What Drives the Price of Solar Photovoltaic Electricity in Developing Countries?

Are recently announced prices for utility-scale solar PV realistic, sustainable, and likely to induce further market expansion?

To find out, this note examines the costs of equipment, access to financial markets, insolation, and other project-related variables in 13 countries.

In the past few years, auctions have emerged as a popular and economically advantageous way to procure power-generation capacity. Traditionally, prices for solar photovoltaic (PV) power were administered through feed-in tariffs (FiTs). But as technology matured, the PV market scaled up significantly, the size of plants grew, and the number of players multiplied, creating a dynamic competitive environment of which auctions have become an important part.

FiTs and auctions can be used in parallel and applied to different market segments, depending on policy and deployment objectives. FiTs fix the tariff and act on the quantity of power procured. They can suffer from lack of agility as solar PV costs fall, offering unreasonably large returns to producers that are paid for by utility customers or the public purse. (Some countries have introduced periodic downward adjustments of FiTs to mitigate this problem.) Additionally, if the capacity eligible under FiTs is not capped, the mechanism can result in excessively rapid deployment, posing grid-integration issues.

Auctions fix the quantities of capacity or power to be procured and act on prices. If not carefully designed, they can engender the opposite weakness: a frenzy to submit the lowest bid possible. Very low bids raise concerns about financial viability and technical quality and can jeopardize the sustainability of the market.

This brief summarizes an analysis of 37 winning bids for utility-scale solar PV plants procured through auctions in 13 developing countries between 2013 and 2016. For comparison, the full report, obtainable from the authors, also describes examples of a failed PV auction in Indonesia and a large, bilaterally negotiated procurement of PV capacity in Nigeria. The 37 plants were selected based on the availability of plant-specific information and the desire to achieve a comprehensive overview of the evolution of auction results across countries and over time, in particular in countries such as Brazil and South Africa that have organized multiple rounds of auctions. The 37 plants were chosen from a set of some 500 winning bids covering more than 50 auctions in 16 countries. Although the sample is relatively small, it is large enough to explain the lowest announced prices and to indicate whether they are supported by market fundamentals.

The analysis includes (i) a simple financial model (based on plant-specific parameters) that explains bidding prices and (ii) a comparison of auction designs in the countries covered, along with descriptions of the conditions under which individual auctions took place. Interviews with stakeholders active in utility-scale solar PV markets—including developers, utilities, consulting companies advising governments, bidders, government officials, and financial institutions—complement the analysis. Stakeholders verified some of the assumptions and conclusions, identified business strategies of market players, provided qualitative details about auction processes, and suggested avenues for bringing more sustainability into future solar PV development.

1. An auction can procure capacity from one or multiple plants.
2. Interviews were conducted with representatives of ACWA Power, Canadian Solar, First Solar India, Fourth Partner India, Iberdrola, ICF International India, Metier South Africa, National Energy Commission Chile, PWC Mexico, Softbank India, and SunPower USA.
How much does solar PV electricity cost today?

Solar PV electricity prices vary widely, although they are rapidly decreasing around the globe.

The reductions are a result of auctions around the world (figure 1) and of decreases in FiTs. The variation comes from differing market segments and large differences in installation sizes. Even within the same market segment, however, prices can differ significantly.

Winning bids in certain markets reflect market-based incentives (such as the proceeds from sales of clean energy certificates), as well as the practice of offering market-entry discounts (in the form of very low initial returns). By placing a winning bid, companies not only gain the right to sell electricity under the conditions of a power purchase agreement (PPA), they also gain access to the market, affording them a measure of market power, access to information, or other benefits. Because the bidding price can reflect these expected benefits, it can differ from the sum of incurred costs and required margins. The price

Figure 1. Results of solar PV electricity auctions in selected countries, 2013–16


Note: Figures show lowest winning bid in each auction. Bars represent ranges of winning bids in auctions in which there were multiple winners. All figures are nominal. Prices in Argentina, Brazil, Chile, Jamaica, Mexico, Peru, and South Africa are indexed.

* For India, only the auctions with the highest and lowest winning bids in a given year are shown (because of the large number of auctions in India).
What Drives the Price of Solar Photovoltaic Electricity in Developing Countries?

Solar PV electricity prices reflect the fact that installed prices have been falling steadily, reaching $1 million/MW or less, especially when procurement is competitive.

Interviews with stakeholders confirm that strategic positioning of some developers in certain markets, such as Latin America, has led to prices that include very slim returns on the initial investment. Bids in Mexico price in clean energy certificates, which will be offered for every kWh of PV electricity produced, even though the market for the certificates will start to function only in 2018.

Solar PV electricity prices reflect the fact that installed prices have been falling steadily, reaching $1 million/MW or less, especially when procurement is competitive (figure 2). Some negotiated procurement has also achieved low prices. FIT-based installations are typically reporting higher prices. Project size has become larger over time, reflecting increased confidence in PV technology and rapid market expansion.

Figure 2. Installed prices of solar PV electricity projects procured through auctions, negotiations, and feed-in tariffs, 2010–16

Sources: World Bank, based on IHS and Bloomberg New Energy Finance databases.

Observed and expected decreases in solar PV prices partly reflect decreases in the prices of PV cells and modules. The costs of semiconductor-based solar PV are falling faster than the costs of other power-generation technologies, which are based on steel and large generation equipment sold in small numbers. The "learning rate" for solar PV is much faster than for onshore wind, biomass, and geothermal technologies (IEA 2015; IRENA 2015b). Solar resources are available globally and in abundance, and technology is highly modular, allowing a wide range of applications and contributing to technological learning. The technology is also at a relatively early stage of deployment, when learning occurs more quickly than it does before the required commissioning date. Yet construction of PV plants typically takes just 6–12 months. In such cases, pricing can take into account the forward curve for the prices of solar PV equipment, thus reflecting the prices expected at the time of construction, not the time of announcement of winning bids. 3 Dubai’s 2014 announcement of a winning tariff of $0.0589/kWh is a typical example. The plant needs to be in operation in 2017. One of the two Zambia sites auctioned at a comparable winning price ($0.0605/kWh) two years after Dubai’s announcement is also expected to start operations in 2017.

Prices are more consistent based on year of expected delivery than on year of announcement. For 2017 (which reflects mostly plants built in 2016), prices are $0.060–$0.085/kWh; prices are $0.030–$0.036/kWh for most plants with delivery expected in 2018 and even lower (less than $0.030/kWh) for plants that will be delivered in 2019 and beyond (figure 3).

3 Forward pricing can be realized through equipment-purchase contracts for delivery in 18–24 months, especially for developers that procure very large quantities of PV panels. Some developers are betting on decreases in equipment price and waiting to procure panels at the time of plant construction—a practice that exposes them to the risk of tight markets at the time of purchase.
The industry expects that the best-in-class manufacturing costs of high-quality modules will fall to less than $0.30/W by the end of 2017.

Prices of equipment typically follow cost changes closely but are also affected by the business cycle of the PV industry, with squeezed margins at times of oversupply. The global costs of PV modules and inverters have fallen steadily over the past few years. In mid-2011 the manufacturing cost of high-quality modules stood at $1.32/W; by mid-2016 the price had fallen to as low as $0.40/W (BNEF 2016a). This trend is attributed largely to the falling cost of materials, efficiency gains in the production of cells and the cells themselves, and better inventory management, among other factors, all spurred by growing demand. The costs of inverters for grid-connected systems fell about 40 percent between 2014 and 2016, driven by increased demand, especially for utility-scale systems.4

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4 Figures in this paragraph are best-in-class numbers.
WHAT DRIVES THE PRICE OF SOLAR PHOTOVOLTAIC ELECTRICITY IN DEVELOPING COUNTRIES?

2017. There is still significant cost-reduction potential in nonmodule costs, such as installation, integration, and financing costs. In India, which has seen larger-scale deployment than most countries covered here—about 7.5 GW in May 2016 (BNEF 2016b)—nonmodule costs fell almost 50 percent between 2012 and 2016. Similar declines can be expected in other countries as their markets mature and scale up. Module costs typically represent one-third of the total cost; together with other equipment, such as inverters and the rest of the plant (auxiliary and supporting equipment), they represent about 60 percent of total costs. The remaining 40 percent can be very specific, reflecting local costs of land, labor, permits, and the quality of the site.

Are the recent prices realistic?

If plant-specific parameters are consistent with market fundamentals and logically explain the plant’s announced electricity price, the price can be considered realistic

The plant-specific elements of the financial model used to calculate the levelized cost of electricity (LCOE) include five groups of variables: net total investment costs, the cost of capital, the plant capacity factor, nontariff costs and benefits (including the terms of the PPA), and other parameters. As the analysis focuses on the lowest reported prices, the conclusions automatically cover the entire range of prices.

The parameters of the 37 plants in the examined bids vary widely but are consistent with current or expected market conditions by the time of expected commissioning. Only about half of the plants in the dataset have been financed; the rest have been announced or permitted but not financed. For these plants the parameters are estimated based on market intelligence. For plants in the financing, construction, or commissioning stage, project-specific information from the Bloomberg New Energy Finance (BNEF) and IHS databases was used for the estimates.

Total investment costs in the dataset range from $600,000/MW (for Chile’s Maria Elena plant, which will most likely start construction in 2019 or 2020) to $2.7 million/MW (for some plants in 2013 auctions) (figure 4). For most plants, the costs of capital (in the currency of the PPA) are 5–10 percent, reflecting the use of development financing. India is a notable exception; its cost of capital is 13–14 percent, reflecting local commercial financing and inflation. The plants studied range from 6 MW (a plant in India) to 800 MW (Dubai’s mega-plant, the largest auctioned to date, to be built in three stages between 2018 and 2020). PPA terms range from 15 to 25 years, with the longer term increasingly common in most countries.

Plant-specific parameters support PV electricity prices of $0.06–$0.08/kWh. Prices significantly below $0.06/kWh are not unrealistic for PV plants with a long time to delivery, plants in locations with exceptional solar resources, and plants with access to long-term and low-cost financing.

The differences in parameters of the 37 plants reflect underlying country conditions—particularly related to financing—that can significantly affect the viability of a PV market. The depth of the local financial market, exchange rate–related issues, local taxes and import duties, and access to low-cost financing can affect the entire market. India’s cost of capital, for example, reflects the local reality of inflation and financing from commercial banks. Yet PV electricity is still very viable in India, because current investment costs are exceptionally low ($0.8/W).

The currency of PPAs resulting from auctions may adversely affect developers’ ability to deliver PV plants in general or to deliver them in a timely manner. Currency affects PV plants through exchange rates, which are relevant for purchases of PV equipment, and through access to financial markets. In countries that lack their own manufacturing base and rely on imported PV equipment, exchange-rate movements can have a severe impact on plant economics, as in Brazil after the real began to depreciate rapidly after mid-2014. The currency of the PPA affects the ability to raise debt, because the financial markets of certain countries lack the depth or appetite for risk to finance relatively new technology such as solar PV, at least not without charging a significant premium.

Well-designed auctions should allocate risks by shifting them to the parties best equipped to manage them. In some auction designs, guarantees are offered upfront as a part of the overall framework to deal with residual risks. Guarantees often make PV development possible in places that would otherwise be considered too risky and therefore hard to finance. They have been one of the key factors behind the success of Zambia’s Scaling Solar tender, for example. Guarantees can cover risks, including default of the off-taker on the payments of the tariff and political risk.
“While preparing auctions, governments need to ensure that the bidding criteria match the policy and fiscal environment, the state and depth of the local financial market, and the policy objectives of PV deployment.”

What are the main drivers of lower prices?

**Auctions have been an effective tool for translating the decreases in investment and financing costs and improvements in capacity factors to PV electricity prices**

Unlike negotiated deals or FiTs with fixed tariffs, auctions follow precise rules, making them more transparent and reassuring for financiers than negotiated deals. A well-structured auction typically attracts a certain level of competition, which forces the bids to reflect the best equipment and financing parameters possible for a given site. Because of market forces, auctions reflect market fundamentals better than other types of procurement.

Auctions are not a panacea, however; flaws in their design, no matter how minor, can lead to insufficient or low-quality competition, disappointing prices, and low-quality plants. (A case in point is Indonesia, where a failed auction in 2013 led to the reintroduction of FiTs.) While preparing auctions, governments need to ensure that the bidding criteria match the policy and fiscal environment, the state and depth of the local financial market (which determines appetite for contracts denominated in local currency), and the policy objectives of PV deployment. They must also define potential risks and other market factors that can influence the design of the auction. IRENA (2015a) offers extensive documentation on the design of auctions.

The decline in PV electricity prices reflects reductions in the costs of equipment and of operations and maintenance, as well as

**Figure 4.** Average total investment costs of 37 solar PV plants studied

the lower costs achieved in dedicated solar parks. Interviews with stakeholders suggest that developers with large, global, solid pipelines of projects can procure modules and other equipment in bulk, achieving economies of scale and lower prices, which can translate into lower bids, particularly during periods of overcapacity in the market for equipment. Some developers are taking advantage of forward contracts with manufacturers that offer quotes for delivery of modules in 2018 that can be locked in today. Developers are also increasingly integrating the whole value chain—including the manufacturing of modules; engineering, procurement, and construction; and ownership of plants—in order to optimize the delivery of plants and decrease their risks. At the same time, automation and stronger local capacities are reducing operations and maintenance prices. Countries interested in procurement on a very large scale are also designing dedicated zones (solar parks), where power evacuation lines and substations are built in advance to ease the grid integration of the new capacity. These areas reduce certain risks related to the site as well as the overall investment costs needed for the plant. The gains can be reflected in lower bidding prices.

Factors that lower the perceived risk of PV projects reduce financing costs and thus drive down prices. The rigor of the auction process—the fact that bidders are aware of how winners are selected—decreases the perceived risks for PV plants. Some large market players have extremely good knowledge of certain countries from their previous involvement with other technologies in these same markets; their pricing of risk in such markets is therefore lower than that of companies that lack such sophisticated market intelligence. Simultaneously, the scaling up of PV markets globally is giving financial institutions confidence in the technology, reducing perceived risks across the board.

Interviews with stakeholders suggest that some companies make initial investments in PV power plants from their balance sheets, refinancing once the plant is up and running. Such financing is cheaper than upfront debt financing, because the risks of a commissioned and performing power plant are lower than those of a greenfield project. This strategy is available only to players with large balance sheets, of course. But it enables them to enter new markets where financing of greenfield development would be prohibitively expensive because of local banks’ lack of knowledge or confidence.

Technological progress in PV cell efficiencies, sophisticated plant design, and expansion of the market to countries with the best solar resources are improving the capacity factors of plants, pushing down PV prices still further. PV cell efficiencies continue to improve (IRENA 2015b), improving the output of panels. Use of single-axis tracking (which requires slightly higher initial investment costs and higher operations and maintenance costs) can increase plant output by up to 25 percent. It is very cost-efficient, however, for sites with high insolation. Markets are opening in places like Chile and Mexico, which are endowed with better solar resources than traditional European and U.S. markets. The combination of resources and the latest technologies can lead to exceptionally high capacity, allowing for very low PV power prices.

A simple exercise of correcting for high capacity factors in certain countries explains most of the very low prices announced over the last two years. To achieve a measure of comparability across countries, we chose the lowest price per country from the 37 deals analyzed and recalculated those prices under the original conditions of the deal but with a standardized capacity factor of 20 percent. Assuming a standard capacity factor of 20 percent, which is characteristic of many locations globally, all LCOEs (except for the one for the United Arab Emirates) rise above $0.06/kWh (figure 5), confirming the initial assessment that prices significantly below this level require at least one exceptional parameter. In the United Arab Emirates, for example, extraordinary financing conditions (tenors likely to exceed 25 years and very low interest rates) complement very good insolation.

The sensitivity of the LCOE to changes in the main parameters reveals that the cost of capital has the greatest influence on the LCOE of PV plants. The relationship between the LCOE and investments costs is linear, unlike for the other parameters, but the differences in the costs of capital can be much larger than the differences in the investments costs or capacity factors for a particular plant.

The ability of developers to influence the two factors is more limited: Capacity factors for the same site with a superior design rarely

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vary by more than 20 percent; possible investment-cost savings are also typically relatively small for a given developer. In contrast, the costs of capital can vary by more than 100 percent. These facts favor development of solar PV even in places with relatively low insolation, as long as financing costs can be kept down. It also means that policy makers have an important role to play by derisking projects and enabling access to low-cost capital.

Are ever-decreasing prices sustainable?

The downward trend in PV electricity prices demonstrates that solar PV is on track to become the least-expensive source of power in many places

Plant- and country-specific factors explain the very low announced prices ($0.029–$0.036/kWh) for a handful of plants in Chile, Mexico, and the United Arab Emirates. Whether other auctions will be able
“The downward trend in PV electricity prices demonstrates that solar PV is on track to become the least-expensive source of power in many places. Solar PV electricity could change the economic paradigm in many countries if integration challenges are met.”

to produce at these prices remains to be seen. Results of recent auctions significantly below $0.06/kWh—in particular in Abu Dhabi ($0.0241), Chile ($0.0291), Dubai ($0.0299), and Mexico ($0.0355)—are raising questions about whether such prices are sustainable and whether the plants will be delivered on schedule and perform as expected.

The model explains the parameters underlying the low prices in Chile, Dubai, and Mexico. All three sites benefit from exceptional insolation conditions, a long lead-time for delivery of power plants (up to five years in Chile), and exceptionally long-term and inexpensive financing. Promotion of the clean energy leadership of the UAE plays an especially crucial role there.

Market fundamentals support the possibility of prices of $0.03/kWh in a few years in many more locations. As the utility-scale solar PV market in many countries is still relatively small and procurement through auctions is relatively new, almost every auction-procured plant today (with the notable exception of those in India) exhibits at least one and typically several exceptionally good conditions that positively affect its price. The plants in question are among the first in their markets, often exploiting the best sites, with significant support of governments and development banks. They are built by companies aiming to make a strategic market entry. These plants, often one-of-a-kind, are typical of the early stages of development of the PV power sector in the developing world.

As markets scale up and mature, exceptional deals will represent a smaller fraction of markets, affecting average prices. Prices need not rise, however, because technology learning continues, driving down the costs of components. Financing from development banks may not be available for every future deal, but commercial banks will price technology risk lower after several plants have been built. Lessons from the first plants will improve processes that affect soft costs.

Sustainable PV prices can be guaranteed by imposing very clear and nonnegotiable auction criteria and strict prequalification requirements—and by requiring developers to take a stake in projects. Interviews with stakeholders suggest that simple and transparent auctions rules and prequalification (or other ways of screening auctions participants) are essential, not only for obtaining low prices but also for guaranteeing the delivery of plants at the expected time and level of quality. Requirements that developers hold a stake in the plant for several years create incentives to deliver better-quality plants.

The downward trend in PV electricity prices demonstrates that solar PV is on track to become the least-expensive source of power in many places. Prices of $0.024–$0.036/kWh are appearing in several countries. Some places may be able to reduce generation costs to $0.02/kWh in the medium term, reflecting the fact that in the next two years module costs are expected to fall to $0.3/W, and reductions in nonmodule costs are also expected.

Solar PV electricity could change the economic paradigm in many countries if integration challenges are met. For resource-poor and underdeveloped countries, it can be a game-changer, granting them access to abundant and cheap power for the first time. Large-scale PV deployment will have to be either combined with batteries (which are still expensive) or integrated with existing generation. But proper planning of generation—that is, the choice of sites and sizes of installations—can help smooth grid-integration challenges.

What prices are reasonable in countries that have not yet developed projects?

Countries that have not started to develop utility-scale solar PV can expect tariffs of less than $0.10/kWh for plants to be commissioned in the next few years

A simple simulation exercise was performed to project the best possible prices attainable based on three representative capacity factors. The calculations assume a favorable policy environment and international competition, no significant risk premiums, several years to develop the plants, no taxes, and no indexation of tariffs.

Under these conditions, prices will depend heavily on financing conditions. But PV prices as low as $0.05/kWh are attainable with favorable financing (8 percent cost of capital) in places with very good insolation. They could be as low as $0.04/kWh if financing were very low (5 percent cost of capital).

Ultimately, the development of utility-scale solar PV in new markets will depend on the overall energy sector strategy and policy
environment, derisking (in some countries), and the ability to attract a large and high-quality group of bidders. But without a conducive policy environment, neither FiTs nor competition through auctions nor negotiated contracts will materialize.

Under favorable policies, procurement choices should depend on the amount of power to be procured and the sizes of plants. Auctions tend to have relatively high fixed costs and are therefore more suitable for large procurement (possibly in multiple rounds over several years). Derisking through optimal auction design and guarantees, where necessary, makes financing possible in places where risks are high. It also increases competition, driving down costs.

FiTs are more suitable for small plants. Tariffs directly negotiated with developers can lead to overly generous rates of return but, in cases of a single plant, they may be the most practical way forward. Even so, FiT laws should take into account the dynamic development of PV costs over time. And careful thought should be given to transitioning from one procurement scheme to another. The pipeline of projects under one scheme needs to be dealt with before a new scheme is adopted, as was demonstrated recently in Nigeria (BNEF 2016c).

What is the proper role of multilateral development banks?

**Multilateral development banks can play an important role in driving solar PV electricity prices down**

They can do so by reducing financing costs, providing assistance with the structuring of procurement, and offering guarantees. Where appropriate, they can provide access to low-cost capital for solar PV power plants and for transmission, distribution, and, in certain circumstances, storage technologies. Their technical assistance can provide policy advice and advice on right-sizing plants and can help increase domestic capacity for installation, operations, and maintenance.

References


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