Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
National Metrology Institute

INTERNATIONAL COOPERATION

Priorities for Quality Infrastructure Development for Photovoltaics in Indonesia

March 2019

german cooperation
DEUTSCHE ZUSAMMENARBEIT

On behalf of

Federal Ministry
for Economic Cooperation
and Development

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Acknowledgements
Within BAPPENAS*, we would like to thank the Directorate for Energy, Mineral and Mining Resources; Directorate for Energy, Telecommunication and Informatics; Directorate for Industry, Tourism and Creative Economy; Directorate for Tertiary Education, Science & Technology and Culture.

This report also benefited greatly from inputs by workshop participants, interviewees and survey respondents from numerous institutions. We would thus like to express our gratitude to the following organizations:
AESI, APAMSI, B2TKE-BPPT, BMKG, BPPT, BSN, BSN/KAN, DJK - ESDM, DJ EBTKE - ESDM, GIZ, Kemenperin, PLN - DIVISI EBT, PLN - PUSERTIF, PPLSA, PPSDM - ESDM, PT CSI, PT INTI, KSNSU-BSN, SESM group, Sucofindo, TML Energy, Tura and TÜV Rheinland.

*BAPPENAS, the Ministry of National Development Planning, Republic of Indonesia, is an Indonesian central government institution which is responsible for formulating national development planning and budgeting. It has also a responsibility to coordinate international development cooperation.

Part 1 – Summarized Recommendations for Policy Makers

It is a priority of the government of Indonesia to increase rural electrification and at the same time promote renewable energies in the national energy mix. The government target for solar photovoltaic (PV) energy was ambitiously set at 6.5 GWp of installed capacity by 2025. A central precondition for the successful implementation of the political targets is the use of safe, high-quality components and PV systems that are adapted to international standards.

Currently, quality issues are common in installed PV systems and locally manufactured components. Additionally, the quality of imported components cannot always be assured. The national quality infrastructure (QI) – including standardization, metrology, testing, inspection, certification and accreditation – plays a vital role in assuring the quality of PV systems. This paper provides recommendations for the development of quality infrastructure services to address quality gaps in the sector and thus foster acceptance and bankability of the technology in Indonesia.

The main recommendations regarding the development of quality infrastructure for the PV sector to support the Government of Indonesia in achieving its target to install 6.5 GWp PV capacity by 2025 are as follows:

Quality infrastructure development, as well as relevant regulations and other framework conditions for the PV sector, need to be addressed with a holistic approach. The decision on which quality infrastructure services should be the priority depends on the approach and focus chosen for PV development. It also needs to be considered that building up competence in the national quality infrastructure institutions takes time. Therefore, it must be prioritized which services to be provided are essential in Indonesia and for which services a coordination with quality infrastructure institutions with existing capabilities in the region can be established.

General recommendations on a systematic development of the PV sector and relevant quality infrastructure:

1. **An overarching national policy is needed to give a strategic direction and guide the development of the PV sector.** The policy should support the creation of a PV market, through government tenders and favourable conditions for the private sector. It should also foster quality through technical regulations (for safety aspects) and through reference to standards in tenders, promotion and funding programs. In this way, quality infrastructure services can be developed sustainably, hand in hand with the national market, and in line with the national demand.

2. **The necessary structures to support the implementation of the policy need to be put in place.** The successful implementation of the national policy and systematic quality infrastructure development depend on clearly defined responsibilities. Therefore, the roles of the different ministries need to be clear, including responsibilities for regulation and ownership transfers of PV systems. Additionally, it is recommended that a National Quality Committee for PV with representation of the relevant ministries, national quality infrastructure institutions and industry be created and that a Centre of Competence for PV be established as a hub of technical expertise, where research, training and testing can be provided.

3. **Human resource development for the PV sector should be a priority.** Capacity development for the local service industry increases quality in the PV sector and strengthens the national economy. Quality aspects need to be taken into consideration from plant design, over installation, to operation. Therefore, qualified personnel for PV plant design, installation and operation and maintenance services are essential for the successful development of the sector. Interventions can include training of trainers and personnel qualification and certification schemes according to international best practice.

4. **The bottleneck of grid-integration of electricity generated with PV systems needs to be addressed.** Management and quality aspects of the grid are key to the achievement of national targets for PV capacity. To assure grid stability and efficient use of solar energy, the grid systems need to be adapted. The resulting limitations for on-grid PV development in the short, medium and long term thus need to be taken into consideration.

5. The following **should be the priorities for quality infrastructure development** for PV in Indonesia considering the current situation:
   - **Update and adoption of relevant standards** for personnel, processes and products throughout the PV value chain; development of best practice and implementation guides that consider the local conditions. *(These standards and guides should be referenced in tenders and contracts to increase quality requirements.)*
   - **Development and harmonization of inspection schemes** for PV systems, **revision or elaboration of personnel certification schemes** for PV practitioners, ensuring that inspection and certification bodies are accredited by an internationally recognized accreditation body. *(These schemes help to implement the quality criteria from standards and implementation guides.)*
   - **Development of testing services with a focus on installed PV systems,** ensuring that testing equipment is regularly calibrated and achieving internationally recognized accreditation for the expanded service scope. *(With these services, the performance and safety of PV systems and components can be checked to ensure the functioning and reliability of PV installations.)*

The following examples of possible PV development scenarios can help guide the decision on how to achieve the government targets (see Table 1). These scenarios should be further developed in a stakeholder dialogue on the political level involving all relevant ministries for the development of the PV sector. They could then be used as a basis for the elaboration of a national PV policy.

Scenarios	**Quality infrastructure needed**
Turn-key imports (all components, plant design and EPC services are imported)	Necessary competency in the country is reduced to market surveillance, including quality criteria in tender documents and adequately commissioning PV plants.
Imported components, local design, installation and/or O&M	The services mentioned above and quality infrastructure for personnel qualification and inspection.
Local component assembly (e.g. as a local branch of international manufacturing)	The services mentioned above and quality infrastructure for selected conformity assessment.
Some components manufactured nationally	Quality infrastructure for selected components, industry development and productivity improvements.
100 % local content	Complete quality infrastructure services, including research and development.

Table 1: Scenarios for the development of the PV sector and quality infrastructure needed

Part 2 – Introduction

2.1. Objective, background and structure

This paper was prepared within the scope of the project "Strengthening Quality Infrastructure for the Energy Sector" and was carried out by PTB, the German National Metrology Institute, in Indonesia. The project focuses on supporting the development of quality assurance services for the photovoltaic sector.

The paper has the following objectives:

- Provide an overview of QI requirements for the PV sector.
- Analyse the current QI situation for PV in Indonesia.
- Give recommendations on priorities for developing the national QI for the sector.

To achieve these objectives, the concept of QI is introduced first (Chapter 3). In Chapter 4, common quality and safety issues in PV are identified along the value chain. Then, the current situation in Indonesia with regards to quality assurance for the PV sector is assessed. Finally, Chapter 6 presents recommendations based on the previous analyses.

The paper was developed in close collaboration with the National Development Planning Agency of Indonesia (BAPPENAS) to inform the government about necessary quality infrastructure development for the PV sector to be considered in the National Medium-Term Plan (RPJMN) 2020–2024.

2.2. Methodology

This input paper was elaborated by a group of experts for QI and PV with knowledge about the current situation in Indonesia. It is based on both primary and secondary data.

First, existing information from studies and expert reports was gathered in extensive desk research. This information was discussed and confirmed in various meetings with local experts and different stakeholders.

Roof-mounted photovoltaic system in Jakarta, Indonesia © Timothy Walsh

Furthermore, major quality issues in PV in Indonesia were discussed and confirmed in a focus group discussion with the participation of representatives from the PV value chain, ministries and institutions of the quality infrastructure. During the same workshop, possible solutions were identified and prioritized with the stakeholders. The collection of information was completed with four stakeholder interviews with representatives from the Directorate General of Electricity (DJK), an Engineering, Procurement and Construction (EPC) provider, the German Society for International Cooperation (GIZ) and the national electricity provider (Perusahaan Listrik Negara – PLN); there was also an online survey for industry representatives.

Finally, the draft version of the paper, including the recommendations, was presented in a second focus group discussion with a similar representation of stakeholders. The participants commented on the general recommendations and reviewed the specific recommendations made for their institutions. The input paper was completed by including the suggestions for adaptations and additional tasks received by the workshop participants.

Part 3 – The National Quality Infrastructure

3.1. Overview of the quality infrastructure system

The national quality infrastructure, as illustrated in Figure 1, comprises the following elements:

- **Standardization** provides requirements and specifications to ensure that products, processes and services are fit for their purpose. The national standardization body is responsible for standards development, their publication, awareness raising and the provision of relevant information.

- **Metrology** is the science of precise and reliable measurements for legal matters, industry and science. The national metrology institute provides high-level metrological services (traceability, calibrations, investigation, etc.) for laboratories and industries. Routine services are provided by calibration laboratories.

- **Testing** allows the characteristics or performance of a commodity or process to be determined following a specific procedure. It is important for research, quality control, for ensuring health and safety and for ensuring compliance with contractual or regulatory requirements.

- **Inspection** services can be used to determine whether a product or process complies with certain requirements.

- **Certification** is usually based on testing and audits and provides assurance that a product or process complies with a standard or specification.

- **Accreditation** is provided by the national accreditation body and consists in the formal recognition of an organization's competence to carry out a specific conformity assessment task. Testing and calibration laboratories as well as certification and inspection bodies can apply for accreditation to prove that they are able to provide reliable services.

The national quality infrastructure is an interrelated system, in which no component can be developed alone without developing the others, since they all complement each other. Moreover, it should not be developed in an isolated way, but linked to the international systems by establishing the respective relations: to the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) for standardization, the International Bureau of Weights and Measures (BIPM) and the International Organization of Legal Metrology (OIML) for metrology and legal metrology, or the International Accreditation Forum (IAF) and the International Laboratory Accreditation Cooperation (ILAC) for accreditation as well as to the respective regional organizations, including the Pacific Area Standards Congress (PASC), the Asia Pacific Metrology Programme (APMP), the Asia Pacific Legal Metrology Forum (APLMF), and the Asia Pacific Accreditation Cooperation (APAC).

This is the ideal strategy to ensure international traceability, comparability and recognition of the local services and to benefit fully from the national quality infrastructure. Also, the national policy framework and relevant public institutions can be seen as a part of the extended quality infrastructure as they establish the framework for the different services (Sanetra and Marbán 2007).

These are the components to provide technical quality infrastructure services to any kind of user. Technical regulation and its enforcement, which is a mandate of the state authorities, and the industry users benefit from quality infrastructure services.

Depending on the different needs of authorities and industry, the provider must develop and offer adequate quality infrastructure services.

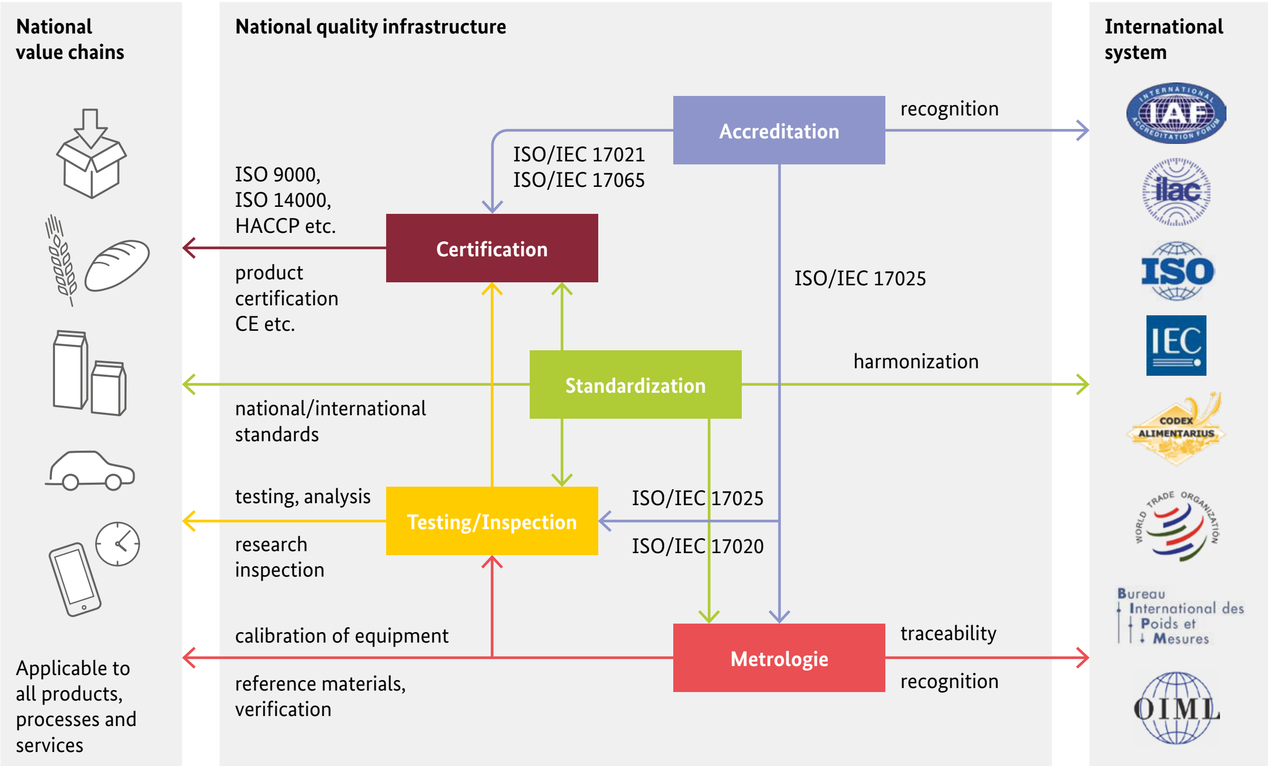

Figure 1: The national quality infrastructure (PTB 2018)

Therefore, the national quality infrastructure must be able to contribute to three key application fields:

- assurance of environmental protection, health, safety and security in line with state regulation
- buyer requirements according to market demand
- innovations and entrepreneurial creativity.

Assurance of environmental protection, health, safety and security is based on related requirements in technical regulations and is usually applied at the national level. The national quality infrastructure institutions should be able to assess whether these requirements are applied correctly. An international recognition of quality infrastructure services is helpful if the national regulator requests strict compliance with international best practices for harmonization purposes and trust building into the national quality infrastructure.

Services in line with market demand depend on the requirements and expectations of buyers, be they public, private, national or international. Such requirements are mostly defined in technical specifications, tenders and/or contracts. This includes the regulated areas of the target market but normally also additional requirements, such as company standards or buyer's own criteria, which are not state-regulated, to satisfy the individual customer expectations. Market-driven demands are dynamic, fast changing and often very specific. State regulation cannot and should not reflect these specifications. In this field, quality infrastructure services are required to enable trustful business relations. Internationally recognized certificates can be a basis but are not sufficient to guarantee high quality standards. Tailor-made measurements, tests and certifications are required, for which in many cases the methods first must be developed.

New developments and specific customer-oriented needs require good knowledge of international best practices and extensive communication with other international institutions. The great difference to the state-regulated area – that aims at assuring environmental protection, health, safety and security – is the mind-set. Where the regulated area is a reaction to market developments and focuses on control and conformity assessment at the final stage, in this market-driven field, dynamic and proactive quality infrastructure institutions are necessary, which provide services to accompany value chains and industrial

processes from design and engineering, through manufacturing, installation, commissioning, after sales service, monitoring, maintenance and repair to end-of-life / recycling. These are multiple additional services compared to the state-regulated conformity assessment.
The field of innovations is even more demanding because no standards exist for new services and products. Contributions by the quality infrastructure to investigation, research and development are necessary. Applied research for the development of tailor-made methods requires close collaboration with the industry, an in-depth analysis of the production processes, instrumentation and a clear understanding of the needed accuracy and measurement or test uncertainty for each situation and application. Collaborations with science and technology institutes, universities and research centres have proven to be particularly well-suited to investigate and address such innovative processes.

3.2. Quality infrastructure institutions in Indonesia

In Indonesia, the national quality infrastructure is composed of several institutions:

Badan Standardisasi Nasional (BSN) is the National Standardization Agency which is tasked with developing and promoting standardization in Indonesia.

BSN relies on technical committees (TC) and sub-committees to prepare the draft standards. So far, the chair of the TCs has been delegated to the respective ministries. With the implementation of Law No. 20/2014 on "Standardization and Conformity Assessment", the National Standardization Agency will take the leading role in all TCs, in line with international custom.

BSN is a full member of ISO. It participates in 258 technical committees, in 159 of which it is an observer and in 99 a participating member. The full list of ISO TCs in which Indonesia is involved can be viewed here: *https://www.iso.org/member/1798.html.*

Indonesia is also a full member of the IEC, with BSN functioning as the National Electrotechnical Committee. Indonesia participates in 25 TCs and is an observer member in 40 IEC TCs: *http://www.iec.ch/dyn/www/f?p=103:5:0.*

Additionally, BSN assumes a national coordination and leadership function for all quality infrastructure components, including testing, inspection, certification as well as metrology and accreditation.

Therefore, BSN manages the National Accreditation Committee (**Komite Akreditasi Nasional – KAN**). KAN has reached formal international recognition in the accreditation of testing, calibration (ISO/IEC 17025) and medical laboratories (ISO 15189) as well as inspection (ISO/IEC 17020) and certification bodies. Internationally recognized accreditation is offered for the certification of quality, environmental, food safety, energy and information security management systems (ISO/IEC 17021) as well as for product (ISO/IEC 17065) and personnel certification (ISO/IEC 17024). Additionally, KAN offers internationally recognized accreditation for proficiency test organizers (ISO/IEC 17043). KAN is a member of the IAF and ILAC, as well as their regional counterparts the PAC and the APLAC.

BSN also coordinated the National Measurement Standards Committee, while the national metrological tasks were performed by the Research Centre of Metrology (RCM) under the Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia – LIPI) and the National Nuclear Energy Agency (BATAN). Since restructuring in late 2018, the Indonesian National Metrology Institute has been integrated into BSN with two directorates under the **Deputy for National Measurement Unit Standards (KSNSU**). One directorate covers the measurement standards for mechanics, radiation and biology. The second one is responsible for measurement standards in the fields of thermoelectricity and chemistry. They have also taken over the role of representing Indonesia at BIPM and as an active member in the APMP. To date, Indonesia has presented 94 Calibration and Measurement Capabilities (CMCs) in acoustics, ultrasound, vibration, electricity and magnetism, length, mass and related quantities and thermometry. This means that the institute participated in scientific comparisons that were peer-reviewed and approved, thus its capabilities in these areas are internationally recognized.

Additionally, for the dissemination of metrology in the industry and conformity assessment bodies, approximately 200 **KAN-accredited calibration laboratories** are available in Indonesia.

In the area of conformity assessment, many private and public institutions provide testing, certification and inspection services. A registry of accredited conformity assessment bodies in Indonesia can be found on the KAN website. To mention just a few, the Agency for the Assessment and Application of Technology (**Badan Pengkajian Dan Penerapan Teknologi – BPPT**) is an important public institution that runs testing facilities. SUCOFINDO is a state-owned enterprise that offers testing, inspection and certification as required for consumer health and safety. The company also runs calibration laboratories. Some of the private institutions are international enterprises and carry out only a part of their services inside of Indonesia, using laboratory facilities in nearby countries for specific customer requests when necessary.

In the state-regulated area, the ministries are responsible for the technical regulation and enforcement, mainly using the conformity assessment bodies accredited by KAN. Those include amongst others the **Ministry of Energy and Mineral Resources**, the **Food and Drug Agency** and the **Ministry of Agriculture**. An important player is the Ministry of Trade with its **Directorate General of Consumer Protection and Trade Order**, which controls import and export, performs border inspections and market surveillance, and is responsible for legal metrology.

Part 4 – Quality and Safety Issues in Photovoltaics and the Role of Quality Infrastructure

4.1. Overview of quality and safety issues and related quality infrastructure services

Quality and safety issues are not always sufficiently considered by policy makers, investors, end users and even industry actors. Additionally, only a limited amount of data on the performance and related problems occurring in PV systems is available, since system operators and component manufacturers often prefer not to publish such information (Solar Bankability 2016).

Nonetheless, industry experts note that quality and safety issues which lead to performance losses and safety risks remain frequent in the PV sector. This was confirmed in a study by TÜV Rheinland, which found that worldwide nearly one third of over 100 PV plants had serious defects (TÜV Rheinland 2015, p.6). It thus needs to be considered that quality gaps can occur along the PV value chain – from component production to operation of the system – and can have a substantial impact on the long-term performance of the PV plant.

Table 2, adapted from a PTB (2016) publication on quality criteria for the financing of PV projects, summarizes the most frequently occurring issues identified in PV plants. Specific issues arising at different stages of the value chain will be discussed more in detail in the following parts of this chapter.

Another study calculated which component issues have the biggest financial impact. The Cost Priority Numbers (CPN) that indicate the highest risks for PV modules and inverters are reported in Table 3. The listed aspects refer to component quality as well as to the quality of installation and operations and maintenance. As the table shows, installation errors have the highest impact in terms of costs. To avert failures like glass breakage, PID (Potential Induced Degradation), snail tracks or damaged backsheets, module quality and careful handling need to be assured (Solar Bankability 2016).

4.2. Quality issues along the photovoltaic value chain

For solar PV, quality infrastructure services are important throughout the value chain, starting from manufacturing of components to electricity consumption. Only with the necessary quality infrastructure services in place can it be guaranteed that the technology and installation have the required quality level so that the expected amount of energy can be safely produced and consumed. This is particularly relevant in cases where a country intends to set up its own manufacturing capacities and to check the quality of imported products or services.

Value chain	Quality issues	Related risks	Examples of QI services that can reduce existing risks
Tendering and contracts	Lack of quality requirements in tenders and contracts.	Insufficient consideration of quality and risk of faults and issues leading to reduced performance.	Definition of clear quality criteria and reference to QI services (e.g. testing of PV plants).
Manufacturing and transport of components	Quality assurance of imported components.	Challenge to ensure imported components are of good quality due to large number of providers internationally.	Testing of components, e.g. module performance, as part of market surveillance. Internationally recognized accreditation of conformity assessment services, e.g. certification, module and inverter testing. Recognition of certificates in country of origin.
	Limited industry and technology experience resulting in possible quality gaps of domestic products.	Varying quality and reliability of locally produced components. Possible underestimation of durability risk.	Application of international standards for PV components. Application of accredited and internationally recognized certification schemes.
	Transportation and storage damage: micro cracks and resulting performance loss.	Possible performance loss and difficulty of assigning responsibility.	Reliable and locally available testing services. Adoption and implementation of existing international standards.
Planning	Lack of reliable irradiance data.	Uncertainty due to poor data as basis and resulting incorrect yield estimations.	Calibration of environmental testing equipment, e.g. pyranometers for solar irradiance measurements.
	Lack of experience and knowledge of the relevant service providers, including EPCs, owner's engineers and lender's technical advisors.	Possible mistakes in the project planning leading to reduced performance and false estimations.	Training and awareness raising on the consideration of quality criteria in the planning phase.
Installation and commissioning	Lack of experience of EPCs and installers resulting in installation errors.	Possible reduced performance, slower payback, reduced return on investment, risk of fire, increased maintenance costs.	Training and certification of installers. Adoption and application of relevant international standards, e.g. for technical installation. Application of inspection and commissioning schemes according to international best practices.
	Poor system documentation.	Higher costs due to inefficiency and possible quality gaps.	Adoption and application of relevant international standards.
	Inappropriate commissioning procedures.	Uncertainty about the performance and safety of the plant from start of operation.	Definition and application of commissioning procedures according to international best practices.
Operations, maintenance and monitoring	Lack of experience of O&M providers. Insufficient cleaning or cleaning instructions.	Reduced performance of the plant.	Creation of procedures and implementation of management systems according to international best practices.
	Lacking monitoring impeding the detection of underperformance and the collection of comprehensive performance data.	Persistent uncertainty about performance of PV systems.	Reliable testing of plant performance. Calibration of performance measurement devices, e.g. electricity meters.

Table 2: Overview of quality and safety problems and resulting risks in the PV value chain (adapted from PTB 2016, p. 13).

Types of PV module failures	**CPN/year (€/kWp)**
Improperly installed	15.45
Glass breakage	10.10
PID (Potential Induced Degradation)	7.75
Snail track	6.48
Defective backsheet	4.43
Delamination	3.59
Hotspot	2.98
Soiling	2.87
Shading	2.02
Broken module	1.65
Failure bypass diode and junction box	1.62
Overheating junction box	1.50
Corrosion of cell connectors	1.10

Types of inverter failures	**CPN/year (€/kWp)**
Faulty installation	2.43
Fan failure and overheating	1.78
Inverter not operating	0.88
Burned supply cable and/or socket	0.78
Error message	0.23
Switch failure/damage	0.20
DC entry fuse failure	0.20
Fault due to grounding issues	0.19
Polluted air filter	0.15
False connection	0.15
Inverter theft or vandalism	0.12
Inverter pollution	0.03
Inverter wrongly sized	0.01

Table 3: Cost Priority Numbers (CPN) for PV modules and inverters (Solar Bankability 2016, pp. 61, 63)

a) Tendering and contracts

Tender documents and contracts often consider only state-regulated safety aspects and lack strict quality requirements and well formulated warranties, making it difficult to assess the quality of the installation, operation and maintenance which reduces contractual pressure on Engineering, Procurement and Construction (EPC) and Operation and Maintenance (O&M) companies. This often leads to insufficient consideration of quality as it is unlikely that service providers proactively put quality first. The definition of technical specifications, including the aspects component selection, installation, commissioning O&M program and performance warranties, is of paramount importance to foster quality in PV systems.

b) Manufacturing and transport of components

Assurance of product quality is crucial for all components of solar PV systems. In many countries, quality control of imported products is lacking, and the market is exposed to low-quality imports. Keeping up with quality controls for PV components is further complicated by the large number of component providers which are active on the global market (PTB 2018). National market surveillance should have the capability and capacity to check incoming components and verify whether the information on the labelling and certificates is correct.

At the same time, locally manufactured PV components are not always able to satisfy international quality standards. This is a common issue in countries with a relatively new PV sector, as the industry is still lacking practical experience. Proficiency can only be achieved over time (PTB 2016).

Strict requirements for module selection are important to reduce risks by obliging the supplier to provide evidence of long-term durability of products. Certification in accordance with international standards should be the minimum quality requirement for PV components (PTB 2016).

Assuring good quality input is also relevant for the local manufacturing industry. Manufacturers need to be able to distinguish between good and bad components before use in local module production, for instance (e.g. solar cells, ribbons, glass, EVA, backsheets, junction boxes, etc).

A further issue is damage to components during transport. Here, a special focus should be put on the PV module as it is the most sensitive component of the PV system, and its functioning is strongly affected by environmental factors and damage caused by improper handling (PI Berlin 2018). Rough transport conditions can cause micro-cracks that can considerably lower the performance of the modules.

An additional risk arises through the difficulty of assigning responsibility for the damage if tests of the modules are not conducted upon arrival (TÜV Rheinland 2014). A standard for the transport of PV modules and available field-testing services can help address this issue.

c) Planning
The planning phase of a PV project is critical for quality assurance as the planning determines the later performance of the plant. For the site selection of commercial grid-connected utility-scale PV power plants, the availability of reliable irradiance data is of utmost importance as it determines the performance potential of the plant (IRENA 2015, PTB 2016). Often, imprecise satellite data and estimations are used, resulting in unrealistic performance predictions.

Considerable know-how is needed to successfully plan and design a PV system, as a variety of factors including orientation, shading, land use, availability of water for cleaning, wind conditions, seismic information and, in the case of rooftop installations, building and rooftop conditions need to be taken into consideration. Moreover, the selection of correct components is key. The selected technology needs to be suitable for the local climatic conditions, and for on-grid installations the inverter needs to be adequate for the system that is being built (PTB 2016).

Poor planning can result in complications in the installation as well as during operation and maintenance. It can impede correct functioning and reduce plant performance significantly.

Some developers and EPC contractors do not have the required skills and experience to conduct a comprehensive site assessment and to consider all the details in site design (PTB 2016). In other cases, the EPC might take advantage of lacking requirements from the investor and design the plant to achieve financial savings rather than quality, thus increasing the risk for the system owner (PI Berlin 2018).

An owner's engineer has the task of defending the owner's interests against the EPC and eventually the various product suppliers. For this purpose, the engineer conducts independent checks and verifications starting at the earlier phases. Similarly, a lender's technical advisor ensures the bankability of a PV project by checking that all steps are carried out to their satisfaction (PI Berlin 2018). Also, these service providers need to have an adequate level of expertise and know-how to properly assure quality from the planning to the operational phases.

Tight timelines and the assignment of tenders to the bidder with the lowest price without specifying sufficient quality criteria can severely affect project quality (PTB 2016).

d) Installation and commissioning
Problems also arise due to a lack of know-how and experience amongst installers or because of lax requirements for installation companies and poor supervision (IRENA 2015, PTB 2016, PI Berlin 2018). Installation faults are very common in PV plants worldwide. An international study by TÜV Rheinland found that installation faults were the cause of more than 50 % of serious defects in PV plants (TÜV Rheinland 2015). Failures in the cabling system are particularly common (TÜV Rheinland 2015, Photon 2013, PI Berlin 2018). PV modules are the most sensitive component of the PV system and their long-term performance can be strongly affected by environmental factors and damage caused by improper module handling during installation (PI Berlin 2018).

Installation failures during the construction phase represent pre-damage of the plant which in many cases cannot be removed during the operational phase. Such mistakes can have devastating effects on plant performance and financial returns (see Table 3). It is pivotal to prevent failures in order to reduce retrofitting costs and revenue losses for the owner. Moreover, lacking documentation of the as-built situation and the installation process make handover processes, maintenance and repairs more difficult (PI Berlin 2018).

Training courses and certification schemes for installers are important measures that help avoid issues during installation.

Potential mistakes during installation should be noticed during inspections and commissioning of the plant. However, there is often a lack of fixed procedures for inspections and commissioning as well as strict qualification requirements for the people involved in the process (PTB 2016). Especially for grid-connected plants, the commissioning process should include strict tests and verifications to ensure plant performance and safety (PI Berlin 2018).

e) Operations, maintenance and monitoring

Operations and maintenance can be both financially and technically challenging, especially when PV systems are installed in remote areas. Often, the system is not maintained correctly, or problems arise that cannot be fixed by the local communities.

Responsibilities for operations and maintenance should be clearly defined, making sure that the assigned operators are competent and/or have an expert whom they can contact when issues arise. Moreover, to avoid performance losses due to soiling, a module cleaning plan based on local conditions should be followed (PI Berlin 2018, PTB 2016).

Ongoing monitoring can help detect performance losses quickly and initiate necessary corrective measures. Moreover, monitoring data as well as proper documentation of failures, related maintenance measures and costs are necessary performance indicators for a regular evaluation of the system (PI Berlin 2018).

Measurement of the IV curve of a photovoltaic system © HT Instruments

4.3. Quality and safety challenges for photovoltaics in Indonesia

All the above-mentioned issues are relevant in the Indonesian context. However, the relatively recent development of PV in Indonesia, the lack of quality awareness among many PV users and the country's geographical specificities, with its vast extent and large number of small islands as well as the tropical climate, imply that some challenges are amplified.

This is the case, for instance, with the lack of skilled service providers available. Installation errors are especially common and jeopardize the reliability of PV systems in Indonesia. As performance ratio guarantees are not used, quality is often neglected (Interview 1). It is also common that the installation does not correspond with the designed system, that non-standardized components are used, and that the performance is lower than expected (Interview 3, Workshop 2). The lack of standardized commissioning procedures and the fact that commissioning is carried out by the EPCs with their own checklists means that performance assessments are not comparable, and underperformance or installation errors are often not detected (Interview 4). Inspections for the Certificate of Readiness for Operation (SLO) are often carried out by personnel with a limited understanding of and experience with solar PV technology (Online survey).

In remote areas, skilled personnel are even more difficult to find. This can complicate the installation, operations and maintenance of PV systems and prevent issues from being detected and/or repaired in a timely manner. Difficult transportation to remote PV locations adds to this problem, as components have to be delivered with various modes of transportation, increasing the risk of incorrect handling (Workshop 1, Interview 3).

The island geography also results in a fragmented electricity grid. This implies challenges for grid management, especially for assuring grid stability when energy from fluctuating sources such as PV is fed into the grid. The lacking quality of grid impact studies adds to this problem, as important factors are often neglected in the planning and are not detected until the PV plant is ready for operation (Workshop 1, Online survey).

The climatic conditions, on the other hand, are demanding for components, as they have to be able to withstand being exposed to a hot and humid environment with a high salt concentration when a plant is installed close to the sea. Quality assurance for both imported as well as locally manufactured PV components is thus essential. Insufficient component quality is particularly common in inverters, batteries, and balance of system (BOS) (Workshop 1, Interview 1).

Given the still limited market for PV in Indonesia and the fact that most local manufacturers produce exclusively for the local market, quality assurance in local production is particularly challenging because production is often stopped between orders. This discontinuity in production disrupts learning processes and quality management. It also impedes manufacturers from benefitting from economies of scale and results in high operational and quality assurance costs because of the limited production quantities. Many manufacturers do not have international certification (Workshop 1, Interview 1).

And finally, unclear or changing ownership of PV systems can affect their quality and performance. Most PV systems in Indonesia are off-grid and were built by the government to provide electricity to remote communities. Usually, the Directorate General of New and Renewable Energies (EBTKE) takes responsibility for the site selection and design of such remote PV systems, with contractors handling the EPC and commissioning aspects.

Typically, after the PV system is commissioned, it is handed over for free to the local government. In most cases, there is no charge to consumers for the electricity provided by the system, and no budget is allocated for operation, maintenance or monitoring. This situation results in a lack of financial incentive for any of the stakeholders in this process to ensure good quality and hence good performance of these PV systems. Consequently, there is also no incentive for the industry to increase the quality of their products, and the use and demand for quality infrastructure services remain limited.

Part 5 – Quality Infrastructure for Photovoltaics in Indonesia

5.1. A holistic perspective on the PV sector and related quality infrastructure services in Indonesia

The Indonesian government set a target of installing 6.5 GWp PV capacity by 2025. This translates to approximately 24 million PV modules that should be installed in the coming years. Some of the installations will support rural electrification and provide off-grid power, while a large part of the capacity will also need to be fed into the grid to assure an efficient use of the generated renewable energy.

So far, however, there is no overarching national strategy to guide the development of PV capacity to meet the desired goal. On the contrary, some of the current framework conditions might impede the achievement of the government target. For example, current local production capacity is still not sufficient for meeting the government target; nevertheless, the local content requirements prescribe the use of locally manufactured components. Also, grid management needs to be taken into consideration, as fluctuating solar energy can jeopardize grid stability. The national electricity provider (Perusahaan Listrik Negara – PLN) estimates that only 1 GWp of the targeted 6.5 GWp PV capacity can be achieved in the next 10 years, and only a part of the installed systems would safely feed electricity into the grids. Obviously, PLN's concerns regarding grid stability need to be addressed if the larger target is to be reached.

With respect to funding, the desired PV development cannot rely solely on government tenders. At the moment, ministries, local governments and PLN are the main drivers of the market, with a limited number of tenders being published. To promote private investment, political framework conditions need to be stable and favourable, the investment needs to be cost effective and generate an acceptable return on investment and the quality of components and the competence of service providers need to be guaranteed.

Quality components and competent, reliable service providers are available internationally. In Indonesia, the PV industry is still developing and gaining experience. Due to the reliance on the still limited national market of most actors and the resulting inability to benefit from economies of scale and invest in quality, the competitiveness of local producers is reduced. The restricted market size also affects service providers as building up the necessary PV-specific expertise is slow.

The development of quality infrastructure services should go hand in hand with industry and market development. Quality infrastructure development requires investment in the installation and maintenance of laboratories, for example, which engender substantial cost outlays. If services are only rarely used, the quality infrastructure institutions cannot gather sufficient experience to build competence and gain recognition and reputation, nor can they operate the services in a financially sustainable way. It is thus necessary to evaluate whether there is sufficient demand for a service beforehand.

At the same time, capacities and know-how need to be strengthened in the state-regulated area to effectively cover border control and market surveillance for consumer protection and health and safety aspects, such as product safety, electrical safety, safe construction, installation and operation, for PV and for the energy sector at large.

How to contribute to the national goal of 6.5 GWp by 2025?
(6 GW = 24 million panels)

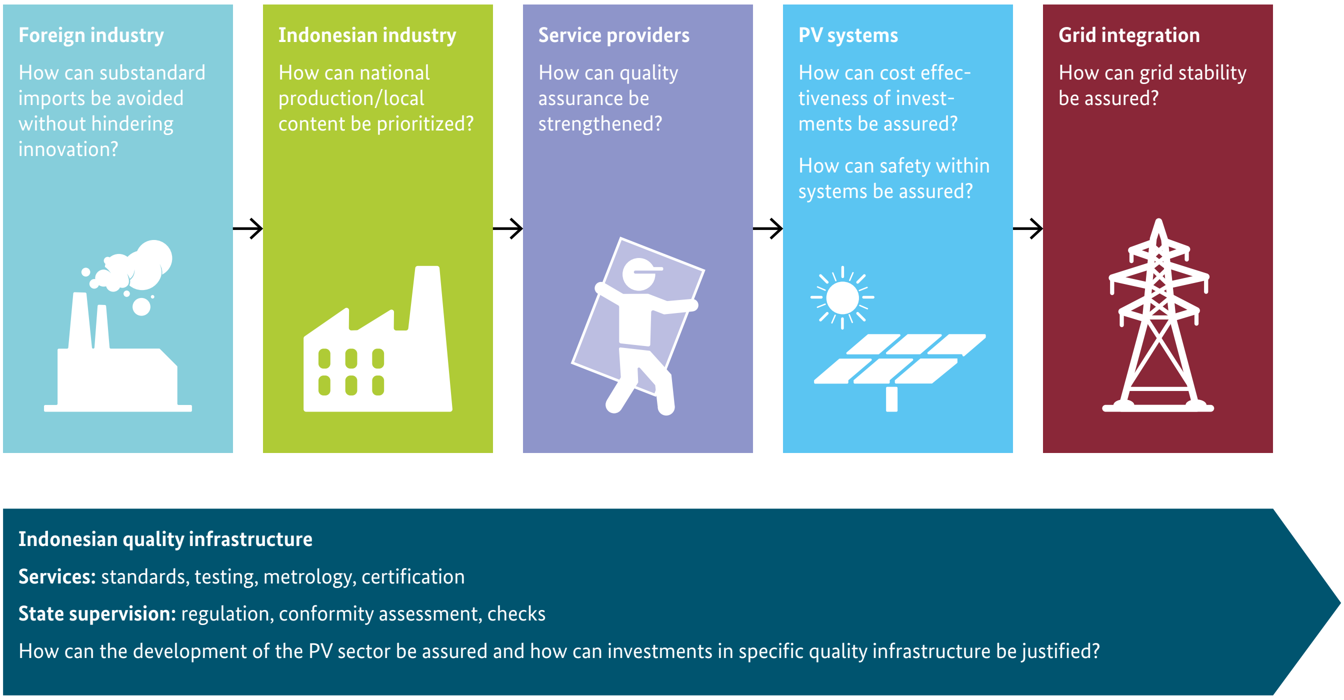

Figure 2: A holistic approach to quality in the PV value chain in Indonesia

The selection of the necessary quality infrastructure services to be developed in the coming years thus depends on the priorities for PV development in Indonesia and the concrete implementation plan for achieving the government target.

Figure 2 depicts the PV value chain, highlighting the most important questions to consider in quality infrastructure development.

5.2. Actors involved in photovoltaics and related quality assurance in Indonesia

The following table provides an overview of the most important stakeholders for PV and quality assurance in Indonesia (see next page).

The stakeholders take initiative and work on several lines of activity to advance PV in Indonesia. Given the multitude of actors, however, coordination is a challenge and different priorities and concerns have led to goals that do not always align. This shows for example in the discrepancies between the government and PLN targets for installed PV capacity, or the protective measures of the Ministry of Industry attempting to support the Indonesian PV manufacturing industry, including the local production of PV cells.

An initiative to better coordinate the efforts of the different actors and guide the development of solar energy in Indonesia was taken with the elaboration of a Roadmap for Solar Energy by a task force under the Directorate General of New and Renewable Energies (EBTKE) of the Ministry of Energy and Mineral Resources (ESDM).

Actor group	Relevant institutions	
Ministries and other public institutions	BAPPENAS BMKG Coordinating Ministry of Economic Affairs Local governments Ministry of Energy and Mineral Resources (ESDM) ■ Directorate General of New and Renewable Energies (EBTKE) ■ Directorate General of Electricity (DJK) Ministry of Industry Ministry of Manpower National Energy Council (DEN)	
Quality infrastructure	BNSP BSN B2TKE-BPPT B4T KAN-BSN	KSNSU-BSN Private conformity assessment bodies (e.g. Caltesys, LSP, TÜV Nord, TÜV Rheinland, TÜV Süd) SMTP-LIPI SUCOFINDO
PV industry, users and associations	AESI APAMSI EPCs IPPs (e.g. PT PJB) METI	Module manufacturers Pertamina PLN PPLSA REI (Real estate)
Universities and research centres	Universitas Mataram Universitas Muhammadiya Yogyakarta	

Table 4: Stakeholders involved in quality for PV in Indonesia

5.3. Current regulatory framework for photovoltaics in Indonesia

The regulatory framework governing PV in Indonesia is complex. Both the Directorate General of New and Renewable Energies (EBTKE) and the Directorate General of Electricity (DJK) of the Ministry of Energy and Mineral Resources (ESDM) promulgate regulations which concern PV. Based on a study by PTB, there are currently at least 16 regulations and PLN directives which are directly related to PV and an additional 18 regulations and directives which are related to PV in some way. The foundation is laid by Electricity Law No. 30.

Nominally, EBTKE is responsible for renewable energy, and DJK is responsible for electricity (including oversight of the state-owned electricity provider PLN). However, since PV is both a renewable energy and an electricity production technology, it is not always clear where the responsibility for developing regulation lies.

The existing regulatory framework covers a broad range of issues such as PV procurement by the government, tariffs, pricing and generation costs, permits and licenses, technical requirements and conformity assessment, local content and parallel operation and connection with the PLN grid.

Some of the most important legislations are (as of November 2018):

- ESDM 50/2017 regarding the purchase of electricity from renewable energy power plants, including PV, with a set tariff (85 % of main generation cost).
- ESDM 1/2017 concerning the parallel operation of power plants with the electricity grid of PLN.
- ESDM 33.207 addressing the provision of solar home systems (LTHSE).
- MOI 5/2017 regarding the use of local content in the development of electricity infrastructure.
- ESDM 38/2018 addressing procedures for accreditation and certification in electricity. With this regulation, the previous regulations on the same subject (ESDM 10/2016 and ESDM 5/2014) are withdrawn.
- ESDM 49/2018 concerning rooftop PV.

Technical specifications which define requirements for the assurance of safety and environmental and consumer protection are included in specific articles of many regulations. Some requirements are very detailed, while others refer to existing standards. Conformity assessment is mainly addressed in ESDM 38/2018 which regulates the provision of the Certificate of Readiness for Operation (SLO). It is generally stipulated that monitoring and supervision are to be carried out by one of the directorates of ESDM. Regarding local content, the above-mentioned MOI 5/2017 legislation specifies the percentage of the PV components and services that need to be made or provided in Indonesia. Certification from the Ministry of Industry is required. The current requirements are detailed and could be difficult to comply with due to the nascent stage of PV manufacturing in Indonesia.

Many regulations were introduced and then withdrawn again within a few years. This lack of regulatory stability was identified as one of the main “roadblocks” for the development of renewable energies in Indonesia because it discourages potential investors and increases project development risk (IISD 2018).

5.4. Available quality infrastructure services for photovoltaics in Indonesia

Standards

Standards are the responsibility of BSN which is currently supported by the line ministries that chair the relevant technical committees. EBTKE is responsible for the development of national standards for PV, since it holds the chair of the national technical committee for standardization for PV and other renewable energy technologies which is known as “KomTek 27-03”.

Standards are applied differently from technical regulations mentioned above. They cover mainly competence and quality criteria and follow new findings and innovations. Standards are voluntary, yet they are often used as buyer’s requirements and, as such, are included by reference in contracts, tender documents or funding programs.

At the moment, there are 28 Standar Nasional Indonesia (SNIs) relating to PV (PTB 2017). Most of these SNIs are adopted from international standards of the International Electrotechnical Commission (IEC); however, the implementation of these standards is not yet widespread.

Additionally, the state-owned electricity provider PLN has, in the past, also published its own standards (SPLN), which it refers to in its own tendering procedures. This adds to the complexity of the normative framework for PV in Indonesia. This could be addressed by aligning and harmonizing the SNI and SPLN so that PLN can refer to the national standards, which are arrived at by consensus.

The Ministry of Manpower has defined National Competency Standards (SKKNI) for PV planners and installers. The process for the definition of competency standards is separated from the above-mentioned standardization activities for PV related to international ISO / IEC standards.

Metrology

In the field of metrology, the two directorates of metrology standards at BSN (formerly RCM-LIPI) have well established laboratories and can provide metrological traceability in the general measurands used in the PV value chain.

According to a gap analysis to identify the needed metrological services for PV modules, which was carried out by RCM, the existing measurement capabilities in resistance and electricity, time, dimensional metrology and mass cover the needs of PV modules. Also, in temperature, the existing capabilities cover most of the needs identified. In the areas of photometry and radiometry, capabilities for illuminance, visible range and UV irradiance exist, but broadband spectral irradiance and total irradiance which are of high relevance for the PV sector are yet to be developed.

Also, private secondary calibration laboratories, such as Caltesys, and the state-owned enterprise SUCOFINDO offer calibration services relevant for the PV sector (e.g. calibration of thermometers and high voltage testing equipment).

The Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) is currently the only institute in Indonesia offering calibration for pyranometers, which is traceable to the World Standard Reference of solar radiation of the World Radiation Center in Davos, Switzerland.

PV-specific services, such as the calibration of solar simulators, reference modules, or solar cells do not exist at the moment. Also, the calibration of devices for grid management including smart meters and syncrophasor measurement units, power quality real time measurement and high voltage and power transformers is currently not available in Indonesia.

Testing

Testing services for PV which are available in Indonesia are provided by the Centre for Energy Conversion Technology (B2TKE) of the Agency for the Assessment and Application of Technology (BPPT). The following testing services are currently available and accredited in accordance with ISO 17025 by KAN (Schoppa 2017):

- power output measurement of solar modules in standard test conditions (IEC 60904-1)
- capacity and cycle testing (part of IEC 61427-1) for batteries
- efficiency tests for inverters up to 5kW (part of IEC 61683)
- performance measurements in installed PV power plants.

These capabilities are being expanded by adding a laboratory for PV module testing according to IEC 61215.

The laboratory of the national energy provider PLN also owns some testing equipment for PV modules. Salt-mist corrosion tests are carried out on PV modules in a self-made chamber.

Electroluminescence testing and visual inspection of photovoltaic modules © Timothy Walsh

Inspection and Certification

PV system inspection is relevant for commissioning and for the issuance of a Certificate of Readiness for Operation (SLO).

Commissioning of off-grid systems is currently carried out by the EPCs according to their own checklists. There are no clearly defined commissioning procedures for PV installations. This means that performance assessment protocols cannot be compared. A commissioning manual is being developed by EBTKE with support from the German Society for International Cooperation (GIZ) (Interview 4).

The SLO of PV power plants is provided by four inspection bodies (PT Andalan Mutu Energi, PT PLN Persero Pusat Sertifikasi, PT Prima Teknik System, PT SUCOFINDO) that are assigned and accredited by the Directorate General of Electricity (DJK). SLO for PV are issued following the checklist in regulation ESDM 10/2016, which is currently under revision (Interview 2).

Certification of PV components is not available in Indonesia at the moment. International institutions such as TÜV Rheinland and TÜV Süd offer certification for which factory audits are usually carried out by the Indonesian offices, while testing is conducted abroad.

Certification for personnel competency is available according to National Competency Standards (SKKNI) by licensed certification bodies, such as Personnel Certification Bodies (LSP). For PV, certification can be achieved for planning and installation.

Accreditation

Accreditation for testing and calibration laboratories as well as for certification and inspection bodies is provided by the National Accreditation Committee (KAN) which is part of BSN.

Certification bodies for competency standards are not accredited by KAN but are granted licenses by the National Body for Professional Certification (BNSP).

Moreover, DJK provides accreditation for inspection and certification bodies in the electricity sector, through the Technical Committee for Accreditation. The Committee coordinates its work with KAN (Interview 2).

5.5. Quality infrastructure services needed to address the major quality challenges for photovoltaics in Indonesia

The major quality challenges for PV in Indonesia (see Chapter 4.3.) and related gaps in quality infrastructure services were identified with stakeholders from the Indonesian PV industry, quality infrastructure institutions and relevant ministries during a workshop, interviews and an industry survey.

The following table (see next page) summarizes the identified recurring issues in PV projects in Indonesia and relevant quality infrastructure services that can help to address the issues.

Value chain	Quality issues	Quality infrastructure services needed
Tendering and contracts	Lack of quality requirements in tenders and contracts. No performance ratio guarantees.	Reference to standards and quality infrastructure services (e.g. specific tests) in tenders. Inclusion of warranties with sanctions in case of non-achievement.
Manufacturing and transport of components	Lacking quality assurance of imported components. Certificates can only be obtained for some materials and components used in manufacturing, most of which need to be imported.	**Expansion of testing services, for example for IEC/SNI 61215 for PV modules, and for other components including BOS.** **Expansion of calibration services for the PV sector.** Improvement of market surveillance for imported materials and components. Acceptance of certificates in the country of origin for materials and components. Regular factory inspections and surveillance audits. Certification of Indonesian PV modules. **Implementation of standards.** Support for industry to implement standards and achieve certification.
	Limited production volumes resulting in possible quality gaps of locally manufactured products. Component quality cannot be assured.	
Planning	Lack of reliable irradiance data.	Awareness raising for calibration of pyranometers for solar irradiance measurements.
	Lack of experience and knowledge of the relevant service providers, including plant designers and EPCs.	Implementation of standards, e.g. for the elaboration of feasibility studies. **Qualification and certification of PV system designers.**
Installation and commissioning	Lack of experience of EPCs and installers resulting in installation errors.	**Training and certification of installers.** **Establishment of certification bodies for personnel (LSP) and products (LSPRO).** Adoption and application of relevant international standards, e.g. for technical installation. Application of inspection schemes according to international best practices.
	Inappropriate commissioning procedures. Lack of competent technical assessors.	Definition and application of commissioning procedures according to international best practices. Strengthening of technical assessors.
Operations, maintenance and monitoring	Lack of experience of O&M providers.	**Qualification and certification of PV system operators to be developed.**
	Lacking monitoring impeding the detection of underperformance and the collection of comprehensive performance data. Often plant locations do not have network coverage.	Reliable testing of plant performance. Testing for potential induced degradation (PID).
	Possible PV module degradation due to salt corrosion.	**Research on PV module degradation.**
	Component failure due to insufficient quality, e.g. inverters, controllers, batteries.	Expansion of testing services for inverters, batteries and BOS.
	Grid stability and connection issues.	Definition of grid codes. Calibration of smart meters and equipment for grid management.

Table 5: Quality infrastructure services needed to address major quality issues in Indonesia (the results are based on various stakeholder workshops, interviews and an industry survey)

Note: Priority quality infrastructure services for the Indonesian stakeholders are highlighted in **bold** (Workshop 1).

Part 6 – Recommended Focus Activities for Quality Infrastructure Development for PV in Indonesia from 2020–2024

6.1. General considerations for the development of quality infrastructure

A systemic approach to quality infrastructure development is necessary to address the quality assurance needs for achieving the national goal to install 6.5 GWp PV capacity by 2025. The following recommendations will thus consider the development potential for standardization, metrology, testing, inspection, certification and accreditation in Indonesia and in collaboration with international institutions as well as possible improvements in framework conditions.

To guide the decisions on further quality infrastructure development for PV in Indonesia, it is recommended that the following examples of possible scenarios be considered (Table 6). Possible future scenarios and their implications should be further elaborated in the frame of political dialogues which involve all relevant ministries.

Generally, it is advisable to prioritize quality infrastructure development on the downstream end of the value chain during the early development stage of the sector to make electricity from PV safe, reliable and economically viable (as shown in Figure 3). Quality infrastructure services for steps further upstream can be developed subsequently, hand in hand with the development of the local industry.

Scenarios	Quality infrastructure needed
Turn-key imports (all components, plant design and EPC services are imported)	Necessary competency in Indonesia is reduced to market surveillance, including quality criteria in tender documents und adequately commissioning PV plants.
Imported components, local design, installation and/or O&M	The services mentioned above and quality infrastructure for personnel qualification and inspection.
Local component assembly (e.g. as local branch of international manufacturing)	The services mentioned above and quality infrastructure for selected conformity assessment.
Some components manufactured in Indonesia	Quality infrastructure for selected components, industry development and productivity improvements.
100 % local content	Complete quality infrastructure services, including R&D.

Table 6: Scenarios for the development of the PV sector in Indonesia and needed quality infrastructure

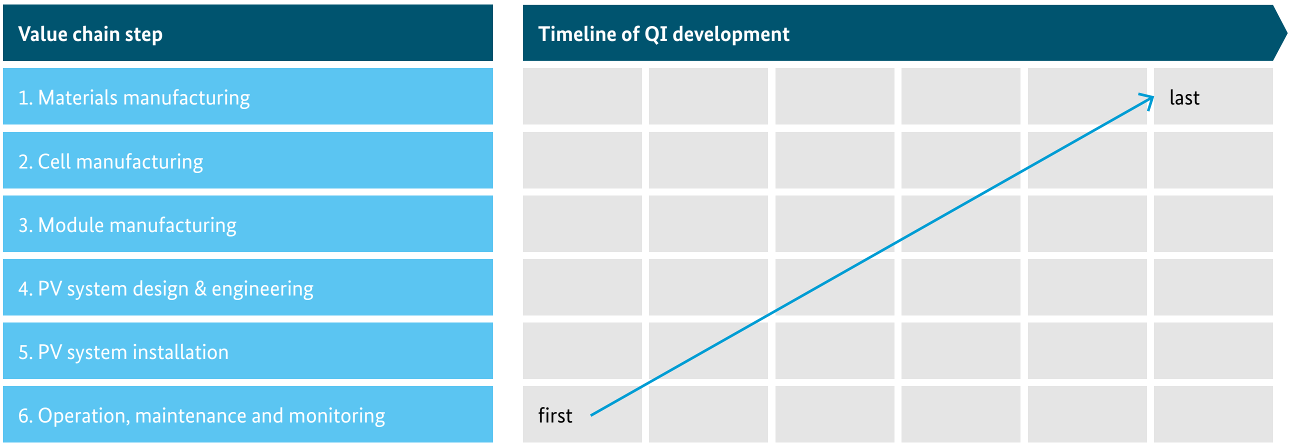

Figure 3: Prioritization of quality infrastructure development along the PV value chain

6.2. Framework conditions, regulation and standardization

National policy on the development of the PV sector

An overarching national policy is needed to provide a strategic direction and guide the development of the Indonesian PV sector. This policy would create the basis for all the relevant line ministries to work together in harmony, formulating specific policies and regulations that will help Indonesia to realize the full benefits and potential of PV technologies for the prosperity of the country.

The policy should:

- Support the creation of a PV market, through government tenders and favourable conditions for the private sector. These may include attractive feed-in tariffs, clear and stable conditions with limited bureaucracy and a fast grid connection. **Quality infrastructure services can only be developed in a sustainable manner if a market exists and such services are required.**
- Make use of different means to foster quality including:
  - technical regulations to address safety aspects without hindering innovations.
  - reference to standards in tenders as well as promotion and funding programs as eligibility requirements for bonuses or rebates to promote quality, innovation and to create demand for new quality infrastructure services.
- Strengthen the local industry where added value is high and alternatives are rare, such as installation and O&M services for the PV sector. **Human resource development should be a priority, including training of trainers, personnel qualification and certification schemes according to international best practices.** Conveying the importance of quality is an integral part of capacity building.
- Consider the necessary modernization of grid systems and the resulting limitations for on-grid PV development in the short, medium and long term.

Required structures to implement the policy

Additionally, the necessary structures need to be set up to facilitate the implementation of the policy and support quality in the PV sector. This can include:

- Creating a **National Quality Committee for PV** to coordinate
  - the inclusion of quality criteria in tenders, commissioning schemes and specifications of public programs.
  - the necessary support for the national industry to increase quality and develop its international competitiveness.
  - the development of the national quality infrastructure, e.g. the definition of certification schemes for PV practitioners or the establishment of a Centre of Competence for PV.
- and to raise awareness about the need for quality PV.

The following institutions could participate in such a committee: BAPPENAS, BSN, BNSP / Ministry of Manpower, B2TKE, DJK, EBTKE, Ministry of Industry, PLN, KSNSU, KAN and industry representatives.

- Establishing an independent **Centre of Competence for PV** that could focus on the following tasks:
  - Research on Indonesia-specific challenges (e.g. microgrid technologies and configurations for remote village electrification) to support the local industry.
  - Education and training for PV practitioners in partnership with universities and technical colleges.
  - Awareness raising for quality and safety in PV.
  - Testing services for the PV sector.

Regulation
Clear responsibilities for regulation need to be defined so that overlaps between different ministries and departments can be avoided and the regulatory framework gains stability and coherence.

Standardization
With respect to standardization, **the Technical Committee should be aligned with the IEC TC 82**, assuring that the standardization in Indonesia is up to date with international developments. For this purpose, the implementation of BSN regulation 4/2018 is pivotal, as it means that the TC can be focused exclusively on PV and it assures the representation of industry and users.

6.3. Metrology

In metrology, the focus for PV-specific services in the medium term should be on the downstream end of the PV value chain. This means that **metrological needs for PV systems and grid integration should be assessed and capabilities should be developed accordingly.**

The National Metrology Institute plays an important role in **strengthening the metrological traceability to international standards and promoting secondary calibration** laboratories in remote areas where local calibrations for PV installations and maintenance are needed. Metrological services with less national demand should be provided by organizations with existing capabilities in the region. An example is the calibration of reference cells.

6.4. Conformity assessment: testing, inspection and certification

Conformity assessment was identified as the area with the most gaps in quality infrastructure in Indonesia. **Testing services for different components as well as field testing services need to be expanded. Also, market surveillance needs to be improved** to impede bad quality products from entering the Indonesian market.

The **training, qualification and certification of personnel for the PV sector**, including PV system designers, installers and operators is perceived as being crucial for assuring quality in the sector.

Moreover, the commissioning procedures need to be harmonized, and inspection bodies should strengthen their competence for PV.

Building up competence in conformity assessment takes time and not all required services can be provided by Indonesian institutions in the coming 5 years. It must be prioritized which services to be provided are essential in Indonesia and for which services a coordination with quality infrastructure institutions with existing capabilities in the region can be established.

6.5. Capacity building, research and innovation

Besides the leading actors mentioned above, other institutions might be able to contribute to quality in the PV sector. The human resource pool should thus be broadened and additional capabilities for complementary services should be involved. **Training centres, technology and innovation centres, research and development institutes and universities and colleges with potential capabilities should be identified and integrated in development plans.**

Additional services, including capacity development and research, are key for the Indonesian PV sector to thrive. Grid stability and necessary measurement and control technology, innovation in production, product or service development, research on performance and lifetime in specific climatic conditions, and the development of new test methods are some areas where increased exchange could be beneficial.

6.6. Conclusion

The paper presents recommendations for the systemic development of quality infrastructure services and necessary framework conditions for PV in Indonesia. However, priorities for service development can only be set if a clear focus on PV development is defined. The elaboration of a national policy that brings together relevant ministries and institutions and guides their activities for the PV sector is thus of utmost importance. Once the direction is defined, quality infrastructure development can be aligned with the concrete needs of the country.

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Abbreviations

AESI	Indonesia Solar Energy Association
APAMSI	Association of Solar Module Manufacturers in Indonesia
APLAC	Asia Pacific Laboratory Accreditation Cooperation
APLMF	Asia Pacific Legal Metrology Forum
APMP	Asia Pacific Metrology Programme
BAPPENAS	National Development Planning Agency of Indonesia
BATAN	National Nuclear Energy Agency
BIPM	International Bureau of Weights and Measures
BMKG	Indonesian Agency for Meteorology, Climatology and Geophysics
BNSP	National Body for Professional Certification
BOS	Balance of System
BSN	National Standardization Agency of Indonesia
B2TKE-BPPT	Center for Energy Conversion Technology of the Agency for the Assessment and Application of Technology
B4T	Center for Material and Technical Products
CMC	Calibration and Measurement Capabilities
CPN	Cost Priority Number
DEN	National Energy Council of Indonesia
DJK	Directorate General of Electricity
EBTKE	Directorate General of Renewable Energy and Energy Conservation
EPC	Engineering, Procurement, Construction
ESDM	Ministry of Energy and Mineral Resources
EVA	Ethylene Vinyl Acetate
GIZ	German Society for International Cooperation
GWp	Gigawatt peak
IAF	International Accreditation Forum
IEC	International Electrotechnical Commission
ILAC	International Laboratory Accreditation Cooperation
IPP	Independent Power Producer
ISO	International Organization for Standardization
KAN	National Accreditation Body of Indonesia
KSNSU	Deputy for National Measurement Unit Standards – BSN
kWp	Kilowatt peak
LIPI	Indonesian Institute of Sciences
LSP	Personnel Certification Body
LSPRO	Product Certification Body
LTHSE	Solar home system
METI	Indonesian Renewable Energy Society
MOI	Ministry of Industry
O&M	Operation and Maintenance
PAC	Pacific Accreditation Cooperation
PASC	Pacific Area Standards Congress
PID	Potential Induced Degradation

PJB	Pembangkitan Jawa Bali (company name)
PLN	Perusahaan Listrik Negara (state-owned electricity company)
PLTS	Solar Energy Power Plant
PPLSA	User group association for solar rooftop system owners
PT	Limited liability company
PTB	Physikalisch-Technische Bundesanstalt
PV	Photovoltaic
QI	Quality infrastructure
RAPBN	Government Budget
RCM-LIPI	Research Center for Metrology of the Indonesian Institute of Sciences
REI	Real estate association
Renstra-KL	Strategic plans of ministries and government agencies
RKP	Annual Government Work Plan
RPJMN	National Medium-Term Development Plan
RPJPN	National Long-Term Development Plan
RUEN	National Energy Planning
SI	International System of Units
SKKNI	Indonesian Personnel Competency Standards
SLO	Certificate of Readiness for Operation
SMTB-LIPI	Research Center for Quality System and Testing Technology of the Indonesian Institute of Sciences
SNI	Indonesian National Standards
SPLN	Standard of the state-owned electricity company PLN
SUCOFINDO	Superintending Company of Indonesia (company name)
TC	Technical Committee
TÜV	Technischer Überwachungsverein (company name)
UV	Ultraviolet radiation

Authors

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Dr. Timothy Walsh has a PhD in photovoltaic engineering and is a technical consultant for various PTB projects related to photovoltaics. Previously, he worked at the Solar Energy Research Institute of Singapore (SERIS) as the head of the photovoltaic module development group and later as the head of the off-grid photovoltaic systems group. He is also a co-founder of Canopy Power Pte. Ltd. Singapore.

Notes

Imprint

Published by
Physikalisch-Technische Bundesanstalt
Bundesallee 100
38116 Braunschweig
Germany

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As of March 2019

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