

Price of Solar PV Electricity in Developing Countries

Prepared by Zuzana Dobrotkova

With significant inputs from Pierre Audinet, Gevorg Sargsyan, Guido Agostinelli, Amit Jain, Abhishek Bhaskar, Kavita Surana, Krishnan Raghunathan and Esra Bozkir

November 7, 2016

This paper has undergone Quality Enhancement Review chaired by Rohit Khanna with peer reviewers Efstratios Tavoulareas, Debabrata Chattopadhyay, Satheesh Kumar Sundararajan, Mariano Salto and Fernando De Sisternes. Additionally, comments and suggestions to the paper and also during the research process were provided by Luiz Maurer, Anil Cabral, Anton Eberhard, Janina Franco, Ashok Sarkar, Oliver Knight, Alan Townsend, Arnaud Braud and Sandra Chavez.

Main messages

- Over the last few years market-based prices of solar PV electricity in developing countries are showing a clear rapidly decreasing trend.
- Single-digit PV electricity prices (per kWh) can now be achieved in most developing countries.
- Typical prices today are in the range USc 6-8/kWh, have been reached in countries with policies conducive to PV deployment, mostly in de-risked environments and are often benefiting from access to low-cost debt.
- Prices significantly below USc 6/kWh announced in some markets are exceptional. These require not only excellent solar resources but also outstanding financing conditions and are likely to include forward pricing of generation equipment.
- At single-digit levels of electricity prices, solar PV has become competitive with conventional sources in many developing countries.
- The low PV electricity prices have been achieved through competitive procurement processes (auctions) governed by clear, concise rules and selection criteria, with realistic timelines and workable local content requirements that have become popular in numerous countries and helped to drive down prices.
- Additionally to the increased use of auctions, low-cost financing, decreases in equipment prices, improvements in capacity factors of plants due to technological progress and market expansion to places with excellent solar resources are the main drivers for decreases in prices.
- Generalizing auction results even for countries with similar insolation remains challenging as underlying policy and economic conditions as well as design of auctions across countries differ.
- Price reductions are expected to continue in the years to come, albeit possibly at a slower pace. Module costs are expected to reach level downward of USD 0.3/W within the next 2 years, representing just about USc 1/kWh in levelized costs of electricity and there is still significant potential in cost reductions in balance of system, installation and financing costs. But moving out of situation of equipment oversupply and low interest rates, moving towards commercial debt conditions for more plants and expansion to countries with less abundant solar resources could impact the rate of price decreases.
- MDBs can play an important role in reducing financing costs by de-risking projects and providing, where appropriate, access to low cost capital along with policy advice and assistance in structuring of solar PV capacity procurement.

Context and Objective

The purpose of this paper is to help stakeholders to understand key factors driving utility-scale solar PV prices and enable good decision-making conducive to healthy development of solar PV sector globally.

This analysis allows us to determine whether recently announced prices are realistic under local conditions like insolation, costs of equipment, access to financial markets, and other project-related variables. We also discuss whether these prices are sustainable over time and allow further healthy market expansion.

In the last few years auctions emerged as a popular way to competitively procure power-generation capacity in many countries, helping to reveal current market prices of power-generation technologies procured in auctions, including solar PV. Most of solar PV prices have been traditionally administered through feed-in tariffs (FITs). As technology matured, PV market scaled-up significantly, size of plants grew, number of players multiplied, creating a dynamic competitive environment in which auctions have become an effective way of procuring solar PV capacity and power in bulk.

Policymakers around the world are keen to understand the dynamics of the solar PV market and choose instruments that are most applicable and economically beneficial to their countries. Policy choice does not necessarily stand between auctions and FITs, both mechanisms can be used but applied to different market segments, depending on their policy and deployment objectives. Auctions fix quantities of capacity or power to be procured and act on prices, while FITs fix the tariff and act on quantity procured. FITs can suffer from the lack of agility to follow rapidly evolving solar PV costs and end up offering unreasonably large returns paid for by ratepayers or budget, even though some countries have introduced periodic downward adjustments of FITs to mitigate this issue. Additionally, if capacity eligible under FITs is not capped, the mechanism can result in uncontrolled speed of deployment causing grid integration issues. Auctions, on the other hand, if not carefully designed, can suffer from the opposite weakness, leading to a frenzy of the lowest bid possible. Very low bids are raising concerns over their financial viability and technical quality and can therefore put to questioning the overall sustainability of PV market.

Approach

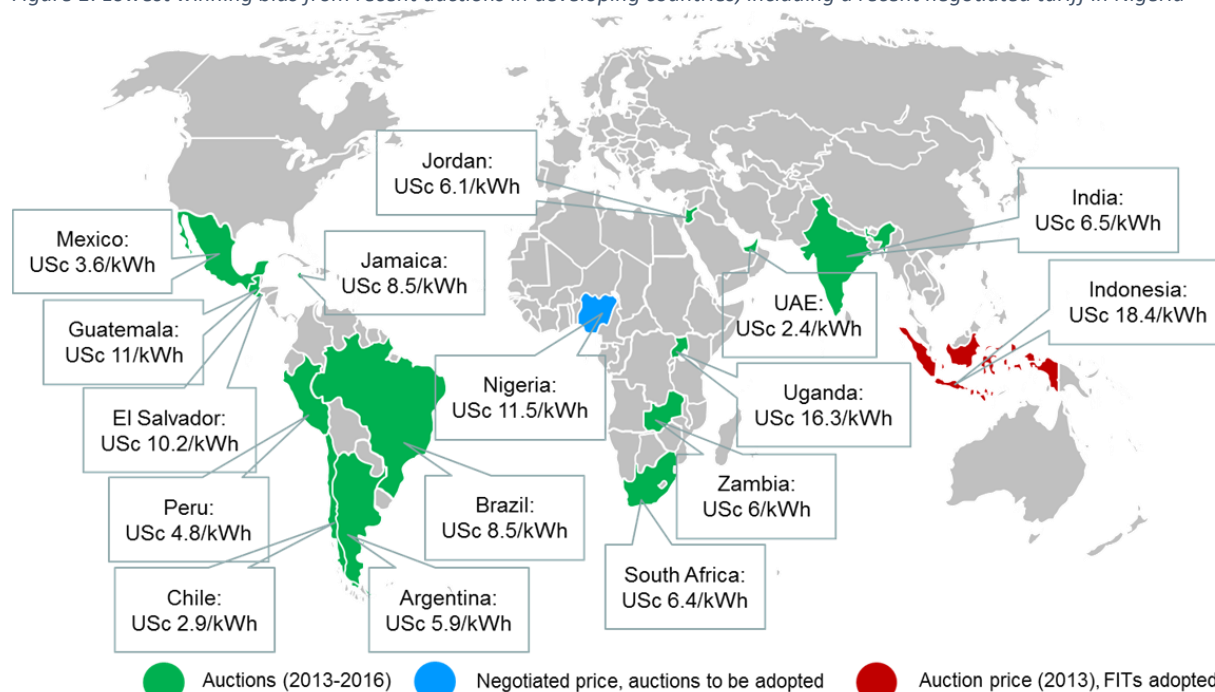
We base our conclusions on detailed analysis of 37 winning bids for utility-scale solar PV plants in 13 developing countries from the period 2013-2016 and procured through auctions (Figure 1). For comparison, we also describe examples of a failed PV auction in Indonesia, and large, bilaterally negotiated procurement of PV capacity in Nigeria. We chose the 37 plants based on availability of plant specific information (e.g. location, developer, investment costs, etc.) and in an attempt to achieve a comprehensive overview of evolution of auction results across countries as well as over time, in particular in countries like South Africa and Brazil that have organized multiple rounds of auctions over the years. The 37 plants were chosen from a larger set of some 500 winning bids covering over 50 different auctions¹ in 14 countries. While our sample is relatively small, it is enough to explain the lowest announced prices, and if those are supported by market fundamentals and therefore realistic, higher prices are also realistic.

Our analysis includes a simple financial model, which we use for explaining bidding prices, as well as detailed examination of conditions under which individual auctions took place (details of the auctions' winning prices and a summary of the 37 bids can be found in Table 1). We complement our analysis with confidential interviews of various stakeholders active in utility-scale solar PV market, including

¹ A given auction can procure an aggregated volume of capacity consisting of one or multiple plants.

developers, utilities, consulting companies advising governments as well as bidders, governments' officials, and financial institutions (List of interviewed entities is provided in Annex). Interviews served as a verification mechanism for some of our assumption and conclusions but they identified certain business strategies of market players and brought qualitative details about auction processes in different countries. Stakeholders also suggested certain avenues of bringing more sustainability into future PV development.

Figure 1: Lowest winning bids from recent auctions in developing countries, including a recent negotiated tariff in Nigeria



Note: Throughout the paper local currency prices were recalculated to USD with exchange rates at the time of announcement of plants.
Source: World Bank

How much solar PV electricity costs today?

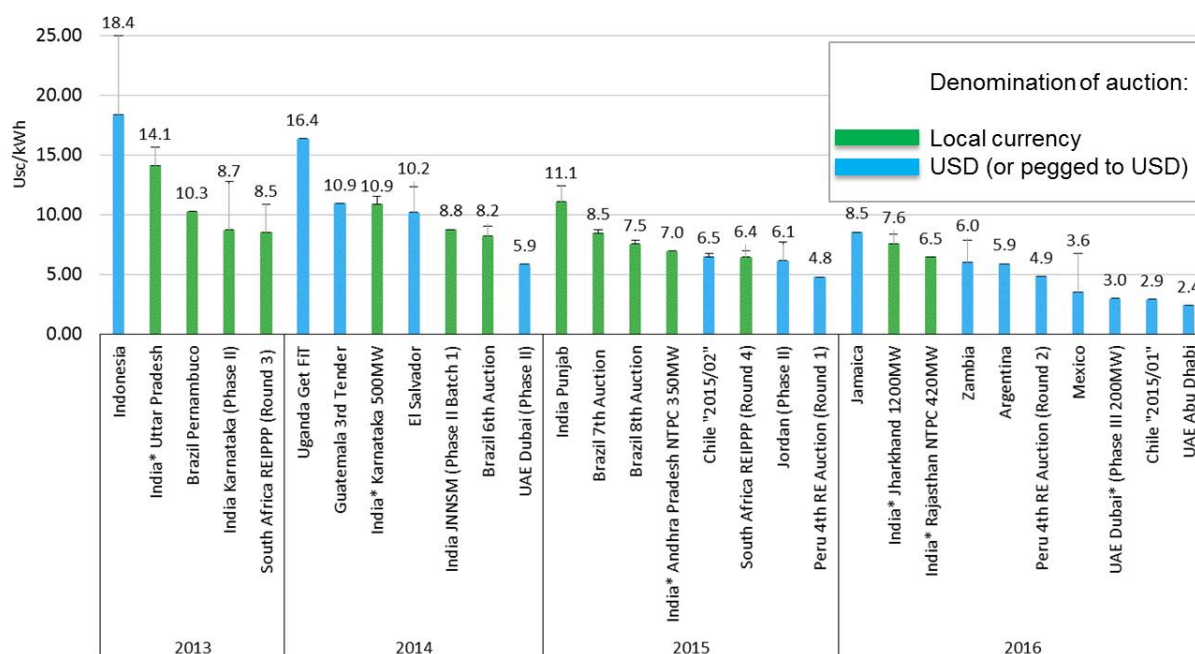
Solar PV electricity prices across the globe vary widely, yet they are showing a rapidly decreasing trend.

The decreasing trend is supported by results of auctions across the globe (Figure 2) as well as by decreases in FITs observed globally and indications from disclosed negotiated deals, as documented by costing publications of the International Renewable Energy Agency (IRENA 2015a, IRENA 2016). The variation comes from differing market segments of the installations and wide spread of installation sizes, but even within the same market segment, prices can differ significantly (e.g. India auctions, as shown in Figure 2).

Winning bids in certain markets are pricing-in market based incentives, like the proceeds from the sales of clean energy certificates, and offer market entry discounts in the form of very low initial returns. By placing a winning bid companies are not only gaining the right to be selling electricity under the PPA conditions, they are also gaining access to this market giving them certain market power, access to information, or other benefits. The bidding price can reflect these expected benefits. This means that bidding price can be distinctly different from the sum of incurred costs and required margins. Price will be higher if risks are priced-in, or lower, if market benefits are taken into account. Our interviews with stakeholders confirm that strategic positioning of some developers in certain markets, e.g. in Latin America, has led to prices that include very slim returns on the initial investment in the given market. Also,

in bids in Mexico include pricing-in of clean energy certificates (CELs) that will be offered for every kWh of PV electricity produced even though the market for CELs will start to function only in 2018.

Figure 2: Results of major auctions in developing countries from 2013–2016 in nominal prices by year of announcement



Note: The lowest winning bid in each auction is shown. Bars above the lowest winning bid represent ranges of all winning bids in every auction in cases when there were several winners. Prices in Argentina, Brazil, Chile, Jamaica, Mexico, Peru and South Africa are indexed. *For India only the auctions with the highest and the lowest winning bid per year are shown (due to too many auctions being organized in India).

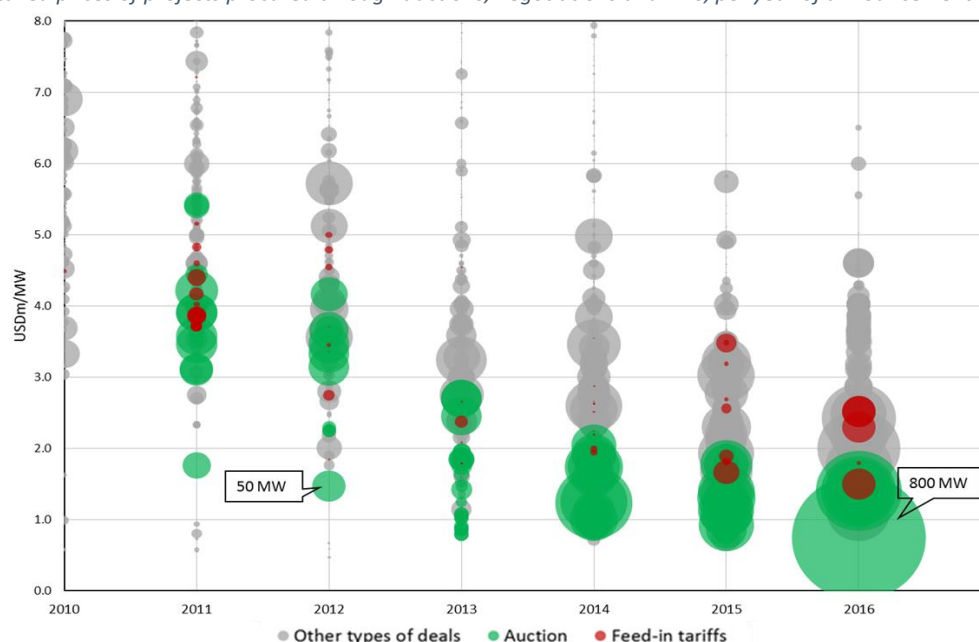
Source: World Bank

PV electricity prices reflect the fact that installed prices of PV have been decreasing steadily, reaching USD 1m/MW or lower, especially when procured competitively (Figure 3). Some negotiated procurement has also achieved low prices while FITs-based installations are typically reporting higher prices. Figure 3 also shows that project size is becoming larger over time, reflecting increased confidence in PV technology and rapid market expansion.

Prices of PV electricity for certain plants seem to include forward pricing of equipment, in particular for plants with expected delivery beyond 2018. Some PPA prices are announced more than 3-5 years in advance of required commissioning date while construction of PV plants is typically a matter of 6-12 months, not years. In these cases, the pricing can take into account expected forward curve for the prices of solar PV equipment, interviewed stakeholders suggest², and as such this is a representation of prices expected at the time of construction and not at the time of announcement of winning bids. Dubai's 2014 announcement of winning tariff US\$ 5.89/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 of US\$ 6.05/kWh two years after Dubai's announcement is also expected to start operations in 2017.

² Forward pricing can be realized through equipment purchase contracts for equipment delivery in 18-24 months, especially for developers that procure very large quantities of PV panels. But some developers are also "betting" on equipment price decreases and waiting to procure panels at the time of plants' construction, exposing themselves to the potential risk of tight markets at the time of purchase.

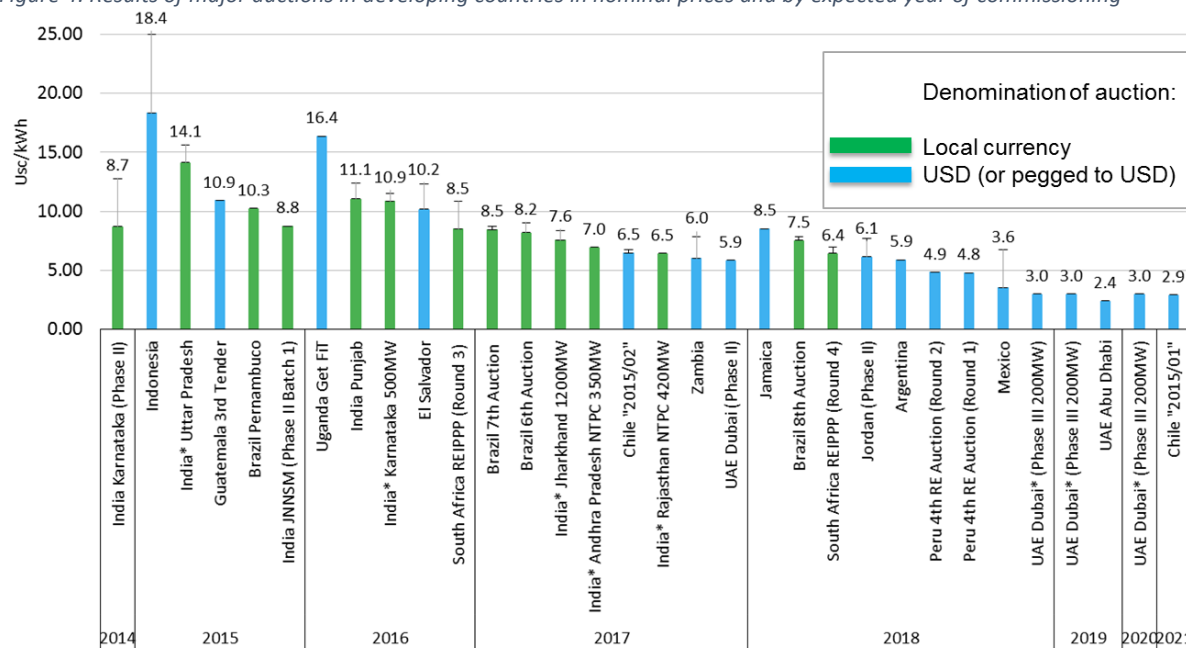
Figure 3: Installed prices of projects procured through auctions, negotiations and FITs, per year of announcement



Source: World Bank based on IHS and BNEF databases

There is more consistency in prices in a given year of expected delivery than if we follow them by their year of announcement (Figure 4). For 2017, i.e. plants that are mostly build in 2016, we observe consistently prices in the range of USc 6–8.5/kWh, while prices decrease to the range USc 3–6/kWh for most of plants with delivery expected in 2018 and even lower, below USc 3/kWh for 2019 and beyond. The full picture of prices by year of announcement and year of commissioning is provided in Figure 5.

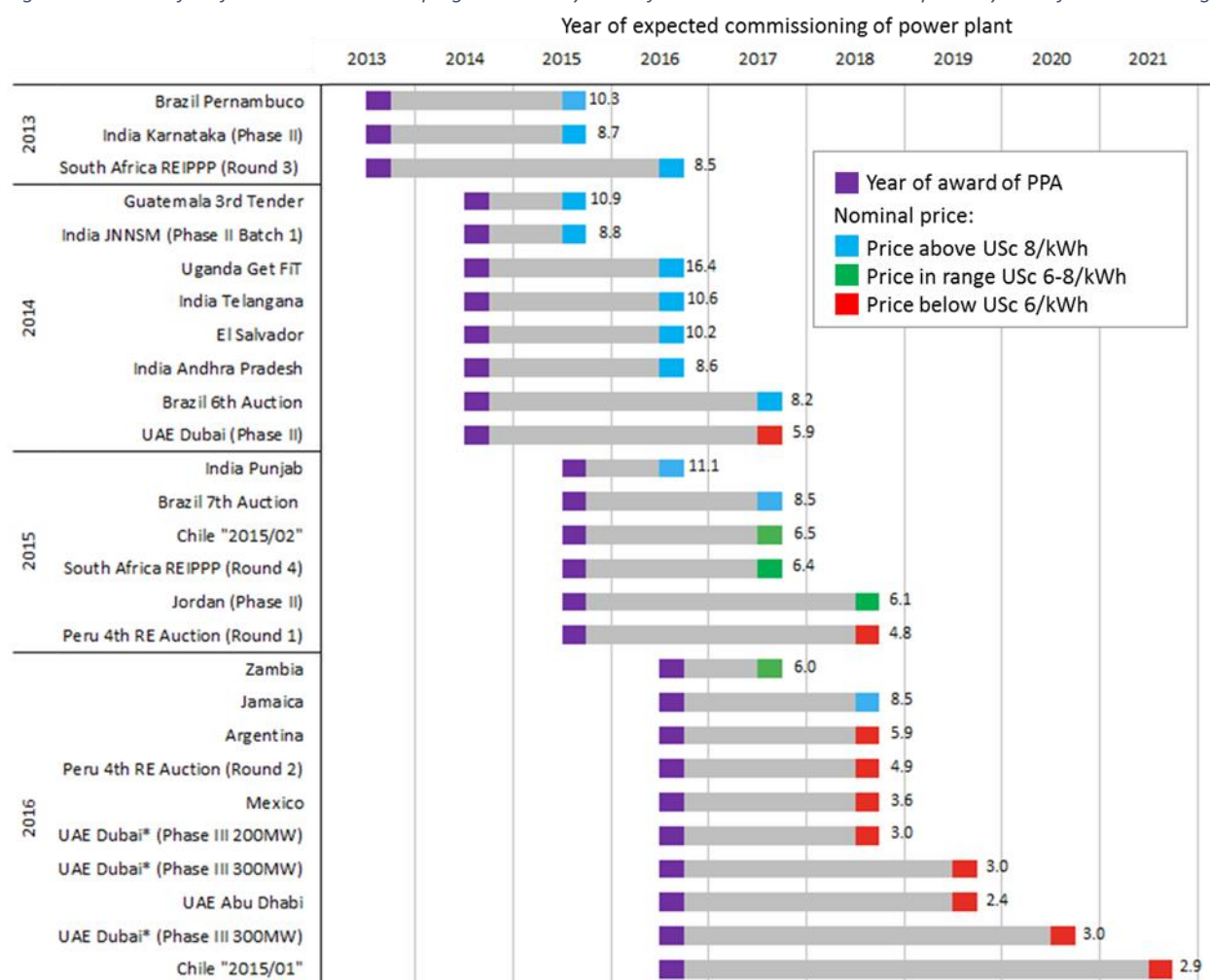
Figure 4: Results of major auctions in developing countries in nominal prices and by expected year of commissioning



Note: The lowest winning bid in each auction is shown. Bars above the lowest winning bid represent ranges of all winning bids in every auction in cases when there were several winners. Prices in Argentina, Brazil, Chile, Jamaica, Mexico, Peru and South Africa are indexed. *For India only the auctions with the highest and the lowest winning bid per year are shown (due to too many auctions being organized in India).

Source: World Bank

Figure 5: Results of major auctions in developing countries by date of announcement and their expected years of commissioning



Note: *UAE's 800MW plant is expected to be commissioned in 3 stages over 3 years.

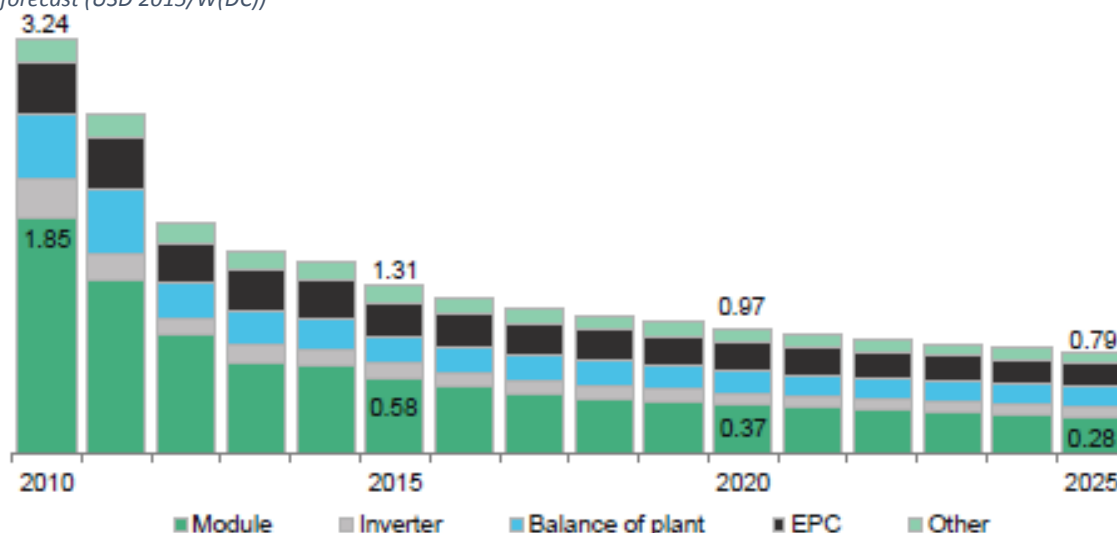
Source: World Bank

Observed and expected decreases in solar PV prices are in part due to decreases in prices of PV cells and modules, following a rapid "learning curve". Unlike other power generation technologies, mostly based on steel and large generation equipment being sold in small numbers, semi-conductor-based solar PV costs decrease more rapidly, as widely documented by empirical "learning curves" produced for different power-generation technologies (e.g. IEA 2015 states learning rate of 18% for solar PV, consistent with IRENA, 2015a, but only 5% for onshore wind, biomass technologies or geothermal). Additionally, solar resource is available globally and in abundance and technology is highly modular allowing a wide range of applications contributing to technological learning. Also, the technology is at a relatively early stage of deployment, when learning occurs faster than for established technologies. All of these factors have enabled PV costs to go down at a much faster pace than costs of other power-generation technologies. Prices of equipment typically follow quite closely cost evolution but are additionally affected by business cycle of the PV industry with squeezed margins at times of oversupply.

Global costs of PV modules and inverters have consistently fallen over the last few years. Manufacturing cost for high-quality modules in mid-2011 stood at USD 1.32/W, are reaching in mid-2016 as low as USD 0.4/W (BNEF, 2016e). This trend can largely be attributed to the falling cost of materials, efficiency gains

in production of cells as well as efficiency of cells and better inventory management, among other factors, spurred by the growing demand. The costs of inverters for grid-connected systems have gone down by around 40% in the last 2 years, also driven by increased demand, especially for utility scale systems. (Numbers reported in this paragraph are best-in-class numbers while Figure 6 shows observed and expected benchmark, i.e. average, costs evolution and composition of costs over time).

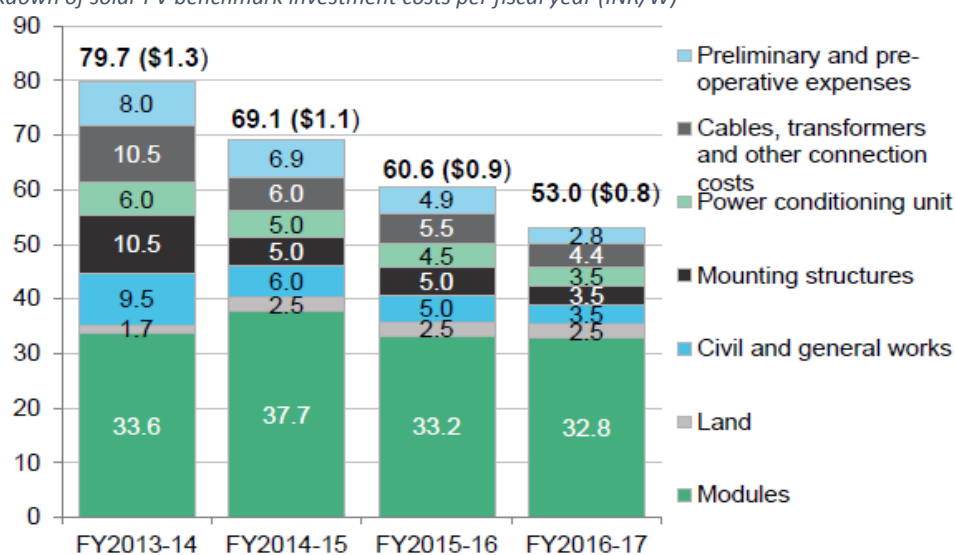
Figure 6: Benchmark module and non-module investment costs for 1MW ground-mounted fixed-axis PV projects, 2010-2015 and 2025 forecast (USD 2015/W(DC))



Source: Bloomberg New Energy Finance

The industry expects that the best-in-class manufacturing costs of high-quality modules will fall under USD 0.3/W by the end of 2017 (down from USD 0.4/W today) and there still is a significant cost reduction potential in non-module costs, such as balance of plant, installation, integration and financing costs. In India, which has seen larger-scale deployment than most countries covered in this study, at about 7.5GW in May 2016 (BNEF, 2016c), non-module costs have fallen by almost 50% in the last 4 years (Figure 7) and we can expect that this will occur also in other countries as their markets mature and scale up.

Figure 7: Breakdown of solar PV benchmark investment costs per fiscal year (INR/W)

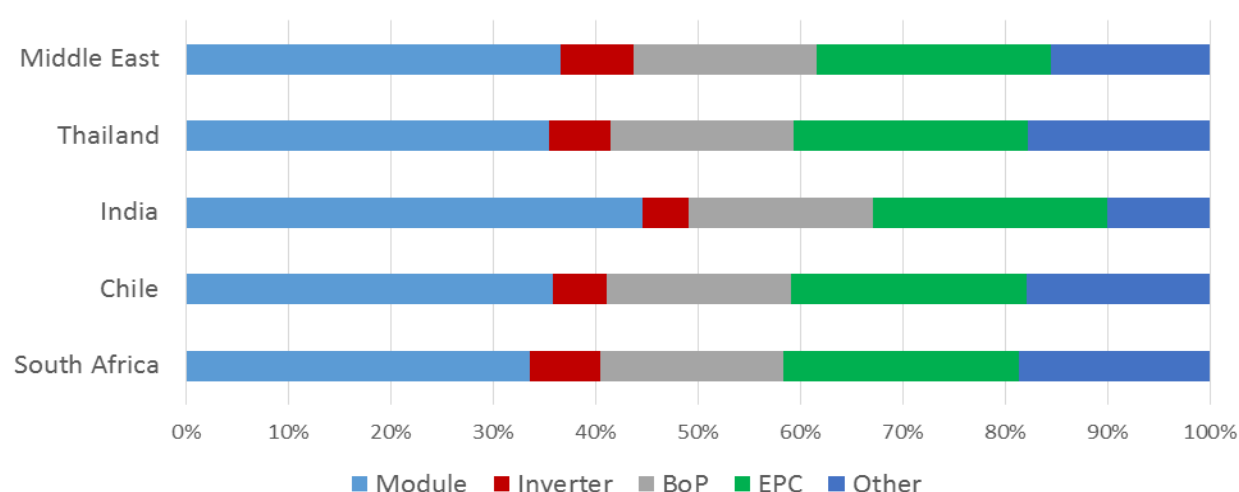


Note: Indian Fiscal year FY 2015-2016 runs from 1 April 2015 to 31 March 2016.

Source: Bloomberg New Energy Finance

PV equipment is only a fraction of the overall costs of power plants, EPC and soft costs play equally important role. Module costs typically represent one-third of the cost, and together with other equipment like inverters and balance of plant (auxiliary and supporting equipment in the plant) represent at about 60% of the total costs (Figure 8³). The remaining 40% can be very transaction-, site- and country-specific, reflecting local costs of land, labor, permits and are affected by the quality of the site (civil works needs, evacuation of generation, existence/lack of substation, etc.).

Figure 8: Average composition of cost components of solar PV plants across regions in 2015



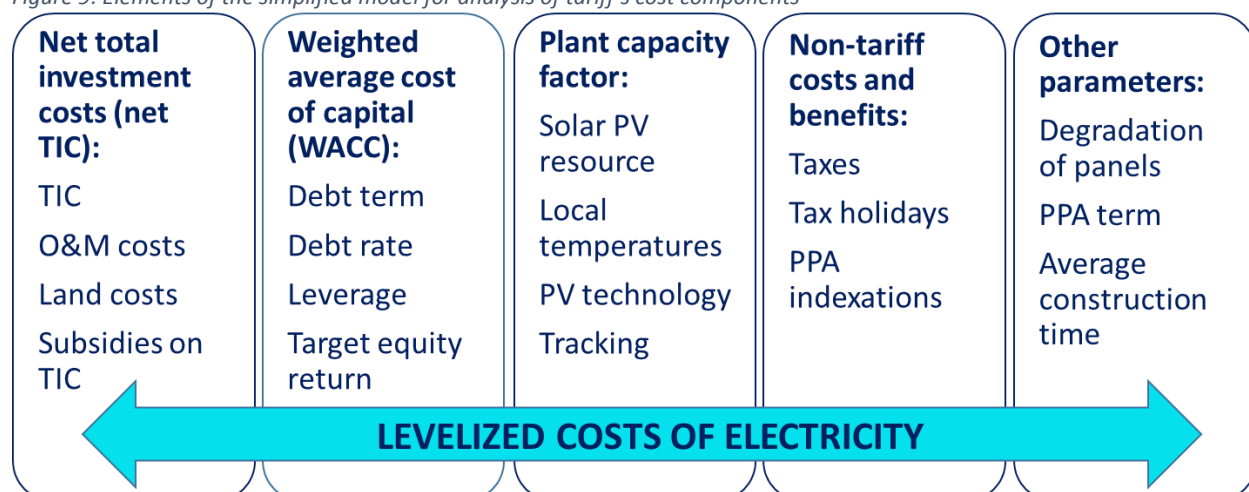
Source: World Bank based on IHS and BNEF

Are these prices realistic?

We consider the PV prices to be realistic if we can explain them by calculating the same LCOE with plant-specific parameters reflecting the particularities of the given plant. The plant-specific elements of the financial model (detailed description of the model is provided in Annex) we used for LCOE calculation included five groups of variables (Figure 9): total investment costs, financing conditions resulting in costs of capital (before tax), capacity factor of power plant depending on local insolation and temperatures, choice of technology and presence or absence of tracking, tax conditions and terms of Power Purchase Agreement (PPA). The calculations for 37 plants studied are presented in Table 1. If plant-specific parameters entering the calculation are consistent with market fundamentals and at the same time explain the plant's announced electricity price we conclude that the given price is realistic. Since we are focusing on the lowest reported prices our conclusions, if positive, are automatically covering the entire range of prices.

³ Figure 8 is depicted for year 2015 which represents a more typical year for the composition of costs components than year 2016. In overheated year 2016 margins are very low and, for example, EPC in some cases represents only 10-15% of costs, skewing the overall percentage composition.

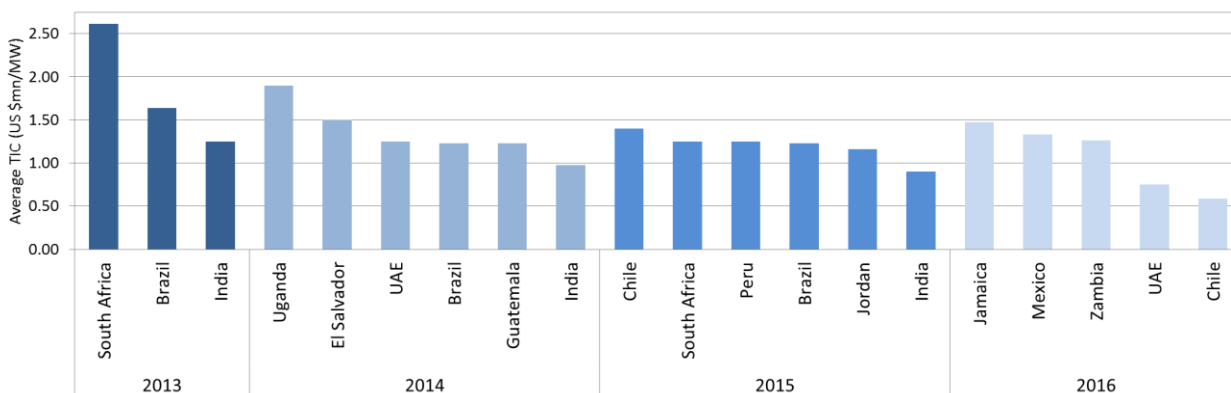
Figure 9: Elements of the simplified model for analysis of tariff's cost components



Source: World Bank

Ranges of parameters entering calculations of prices of the 37 plants vary widely but are consistent with current or expected market conditions by the time of plants anticipated commissioning. Since we are studying recent auctions, only about half of the plants in our dataset have been financed to date. The rest have only been announced or, in some cases permitted, so only little actual data is available for them at this stage. For such plants we assume parameters entering calculations based on market intelligence. For plants in financing, construction or commissioning stage we use data available from BNEF and IHS databases containing project-specific information. Total investment costs in our dataset range between USDm 2.7/MW for certain plants from 2013 auctions all the way down to USDm 0.6/MW assumed for Chile's Maria Elena plant, a winner of recent auction, which will most likely start construction in 2019 or 2020 (Figure 10). For most of plants costs of capital (in currency of the PPA) are low to very low, between 5–10%, reflecting the fact that for most of these plants development financing was used or is assumed to be available. India is a notable exception, with costs of capital of 13–14%, reflecting local commercial financing and local inflation. Plants range from 6MW size for a small allocation in one of India's auctions all the way to Dubai's 800MW mega-plant, the largest auctioned to date, to be built in 3 stages between 2018 and 2020. PPA terms range from 15 years in Mexico and Guatemala, to 25 years becoming more and more common in most countries given the guaranteed durability of the technology (Table 1).

Figure 10: Average total investment costs for the 37 PV plants covered in this analysis, per country and by year of announcement



Source: World Bank

Table 1: Details of the 37 analyzed deals

Country	Brazil			Mexico						Peru		Chile		Guatemala	El Salvador	UAE		Jamaica
Auction	Pernambuco State Solar Auction	6th Capacity Auction	7th Capacity Auction	1st Clean Energy Auction	1st Clean Energy Auction	1st Clean Energy Auction	1st Clean Energy Auction	1st Clean Energy Auction	1st Clean Energy Auction	4th Renewable Energy Auction (Round 1)	4th Renewable Energy Auction (Round 2)	"2015/01"	"2015/02"	3rd Energy Tender	100MW Renewable Power Tender	Maktoum Solar Park Phase III	800MW Sheikh Maktoum Solar Park Phase III	37MW Renewable Energy
Developer	Enel Green Power	Enel Green Power	Enel Green Power	Enel Green Power	SunPower	Jinkosolar	Recurrent	Thermion	Alter Enersun	Enel Green Power	Enersur (Engie)	Solarpack	First Solar	Anacapi / Onyx	Neoen / Almaval	ACWA	Masdar / FRV (Abdul Latif Jameel of Saudi Arabia)	Eight Rivers Energy Company (Neoen / Rekamniar)
Location (Plant)	Fontes Solar (I and II)	Ituverava (I to VII)	Bom Jesus da Lapa	Parque Solar Villanueva	Guajiro	Las Viborillas	Aguascalientes 1	Sol de Insurgentes	Kambul	Rubi	Intipampa	Maria Elena	Luz del Norte	Onyx Horus II	La Paz	Maktoum Solar Park Phase III	Sheikh Maktoum Solar Park Phase III	Westmoreland
Award Year	2013	2014	2015	2016	2016	2016	2016	2016	2016	2015	2016	2016	2015	2014	2014	2014	2016	2016
Commissioning Year	2015	2017	2017	2018	2018	2018	2018	2018	2018	2018	2018	2021	2017	2015	2016	2017	2018	2018
Status	Commissioned	Financing secured	Financing secured	Announced	Announced	Announced	Announced	Announced	Announced	Announced	Announced	Announced	Announced	Commissioned	Financing secured	Financing secured	Announced	Announced
MW	11	260	75	580	100	100	63	23	30	140	40	100	141	30	100	200	800	33
Net TIC (mUSD/MW)	1.64	1.23	1.23	1.40	1.40	1.40	1.20	1.40	1.20	1.13	1.38	0.59	1.40	1.23	1.50	1.25	0.75	1.47
Cost of Capital (calculated)	7.3%	8.6%	8.2%	4.6%	6.1%	7.6%	6.0%	6.5%	7.6%	6.0%	4.0%	5.4%	5.6%	11.8%	6.9%	5.0%	5.2%	5.2%
Capacity Factor	23%	23%	23%	34%	31%	32%	25%	30%	21%	29%	29%	25%	25%	22%	20%	20%	25%	20%
PPA Term	20	20	20	15	15	15	15	15	15	20	20	20	20	15	20	25	25	25
Actual bid (US\$/kWh)	10.25	8.66	8.52	3.55	4.40	4.73	4.80	4.81	6.75	4.80	4.85	6.48	6.76	10.94	10.19	5.85	2.99	8.54

Country	South Africa						Uganda	Zambia		Jordan				India					
Auction	REIPPP Round 3	REIPPP Round 3	REIPPP Round 3	REIPPP Round 4	REIPPP Round 4	REIPPP Round 4	Get FIT	100MW Solar Auction	100MW Solar Auction	Phase II	Phase II	Phase II	Phase II	Karnataka Phase II 130MW	Andhra Pradesh 500MW	Karnataka 500MW	Telangana 500MW	JNNSM Phase II Batch 1	Punjab 250MW
Developer	Enel Green Power	Total / Sunpower	Sonnedix	Scatec Solar	BioTherm Energy	SunEdison	EREN / Access Energy Group	Neoen / First Solar	Enel Green Power	ACWA Power (bought from winner)	Saudi Oger	Abdul Latif Jameel / Fotowatio	Hareon Solar Technology	SCCPL	First Solar	Azure Power	Rays Power	ACME	Azure Power
Location (Plant)	Adams Solar PV 2 (Aurora)	Prieska	Mulilo Prieska	Sirius Solar	Konkoonsies II	Droogfontein II	Soroti	West Lunga	Mosi-oa Tunya	Marfaq	Marfaq	Marfaq	Marfaq	Bidar	Anantapur	Chitradurga	Kalwakurthy	Rajdhani	Killianwali
Award Year	2013	2013	2013	2015	2015	2015	2014	2016	2016	2015	2015	2015	2015	2013	2014	2014	2014	2014	2015
Commissioning Year	2016	2016	2016	2018	2017	2018	2016	2017	2017	2018	2018	2018	2018	2015	2016	NA	2016	2015	2016
Status	Financing secured	Financing secured	Commissioned	Permitted	Permitted	Permitted	Financing secured	Announced	Announced	Financing secured	Announced	Financing secured	Announced	Commissioned	Commissioned	Financing secured	Commissioned	Commissioned	Commissioned
MW	75	75	75	75	75	75	10	45	28	50	50	50	50	6	40	140	10	20	28
Net TIC (mUSD/MW)	2.45	2.70	2.70	1.25	1.25	1.25	1.90	1.10	1.43	1.13	1.13	1.18	1.20	1.25	0.90	1.10	1.00	0.90	0.90
Cost of Capital (calculated)	6.0%	7.9%	8.0%	8.0%	8.0%	8.0%	9.4%	5.9%	5.9%	4.8%	5.4%	5.5%	6.9%	14.2%	13.2%	12.8%	14.2%	14.5%	14.5%
Capacity Factor	23%	25%	23%	23%	22%	21%	18%	23%	23%	20%	20%	20%	20%	19%	19%	19%	19%	21%	17%
PPA Term	20	20	20	20	20	20	20	25	25	25	25	25	25	25	25	25	25	25	25
Actual bid (US\$/kWh)	8.54	9.74	10.87	6.43	6.55	6.94	16.37	6.02	7.84	6.13	6.49	6.91	7.67	10.97	8.56	11.17	10.76	8.75	11.59

Legend:

Reported Data from BNEF, IHS databases and auction documents	Bloomberg New Energy Finance Estimate	World Bank Estimate (based on market intelligence and interviews)
--	---------------------------------------	---

Source: World Bank

Our calculation in the financial model based on the plant-specific parameters allowed us to recalculate the announced PV electricity prices. Calculations support PV electricity prices of USc 6–8/kWh using parameters observed in today’s markets. Prices significantly below USc 6/kWh in our dataset are typical for PV plants with long time-to-delivery, in locations with exceptional solar resources and access to long-term and low-cost financing. Using these exceptional parameters we are able to replicate even these very low prices in the LCOE model.

The differences in parameters of the 37 plants also reflect underlying country conditions – typically related to financing – that are not necessarily PV technology-specific but can significantly impact viability of PV market in a given country or level of prices. Depth of the local financial market, exchange rate-related issues, local taxes and import duties and ability to access cheap financing, either through development banks or in other ways, can bring very specific financing conditions in a given country, affecting the entire market. For example, India’s cost of capital is higher than in other places but reflects the local realities of inflation and financing from commercial banks. On the other hand, India’s current investment costs are exceptionally low, at USD 0.8/W (for more details see Box 1).

Box 1: India – Fully commercial solar PV market with grid parity

Since late 2014, India has an ambitious renewable energy target of 175GW to fulfill by 2022, of which 100GW is to be delivered by solar energy. In order to meet the government’s target India needs to add almost 20GW of renewable capacity every year and solar therefore needs to ramp up to about 10-12GW per year. Federal government has a large role to play in order to achieve the target, both by pushing its own renewable energy initiatives, like the National Solar Mission, as well as through promoting laws that push responsibilities onto states and individual distribution companies.

On top of very active rooftop solar market, in particular in commercial and industrial segments, dynamic auctions market for utility-scale projects helps to deliver the ambitious solar target in cost-effective ways. Cumulative solar installations in India crossed the 7.5GW mark in May 2016. There is at about 2.9GW of solar projects in the pipeline of capacity that was awarded through auctions but many projects are facing delays, as only about 1.2GW of them have signed PPAs.

After a race to decrease prices, and with a few instances of achieving an equivalent of USc 6/kWh, the prices in India stabilized at USc 7–8/kWh, leading to project IRRs of 15%. The comparatively high IRRs are possible to achieve thanks to very low local TICs of USD 0.8/W. Local banking sector is not comfortable to finance bids under 8 cents for individual projects and under 7 cents for solar parks, due to concerns over quality of such bids.

Solar parks in India like Karnataka (2000MW), Madhya Pradesh (750MW), are de-risking solar investments by offering a ‘plug and play’ model, where land, PPA, and transmission risks are taken care of by the solar park developer, bringing the risk and the cost down for the developer. This approach makes it possible to shave of USc 1 off the bids compared to individual projects. India is currently counting with a total of 40GW of solar parks by 2022.

Indian solar PV market is large and has been around for longer than in most countries, therefore it had time for learning-by-doing and natural evolution over the years. Interest rates for solar projects has come down over time. In 2012, a large scale ground mounted solar project could get a debt financing at about 13% for 10–15 years, similar projects today can get financing at about 10.5–12% for similar tenure. Also, several commercial banks have started looking at solar projects in project financing mode rather balance sheet financing. In 2012–2013, First Solar got several projects with OPIC and US EXIM debt financing, currently Softbank is raising debt from Japanese market. Most of the other players raise debt from local commercial banks, which is not common in other markets discussed in this study.

Solar PV has come a long way in India, it has become a mainstream technology that is bankable locally. Moreover, over the years solar PV has achieved grid parity in India: solar prices from auctions are now competitive with the new coal plants. This can potentially change the entire power system planning paradigm, where least cost technology is also the most environmentally friendly and with resource available in every corner of the country.

Sources: World Bank, BNEF (2016c)

Currency of PPAs resulting from auctions may adversely affect ability of developers to deliver PV plants in general or deliver them in a timely manner. Currency impacts PV plants through exchange rates, relevant for purchase of PV equipment, and through access to financial markets, which is typically more limited for smaller local currencies than for USD. Currency is therefore impacting equipment costs and financing costs of PV plants. In countries that do not have their own equipment manufacturing base and rely on imported PV equipment exchange rate movements can have a severe impact on economics of plants (see Box 2 on Brazil as an example). Currency of the PPA is influencing the capability to raise debt, since financial markets of certain countries simply do not have depth and appetite for risk to finance relatively new technology like solar PV or place a significant premium on their financing of solar PV.

Box 2: Brazil – Macroeconomics challenging solar PV development

Brazil has been a pioneer in using auctions to contract future power generation capacity. Several different types of auctions have been used over the last few years, typically with expected delivery of power plants in 3 and 5 years. Solar PV technology was among winners of auctions since the 6th capacity auction in 2014, and PV capacity was also awarded in the 7th and 8th capacity auctions in 2015. Each of these, respectively, contracted slightly more than 1GW of solar PV power plants, to be commissioned in 3 from the time of award.

However, since mid-2014 Brazilian economy is in depression, causing a sharp increase in interest rates and at the same time also depreciation of the local currency, the Brazilian Real. As a result of the shrinking economy the country's power demand keeps decreasing. Macroeconomic situation has a direct impact on solar PV development in Brazil, not only through increase in interest rates but also because all PPAs from auctions are awarded in local currency while imported PV equipment is a commodity with prices pegged to US dollar. Local PV manufacturing is not well developed because, given the macroeconomic situation, the country has not been an attractive ground for foreign investments.

At the same time, to be eligible for preferential financing from the Brazilian National Development Bank, BNDES, PV plants have to use equipment that satisfies certain local content rules, announced in August 2014. As of June 2016 only 6 companies, with current manufacturing capacity of 265MW/year, are registered with BNDES as complying with the local content requirements.

As a consequence of macroeconomic decline, winning prices of the 6th capacity auction for solar PV plants of BRL 0.205–0.22/kWh, translating back in 2014 to USc 8.3–8.9/kWh, are with 2016 exchange rates worth USc 5.8–6.2/kWh. This is a significant impediment to financing and ultimately to the future profitability of these plants that are due to start to deliver power in 2017. In April 2016, 7 out of 8 solar PV winners of the 6th capacity auction requested a permission to postpone commissioning of their power plants from 2017 to 2019, and, based on the contractual obligations, were supposed to pay penalties for this delay. According to the latest news, Brazil will let these developers to cancel their contracts.

The only company that was able to finance and start to develop its portfolio from the 6th capacity auction is Enel Brasil Participacoes Ltda., with 7 power plants totaling 260MW. Enel has also secured financing and started construction of its portfolio from the 7th capacity auction. Based on our calculations, with the current exchange rates, Enel's cost of capital for the 6th capacity auction portfolio ranges between 4–5% (down from some 9% based on 2014 exchange rates), consistent with low-cost foreign debt financing that Enel can access and slim equity returns. Moreover, some Enel plants are assumed to be financed off their balances sheet. But this subsidiary of the Italian government-majority-owned company operates with longer time horizons and lower expected returns than most other market players. Despite slim returns we expect that Enel considers these investment as valuable part of their broader strategy to gain market share in the Brazilian power system.

Sources: World Bank, BNEF (2016b) and Bloomberg News (24 August, 2016).

Auctions develop in their design optimal allocation of risk by shifting it to parties that are best equipped to manage them. In some auction designs guarantees are offered out front as a part of the overall framework to deal with residual risks. Guarantees are often making PV development possible in places that would be otherwise considered too risky and therefore hard to finance. They have been one of the key factors behind the success of the Zambia's Scaling Solar tender, described in Box 3. Guarantees can cover risks including default of the off-taker on the payments of the tariff or risks related to political instability of countries (political risk). Guarantees therefore can open markets with interesting resource conditions and local technical capabilities and enable financing of plants that would otherwise not be possible or would be prohibitively expensive.

Box 3: Zambia – Dispelling myth of expensive PV in sub-Saharan Africa through de-risking

Scaling Solar is a WBG program that makes it easier for governments to quickly procure and develop large solar projects with private financing. It includes a package of expert advice, fully templated documents, pre-approved financing, insurance products, and guarantees. Results of Scaling Solar in Zambia are a proof that a well-structured and credible process can bring low solar PV prices for countries that need it the most – countries lacking stable and sufficient power supply, troubled by complicated macroeconomic and political situation.

To maximize the participation, minimize risk and bring economies of scale, the bidders in Zambia could only win one site. The sites, allowing to accommodate up to 50MW each, were selected based on insolation as well as considering grid capacity and stability and with attention to the future management of variable power to be generated by the PV plants. Bidding for well-specified sites streamlined the comparisons between bids for each site.

Scaling Solar approach brought results in just 9 months after the Government of Zambia engaged with the WBG on the solar IPP tender process. The tender initially attracted 48 international developers of which 11 prequalified and 7 submitted their final bids. Neoen S.A.S./First Solar Inc. and Enel S.A., won the two auctioned sites at just USc 6.02/kWh and USc 7.84/kWh (for more complex of the two sites), respectively. Since these prices are not indexed, the lower 6-cents bid corresponds in current dollars to an average USc 4.7/kWh over the lifetime of the project.

In Zambia the detailed contributions of individual WBG institutions to the Scaling Solar approach were as follows:

- IFC Advisory acted as transaction advisor
- WB offered IDA payment guarantees covering the liquidity security in the PPA and IDA loan guarantees for commercial lenders in case of a Government breach of its obligations resulting in a missed payment, including termination
- IFC offered loans with a blended finance component and possible syndication of the rest of the debt
- MIGA offered political risk insurance (PRI) for equity and debt

All bidders who submitted an offer requested the IDA payment guarantee, no IDA loan guarantee was needed. It is likely that one or both of the winning bidders will use IFC financing, one winning bidder may use MIGA PRI. Round 2 of PV auctions in Zambia for 200MW has already been announced. The second round will clearly benefit from the templated Scaling Solar approach, as bidders will face the same procedures and documents as in the first round.

Sources: World Bank and IFC (2016).

What are the main drivers for decreasing PV prices?

Auctions have been an effective tool for translating the decreases in investments and financing costs, and improvements in capacity factors to PV electricity prices. Unlike negotiated deals or FITs with fixed tariffs, auctions are a competitive type of procurement and therefore they put direct pressure on obtaining best prices possible. Auction is a structured process following precise rules making it more transparent and therefore more reassuring for financiers than negotiated deals. A well-structured auction typically attracts a certain level of competition, which in turn forces the bids to reflect best equipment

and financing parameters possible for a given site. Because of market forces auctions reflect closer market fundamentals than other types of procurement.

However, auctions are not a panacea; flaws in auction design, no matter how minor, can lead to insufficient or low-quality competition, producing disappointing prices or low-quality power plants (an example of failed auction is provided in Box 4). While preparing auctions governments need to take into account their local policy and fiscal environment, state of local financial market, policy objectives for PV deployment, define potential risks and other market factors that can influence the design of auction (design of auctions is extensively documented in IRENA,2015b). Main factors characterizing auctions in countries from which we selected our database of 37 plants we analyzed in detail are summarized in Table 2. Flaws in design can lead to suboptimal results and failing original objectives of auctions to procure PV power in bulk and at competitive prices.

Box 4: Indonesia – Adopting solar PV feed-in tariffs after a failed auction

In 2013, after a long consideration of feed-in tariffs (FiTs), Indonesia surprisingly introduced auctions to allocate solar PV capacity as determined by country's solar development plan, updated on a yearly basis. A total of 140MW of PV capacity in 82 locations across country and sizes of 1-6MW was available, to be awarded in several individual tenders/rounds.

The conditions of the auction included:

- Auction documents and bids required in local language, Bahasa Indonesia
- Payments in local currency and in current exchange rates
- PPA with national utility PLN (Perusahaan Listrik Negara) set for 20 years without indexation
- Auction open to Indonesian state-owned, local-government and private enterprises or consortia
- International companies only able to participate through joint ventures or consortia with Indonesian enterprises
- Ceiling tariffs of USD 0.25/kWh for projects using imported and USD 0.3/kWh for projects using local PV modules
- Very ambitious timeline with only 2 weeks available for preparation of bids

Out of the 82 locations available the first round of the auction tendered 11 but only 7 projects were awarded due to breaches in tender conditions by participants in the remaining 4 sites. The lowest winning bid price was USD 0.184/kWh, for a plant using imported modules.

By 2014 the FiTs program was again under consideration and at the same time the Supreme Court declared auctions unconstitutional following lawsuit of the Indonesian Solar Module Manufacturer Association claiming that solar developers were not using enough of local content. Irrespectively of the Supreme Court decision, the results of the first tender were disappointing. Sentosa (2014) attributes auction's underperformance to the lack of precise data for auctioned sites - including insufficient or lacking data on points of connection to the grid - combined with the very ambitious timeline for bid submission and very strict evaluation of bids, with even slight errors causing bid elimination. Additionally, local content requirements (local language, local companies, local equipment) made participation of international players very difficult, significantly shrinking the possible pool of competitors.

By 2016, only 2 of the 7 projects awarded back in 2013 have been built, representing a total of 8MW of capacity. In July 2016 the Government introduced solar FiTs, ranging between USD 0.145-0.25/kWh, depending on the project location. The FiTs are available for 250MW of capacity overall, with Java island allocated 150MW. Individual projects size cannot exceed 20MW and projects will be granted power purchase agreements for 20 years. To continue to support local manufacturing, the FiTs policy includes minimal local content requirement of 43.85% for all projects and the failure to fulfill the requirement significantly decreases tariffs received. It is not yet clear how the local content will be measured and whether the policy will prevent imports of foreign PV modules. However, the current manufacturing capacity in Indonesia stands at 90MW, well below 250MW eligible for the tariffs and it is not clear whether Indonesian modules will be bankable, in particular with international banks.

Sources: BNEF (2013), BNEF (2016a) and Sentosa (2014).

Table 2: Qualitative characteristics of auctions per country (Guatemala and El Salvador are excluded due to lack of information)

	India	UAE	Jordan	South Africa	Zambia	Uganda
Type of auction	Solar PV	Solar PV	Solar PV	Renewables	Solar PV	Solar PV
Project location	Auction dependent	Pre-selected	Open with priority zones	Open	Pre-selected	Priority zones
Land costs	Borne by developer except for solar parks	Leased to developer by DEWA	Borne by developer	Borne by developer	Leased to developer	Borne by developer
Grid interconnection costs	Borne by developer	Existing interconnection	Borne by T&D company	Borne by ESKOM	Existing interconnection	Borne by developer
Currency	Indian Rupee	US Dollar	Jordanian Dinar (pegged to USD)	South African Rand	Zambian Kwacha indexed to US Dollar	US Dollar
Indexation of tariff	Typically fixed	Not yet clear		Indexed	Fixed	Fixed
PPA duration	20 years	25 years	20 years	20 years	25 years	20 years
Access to debt	DFIs and commercial Banks	Commercial Banks	DFIs	DFIs and commercial Banks	DFIs	DFIs
Offtaker	State distribution companies (through SECI/NTPC)	State-owned utility	State-owned transmission company	State-owned utility	State-owned utility	State-owned transmission company
Guarantees	NVVN and SECI payment guarantees for some projects	None	Sovereign guarantee	Sovereign guarantee for regular PPA payment of ESKOM	IDA payment guarantee	IDA partial risk guarantee offered but not used
Pre-qualification in auctions	Yes			No, but compliance criteria	Yes	Yes
Local content requirements	Yes (for central government schemes)		Encouraged though financial incentives	Yes	Encouraged (not mandatory)	None
Tax breaks	Accelerated depreciation		100% for 10 years	Accelerated depreciation		Yes
Import duties and taxes on equipment		Exempt	Exempt	Yes	Some exceptions	Yes
Other conditions	JNNISM Phase II Batch I was a Viability Gap Funding auction.			Bids evaluated 70% on price, 30% on a basket of economic development criteria.	The same bidder was not allowed to win both auctioned sites.	Restricted to 5 MW plants. Bidding for the difference between FIT at USc 11/kWh and cost of PV. Difference financed by donors for 20 years but fully disbursed in 5 years.
	Brazil	Mexico	Peru	Chile	Jamaica	Argentina
Type of auction	Depends on auction	Clean energy	Renewables	Technology neutral	Renewables	Renewables (fixed MW per technology)
Project location		Priority zones	Open	Open	Open	Interconnection points given (each with max capacity)
Land costs	Borne by developer	Borne by developer	Borne by developer	Borne by developer	Borne by developer	Borne by developer
Grid interconnection costs	Borne by developer	Borne by developer	Borne by developer	Borne by developer	Borne by developer	Borne by developer
Currency	Brazilian Real	Mexican Pesos Indexed to US Dollars	US Dollar	US Dollar	Quoted in USD Paid in Jamaican Dollar	US Dollar
Indexation of tariff	Indexed	Indexed	Indexed	Indexed	Indexed	Indexed
PPA duration	20 years	15 years	20 years	20 years	20 years	20 years
Access to debt	BNDES (local DFI) and commercial banks	DFIs for some deals	Commercial banks	Commercial banks	DFIs and commercial Banks	
Offtaker	Electricity Commercialization Authority	State-owned utility	Wholesale market	Distribution companies	Sole distributor of electricity	Wholesale electricity market administrator
Guarantees		None	None	None	None	IBRD payment guarantee (for termination)
Pre-qualification in auctions	Yes	Yes	Yes	Yes	Yes	No, but compliance criteria
Local content requirements	Required for BNDES financing	None	None	None	Encouraged, esp. for local labor	Encouraged though financial incentives
Tax breaks		1-year accelerated depreciation (100%)	5-years accelerated depreciation	None	Yes	
Import duties and taxes on equipment	Yes	Yes	Yes	Yes	Exempt	Some exemptions
Other conditions		Tradable clean energy certificates for 20 years for every MWh generated. Regional adjustments factors to incentivize projects in specific regions.	Penalizes if energy committed in the auction not produced.	Bidding for blocks of the day. Mechanism to postpone start of supply for two years. It can be used within the first three years after signature of contract. Penalties apply.		For Round 1, developers need to have advanced technical and E&S studies and approvals.

Source: World Bank

Fall in PV electricity prices reflects reductions in investments costs using strategies for decreasing costs of equipment and O&M costs and lower costs are also achieved in dedicated solar parks. Interviews with stakeholders suggest that developers with a large, global and solid pipeline of projects can procure large volumes of modules and other equipment in bulk, achieving economies of scale and lower prices, which can be reflected in lower bids. This is in particular the case in times 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 manufacturing of modules, EPC and ownership of plants. This helps optimizing delivery of plants and decreasing their risks. O&M prices are decreasing through automatization and improving local capacities in countries. Finally, countries interested in very large-scale procurement are designing dedicated zones, or solar parks, where power evacuation line and substation are built in advance and to ease the grid integration of the new capacity. This decreases certain risks related to the site as well as decreases overall investment costs needed for the plant. These gains can be then reflected in lowered bidding price for such sites.

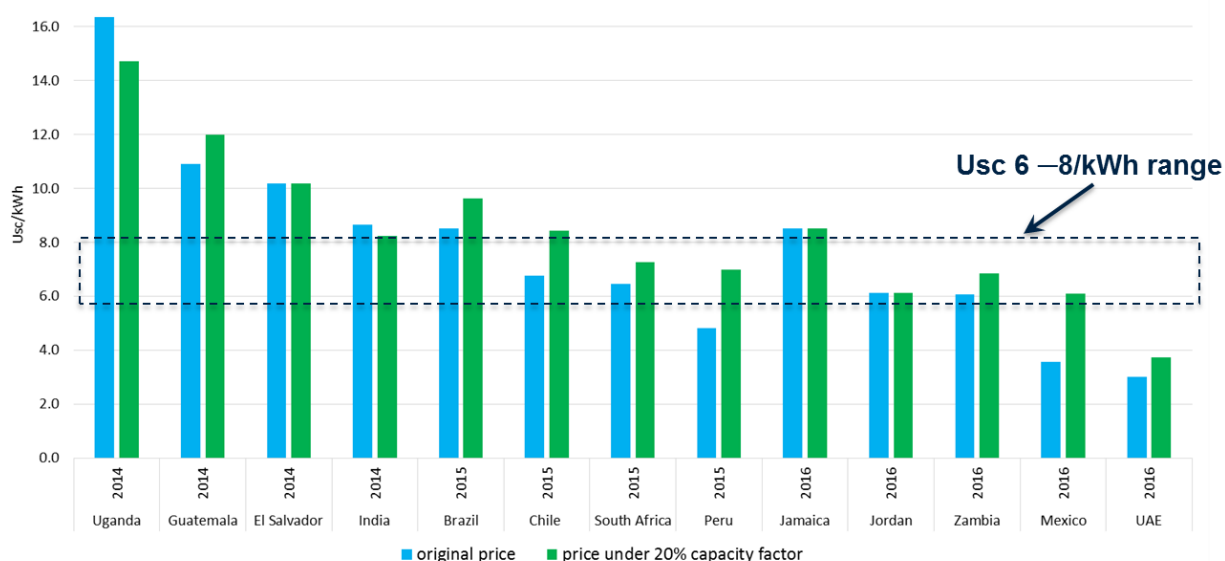
Factors acting to lower perceived risk of PV projects help to decrease financing costs and therefore drive down prices. Rigor of the auction process where bidders are aware of the precise set of rules that will be followed in determining the winners is one of the elements that decreases perceived risks for PV plants. Some large market players have extremely good knowledge of certain countries from their previous involvement in other technologies in these markets and therefore their pricing of risk in these markets is lower than for companies that do not have such sophisticated market intelligence. Scaling-up of PV markets globally is giving financial institutions confidence in the technology, lowering the perceived risks. Larger global PV market and involvement of large number of players, including traditional players with excellent local market intelligence, together with rigorous procurement processes decrease perceived risks of PV deployment.

Some developers use balance sheet financing as a cost-decreasing strategy, allowing them to offer lower prices than their competitors. Interviews with stakeholders suggest that some companies do initial investment in PV power plants from their balance sheet and refinance once the plant is up and running. Such financing is cheaper than up-front debt-financing since the risks for a commissioned and performing power plant are lower than those of a greenfield project. This strategy is available only to players with a large balance sheet but it enables them to enter new markets where financing of greenfield development would be prohibitively expensive due to lack of knowledge of and trust in technology by local banks or due to country-specific risks.

Technological progress in PV cell efficiencies, sophisticated plant design and expansion of global market to countries with best resource are improving capacity factors of plants allowing to drive down PV prices. PV cell efficiencies continue to improve (IRENA, 2015a) improving power output of panels. Output of a plant can be increased by up to 25% by using single-axis tracking, even though it requires slightly higher initial investment costs and higher O&M costs. But using tracking is very cost efficient for sites with high insolation. Moreover, markets are opening in places like Mexico or Chile, endowed with solar resources superior than those found in traditional EU and US markets. In these places the combination of resource and latest technologies can lead to exceptionally high capacity factors of power plants, allowing for very low PV power prices.

Simple exercise of correcting for high and very high capacity factors in certain countries explains majority of the very low prices announced over the last two years. From the 37 deals analyzed in this paper we have chosen the lowest price per country and recalculated these prices under original conditions of each deal but with standardized capacity factor of 20% to achieve certain comparability across countries (even though auction designs and underlying policy and market conditions differ and we are not able to correct for those to allow direct comparison). Under standard capacity factor of 20%, characteristic for many locations globally, all levelized costs of electricity but the one for the UAE rise above USc 6/kWh (Figure 11), confirming our initial assessment that prices significantly below USc 6/kWh require at least one exceptional parameter, in these cases capacity factors derived from excellent insolation conditions and use of tracking systems in certain plants. In the case of the UAE very good insolation is complemented with extraordinary debt conditions with tenor exceeding 25 years and very low interest rate.

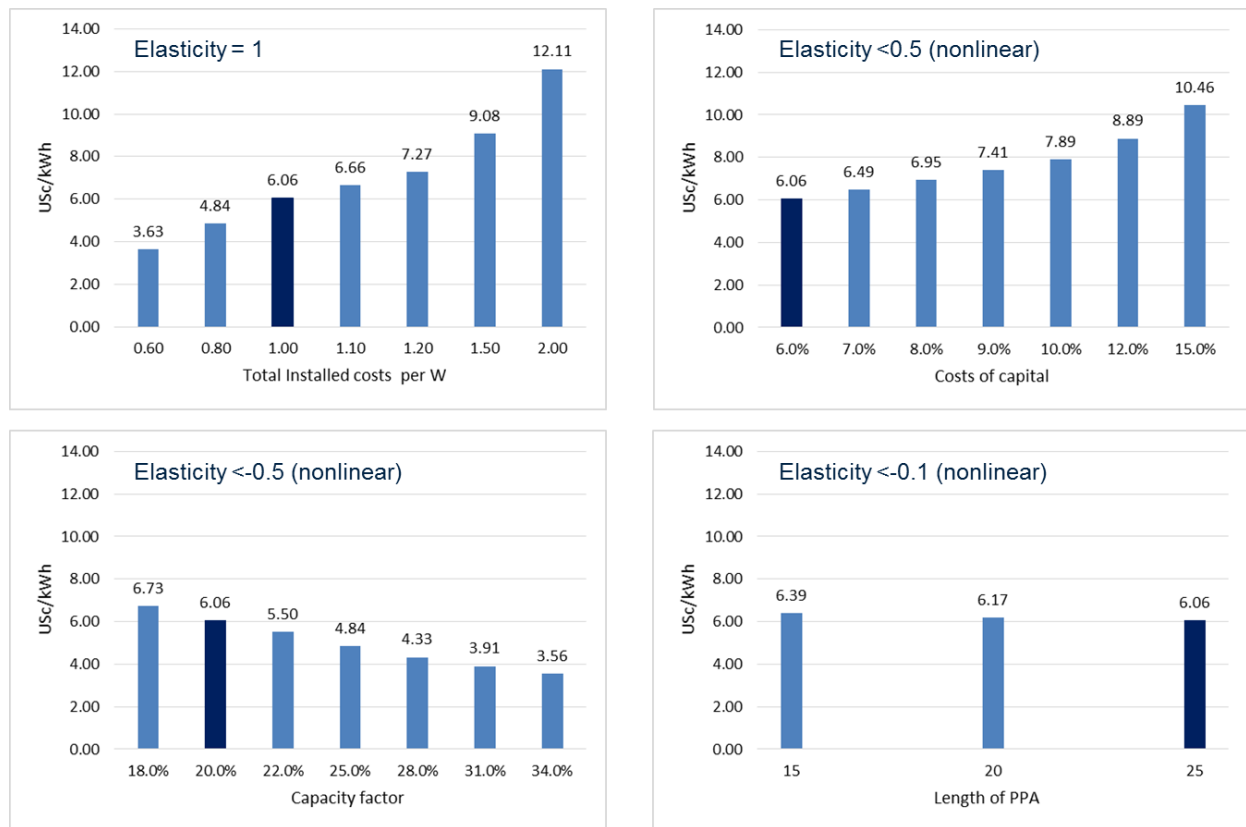
Figure 11: Impact of solar resource differences on prices



Source: World Bank

To complement analysis of drivers of price decreases we analyzed sensitivity of LCOE to the changes in main parameters and concluded that cost of capital is the parameter with highest influence on LCOE of PV plants. Sensitivity analysis calculations are displayed in Figure 12. While relationship of LCOE and investments costs is linear and therefore very prominent, the relative differences in costs of capital can be much larger than the relative differences in the investments costs or capacity factors for a particular plant. The ability of developers to influence the later 2 factors is more limited (capacity factors improvement for the same site with a superior design and rarely vary by more than 20% and possible investment costs improvements are also typically relatively small) while costs of capital can vary significantly (more than 100% between 2 different types of financing). These facts favor development of solar PV even in places with relatively lower insolation as long as financing costs can be kept down and at the same time it also means that policy-makers have an important role to play in helping to further decrease costs of PV by bringing financing costs down through de-risking projects and enabling access to low-cost capital.

Figure 12: Sensitivity of the main parameters entering LCOE calculations



Note: The default (dark blue) case is calculated for USD 1/W installed costs, 6% cost of capital, 20% capacity factor and 25 years PPA. Elasticities of LCOE to change in all parameters but TIC are nonlinear and are indicated for calculations under the default conditions. In reality they are each dependent on a multi-parameter formula. Source: World Bank

Are ever-decreasing prices sustainable today and over time?

We are able to explain the very low announced prices of USc 2.9-3.6/kWh for the handful of plants in the UAE, Mexico and Chile but we need to wait to know whether such results will generalize into this very low price level for many more plants. Recent results of auctions significantly below USc 6/kWh, in particular Dubai (USc 2.99/kWh), Mexico (USc 3.55/kWh), Chile (USc 2.91/kWh) and Abu Dhabi (USc 2.41⁴/kWh) are raising questions whether such prices are sustainable and plants will be delivered and will perform as expected. First, it is important to realize that those prices for 4 particular power plants and not generalized price level, unlike for the previously discussed prices of USc 6-8/kWh that are observed for hundreds of plants. Case by case, for Dubai, Chile and Mexico deals, we are able to explain the parameters underlying these low prices. On top of exceptional insolation conditions for all 3 locations, long time of delivery of power plants (up to 5 years in case of Chile), exceptionally long-term and low-cost financing and promotion of the clean energy leadership of the country play a crucial role in the UAE. However, there is no reason for pessimism; market fundamentals support the possibility of very low PV prices of USc 3/kWh in a few years for many more locations.

⁴ Abu Dhabi winning bid was announced at the time of writing of this paper, thus it is not included in our analysis.

Since utility-scale solar PV market in many countries is still relatively small and procuring using auctions is relatively new, almost every auction-procured plant today, with the notable exception of Indian market, exhibits at least one, but typically several exceptionally good conditions affecting positively its price. Plants that are currently procured are among first ones in their respective markets, often exploiting the best sites, with significant support of governments and development banks, obtained by companies that are trying to strategically enter a market. As such, these plants can be “one-of-a-kind” in their respective markets and are a typical characterization of the early stages of development of PV power sector in the developing world.

As markets scale-up and mature, the exceptional deals will naturally represent a proportionately smaller fraction of markets, impacting average prices. This does not however mean that the prices will go up. Technology learning continues driving down costs of components. Financing from development banks may not be available for every future deal but commercial banks will price technology risk lower once several plants have been built. And lessons from the first plans will serve for optimizing of processes that affect soft costs.

Sustainable PV prices can be guaranteed by imposing very clear and non-negotiable auction criteria, strict prequalification, and requiring developers to take stake in projects. Based on our interviews with stakeholders, simple and transparent rules of auctions are crucial for efficient procurement. Interviewees also suggest that pre-qualification or other way of screening of auctions participants is essential not only for obtaining low prices but more importantly for guaranteeing the ultimate delivery of plants at expected time and in expected quality. Requirements on developers to hold stake in the plant for several years creates incentives that make them to deliver better quality plants.

The observed trend in PV electricity prices demonstrates that solar PV is on track to become the cheapest source of power in many places around globe. As we already noted, first signs of prices in the range of USc 2.4-3.6/kWh are appearing in several countries. It is not unreasonable to expect that some places around the globe will be able to attain PV generation costs of USc 2/kWh in mid-term, reflecting the fact that in 2 years module costs are expected to fall to USD 0.3/W and improvements in non-module costs are also expected globally.

PV could change economic paradigm in many countries as long as integration challenges are dealt with. Solar resource is free and available in all countries and PV-based power production is poised to become the cheapest way to generate electricity. For resource-poor and underdeveloped countries this can be a game-changer allowing, for the first time, access to abundant and cheap power. However, large-scale PV deployment will have to be either combined with batteries, which still remain costly, or integrated with the existing generation. Proper planning of generation, i.e. choice of sites and sizes of installations, can help to smooth grid integration challenges.

[What prices could we expect in countries that are yet to develop first projects?](#)

PV tariffs for first projects in countries that are yet to start to develop utility-scale solar PV can be expected in single digits USc/kWh for plants to be commissioned in a couple of years. Table 3 below shows the results of simple simulation exercise to calculate the best possible prices attainable with three representative capacity factors. The calculations are assuming favorable policy environment and international competition are in place and no significant risk premiums are charged in these markets. We also assume that these plants would take a few years to develop, so investment costs could be in the

range of the very best-performing countries today. We assume no taxes and no indexation of tariffs. Under those conditions the resulting prices would depend heavily on the financing conditions (Table 3). We can conclude that PV prices as low as USc 5/kWh are attainable with favorable financing (8% costs of capital) in places with very good insolation. Prices could be even lower, USc 4/kWh, if very low cost financing (5% cost of capital), e.g. from Multilateral Development Banks, was available for these plants.

Table 3: Estimates of possible PV prices in markets with favorable market conditions:

Net TIC (mUSD/MW)	1.2	1.2	1.2	1	1	1	0.8	0.8	0.8
Capacity Factor	19%	22%	25%	19%	22%	25%	19%	22%	25%
LCOE (USc/kWh) at 5% cost of capital	7.84	6.77	5.96	6.53	5.64	4.97	5.23	4.51	3.97
LCOE (USc/kWh) at 8% cost of capital	9.39	8.1	7.12	7.81	6.75	5.94	6.25	5.40	4.75
LCOE (USc/kWh) at 11% cost of capital	11.08	9.57	8.42	9.23	7.97	7.02	7.39	6.38	5.61

Note: Calculations under assumptions of 25 years PPA, leverage of 80% and debt term of 17 years

Source: World Bank

Box 5: Nigeria – 1.2 GW of solar PPAs signed at fixed price, now heading towards auctions

Nigeria is suffering from severe shortfall of power. Even though installed power is over 12GW, only up to 4.5GW actually generate power, while demand stands at 12.8GW. Privately owned diesel and gasoline generators are used to cover the shortfall, producing power at costs 3–4 higher than costs of grid-based power.

The Nigerian offtaker, Nigerian Bulk Electricity Trader (NBET), mandated to work as a creditworthy intermediary between generation companies and distribution companies, has been for a couple of years in bilateral negotiations with 15 different developers proposing to build solar PV power plants of 57.5–135MW size. At first NBET could not agree with developers on tariffs and therefore it was planning to run an auction for 1.2GW of solar plants, with first 500MW auctioned in a closed auction for the 15 developers and subsequently an open auction permitting new entrants for the remaining capacity.

However, early July NBET agreed with 12 out of the 15 companies to sign a standardized PPA with tariff of USc 11.5/kWh for 20 years because the auction design was not yet fully finalized. The tariff is denominated in USD, but paid in local currency, Nigerian naira, in order to hedge out exchange risk. The penalties for delays in operation are designed as a decrease in tariff for every day of delay. Also, developers must deposit USD 20,000 for every MW planned, which they will lose if they will not reach financial close or fail to operate. There is no escalation in the PPA tariff even though the expected inflation in Nigeria averages almost 8% per year over the next 20 years, impacting operation and maintenance costs. Lack of indexation of tariff in part explains the relatively high agreed tariff.

Based on the information directly from the developers, reported by BNEF, expected average total investment costs are USD 1.48/W, which is twice as much as in India today. The high costs can be explained by the fact that most developers are local, with much less experience than large international players. Also, the plants often need to include substations and evacuation lines, adding to the overall costs. BNEF expects that Nigerian projects will attract international development financing, given that tariff is USD-denominated. Assuming that capacity factors attainable in Nigeria range from 20–23%, all the above parameters lead to average projects' pre-tax IRRs of 9–10%, which are not as generous as the tariff could suggest. However, expected investment costs seem unnecessarily high and if these could be improved IRRs could increase substantially.

In the future, NBET plans to run open auctions for independent power producers with the hope to attract not only local but increasingly more international players that could achieve much lower prices. The process is expected to be set up as a reverse auction with a pre-set target installed capacity by a specific date. NBET should publicly release the PPA value for each winner, duration of PPA, capacity to be delivered and the expected operation date.

In parallel Nigeria also has a feed-in tariff for solar PV plants of 1–5MW size, but since the tariff is to be paid directly by distribution companies, and not by government-backed NBET, increasing significantly the risk of non-payment and therefore it is not expected to bring significant deployment.

Source: Based on BNEF (2016d).

Ultimately, development of utility-scale solar PV in new markets will depend on overall energy sector strategy and policy environment, de-risking crucial in some countries and ability to attract a wide and high-quality competition. Without conducive policy environment neither FITs, nor competition through auctions, nor negotiated contracts will not materialize. Under favorable policies procurement choices should depend on the amount of MW to be procured and sizes of plants. Auctions tend to have relatively high fixed costs and are therefore more suitable for large procurement (it can happen in multiple rounds over several years). De-risking through optimal auction design and guarantees, where necessary, makes financing possible in places where risks are high and also brings competition driving down costs. FITs are more suitable for small plants however FIT laws need to take into account dynamic development of PV costs over time. Tariffs directly negotiated with developers can lead to overly generous rates of return for developers but in cases of a single plant procurement can be the most practical way forward. Important consideration should be given to transition from one procurement scheme to another and legacy pipeline of projects of the existing scheme needs to be dealt with before a new scheme is adopted. Box 5 showcases the recent case of Nigeria and their solution to the transition from FITs to auctions.

Conclusions

MDBs can play an important role in driving solar PV electricity prices further down by reducing financing costs through de-risking projects by assistance with structuring of procurement and/or by providing guarantees. MDBs can provide, where appropriate, access to low cost capital for PV power plants as well as enabling transmission, distribution and certain circumstances also storage technologies. Through technical assistance programs, MDBs can, along with providing policy advice, also provide advice on rightsizing of plants and help improving domestic capacity of installation, operation and maintenance, which contribute to lowering of costs.

References:

BNEF (Bloomberg New Energy Finance), 2013. “Indonesia goes the auction route for solar projects.” Renewables – Asia – Research Note, 25 June 2013.

BNEF, 2016a. “The first solar FiT lights up Indonesia”. Policy – APAC – Research Note, 12 August 2016.

BNEF, 2016b. “H1 2016 Brazil Market Outlook: Crises, financial and political”. 27 June 2016.

BNEF, 2016c. “H1 2016 India Market Outlook: Solar takes the lead”. 29 June 2016.

BNEF, 2016d. “Nigeria agrees to sign 1.2GW of on-grid solar PPAs”. Solar – Europe, Middle East and Africa – Analyst reaction. 8 July 2016.

BNEF, 2016e. “Q3 2016 PV Market Outlook: Solar power- not everyone needs it right now”. 1 September 2016.

Bloomberg News, 2016. “Brazil to let developers cancel contracts for first solar farms”. 24 August 2016.

IFC (International Finance Corporation), 2016. “Scaling Solar’s First Auction in Zambia Sets New Regional Benchmark for Low-Cost Solar Power”. IFC press release, 13 June 2016.

<http://ifcextapps.ifc.org/ifcext/pressroom/ifcpressroom.nsf/0/E5F6A9E9D7C08B5A85257FD100651286?OpenDocument>

International Energy Agency (IEA), 2015. “WEIO 2014-Power Generation Investment Assumptions”, <http://www.worldenergyoutlook.org/media/weowebiste/2014/weio/WEIO2014PGAssumptions.xlsx>

International Renewable Energy Agency (IRENA), 2015a. “Renewable Power Generation Costs in 2014”. http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_2014_report.pdf

IRENA, 2015b. “Renewable Energy Auctions: A Guide to Design”. http://www.irena.org/DocumentDownloads/Publications/Renewable_Energy_Auctions_A_Guide_to_Design.pdf.

IRENA, 2016. “Solar PV in Africa: Costs and Markets”. http://www.irena.org/DocumentDownloads/Publications/IRENA_Solar_PV_Costs_Africa_2016.pdf

Sentosa, E.C., 2014. “FiT Solar Auctions in Indonesia: Lessons Learned from Participation of a Local EPC Company.” Presentation at the German-Indonesia Business Forum on Grid-Connected PV Systems, http://indonesien.ahk.de/fileadmin/ahk_indonesien/Dokumente/PV_ongrid_2014/4_Suntech.pdf, Suntech Solar System, 2014.

Annex

List of interviews:

- 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
- SunPower USA

Description of the financial model used to assess market prices:

The simple excel model used to arrive at LCOE across countries in this study included the following:

1) As major inputs into the model it had

- a) Net total investment (including operating costs);
- b) Cost of capital (derived from required return on equity, term and rate for debt, leverage ratio);
- c) Projected generation (dependent on capacity factor determined based on insolation and degradation of panels);
- d) Taxes;
- e) PPA terms (length of PPA, indexation).

2) Typically project financial models arrive at an equity rate of return based on revenues (for given generation and tariffs), costs and debt servicing requirements. We calculated the tariffs required in year 1 for given revenues, costs and debt and equity repayments required. These costs are projected over the life of PPA, and effective tariff in first year of operations that should return the target cost of capital is calculated iteratively.

3) Cost of debt and equity (in same currency as currency of tariff) is taken along with leverage to arrive at debt servicing costs and equity repayments required to arrive what the tariff should be. Weighted average cost of capital (WACC) is not calculated as in practice there are typically tax holidays and accelerated depreciation initially skewing the tax impact on capital.

4) Total investment costs (TICs) are taken as a single figure (including both EPC, financial and soft costs). The cost of operations and maintenance enters the model as a percentage of the total investment cost. Any capital subsidies are subtracted from TIC to arrive at net TIC.

5) Since the generation depends on number of factors like site insolation, tracking systems, internal losses, module efficiency in operating conditions, etc., the model uses a single input of plant's capacity factor to

arrive at GWh/ MW generated by the plant. A yearly generation reduction factor enters to model to account for module degradation over time.

6) Key PPA terms modeled include annual indexation and length of PPA contract.

7) In addition to any capital subsidies, tax holiday period (to account for any depreciation benefits or direct tax holidays) and effective corporate income tax after tax holiday is part of the model. Any further distribution, dividend or withholding taxes to equity are not assumed. So equity returns given are pre-tax equity rate of returns for investors.

8) Other factors: Number of months to commercial operations from investment. For simplification, all TICs are assumed to be invested initially rather than have any disbursement schedule over construction.

9) The tariff, if in local currency, was changed to dollar based on the exchange rate of the year of the auction/contract award date.