IRENA
International Renewable Energy Agency

# Quality Infrastructure for Renewable Energy Technologies

## Guidelines for Policy Makers

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## About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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# CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

# ABBREVIATIONS

| | |
|---|---|
| AIST | National Institute of Advanced Industrial Science and Technology (Japan) |
| ANSI | American National Standards Institute |
| BIPM | International Bureau of Weights and Measures (Bureau International des Poids et Mesures) |
| CIPM | International Committee of Weights and Measures (Comité International de Poids et Mesures) |
| COPANT | Pan American Standards Commission (Comisión Panamericana de Normas Técnicas) |
| EN | European standards |
| ESTIF | European Solar Thermal Industry Federation |
| EU | European Union |
| EUR | Euro |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| ILAC | International Laboratory Accreditation Cooperation |
| IRENA | International Renewable Energy Agency |
| ISO | International Organization for Standardization |
| kW | Kilowatt |
| MCS | Microgeneration certification scheme |
| MLA | Multilateral recognition arrangement |
| MRA | Mutual recognition agreement |
| NAB | National Accreditation Body |
| NGO | Non-governmental organisation |
| NIST | National Institute of Standards and Technology (United States) |
| NMI | National Metrology Institute |
| NMIJ | National Metrology Institute of Japan |
| NPL | National Physical Laboratory (United Kingdom) |
| NSB | National Standards Body |
| O&M | Operations and maintenance |
| PT | Proficiency test |
| PTB | Physikalisch-Technische Bundesanstalt (German National Metrology Institute) |
| QA | Quality assurance |
| QI | Quality infrastructure |
| QMS | Quality Management System |
| SDO | Standard Developing Organisation |
| SHAMCI | Solar Heating Arab Mark and Certification Initiative |
| SI | International System of Measurement Units |
| SRCC | Solar Rating & Certification Corporation |
| SWH | Solar water heating or solar water heater (depending on context) |
| SWT | Small wind turbine |
| UL | Underwriters Laboratories |
| USD | United States Dollar |

# ABOUT THIS REPORT

This report is part of a series prepared by the International Renewable Energy Agency (IRENA) in the field of quality infrastructure (QI) for small-scale renewable energy technologies. To date, the series, *Quality Infrastructure for Renewable Energy Technologies,* includes:

*Guidelines for Policy Makers.* This publication explains the essential concepts, along with the benefits of developing and implementing QI, and provides guidance on how to incrementally develop QI in support of national renewable energy technology markets.

*Small Wind Turbines.* This publication analyses the challenges and offers recommendations for developing QI for small wind turbines (SWTs), as well as highlighting the experiences of several countries in developing and implementing QI for SWTs. The SWT guide concludes by applying guidelines for incrementally developing QI to the particular case of SWT markets.

*Solar Water Heaters.* This publication analyses the challenges and offers recommendations for developing QI for solar water heaters (SWHs), as well as highlighting the experiences of several countries in developing and implementing QI for SWHs. The SWH guide concludes by applying guidelines for incrementally developing QI to the particular case of SWH markets.

Readers are invited to select the report that is most relevant to their needs in the publications section of IRENA's website. For queries, please contact us at *secretariat@irena.org.*

# EXECUTIVE SUMMARY

Quality assurance (QA) has proven to be indispensable for establishing an enabling environment for a rapid uptake of renewable energy technologies. Quality assurance consists of standards which are intended to ensure that products and services perform as expected, as well as the mechanisms to verify that such requirements are fulfilled, *e.g.* testing and certification. QA builds the credibility necessary for the creation of healthy, efficient and rapidly growing technology markets and ensures that expectations from investors and end-users for technology performance, durability and safety are met.

Policy support schemes which integrate QA standards and instruments produce higher-quality products and services and support renewables deployment. Incentive policies for renewable energy technologies increase their effectiveness by having in place mechanisms which ensure that supported technologies and systems deliver as intended. At present, for example, 14 states in the United States require contractor licensing, and 4 states request equipment certification for either solar or wind energy technologies. For solar photovoltaic (PV) and thermal technologies in the US state of Arizona, residents are required to use certified equipment to be able to access the personal income tax credit.

Projects can also more easily access financial sources when debt does not bear the technology risk. Commercial banks often require the use of certified equipment – according to international standards – to grant loans. Emerging markets need QA to prevent unsafe, underperforming and failure-prone products from tarnishing perceptions of the technology and poisoning the market.

The establishment of QA frameworks requires an institutional infrastructure. This quality infrastructure (QI) encompasses standards, metrology, testing, certification, inspections, accreditation and quality management systems. QI can be defined as the total institutional network (public and private) and the legal framework that:

- Regulates, formulates, edits and implements standards; and
- Provides evidence of its fulfilment (*i.e.* a relevant mixture of measurements, accreditation, tests, certification and inspections).

QI benefits all stakeholders and market actors involved with the technology, and it provides the following benefits for stakeholder groups:

- **Policy makers:** nurtures emerging markets, enables sound technology promotion and attracts new businesses and jobs.
- **Manufacturers:** reduces regional and international trade barriers, improves product design and improves manufacturing quality.
- **Practitioners:** improves wages and mobility (for professionals involved in the design, installation, operation and maintenance of renewable energy technologies), and attracts new talent.
- **End-users:** builds end-user trust, enables sound product comparison and increases financial resources.

Key QI challenges and potential solutions for policy makers are as follows:

- **Cost.** A comprehensive QI is costly to the government and the industry. Government investment is needed to initiate practitioner training, test laboratories, certification bodies, accreditation of test laboratories and certification bodies, and a standards developing organisation. Facing these costs, there is justifiable fear that system prices will increase with QI implementation. Implementing QI should begin with a small effort (*e.g.* beginning with practitioner training and durability testing at unaccredited laboratories) to keep costs low.

Participating in development of a regional network in which resources are shared among countries presents an opportunity for drastic cost reductions. National standards development costs are reduced drastically by adopting the most relevant sections of existing international standards while reducing transaction costs and facilitating technology trade through harmonised standards.

- **Early technology failures.** Early use of new technologies may result in failure, not only due to the quality of the equipment, but also as a result of installation errors. For solar water heaters (SWHs) and small wind turbines (SWTs), installations are somewhat complex and are too often prone to errors. Providing for training early and throughout the market stages is a solution.
- **Lack of renewable systems knowledge.** Policy makers or their staffers often do not have the technical skills required to guide programme and policy development strategies. Even choosing which technologies to

promote can be daunting. The use of international technical standards may bridge this gap significantly.

- **Lack of existing infrastructure to enforce QA.** There may be no existing infrastructure to ensure that standards are followed when required and that systems that receive incentives are properly certified. In these cases, it is necessary to implement the necessary infrastructure required, including testing, certification, accreditation and mechanisms for market surveillance.
- **Inferior imports.** A number of experts interviewed for this study expressed dismay about poor-quality imports poisoning an emerging market. In emerging markets, cost tends to dominate consumer decision making, as there is often no information about lifetime and performance. One approach is to require that imports have an acceptable certification performed prior to import, according to international standards.
- **Improperly designed subsidies.** It is common for governments to use incentives such as subsidies for renewable energy technologies to spur emerging markets. However, subsidies are less effective if they target technologies or systems with high technical risk. Policy mechanisms to support renewable energy markets may mitigate this technical risk and become more effective by incorporating QA requirements that screen out poor-quality systems.

Recommendations for policy makers at each market stage are given below. Note that funding for market surveys and programme assessments to ensure the accomplishment of policy goals and objectives is necessary at every stage.

- **Market assessment stage.** At this stage, a market does not yet exist, and studies are needed to decide how a government should best proceed, including which technologies to promote. Country opportunities must be understood in the areas of physical resources, technology expertise, manufacturing, distributors/practitioners, existing energy use, industry groups and QI plans. An industry association should be set up to help develop QI/QA.
- **Market introduction stage.** At this stage, the market is very small, with no strong industry actors or associations. Such new markets may likely start by importing products. Recommendations include requiring external certification for any imported products according to international standards, implementing initial QI, funding training, mandating that national standards

take into account the adoption of international standards, researching regional schemes and funding demonstration projects.

- **Market growth stage.** At this stage, the market is small but growing from a combination of imports and locally produced products. Training of certified practitioners to correctly install, operate and maintain the systems is essential. National standards are evolving appropriately and now specify durability testing and an initial level of certification. Test labs and certification organisations are founded, with an emphasis on reliability testing.

- **Market consolidation stage.** In this stage, the market is large enough to support the QI development needed for the market to reach full maturity. Support is provided for certification bodies and improving the test laboratories so that they can fully implement accepted international standards. End-user incentives linked to QI requirements can be confidently used to help grow the market, as there is a high level of assurance that the devices perform as expected and will be durable and reliable. Recommendations include rigorous certifying of products, publishing product ratings, supporting test laboratories, continuing standards making and training.

- **Market maturity stage.** As the market matures at higher volumes, industry cash flows increase and industry is able to absorb increased QI costs, such as for testing and certification, without significant price impact. The main difference between this stage and the previous stage is that accreditation of test laboratories and certification bodies is completed to increase confidence in certified products and installations and to spur international trade. Recommendations at this stage include requiring accreditation of all entities, supporting standards maintenance and strengthening international QI.

# 1 INTRODUCTION

The International Renewable Energy Agency (IRENA) supports its members by providing a framework for technology policy aimed at accelerated renewable energy development and deployment. Quality assurance (QA) for renewable energy technologies is a particularly relevant instrument to achieve this goal, as it plays a key role in strengthening rapidly growing markets and reducing the transaction cost for these technologies. This was shown in the 2013 IRENA publication *International Standardisation in the Field of Renewable Energy,* which examined quality infrastructure (QI) and standards for renewable energy technologies. IRENA then focused on how the national infrastructure needed to implement QA mechanisms for renewable energy technologies can be developed and implemented, considering the specific country context.

This work on QI for renewable energy uses the case of two specific technologies to illustrate how such infrastructure is developed: solar water heaters (SWHs) and small wind turbines (SWTs). The results from the study are contained in three reports: 1) a report on QI/QA for SWHs, which is geared towards SWH stakeholders; 2) a report on QI/QA for SWTs, which is geared to SWT stakeholders; and 3) a policy-maker report for focusing on the key insights that can help policy makers develop QI in their countries.

This report provides clear guidance on a balanced strategy that enables countries to establish QA schemes. This study will enrich the understanding of the roles of QI and QA in renewable energy deployment. The study is based on IRENA's previous studies, on interviews with QI experts and on the primary authors' experience and research.

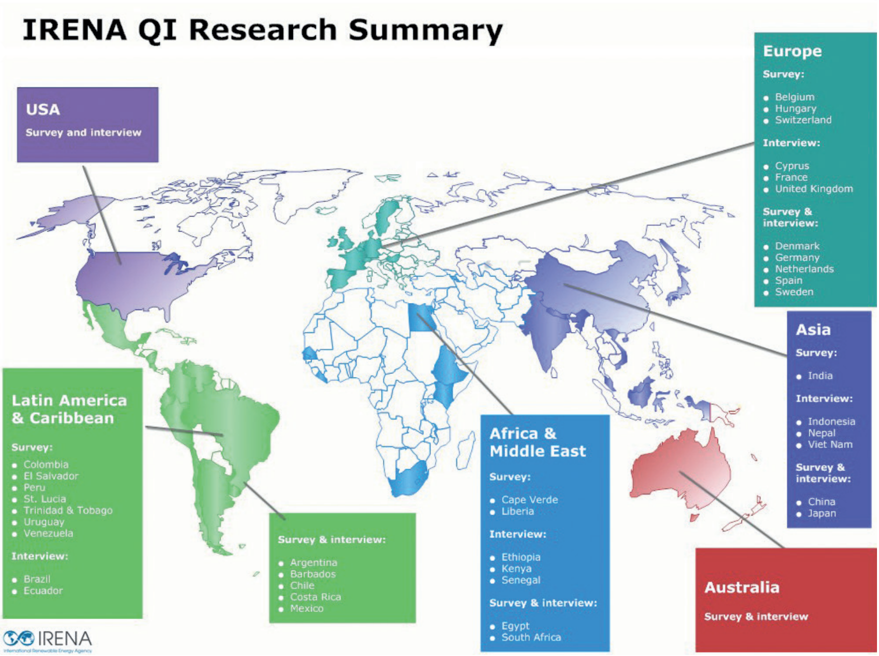
The series of reports *Developing Quality Infrastructure for Small-Scale Renewable Energy Technologies* uses data from 83 survey respondents as well as invaluable feedback from interviews with 34 QI, solar thermal and wind power technology experts.[1] These experts have varied backgrounds and represent countries around the world. Some are directly involved with QI (*e.g.* working with metrology institutes, test laboratories and certification bodies), some are directly involved with broader QA frameworks (*e.g.* manufacturing quality, installer quality, etc.) and some are involved in the technology market (*e.g.* as policy makers, manufacturers, project developers, etc.). The report documents experiences and lessons learned from all of these sources. The recommendations and conclusions incorporate a wide variety of perspectives, interests and business strategies gleaned from the survey and

1 For the interview summaries, please contact IRENA at secretariat@irena.org.

interviews. Figure 1 shows the country of the experts that participated in the survey, the interviews or both.

Section 2 of this report provides an overview of QI benefits. The text in Section 3, kindly provided by the German National Metrology Institute (PTB), offers a discussion of QI elements, and section 4 gives guidance on QI for renewable energy technologies. The German National Metrology Institute (PTB) kindly provided the text and figures contained in section 3.

***Figure 1: IRENA quality infrastructure research summary showing participating countries***



# 2 BENEFITS OF QUALITY INFRASTRUCTURE FOR RENEWABLE ENERGY TECHNOLOGIES

QI provides a wide range of benefits that generally far outweigh the costs of developing and implementing the QI, when it is implemented appropriately for the market. In this section, the array of benefits from developing QI for renewable energy technologies is considered generally, in the sense that the benefits apply to almost all renewable technologies. The treatment is qualitative. The benefits of a well-functioning QI are summarised in table 1 and discussed further below.

## 2.1 Policy-maker benefits

### Nurturing emerging markets

Interviewees from emerging markets often pointed out that QI is needed to screen out technically inferior products whose failures can devastate the market.[2] Just as the farmer protects a seedling from harmful attacks of pests, QI protects an emerging market from the harmful effects of inferior products. Such products may originate from unethical firms or from under-capitalised firms testing their newly developed products in the market. Widespread failures are often well-publicised, tainting consumers' views of the practitioners and of the technology.

Markets can be damaged by these failures for many years, as was experienced in the United States when the SWH market collapsed in 1985 after consumer subsidies were discontinued in 1984. Numerous reports of widespread failures circulated during the 1980s, and the market never recovered even when similar federal, state and utility incentives were re-instated in 2005. Although the reduced cost of natural gas and high U.S. system costs are factors, the continued market depression can be attributed in part to the residual poor reputation of SWH technology in the country (Ghent and Keller, 1999).

Another issue is market understanding of invalid or fake certification. Controlling certificates through the use of a global website may provide a long-term answer, but there is also increased validity when certificates come from accredited organisations that have the proper accreditation to evaluate a specific product.

2 Most country experts made this statement. See sections 3 and 4.

### *Benefits of QI for different stakeholders*

| | |
|---|---|
| **For Policy Makers** | |
| Nurturing emerging markets | QI helps to screen out inferior products, protecting fragile, growing markets and enabling larger markets and technology impacts. |
| Enabling technology promotion | QI provides assurance that desired performance will be achieved and that market stimuli such as incentives and publicity are a sound investment. |
| Stimulating new businesses | Growing markets, secured by appropriate QI, attract capital to feed new business ventures, creating jobs and growing the economy. |
| **For Manufacturers** | |
| Reducing trade barriers and expand markets | QI creates expanded markets by reducing costs of international trade through reciprocity based on mutually accepted QI. |
| Improving product design | Testing and certifying of products help to refine specific design elements, leading to a more robust commercial product; the results also provide marketing materials. |
| Improving manufacturing | When a quality management system (QMS) is developed that conforms to accepted high standards, the product quality is improved and manufacturing volume can be increased without sacrificing quality. |
| **For Practitioners** | |
| Improving hiring and competitiveness of installation firms | Hiring certified installers makes the hiring selection easier and more reliable and increases competitiveness for bidding on bigger jobs. |
| Improving wages and mobility | Certified practitioners are hired first, are afforded higher wages and are more mobile than non-certified practitioners. |
| **For End-Users** | |
| Building confidence in product | Strong QI enhances end-user confidence that the product will work as advertised, produce as expected and save money. |
| Enabling sound product comparisons | QI provides objective information on product performance and durability, which is needed for a reliable product comparison. |
| Increasing financial resources | Strong QI offers financial organisations assurance that products are high-quality and that product loans will be paid, resulting in more available loans. |

Another example is the reduced number of SWTs incentivised in California. According to an interviewed expert: "We have seen a reduction in the number of immature products being offered for sale with exaggerated performance claims. In 2009, the California Energy Commission's Emerging Renewables Program had 184 SWTs under 30 kilowatts (kW); 114 were imported without quality requirements, and after implementing certification requirements, the number of these imported products decreased to four."

### Enabling sound technology promotion

Typical incentive fund project managers have many responsibilities and are not able to serve as technical experts for the technologies for which they create incentives (APEC, 2006). As a consequence, having credible technical guidance from a strong certification scheme is imperative. Incentive fund managers will promote only those emerging renewable energy technologies that can contribute substantially to public goals and that have a supporting QI needed for the industry to develop and to ensure that incentives are well spent. Incentives tied to certification are nearly universal today.

Testing and certification inherent in QI provide ratings, listings, labels and certificates of the system performance needed for incentive organisations to estimate the energy and pollution impacts of the rated technology. The QI structure is especially beneficial when it provides performance ratings that can be directly adopted by the incentive organisation for calculated performance-based incentives. In the United States, the Arizona state programme and the Arizona Public Service solar thermal incentive programme use published annual savings ratings for certified SWHs to calculate their performance-based SWH incentives, citing their use of published ratings as a key factor in reducing programme development costs (Nelson, 2014).

### Stimulating new businesses and job growth

When standards and certification procedures exist, the market is more likely to be stable, and new business ventures can be created based on predicted costs and performance for the market environment. The economy is stimulated as a result of new businesses and jobs. Both start-ups and larger companies venturing into a new renewable energy technology benefit from QI. Start-ups need assurance that low-quality/low-priced products will not dilute the market. Larger firms are hesitant to invest the capital and resources to enter a new market until there is some indication that it is a controlled market with high growth potential, as provided by QI.

## 2.2 Manufacturer benefits

### Reducing regional and international trade barriers

In the past, national QI structures were designed to protect the domestic industry from foreign competition (Fischer and Kovacs, 2014). Although imports typically were not banned, the manufacturer wanting to import was forced to meet different QI requirements in each country's market, adding significant cost and resource burdens. This trend is reversing, as it is believed that expanding markets through reciprocity or harmonisation among the national technical regulations trumps the effect of increased competition, driving down cost and improving performance. The basis for open international trade is the development and promulgation of international standards that ideally would be adopted by all countries, opening worldwide free trade and competition.

Specifically, some countries have made it difficult to enter their country's SWH marketplace without the use of their QI. This has created trade barriers, but initiatives such as the Solar Keymark Network, elaborated in the SWH report, have been changing this for the European region.

Regional QI can be very difficult due to country and climate differences, already-established regional and international standards (such as European "EN" standards and ISO standards) and ongoing harmonisation initiatives (*e.g.* from Underwriters Laboratories, UL [UL, 2015], and the International Electrotechnical Commission [IEC], for PV systems). A global collector certification is being pursued in the International Energy Agency's (IEA) Solar Heating & Cooling Programme Task 43: Solar Rating and Certification Procedures.

The following quote describes the state of the market in Latin America, a reality that is shared by many countries:

> *"Thirty-one countries, 31 legislations, and 31 different quality standards – this is the reality for many products in Latin America, forcing manufacturers to waste time and resources on adapting their products to every single national standard, even in the case of small country markets."*
>
> *– Rosell, 2015*

For SWTs, country QI experts have worked hard to develop strategies and national standards in harmony with each other. This has been the basis of conditionally accepting other countries' national certification. IEA Wind Task 27 has developed the recommended practice on SWT consumer labelling that could be accepted by all countries. The SWT country QI expert relationships have been the basis for including the IEA Consumer Label in the IEC standard as an informative annex.

## Improving product design

As Lord Kelvin said, "If you cannot measure it, you cannot improve it." Once manufacturers uniformly test their products under a QI scheme that publishes performance ratings, their products are publicly and objectively compared with other products. To gain an edge in the market, many manufacturers invest in improving their product to get higher performance ratings. A 36% improvement in the efficiency of collectors was observed, starting in 1977 and levelling out around 1981. A 1976 compulsory testing standard for the US state of Florida spurred the collector testing, which drove the performance improvement.

### Improving manufacturing quality

Higher stages of QI will require inspection and accreditation of manufacturing facilities, which can be an accredited or an unaccredited service. The facilities are inspected for conformity to a set of practices embodied in the standards used to certify the facilities. A quality management system typically is implemented to document materials and manufacturing process, calibrations, etc. Once a QMS is in place, attention will be paid to continuous improvement, the manufacturing variances are reduced, and overall product quality is improved.

> *"Making a production line where every turbine survived and every turbine had the same level of quality is certainly a key part of the needed quality assurance."*
>
> *– Interviewed expert from the Netherlands*

## 2.3 Technician benefits

### Mitigating risk for installation firms and improving competitiveness

As the market grows, practitioner licensing or certifying will grow. Dealers, distributors and installers with the skills to install and maintain renewable energy technologies will be in high demand. These installers may begin with informal, hands-on training and then evolve to formalised training and testing that can meet part of the certification criteria. As installation firms develop, hiring certified installers may make the firm's insurability less costly and increase the firm's competitiveness for bidding on bigger jobs.

### Improving technicians wages and mobility

Trained and certified practitioners will be more capable, have fewer call-backs and be more efficient in completing and validating the installation, making them more desirable to hire. As a result, they will command higher wages compared to uncertified practitioners while producing higher profits for the employer than uncertified employees. Furthermore, a certified employee with credentials can better compete for employment at any location honouring his certification. This increases practitioner mobility, allowing employees to move to better locations or jobs as desired.

## 2.4 End-user benefits

### Building end-user trust

All consumers want a product that will perform and last as advertised. When market quality is unregulated, consumers cannot easily distinguish the relative merits of products. It is easy to understand how a few well-publicised failures can induce distrust in all suppliers and a market decline. When the basis of the value proposition is economic (the technology will save money), the performance and the lifetime are the focus. Although certification does not guarantee a given lifetime, it generally will instil confidence that the unit can survive the expected extremes seen in testing.

> *"The benefits of QI are huge. If you do not have QI, you have erosion of market confidence. The uptake of renewable energy technologies can only increase if consumers have confidence."*
>
> *– Interviewed expert from Kenya*

### Enabling sound product comparison

In an uneducated market, manufacturers and suppliers are unconstrained and can advertise inflated performance and durability data. Also, end-users cannot readily compare products. With published information on performance and durability, end-users can make sound comparisons. Careful comparison helps screen out the poorer products, and sagging sales will prompt the poorer-quality manufacturers to improve.

### Increasing financial resources

To increase financial resources and lower interest, lenders want increased assurance that loans will be repaid. If the product does not perform as advertised, the owner will grow dissatisfied and be more likely to default. If the product makes money for the owner as expected, there is a higher probability that the unit will be maintained and the loan will be paid. Commercial banks do not want to bear technical risk for renewable energy projects. A common requirement from banks to grant loans is the use of certified equipment according to international standards.

# 3 WHAT IS QUALITY INFRASTRUCTURE?

Emerging markets need quality assurance to prevent unsafe, underperforming and failure-prone products from tarnishing perceptions of the technology and poisoning the market. Quality infrastructure is established to provide QA to the market. QI can be defined as the total institutional network (public and private) and the legal framework that:

- Regulates, formulates, edits and implements standards; and
- Provides evidence of its fulfilment (i.e. a relevant mixture of measurements, accreditation, tests, certification and inspections).

Besides nurturing emerging markets, QI aims to promote the equality of products, processes and services for desired purposes, to impede commercial barriers and to facilitate technical co-operation (Sanetra and Marbán, 2007).

A well-organised and reliable QI is a precondition for a functioning international exchange. Standards support compatibility and diminish costs by using equivalent specifications and methods. They are important for creating new industries and when using potential new technologies. Standards allow access to new markets and for the position to be maintained once gained.

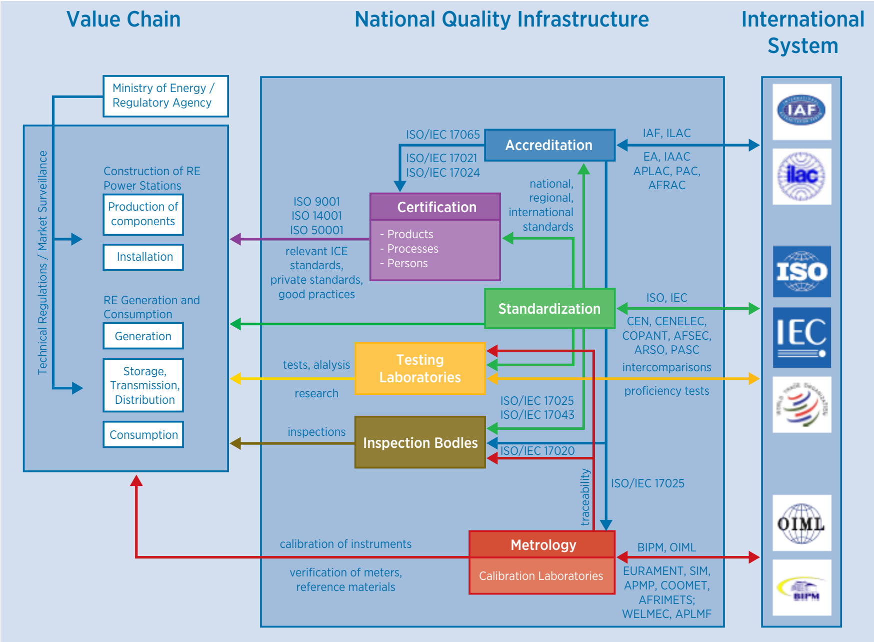
Thus a country requires not only physical infrastructure (*i.e.* roads, energy generation and transmission, or basic services like education and health) for its evolution, but also a network of institutions that ensures the quality of products and services: the QI. This basic framework and its correlation with regional and international networks are necessary for sustainable economic and social development. This network has a national, regional and global dimension and is composed of many public and private actors and stakeholders who work together, directly or indirectly.

It is the government's duty to enable access to these institutions for its citizens. Some aspects of the QI are clearly public goods (*e.g.* the custody and the maintenance of the most important national measurement standards as part of the metrology) (Musgrave and Musgrave, 1979). The most important elements of the QI system are shown in Figure 2.

The right side of Figure 2 shows the national QI with its main components and their relationship to the international QI with their international organisations, which define the standards and rules of the worldwide system.[3] The left side

3 Unaccredited market surveillance is used as well to help beginning markets with minimal QA.

*Figure 2: Elements of quality infrastructure*




Source: PTB, 2014

shows the renewable energy value chain with its two main components: 1) the production of the components and the installation of the renewable energy technology, and 2) the generation, storage, transmission/distribution and consumption of renewable energy. The main relation to the national QI is realised by the conformity assessment institutions (testing and certification), inspections, standardisation and calibration of the measurement instruments. The technical regulations and market surveillance are tasks of the relevant regulatory agencies and ministries that consider the international standards and adopt them to national particularities.

The QI network is very complex and dynamic, with many public and private stakeholders. The main efforts of past years were concentrated on establishing rules and making the system transparent, comparable and reliable, as well as ensuring the technical competence of the institutions and their collaborators. This is only for electricity output, but it covers general QI. The main instruments are:

- The international standards and guides developed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).
- The mutual recognition agreements (MRAs) or multilateral recognition arrangements (MLAs) within the international organisations that secure the conditions for international recognition of the measurement and testing results.
- The results of inspections and certifications.[4]

The main pillars of a national QI are the National Standards Body (NSB), the National Metrology Institute (NMI) and the National Accreditation Body (NAB) (see Figure 3), which form part of the international QI and ensure the relationship with it. All of these elements, adding Testing Laboratories and Certification Bodies, are interrelated and must instil confidence in the buyer, the user or the authorities that the product, the process and the service conform to expectations.

4 The International Laboratory Accreditation Cooperation MRA is regulating the mutual recognition of calibration and testing results. The International Accreditation Forum MRA is dedicated to the mutual recognition of quality management certifications; see www.iaf.nu/articles/MRA_Documents/39. The International Committee of Weights and Measures (Comité International de Poids et Mesures, or CIPM) MRA is regulating the mutual recognition of the measurement certificates; see CIPM (2003).

## 3.1 Standards and technical regulations

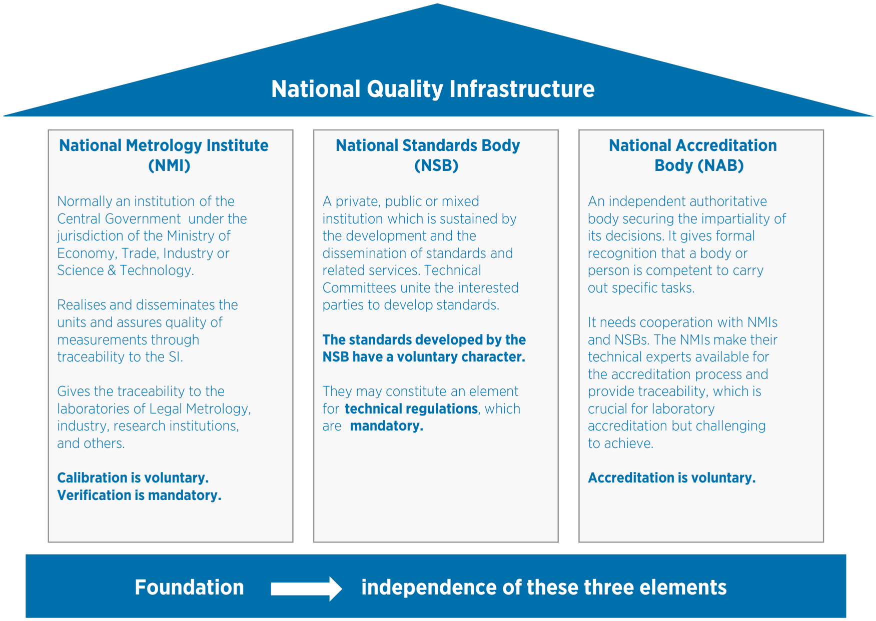
A standard is defined as "a document, established by consensus and approved by a recognised body, which provides for common and repeated use, rules, guidelines, or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" (IRENA, 2013a).[5] Standards can address a wide range of topics, including safety issues, design issues, performance, reliability, etc. They are defined in a formalised document that determines the requirements for a product, process or service.

There is a distinction between formal international, regional or national standards and private standards (ISO, 2010b). Formal standards exist on the international, regional and national levels. ISO, IEC and the International Telecommunication Union develop formal, technical international standards. An example of a formal international standard is the recently approved EN ISO 9806 as the new global standard for solar thermal collector testing procedures. The regional and national standards are also formal standards. In most cases, they are based on formal international standards (unless specific international standards for products and services are not available).

Private standards can be developed by companies or non-governmental

5 This formulation is based on the ISO/IEC 17000 definition.

*Figure 3: Main pillars of national quality infrastructure*




*Source: PTB, 2014*

organisations (NGOs) (in particular producers, retailers and consumer organisations) for their internal use. They are becoming more important as the consumer demand for safer products increases (*e.g.* in the food sector).[6] Sometimes producers and other stakeholders develop private standards when new products enter the market. An example is the Solar Keymark Network, a voluntary third-party certification mark for solar thermal products that was developed with the support of the European Solar Thermal Industry Federation (ESTIF).[7]

Government regulatory authorities develop technical regulations to address public security, health or other issues of national interest. The regulations usually are based on international standards. A key difference is that standards are voluntary, while technical regulations, which can be based on standards, are

6 For example, see GlobalG.A.P.: *www.globalgap.org/uk_en/*.

7 The Solar Keymark Network demonstrates to the end-users that a product conforms to the relevant European standards and fulfils additional requirements. The Solar Keymark Network is increasingly recognised worldwide.

mandatory. Good examples of national regulations are those adopted in a number of countries for the use of alternative energy sources or energy efficiency (in the case of mandatory labelling programmes).

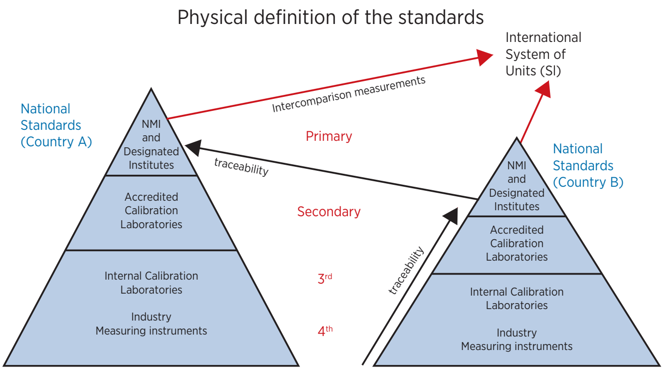
In some countries, the NSBs are private institutions financed by the development and dissemination of standards or by their work as certification bodies. In other countries, they are public entities with Standardisation Committees, which are mirror committees to the ISO and IEC Technical Committees. All interested parties usually are represented in these committees. Other relevant organisations in this field are the standards developing organisations (SDOs). According to the American National Standards Institute (ANSI), SDOs include professional societies, industry and trade associations, and membership organisations that develop standards within their area of expertise. In the United States, SDOs may choose to develop standards that are submitted to ANSI for approval as American National Standards (ANSI, n.d.).

The standards developed by the NSB are voluntary, but they can serve as the basis for technical regulations. Good co-operation among the NSBs, the regulatory agencies and industry is very important and required (ISO, 2010a).

## 3.2 Metrology

Metrology is defined by the International Bureau of Weights and Measures (Bureau International des Poids et Mesures, or BIPM) as "the science of measurement, embracing both experimental and theoretical determinations at any level

*Figure 4: Traceability chains*




*Source: PTB, 2014*

of uncertainty in any field of science and technology" (BIPM, 2015). Metrology covers three main activities:

- Definition of the international units of measurement;
- Realisation of the units of measurement by scientific methods; and
- Establishment of uninterrupted traceability chains from the International System of Units to the end-user by determining and documenting the value and the accuracy of a measurement (EURAMET, 2008) (see Figure 4).

Metrology can be distinguished in the following ways:

- Scientific metrology describes and disseminates the measurement units.
- Industrial metrology utilises calibrations to guarantee measurement instruments, used in production and in tests.
- Legal metrology utilises verification to secure the accuracy of measurements in those cases that influence the transparency of economic transactions, health and security.

In general, the national metrological hierarchy consists of:

- An NMI, which represents the highest level of measurement standards and technical competence.
- Secondary calibration laboratories, which receive the traceability of their secondary measurement standards from the NMI.
- Industrial calibration laboratories, which receive the traceability from the secondary calibration laboratories.

Figure 4 shows the situation of two NMIs. Country A possesses an NMI that relies on primary national standards in primary laboratories, which their traceability put down directly to the International System of Measurement Units (SI). They prove their measurement capabilities by (key) intercomparison measurements with other NMIs. Examples for Country A's NMIs are the National Institute of Standards and Technology (NIST, USA), PTB (Germany), the National Physical Laboratory (NPL, United Kingdom), the National Metrology Institute of Japan (NMIJ) and the National Institute of Advanced Industrial Science and Technology (AIST, Japan).

Country B represents the majority of developing and emerging countries that have only national secondary standards in national reference laboratories belonging to their NMIs, where the traceability is assured by calibrations in one of the leading NMIs of the "A" countries. Their laboratories usually are accredited by an internationally recognised NAB. If their quality management systems are already recognised by a peer evaluation of one of the regional metrology organisations or the BIPM, these

NMIs also can participate in bilateral or supplementary intercomparisons, proving their measurement capabilities in which one of the leading NMIs (Country A) acts as a pilot laboratory. In both cases, the traceability chain of measurements from industry to the SI is assured.

To ensure the quality and accuracy of the measurements, the QMS of the NMIs must be recognised by a peer review of the regional metrology organisations, the BIPM, or the International Laboratory Accreditation Cooperation (ILAC). The technical competence of an NMI is evidenced by the relevant entries of their Calibration and Measurement Capabilities in the BIPM database. The secondary calibration laboratories have to be accredited by an internationally recognised accreditation body, according to ISO/IEC 17025:2005 "General requirements for the competence of testing and calibration laboratories".

In the majority of countries, the NMI is a public institute with its own government budget. If the NMI is managed by the private sector, the NMI's obligations usually are fixed in a contract (*e.g.* custody and maintenance of the national measurement standards, representation of the country in international organisations) and also in government documents (financial means).

## 3.3 Testing

Testing determines the characteristics of a product in comparison with the requirements of a standard. The tests can vary from a simple visual evaluation or a non-destructive evaluation (*e.g.* tests with x-rays or pressure tests after which the products can be used) to a totally destructive analysis (*e.g.* chemical, mechanical, physical or metallurgical tests, after which the products cannot be used) or any combination of both.

An internationally recognised NAB should accredit the quality management of testing laboratories in accordance with ISO/IEC 17025:2005. Laboratories also should follow procedures according to the specific test objects. In many cases, standards or guides define these testing procedures. Sensors and test equipment should meet or exceed the minimum requirements set forth in those protocols for accuracy, precision and reliability. Sensors and test equipment should be calibrated in an accredited calibration laboratory or in an NMI. This is also a requirement of accreditation bodies within the accreditation process (BIPM, 2005).

An important aspect of ensuring and improving the technical test competencies and the comparability of the test and measurement results are inter-comparisons or proficiency tests (PTs), in which a group of interested laboratories conducts tests and/or measurements with identical products, reference materials or measurement instruments. PT providers lead and co-ordinate the PTs, which have to be accredited in accordance with ISO/IEC 17043:2010 "Conformity assessment

– General requirements for proficiency testing". Participation in PTs is often a requirement for the accreditation and re-accreditation of the testing laboratories.

## 3.4 Certification

Certification is the formal verification that a product, service and management system of an organisation, or the competence of a person, corresponds to the requirements of a standard. The certification is realised by conformity assessment bodies, which demand recognition of their technical competence by an internationally recognised accreditation body:

- Certification bodies for QMS according to ISO/IEC 17021 "Conformity assessment – Requirements for bodies providing audit and certification of management systems"
- Certification bodies for products according to ISO/IEC 17065:2012 "Conformity assessment – Requirements for bodies certifying products, processes and services"
- Certification bodies for persons according to ISO/IEC 17024:2012 "Conformity assessment – General requirements for bodies operating certification of persons".

## 3.5 Inspections

Private clients, organisations or government authorities can conduct inspections. They examine the design of products, services, procedures or installations and evaluate their conformity or non-conformity with requirements, which exist in the form of laws, technical regulations, standards and specifications.

An accreditation body should accredit inspections according to ISO/IEC 17020:2012 "Conformity assessment – Requirements for the operation of various types of bodies performing inspection". If they are contracting testing laboratories for their work, the use of accredited entities is recommended.

All accredited testing laboratories, certification bodies and inspections are conformity assessment bodies that have to prove their technical competence with accreditation by an internationally recognised NAB.

## 3.6 Accreditation

Accreditation provides an independent confirmation of the technical competence of an individual or an organisation delivering services (*i.e.* calibrations, tests, certifications, inspections). The most important formal recognitions by accreditation certificates and the respective ISO standards are:

- Testing and calibration laboratories (ISO/IEC 17025:2005 "General requirements for the competence of testing and calibration laboratories")
- Certification bodies for QMS (ISO/IEC 17021 "Conformity assessment

– Requirements for bodies providing audit and certification of management systems")

- Certification bodies for products (ISO/IEC 17065:2012 "Conformity assessment – Requirements for bodies certifying products, processes and services")
- Certification of proficiency test providers (ISO/IEC 17043:2010 "Conformity assessment – General requirements for proficiency testing")
- Inspection bodies (ISO/IEC 17020:2012 "Conformity assessment – Requirements for the operation of various types of bodies performing inspection")
- Persons (ISO/IEC 17024:2012 "Conformity assessment – General requirements for bodies operating certification of persons").

The NAB is an institution independent of the others, therefore securing the independence of its accreditation decisions. This does not mean that strong co-operation is not necessary with NMIs and NSBs. The NAB's technical competence is recognised by a peer review from ILAC (laboratories) and/or the International Accreditation Forum (QMS) or regional accreditation associations that have signed the MLA/MRA with the two international organisations. This procedure ensures that the accreditation certificates are internationally recognised.

Accreditation is a voluntary process. Regulatory agencies can define that they are working only with accredited entities.

NABs are mostly private entities, but with government participation; their activities are regulated by the QI's legal framework. But government bodies also exist in a legal form, which guarantees that the government cannot intervene in the technical decisions. Public-private partnership within the NAB is important.

## 3.7 Quality management systems

Another important element to ensure product integrity is the implementation of QMS for equipment manufacturers or service providers (*e.g.* equipment installers). QMS validate that manufacturing processes result in products with a uniform and replicable quality level and that they are installed, operated and maintained according to sound and documented processes. This is key because product certification is for a specific configuration, and the assumption is that all certified products are manufactured and installed consistently and have the same form, fit and function as the certified product. Consequently, ensuring product consistency becomes another part of the QI framework, which is not covered in this report but is addressed by ISO 9000:2005 "Quality management systems" requirements.[8]

8 See www.iso.org/iso/iso_9000.

# 4 GUIDANCE FOR POLICY MAKERS ON DEVELOPING NATIONAL QUALITY INFRASTRUCTURE FOR SMALL-SCALE RENEWABLE ENERGY TECHNOLOGIES

Governments promote renewable energy markets to meet macro-objectives of national interest, such as energy security, energy independence, energy access, environmental and sustainability targets, job creation or other goals. A strong interaction exists among government policy, market development and the QA requirements needed for a robust market.

The development of a quality infrastructure generally requires seed funding until the industry is sufficiently large to cover the QI costs without government support. Securing funding depends on high-ranking champions in the government structure who understand the benefits of QI and can coherently and forcefully make the case for supporting QI development. The relevant government authorities have to be included at every stage of QI evolution, as they are central to this process.

This section of the report provides information for policy makers, including key insights on developing QI, the main challenges of QI for small-scale renewable energy technologies, and guidance on how to develop and implement the required QI for these technologies.

## 4.1 Key messages for policy makers

A few key messages relevant to policy makers in the renewable energy sector deserve reflection, in a general sense and as they apply to individual countries. These messages, which evolved out of interviews with QI leaders in small-scale renewable technologies, are as follows:

- Lack of QI leads to a dysfunctional and handicapped industry.
- Strategies to develop QI should be incremental and go hand-in-hand with the market development.
- QI and the market progress most rapidly when any market incentives require QI.

- Practitioner training and certification are very important for both emerging and mature markets.

## 4.2 Key survey results

IRENA invited more than 270 people active in QI and small-scale wind or solar thermal technologies to respond to an online survey concerning QI for these two technologies. Eighty-three experts from around the world responded to the survey, 58 of whom were policy makers. All respondents felt that there was an existing SWH and SWT market in their countries. More responses were received for solar thermal systems, probably because global SWH markets have been more active for a longer period of time compared to SWT markets, and the solar resource is globally more distributed than the wind resource. Appendix A shows detailed survey results. Some key results are summarised here:

- The vast majority of respondents (>88%) agree that QA is an important tool to support small-scale renewable energy technology markets.
- Issues related to poor installation, operations and maintenance (O&M) and systems design have the most negative impact on their national markets, as opposed to the hardware itself.
- Policy incentives, strong QA requirements for the products and certified practitioner training are crucial for creating and expanding stable markets.

## 4.3 Key challenges and possible solutions

As discussed in section 3, a complete QI is complex, involving many interacting organisations and stakeholders. The key challenges to implementing QI, and possible solutions, are discussed below.

### Cost

A comprehensive QI is costly to the government and to the industry. Government investment is needed to initiate practitioner training, test laboratories, certification bodies, accreditation of test laboratories and certification bodies, and SDOs. These costs can exceed millions of EUR. Testing and certification of a product line of systems, for SWH for example, varying in size only, costs more than EUR 20 000 in the European Union (EU).[9] Facing such costs, there is justifiable fear that product and system prices will increase with QI implementation. Nonetheless, as discussed in the previous sections, the lack of QI is costly as well, as it can result in a market collapse due to mistrust in the technology.

*Solutions:* QI development should be incremental with the market. For example,

9 A range of costs was provided in the country interviews. The given costs for QI and for system certification are typical costs quoted in EU countries. Although costs will be less in other regions, these costs will nonetheless be uncomfortably high.

new markets implementing QI should begin with a small effort (*e.g.* beginning with practitioner training, demonstration projects and end-user education) to keep costs low.

Participating in development of a regional network where resources are shared among countries presents an opportunity for drastic cost reductions and should always be seriously considered. Regional QI networks can share costs, reducing the cost per country by sharing infrastructure such as training facilities, test laboratories and certification bodies. Each country is spared from fully investing in all QI elements. Examples of regional networks have been set up for SWH but not for SWTs. National standards development costs are reduced drastically by adopting or adapting the most relevant sections of existing international standards while facilitating exports through shared standards.

*Notably, system costs ultimately decrease after QI has been appropriately implemented.* QI supports growing markets for industry and creates competition among equipment suppliers and installers. It is desirable also to ensure competition between test laboratories and certification bodies, which helps keep testing and certification costs down as well. Regional networks facilitate both industry and QI competition.

## Poorly trained practitioners

Early use of new technologies often results in failure. Using best-available and certified equipment does not ensure that systems will deliver as expected if the equipment is installed, operated or maintained incorrectly. For SWH and SWTs, installations are somewhat complex and too often are prone to errors (TÜV Rheinland, 2013).

*Solutions:* Practitioner training is critical at the beginning of the market and is needed throughout market expansion to reduce operational problems with new technologies. There are several existing practitioner training organisations and regional and national practitioner approaches. Practitioner training typically is addressed after product certification, but for countries that will not be manufacturing products, development of practitioner skills takes on the major focus. It is likely that practitioner certification schemes will also provide end-user information that will help move local markets.

## Insufficient infrastructure to enforce quality assurance

One of the barriers is QI implementation. If there is no existing infrastructure to ensure that the standards are followed when required and that systems that are receiving incentives are properly certified, then the QI and the market may fail.

*Solutions:* It is necessary to implement some sort of market surveillance with significant penalties for non-compliance. Visits can be made to installations of incentivised systems to see if the proper system is installed correctly; if there are problems, incentives can be withheld to the offending parties, essentially removing them from the market until the problems are addressed. These site visits can be under the aegis of the certification bodies or an independent organisation. When the market is just beginning with few actors, it may be that few of these visits are conducted. The number can increase as the market grows. It may be very challenging to implement surveillance of inspection bodies when this is not routinely performed for other industries.

### Inferior imports

A number of interviewees expressed dismay about poor-quality imports poisoning an emerging market. In emerging markets, cost tends to dominate unrealistically, as there is often no information about lifetime and performance to balance against first cost. If the cheapest product wins, it is likely that someone will find and import unsuitable lowest-cost, inferior products.

*Solutions:* One approach is to require that imports have an acceptable certification from their country of origin prior to importation. To avoid conflicts with international trade agreements, quality control should be based on international standards. The product certification information should be included on a website listing hosted by credible organisations like Solar Keymark and the Microgeneration Certification Scheme (MCS). There may also be a way to develop country- and regional-specific requirements based on other product certifications, listings and labels.

### Quality assurance requirements supporting incentive policies for renewables

It is common for governments to subsidise renewable energy technologies to spur emerging markets. However, subsidies do not always succeed. There is a risk that subsidies can be given to inferior systems that are lowest in first cost and will tend to dominate the market. These systems typically do not save expected energy and may fail prematurely, wasting money and tarnishing the industry reputation. New capital demands low technology risk in order to justify their investments.

*Solutions:* Policy mechanisms to support renewable energy markets are more effective when incorporating QA requirements that screen out poor-quality systems. If certification is not required, manufacturers generally will not submit their systems for certification. When certification is voluntary but there are significant incentives requiring it, certification becomes *de facto* required, and it is not necessary to impose mandatory certification.

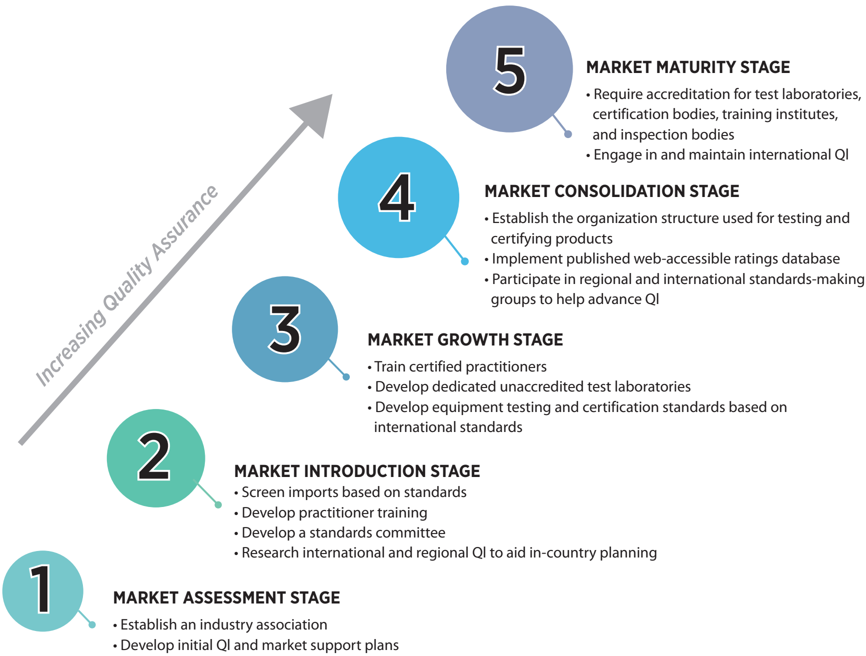
## 4.4 Recommendations for policy makers: the incremental approach to QI for RETs

Interviewees mostly emphasised that the enforcement of QA requirements and the associated development of QI should be incremental in developing markets, building up protections that are suitable for the market as it exists currently. Imposing too strict a regime would create unnecessary cost barriers when the market is starting. Similarly, to avoid damaging the industry's reputation, there must be an appropriate level of protection, especially in early stages.

In this section, the progression of QI elements is linked to five market stages. Figure 5 summarises recommendations for policy makers, based on the market development stage. Each market stage is discussed further below. Which QI elements are best at any stage will depend on the circumstances in each country and region.

Some activities are common to all stages. Market surveys and programme assessments ensure that policy goals and objectives are being met. Market assessment should be performed regularly, every several years, especially before/after there is a change in incentives. Another activity common to all stages is the

*Figure 5: Summary of recommendations for policy makers for each market stage*



development of increasingly broad and rigorous national standards by a national standards committee, based upon accepted international standards. Similarly, at each stage it is necessary to continuously revise the planning documents, as experience will undoubtedly force revisions in the plan. These ongoing needs are not discussed in detail further, but are implicit at all stages. Only the activities entering at a given stage are highlighted in Figure 5 and in the discussion below.

## Stage 1: Market assessment

In this stage, a market of any significance does not yet exist. Background studies and planning are needed. Setting up an industry association is recommended, as it is a key partner to government and other stakeholders for guiding QI/QA evolution and facilitating industry acceptance of QA requirements.

### *Establish an industry association*

Serious consideration should be given at this nascent stage to developing an industry association, if one does not exist already. The industry association consists of those with a business interest in the technology, including manufacturers, distributors and practitioners. The industry group can help the government and others promote the markets, develop QI/QA plans and promulgate QA requirements. The industry group should be in close communication with those developing QI/QA plans. This should be a low-cost item for the government, basically consisting of the initial communications with industry leaders promoting the concept. Once initiated, the industry fully funds the activities of the association.

### *Develop initial QI and market support plans*

A flexible plan is needed to set expectations and estimate government costs over time for establishing a QI framework. Government and industry costs at various stages of QI (*e.g.* extent and rigor of test labs, certification bodies, standing standards body, accreditation) should be estimated as a function of time, perhaps using the market stage framework elaborated below. Some consideration should be given as to future incentives to put in place to promote the market once QA has been established.

Requiring certified imports based on international standards is important, as they likely will dominate initial markets. However, there may be legal issues and procedural mazes in regard to banning non-certified imports that can take some time and require resolution at this early stage.

## Stage 2: Market introduction

The market is very small and beginning to grow, with no strong industry actors or associations. Such new markets may likely start by importing products. Local manufacturing development depends on having a sufficient market, as well as other factors related to the available technical skills and industrial capacity of the country.

### *Standards for screening imports*

QA screening of *imports* based on international standards avoids the need to set up the national-level QI elements.[10] Import surveillance may be used. Funding must include developing and training import inspectors on certification documentation required for imports.

*Practitioner training* is a key element in QI/QA, as a quality system requires quality equipment and quality installation and quality maintenance. Good, certified hardware can be imported, but installation and maintenance are necessarily local and must be addressed locally. To keep investment low when no industry infrastructure exists, engineering departments at higher education institutions are good places to start training development, because expertise – especially when integrated across departments – may exist already.

Although national standards are the basis for all national QI, such standards will mainly refer to or adopt international standards. A *standards committee* must be set up to oversee the development and maintenance of these standards. This committee will exist throughout the entire market development cycle, although activity and funding will vary. Although the committees usually are made up of volunteers from academia, government, industry and other stakeholders, funding is necessary to seed the process, manage the groups and contract for any studies needed to support the standards.

Most interviewees recommended that the *existing international standards be followed as much as possible* when developing national standards. *This should be a mandated policy for the standards committee.* With this strategy, the risk of technical blunders is eliminated, the cost of standards development is drastically reduced and the end-users will be more confident. It is recommended for SWH and SWT cases that the national standards be developed incrementally, with the reliability tests deemed most relevant to an emerging market to be implemented first. Nonetheless, these initial tests still should follow closely (or be identical to) the relevant international standards, coming closer to the international standards as the market matures and QI is expanded.

These simpler, lower-cost efforts are a higher priority at this stage perhaps than developing a formal test facility or certification body, which are not really needed at this stage and are expensive to create.

### *Research into global and regional QI*

International and regional QI schemes are a good way to reduce costs of QI development. Partnerships with other countries will reduce costs, increase flexibility and nurture regional trade for local manufacturers and practitioners. This should

10 In emerging markets where national-level QI is already established, imported products could be required to obtain national certification, as implemented in Brazil.

be a serious option investigated at this stage. An assessment must be made of the viability of any proposed international and regional scheme. For SWTs, there are agreed-upon international standards and international templates for IEA/IEC Consumer Labels that provide sound basis for a regional SWT certification

Some interviewees raised the issue of climatic differences trumping regional schemes. However, *climate variations are not a barrier to a regional scheme*, as all accepted performance standards produce general performance models which are applicable in any climate. When climatic variations are large (*e.g.* hard freeze to non-freeze climates), it is necessary to specify options for testing (*e.g.* heat pipes freeze/burst test mandated only for freezing climates) and for system requirements (*e.g.* freeze protection mandated in freezing climates, or corrosion-resistant coatings mandated for marine climates) that can be applied when appropriate.

## Stage 3: Market growth

At this stage, the market is small but is growing rapidly from a combination of imports and locally produced products. Training of certified practitioners to correctly install, operate and maintain the systems is essential at this stage.

### *Certified training, laboratories, certification organisations*

*Training.* Certified practitioners should become available to the market. Training courses for SWHs and SWTs have been developed previously, and getting materials from these organisations is probably the lower-cost option compared to developing the training infrastructure (criteria, courses, testing, administration/rules) from scratch. Certificates should be issued by the training organisation(s), and a public posting should be made listing certified installers and their firms. Training may be subsidised initially, as class size may be too small initially to be self-sustaining.

*Testing.* Dedicated albeit unaccredited test laboratories should be developed, if not already provided by a regional partner. When developing the lab from scratch, tests should be limited at first to reliability testing. These tests should meet the corresponding requirements found in the international standards. The first goal of the testing is to limit hardware-related failures through durability testing. Subsequently, performance ratings can be considered. The ratings may be limited in scope or accuracy, to keep testing costs low. The test and rating results could be posted online, posted in appropriate locations or shared for use in other public documents. There may be university or educational programme involvement; these groups have expertise and can become the centre of information for end-users on product durability/duration and performance.

*Standards* for equipment testing and certification need to be developed incrementally by the national standards committee based on international standards.

*Certification.* An organisation attesting that the system meets the criteria laid out in the national standards is needed. It is necessary to set up guidelines for system reviewers, aiding in determining compliance. Reviewers may be contracted externally on a per-system-review basis, to start the process without undue delay. The certification may be done by the testing lab initially, but the certification body should be made financially and politically independent of the testing lab as soon as is feasible.

### *Deciding on regional collaboration*

By this stage, decision makers should see more clearly whether a regional or international scheme for standards and certification should be pursued for QI development or if these entities must be developed entirely in-country. Such decisions can significantly affect the costs of QI development, with regional collaboration generally helping to reduce costs for national governments.

## Stage 4: Market consolidation

In this stage, the market is large enough to support the cost of expanded QI needed for the market to reach full maturity. Support is provided for certification bodies and for improving the test laboratories so that they can fully implement accepted international standards. If a regional certification is being pursued, the recommendation applies to the overall region of multiple countries, rather than to an individual country.

### *Unaccredited testing, certification and published ratings*

*Organisations.* The next step is to establish the whole institutional structure for certifying products. At this stage, the test laboratories and certification bodies need not be accredited, but they must closely follow international standards and be preparing for accreditation. Test laboratories provide results to certification bodies. The laboratory and the certification body must be separate to avoid conflicts of interest, as emphasised in section 3.

The certification body will review the design for meeting criteria related to health, safety, performance from test results, durability/duration and/or aesthetics, and attest that it will meet the criteria defined in the national standards. It is important to certify that a given product meets the criteria established in national standards. Some product criteria are determined by the test laboratory, particularly including the required durability tests.

The test laboratories must be able to implement all aspects of the international standards at the accuracies specified in those standards. *A key testing shortfall that has been identified is traceability of the measuring instruments, as discussed in section 3.* The effort should support test laboratories in this stage as preparation for their accreditation as the final step in the next stage.

Test labs and certification bodies must have sufficient capacity to handle the volume of applications generated by the marketplace. It is especially important to plan for building QI capacity when planning for new incentives. In China, for example, the number of available commercial SWH products and manufacturers that grew exponentially after promotion programmes were introduced overwhelmed test laboratories and certification bodies, making certification difficult or impossible to get. It was effectively ignored by smaller manufacturers. Long processes to develop and implement national QI can seriously harm the market and breed ill feelings with manufacturers and suppliers who are waiting for certification and unable to enter the market.

*Published ratings* should make essential data available, as this eliminates false advertising claims by suppliers, provides them with independent, trustworthy information for advertising, and bolsters consumer confidence in the products in question. Ratings are important to the following groups:

- **Consumers**: to compare systems and calculate their own expected system economics
- **Manufacturers**: to provide product advertisement data and objectively compare with other manufacturers
- **Incentive organisations**: to provide a low-cost basis for performance-based incentives
- **Analysts:** to improve accuracy of national saving studies and refine subsidy structures.

The ratings for SWHs may be published by the certification body based on the test laboratory reports, as in the United States. In other SWH cases, the ratings may be issued by a body separate from the test laboratory and the certification body, as in Solar Keymark.[11] The certificates and labels may be published for SWTs by certification bodies and other entities.

## *Advancing regional and global QI*

Participation in regional and international standards-making groups helps ensure knowledge of and ability to influence standard changes. Therefore, countries with a consolidated market for a renewable energy technology should support the participation of national experts in technical committees at ISO or IEC, which develop the relevant international standards. This participation facilitates incorporating national-specific aspects into international standards and thus best facilitates trading in international markets.[12]

11 The ratings will be based on a set of *rating conditions* that include the *use conditions* and the *site weather*. The test reports provide models that incorporate any chosen rating conditions to give the rated performance.

12 ISO/TC 180 (Solar Energy) is working to incorporate into ISO 9806:2013 "Solar energy – Solar thermal collectors – Test methods" the aspects of evacuated tube systems that were incorporated in early Chinese national standards.

## Stage 5: Market maturity

As the market matures at higher volumes, industry cash flows increase and industry is able to absorb increased testing and certification cost without significant price impact. The main difference in QI between this stage and the previous stage is that accreditation is completed, to increase confidence in products and installations, and to spur international trade.

### *Full implementation with accreditation*

*Accreditation* should be required for test laboratories, certification bodies, training institutes and inspection bodies. One challenge in a mature market is the time required to achieve accreditation, which could take up to two years for a test laboratory or certification body. In Chile, the national bureau provides an interim or conditional approval for those test laboratories and certification bodies that have begun the accreditation process to the new standard. Government funding for QI development should be diminishing, with the goal being that industry supports maintenance of the QI infrastructure in its entirety.

### *Engage in international quality infrastructure*

Ideally a global market is opened through the implementation of globally accepted standards and certification requirements. This is just beginning to happen for SWHs, particularly with regard to collector standards. For SWTs, national standards have already mostly been distilled into accepted international standards. The thrust in the international standards community appears to be to move from national to regional and finally to unified international QI, exploiting the many benefits of multi-country standards. Regional SWT standards likely may develop, as they have for SWH.

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# APPENDIX A:

## Summary of the study's survey results

In addition to the telephone interviews with the 34 experts to collect relevant insights for this study, IRENA invited more than 270 people active in QI and small-scale wind or solar thermal technologies to respond to an online survey with questions concerning QI for these two technologies. Eighty-three experts from around the world responded to the survey.

The survey utilised skip logic, so survey takers were directed to different paths depending on their responses. First, all survey takers indicated whether they are policy makers. Fifty-eight respondents answered "no" and were directed to a different path from the remaining 25 respondents who answered "yes". Policy makers were asked a series of questions related to policy, while non-policy makers were directed to a question asking which technology they are more involved with, SWH or SWTs.

Respondents who selected "solar water heating" were directed to a path containing questions related to that technology, and respondents who selected "small wind turbines" likewise answered questions related to that technology. Once the survey takers completed the technology-specific questions, they joined the policy-maker survey takers in answering one general question (see Figure A-2) before being asked to complete demographic information.

This appendix provides a summary of survey highlights.

## A.1 General survey results

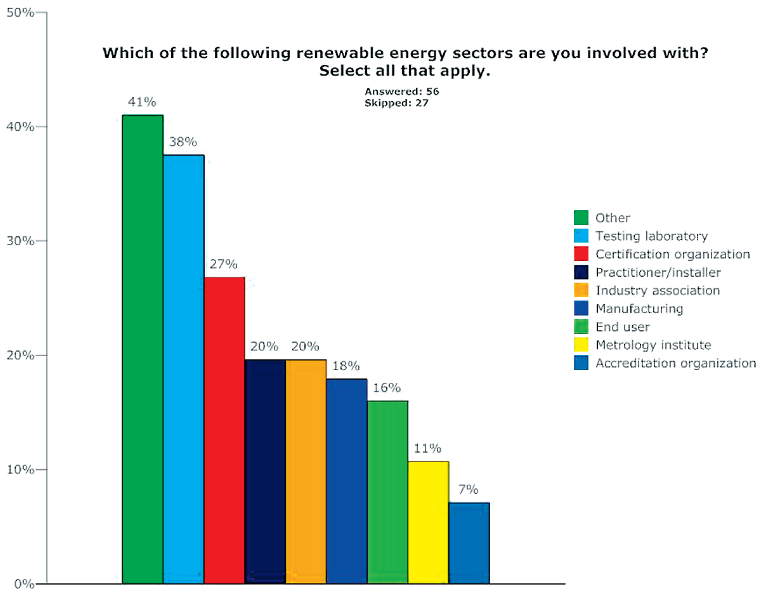
Figure A-1 shows the renewable energy sectors represented by the respondents who indicated that they were *not* policy makers.

The overwhelming majority of respondents, policy makers and non-policy makers, agreed that quality assurance is an important market tool for small-scale renewable energy applications (see Figure A-2).

## A.2 Market survey results

The international SWT market is not as well developed as the international SWH market. As shown in Figure A-3, all policy makers responding to the question of whether there is an existing market for SWH in their country selected "yes" or "no"; no one selected "do not know", which demonstrates that the policy-maker respondents have a definitive view of the state of the market.

*Figure A-1: Renewable energy sub-sectors represented by non-policy-maker survey respondents*



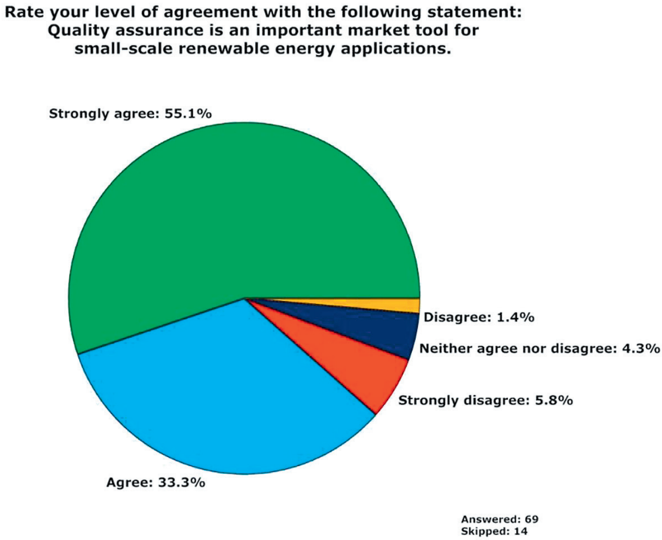

*Note: Percentages total more than 100% because respondents were instructed to "select all that apply"; many respondents represent more than one renewable energy sub-sector.*

This is not the case with SWTs. The SWH technology seems ready to become a commodity in many countries. One possible reason is that typically opportunities exist to manufacture SWH components locally; SWT systems, however, are more difficult to produce locally, leaving local markets to rely on turbines imported from elsewhere. Another reason may be the length of time that the technology has been used in the global marketplace.

Non-policy makers shared similar views about the existence of markets for their technologies. SWH experts were certain (100% indicated an existing market), while SWT experts were not so sure (73% indicated an existing market).

One question asked of respondents was: do you have any comments on how to strengthen QI for small wind turbines or solar water heating in your region?

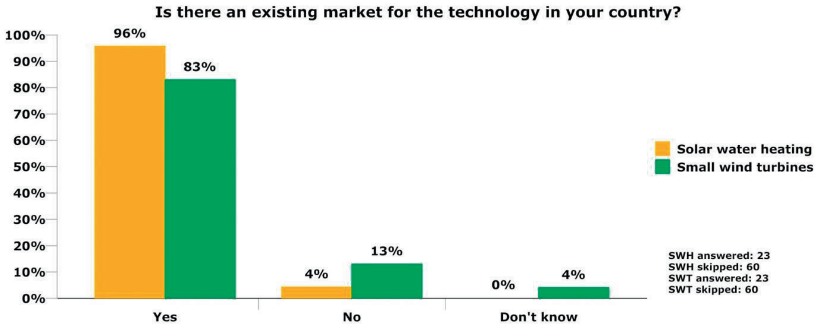
*Figure A-2: Survey respondents' level of agreement with the importance of quality infrastructure as a market tool*




The survey respondents' comments included the following:

- "More information dissemination, education and training activities across the stakeholders that is supported by adequate legal and regulatory mechanisms, certification of technicians and service providers, and incentive schemes necessary to strengthen QI."
- "Improve practitioner training and make it more focused."
- "A local partner, quality assurance and certification will guarantee success of the technology and long-term results."
- "Implement a system certification process that is accredited by a third party."
- "The main aspects to strengthen QI for SWT would be education and promotion with examples of use, and public policies and incentives."
- "Clear requirements for technology eligibility for incentives are required."
- "Two things need to be in place: policy and institutional framework and human resource development."
- "South-south co-operation could be a useful tool for this purpose at the regional level (those at similar

*Figure A-3: Policy-maker survey respondents on whether solar water heating and small wind turbine markets exist in their countries*




latitudes and climate conditions working together)."

- "Train key stakeholders in best international standards."

Survey respondents believe that one way to strengthen QI for SWTs is via education and promotion, with examples of use and a demonstration project.

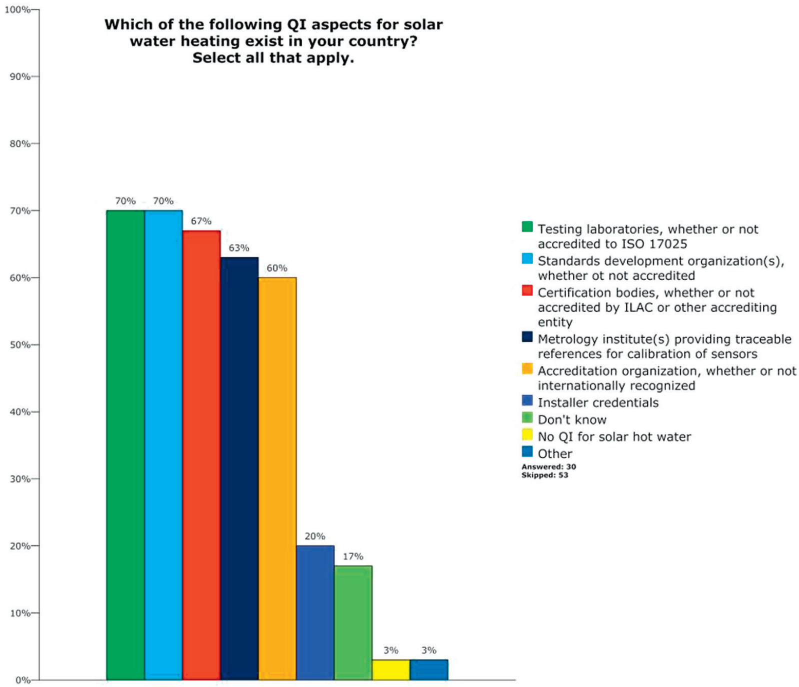
## A.3 Selected solar water heater survey results

Question: "Which of the following QI aspects for solar hot water technology exist in your country?"

IRENA received 30 responses from survey takers who indicated that they are mostly involved with SWH technology, as shown in Figure A-4. Testing laboratories and the standards development organisation are the two dominant aspects of implemented QI, followed closely by certification bodies and metrology institutes. Survey and interview data show that the majority of countries have standards development organisations participating in IEC and national standards, as well as a testing laboratory using ISO series or national standards. Another noticeable point is that installer credentials do not seem to exist for many countries surveyed.

The 30 respondents then identified aspects having a negative effect on their country's SWH market, summarised in Figure A-5. These results point to the

*Figure A-4: Existing quality infrastructure activities for solar water heating, as identified by experts*




need to improve installation skills to remove the noted negative impact that this leaves in the marketplace.

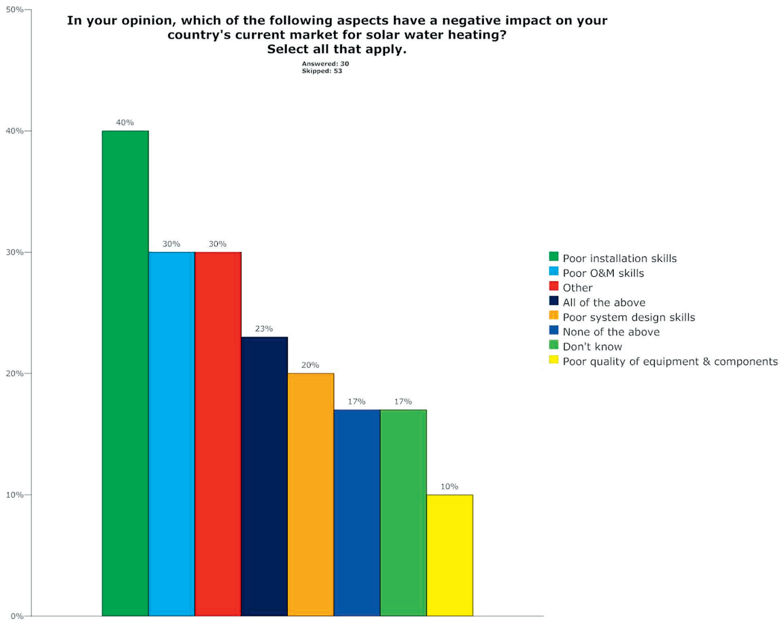
When asked to define "other" negative impacts, respondents answered:

- "Installation is the major aspect where failures occur. Whilst there are failures relating to other aspects, these are generally not the case."
- "The overall situation focusing on electricity rather than on heat."
- "High costs."
- "Subsidised fuel cost, low electricity rates."
- "Competitive prices. Gas is very cheap here now."
- "Building crisis, components price."

Survey takers asked to identify ways to strengthen the QI for SWH in their regions responded with the following suggestions:

- "Establish a better QI system and better implementation, an incentive

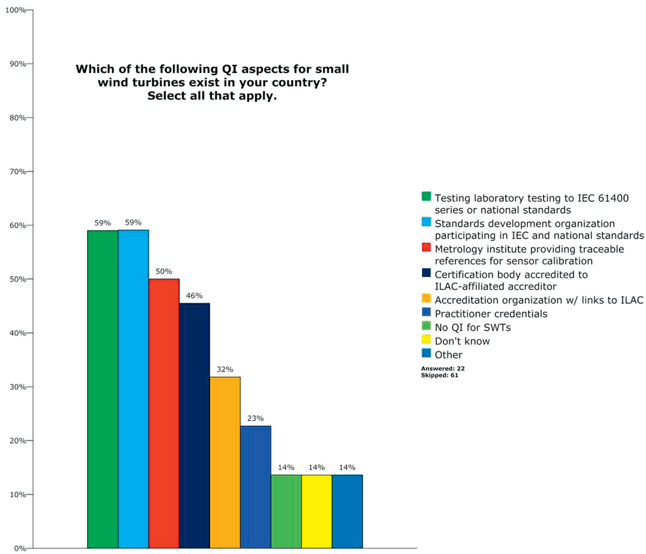
*Figure A-5: Negative factors for solar heating markets, according to respondents mainly involved with solar heating*




program, and a better monitoring system."

- "In the Asia Pacific region, it varies considerably and is different across countries."
- "Lower taxes and train in quality."
- "Develop the regional capacity to test solar water heaters."
- "Incorporate quality requirements in national legislations and suppliers."
- "Incentives should be conditional on approved products."
- "Installers should be held responsible for poor installations. Non-compliant products should be removed from the market. Safety outweighs cost!"
- "Building regulations should require the use of certified products and installers."
- "Create buy-in for regional certification quality markets (*e.g.*

*Figure A-6: Existing quality infrastructure for small wind turbines, as identified by experts*




Solar Heating Arab Mark and Certification Initiative [SHAMCI] in the Middle East and North Africa, support countries that build proper testing and accreditation infrastructure)."

- "Update legislative requirements, including efficiency requirements."
- "Strengthen national renewable energy policy."

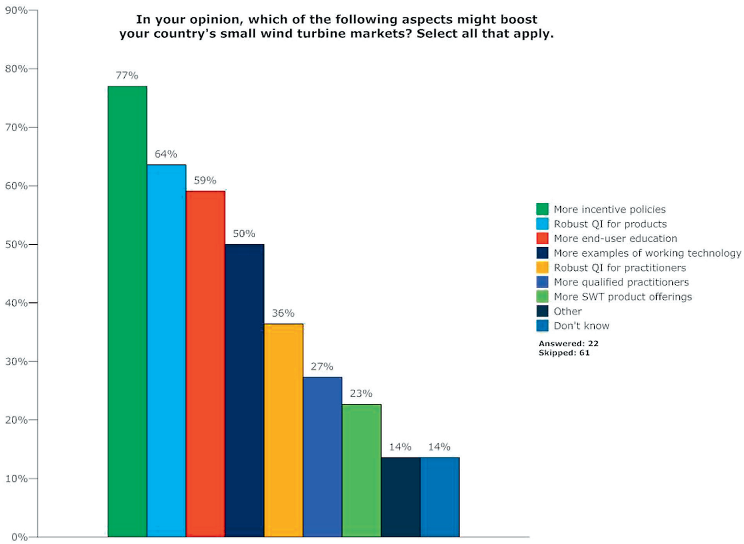
## A.4 Selected small wind turbine survey results

Question: "Which of the following QI aspects for small wind turbines exist in your country?"

As shown in Figure A-6, the 22 respondents who indicated that they were mostly involved with SWT technology identified a focus on standards development and testing laboratories. Note that, again, practitioner credentials currently do not exist in many of the survey respondent's countries.

Respondents also identified QI aspects that might boost their countries' SWT markets (see Figure A-7). The ranking starts off with incentive policies, robust QI for products and more end-user education, followed by more demonstration projects or examples of working technology. After that there is recognised need for practitioner QI, which is also

*Figure A-7: Quality assurance factors that could boost small wind turbine markets, according to respondents*

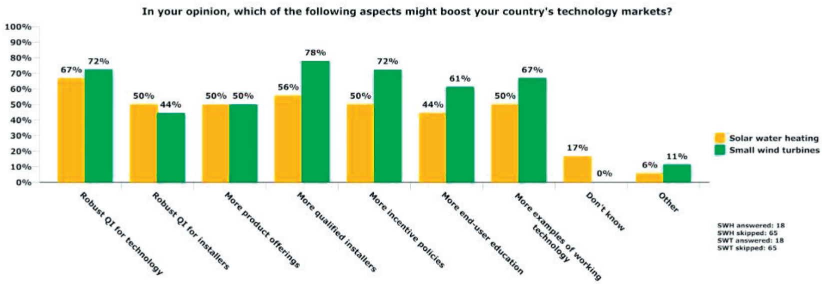



mentioned in other survey results and interviews.

Survey takers asked to identify ways to strengthen the QI for SWT in their regions responded with the following suggestions:

- "Only certified products should be considered for incentives."
- "Establish a support scheme for small wind turbines that is only applicable for certified products."
- "The Alliance for Rural Electrification mandate covers all developing countries and emerging markets. Conditions differ widely from country to country. In general, there is the need for the following interventions:
- Develop trainings on standards and certifications to technical staff of public institutions and bodies (*e.g.* Ministry of Energy, Regulator or Rural Electrification Agencies) in charge of formulating the policy and regulatory framework.
- Mainstream standards and certifications in the country's regulatory framework.
- Ensure proper enforcement of the established regulation (*e.g.* technical staff of the regulator in charge of

*Figure A-8: Factors that could boost national technology markets, according to respondents*




the issuing the licenses and border control agencies).

- Need to train the non-state stakeholders on the new regulatory framework."
- "Certification to a standard like The American Wind Energy Association's 9.1-2009 should be required. IEC standards focus on safety, which is not a problem, and do nothing for being truthful about performance, which is a huge problem."
- "Certify products and installers in the market; currently too many are uncertified."
- "Certified test sites and training. Informed customers."
- "Public regulation."
- "Enforce certification requirements and clearly define certification requirements for consistency from all certification agencies."
- "More publicity."
- "Link incentives to higher requirements."
- "Develop the standards, testing, certification, and labelling."
- "Make certification a requirement for loans and/or permits for installation of machines."
- "Educate the manufacturer on the requirements of the standard, performance, and design evaluations."

These results point to the need to improve installation skills to remove the noted negative impact that this leaves in the marketplace.

# APPENDIX B:

## Pico PV lighting market and quality

*Based on an interview with Arne Jacobson, Director, Schatz Energy Research Center, Humboldt State University, United States*

Pico-size PV products are used mainly in the developing world. The products range from small solar task lights to mini-solar home systems with PV modules of 10 watts or less, with affordable prices for low-income consumers (up to approximately EUR 118). The quality found in the pico-size PV markets in Africa highlight low-cost ways to institute QI without direct government support. The effort to develop QI for this application in this market cost approximately EUR 736 000.

In 2007, the World Bank funded an effort to ensure quality of pico-size PV systems; at that time, no test methods or standards had been implemented. A focus group developed a simple test procedure and a Lighting Global Minimum Quality Standard that balanced desired test information and affordability. These were the basis for the test protocols; once they were finalised, commercial testing began at the Fraunhofer Institute, a test laboratory offering unaccredited pico-size PV testing.

Dialogue among pico-size PV stakeholders expanded from developing the test protocol to communicating with suppliers, bulk purchase buyers and distributors, who developed an understanding of the value of QI, the test procedures and results. This scenario highlights the most cost-effective way to reach consumers and provide quality information; any other approach requiring direct consumer education would be expensive, particularly for dispersed populations.

The website LightingGlobal.org has a QA section showing minimum standards, test methods, a list of all products that meet minimum QA standards, programme statistics and information on revoked products. The site's current statistics show that 100 products have been tested; 59 of those products met the Lighting Global Minimum Quality Standard, and 19 met the standard after receiving feedback from Lighting Global. In sub-Saharan Africa, 2.7 million products were sold with the label through June 2013.

Developing an IEC standard for this technology has been a critical issue in receiving government support from other countries. The cycle time to develop IEC 62257-9-5 edition 2 was 15 months, a very short cycle for typical international standard development. The technical specification includes test methods, quality metrics and recommended passing thresholds.

There are three levels of testing: 1) test according to the QI test method, 2) initial product screening and 3) market check testing. One test laboratory in Germany and two in the United States can accommodate the first level of testing. A test laboratory in Nairobi performs the second and third levels; new test laboratories in Senegal and New Delhi will have the same test scope. Plans are under way to build a new test laboratory in Southeast Asia, close to the manufacturers. The third test should be developed regionally; the strategy so far has been not having a test laboratory in every country. Test laboratory work is transitioning from universities to private test laboratories.

The cost to develop test procedures has been several hundred thousand Euros, and every time a standard is revised it costs about EUR 74,000 to develop new test protocols and educate the market stakeholders about the changed standards. Being engaged with IEC in standards making and going to meetings cost approximately EUR 74,000 for travel and labour for two-and-a-half years. The website, which is relatively inexpensive to administer, includes verification letters and other information.

Manufacturers submit their products as part of the voluntary programme for testing and business support, including participation in workshops and trade shows, consumer awareness campaigns, marketing support and introductions to financial institutions. (Sometimes microfinance institutions will help them market their product.) A number of the distributors and financial institutions insist on certification, but the governments do not request certification.

Some products have failed based on random market checks or surveillance, and those are listed on the website. A pico-size PV product is purchased in the retail market and then is tested to the test procedure. If it passes, the product is certified for two years. During that time, the manufacturer could swap out components, so random market checks are performed. This framework is independent of government involvement.

The initial scope of this work was in Kenya and Ghana. Efforts currently are focused on other African countries and India; programme leaders would like to expand to Bangladesh and Nepal.

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