International Renewable Energy Agency

BOOSTING SOLAR PV MARKETS:

THE ROLE OF QUALITY INFRASTRUCTURE

SUMMARY FOR POLICY MAKERS

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.

The information in this summary is analysed more extensively in IRENA's full report on the subject.

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Summary for Policy Makers

The upsurge of solar photovoltaics

By the end of 2016, the global cumulative installed capacity for photovoltaic (PV) power had reached an estimated 290 gigawatts (GW), indicating nearly 50 times the growth in cumulative installed capacity within a decade (see Figure 1.1). The uptrend of new installed capacity is expected to be maintained in the years to come as new markets expand, such as those of Latin America, the Middle East, North Africa and Southern Asia. Projections for total PV installed capacity by 2030 range between 1760 GW and 2500 GW. This can be attributed in large part to a continued decrease in the levelised cost of electricity (LCOE) expected for solar PV.

The decrease in PV system LCOE over the past decade has been driven by substantial PV module cost reductions, although projected reductions in the coming decade will be largely driven by a decrease in Balance of System (BoS) costs. IRENA estimates that global average total installed cost of new utility-scale PV systems could fall from approximately USD 1.8/watt (W) in 2015 to USD 0.8/W in 2025, a 57% reduction within a decade. A breakdown of typical costs over time is depicted in Figure 1.2.

Figure 1.1. Evolution of cumulative installed capacity for photovoltaic

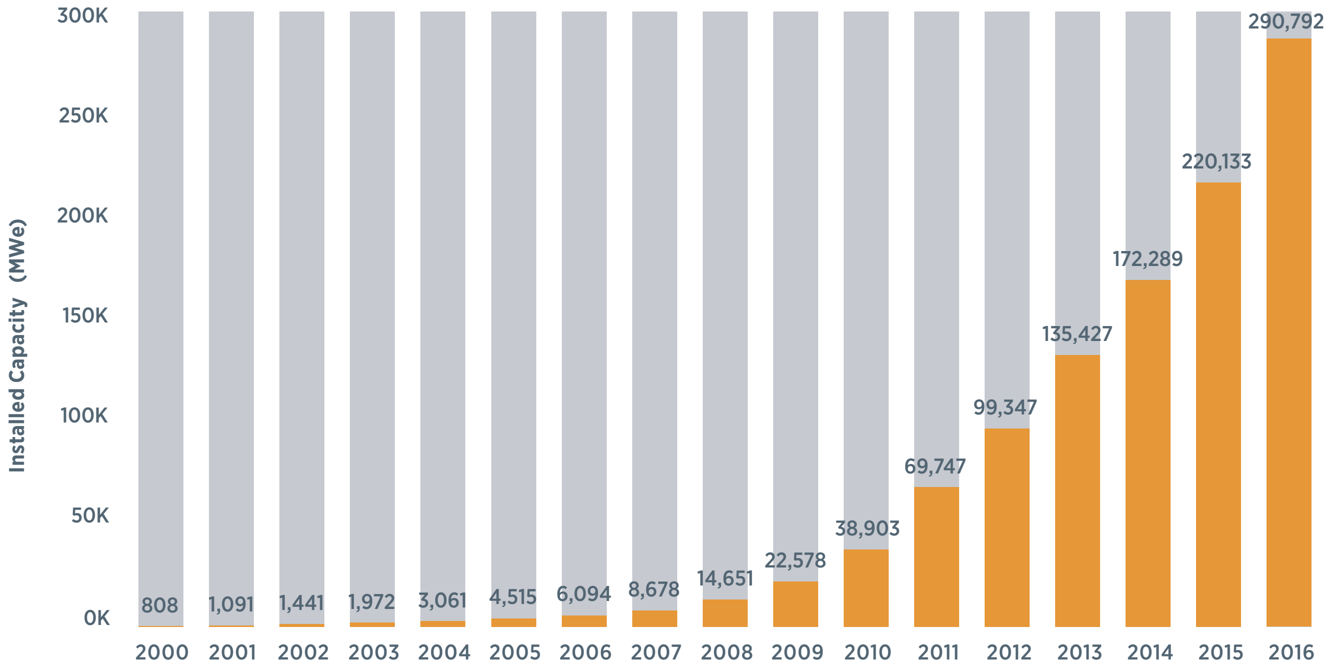
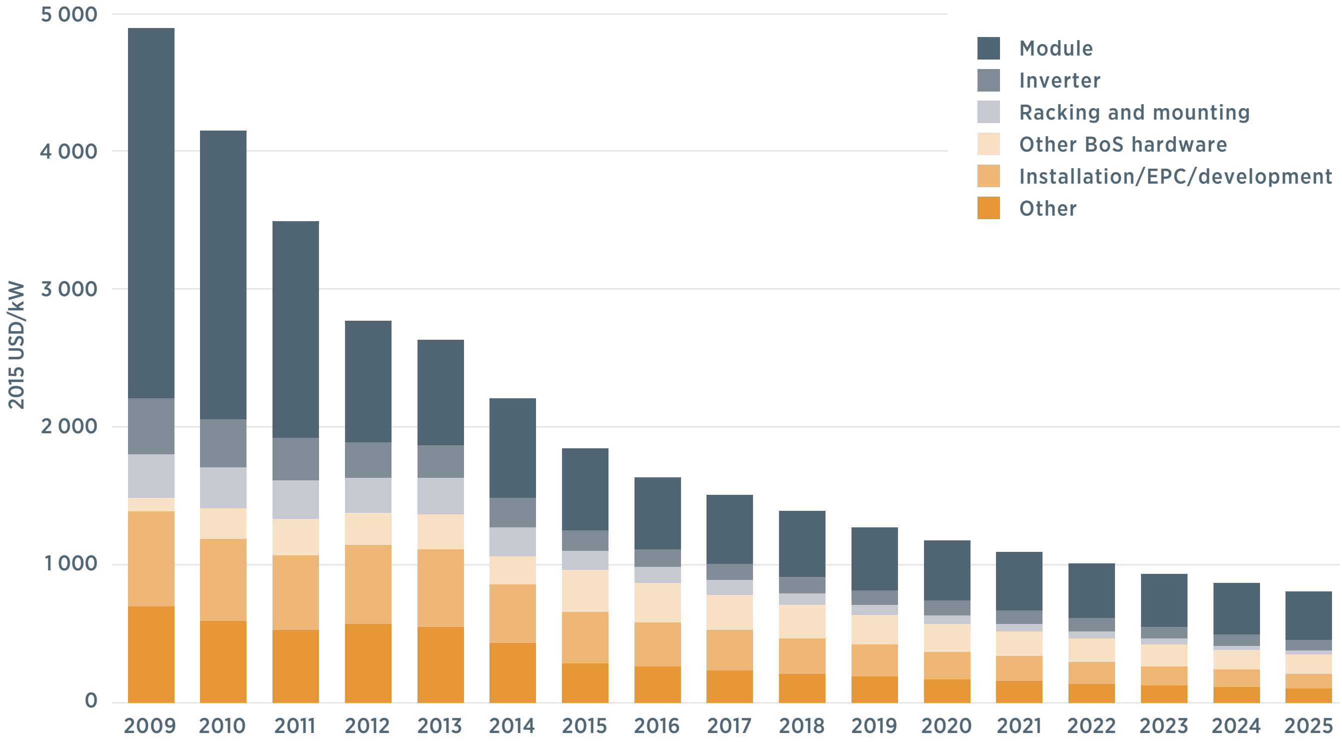


Figure 1.2. System investment cost breakdown for utility-scale photovoltaics: Global weighted average



Technical risk mitigation

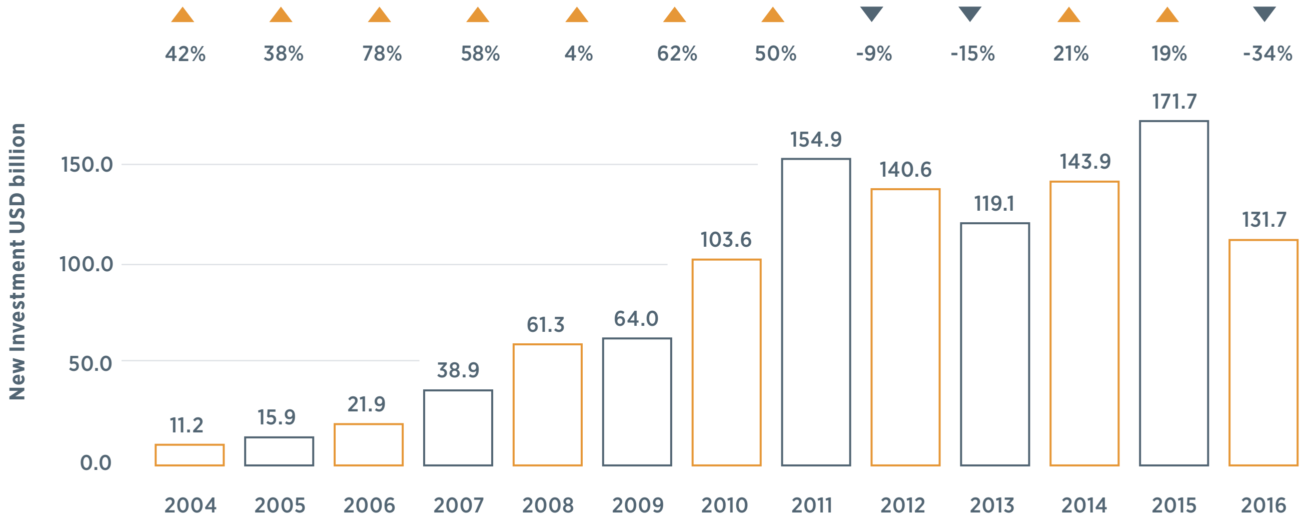
As PV systems reach competitiveness, future market growth will depend on assuring their performance and durability.

The last 5 years, investments in Solar PV overpassed USD 110 billion annually, as reflected in Figure 1.3. 2016 shows lower investments compared to other years, however it was a record year for annual net additions in solar PV technology, this decrease reflects the effect costs reductions are having in this technology. Between 2016 and 2030, investments in PV in the order of USD 2 trillion would be required to achieve the projected approximation of 1500 GW of additional installed capacity. With PV systems rapidly becoming a very competitive power supply option, with trillions of U.S. dollars at stake, more efforts should be made to ensure that these systems deliver as expected throughout their lifetime. Thus, in order to lay the foundation for sustainable market growth, credibility on the technology must be enhanced, and the risk for investors, policy makers and consumers alike must be reduced.

Past results indicate that along the project lifecycle, PV systems observe a failure rate with a ‘bathtub’ curve. Failure rates are higher at early stages due to technology infancy failures, as are end-of-life stages due to wear (see Figure 1.4). At the early stages of project development, the high risk of failure is commonly borne by the engineering, procurement and construction (EPC) holder and the project developer. These stakeholders are often liable for only a few years, which leads them to focus on ensuring short-term quality. Technology failures may decrease in midlife, leading to higher revenues for lenders and project owners, although the curve – at the end of the lifecycle – will reveal a growing trend in breakdowns due to wear. These risks are ultimately assumed by public entities or communities.

Quality assurance (QA) is crucial in order to reduce electricity costs, since it contributes to ensuring stability for the investors and other stakeholders and it is an essential instrument to protect and accelerate future investments in PV deployment. QA helps to reduce risk by providing the confidence that a product or service will meet expectations which, in turn, lowers capital costs, raises performance, increases module lifespans and, finally, lowers LCOE. As shown in Figure 1.4, QA mechanisms may have a substantial positive impact on changing the failure curve shape.

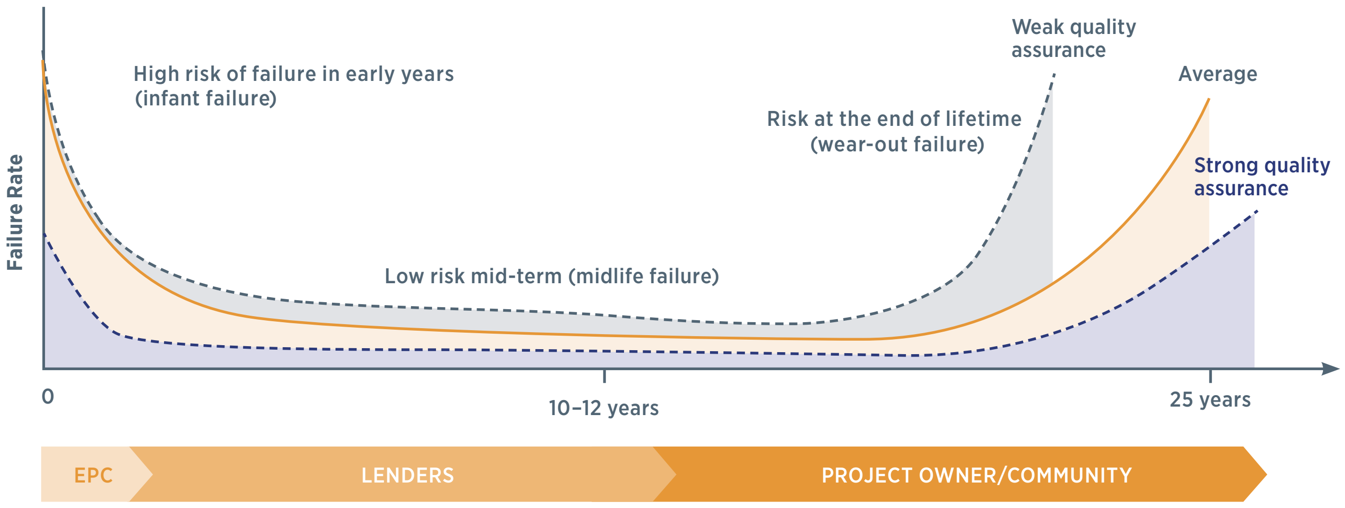
Figure 1.3. Global trends in solar energy investment



Based on: FS – UNEP Centre and Bloomberg New Energy Finance, 2017

Notes: Investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals. USD = U.S. dollar.

Figure 1.4. Failure curve of solar photovoltaic system



Based on Solar World, 2016

Note: EPC = engineering, procurement and construction.

Bolstering the investment outlook

The implementation of a comprehensive QA framework requires a physical and institutional infrastructure, referred to as quality infrastructure (QI).

QI comprises the entire institutional network and legal framework necessary to regulate, formulate, edit, and implement standards for the common and repeated use of products and services. It also includes the provision of evidence for its fulfilment, including testing, certification, metrology and accreditation.

Within the investment context, QI implementation impacts the key parameters that lie behind the LCOE. Technical risk and the relevant financial rates, the lifetime of the project, and projected energy production are parameters for which QI can significantly reduce uncertainty and enhance performance. A quality-driven environment for emerging technologies and projects can increase investor confidence, enable lower weighted average costs of capital and attract more investments for solar PV technologies.

The importance of quality infrastructure across the value chain

To assure the quality of products will require going beyond the performance role of equipment. It will require the implementation of QI, which will benefit PV systems across the entire value chain.

Quality requires a holistic approach. The implementation of a QA framework covers not only the equipment, but the entire system, including design, installation, operation, maintenance services and disposal. Enacting proper quality schemes, as well as incorporating international practices and stakeholder consultation can impact positively on each of the stages of the technology lifecycle.

A well-developed QI is essential for the sustainable growth of solar PV. At the market level, a national QI that is aligned with international best practices assures quality and safety in the sector. Implementation of QI is effected through the deployment of the elements listed in Figure 1.6.

Figure 1.5. Quality in different aspects of the value chain

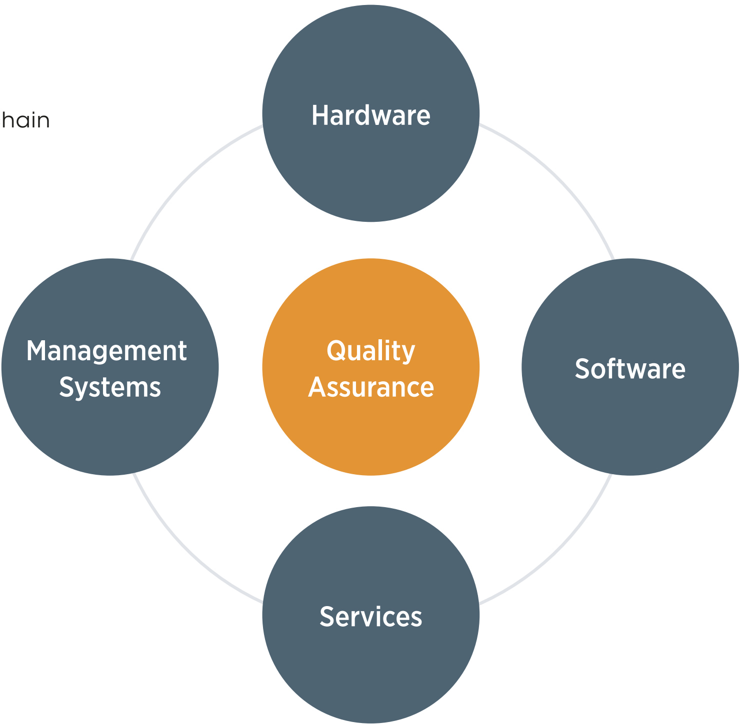


Figure 1.6. Elements of quality infrastructure

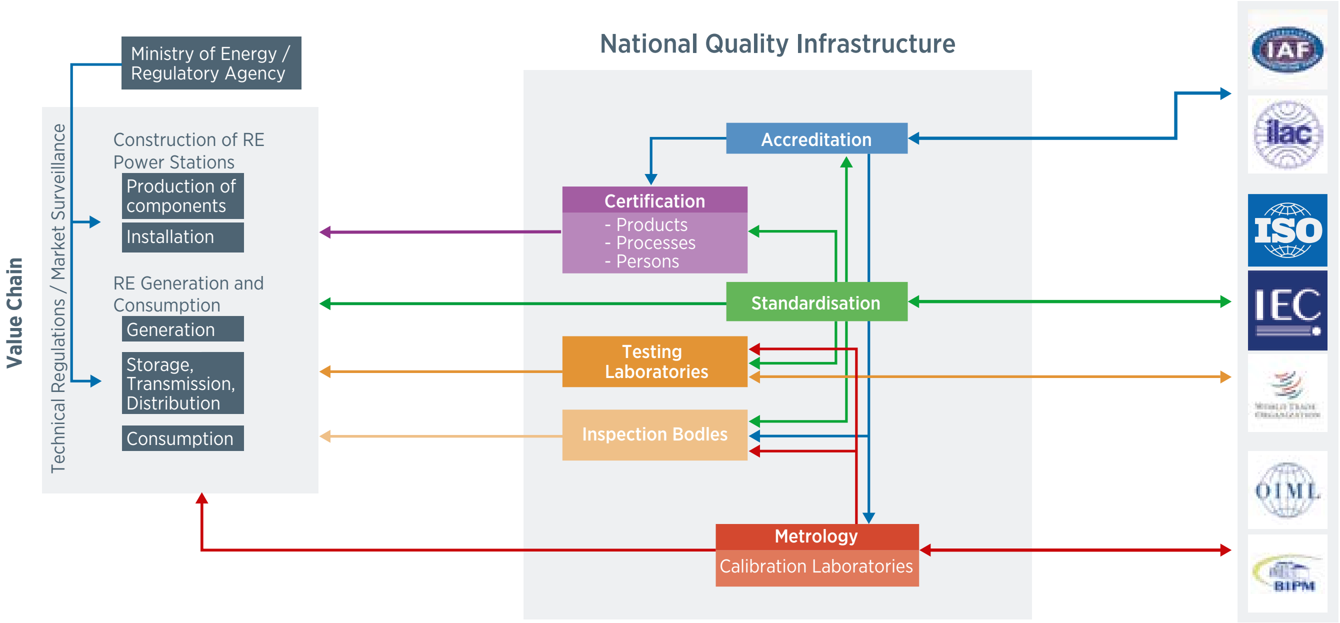
Implementation of Quality Infrastructure is through the deployment of:

STANDARDS	Defining methods and specifications
CERTIFICATION	Meeting requirements of standards
TESTING PROCESSES	Verifying conformity by testing
ACCREDITATION	Evaluating conformity-assessment bodies
INSPECTION BODIES	Conformance with requirements
METROLOGY	Determining conformance by measuring
MARKET SURVEILLANCE	Monitoring market status

Implementing QI in the solar PV market benefits the entire value chain and involve all stakeholders, including governments, financiers, project developers, manufacturers, installers and end users.

Figure 1.7. indicates the elements of a QI, such as described above, and the relevant international institutes that relate to each element.

Figure 1.7. Quality infrastructure framework

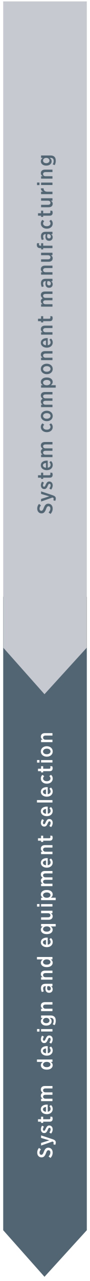


Based on The National Metrology Institute of Germany (Physikalisch-Technische Bundesanstalt), 2010

Standardisation

There is a core group of international standards, developed by the International Electrotechnical Commission (IEC) and used broadly on a global scale. In addition, there are country-specific standards that exist, most of which are based on international standards. These measures cover every aspect of the PV value chain, from the system component manufacturing phase through to the end of the technology's life. Specific examples are featured in Figure 1.8.

Figure 1.8. International and country standards applicable to the photovoltaic value chain



International – PV Module

IEC 61730 – Photovoltaic (PV) module safety qualification

IEC 61215 – Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval

International – Inverter

IEC 62109 – Safety of power converters for use in photovoltaic power systems

IEC 62093 – Balance-of-system components for photovoltaic systems

The USA – PV Module

UL 1703 – Safety of Safety for Flat-Plate Photovoltaic Modules and Panels

IEC 61215 – Crystaline silicon terrestial photovoltaic (PV) modules – Design qualification and type approval

IEC 61646 – Thin-film terrestrial photovoltaic (PV) modules - Design qualifications and type approval

The USA – Inverter

UL 1741 – Standard for Inverters, Converters, COntrollers and Interconnection Systems Equipment for Use With Distributed Energy Resources

UL 62109 – Standard for Safety of power converters for use in photovoltaic power systems – Part 1: General requirements

* China has developed its own standards

International

IEC 62548 – Photovoltaic (PV) arrays – Design requirements

IEC TS 62738 (Technical Specification) – Design guidelines and recommendations for ground-mounted photovoltaic power plants

IEC 62257 – Recommendations for small renewable energy and hybrid systems for rural electrification – Part 1: General Introduction to IEC 62257 series and rural electrification

IEC 62116 – Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures

Australia

AS/NZS 4777 – Grid connection of energy systems via inverters

AS/NZS 3100 – Approval and test specification – General requirements for electrical equipment

China: **GB50797-2012** – Code for design of photovoltaic power station

The USA: **NEC Article 690** – Solar Photovoltaic (PV) Systems

* Rollout of **national standards** for intallations and certification of installers

Installation and commissioning

International

IEC 62446 – Grid connected photovoltaic systems -- Minimum requirements for system documentation, commissioning tests and inspection

IEC 61724 – Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis

The USA: ASTM E2848 - Standard Test Method for Reporting Photovoltaic Non-Concentrator System Performance

Performance and operation & maintenance (O&M)

International

IEC 61724 – Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis

IEC 62446-2 – Photovoltaic (PV) – Requirements for testing, documentation and maintenance

The USA: Standard Test Method for Reporting Photovoltaic Non-Concentrator System Performance

End-of-Life

International

Decommissioning and waste management options need yet to be properly addressed in international standards.

Directives: like the European Waste Electrical and Electronic Equipment (WEEE) directive, are implemented awaiting transposition into national laws and standards.

Notes: IEC = International Electrotechnical Commission; PV = photovoltaic; NEC = National Electrical Code; AS/NZS = Australian/New Zealand Standard; GB = Chinese Standard.

These are the primary standards most often called upon for project approval or due diligence engineering on behalf of financiers. Further standards that govern manufacturing and testing equipment, sensors, measurements and others provide the QA foundation for product safety and performance. While not specific to PV installations, these standards are relevant and applicable to a variety of other sectors within the electrical industry.

Quality infrastructure development and its different contexts

Successful experience with QI development around the world highlights the benefits of off-grid, distributed generation and utility-scale PV systems.

Table 1.1. lists 11 cases that include developed and developing countries for which the challenges and solutions in developing and implementing QI are indicated. These examples showcase specific measures that relate to the various market development stages. The implementation of QI elements appears highly dependent on country experience and the maturity of the PV market.

Table 1.1. Challenges and solutions for quality infrastructure development

Market	System	Challenges	Solutions
Developing	**Utility-scale** *(e.g. Egypt, Chile)*	• Lack of lender and developer confidence for ambitious governmental programmes due to political instability	• Creation of an organisation responsible for regulation, monitoring and quality assurance
	Distributed generation *(e.g. China, the Philippines)*	• Lack of quality infrastructure (QI) awareness • QI hampered by unattractive incentive scheme • Market allows for substandard products	• Certification of photovoltaic (PV) installers • Guidelines for testing and certification • Increasing awareness of QI elements for rooftop PV owners
	Off-grid *(e.g. India, Tanzania)*	• Lack of certification process for installers and limited quality assurance for technology, installers and installations	• QI improvements in component testing; adoption of international standards; certification and inspection schemes; inclusion of quality criteria in public programmes; and criteria for commissioning and accreditation of public laboratories
Developed	**Utility-scale** *(e.g. U.S., Germany)*	• Transmission and distribution capacities require adjustments in line with increasing PV capacity to meet state utility requirements	• Adoption of International Electrotechnical Commission standards in national regulatory frameworks
	Distributed generation *(e.g. Singapore, The Netherlands)*	• Unstructured market surveillance • Lack of national measurement institutes • Private owners are unaware of PV system quality • Installations require high-quality assurance	• Arrangement for mandatory registration of PV installations • Establishment of national solar testing facilities • Provision of information about PV system quality to end users • Adequate skill requirements for installers
	Off-grid *(e.g. Australia)*	• Reducing investor uncertainty through regulatory framework that incorporates quality assurance • Installers not appropriately trained for utility-scale projects • Clean Energy Collective solar component approval process not adequately thorough	• Improved solar component compliance procedure and establishment of a solar retailer code of conduct

The significant effects of quality

The benefits of QI services outweigh their costs. Implementing QI for PV systems may result in significant additional revenue for project owners.

QI implementation and execution measures have an associated cost and require effort. The rationale for implementing a QI, however, is to achieve a positive economic balance by increasing revenues for various actors across the value chain, improving consumer protection, and reducing the carbon footprint.

In the long term, the mitigated costs will outweigh those that relate to the development and implementation of QI. Currently, the costs of reduced quality are partly absorbed by warranty claims and liquidated damages, and these are insufficient to cover all costs of associated quality issues.

Table 1.2. provides an overview of five examples of QI services, as well as the associated costs and expected benefits. These examples were selected based on their capacity to allow for cost benefit analyses.

Table 1.2. Cost/benefit analyses of implementing specific quality infrastructure services

Quality infrastructure service	Cost	Benefit
Development: Solar resource and yield uncertainty		
Energy Production Assessment (EPA) based on measured irradiance data	Measuring local irradiance for at least one year	Reduction of uncertainty in EPA from 8% to 6% leads to an increase in P90 values by 3%. Rewarded through improved loan conditions.
Preconstruction: Prevention of low plant yields		
Batch acceptance testing for wholesale and utility projects	The cost of a batch acceptance test (Typically USD 50 000–55 350 for a 20 megawatt (MW) plant)	A reduction of the degradation rate from 0.75% a year to 0.4–0.6% a year in a project's financial model (Resulting in USD 450 000–1 000 000 of increased revenue over 25 years for a 20 MW plant)
Construction: Performance testing		
Includes independent testing in engineering, procurement and construction contracts on photovoltaic systems performance	The cost of batch testing for a 20 MW plant is USD 276.75–553.50/MW	Photovoltaic module manufacturers deliver modules exceeding contracted performance by 2–3% when batch testing is announced. (Earning an additional EUR 4 000–6 000/MW a year increased generation for a 20 MW plant) (USD 4 428–6 642/MW/year)
Operation and maintenance		
Potential induced degradation (PID) reduction. Inspections to detect, classify and mitigate PID effects	Cost of inspection and corrective actions (for a 6 MW plant in Western Europe: EUR 2 500–4 000/MW) (USD 2 767.5–4 428/MW)	Tackling PID reduces underperformance of 3–5%; however, recovery is not immediate (for the 6 MW plant, EUR 6 000–10 000/MW/year) (USD 6 642–11 070 MW/year)

Quality now and in the near future: Action required

QA is essential to establish the necessary credibility among stakeholders and to enable market growth.

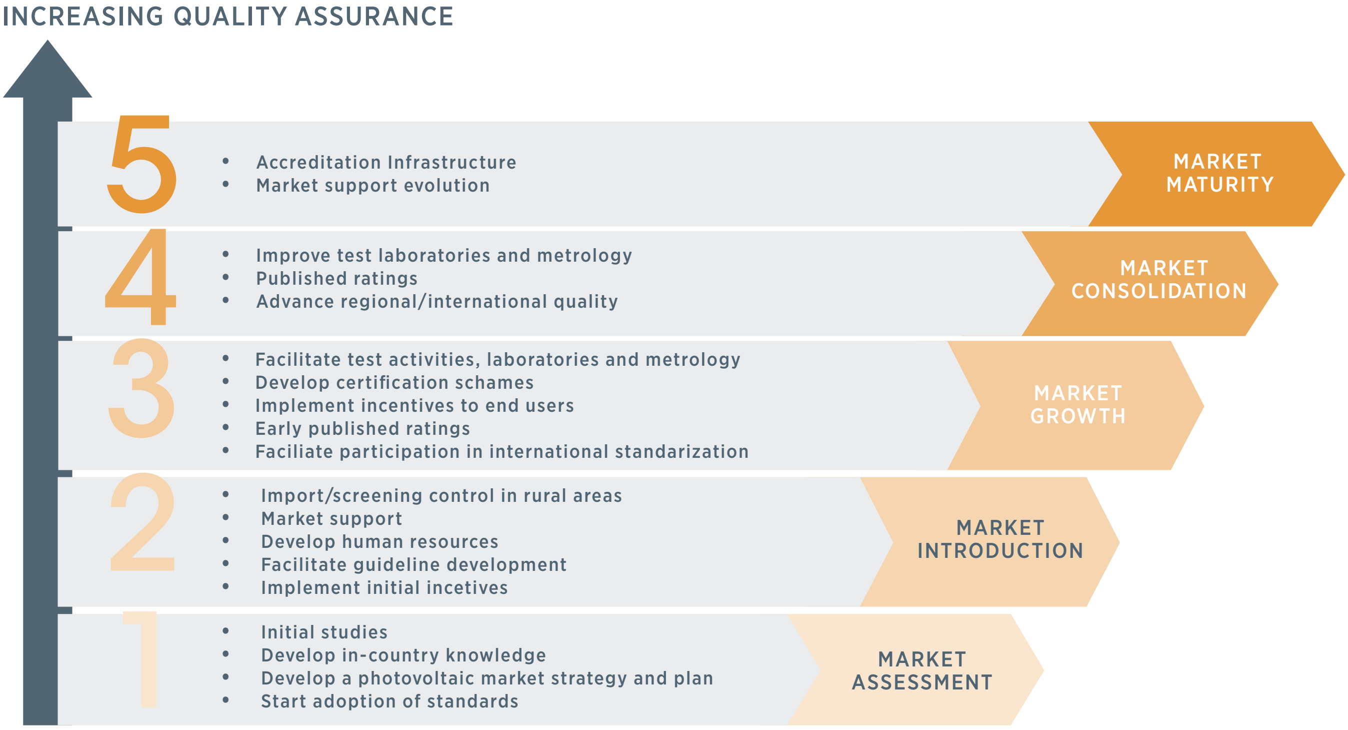
Policy makers can use a staged approach to understand and initiate appropriate measures in developing QI for PV systems. They should bear in mind that quality requirements must be implemented in conjunction with market growth.

QI also acts as a tool to support policies and regulations along the value chain, since it refers to a system that provides the means to appraise conformity with appropriate standards and compliance with relevant regulations. A well-tuned incremental approach can help raise the bar for quality requirements as country capacities and PV markets grow. Well-designed QI requirements are balanced in a way that they do not allow for the deployment of subpar systems; neither are they so stringent that local suppliers and institutions are unnecessarily restricted. Incentives and specific programmes are deployed in most countries to support PV development in line with market growth.

Nevertheless, photovoltaic equipment and applications may sometimes appear to lag in terms of QA schemes that encourage a sustainable and accelerated deployment of this type of technology. Further research on this topic highlights the fact that the cost of implementing testing and certification requirements, the prevailing absence of capacity issues, and the lack of awareness of QI benefits could contribute to the primary challenges of establishing quality schemes.

In order to maintain the balance between market needs, building affordability and QI implementation for solar PV, the approach should be incremental and linked to the level of PV market maturity. Measures at each stage of market development should be sufficiently flexible to allow for various country considerations. The steps proposed in this report will contribute to the effective development of a PV market through QI measures that are successively implemented.

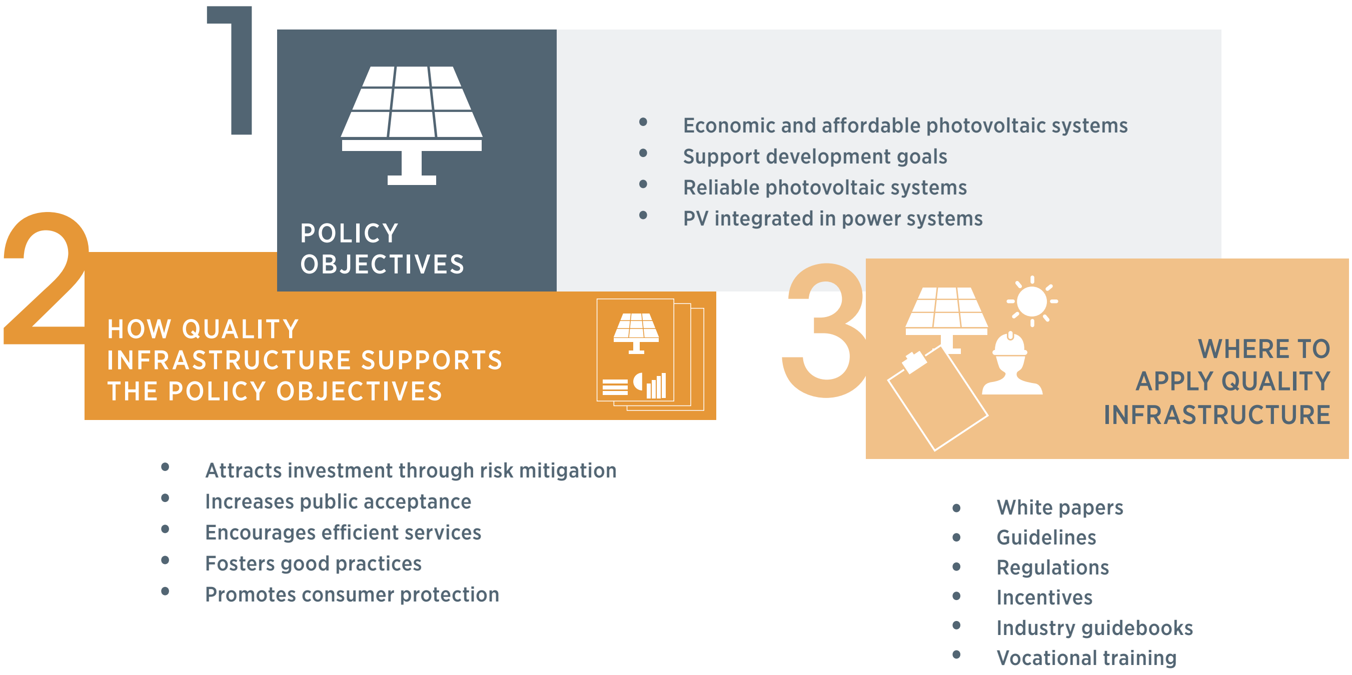
Figure 1.9. Steps in quality infrastructure development linked to market maturity indication



Making the work of policy makers and regulators easier with quality infrastructure

QI is essential to enable the achievement of renewable energy (RE) policy objectives more effectively. It also facilitates the efforts of relevant key decision makers.

Figure 1.10. Contributing to policy objectives through the implementation of quality infrastructure



Policy makers require instruments that help them reconcile two key macro objectives in the energy sector: i) providing citizens with affordable and reliable energy supply; and ii) fostering sustainable economic growth through deployment of clean and modern technology. QI bridges these two objectives, ensuring that suitable energy technologies promoted by governments deliver as required to effectively fuel economic growth and well-being. However, the importance placed by policy makers on ensuring the quality of renewable energy systems deployed in the country seems to be small in comparison to other factors, such as technology affordability. It is worth noting that focusing on QI may also lead to lower life-cycle costs.

Figure 1.11. Different levels of public policy

COMPLIANCE

- Mandating adoption of (inter) national standards relating to procurement and installation
- Permitting and authorisation involving testing, installation and grid code compliance
- Penalties for non-compliance

CONFORMITY

- Guidelines on international standards and codes of practice
- Photovoltaics guidebooks
- Development of national standards (non-mandatory)

The work of policy makers can be eased by using standards, testing and certification in conjunction with policies and regulations. This report illustrates how policy makers can benefit from QI requirements through voluntary and legislative actions including guidebooks, laws, technical regulations, decrees and other actions outlined by a statutory body.

> *PV markets that achieve a level of maturity reflect lower equipment costs, with quality assurance playing a key role in the mitigation of technology risk and improving equipment performance. Thus, putting QI in place encourages further deployment of solar technologies.*

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