the industry has typically been described as Solar Water Heating (SWH), rather than Solar Heating and Cooling (SHC). In the late 1970's and early 1980's, the U.S. SWH market enjoyed explosive growth in response to the energy crisis and relatively sudden awareness of the need for energy efficiency and renewable energy. To encourage SWH growth a tax incentive on the installed cost of SWH systems was implemented. Hundreds of manufacturers and installation companies were created seemingly over-night, hundreds of thousands of solar panels were installed. Unfortunately, the incentive language was not well written, so abuse and misuse of the incentive was rampant. Some knowingly abused the program, "gaming the system". Others had good intentions but did not understand that SWH requires more complexity and durability than "just a plastic garden hose laying in the sun". Further, many systems were installed simply to take advantage of the tax benefit, with little regard to reducing thermal loads or to sustainability.

No substantial QI structure was in place to address QI needs for SWH. FSEC was created to test and certify SWH collectors in Florida. Several other states also quickly developed certification programs and started test labs, but consistency across state lines did not exist and quality was highly variable. In response to this issue, the Solar Energy Industries Association brought many of the states together to create the SRCC in 1980. Only Florida maintained its SWH standards and certification program because its existence was mandated by state law. As it turned out, FSEC's mandate served the industry well, because it became one of only two test labs in North America to survive the collapse of the industry and the subsequent loss of profitability for testing solar collectors. Over the years, SRCC committees created and promulgated several standards. These were built on state protocols, ASHRAE standards, and guidelines developed by the federal agency Housing & Urban Development (HUD). Since then and through today, these standards have been continuously reviewed, revised, and updated in a transparent, consistent and fair manner by a volunteer consensus committee made up of voting members representing a balanced cross section of stakeholders. Proposed changes or issues that are brought to the attention of the SRCC Standards committee typically include how to address new technologies, how to interpret and clarify vague language, how to reflect changes in similar trades such as plumbing or heating.

In 1985, the tax incentive program was suddenly discontinued. The loss of the federal tax credit is generally blamed for the almost immediate collapse of the SWH industry. It is not as well-documented, but around the same time as the loss of the incentive in 1985, the poor quality systems began to fail, some failing spectacularly. Many installer companies continued to survive only by running repair, replacement and removal businesses. Others moved to solar pool heating, whose polymer collectors were able to compete with fossil pool heating without incentives. Most companies and test labs simply closed shop and sought work in non-solar industries. Although the SRCC had been in existence for several years but this point, its national certification program was voluntary. Also, many of the failed systems had been installed prior to SRCC gaining traction and recognition, or they were installed using technology that pre-dated the standards developed by SRCC.

There were some SWH systems which were properly installed in spite of the lack of good standards. It is telling to note that, many of those high-quality installations (properly designed, manufactured, installed and maintained) continued to operate and provide excellent service for decades after installation. A small few have been found still in operation well more than 30 years after installation. However, the poor reputation that the bad installations gave to the industry endured for decades. Throughout the 1990's, conventional wisdom was that "SWH could be great for the environment someday in the distant future, but today it is ugly, it is too expensive, and it does not work!" Of course, these statements were and are NOT true. Even in the 1990's in the U.S., SWH benefited the environment, it did not need to be ugly, in many niche applications it was competitively priced. Also, if proper QI was followed then it worked well for many decades.

In the mid-2000's, the U.S. federal government approved an incentive that increased the benefit to the owner, was more explicit in what it covered and did not cover, required certification as a condition for incentive, and (perhaps most importantly) was guaranteed for almost a decade after inception (i.e. to 2016). This last item allowed manufacturers to make long term marketing plans and develop the infrastructure required to consistently deliver quality products. The SRCC had already been in place for two decades developing consensus standards and proper certification programs. These structures were then available to respond to the second surge in the SWH industry in the 2000's. While the U.S. SWH industry growth 2008-2013 has not come close to the explosive growth during the "glory days" of the early 1980's and while SHW growth has stagnated recently due to the recession and down turn in residential home building, the industry growth is now much more manageable and robust. This can be attributed to a relatively mature and stable QI for the SHC industry, of which quality standards are a significant component.

8. Acknowledgements

All opinions and statements not explicitly attributed to others are the responsibility of the author. IRENA's Innovation and Technology Centre (IITC) initiated a study of existing Quality Infrastructure (QI) programs in the two small scale renewable energy technologies of Small Wind Technology and Solar Water Heating to provide guidance on how QI might be implemented to promote and expand these renewable energy technologies. Much of the content of this paper was developed in support of that work.

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