IRENA

International Renewable Energy Agency

# Quality Infrastructure for Renewable Energy Technologies

## Small Wind Turbines

December 2015

## 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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# ABBREVIATIONS

| | |
|---|---|
| AC | Alternating current |
| ANSI | American National Standards Institute |
| AWEA | American Wind Energy Association |
| BWEA | British Wind Energy Association |
| CEDER | Centre for the Development of Renewable Energy (Centro de Desarrollo de Energias Renovables- Spain) |
| CIEMAT | Research Centre for Energy, Environment and Technology (Centro de Investigaciones Energéticas, Medioambientales, y Tecnológicas – Spain) |
| DAS | Data acquisition system |
| dB | Decibel |
| EN | European standards |
| ENAC | National Accreditation Entity (Entidad Nacional de Acreditación – Spain) |
| HAWT | Horizontal-axis wind turbine |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| IECRE | IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications |
| IREC | Interstate Renewable Energy Council (U.S.) |
| IRENA | International Renewable Energy Agency |
| ISO | International Organization for Standardization |
| ISP | Institute for Sustainable Power |
| ITAC | Interstate Turbine Advisory Council |
| JSWTA | Japan Small Wind Turbine Association |
| kW | Kilowatt |
| MCS | Microgeneration Certification Scheme |
| MEASNET | Measuring Network of Wind Energy Institutes |
| NABCEP | North American Board of Certified Energy Practitioners |
| NWTC | National Wind Technology Center (U.S.) |
| O&M | Operations and maintenance |
| PV | Photovoltaic |
| QA | Quality assurance |
| QI | Quality infrastructure |
| R&D | Research and development |
| RPM | Rotations per minute |
| SWAT | Small Wind Association of Testers |
| SWCC | Small Wind Certification Council (U.S.) |
| SWH | Solar water heating system |
| SWSA | Small wind site assessor |
| SWT | Small wind turbine |
| UL | Underwriters Laboratories |
| VAWT | Vertical-axis wind turbine |
| WWEA | World Wind Energy Association |

# 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 has proven to be indispensable for establishing an enabling environment for a rapid uptake of renewable energy technologies. Quality assurance 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. Quality assurance 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.

Emerging markets need quality assurance 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.

This report examines QI as it relates to technology for small wind turbines (SWTs), starting with an overview of SWT technology and markets. This is followed by a discussion of established international and national standards, testing and certification, as well as examples of implementation in select countries. Challenges and recommendations for developing QI for SWTs are given, focusing on policy-rich, grid-connected expanding markets.

A key challenge for developing and implementing QI for SWTs is how to contain the costs while maintaining the integrity and reliability of QI and keeping in synch with the market. Key insights are:

- Base any regional or national standards for SWT testing and certification on existing international standards, including:
- IEC 61400-2:2013 "Wind turbines – Part 2: Small wind turbines"
  - IEC 61400-11:2012 "Wind turbines – Part 11: Acoustic noise measurement techniques"
  - IEC 61400-12-1:2005 "Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines"
  - ISO/IEC 17025:2005 "General requirements for the competence of testing and calibration laboratories"
  - ISO/IEC 17065:2012 "Conformity assessment – Requirements for bodies certifying products, processes and services"
- Harmonise country requirements for beginning markets, for example using the IEC Consumer Label for SWTs, which are based on testing only.
- Consider developing QI for SWTs as part of a regional or international network, sharing costs and organisation development and responsibilities among nations. An example is for solar water heating (SWH) technology, which has a regional certification scheme called Solar Keymark.
- If there are no opportunities for developing in-country or regional QI, require certifications as part of import control.

- Since proper installation is key to properly functioning systems, it is crucial to develop rigorous training for installers (necessarily local), especially as the market is beginning.
- SWT product maturity has evolved over time through design and testing activities; it is important to select the right time for testing in the product life cycle. The SWT should be a stable, commercial product before testing to the IEC duration test requirements; no changes to the SWT under test are allowed during the test period.
- To keep costs low for manufacturers and suppliers in developing markets, develop QA requirements gradually as the market matures and as local manufacturing develops, starting with durability testing and simpler (albeit less-accurate) means of testing and predicting performance. A QI development sequence is recommended for five market stages.

This publication – part of a set on developing QI for small-scale renewable energy technologies – is meant to provide helpful examples and guidance for anyone involved in planning or promoting SWT solutions, along with energy sustainability in broader terms.

# 1 INTRODUCTION

One of the ways the International Renewable Energy Agency (IRENA) supports its member countries is 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.

This report, which is part of a series of reports in the field of QI for renewable energy technologies, focuses on QI/QA for small wind turbines (SWTs). It provides clear guidance on a balanced strategy that enables countries to establish QA schemes for SWTs while securing the financial feasibility of SWT implementation and overcoming capacity deficits. This study will enrich countries' understanding of the roles of QI and QA in SWT deployment. The study is based on IRENA's previous studies and expertise on standards for renewable energy technologies, and on the primary authors' experience and research.

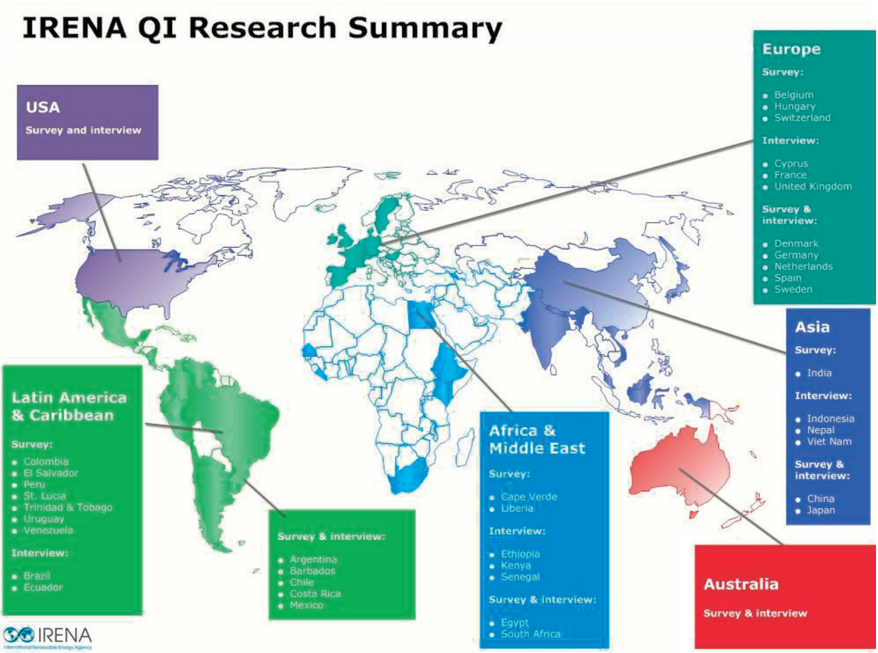
The series of reports *Developing Quality Infrastructure for Small-Scale Renewable Energy Technologies* uses data from 83 survey respondents as well as invaluable feedback from interviews with 34 QI, solar thermal and wind power technology experts.[1] These experts have varied backgrounds and represent 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 interviews. Figure 1 shows the countries of the experts that participated in the survey, the interviews or both.

Section 2 of this report discusses SWT specifics, including an overview of the technology and its applications and a summary of the global market.

Section 3 discusses international standards and common practices, global certification and key test equipment used.

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

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




*Where VRE: variable renewable energy*

Section 4 summarises selected country QI for policy-rich, grid-connected SWT markets.

Section 5 summarises all of the input into key challenges, and section 6 discusses recommendations on how to start QI for different market levels.

# 2 AN OVERVIEW OF SMALL WIND TURBINES

This section examines SWT technology and markets. SWT technology is a specific market and is not as developed as solar water heating or other renewable technologies. The market applications that produce electricity are divided into off-grid and on-grid (utility grid-connected or grid-connected). In most of the world, SWT are used for battery charging or off-grid electricity solutions, but the recent focus on financial incentive policies for grid-connected turbines has resulted in the development of a QA framework that will be discussed in section 3.

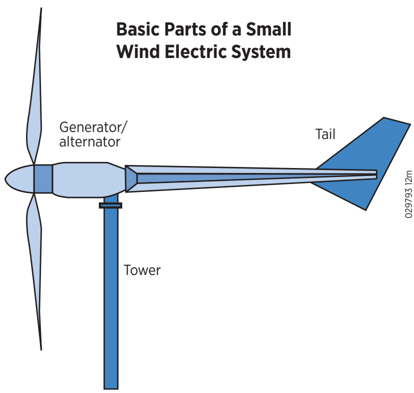
## 2.1 Technology

Wind turbines convert the wind's kinetic energy from mechanical energy collected by the rotor into electrical energy through the generator. Main components of wind turbines (see Figure 2) include a rotor, a generator/alternator (and inverter), a tower and a tail (to keep the turbine pointed into the wind and to enable furling or folding at high rotational speeds).

A permanent magnet alternator configuration is the most typical of small wind generator technology. These direct-drive machines with a permanent magnet alternator produce 'wild' alternating current (AC) or variable frequency and voltage electricity, which must be converted through an inverter. Another common generator configuration is a turbine rotor shaft connected to a gearbox and an induction or constant-speed generator. Constant-speed generators produce AC electricity, so power conversion is not required. Typically, a gearbox is used to convert the RPM of the rotor to what the generator needs.

Wind turbines can be found in a variety of sizes and designs, usually categorised by whether they rotate around a horizontal axis (HAWT) or a vertical axis (VAWT).

***Figure 2: Basic parts of a small wind turbine***




*Source: Open Energy Information, 2015*

The vast majority of SWTs sold utilise a three-bladed, horizontal-axis configuration, although designs exist which use different numbers and types of blades and different axes of rotation. Currently, many of the commercial HAWTs and one VAWT hold certificates from accredited certification bodies based on accredited test laboratory results to national standards.

A critical design feature for wind turbines is an overspeed control to keep the SWT within a safe operating range. SWTs commonly use mechanical activation, which includes furling or blade twist at a given rotor RPM, and electrical activation, such as pitching blades into and out of the wind. Control methods are typically a combination of both mechanical and electrical methods and can include strategies such as stall control, pitch control, braking, etc.

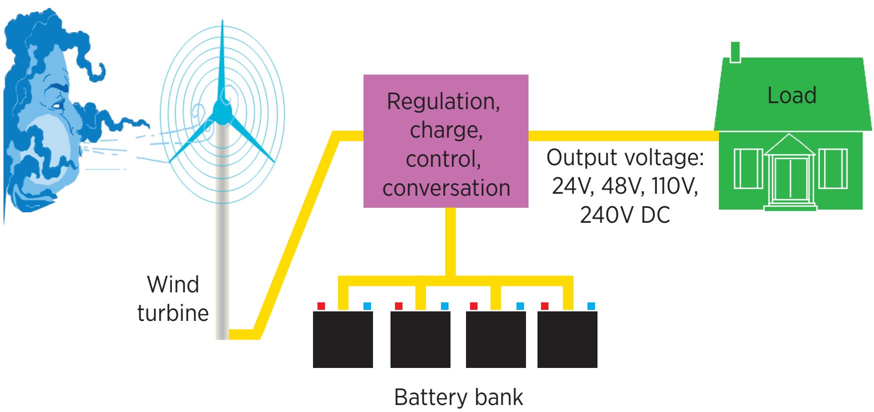
There are different definitions of 'small' wind turbines, but the third revision of the international small wind design standard IEC 61400-2 defines them as wind turbines with a rotor-swept area less than 200 square metres ($m^2$). This definition corresponds to approximately 50 kilowatts (kW) of nominal generation capacity or less.

A tower or support structure suitable for the SWT and its location should be selected. Because wind speed increases at greater heights, end-users tend to install the turbine on as high a tower as possible. However, SWT operations and maintenance (O&M) need to be considered in tower height selection.

## Small wind turbine applications

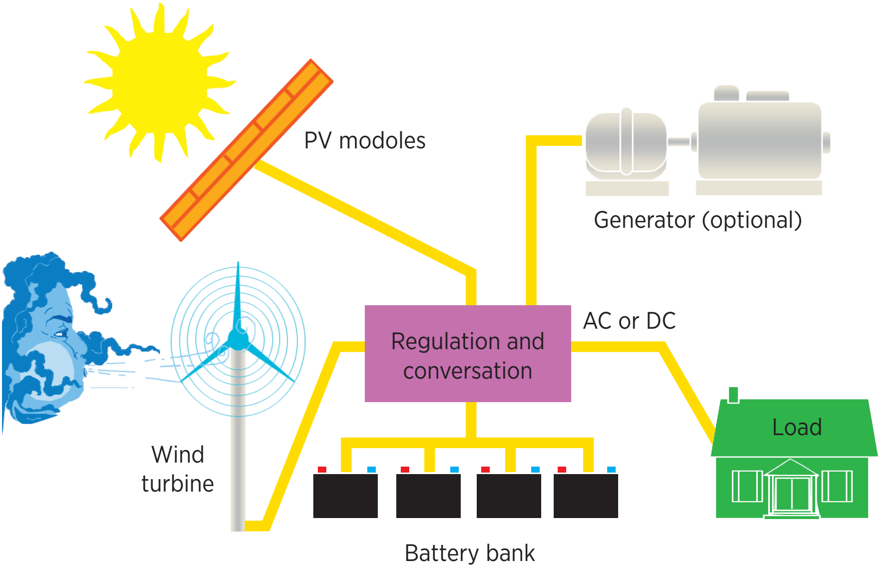
SWT technology can provide power for many countries because of its ability to be

***Figure 3: Off-grid schematic***




*Source: Green, 2003*

*Figure 4: Mini-grid/hybrid power schematic*



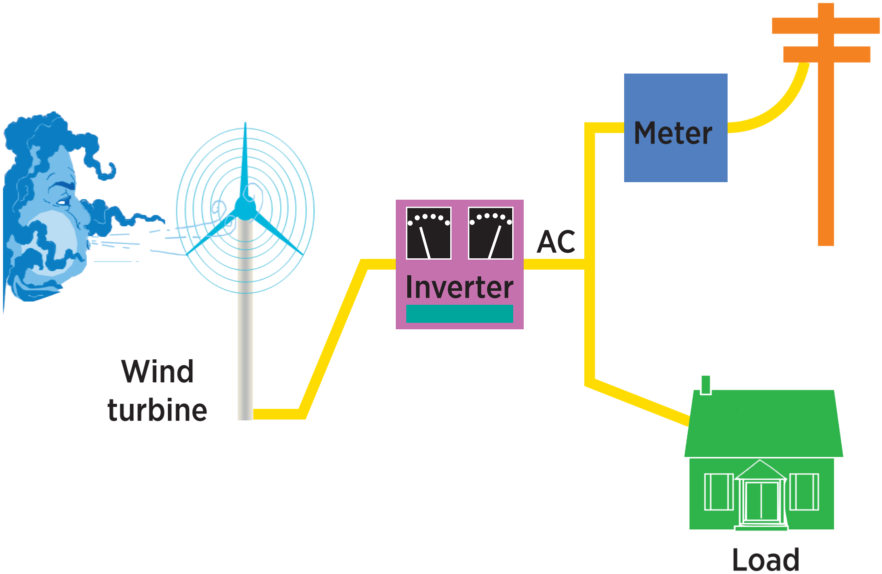

*Source: Green, 2003*

either completely off-grid (see Figure 3), part of a mini-grid/hybrid power system (see Figure 4) or interconnected to the centralised utility grid or grid-connected (see Figure 5) (Green, 2003).

The off-grid application and the system design typically have an ability to choose the output voltage of the off-grid system. Although higher voltages have more-efficient electrical conversion, lower-voltage systems are more typical of global off-grid applications. Battery bank sizing involves careful consideration of the electricity needs and likelihood of lack of wind.

Different renewable and conventional electricity technologies can be merged to produce mini-grid or hybrid systems which produce a more constant supply of electricity. Generators, while optional, can be dispatchable and affect the quantity of batteries needed to maintain consistent electricity. In general, using wind and solar technology is ideal because the wind and solar resources complement one another. On a daily cycle, there may be more solar-generated electricity during the day and more wind-generated electricity at night. There are also seasonal variations; during months with fewer sunlight hours, the wind system may produce more electricity.

*Figure 5: On-grid or grid-connected schematic*




*Source: Green, 2003*

Conversely, during the months with more hours of sunlight, there may be less wind and more solar electricity production.

Figure 5 shows a schematic of how SWTs generally can be used to interconnect with the utility grid and deliver electricity at the same voltage and frequency as the utility grid. The inverter not only outputs electricity in a grid-compatible form, but it must also turn off automatically if the utility grid goes down. If that happens, the home is without power, unless the system incorporates a battery bank for backup power during a utility outage.

## 2.2 Market status

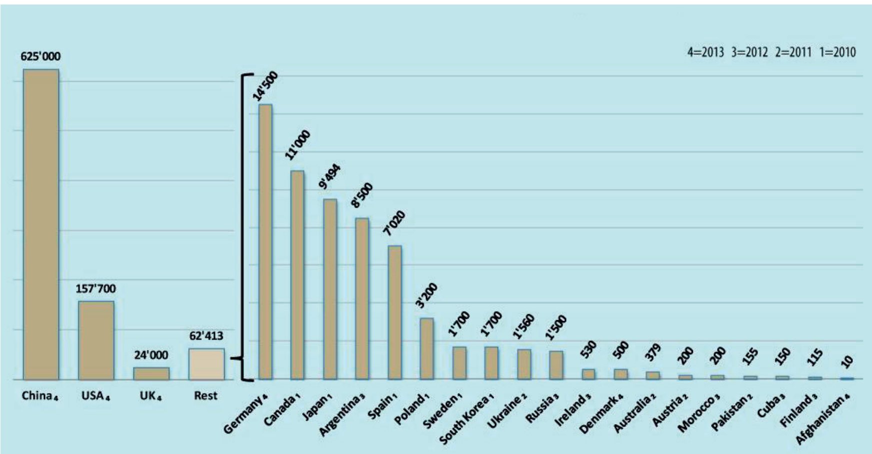
There is a large market for off-grid, local electrification solutions throughout the world. A market for grid-connect systems also exists in industrialised countries. Although relatively new in comparison to the decades of off-grid living, the grid-connect market is growing where there is access to a centralised utility grid, higher electricity prices and good wind resource. In built-up areas, taller towers can compensate for the poor wind resources sometimes found near the ground among a high density of people and buildings.

Grid-connect turbines can be connected with the local utility grid and used to meet a variety of incentive policies. The World Wind Energy Association (WWEA) issues an annual report that assesses the international SWT market. The report highlights feed-in tariffs for 14 countries or regions, all of which are for grid-connected turbines (except in Greece). Both the grid-connect and off-grid market sectors continue to grow globally.

The WWEA (2015) report notes: "As of the end of 2013, a cumulative total of at least 870,000 SWTs were installed all over the world. This is an increase of 8% compared with the previous year, when 806,000 units were registered." Most of this growth is in China, the United States and the United Kingdom. China dominates in the number of installed units, with the majority of that market being smalloff-grid turbines.

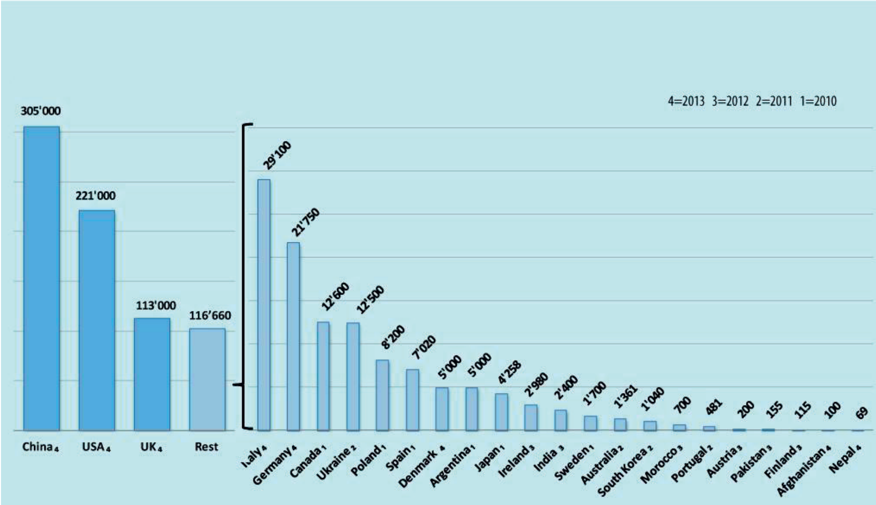
Figure 6 shows the number of installed small wind units by country, and Figure 7 shows the total installed small wind capacity by country. Note the high degree of penetration in certain countries. The majority of capacity is located in just three countries: China, the United States and the United Kingdom. China leads for both number of installed units and installed capacity. The United States and the United Kingdom have incentive policies that help motivate end-user purchases. Germany ranks fourth for the total number of installed units, while, as Figure 7 shows, Italy ranks fourth for total installed capacity.

***Figure 6: Total cumulative installed small wind units by country***




*Source: WWEA, 2015*

*Figure 7: Total cumulative installed small wind capacity by country (KW)*




*Source: WWEA, 2015*

While there is global geographic diversity of SWT technology, the industry faces a continuous and highly damaging influx of products with inflated performance claims and/or misleading product labels. Consumers, including public sector entities, often cannot distinguish between realistic and unrealistic claims. These fringe products have done tremendous damage to both the image and the sales of the legitimate SWT industry; therefore, the major SWT manufacturers worldwide strongly support SWT standards and certification requirements (WWEA, 2014).

# 3 DEVELOPING QUALITY INFRASTRUCTURE FOR SMALL WIND TURBINES

QI requires the development of testing laboratories and certification bodies, along with the supporting organisations for accreditation, inspection, installer training and standards development. In this report, we focus on the testing laboratories, highlighting the equipment and related standards.

## 3.1 International standards

### Standards

The international community has worked hard to harmonise QI for SWTs, initially through an International Energy Agency (IEA) Recommended Practice, then as an informative annex to the International Electrotechnical Commission (IEC) standard IEC 61400-2 as a Consumer Label. IEC standards have been developed that set the baseline for safety, design, testing and certification for all wind turbines, large and small, as well as for other electricity-producing products.

The third revision of IEC 61400-2, released in December 2013, was modified to include an introduction of dynamic analysis requirements, an addition of high-wind test conditions to meet the duration test requirements, information on environmental conditions affecting SWTs and the inclusion of a recommended template for an IEA/IEC Consumer Label for SWTs. Some improvements to the third revision of IEC 61400-2 are based on the national country standards of Japan, the United Kingdom and the United States.

To meet international and national standards, there is a need to conduct specific tests, models and analyses as identified in the standards. Table 1 summarises the relevant IEC standards for SWTs. Meeting all of these standards is not currently required by certification bodies. For example, IEC 61400-22 is being retired as a standard on conformity and testing. IEC 61400-13 offers guidance for using loads measurement as the method to validate loads. In IEC 61400-2, two other methods are allowed: simplified loads equations and aeroelastic simulation models.

The IEC standards form the basis for the national standards that were developed by the following organisations:

- American Wind Energy Association (AWEA);
- RenewableUK, previously British Wind Energy Association (BWEA);

*Table 1: IEC small wind turbine suite of standards*

| IEC standard | Standard title | Status |
|---|---|---|
| IEC 61400-2 | Wind turbine – Part 2: Small wind turbines | 1st Revision 1995<br>2nd Revision 2006<br>3rd Revision 2013 |
| IEC 61400-11 | Wind turbine generator systems – Part 11: Acoustics noise measurement techniques | 2006 |
| IEC 61400-12-1 | Wind turbines – Part 12-1: Power performance measurements of electricity-producing wind turbines | 2006 |
| IEC TS 61400-13 | Wind turbines – Part 13: Measurement of mechanical loads | 2001-06 |
| IEC 61400-14 | Wind turbines – Part 14: Declaration of apparent sound power level and tonality values | 2005 |
| IEC 61400-22 | Wind turbines – Part 22: Conformity testing and certification | 2010 |

- Japan Small Wind Turbine Association (JSWTA).

Different national standards are similar in part because, historically, they were developed in a short period of time. US SWT standards-making created a draft that was adopted by the United Kingdom's BWEA before adoption in the United States. Having identical standards immediately opened up these two markets.

The JSWTA standard followed and has similarities as well as differences from the AWEA and BWEA standard. But the similarities within these standards make it less costly for manufacturers to meet certification requirements.

Countries that do not have SWT QI policies could adopt the IEC standards or existing national standard to enable harmonisation and reciprocity agreements.

Over time, the UK stakeholders have refined their national standard to be very short, since it references specific IEC standards in whole. This represents an increase in the rigor needed to have a certified SWT, and, as the market matures, so should the product and the QI requirements.

## IEA/IEC consumer labelling

Note that an IEA/IEC Consumer Label is based on test data, a subset of certification requirements for both national and international certification. It offers the early markets a way to develop early QI.

Consumer labelling has been developed internationally with an IEA-recommended practice and an informative (not required) annex in the third revision of the IEC 61400-2. The IEC standard requires that test results be provided by a test laboratory meeting ISO 17025.

The sample IEA Recommended Practice Consumer Label is shown in its generic form in Figure 8. The information includes annual energy production estimates based on power performance testing per IEC 61400-12-1,[2] sound information based on acoustics testing and analysis per IEC 61400-11 (and possibly IEC 61400-14), and occasionally design classification or turbine test class as specified in IEC 61400-2. Having accurate and comparable test results will help consumers understand energy production and sound information.

Different national standards handle acoustic emissions differently. Manufacturers have expressed strong concerns about reporting the Sound Power Level because this measurement is at the location of the wind turbine and is much higher than any observer on the ground would hear. Ground-level acoustics can be calculated and reported as the Sound Pressure Level.

***Figure 8: Sample IEA-recommended practice consumer label***

| Test Results | |
|---|---|
| **Manufacturer** | **Manufacturer** |
| **Model** | **Model** |
| **Reference Annual Energy**<br>at 5 m/s average wind speed, actual production will vary depending on site conditions | **### kWh/yr** |
| **Declared Sound Power Level**<br>at 8 m/s | **## dB(A)** |
| **Turbine Test Class**<br>(I-IV or S for Special) | **II** |
| **Tested by** | **Test Organisation** |
| **Published Date**<br>(Year-Month-Day) | **2011-03-04** |
| For more information, see | www.ieawind.org |

*Source: IEA, 2011*

Some countries now require IEA/IEC Consumer Labels as part of their certification scheme.

## Climate conditions

The third revision of IEC 61400-2 discusses different climate and environmental conditions in the normative references, including dust, typhoons, saltwater corrosion, tropical conditions, etc. Islands experience different conditions; a special test should be defined for the island saltwater environment for the turbine system, including the electrical systems

2 The third revision of 61400-2 has an informative annex on consumer labelling, which is similar to the Consumer Label developed under IEA Task 27 Recommended Practice. See IEA (2011).

where saltwater and tropical conditions can be found.

### Technology neutrality

The IEC 61400-2 standard does not allow for the calculation of simplified loads for VAWTs, making it more time-consuming for VAWTs to meet certification requirements. The IEA/IEC Consumer Label creates equity in the certification process and in the time to develop the label, creating equal market access regardless of SWT technology type.

### Future international IEC conformity assessment

The new conformity body IECRE (IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications) will list many renewable energy products – including SWTs, solar PV, marine technologies, etc. – that meet IEC standards or other credentials. The organisation will perform near-term work developing requirements, strategies and implementation of posting of renewable energy certifications and/or labels through its dedicated website.

Since there is a common international agreement on the IEA/IEC SWT Consumer Label, it is likely that SWT technology may be one of the first technologies highlighted on the IECRE website. Although the use of the IEA/IEC Consumer Label has been limited to date, there are products with certificates and IEA/IEC Consumer Labels ready for posting.

## 3.2 Testing

There are a variety of levels of testing and associated costs, ranging from low-cost duration and performance testing to unaccredited testing and finally accredited testing. Accredited system tests and certification costs for SWTs cost roughly EUR 60 000 - EUR 130 000 per turbine model. This is a huge burden for manufacturers but is often a requirement for entering the policy-rich incentivised national markets. Some markets have further requirements to meet quality management systems per ISO 9001 or factory production control review. While these are important steps to guarantee consistent quality, they are expensive.

Low-cost testing can offer all of the stakeholders, including test organisations, an opportunity to learn about SWTs and testing. This level of testing may be appropriate for new turbines that are not yet well understood. During initial testing, the turbine should exhibit safe operation during start up, shut down and other wind conditions. Basic wind and turbine data collection can be started to help characterise power production.

An incremental increase in testing capabilities can be developed by following ISO 17025 and the IEC SWT standards as much as possible. As incentive policies are created and as markets develop, there will be a need for more-accurate test results. Eventually, accredited, accurate test results will become a minimum QI level. There are few global test laboratories for SWTs, and their test reports fulfil partial certification requirements. Most accredited certification bodies will accept only accredited test results (although there is some allowance for unaccredited test laboratory results to be used if the procedures and results are audited by accredited certification bodies).

When completing testing to meet duration test requirements, the SWT may not be changed within the test period, which must be a minimum of six months and 2 500 run-time hours. Specific high-wind speeds and hours of operation are also required. For some test laboratories, it may take longer than six months to reach the 2 500-hour minimum.

## Test sites

Test laboratories can be accredited or unaccredited, with accredited test laboratories providing greater assurance of reliable and accurate test results. Accredited test laboratories must use instruments and data acquisition systems that are calibrated per the standard's requirements, and those calibrations must be traceable to a national metrology institute. There are also requirements for the staff conducting testing and the need for a quality management system.

Because of the high up-front costs to develop a test site, testing of SWTs to standards in support of certification programmes typically is subsidised by governments or is part of a for-profit business. Often test facilities may produce test results for different certification and scheme requirements. Accredited test laboratories with an International Laboratory Accreditation Cooperation connection can be the basis of many national and international certifications. With accredited test results, it is possible that a "test once, certify everywhere" approach may work.

Test sites are typically selected in areas with high winds, on rural or undeveloped land, and away from local settlements and the turbulence created by trees, buildings, or other structures. Usually these test laboratories are sited on large tracts of land so that test sites can be developed as needed. (To meet IEC power performance test requirements, there must be an unobstructed area upwind of the turbine, 20 times the turbine diameter in the prevailing wind direction.)

Before setting up the specific test sites, wind resource information should be collected. Consideration of meeting duration test requirements should be taken into account. Measurements of the wind speed and direction over time are needed to help determine the prevailing wind direction and to the seasonal and yearly variability in the wind resource. Variability between years can be as much as 20%.

For some parts of the world, accredited and unaccredited test labs exist that can conduct SWT tests. Typically these test labs are found in countries and regions with incentives, such as the United States and the United Kingdom, which both have accredited test laboratories.

For the majority of the world, however, SWT test laboratories do not exist, and they likely would be challenged by not having enough testing work. It may become practical to associate the test laboratory with a university or other educational institute so that faculty and students can use SWTs for demonstration and research projects. Test lab projects can start as demonstration projects and transition to unaccredited testing following ISO guidelines.

In the United States, some unaccredited test results are used to meet the AWEA standard, if the certification body audits the test results. These same test results can be the basis for the IEA/IEC Consumer Labels and used in the interim until certification requirements can be fully developed.

## Small Wind Association of Testers

Current IEA Wind Task 27 activities include launching a global annual meeting and technical exchange for test laboratories. The Small Wind Association of Testers (SWAT) was convened with the intention of sharing testing knowledge, refining the understanding of standards-based testing and conducting proficiency tasks. SWAT members discuss the details of testing SWTs to IEC standards. The association and its international collaborative network foster market growth and consolidation by ensuring better, more comparable test results. In the process, the network also raises awareness about consolidation opportunities among SWT actors.

## Key equipment required for SWT test laboratories

Table 2 lists typical measurement equipment needed to meet the requirements of testing to the international standards. These measurements can be the basis of certification if the results are from an accredited test laboratory, or the basis of labelling if the results are from an unaccredited test laboratory using ISO 17025. Either way, the goal is to test per the IEC or national standards and to meet the requirements as closely as possible.

Unique test equipment for SWTs includes a meteorology mast with anemometers and wind vanes for measuring wind speed and direction. Temperature and pressure data help to provide understanding for atmospheric characteristics. A data acquisition shed houses the data acquisition systems (DAS), turbine inverter (if appropriate), measurement equipment and computers.

The meteorology mast typically is installed two to four rotor diameters upwind of the turbine in the prevailing wind direction (the preferred distance is 2.5 times the rotor diameter). The wind anemometers should be installed at two heights, one of which is at the turbine hub height to help determine shear and to accurately measure the wind entering the rotor.

## Proficiency testing for accredited testing

Many accredited test laboratories that test large wind turbines join the Measuring

*Table 2: Tests and equipment necessary for small wind turbine testing*

| Test | Equipment | Description |
|---|---|---|
| Performance test to IEC 61400-12-1, duration test to IEC 61400-2 | Anemometers, primary and reference | Device that measures wind speed in two or three dimensions |
| Performance test to IEC 61400-12-1, duration test to IEC 61400-2 | Power transducer | Device that measures the amount of power produced |
| Performance test to IEC 61400-12-1, duration test to IEC 61400-2 | Wind vane | Device that measures the wind direction; certain sectors of wind direction information may be discarded in the analysis phase |
| Performance test to IEC 61400-12-1, duration test to IEC 61400-2 | Current transducer | Device that measures the current produced by the wind turbine system |
| Performance test to IEC 61400-12-1 | Temperature transducer | Device that measures the ambient air temperature |
| Performance test to IEC 61400-12-1 | Pressure transducer | Device that measures the ambient pressure |
| Performance test to IEC 61400-12-1 | Precipitation sensor | Device that measures the start and end of precipitation |
| Performance test to IEC 61400-12-1, duration test to IEC 61400-2 | DAS | System that collects and analyses data measured by the above devices. More than one DAS can be used for a complete system test. |
| Duration test to IEC 61400-2 | Rotor-speed sensor | Device that measures the rotational speed of the rotor |
| Acoustic test to IEC 61400-11 | Digital recorder and signal analyser and signal conditioners | Devices that record acoustic signals, analyse those signals and possibly condition or amplify the signals |
| Acoustic test to IEC 61400-11 | Microphone | Device that converts acoustical waves to electrical current |
| Acoustic test to IEC 61400-11 | Calibrator | Device used for calibrating measurement devices, recorders and sound analysers |

Network of Wind Energy Institutes (MEASNET[3]), which offers proficiency testing and a community for sharing experiences within accredited test laboratories. MEASNET was established in 1977, and its membership is predominantly European Union wind turbine test laboratories.

The goal of MEASNET is to improve and ensure the quality of wind energy technology measurements carried out by the members in order to allow mutual recognition and interchangeability of results and to achieve uniform interpretation of standards and recommendations (MEASNET, 2008). There is an application process to become a member and maintain that membership. MEASNET has a primary focus on measurements of wind velocity and wind turbine generator systems that can be used for investors and bankers in the wind farm business.

## Acoustic testing and reporting

Acoustic testing provides information on wind turbine sound and is one of the more difficult tests due to the sensitivity of the instruments, costs to acquire the full DAS and the need to wait for the wind to be the correct speed and direction for testing.

Acoustic measurements are taken when the turbine is not operating to gather background acoustic output, as well as when the turbine is operating to gather turbine acoustics, and both measurements are reported. Wind speed and direction information is also gathered to be used during data analyses. Wind speed information is averaged with a one-minute interval; the same averaging period is used in power performance testing.

The sound power level is the sound at the source, whereas the sound pressure level is the sound at a specified distance from the turbine. Sound pressure level is measured by microphone. Acoustic details often are presented in units of decibels (logarithmic scale), or dB, for sound power and sound pressure levels, further confusing the information.

Noise test and analysis results are reported differently depending on the national standard used, making direct comparability difficult. Although specific sections for SWT within the IEC 61400-11 help bring specificity to the testing needs, there is still a need to tailor acoustic reporting to the permitting data requirements for a particular country. Acoustic test results may also be analysed per IEC 61400-14, as required by national standards.

## Low-cost duration and power performance testing

One way to simplify testing for SWTs is to use lower-cost calibrations; low-cost wind tunnels could be developed for calibrating anemometers, and/or field installations of side-by-side anemometer comparisons could be explored. A wind tunnel can be designed that gives the calibration needed to meet uncertainty levels for power

3 See www.measnet.com.

meters, anemometers, etc. However, the lack of instrument traceability will make it impossible to achieve accreditation. Universities or other educational entities can be used as a cost-effective beginning for test laboratories, bringing multiple benefits to the professors, students, communities and practitioners.

Both duration and power performance tests can be conducted using the same DAS and analysis tools; there is only a difference in the sampling time requirements, which can be handled in the data processing and reduction part of analyses. Temperature or pressure measurements are not required for simplified, lower-cost testing.

### Test article selection

Design detail aspects – such as structural loads, reliability, materials or manufacturing quality issues – have a greater influence on duration test results than on power performance test results. The duration test is strongly dependent on the turbine's manufacturing quality, so the test article should be selected randomly and acquired in a way that end-users would use.

Another approach is selection of the turbine to test by independent representatives at the factory. The goal is to use a standard method for test article acquisition, instead of an enhanced product designed for test success and not the commercial market. Power performance is less dependent on manufacturing QA.

## 3.3 Certification

The EU utilises self-certification in the form of the European CE mark. Part of the requirements includes back-up reports on which the CE mark is based. Accessing these reports can be difficult and is not easily understood by end-users.

IEC 61400-22 is still a conformity standard used dominantly by the large wind manufacturers and developers. It also is used as the basis to meet the Danish Executive Order for SWT approval. This standard is in transition as the new conformity body IECRE is being developed.

A complete QI system is to meet IEC 61400-22 requirements. IEC 61400-22 covers all sizes of turbines, prototype and commercial, and their installations. This includes project certification, prototype certification and type certification. For SWTs, the referenced design document within IEC 61400-22 is IEC 61400-2. Certifying to IEC 61400-22 represents implementation and the highest level of QA. Although Denmark is the only country with these requirements, this represents increasing QA and 25 years of experience in implementing incremental QI.

## 3.4 Developing quality infrastructure for practitioners

SWTs are small-scale renewable energy systems that require a fairly complex installation process and (usually) interfaces with an existing electrical grid. An SWT is not a "plug-and-play" device that can be installed easily by homeowners, even if they have significant practical skills in rigging and hoisting, mechanical and electrical work. The best system can be rendered useless (or worse) by a poor installation. This phenomenon, noted repeatedly in the solar water heating industry applies to the uptake of any new energy technology, including small wind turbines.

### Background survey results

The survey found in the report *Developing Quality Infrastructure for Small-Scale Renewable Energy Technologies: Guidelines for Policy Makers* showed that most of the respondents involved in SWT markets indicated that installer credentials do not exist in their countries. The needs for in-country expertise are not trivial for all market segments, but particularly so for early markets. SWTs are not designed to have zero maintenance, so in-country experts may be needed to help maintain these machines.

### Relevance of training and training certification for practitioners

While discussing issues related to a well-developed QI, it is important to remember that a successful renewable energy system is the combination of good products, a sound installation and proper O&M over the system's lifetime. The latter two elements are the province of practitioners. Having top-quality components improperly installed or maintained can result in a shortened equipment lifetime, lowered performance and even safety issues for end-users.

As renewable energy technologies mature, the quality of the hardware tends to improve. At the same time, the number of failures due to poor installation and O&M of equipment is increasing (TÜV Rheinland, 2013). Even moderate failure rates can damage the public's trust of the technology. Training and certification of practitioners offer the public a high degree of confidence because practitioners need to document extensive experience and/or training and to pass an exam to qualify for certification. They also offer practitioners a way to distinguish themselves from their competition.

Several experts interviewed in this study consider training and certification of practitioners more important than the testing and certification of equipment, particularly in small emerging markets, and they believe that this should be the first QI aspect developed.

One rationale for this position is that emerging markets may start by importing equipment rather than producing it locally, making installation quality a higher priority than production quality. In addition, product quality can be handled by requiring adequate equipment certification from the country of origin, which effectively provides equipment QA at no cost.

Nonetheless, most countries with emerging markets do not focus on practitioner certification; in practice, this tends to happen too late in the QI development process. The need for practitioner training early in the market development is emphasised again in section 6.

## International and national expertise

### *International training accreditation*

The Institute for Sustainable Power (ISP) developed an international standard (ISPQ #01022) that provides metrics for training administration, appropriate facilities, training hardware, training staff experience and competencies, and quality standards. The six accreditation and certification recognitions are: Accredited Training Program, Accredited Continuing Education Provider, Certified Affiliated Master Trainer, Certified Independent Master Trainer, Certified Affiliated Instructor and Certified Independent Instructor. Each clean energy technology developed a task analysis that in some tiers must correspond to the course contents of the training institution. The standard was initially licensed and used by entities in various countries.

The US Department of Energy required the Certified Affiliated Instructor standard for the accreditation of energy-efficiency training institutions. Standards for online classes exist as well. ISP provided the standard for a comprehensive framework for developing an accreditation programme for training institutions and a certification programme for trainers.

During the past three years, ISP transferred the rights to ISPQ #01022 to the Interstate Renewable Energy Council (IREC). IREC continued to use the standard to promote consistent and quality workforce standards and recently updated it and developed IREC Standard 01023:2013, General Requirements for Renewable Energy, Energy Efficiency, and Distributed Generation Training.

### *Denmark*

This market is mature and has been in place for over 25 years. There are requirements for approved installers in Denmark, but an exemption permits owners to install their own turbines (up to 40 $m^2$ swept area). Installers that are approved by the Danish Energy Authority are required for turbines up to 600 kW if they use stall-control designs.

### *United Kingdom*

Practitioners are required to meet Microgeneration Installation Standard 3003 to be Microgeneration Certification Scheme (MCS)-certified, and only certified installers can access the policy incentives. Currently the MCS website shows 93 certified installers in the UK market. This number will change over time, but after the MCS criteria were first set in 2009, a number of people expressed interest in becoming SWT installers. This helped to grow the market because as more certified installers were created, more end-users became interested in the feed-in tariff policies that initially were very lucrative. Over time, these policies have been reduced, having less of an economic impact.

### United States

The main credentialing organisation for renewable energy practitioners in the United States is the North American Board of Certified Energy Practitioners (NABCEP).[4] NABCEP was formed in 2002 and launched certification for solar PV installers in 2003, for SWH installers in 2006 and for SWT installers in 2010. NABCEP has been formally accredited according to ISO/IEC17024 "General requirements for operating certification systems of persons".[5] NABCEP certification is intended to be a voluntary credential. However, many state renewable energy incentive programs require NABCEP installer certification before a project can qualify for an incentive.[6] Installer certification in such circumstances is essentially mandatory.

Voluntary certification programmes accomplish three important goals:

- Provide a measure of protection to the public by giving them a credential for judging the competency of practitioners.
- Improve system performance and installer quality, and therefore public perception of the given technology, subsequently increasing the industry's prominence.
- Provide practitioners with a way to distinguish themselves from their competition.

Developing a certification programme is a complex and time-consuming process, requiring up-front funding, a strong commitment from volunteers from all stakeholder groups, and creation of an administrative organisation to maintain oversight and quality. The job task analysis and resource guides for SWTs are available (NABCEP, 2010; NABCEP, 2011).

### NABCEP small wind turbine practitioner certification

The small wind practitioner certification development began in 2007 and was rolled out in 2010. Due to the small market for SWTs, the certification was discontinued in 2012 after certifying 18 practitioners in the first two years. An entry-level programme for small wind installers was developed in 2013 to identify those with a good background in SWTs. The last document to develop for the small wind entry-level package is a resource guide; that project has not yet begun. A Small Wind Installer Tower Climbing Safety Best Practices was later developed by the small wind community, outside of NABCEP. The development of this document followed NABCEP protocol for the development of other such documents.

### Small wind site assessor certification

The small wind community began work on a Small Wind Site Assessor (SWSA) certification in 2011, completing the job

4 Others include Underwriters Laboratories and ETA International.

5 See www.iso.org/iso/home.

6 See Database on State Incentives for Renewables & Efficiency (DSIRE), www.dsireusa.org.

task analysis and a substantial portion of the resource guide.[7] The site assessor credential was never fully developed, so NABCEP never certified any SWSAs.

Site assessments were required, first in the state of Wisconsin, followed by other policy incentive programmes, as a pre-requisite to access incentive programmes. Historical review of some of the site assessments show a high degree of accuracy in estimating electricity production from the local wind resource, provided that the guidance in the site assessment was followed.

### *The SWT practitioner today*

NABCEP currently is focused only on solar PV and SWH practitioner certification. No SWT installer or SWSA credentials or credentialing organisations exist, and the future is unclear. The small wind community is very interested in working with any stable organisation that can establish these two credentials.

A number of technical schools in the US states of Minnesota and New York offer SWT training. The Midwest Renewable Energy Association in Wisconsin also offers a training course.

### *Major challenges for practitioner certification*

From discussions with interviewed experts, the following barriers to practitioner certification were identified:

- Finding industry partners in the country that are willing to help develop practitioner QI
- Finding dedicated volunteers or organisations willing to commit time and money to start the process and create the administrative structure
- Finding an organisation willing and dedicated to hosting the certification effort for the long haul
- Finding an initial funding stream for the first three to five years
- Identifying the subject-matter experts and individuals from various related fields who are willing to participate on various committees
- Attaining buy-in from the key stakeholders
- Attracting enough business to be self-sustaining without government support.

### *Sustainability of human resources*

Many countries have experienced a human resource barrier to developing and continuing test laboratories. Most new and growing markets will need to develop in-country expertise, but because of their unique knowledge, these experts will be sought after and therefore unlikely to stay at one test laboratory for any length of time. Strategies should be developed that find ways to encourage longer-term staff commitment, yet provide ways to improve knowledge of SWTs.

7 The SWSA Resource Guide was never published. However, many of the resources included in that guide can be found in NABCEP (2011).

# 4 QUALITY INFRASTRUCTURE FOR SMALL WIND TURBINES IN SELECTED COUNTRIES

The main source of the data and other information in this section is based on the interviews conducted with internationally recognised SWT experts.[8] The summaries of the interview discussions are presented in alphabetical order for selected countries.

## 4.1 China

China has the largest market for SWTs in installed capacity and the number of units installed (70 000 units in 2012 according to the WWEA, almost exclusively for off-grid applications. Recent Chinese SWT markets are being considered for grid-connected turbines. The market for off-grid SWTs typically does not have direct incentives or certification requirements. It is expected that as the grid-connect market grows, utilities will require certification to be interconnected. In February 2012, an opinion was granted that small and medium-sized wind turbines can be interconnected.

### Challenges

In urban areas of China, few people live in single houses with the space to install a SWT; most people rent apartments in multi-family buildings. End-users who live in rural areas may not own enough land to install a turbine, but there is still a significant market for off-grid SWTs for fishermen and herdsmen, and in other global locations where the conventional electricity system is not available. In remote sites, quality and reliability are becoming important criteria in the end-user purchase decision.

### Possible scenarios for building quality infrastructure

Establishing QI at the national level instils market fairness and can be the basis for developing regional QI. In Asian countries, the market for SWTs can benefit from policies similar to the Golden Sun programme, which required system testing to qualify for solar PV incentives. Historically, the Chinese government has supported QA frameworks for large wind turbines and PV technologies.

### Standard

The second edition of IEC 61400-2 recently was translated into Chinese. Chinese experts are considering specific requirements for different environmental

8 The opinions expressed may not represent the views of all stakeholders.

conditions, including marine, high elevation, desert and very low-wind-speed sites. Another consideration is whether to reduce or modify the requirements based on turbine size: less than 1 kW, 1-10 kW and 10-50 kW (200 m$^2$). Testing and certification requirements would increase from the smallest to the largest turbine subcategory.

### Testing

The Chinese Ministry of Science and Technology recently supported the establishment of two test sites. The test site near the Yellow River in Dongying City, Shangdong Province has six test sites in an environment of marine, high salt and fog. The Inner Mongolia, Saihantala test site has four test sites and is in an environment of low temperature and hot temperature/blowing sand. Figure 9 shows Chinese testing experts at the Inner Mongolia University of Technology test site. Both of these test sites are designed for SWTs up to 100 kW.

***Figure 9: Installing an anemometer at the Saihantala test site***

*Photograph: courtesy of Charlie Dou*

### VAWT Standard

China developed and implemented a standard for small VAWT design in October 2013. This is significant work because, in contrast to HAWT, VAWT lacks simplified test methods at present. For example, for VAWT, simplified loads test methods do not exist, and also there are no common aeroelastic codes and models for the VAWT configuration, which is the second method of meeting loads requirements found in the international standard IEC 61400-2. This leaves VAWTs to meet the IEC load requirements by conducting more complex and costly loads measurements per IEC 61400-13, a high-level standard designed for larger, multi-megawatt turbines.

## 4.2 Denmark

Denmark has been developing SWT QA requirements for more than 25 years. During that time, industry stakeholders have gained considerable experience, leading to continuous improvement and updating of the Danish national standards. Executive Order 73, dated 25 January 2013, requires certification per IEC 61400-22 for new SWTs to access the Danish retail electricity markets. (Prior to January 2013, applicants met the requirements found in Executive Order 651 for SWTs with a rated capacity of 25 kW or less.)

Denmark's certification scheme represents a comprehensive QA framework found in a mature market, which includes all QI elements: accredited test laboratories and certification bodies based on IEC 61400-22. Project oversight from the Danish Energy Agency administrator exists throughout the SWT life cycle, and with the executive order, or law, in place, all QI elements and aspects of the turbine projects are enforceable.

The Danish market flourishes because the SWT policy allows end-users to sell their electricity through net metering at the retail rate, which is twice the value of electricity generated by large wind turbine projects.

### Challenges

The main barrier to QA in Denmark is in planning approval and complying with European grid codes. There is still a need for research and development (R&D) funding for SWTs to improve IEC 61400-2, for refinement of required aeroelastic codes and models, and for fatigue requirements. SWTs must incorporate simple yet sophisticated designs to handle the dynamics found during typical operation.

### Possible scenarios for building quality infrastructure

Danish administration of the policy and of the Danish Energy Agency certification scheme has been developed over time. Consequently, all the rules, policies and administrative paperwork necessary to implement the Danish scheme can be replicated by other countries at little cost.

### Executive Order 73

In Denmark, the Energy Agency's Secretariat for the Danish Wind Turbine Certification Scheme has authority over the entire certification scheme for SWTs, including reporting of certified SWTs, project oversight and reporting, maintenance and service, approvals, administration, and supervision and control. Technical authority is empowered to act under Executive Order 73 (DEA, n.d.). Some highlights include:

- SWTs with less than 5 $m^2$ of rotor-swept area may be exempt from certification but are still required to be registered.
- Turbines less than 40 $m^2$ may be exempt from certification for a variety of specific conditions, or they can meet the specific certifications found in the Executive Order. One of those is an allowance to certify a prototype or early commercial turbine to the 61400-22 prototype certification; Denmark is the only place in the world to make an allowance for small, prototype turbines to enter the market with the limited three-year option.
- Turbines larger than 40 $m^2$ are now required to meet IEC 61400-22 and receive a type certification. There are requirements for approved installers, but an allowance

enables owners to install their own turbines (up to 40 $m^2$ swept area). Approved installers are required for turbines up to 600 kW if they use stall-control designs.

IEC 61400-22 is a conformity assessment standard that sets the requirements for project, prototype and type certifications. Type certification wind turbines can address all designs, most typically specified as IEC 61400-1 design standard for all turbines, and IEC 61400-2 design standard for SWTs. Type certification includes not only design requirements, but also requirements to meet other standards, to conduct component and system testing and to meet manufacturing quality requirements. In this way, it is the standard that certification bodies use to offer a type certificate, the highest level of wind turbine standard compliance.

## 4.3 Japan

The market in Japan is still in an embryonic stage but is being incentivised through a lucrative feed-in tariff. This policy was influenced by the 2011 Fukushima nuclear power plant disaster and has a goal to provide a larger percentage of electricity from renewables. This put pressure on SWT stakeholders to develop and adopt standards and set up a certification body. There are no SWT test sites in Japan. The JSWTA quickly developed a national SWT standard in 2011. Class NK, a certification body, has certified seven SWTs for the global market, but as of this writing, few SWTs had been interconnected to the utility grid. (As of April 2014, 17 units had been approved to use the feed-in tariff.) Specific inverter requirements lead to the use of inverters for the SWT installations produced in Japan.

### Challenges

Even though the feed-in tariff is in place, all of the other issues for local installation have not been institutionalised. The largest barrier is grid connection for small turbines, specifically unique inverter requirements that disqualify inverters that are used safely and effectively in other countries. Reciprocity agreements with select US and UK certification bodies and the use of field audits of unaccredited test laboratories have reduced the need for a specific Japanese accredited test laboratory.

### Possible scenarios for building quality infrastructure

Establishing an Asian regional QI system would be useful, valuable and practical. A key aspect will be to learn the different environments that affect turbines and where those environments are found regionally. This could be used to help end-users decide whether specific SWTs meet local requirements. Another advantage of regional certification is that it immediately opens up the regional market for SWTs.

### JSWTA national standard

The national standard finalised in November 2011 incorporated portions of the IEC, AWEA and BWEA standards. The JSWTA standard has some differences from the national standards, such as allowing for test data collected by manufacturers and reviewed by the certification board, requiring a static blade test and measured yaw rates for use in the IEC 61400-2 simplified loads methodology. An annex C has been created that addresses design equations for VAWTs.

## 4.4 Spain

Although Spain has been very active with large wind and solar PV technologies, markets and policies, there is presently no market for SWTs in part because there is no incentive policy. Everything must be certified in Spain, but there are no market requirements to get certification. Manufacturers are waiting for the government to require mandatory certification to access incentives such as feed-in tariffs. Until there is an incentive, there is no agreement on possible quality requirements.

### Challenges

Establishing QI is expensive, but there must be competition among QI service providers (*e.g.* testing facilities and certification bodies) to minimise monopolies and ensure competitive costs. The market and QA/QI requirements must be developed together to avoid squelching the market.

The cost of testing services creates a barrier because the manufacturers must pay the testing costs. Cost-effective test laboratories are challenging to develop since there is such a small market opportunity for accredited SWT test results. Manufacturers cannot bear the full cost of developing and accrediting a test site plus testing services. Test laboratories need funding to maintain accreditation and to implement accredited test laboratory procedures, such as by purchasing calibrated instruments.

### Possible scenarios for building quality infrastructure

The best way to build QI in Spain is to require certification to IEC standards and to invest money in developing a QI structure to offer certifications. There is no desire to develop a Spanish national standard for SWTs, but consideration would be given to adopt the IEC standards. National standards and schemes are temporary solutions, and an international standard is a better way to normalise quality globally.

### Accredited testing

Spain is home to the "Centro de Investigaciones Energéticas, Medioambientales, y Tecnológicas" (CIEMAT), an accredited small wind test site in Soria, and a public test organisation accredited by "Entidad Nacional de Acreditación" (ENAC) for power performance testing acoustic noise emission measurements, duration, and safety and function testing. CIEMAT offers the complete suite of IEC SWT tests required for the existing SWT national

*Figure 10: CIEMAT – CEDER PEPA 5 test facility in Soria, Spain*

*Photograph: courtesy of Ignacio Cruz*

and international certification schemes. Figure 10 shows PEPA 5, one of the CIEMAT/CEDER test sites. Barlovento, a private test laboratory, is accredited for power performance testing, acoustics, and duration testing, and it has its own test plant.

## 4.5 Sweden

The QA requirement in Sweden is the legally binding CE marking, which is a self-declaration of compliance to IEC standards (the low-voltage and machinery directives). This is a shared European flexible approach with likely credibility drawbacks.

There are no government incentives except regional SWT subsidies for farmers. Public organisations working with farmers are not aware of aspects of any QI elements. Without incentives, the economic calculations are not attractive for SWTs, so the focus in Sweden has been on large wind turbines. Consequently, SWT manufacturers struggle to survive in the small market; certification and labelling add additional costs for an unstable and small market.

### Challenges

The largest barrier is a lack of QI interest from national and regional authorities who have a relation with farmer subsidies. There is no formal assessment body for the technology or practitioners. Educating and enabling local agencies to understand Consumer Labels and to use them as a basis for subsidisation and approval is a challenge.

### Possible scenarios for building quality infrastructure

Studying how the United Kingdom implemented a feed-in tariff with QI requirements might provide a model for how to further develop QI in Sweden. A step-wise approach should be considered. The first step is to fulfil CE mark legal requirements (only relevant for European markets). The second step is using the international SWT Consumer Labelling scheme. The third step would be third-party, independent certification to standards like IEC 61400-2.

Using international standards not only streamlines the process, but also simplifies the process of fulfilling legal requirements.

### Testing

Intertek operates an island test site between Sweden and Finland. Figure 11 shows the test site where a meteorology mast was installed next to an existing WindEn 45 turbine for testing. The SP Technical Research Institute of Sweden and some universities can also perform SWT testing in Sweden. Intertek conducts accredited testing and certification services for SWTs. The resulting Consumer Label will be published according to the IEC standard, together with the test summary report.

## 4.6 United Kingdom

For the past several years, the United Kingdom has had a feed-in tariff incentive policy, which dramatically expanded the UK SWT market, increased electricity produced by SWTs and improved product quality levels. This policy is linked to QA requirements defined in the MCS, and it gives financial benefit to the end-user if they use certified SWTs. Currently, there are 38 certified turbine SWTs.

The MCS was established in 2006 following the Solar Keymark model, but it has been used for several distributed renewable energy technologies. The MCS 001 is based on three review aspects: quality of product as designed, quality of installation and verification of manufacturing processes used to build the product. The MCS SWT requirements require that the turbine meet the SWT design standards per MCS 006, factory production control per MCS 010, and practitioner competence per Microgeneration Installation Standard 3003.

The MCS 20 document is applicable only in the United Kingdom and includes

*Figure 11: A WindEn 45 turbine undergoes testing by Intertek*

*Photograph: courtesy of WindEn*

requirements for planning permission documents. It also offers useful advice for turbines in the built environment and guidance on where to site SWTs.

## Possible scenarios for building quality infrastructure

All of the QI elements as required by the MCS scheme have been developed in the UK market, so there are no barriers to implementing a sound QI framework.

The nearest thing to a regional European quality requirement is the CE marking. The feasibility of developing regional QI seems challenging given the unique country health and safety requirements, acoustic (noise), electrical infrastructure and environmental requirements (typhoon, etc.). Although these differences make it difficult to achieve the uniformity of certification requirements, it is still easy to have uniformity of standardised testing and the resulting consumer labelling.

## Standard

In December 2013, RenewableUK released a new version of the SWT standard, a revision to the previous BWEA standard. The criteria in the new RenewableUK standard reference the IEC standards in whole, creating a more technically demanding standard. One implication of that change is the requirement for a static blade test. A sunset clause allows manufacturers to certify their SWTs to the BWEA standard for three years. The new RenewableUK standard has been reduced from 20 to 5 pages due to referencing whole IEC standards instead of sections. This represents the evolving QI requirements found in a mature market.

There should be continuous improvement of the existing international standard, specifically the simplified loads methodology, which should be refined based on new technical test data and loads models as documented by TUV NEL and others.

In the United Kingdom, grid connection complies with the G83 (installations less than 16 amps per phase – about 10 kW) and G59 (installations above 16 amps per phase) grid codes. An additional requirement for power conditioners is identified under a "Technical note to facilitate wind turbine inverter change and modification for MCS" (RenewableUK, 2013).

### Accredited testing

The United Kingdom has one government-owned, jointly used test field at Myers Hill that was established 30 years ago with funds of EUR 2.75 million. The total cost to establish an operating testing site would be approximately EUR 6-12 million including infrastructure (*e.g.* roads, electrical infrastructure, meteorology masts, buildings and instrumentation) and required highly trained staff. Staff costs will increase if staff must be recruited or trained. The test facility and all of the measurement equipment, site buildings and site met masts must be maintained, adding another requirement for staff.

Interviewed experts indicated that the cost estimate to attain accreditation for a test laboratory is approximately EUR 675 000 for internal time to document the testing process and procedures and to add the extra level of rigor for traceability of calibrations.

### Certification

There are seven certification bodies in the United Kingdom, several with reciprocity agreements with other national or international certification bodies. The majority of the UK certifications have been completed by TÜV NEL, a privately held global company. According to interviewees, the cost for certification and testing to the MCS ranges from EUR 100 000 to EUR 140 000.

## 4.7 United States

In the United States, state incentives started the grid-connect markets in 1998, with California's list of approved turbines. Approval was based on either certification to IEC 61400-2 or proof of one-years' operation at a 12 mph annual average site. One of the first lessons learned was that not all of the listed products were good commercial products because the required field experience could be falsified too easily.

In 2009, the AWEA 9.1 Small Wind Turbine Performance and Safety standard was adopted and was followed immediately by the Small Wind Certification Council (SWCC) offering certification. Until 2010, there was no standard for QI and no certification body for SWT certification. The work to start up the certification body started in 2004 with the support of publicly and privately funded stakeholders, followed by global certification bodies entering the US market.

Qualifying for state incentives and obtaining installation approvals may require the following: wind turbine certification to AWEA 9.1 or IEC 61400-2, turbine electrical safety certification to Underwriters Laboratories (UL) 6142, tower and foundation designed and "stamped" by a licensed (in the particular state) professional engineer, inverter safety certification to UL 1741, and electrical wiring conforming to Article 694 of the National Electric Code.

Many states offer policy incentives for SWTs that require certification to the AWEA standard. Consulting organisation CESA Interstate Turbine Advisory Council (ITAC) developed a SWT product listing that requires SWT certification but also evidence of O&M support and manufacturer customer service. SWCC and Intertek have certified more than 13 SWTs to the AWEA standard.

## Challenges

Since US SWT manufacturers are in the market globally, they have to understand different countries' QI requirements. Although these requirements change over time, overlap of standards helps to reduce certification costs to manufacturers. It is believed that, over time, one SWT design standard will be used in whole, the IEC 61400-2.

There are few incentives and requirements for credentialed practitioners, and the lack of demand has resulted in no national practitioner credentialing in the United States. Credentialing is required in some active incentive markets, such as New York. This has created an unstable market for small wind installers and site assessors, as well as for training institutions teaching these skills.

## Possible scenarios for building quality infrastructure

QI needs to start where stakeholders can gather consensus and then ratchet up in the requirements over time as the market develops. It is anticipated that, over time, US manufacturers will want more access to global markets and to be certified to the IEC standards.

## Standards

The development of AWEA 9.1-2009, however, was not government funded. It was a voluntary effort of the industry, institutions and various other stakeholders.

The former BWEA and the present AWEA standard were nearly identical because the BWEA adopted the AWEA draft standard. The only difference between the standards is the method of reporting acoustic information. Because of the shared standard, accredited test laboratories and certification bodies found efficient ways to develop easy reciprocity.

The Tower Industry Association, another standards developing organisation approved by the American National Standards Institute (ANSI), has developed a draft SWT tower standard that currently is under consideration.

### Testing

Accredited testing is conducted at the National Renewable Energy Laboratory's National Wind Technology Center (NWTC), which was developed with federal funds. The NWTC test site has very high winds with a low average annual wind speed, so testing to meet the IEC duration run-time hour requirements requires one year or longer. Intertek operates an accredited test site in Cortland, New York, and UL operates an accredited test site in Canyon, Texas.

Some of these test sites were part of a US Department of Energy regional test centers project, which was set up to transfer knowledge from test experts conducting accredited tests to those conducting unaccredited tests. Some certification bodies allow testing to be performed by unaccredited testing organisations if witnessed by the accredited certification body. Those unaccredited test sites are listed on the SWCC website.

### Certification

Two organisations offer accredited certification for SWTs in the United States: Intertek, a privately held global company with accredited SWT testing and certification services, and the SWCC, an accredited certification body established specifically for SWT certification. Intertek and the SWCC have identified 13 certified SWTs in the US market. The estimated cost for the certification and testing equals EUR 100 000, with approximately EUR 40 000-75 000 for testing and EUR 25 000-50 000 for certification (including in-house costs).

### Electrical requirements

Throughout the world, national electrical safety and installation and grid interconnection standards vary, making it difficult for an international standard to provide specific national guidance. Electrical standards commonly are developed at a national level and may be referred to as grid codes or standards.

Some countries also use national electrical standards as a trade barrier. The US electrical safety standard for SWTs under 200 $m^2$ is UL 6142 and is bounded by the fact that personnel cannot enter the SWT. (This standard references UL 1741 for inverter safety.) Both are private standards developed under the ANSI process.

## 4.8 Other countries

In general, SWTs are new to many countries, particularly countries that do not have incentive policies specific to SWTs. In countries like Germany that are engaged with QI for other renewable technologies, there are no QI requirements for SWTs due to the lack of government incentives. The Netherlands also lacks government incentives, except for farmers. Another consideration for both of these countries is the dense population, which invariably leads to a landscape of houses, barns and other clutter, which invariably reduces the wind speed and increases the turbulence, making SWTs less productive. An SWT market assessment should be considered before QI systems are developed.

### Germany

SWTs must meet two standards in Germany: the IEC 61400-2, and the Deutsches Institut für Bautechnik standards for structural requirements. In general, there are two steps to developing QI. One is to grow a strong market with government support that requires QA, and the second is to use testing and labelling to establish low-cost quality. With poor economics for SWTs, there is low potential for market expansion, and the cost for certification is not supported by the market size.

### The Netherlands

In the process of developing a Dutch standard for SWTs, the Dutch Small Wind Association concluded that the market is very small, and it halted development of its standard. There are no incentive policies, resulting in poor economics for SWTs, which is aggravated by a 15-m tower height limit (resulting in less harvestable wind). Dutch SWT manufacturers have focused their efforts on exporting (*e.g.* to Africa and Southeast Asia) or are now bankrupt. Results from an unaccredited, urban test laboratory convinced stakeholders that SWTs are not commercially viable in the more cluttered or urban environment of the Netherlands.

## 4.9 Compilation of quality infrastructure for small wind turbines in selected countries

Appendix A lists the QI details for several national schemes. It is organised by metrology, standards, certification bodies, test laboratories, accreditation organisations and grid codes. The market for SWTs and QI work is relatively new and is used only in a few countries. The concept of a regional QI has not been discussed but could lead to cost-sharing for setting up comprehensive QI. Commonality in standards, test laboratories and certification bodies can reduce global certification costs.

## 4.10 Global certification of small wind turbine technology

Currently, privately owned certification bodies award international certificates based on the suite of IEC standards. These entities have provided SWT certification for some time, but there has been little market uptake due to the cost. Instead, SWT manufacturers are opting out for more inexpensive certification to national standards. All the national standards reference parts or the whole of IEC standards. Depending on the certification body, there may be synergies between the national and international certification work.

Over a period of time, an incentivised market can naturally ratchet up its QI requirements. For example, the United Kingdom now requires certification meeting all IEC standards.

# 5 KEY CHALLENGES AND OPPORTUNITIES FOR DEVELOPING QUALITY INFRASTRUCTURE FOR SMALL WIND TURBINES

The key issue for emerging renewable technologies is cost, and the same is true in QI development. Cost issues, methods to contain costs, and other issues are discussed briefly in this section.

## 5.1 Cost

- ***Standards.*** Standards development is a very costly endeavour, particularly in early work, and it will require very high levels of activity during development.

  *Solutions:*

  - Recognise that international IEC standards for SWTs represent the benchmark for the technology and should form the basis for national/regional standards.
  - Consider adoption of other national standards.
  - Collaborate with other nations to develop regional networks that will share costs of developing and maintaining standards, test laboratories and certification bodies.

  Because standards represent the consensus work of experts, requirements typically lag behind the technology, making the need to revise and maintain standards very important.

- ***Test laboratories.*** Setting up small wind test sites might be costly. The United Kingdom, for example, established the Myers Hill test site 30 years ago for approximately EUR 2.75 million.

  *Solutions:*

  - Determine the test site needed and whether there are funds to develop this completely or incrementally. Test costs can be kept low to start by initially using lower-cost instrumentation and keeping the tests simple and focused on duration and production.

- Ratchet up test requirements to meet the tests needed to develop an IEA/IEC Consumer Label. In order to meet the IEC label requirements, the test laboratory must use ISO 17025.
- Achieve accreditation for testing per IEC standards.

There should be mandatory certification only in mature markets where the market is profitable and manufacturers can absorb the cost without substantially raising prices. Sites should be selected carefully to minimise the need for site calibration and to minimise the work in setting up specific test sites. Measuring the wind resource also can be performed at different heights and with different requirements and calibrations. The hub-height wind resource must be quantified. The specific location and the instrument calibration and traceability become very important in understanding the validity of the test results. Increased traceability and calibration requirements will increase the accuracy and repeatability of the measurement.

- ***Certification bodies.*** It is costly to set up a certification body, involving the establishment of design review guidelines from the certification standard, hiring staff with the technical capabilities to assess design, setting up procedures for generating ratings, creating/maintain websites, accrediting the body, etc.

*Solutions:*

- Currently, multiple global and national organisations offer accredited certification services. Some are publicly funded through government support, and others are privately funded through for-profit companies. Some have been commercially engaged in QA for decades or hundreds of years.

If the market is new and dominated by importers, requirements for certification can come from the country of origin, or a national certification body can be created to access qualification needs for policy incentive programmes. As mentioned earlier, the new international conformity assessment group IECRE plans to list renewable energy products on their website.

- ***Manufacturers.*** System tests and certification costs for SWTs are roughly EUR 59 000 to EUR 132 000 per turbine model. Some markets also require manufacturers to meet quality management system requirements per ISO 9001 or to conduct a factory production control review, both of which validate the use of manufacturing quality system (but at different levels).

*Solutions:*

- Carefully select the country markets for SWT sales;

- understand their import or certification requirements and the accompanying policy.

Some countries' markets may open with Consumer Labels, others with certification to a variety of national and sometimes, international standards.

Once the product is stable, start certification testing, which typically includes a duration test (a minimum of six months and 2 500 run-hours) that does not allow for any changes to the test turbine during the test period. Consider testing and certifying to IEC standards, which will meet certification criteria for the majority of country markets.

## 5.2 Other challenges

Many ideas were shared through survey comments and interviews, but the key insights listed below were mentioned repeatedly.

- ***Country expertise.*** It is critical to develop in-country expertise, and it is likely that once people are trained they will sell their skills to someone who will pay more. In a way this is an effective dispersion model for developing in-country expertise, but care should be taken to select key individuals for long-term assignments such as developing and training installers, site assessors, import inspectors and others. However, experience has shown that if there is insufficient business opportunity, these skilled practitioners quickly will migrate to other industry sectors. Public policy and sufficient market incentives are critical to maintaining the fruits of this capacity-building effort.

  *Solutions*:

  Working with universities, colleges or training programmes may help provide longer-term stability to developing the in-country expertise and dispersion of this resource. Demonstration projects allow for initiating the development of in-country expertise. These early projects help expand end-user knowledge of the technology and also can be used as training for future installations.

- ***Lack of consumer information.*** It currently is difficult for end-users to compare different turbine products. The standardised performance ratings introduced in the AWEA/BWEA/JSWTA standards are not well-advertised and have low consumer recognition.

  *Solutions*:

  There is an internationally agreed-upon SWT consumer label with limited use so far, the IEA/IEC Consumer Label. There alsomust be accompanying cosumer education information on the technology, its applications, limitations and credentials.

- ***Need for harmonised standards.*** The test laboratories, certification bodies and manufacturers spend more time and money to comply with the diverse global market's standards and certification requirements.

  *Solutions*:

  International IEC standards for SWTs were first developed in 1995 and have provided a basis, in whole or in part, for the development of all national standards. This has created some overlap in specific standard requirements such as usage of test results, loads analysis, etc. The future, especially for mature markets, is certification to the latest and appropriate global IEC standards. However, the IEC 61400-2 standard must achieve a level of quality and appropriateness that some experts feel it has yet to achieve. Until then, there likely will continue to be national standards that seek to overcome problems perceived in the international standard. The next opportunity for revising IEC 61400-2 will be in 2018.

- ***The "chicken and egg" paradox.*** There is a classic conundrum in QI: Which comes first, the chicken (market) or the egg (QI)?

  *Solutions*:

  The market should dictate the level of QI development needed. If it is too strict (requiring accredited testing initially), it will inhibit the market. If it is too lax or if QI is not required by law for incentives, cheaper, poor-quality systems inevitably tarnish the market reputation.

# 6 RECOMMENDATIONS FOR DEVELOPING AND IMPLEMENTING QUALITY INFRASTRUCTURE FOR SMALL WIND TURBINES

QI development should be in balance with market development. This section suggests a set of QI stages for SWTs corresponding to five qualitative stages of the market. Figure 12 shows the build-up of QI as the market develops. Some discussion of the actions recommended at each stage follows. These actions are not rigid and should be modified for specific national needs and conditions.

For most countries, the market is at the starting level and there may be little experience domestically with the technology; education is an important place to start. For those countries with grid-connected SWTs in either a policy-rich, incentive market or a market where electricity's true cost is captured in the retail rate, QI already will be developed. Mature markets will have country schemes formalising and legalising QA requirements using a QI scheme that covers practitioner and product certification at the highest levels.

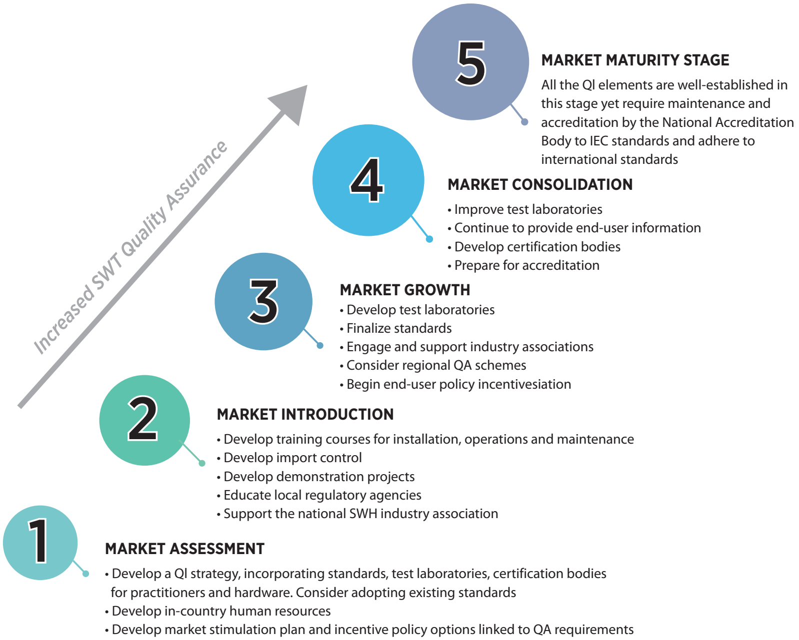
The lesson is that government and policy must promote SWTs at the same time that it needs to establish QA frameworks. One without the other or one in excess to the other may lead to market failure. The hope is that the market will regulate itself, but this can be difficult if government policy does not engage and require SWTs with a high level of quality initially.

## 6.1 Suggested quality infrastructure stages for small wind turbines

### Stage 1: Market assessment

Assuming there is interest in developing a market for SWTs in the country. Projection of benefits and risks is important in prioritising activities. This requires quantitative knowledge of the wind resource. Understanding existing in-country QI and expertise (such as the installed base of SWTs, university/training organisations focused on practitioners, professional associations, test laboratories, etc.) will be helpful in establishing a baseline for future QI work.

*Figure 12: Market stages and recommendations for small wind turbines*




Market assessment involves specific actions:

- *Develop a QI strategy.* This must incorporate standards, test laboratories and certification bodies for both practitioners and hardware. Consider developing regional QI, sharing existing standards, requiring certified turbines from importers, etc. These items should address the needs to resolve specific barriers (hardware certification, practitioner certification, grid connect, electrical safety, siting/permitting permissions, etc.).
- *Develop the in-country human resources.* Expertise needs could include small wind technology training, site assessment, installation training, standards used for import control and assessment of SWTs to those standards, and others. Consider joining competence training networks such as ISPQ or NABCEP that have established training courses and curricula that can be licensed with much less cost than funding the development of the materials. Retention and technical knowledge need to be balanced with employment commitments.

It is likely that new SWT expertise will be highly sought for market introduction.

- *Adopt existing standards.* The international IEC standards for SWTs are the basis for QI and national SWT standards. Another option is adopting a specific country's standard, which may set up trade openness based on country-of-origin certification reciprocity.
- *Develop a market stimulation plan.* Research and consider other SWT markets. Search for similar approaches that could form the basis of regional partnerships. (Note that the partner does not have to be a bordering nation.) Develop incentive policy options with linked to QA requirements. Most markets grow very locally, so consideration of initial markets and possible diffusion should be evaluated.

## Stage 2: Market introduction

Designs for home-built SWTs would be difficult to certify because of the lack of quality control in the product build. But home-built SWTs based on the designs of Hugh Piggott and others are made in many places, and this activity serves an important function in familiarising end-users with the technology and beginning market introduction.

Training for practitioners is the highest-priority item. Imports need to be controlled to protect a fragile, emerging market. Some consideration should be given to supporting demonstration projects, which provide training opportunities and educate the public and potential manufacturing groups about the technology. At this time, it is not worth setting up testing or certification unless there is local manufacturing producing at moderately high volume. In that case, unaccredited, third-party, independent testing of prototypes per stage 4 below would be recommended.

This stage may involve the following actions:

- *Develop practitioner training.* Develop training courses on small wind resource assessment, turbine selection, installation and O&M to expand in-country expertise. Courses should include: 1) general understanding: physics of operation, principles of electricity, tower climbing, and basic techniques such as rigging and hoisting, safety operations, etc; and 2) specific techniques for turbine installation, and safe methods of providing O&M support. Training often has been a low priority in QI schemes, leading to too many system failures; it needs to be emphasised in emerging markets. Manufacturers should provide installation and O&M manuals as well as access to troubleshooting and customer service.
- *Develop import control.* One relatively easy way to implement import

control is to require an approved certification, based on international standards, for SWTs from the country of origin or other country QI scheme. It will be necessary to develop lists of approved certification products, documentation needs and procedures for affirming that appropriate certification exists. The approved list could include certification to international standards such as Denmark's Executive Order 73, Japan's JSWTA 0001, RenewableUK's Small Wind Turbine Standard and/or US AWEA 9.1. Some funding is required for instituting these processes and training the staff members that regulate the imports.

- *Develop or adopt standards.* These standards will form the foundation of country/regional QI schemes. Standards may need to be modified to address local environmental conditions. The decision to adopt a standard may lead to opening trade barriers. Ideally standards-making organisations will start with existing standards and accept what they can come to consensus around.
- *Educate the local regulatory agencies.* Enable local government agencies that oversee to learn about certification and how to use the certificate for permitting approval.

### Stage 3: Market growth

The market is small but emerging and has promise for contributing to national goals. Installer training should be made more rigorous and comprehensive. Imports should continue to be controlled by demanding external certification. There are likely local manufacturers, and if so, some QA is needed. End-users and other stakeholders will begin to have some understanding of potential performance of SWTs.

This stage may involves the following steps:

- *Develop test laboratories.* Identify and support initial development of test laboratories. Testing should emulate ISO 17025, and SWT testing standards should be followed. Begin to measure the wind and test turbines with low-cost duration and performance testing. This entails setting up a meteorology mast to get wind speed and direction, with an anemometer at the turbine hub height. The met mast would be installed upstream of the turbine and in the prevailing wind direction.
- *Finalise standards.* Revision or creation of standards to be used as the basis of QI should be finalised. Without a standard to follow, manufacturers struggle to determine the market and incentive policy rules. The standards include SWT design and testing, and grid codes.
- *Engage and support industry associations*. Industry associations can help to educate all the stakeholders involved with QI elements and

projects, including government officials for zoning/planning, hybrid system developers, utility and electrical inspectors for grid-connected applications, and end-users.

- *Consider regional QA schemes.* QI for SWTs typically is not affected by different climates. However, coastal uses have a unique problem in longevity in corrosive, sea-salt environments. Establishing different country environmental conditions could lead to easy comparability and become the first step to building regional QI. Different QI elements can benefit from shared market and resources, but there is a need to ensure cost-competition of QI services.
- *Begin end-user education*. Develop a QI plan that allows for the development of policy incentives and market requirements needed to get the market started. End-user education should accompany policy incentives.

## Stage 4: Market consolidation

In this stage, the market is moderate-to-large and still growing. All of the elements of a comprehensive QI system are instituted, and most all of the elements of the international standards IEC 61400-2, 61400-11 and 61400-12-1 are in place at the test laboratories. Installer training should have defined curricula and testing for master trainers, instructors and installers. However, these bodies are not all or even generally accredited.

This stage may involve the following steps:

- *Improve test laboratories.* Complete the duration, system safety and function per IEC 61400-2; the power performance per IEC 61400-12-1; and the acoustics per IEC 61400-11 and 61400-14. Develop the IEA/IEC Consumer Label. Work with IECRE or other hosts to post the labels and provide end-user education on the value of labels, certifications and use of SWTs. Evolve test laboratories towards accredited testing.
- *Continue to provide end-user information.* SWTs have complex moving parts and electrical conversion systems and are not as easily understood as other renewable technologies. Providing end-users with information on the technology, its costs and likely production will help open the market. In this stage there are consumer labels for easy comparison.
- *Develop certification bodies.* If there are locally manufactured SWTs, there will be a need for certification, particularly to enter the world market. Some certification bodies are for-profit entities, but they will not enter an undeveloped QI market. This may require the development of publicly funded certification bodies, which typically take a long time to start up. At this stage, the goal is to have certification bodies

certify to national standards and work towards accreditation.

- *Prepare for accreditation.* The process of preparing for accreditation is detailed and specific, so it may take some time to develop the policy and documentation of the processes. Identifying accreditation requirements early may help in developing policy and procedures. Some countries may offer a conditional or temporary accreditation for those organisations seeking accreditation but that are still in the process of being accredited.

### Stage 5: Mature market

All of the QI elements are well-established in this stage and are accredited by the national accreditation body to IEC standards. Accreditation is the final step necessary to guarantee the adequacy of the testing, certifying and training bodies. All of the QI elements are brought up to international standards. It is the final stage of bringing the QI up to the highest level.

## 6.2 Conclusions

Small wind turbine technology is still in its infancy compared to other renewable energy technologies, yet there has been significant international work to align the Consumer Label for the world market. This is a simple approach that can be used by many countries, and while QI has been developed to its highest level for a few country markets, other countries can learn from those experts and more efficiently establish a QI strategy. There are options to pick and choose partners and to consider regional QI, something that has not happened yet in the SWT market but that has been done for solar water heating technologies.

This report highlights that in order to balance costs and benefits of developing and implementing a national QI, it is reasonable to gradually phase in QI as the market develops. Starting with low-cost methods that assure quality first, and then to morph into more-rigorous but more costly methods as the market grows and is able to absorb certification costs. Five levels of market are defined, from beginning to fully mature. It is important to involve the local industry at all levels of the QI and market development, through a national industry association. With appropriate QI, small wind turbines can be an important mean to help attain country goals for renewables.

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# APPENDIX A

## Summary of country schemes for small wind turbines

***Table A-I: Quality infrastructure schemes for small wind turbines in selected countries, as of June 2014***

| Country/ scheme | Standards used | National metrology institute | Test laboratories (U = unaccredited, A = accredited) | Certification bodies (U = unaccredited, A = accredited) | Accreditation organisations | Grid codes |
|---|---|---|---|---|---|---|
| China | IEC 61400-2 2nd revision (translated) | http://en.nim.ac.cn | U: Inner Mongolia Poly-tech University & Inner Mongolia Agricultural Machinery Test Station<br>U: Dongying Huifeng Energy Technology Co. Ltd. | China Classification Society Quality Assurance Ltd. (CCSC)<br>China General Certification Center (CGC) | China National Accreditation Service for Conformity Assessment (CNAS) | |
| Denmark www.wt-certification.dk/UK/Rules.htm | IEC 61400-22, references: 61400-2, 61400-11 and 61400-12-1 | www.dfm.dtu.dk | | Danmarks Vindmølleforening (<40 m²)<br>A: Det Norske Veritas (DNV)/ KEMA<br>A: DTU Vindenergi<br>A: Germanischer Lloyd<br>TD Engineering<br>TÜV Nord – Denmark<br>TÜV Sud | Danish Accreditation & Metrology Fund (DANAK) | EU Grid Code TF321 (< 16A) and TF325 (>16A) IEC 61400-21 |
| Japan | Japan Wind Energy Association national standard JSWTA0001 (www.jswta.jp), references: 61400-2, 61400-11 and 61400-12-1 | www.nmij.jp | U: www.aist.go.jp | Class NK, www.classnk.or.jp/hp/ja/index.html | JAB, www.jab.or.jp/ to ISO/IEC 17065, JIS Q 0065 – accreditation for certification bodies | JEC-2137 and JEC-2130 |
| Spain | UNE 61400-2, UNE 61400-11 and UNE 61400-12-1 | www.welmec.org/welmec/country-info/spain.html | A: Centro de Investigaciones Energéticas, Medioambientales, y Tecnológicas (CIEMAT), www.ciemat.es | A: Intertek, www.intertek.com | Entidad Nacional de Acreditación (ENAC), www.enac.es | |

| Country/ scheme | Standards used | National metrology institute | Test laboratories (U = unaccredited, A = accredited) | Certification bodies (U = unaccredited, A = accredited) | Accreditation organisations | Grid codes |
|---|---|---|---|---|---|---|
| Sweden | SS-EN 61400-2 | www.smhi.se | A: Intertek, www.intertek.se www.sp.se | A: Intertek, www.intertek.se | www.swedac.se | |
| United Kingdom U.K. Micro-generation Certification Scheme (MCS), www.microgenerationcertification.org, MCS 001 | MCS 060 SWT certification MCS 010 manufacturing quality assessment or factory production control RenewableUK national standard, references IEC 61400-2 (3rd edition), IEC 61400-11,IEC 61400-12-1 and IEC 61400-14 in full, except where noted. IEA/IEC Consumer Label is mandatory. | National Physical Laboratory, www.npl.co.uk | MCS 011 – 3 testing routes: - accredited organisations - unaccredited organisation working with ISO 17025 - manufacturer or third parties that demonstrate they can meet ISO 17025 A: TÜV/National Engineering Laboratory – Myers Hill | Ascertiva Group BRE Global British Board of Agreements BSI A: DNV/ Germanischer Lloyd A: Intertek, www.intertek.com A: TÜV/ National Engineering Laboratory BAA | United Kingdom Accreditation Services, www.ukas.com | G83 G59 |
| United States | AWEA 9.1 Small Wind Turbine Performance and Safety Standard (2009), references portions of IEC 61400-2, IEC 61400-11 and IEC 61400-12-1 | NIST, www.nist.gov | A: NREL's National Wind Technology Center A: Intertek A: WT/UL Wind Turbine Test Laboratory U: High Plains Small Wind Test Center U: Windward Engineering | A: Small Wind Certification Council, www.smallwindcertification.org A: Intertek, www.intertek.com | American Association of Laboratory Accreditors, www.a2la.org | UL 6142 National Electric Code 2014, Article 694 |

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