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Technical requirements in public auctions to make solar plants shine

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Designing technical requirements for solar auctions

The deployment of solar photovoltaic (PV) technology is accelerating across the globe, as prices continue to fall and countries begin their transition from fossil to renewable energy. Public auctions have become the dominant policy tool for solar PV deployment: 106 countries held renewable energy auctions (dominated by solar) by the end of 2018 (IRENA a, 2019). One third of the 55 countries that held renewable auctions in 2017–2018 did so for the first time (ibid.).

Little solar-specific experience and capacity in newly adopting countries can result in technical failures and lower solar plant performance (IRENA 2017). For instance, it was reported that 30 percent of nearly 100 analysed projects in different countries indicate severe defects that impact performance (TÜV Rheinland 2015). This makes investment in solar plants in newcomer countries risky, hindering the development of the solar sector and undermining political targets of solar energy deployment in these countries.

In this context, international organisations have suggested that policymakers in adopting countries include international quality standards[1] as technical requirements in the design of public auctions. This policy brief outlines the potential benefits and challenges of doing so, highlighting the crucial role of the Quality Infrastructure (QI) system in newcomer countries. Key lessons learnt are synthesised from international experiences with technical requirements in solar PV auctions. On this basis, entry points are identified for the development of strategies for their introduction in newly adopting countries. The two key things policymakers should consider are the adoption of appropriate standards based on the specific country context and the implementation of real-time data monitoring.

- **Recommendation 1:**

Define technical requirements in line with national solar policy objectives
The specific country context and policy objectives for the development of the solar PV sector play an important role when devising a strategy for the introduction of technical requirements in auctions. In particular, the state of the national Quality Infrastructure system should be taken into account, ensuring that local project developers can access the services needed to fulfil the technical requirements.

- **Recommendation 2:**

Promote the use of international quality standards
Clear and accessible communication of technical requirements is key to increasing quality and ensuring compliance with standards in the solar sector. Highlighting their links to policy objectives can foster concerted work towards a common mission, while effective incentives should be used for the PV industry to adapt to new quality requirements.

- **Recommendation 3:**

Monitor compliance with international quality standards
Public authorities should monitor compliance with the quality standards required in the tender documents. Proof of compliance can be guaranteed through in-person inspections at the plant commissioning stage as well as remote, digital monitoring of real-time generation data once the power plant is in operation. This would also allow for the impact of quality standards on the plant performance to be evaluated.

[1] International quality standards are defined here as formal standards issued by the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) pertaining to solar PV plant component performance and durability, transport, installation, and commissioning. We also included national standards (i.e. UL 1541, IEEE 2030.5, EN 1991 and EN 1997) that are broadly recognised internationally.

Benefits of technical requirements in solar auctions

Introducing technical requirements in public auctions comes with a number of benefits, the most important of which are highlighted in the following and also shown in Figure 1.

Improving solar plant performance

Solar PV plants around the world frequently experience technical defects (Ukar 2017, TÜV Rheinland 2015) that increase operation costs and reduce electricity production and revenues, in turn leading to volatility in the electricity grids (IRENA 2017). Including stringent technical requirements based on international quality standards in the tender documents can help prevent technical failures if compliance is monitored and the right requirements are chosen.

Technical requirements in public auctions

Government-organised auctions drive solar PV capacity deployment worldwide. Tender documents invite domestic and/or international project developers to submit a bid to build a solar PV plant. The most common mechanism for solar energy auctions is represented by **reverse auctions**, where the auctioneer defines a maximum price and the project developer (bidder) who offers the lowest price below this value wins. Bids are evaluated based on **eligibility criteria**, for example financial stability and technical capacity, and **evaluation criteria**, such as the bidding price. Some countries, for instance Chile, do not formulate any technical requirements but leave the choice to the private sector.

The winner(s) of an auction enter(s) into a contract with the government (offtaker). The most common contracts are **Build-Own-Operate** (BOO) associated with **power-purchasing agreements** (PPA). In BOO contracts, the private project developer receives a fixed amount for each kWh of electricity produced over the contract period of generally 25 years. Other contracts are of the type **Engineering-Procurement-Construction** (EPC) and include an **Operation & Maintenance** (O&M) period of 2 to 25 years. At the end of the O&M period, ownership is transferred to the government, or the plant is sold.

Fierce price competition and the distribution of risk among multiple stakeholders over the PV project life cycle are additional factors that motivate the use of technical requirements. Project developers under price competition have a strong incentive to cut corners in terms of quality, e.g. in components and labour (installation, O&M). If project developers sell or transfer the plant to a third party after a period of less than 10 years, they have no incentive to provide long-term, high-quality components and labour. Finally, inexperienced project developers in countries that are solar newcomers also engage in adventurous or strategic bidding, either unintentionally or intentionally neglecting quality. Stringent technical requirements in auctions can help promote sustainable project development practices.

Supporting local firms in catching up with the global technology frontier

Local firms starting to develop or produce components for solar PV plants often lack experience and capabilities. Technical requirements based on international quality standards can help these firms adopt state-of-the-art solar PV technologies and practices. International quality standards reflect the consensus at the frontier of industrial development and therefore embody codified knowledge about the accepted practices in solar PV. Accordingly, national energy agencies can use international standards to guide local component producers and project developers and promote gradual quality and performance upgrading. Given that power-purchasing agreements with the government are interesting business opportunities with high investment security, local project developers and manufacturers will be strongly incentivised to invest in upgrading their production methods and products in accordance with technical requirements.

Boosting long-term investment

The transition to a decarbonised society requires vast investments in solar energy in the next decades (IRENA b, 2019). Compared to fossil fuels, solar PV plants have relatively high upfront capital costs, while operation costs are relatively low. At the same time, solar PV investment is still considered risky by many international investors (Egli 2020, Solar Power Europe 2020, p. 23). There are various reasons for this lack of trust, including technical risk. There is a shortage of data on plant performance and input parameters such as local irradiation, component degradation, and resistance to context-specific environmental conditions. Low investor confidence is particularly prevalent in countries where investors lack trust in the overall investment climate – and this applies to most countries planning to adopt solar PV in the near future. Technical requirements based on international quality standards can support the de-risking of investments in solar PV by mitigating technical risks, lowering capital costs and attracting a broader pool of investors in the process. In the absence of reliable performance data, policymakers can use compliance with international quality standards as a means to signal to investors that solar PV plants will be built in line with the state of the art.

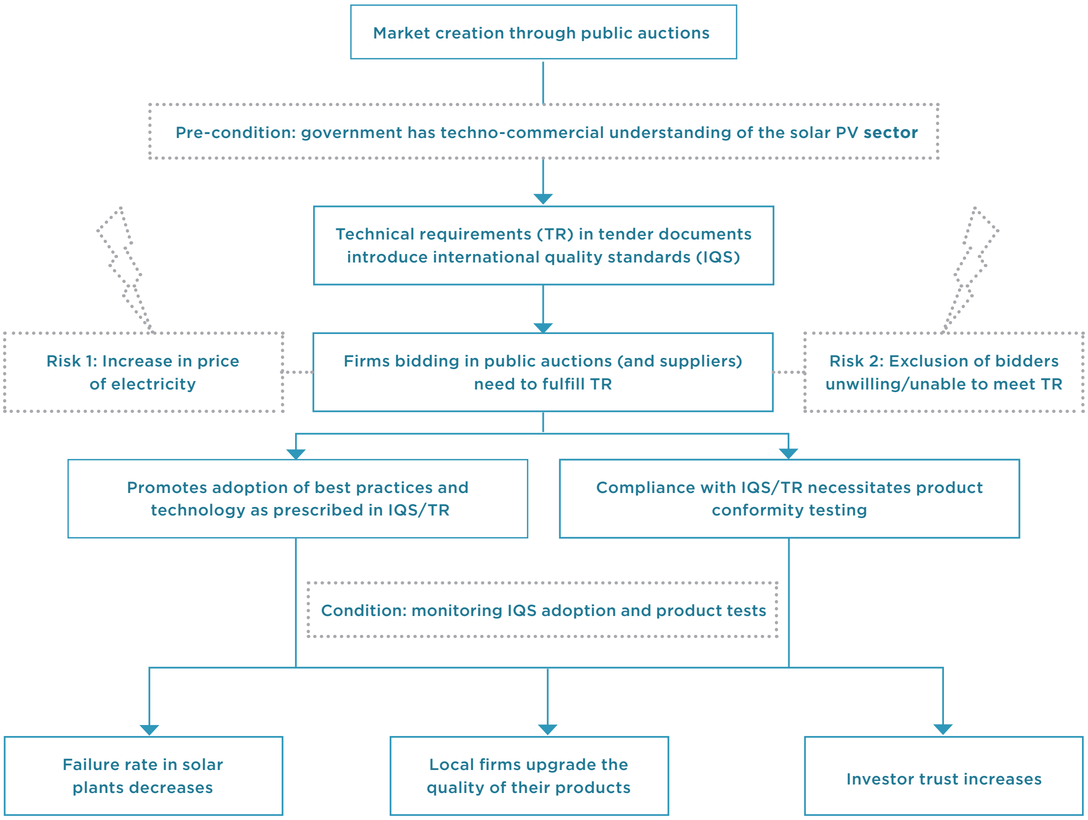


Figure 1: The impact of technical requirements in solar auctions

Challenges for technical requirements in solar auctions

The flow chart in Figure 1 also highlights some of the challenges associated with the inclusion of technical requirements in solar PV auctions, as explained in detail below.

Requires governmental capability and cooperation

The formulation of technical requirements necessitates a nuanced understanding of solar PV installations and their components. Not every government, in particular in developing countries with no solar PV history, has well-trained staff to assess the pertinence of specific international quality standards for the given local context. Moreover, expertise may not be located in those government entities taking strategic policy decisions. Correspondingly, the strategic introduction of international quality standards may increase the need for multiple government agencies to cooperate. For example, the Ministry of Economy or Ministry of Energy may care most about rapid and large-scale deployment of new power plants, but they may not be aware of the importance of technical requirements. On the other hand, institutions such as the auctioning authority, national standardisation institutes and testing laboratories are technically well-versed but may lack the needed strategic perspective and may not be aware of the potential links to national policy goals, such as building up export-competitive solar industries.

Might exclude or deter (domestic) bidders by being too stringent

Compliance with international quality standards can set a high bar and potentially exclude new players. To require no international quality standards at all, however, also comes with risks. Beyond low solar PV performance and frequent technical failures, countries risk getting locked in a low-quality trap where local producers are likely to import cheap components from international markets and/or lobby for government protection from foreign competition. Ideally, policymakers would help local firms engage in learning by doing and keep the development of solar plants open to competition. Hence, the introduction of technical requirements also requires a strategy of phasing-in, where stringency increases in tandem with local capacities. The latter can benefit from corresponding capacity building efforts.

May increase energy prices

Price discovery and price reduction are the central motivation for using auctions rather than the initially dominant feed-in tariffs as a policy instrument to promote solar energy. Affordable energy prices and extending reliable energy access to budget-constrained firms and citizens are key policy objectives. Policymakers may perceive compliance with international quality standards as a potential driver of higher bidding prices as project developers need to invest in high-quality components. However, as mentioned above, in the absence of technical requirements, project developers may cut corners in terms of quality. This could lead to lower yields, longer periods of shutdowns, or new investment in spare parts and quality upgrading to keep the plant running (Moser et al. 2017, IRENA 2017). As the share of renewables increases, frequent technical failures could undermine grid stability and force producers to buy electricity on the spot market to meet consumer demand and contractual obligations. Overall, potential increases in bidding tariffs due to more stringent international quality need to be weighed against the system-wide costs of lower quality and lower-yield solar installations.

Quality Infrastructure and technical requirements in solar auctions

The Quality Infrastructure (QI) system and its individual components constitute the basis for compliance with international quality standards along the entire PV value chain. Project developers need them to meet the technical requirements specified in the tender documents.

Components of the QI system

The life cycle of a solar plant does not start with installation, but begins much earlier and comprises all the stages shown in Figure 2.

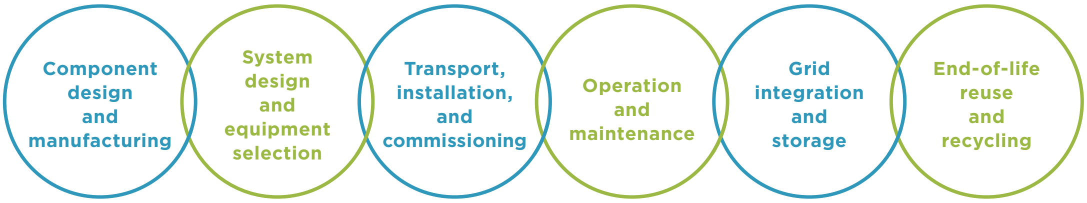


Figure 2:
PV value chain

QI services across all stages ensure that the full energy generation potential of the PV plant is exploited while at the same time not compromising safety and sustainability aspects. These services include all QI components, namely metrology, standardisation, accreditation, and conformity assessment (testing, certification, and inspection).

Example: The standard IEC 61215

The standard IEC 61215 defines tests to ensure the reliability of PV modules so that field failures during long-term operation in open-air climates can be prevented.

Compliance tests with IEC 61215 are offered by **testing laboratories** that check the electrical and thermal characteristics of modules, for instance their capability to withstand climatic stress. The **National Metrology Institute** ensures that testing laboratories have access to traceable calibration services for their equipment. For example, a calibrated reference cell is needed to run a sun simulator, the key equipment for current and voltage tests. Based on the test results, a module is certified by a **certification body**. This is particularly important for export purposes or if proof of certification is required in a public auction. IEC certificates are recognised globally. Accordingly, a PV module has to be tested and certified only once. Finally, an internationally recognised **accreditation body** assesses the technical competence of testing laboratories, certification and inspection bodies and officially acknowledges them as trustworthy (or not).

Accessibility of QI services

To comply with technical requirements referenced in tender documents, project developers need access to QI services, such as module certification, cell calibration, etc., at a reasonable price and within a reasonable time frame. Depending on their specific objectives and existing capacities, countries can choose to build up all relevant QI services nationally or to cooperate with other countries.

All QI components are ideally interlinked and embedded in an international system for metrology, accreditation and standardisation, which is the basis for establishing an internationally recognised national QI system (see Figure 3). Membership and participation in this international system ensure that services offered to a particular sector – for instance PV – are regarded as compliant with the requirements laid down in ISO or IEC standards.

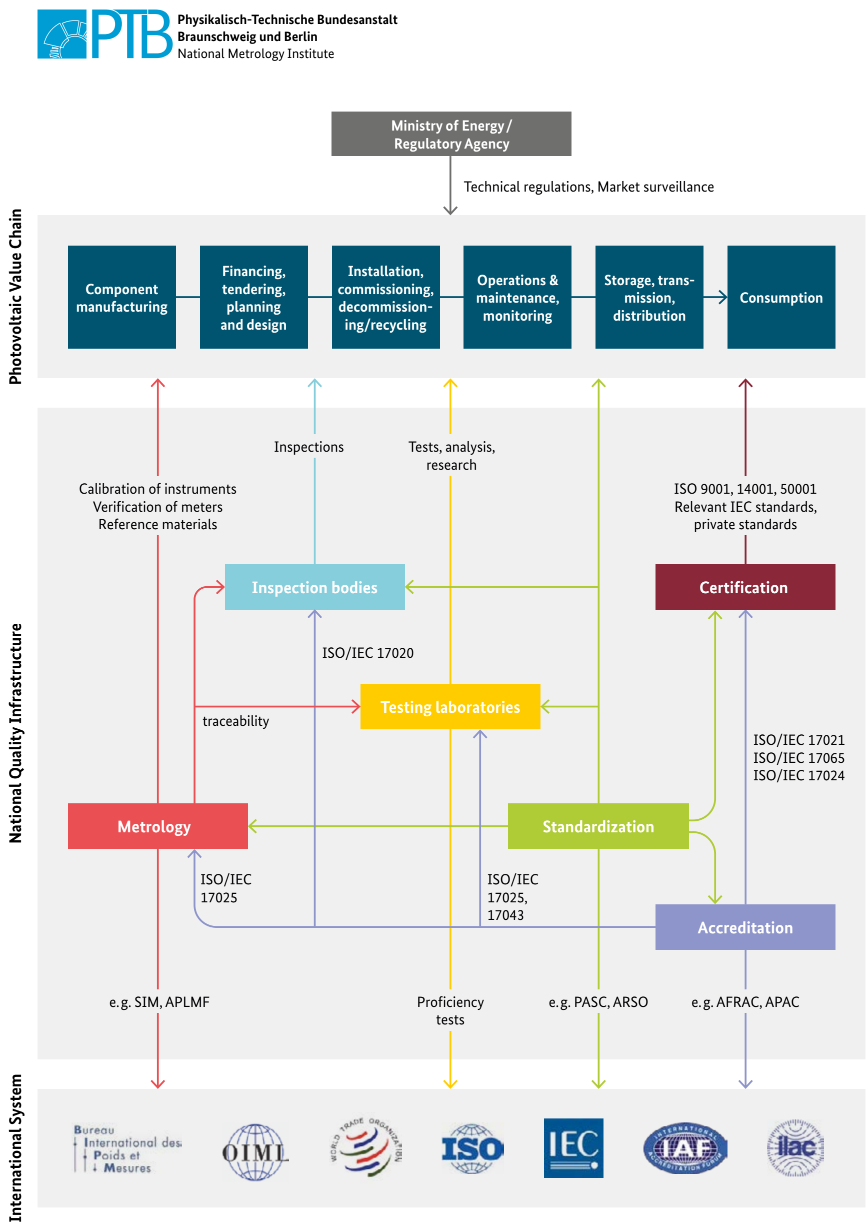


Figure 3: Quality Infrastructure system for the PV sector

Source: Physikalisch-Technische Bundesanstalt, November 2021

Preventing frequent technical defects in solar plants worldwide

Documenting technical defects

Audit data from 84 solar PV plants collected between 2011 and 2021 in India (35 plants), Germany (29 plants), Morocco (16 plants) and Chile (4 plants) reveal that quality defects are frequent and similar around the world. As measured by the height of the bars in Figure 4, the most frequent failures are related to cracks, inactive cell areas, snail trails, and hot spots. These failures are due to both poor installation practices and product quality defects, which can occur in every country, as illustrated by the percentages showing the prevalence of defects in the four countries studied. However, considering that there are many classifications for product quality defects, their importance is found to be somewhat higher than that of installation failures. Climate-related failures are not as common and vary depending on the country of origin. They are strongly related to product defects and/or intrinsic degradation mechanisms triggered by environmental conditions.

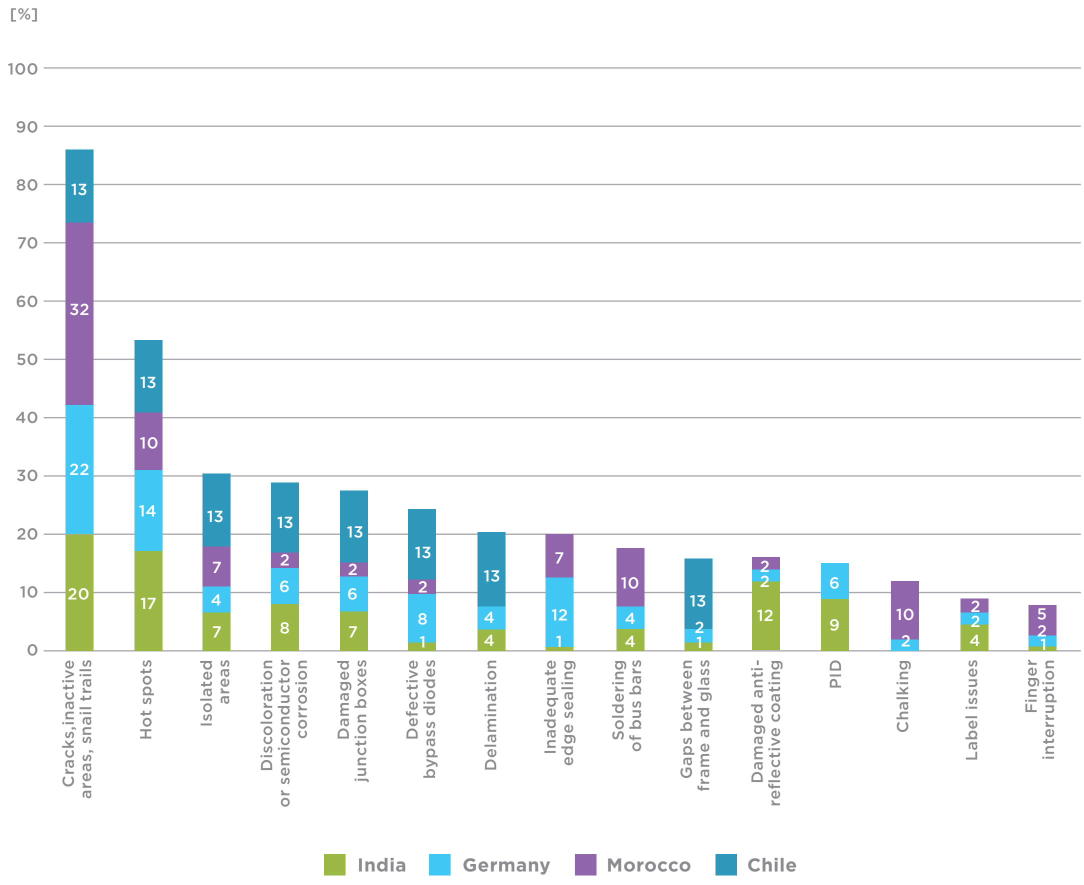
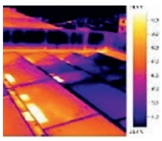
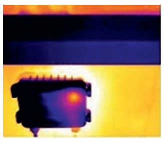


Figure 4: Most frequent quality defects and their distribution in the four countries investigated

Technical requirements to prevent defects

The following table describes the origin, consequences and mitigation measures of three selected defects that have a strong impact on performance and safety at both the module and plant level.

Defect	Description	Consequence for plant performance and safety	Standard that would have prevented the defect	Costs and benefits of preventive measures
Cracks in cells and back sheet 	Cell cracks are breaks or fissures on the front and back of solar modules. Back sheet cracks are damage on the back side, which is responsible for isolating the solar cells from their surroundings.	As cracks increase in size, cells may become partially or completely inactive, and hot spots may arise. Both issues could be responsible for performance decline in the mid and long term. Many cracks may lead to an expensive replacement process, especially as they are not covered by warranty.	Module installation manuals and industry practices in EPC contracts are reference frameworks. IEC 61215 stipulates visual inspection and IEC TS 60904-13 electroluminescence to identify cell or back sheet cracks.	Adequate module handling is key to avoiding cracks during plant construction. Proper packaging and transport also reduce the occurrence of cracks. Training sessions before construction can almost totally prevent these defects.
Hot spots 	Hot spots occur due to high resistance in the PV module. Resistance is caused by internal defects or shading from the environment. The affected area becomes very hot, sometimes exceeding 250°C.	Hot spots can lead to the destruction of the affected PV module or even to a fire due to their excessive heat. Once the module is damaged, safety issues may arise immediately.	IEC 61215-2:2016 related to hot spot endurance tests	The total costs associated with hot spot and diode tests range from 300 to 700 USD per module. As they are typically conducted on very small samples, the costs represent a negligible share of capital costs. However, such tests require ISO 17025 accredited laboratories.
Defective bypass diodes 	Bypass diodes prevent reverse current flow for broken or shaded PV cells. Failures can occur if either the diodes or the boxes in which they are housed do not comply with established standards.	Defective diodes cause heating problems, which can leave one cell or the entire panel inactive. Power loss ranges from 33 % to 100 %, depending on the number of affected diodes.	IEC 61730, section 5.3.10, in particular thermal and functionality tests; IEC 62446-1, section 7.3.3.4, in particular IR tests to detect anomalous diode temperatures; IEC 62548 annex C	

Technical requirements in auctions

As a concrete case, the technical requirements from 100 solar auctions conducted in India between 2013 and 2019 were recently examined (Münch and Marian 2022). The analysis reveals that the use of technical requirements was motivated by the government's risk exposure to low-performing solar PV plants. Helping local firms catch up with the global technology frontier and attracting investment did not play a role. In fact, international quality standards became more stringent in EPC but not BOO auctions (which account for about 60 percent of the auctions and the large majority of auctioned electricity in India). Over time, the government exclusively required more international quality standards in EPC auctions where ownership of the plant transfers to the government after less than 10 years of O&M. In BOO auctions, where the ownership and risk lie with the private project developer, and EPC auctions with O&M contracts longer than 10 years, no change occurred, as illustrated in Figure 5.

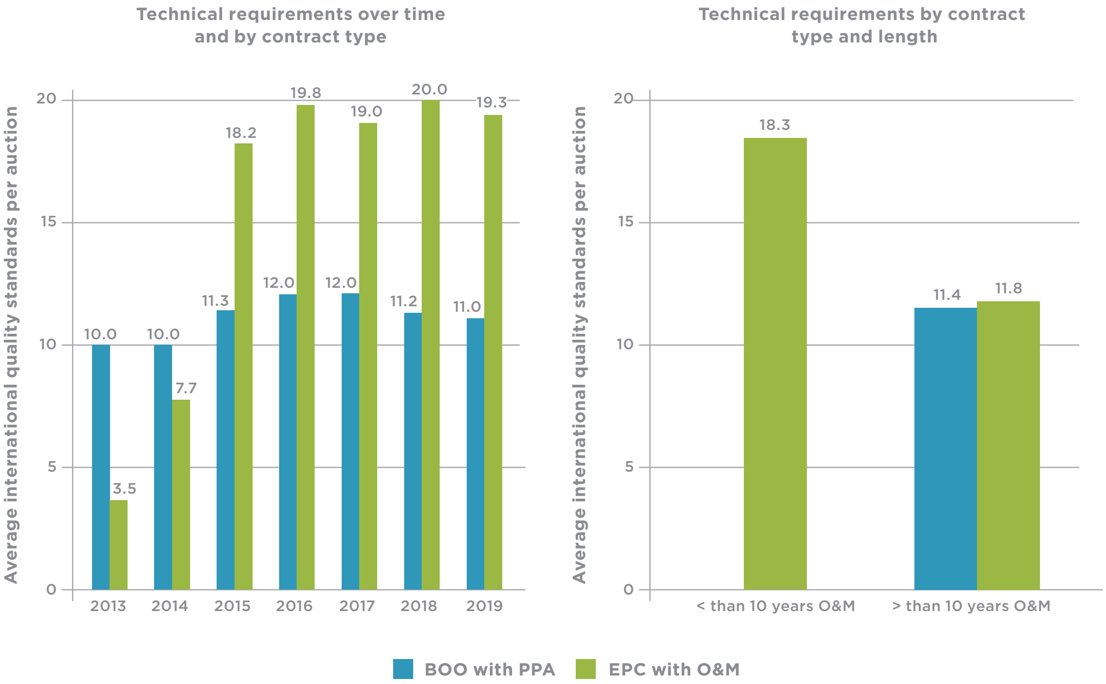


Figure 5: Technical requirements in Indian solar auctions

Define technical requirements in line with national solar policy objectives

The appropriate choice of international quality standards depends on the country-specific context and policy objectives, as sketched in Figure 6. Countries may use solar energy either to only generate electricity while importing components from abroad (case 1), or manufacture and export the components but not produce electricity (case 2), or both to manufacture components and generate electricity (case 3). In any case, the inclusion of technical requirements in tender documents necessitates QI services and should thus be preceded by a systematic analysis of the national QI and potentially a national plan for its development.

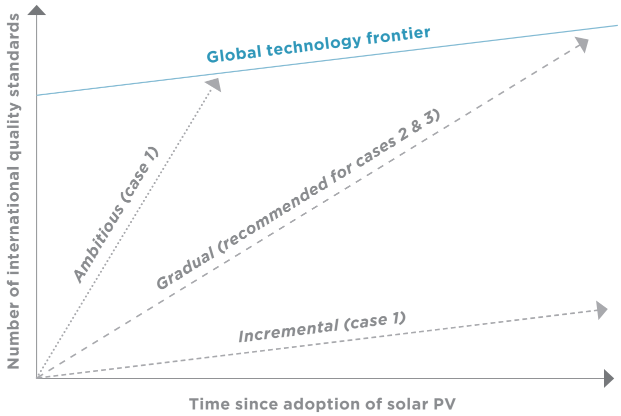


Figure 6
Domestic learning curve for catch-up with global technology frontier

Case 1: Either an ambitious or an incremental policy could be adopted. In an ambitious policy, the most important international quality standards are required from the beginning, which implies that bidders are limited to internationally established companies. This policy option is interesting for countries that value long-term reliability and/or want to own the plants after some time (EPC contracts). Access to QI services can be provided through cooperation with relevant institutions located abroad if services are not available domestically. On the other hand, an incremental policy requires only a few international quality standards. This scenario is the most interesting for countries that want to promote domestic businesses in solar PV plant development and have a strong preference for low prices and/or entrepreneurial freedom.

Cases 2 and 3: Countries aiming to also develop a domestic manufacturing industry are recommended to adopt a gradually increasing approach. In this scenario, national industry is provided with timely and cost-effective access to build up a national QI in accordance with newly introduced criteria. As mentioned, excessively stringent quality standards risk excluding or deterring new local firms. However, permanently low-quality standards complemented by reverse auctions are unlikely to promote investment in quality upgrading and learning by doing, and domestic manufacturers would lack incentives to develop export-competitive production facilities.

Also, governments can focus on international quality standards for specific components, e.g. glass, modules or cells, or on specific tests in accordance with their national economic policy objective. It is important to be aware that the development of the national QI requires both time and investment in equipment, human capacity and organisational know-how. But the gradual introduction of international quality standards aligned with QI development following a long-term plan will strengthen both the quality and the international competitiveness of a country's PV sector.

Promote the use of international quality standards

To enable the national PV sector to comply with international quality standards, it is crucial to communicate the underlying long-term targets and use incentives in an effective manner.

Communicate technical requirements in an accessible way

The long-term objectives of PV sector development and the stringency of technical requirements should be clearly communicated in auctions. Renewable energy development can be part of a national initiative for "mission-oriented innovation", contributing to climate change prevention and enabling sustainable economic growth[2]. An example for such an initiative is India's National Solar Mission, which aims to install 100 GW of solar PV capacity by 2022 (IEA 2021).

The gradual introduction of quality standards should be communicated as part of the long-term objectives for the development of the PV sector. The step-by-step increase in technical requirements should be announced well in advance and follow a concrete timeline to provide time for adaptation and investment security to the national PV sector. Information material about technical requirements should be published to ensure transparency. In addition, workshops and training with stakeholders, such as the responsible ministry, tendering agencies, financial institutions, PV sector associations, standardisation organisations, laboratories and certification bodies can help to foster coordinated work towards a common mission and create awareness of the relevance of QI services. Case studies about the return on investment for quality assurance measures can help explain the rationale for stringent technical requirements.

Incentivise the use of technical requirements

Communication alone may not be sufficient to promote the acceptance and use of international quality standards. Parallel to this, the adoption of new technical requirements can be fostered through support mechanisms and incentives. Firstly, support can for instance consist of subsidies for R&D measures advancing the required technology improvements. Secondly, access to other subsidy, financing or preference mechanisms, such as local content requirements or preferential interest rates, should be made conditional on compliance with international quality standards. Thirdly, international quality standards can be used as evaluation rather than eligibility criteria for bids, as bidders would not be automatically excluded from the auction if they did not comply. This would allow them to compete based on quality.

Any support mechanisms should be accompanied by public investment in development of the most demanded QI services and aligned with the national objectives to enable a step-by-step increase in quality in the sector.

[2] Mission-oriented innovation includes new or improved technological, social and organisational solutions (product, process and service) that aim to respond to one or several of the great societal challenges (missions) and create public value for society (e.g. mitigation of climate change, clean oceans, sustainable economic growth, automation and the future of work, etc.). A mission-oriented innovation policy is a coordinated package of policy and regulatory measures tailored specifically to mobilise innovation to address well-defined objectives related to a societal challenge (Larrue 2021).

Monitor compliance with international quality standards

The illustrated benefits of technical requirements are contingent on the compliance of project developers. Apart from requiring quality standards in the tender documents, centralised, real-time monitoring of the PV plants is essential as it enables governments to identify and analyse discrepancies between expected and generated electricity. This in turn provides the basis for setting more realistic solar PV deployment targets and forecasting the expected impacts of deployment policies more accurately.

Monitor implementation of technical requirements

In principle, quality assurance as defined in quality standards falls under the responsibility of the project developer. However, the government can contribute to good PV plant performance throughout the tendering process by setting technical requirements for quality assurance. This comprises market surveillance of components according to these technical requirements, including control of imported components and factory inspections at the manufacturing stage. Proof of compliance through in-person monitoring at each stage of the project is quite labour-intensive. Hence, it is established practice that compliance with technical requirements is verified at the plant commissioning stage. Smart, resource-saving arrangements might involve partnerships with the grid regulatory agencies responsible for inspecting plants at the commissioning stage.

Moreover, the tender documents should require project developers to monitor their power plants in the field; this includes their design, commissioning, installation, operation, and maintenance. In each of these stages, effective quality assurance procedures should be developed and applied to mitigate risks. The specific procedures can be adjusted depending on the plant location, but field inspections may include (i) the use of in-plant measurement equipment; (ii) periodic measurements in an external laboratory; (iii) preventive maintenance plans; and (iv) the use of digital twins (digitisation) and the post-processing of large-scale data. To avoid defects down the road, it is key to pre-qualify components according to IEC standards, review design, monitor construction, witness cold and hot commissioning procedures, and continuously update preventive and predictive O&M programmes.

Monitor plant performance through real-time data

Monitoring real-time generation data from industrial-scale power plants can provide governments with important data for improved electricity sector planning[3]. An overview of generated electricity can help governments with system optimisation, while project developers can utilise the data to reduce operating costs, increase plant performance, and improve service delivery. Keeping track of the amount and efficiency of electricity generated will reduce information asymmetry between project developers, investors, and state utilities. In this way, the link between compliance with quality standards and the performance of the power plant can be evaluated.

Data quality is key, so the monitoring system should have sufficient hardware and software support. Thanks to advances in big data processing, today's monitoring systems are able to not only predict the performance of a PV plant in the short term but go a step further by predicting when certain components will begin to fail. Anticipating failures reduces the cost of corrective maintenance and decreases down time. Both factors are essential for reducing electricity costs. In addition, predictions can be used by system operators to ensure grid stability.

[3] As an example, Chile carries out real-time monitoring that is also publicly accessible, see for instance **https://techossolares.minenergia.cl/?page_id=3729**

Conclusions and outlook

This policy brief outlines the benefits and challenges associated with introducing technical requirements in solar auctions. Technical requirements in the form of international quality standards primarily aim to reduce frequent quality defects that were extensively documented in audits across different countries and climate conditions. To illustrate this, our analysis maps these defects to the international quality standards that could have prevented them.

Overall, there is a mismatch between the awareness and opportunities associated with technical requirements for solar PV plants. The data suggests that technical failures occur on a large scale and are not only limited to emerging economies; they are still present even in mature markets like Germany. Quality defects occur due to both limited product testing at the manufacturing stage and poor installation and maintenance practices. Hence, there is room for improvement and more active policymaking in both new and mature solar PV markets.

The potential benefits to be gained from a more active use of technical requirements are substantial: in addition to reducing quality defects, technical standards may help attract longer-term private investment and guarantee that local producers upgrade to the global technology frontier. For these benefits to materialise, policymakers should set clear national goals, e.g. in the form of a mission, and gradually introduce technical requirements while taking into account the access of local stakeholders to Quality Infrastructure services. Moreover, the content of technical requirements should be communicated in a clear and effective way, and compliance with international quality standards should be monitored at all stages of the PV project.

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Adela Marian joined the IASS in February 2011 and works on topics related to the energy system. Her current research interests include the implications of the emerging hydrogen economy for the global energy transition, superconducting electric lines, and renewable energy auctions in India. From 2015 to 2018, she was responsible for the scientific coordination of the demonstration area Demo 5 within the European project Best Paths, which resulted in the first validation of a 3-gigawatt-class superconducting cable system.

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