Renewable Energy 97 (2016) 656–670

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Designing renewable energy auctions for India: Managing risks to maximize deployment and cost-effectiveness☆

Gireesh Shrimali [a, b, *, 1], Charith Konda [a], Arsalan Ali Farooquee [a]

[a] Climate Policy Initiative, New Delhi, 110017, India
[b] Stanford University, Stanford, CA 94305, USA

ARTICLE INFO

Article history:
Received 26 October 2015
Received in revised form
2 May 2016
Accepted 23 May 2016
Available online 17 June 2016

Keywords:
Renewable energy auctions
Competitive bidding
Electricity auctions
Effectiveness of auctions

ABSTRACT

We examined 20 renewable energy auctions in India and elsewhere to answer two questions: first, have auctions been effective; and second, how can they be designed to achieve India's renewable energy targets? The significant contributions lie in the larger sample size, use of secondary and primary research, and application of quantitative and qualitative analysis. We found that auctions are almost always *cost-effective*, with savings up to 58% from baseline feed-in tariffs. However, auctions may not always be *deployment-effective*, with only 17% of the auctions with greater than 75% deployment. We then examined how to best design auctions by assessing seven major risks, and found the following: first, for every 1% increase in total risk, deployment effectiveness decreased by 2% points; second, project specific risks have 60% greater impact than auction specific risks; and third, deployment effectiveness is most affected by auction design, completion, and financial risks. We also found that effectiveness of auctions in India can be improved by ensuring competition, improving transmission infrastructure, providing payment guarantees, using pay-*as*-bid auctions, including stringent penalties for delays, and introducing auctions in a controlled manner.

1. Introduction

1.1. Motivation

Auctions and feed-in tariffs are two popular procurement mechanisms for renewable energy worldwide. In India, typically governments have been using auctions for solar power and feed-in tariffs for wind power procurement.

Under feed-in tariffs, governments offer long-term contracts and guaranteed payment for electricity at a fixed rate. Although feed-in tariffs are a popular mechanism, governments may not always have the best information to set the correct, competitive tariff, which can lead to cost inefficiency if too high, or non-deployment if too low [19,28].

Governments around the world are increasing the use of auctions as a means to procure renewable energy, due to their potential as a more cost-effective mechanism [19]. Under auctions, a renewable energy buyer (governments or utilities) announces interest in buying a set amount of electricity from renewable energy sources. Renewable energy sellers (project developers) who meet predefined technical and financial criteria then submit price bids to the renewable energy buyer, who typically selects the winning sellers based on the lowest bids.

Given India's budget constraints for supporting renewable energy, a cost-effective policy path is crucial to achieving the country's renewable energy targets [15]. The budget allocated to India's Ministry of New and Renewable Energy (MNRE) was reduced from INR 15 billion (USD 246 million)[2] in FY2013-14 to INR 4.41 billion (USD 72.3 million) in FY2014-15 [30,33]. Auctions, if designed properly, could help deploy renewable energy capacity in a cost-effective and transparent manner.[3]

However, in our interactions with policymakers in India, they have raised questions about the ability of auctions to achieve the

☆ A version of this paper has appeared as a Climate Policy Initiative Working Paper, "Reaching India's Renewable Targets Cost-effectively: Effective Project Allocation Mechanisms".

* Corresponding author. Climate Policy Initiative, New Delhi, 110017, India.
E-mail address: gireesh.shrimali@cpidelhi.org (G. Shrimali).
[1] Gireesh is also a Fellow at the Steyer-Taylor Center for Energy Policy and Finance at Stanford University.

[2] All exchange rate conversions are at 2014 average rate (1 INR = 0.0164 USD).
[3] We discuss different types of auctions in the Online Appendix.

http://dx.doi.org/10.1016/j.renene.2016.05.079
0960-1481/

expected goals and whether risks in auctions can be properly managed. To assist policymakers in India, we assessed the following two questions, as identified in Ref. [18]:

- Have auctions been effective as a mechanism to procure renewable energy?
- How can auctions be designed to manage risks to achieve India's renewable energy targets?

Also, while India is already using auctions to procure solar power, attempts to use auctions for procuring wind power were stalled in the past due to opposition from the wind power industry [34,41]. Given this, we gave special attention to assessing the feasibility of wind power auctions in India.

1.2. Prior work

A number of studies have examined the use of auctions for renewable energy procurement globally. These studies had a similar goal of examining whether auctions have resulted in achieving the stated policy objectives. We discuss a few key studies below.

Kreycik et al. [23] evaluated feed-in tariffs and auctions on four criteria. They found that feed-in tariff regimes provide price certainty, which can increase investments and encourage sustained development; however, they may not result in least-cost projects. Auctions, on the other hand, while helping discover market tariffs, have challenges in terms of requirement of a large market size for bids to be competitive.

Maurer and Barroso [28] discussed efficient practices in electricity and renewable auctions. They focused on both developed and developing countries: Brazil, Chile, Peru, Mexico, Vietnam, Philippines, Europe, and North America. They concluded that, if auctions are successfully designed and implemented, they might lead to far superior results than other procurement mechanisms, such as feed-in tariffs.

Becker and Fischer [2] compared feed-in tariffs with auctions for renewable energy procurement with the experience in three emerging countries viz., China, India, and South Africa. They highlighted the importance of policy objectives on policy choice and design. They concluded that India and South Africa could achieve their capacity targets in a cost-effective manner using auctions.

Cozzi [7] assessed the success and failure of reverse auctions for renewable energy with case studies on U.K., China, and Brazil. He identified success and failure with regards to policy goals, and concluded that reverse auctions can be used for renewable energy deployment at low cost, but design elements need to be present to prevent underbidding and breach of contract.

Conti [5] examined how reverse auctions work in practice using three case studies: California, Brazil, and Texas. He concluded that − auctions: 1) have the potential to contract large volumes of renewable energy at attractive prices, 2) would require robust pre-screening criteria to avoid winner's curse, and 3) would be more successful in price reductions if paired with other supply-side incentives.

IRENA [19] analyzed the design of renewable energy auctions in selected developing countries viz., Brazil, China, Morocco, Peru, and South Africa. They discussed the role of design elements for designing successful auctions, such as the type of auction, ceiling prices, auction volumes, administrative procedures, and guarantees and penalties.

Santana [40] examined the cost-effectiveness of project allocation mechanisms, such as renewable portfolio standards, feed-in tariffs, and auctions. He also examined the effect of these mechanisms in reduction of costs in the long term. Renewable portfolio standards and auctions were found to be cost-effective in the short term; however their long run effectiveness depended on technology specific approaches.

Kylili and Fokaides [24] reviewed auctions for power generation from renewable energy. They presented case studies from five countries in depth to identify the defects of the auction mechanism and to offer recommendations. They identified underbidding to be a major problem in auctions and suggested the inclusion of minimum viability criteria as well as sealed-envelop auctions.

Rohankar et al. [38] examined the viability of solar power projects in India, allotted under various central and state government policies. Specifically, they evaluated long-term sustainability of the projects deployed, given much lower tariffs than benchmark tariffs. The authors also identified underbidding as an issue with auctions and recommended the use of feed-in tariff in addition to enforcement of RPO/REC markets.

Malagueta et al. [26] assessed the impact of large-scale integration of concentrated solar power (CSP) plants in the Brazilian electricity system through auctions. They concluded that CSP is not yet competitive in the Brazilian electricity market and noted that CSP plants would more likely have to replace hydroelectric power plants, where investments in RE is largely driven with the motivation to replace fossil fuels.

Contreras and Rodriguez [6] developed a Public Private Partnership (PPP) model for development of wind power in isolated areas in Columbia. They modeled the relationship between public sector and private investors using a bi-level programming method including an auction mechanism. They highlighted the importance of a stable regulatory framework for decentralized wind power development in the country.

Butler and Neuhoff [4] compared the feed-in tariff policy in Germany with competitive auctions in the U.K. They concluded that the long-term price guarantee provided by feed-in tariff reduced regulatory and market risk in Germany. This ensured less-than-expected higher prices in Germany compared with the price discovered in the U.K. They also suggested that support policies play a critical role in determination of prices.

Ferruzzi et al. [16] proposed a decision making model (for a prosumer dealing in low-voltage grid-connected micro grid) to formulate an optimal bidding model in the Day-Ahead energy market, considering the uncertainty of solar PV power production. The authors present an original approach based on Analog Ensemble method to estimate the uncertainty linked to solar PV power production in a micro grid setup. Results indicate different optimal bids based on the risk adversity of the prosumer with respect to the uncertainty involved in Solar PV power production.

Rio [36] examined the interactions between energy efficiency and renewable electricity support schemes to assess whether choice of specific instruments and design elements within those instruments affects the results of the interactions. The author went beyond the previous work in this area by considering instruments such as feed-in tariffs in addition to tradable certificates. The author concludes that for a support instrument to qualify in the optimal set of policy measures, it should complement existing measures and should not overlap or lead to conflicts [37]. aimed to clarify the differences between the two approaches used to measure the cost-effectiveness of renewables support policies. The authors note that the equimarginality principle and the lowest costs of support principle could partly overlap and their policy implications clearly differ, leading to different policy prescriptions. While the former favors technology neutral instruments and design elements, the latter approach favors instruments and design elements that adjust support levels to the cost of the technologies.

Though some of these studies provided insights into designing auctions for renewable energy, there is scope for further study. First, most of these studies – e.g., Cozzi [5], Conti [7], and IRENA [19] – primarily used qualitative analysis, as opposed to drawing conclusions from quantitative metrics. Second, most of these studies – e.g. Maurer and Barroso [28] and IRENA [19] – examined auctions in developing countries other than India; only a few – Becker and Fischer [2] and Kylili and Fokaides [24] – examined renewable energy auctions in India, but they not only limited their scope to the national auctions but also did not examine deployment effectiveness. Finally, many studies – e.g., IEA [18] and Santana [40]; – discussed merits of auctions, but did not examine individual auctions in detail.

1.3. Our work

Our work adds to previous work on designing effective auctions in three significant ways. First, we used the largest data set of (twenty) auctions, including auctions in India and elsewhere, comprising developed and developing countries. Second, we used both qualitative and, more importantly, quantitative metrics to arrive at our findings. The use of quantitative analysis remains the biggest contribution of our study. Third, we collected data and information through many different sources, including primary research and secondary research.

We examined Indian solar power auctions in depth by analyzing both national- and state-level solar power auctions. We looked into effectiveness and feasibility (in terms of managing risks) of auctions by developing quantitative metrics for both. We assessed effectiveness by examining whether auctions achieve the expected policy objectives of high deployment, low cost, and equity. We evaluated feasibility by investigating how different risks affect auctions' effectiveness, and how auctions can be designed better to manage these risks. We also examined the specific case of introducing auctions for wind power procurement in India given the challenges faced by the industry in the country as well as the pressure on policymakers to introduce competitive auctions for procuring wind power.

2. Methodology and data

2.1. Methodology

Based on *secondary research* and *primary research* as well as *qualitative* and *quantitative* analysis, this study focused on the benefits and risks of energy auctions, which in turn helped us to measure the effectiveness of auctions from policymakers' perspective. Section 2.1 presents detailed methodology, followed by a discussion of data in Section 2.2.

As part of secondary research, we followed the *case study approach* for each of the countries in which the auctions were held. We selected case studies based on the *theoretical sampling method* [14,17]. We studied the context in which the auctions were held, by technology, and systemic problems present in each of these countries. We also crosschecked our secondary research findings with inputs from interviews and our own analysis.

In primary research, we interviewed three project developers, three subject-matter experts and a federal-level policymaker in India. Our questionnaire for policymakers and experts aimed to gather information on the objectives of holding auctions, metrics to be used for measuring success/failure of auctions, and aspects of design of auctions related to ceiling tariff, ensuring competition, and the necessary qualification criteria to overcome the risks. Questionnaire for project developers was designed to understand the perspective of project developers on energy auctions vis-à-vis other prominent mechanisms such as the feed-in tariff. We posed questions to know whether auctions provide correct investment signals for all sources of energy and the reasons thereon. In addition, we also enquired if there are any additional costs and risks for project developers with regard to auctions compared with feed-in tariff mechanism. Both the questionnaires are available in the Online Appendix.

To examine the effectiveness of auctions, based on the metrics defined in Section 2.1.1, we measured the success/failure of auctions in achieving their objectives (Section 3.1). Our preliminary research findings (discussions with policymakers and experts [2,18,28,29]; indicated that three main objectives of using auctions for energy procurement are (see Section 2.1.1):

- *Cost-effectiveness*: This indicates that auctions are competitive and that policy goals are achieved in a cost-effective manner.
- *Deployment effectiveness*: This indicates the ability of auctions to increase deployment of renewable energy.
- *Equity in allocation*: This indicates that policy goals are achieved in an equitable manner.

We also examined whether auctions can be designed to manage risks in order to achieve policy objectives (Section 3.2). As a first step, we identified 13 risks from the universe of risks that could impact renewable power projects in general and auctions specifically (Table 1): We started by identifying general risks from Standard and Poor's general project finance criteria for solar PV projects [42]; we then added additional risks presented by auctions from literature review (Section 1.2). Details of the risk assessment methodology are provided in Section 2.1.2.

We found that some of the identified risks are similar in nature and, therefore, could be combined. For example, flawed tariff determination method, lack of competition, technology-neutral auctions, and contract re-negotiations are risks related to auction design and hence could be categorized under auction-design risk. Combining similar risks not only enabled us to focus on a few risks, but also enabled effective statistical analysis.[4] We also categorized these seven risks under the heads *auction-specific* and *project risks*, i.e., risks common with other procurement mechanisms such as the feed-in tariff regime.

We analyzed the impact of the identified risks on the cost- and deployment effectiveness of the auctions we selected both qualitatively and quantitatively. We explained the metrics we used to measure these risks in detail in Section 2.1.2.

2.1.1. Metrics for effectiveness

To measure the success of auctions, we measured the performance of individual auctions against their objectives using the following metrics:

2.1.1.1. Cost-effectiveness. Cost-effectiveness was defined as the reduction for auction discovered tariff from a benchmark tariff, as follows:

$$Cost - effectiveness = [(Benchmark\ tariff - Auction\ discovered\ tariff)/ \times (Benchmark\ tariff)]*100 \quad (1)$$

Tariff reduction achieved through reverse auctions could be measured in various ways. A benchmark tariff has to be identified to compare the tariff discovered through reverse auctions. The ideal

[4] Statistical analysis requires that the number of data points in a sample – i.e., number of auctions in our study – is considerably higher than the number of independent variables – i.e., risks.

Table 1
Risks for renewable energy projects under auctions.

Sl. No.	Risk factors	Potential impact	Individual risks as we considered	Risk category
1	Flawed tariff determination	Deployment effectiveness	Auction design	Auction-specific
2	Lack of competition	Cost-effectiveness		
3	Favoring a specific technology (technology neutral auctions)	Deployment-effectiveness (of new technologies as matured technology would be more competitive)		
4	Contract re-negotiations	Cost- and deployment effectiveness as developers seek higher tariff and negotiate for new power purchase contracts		
5	Aggressive and unrealistic bids by non-serious bidders	Deployment effectiveness	Underbidding	
6	Lack of tariff reduction due to strategic behavior	Cost-effectiveness	Collusion	
7	Delay in land acquisition	Deployment effectiveness	Completion	Project risks (Common with feed-in tariff mechanism)
8	Delay in environmental and other regulatory permits	Deployment effectiveness		
9	Delay in transmission interconnection	Deployment effectiveness		
10	Projects not able to achieve financial closure	Deployment effectiveness	Financial	
11	Payment default by procurer	Deployment effectiveness(financial viability of a commissioned project)	Off-taker risk	
12	Resource variability	Deployment/generation effectiveness (decrease in revenues if quantity of resource falls short of the expected quantity)	Technology	
13	Lack of accurate resource data	Deployment/generation effectiveness (impacts production of commissioned plant as developers lack prior knowledge of the resource		

Source: CPI Analysis, MNRE, Standard & Poor's.

metric would be the counterfactual feed-in tariff – i.e., the feed-in tariff that would have been used if the auctions were not introduced.

However, by definition, this counterfactual for a benchmark tariff does not exist and, therefore, we used a proxy – *percentage price reduction from feed-in tariff*. For this purpose, we considered the *feed-in tariff* that existed in that country/region previously or the feed-in tariff that existed in a comparable region at the same time as these tariffs would have continued or adopted in case auctions were not introduced. For example, to measure the tariff reduction achieved in India's National Solar Mission Phase 1 Batch 1 auction (2010), we used Gujarat's Solar PV feed-in tariff (2009) that existed prior to the introduction of the National Solar Mission as the benchmark.[5]

We believe the above definition is an appropriate metric to measure (static) cost-effectiveness of auctions, which refers to the ability of auctions to achieve targets in the least cost manner. However, we acknowledge that this metric is not perfect given that our proxy (especially where we considered previous feed-in tariff) may be higher than the counterfactual feed-in tariff. This would especially be true in the case of Solar PV, of which tariffs have reduced drastically year-on-year in the last five years. Thus, our results with respect to cost-effectiveness could be somewhat overstating the benefit of auctions.

We also considered other possible benchmark tariffs such as the *ceiling tariff* for an auction *and the competitive tariff* relevant to a specific auction. A ceiling tariff is estimated by the policymakers, which would have been ideally used as feed-in tariff if auctions were not introduced. However, as ceiling prices were not announced for many of the auctions worldwide we could not use this metric. Comparison with competitive tariff would have indicated whether auctions are discovering the correct tariffs or not. However, we did not have the required data to estimate the competitive tariff applicable for auctions in other countries.

We used the following thresholds to categorize the successes and failures –

- Tariff reduction of 0–10%: Somewhat successful;
- Reduction of 10–20%: Successful; and
- Reduction of more than 20%: Highly successful.

This categorization allowed us to assess the relative performance of auctions with respect to cost and deployment effectiveness and for measuring risks. We created the categories by dividing the range available equally. We have more categories when the range is large and vice versa. This scale is similar to well-known scales such as the Likert scale [25].[6]

To check whether auctions are helping in discovering tariffs that are closer to the market prices, in the case of Indian solar PV auctions, we estimated proxies for competitive tariffs using our cash flow model based on assumptions of key parameters for benchmark tariffs of Central Electricity Regulatory Commission (CERC) and data collected through primary research.[7] This would also indicate whether auctions are tracking cost reductions dynamically. We limited this analysis to Indian auctions as we could not find all the data required for auctions in other countries.

We understand that, in addition to auction-specific risks, policy-specific costs, and business innovation could influence the bids in auctions. Some of these factors could affect the cost-effectiveness of auctions, as financial costs tend to increase with perceived risks for investors [1]. Hence, we considered the following additional questions: Do auctions drive business and financial innovation? Do auctions increase risk and thereby costs for developers? Do auctions increase transaction costs for developers?

2.1.1.2. Deployment effectiveness. We considered the metric - *percentage capacity commissioned of the total capacity auctioned* - to

[5] For subsequent state level auctions, we used CERC's benchmark tariff applicable for that year, as states would have most likely adopted it as their feed-in tariff had auctions were not introduced.

[6] The commonly used Likert scale is a symmetric one with 5–7 categories, which includes the same number of positive and negative categories. In most cases we have smaller number of categories given that our data is not that nuanced at the level of individual risks.

[7] We disclose the assumptions we made in estimating the competitive tariff in the Appendix A.

measure the performance of auctions in terms of deployment of capacity.[8] That is,

$$\textit{Deployment effectiveness} = (\textit{Capacity commissioned}/\textit{Capacity auctioned})*100 \quad (2)$$

We also contemplated the metric –*Percentage capacity online* (say 2 or 5 years after the date of commissioning) – which would indicate the quality of projects being commissioned under auctions. However, given that the majority of the renewable energy auctions were recently introduced, we do not have the required data for using the second metric.

We used thresholds to measure success and failure of auctions with respect to capacity deployment. We used the following four ranges to categorize their performance (Shrimali et al., 2014):

- Deployment of greater than 75% of planned capacity: Successful;
- Deployment of 50–75%: Somewhat successful;
- Deployment of 25–50%: Unsuccessful; and
- Deployment of less than 25%: Highly unsuccessful.

In addition, we also examined the metrics – *percentage bids received of the total capacity auctioned* and *percentage capacity contracted of the total capacity auctioned* to understand the performance of auctions in more detail. The former indicates the attractiveness of a particular auction and the overall participation, which is a function of market timing and the design of an auction. The latter indicates robustness of the selection criteria and/or the market's readiness to meet the demand created by the auction.

Although we did not include results from these metrics in this paper, these metrics helped us to closely scrutinize each of the auctions and aided us to understand at which stage and due to which risk the auctions have succeeded or failed in deploying capacity.

2.1.1.3. Equity. Under auctions, governments allocate renewable energy capacity based on the price quoted by project developers, and usually the lowest bidders win. A single large dominant player could place the lowest bid for a project that garners the majority of the capacity auctioned, if no restrictions are in place. This concentration would increase the risk of projects not being commissioned due to developer-specific risks, such as bankruptcy.

High competition among bidders and a competitive allocation of planned capacity not only reduce risks to deployment in the short-term, but also help develop a longer-term sustainable market, which requires more than a few large developers in the market. A long-term competitive market results in improved market efficiency, including long-term cost-effectiveness, over time. To measure the fairness and competitiveness of auctions, we used the Herfindahl-Hirschman Index (HHI).

The HHI is calculated by squaring the market share of each successful bidder in an auction and then totaling the resulting numbers. The HHI is calculated with the formula:

$$\text{HHI} = \text{S1}\hat{2} + \text{S2}\hat{2} + \text{S3}\hat{2} + \ldots\ldots + \text{Sn}\hat{2} \quad (3)$$

Where S1 is the market share of bidder 1, S2 is the market share of bidder 2, and so on.

The resulting HHI ranges from close to zero to 10,000. The closer the number is to 10,000 the higher is the market concentration. We utilized the classification used by the U.S. Department of Justice [43] in evaluating the market place with HHI, which is:

- A score of less than 1000: Un-concentrated/competitive
- Score of 1000–1800: Moderately concentrated
- Score of greater than 1800: Highly concentrated

2.1.2. Metrics for diagnosis

We studied the risks involved in auctions to understand the feasibility of using auctions on a continuing basis. We rated each of the seven identified risks on a scale of one to three, with one representing a low intensity risk, two medium, and three representing the highest intensity for each of the auctions we examined. Though a higher granularity of risks would be desirable, such detail was hard to capture via the limited data available through secondary and primary research.

We then examined the relationship between these risks and the success/failure metrics, which were identified in the Section 2.1.1. This was examined via correlation (via Goodman and Kruskal Gamma) and regression analysis.

We followed a three-step statistical approach for this analysis; first, we measured the impact of total risk, which is the combination of all the seven individual risks; second, we measured the impact of risk categories i.e., auction-specific and project risks (which are common to all procurement mechanisms); and third, we measured the impact of each individual risks. We combined this statistical analysis with in-depth qualitative analysis to arrive at our findings.

2.1.2.1. Measurement of individual risks. **Auction design risk:** Includes risks related to the design of auctions including the lack of competition, flawed tariff determination etc. While certain design elements could increase or decrease the chances of underbidding or collusion from occurring, merely having a design feature would not eliminate the chances completely. Hence, we dealt with underbidding and collusion risk separately. We rated the intensity of auction design risk based on literature review and discussions with industry stakeholders.

Underbidding[9]: We aimed to capture the risk of underbidding involved in an auction under this head. For Indian auctions, for which we have bid-level data, we measured the presence of underbidding by examining the distance of the average bid from our estimated competitive tariff. If the average bid was lower in the range of INR 0–1/kWh, we rated as 1 indicating less risk. Similarly, an average tariff lower in the range of INR 1–2/kWh was rated 2 and in the range of INR 2–3/kWh was rated 3.

Collusion: We aimed to measure collusion among bidders by calculating standard deviation of bids from the average bid with the assumption that higher the concentration of bids the more likelihood that there was collusion among bidders. If the standard deviation is in the range of 0–1 we ranked the risk intensity as 3 indicating high chances of collusion. A standard deviation of in the range of 1–2 was ranked 2 and in the range of 2–3 was ranked 1 indicating low risk of collusion.

Completion risk: Includes all factors that could delay the commissioning of the projects. For example, delays in land acquisition, environmental and regulatory permits, and transmission

[8] We measured deployment achieved by the date of our research, Sept–Oct 2014. The ideal metric is deployment achieved by the commissioning deadline specific to each of the auctions, but there were a number of instances of extension of deadlines and lack of data of commissioned capacity by deadlines. We excluded those auctions that haven't reached their original commissioning deadlines (e.g., South African auctions) from the assessment.

[9] It is important to note that not every bid below the competitive tariff may have been an underbid. Bidders may have different cost structures or may have availed concessional finance, which allow them to bid lower than the normal market cost.

interconnection. We have rated the intensity based on literature review and discussions with industry stakeholders.

Financial risk: Derives its value from several factors such as the bid placed, off-taker risk, developer credit-worthiness, technology (wind or solar), or presence of any specific design element such as payment security mechanisms etc. As we don't have information on all the factors that influence the financial closure, we primarily based financial risk intensity on bid placed (underbidding or not) and off-taker risk. However, the values assigned to the financial risk are not the summation of these two risks, but a synthesis of different risks.

Off-taker risk: Off-taker risk is especially applicable in the case of Indian state auctions where the procurers are state distribution utilities, the majority of which suffer from poor financial health. To measure this risk, we used the state utilities rankings of ICRA, CRISIL and CARE.[10] Auctions for which the procurer was rated A+ and A, we have taken risk intensity of 1 indicating low off-taker risk. Similarly, for B+ we have taken 2 and B, C+, and C we have taken 3 indicating high off-taker risk.

Technology risk: For renewable energy auctions, technology risk is predominantly the risk of reliability of resource assessment studies. This risk is somewhat high for Indian auctions compared with auctions in other countries due to lack of accurate on-ground resource assessment data.

2.1.2.2. Risk management. We examined how the identified risks can be managed or overcome through auction design. For example, underbidding can be countered through stringent qualification criteria and penalties for failing to commission the projects. Likewise we explored other design features of auctions that could help manage the identified risks.

2.2. Data

We also undertook extensive secondary research of available literature, some of which we discussed in Section 1.

To measure the performance of auctions against the objectives we identified we selected a sample of renewable energy auctions to study in detail. Our criteria for selecting these auctions are: 1) auctions in similar large developing countries; 2) auctions that provide variation in the sample – e.g., auctions in developed countries or auctions which were perceived to be failure or successful in popular literature; and 3) data availability.

We applied these criteria on a larger universe of auctions (Table 2) to select the most suitable auction programs to study in detail.

3. Results and discussion

3.1. Effectiveness

3.1.1. Cost effectiveness

Auction-discovered tariffs were almost always lower than the baseline feed-in tariffs for the 17 auctions we studied (Fig. 1).[11] Tariff reductions ranged from 3 to 58% in the case of solar PV auctions and 0–30% in the case of wind auctions.

Tariff reductions were greater in solar auctions than in wind auctions because solar power has been experiencing significant reductions in capital costs. However, wind power auctions are still an attractive mechanism to achieve cost-effectiveness.

Based on the scale we defined in Section 2.1.1, 60% of the solar auctions were *highly successful*, 30% were *successful*, and 10% were *somewhat successful*. Among the wind auctions, 29% of the auctions were *highly successful*, 14% were *successful*, and 57% were *somewhat successful*.

We also examined whether auctions are discovering competitive tariffs, or in other words, tariffs that are closer to prices of renewable energy in a competitive market. Ideally auction-discovered tariffs should be similar to tariffs that would be discovered in a competitive market. Tariffs that are too high are not as cost-effective as they could be; too low and they raise the risk that the winning bidders do not deploy.

We compared the tariffs from Indian solar power auctions to an estimate of a competitive tariff, which would also indicate if auction-discovered tariffs were tracking reductions in renewable energy costs.[12] We found that, while auction-discovered tariffs are lower than competitive tariffs, they have moved closer to the competitive tariffs over the past four years. Auction-discovered tariffs moved from within 23–35% of the competitive tariffs in 2010–2011, to within 1–6% in 2012–2013 (Fig. 2). It appears auctions are dynamically tracking reductions in costs of solar power (which is reflected in competitive tariffs), at least in the case of solar auctions in India.

Although auction-discovered tariffs have moved closer to competitive tariffs, they are still somewhat lower, possibly either because of underbidding by inexperienced players due to a lack of understanding of the true costs [10] [13] or because CERC improved its estimates of benchmark tariffs over time with more experience, upon which our estimated competitive tariffs largely relied.[14]

We also examined whether auctions led to an increase in transaction costs for renewable energy project developers, which would in turn decrease the cost-effectiveness of auctions by increasing the bid prices. In our research and discussions with project developers, we did not systematically find additional tangible transaction costs for auctions when compared with feed-in tariffs.

In fact, in some situations, auctions may actually be less costly than feed-in tariffs, especially for developers who commission projects on time. For example, in the state of Karnataka, commissioning a solar PV plant under Karnataka's auctions is cheaper than under the feed-in tariff policy, with a non-refundable fee of INR 10,000 (USD 164) under auctions compared to a non-refundable fee of INR 0.11 million (USD 1804) per MW under the feed-in tariff policy [20,21]. On the other hand, in the same state, penalties for not commissioning a project on time, which are typically collected upfront as security deposits and are refunded when the projects are commissioned on time, are much higher under auctions. These penalties, in the form of various refundable fees, are INR 2.11 million (USD 34,604) per MW under auctions compared with INR 0.5 million (USD 8200) per MW under feed-in tariffs.

Despite a lack of evidence of additional transaction costs under auctions, it is important to note that project developers are concerned about the intangible cost of business uncertainty under auctions.[15] Project developers have to incur costs and raise money,

[10] Investment information and Credit Rating Agency (ICRA), Credit Rating Information Service of India Limited (CRISIL), and Credit Analysis and Research (CARE) are India's credit rating agencies.

[11] Out of the 20 auctions we selected for this work, 3 did not have available data for the baseline feed-in tariff, so we examined 17 auctions.

[12] We explain how we estimated the competitive tariff in the Appendix A. Our analysis is limited to Indian auctions due to data availability.

[13] Some reports indicate that internal rate of return (IRR) for the projects commissioned under JNNSM Phase 1 Batch 1&2 could be as low as 10% and 12% respectively [11].

[14] Based on primary research.

[15] Based on our discussions with project developers.

Table 2
Selection of auctions.

Auction program	Similar country as India	Variation – success (S)/failure (F)[a]	Data availability	Selected for overall further study – 20 auctions	Selected for cost-effectiveness analysis – 17 auctions	Selected for deployment effectiveness analysis – 12 auctions
India JNNSM Phase 1 Batch 1 (Dec 2010)	Yes	Yes (S)	Yes	Yes	Yes	Yes
Karnataka Solar PV Phase 1 (Oct 2011)	Yes	Yes (S)	Yes	Yes	Yes	Yes
India JNNSM Phase 1 Batch 2 (Dec 2011)	Yes	Yes (S)	Yes	Yes	Yes	Yes
Tamil Nadu Solar PV Phase 1 (Dec 2012)	Yes	Yes (F)	Yes	Yes	Yes	Yes
Andhra Pradesh Solar PV (Feb 2013)	Yes	Yes (F)	Yes	Yes	Yes	Yes
Uttar Pradesh Solar PV (Mar 2013)	Yes	Yes (F)	Yes	Yes	Yes	Yes
Bihar Solar PV (Jul 2013)	Yes	Yes (F)	No	No	No	No
Karnataka Solar PV Phase 2 (Aug 2013)	Yes	Yes (S)	Yes	Yes	Yes	No (Too early - commissioning data not available)
Madhya Pradesh Solar PV (Jan 2014)	Yes	Yes (S)	Yes	Yes	Yes	No (Too early - commissioning data not available)
UK NFFO-1 (1990)	No	Yes (F)	Yes	Yes	No (lack of comparable FIT)	Yes
UK NFFO-2 (1991)	No	Yes (F)	Yes	Yes	No (lack of comparable FIT)	Yes
UK NFFO-3 (1994)	No	Yes (F)	Yes	Yes	Yes	Yes
UK NFFO-4 (1997)	No	Yes (F)	Yes	Yes	Yes	Yes
UK NFFO-4 (1998)	No	Yes (F)	Yes	Yes	Yes	Yes
Peru Wind (2009)	Yes	Yes (S)	No	No	No	No
Peru Solar PV (2009)	Yes	Yes (S)	No	No	No	No
Brazil Wind Phase 1 (Dec 2009)	Yes	Yes (F)	Yes	Yes	Yes	Yes
Brazil Wind Phase 2 (Aug 2010)	Yes	Yes (S)	Yes	Yes	Yes	No (Data not available)
California RAM 1 & 2 (Nov 2011 & Apr 2012)	No	Yes (S)	Yes	Yes	No (lack of comparable FIT)	No (Too early - commissioning data not available)
Morocco Wind Phase 1 (2011)	Yes	Yes (S)	No	No	No	No
Morocco Solar (2012)	Yes	NA	No	No	No	No
S. Africa Wind Phase 1 (2011)	Yes	Yes (F)	Yes	Yes	Yes	No (Too early - commissioning data not available)
S. Africa Solar PV Phase 1 (2011)	Yes	Yes (F)	Yes	Yes	Yes	No (Too early - commissioning data not available)
S. Africa Wind Phase 2 (2012)	Yes	Yes (S)	Yes	Yes	Yes	No (deadline for commissioning is around Apr 2015)
S. Africa Solar Phase 2 (2012)	Yes	Yes (S)	Yes	Yes	Yes	No (deadline for commissioning is around Apr 2015)

[a] The success/failure cited here are preliminary findings from literature review and not from our own analysis.

but face the uncertainty of not winning a project under auctions. Developers are also subjected to the stop-and-go approach of auctions as they have to wait for the government/procurer to hold auctions at timely intervals. Some studies indicate that because of these intangible costs, financing costs of projects under auctions could increase compared with projects under feed-in tariffs, due to uncertainty and higher perceived risks for investors [1].

3.1.2. Deployment effectiveness

For the auctions we studied, although some auctions were able to deploy capacity successfully, many were not able to deploy the full-intended amount, due to poor risk management. Only 17% of the auctions were *successful* with greater than 75% deployment, while 8% were *somewhat successful* with 50–75% deployment, and 75% were *highly unsuccessful* with less than 25% deployment (Fig. 3).[16]

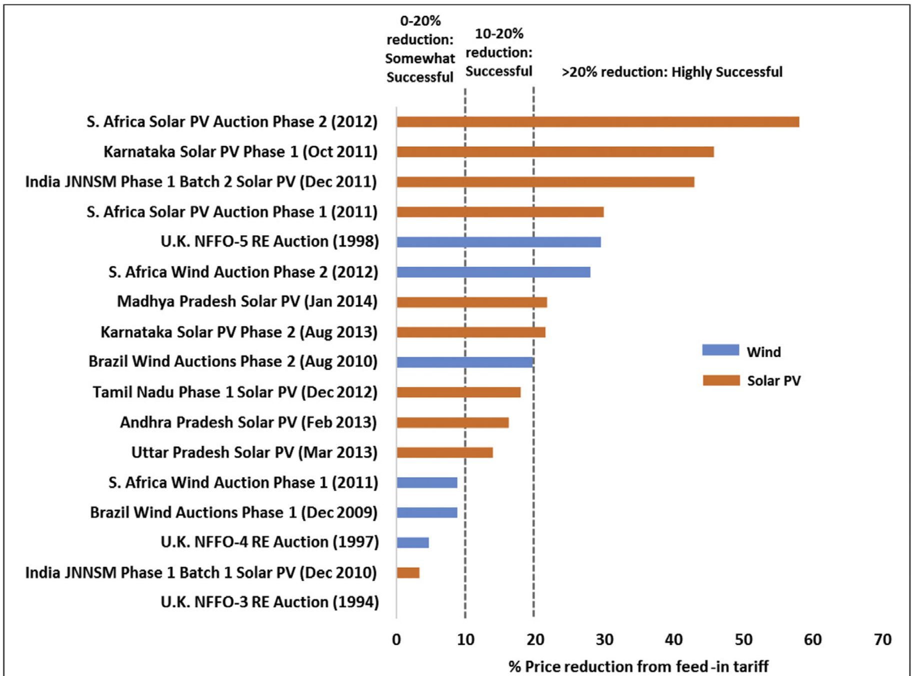
Deployment effectiveness was primarily impeded by poor risk management. It is important to note, however, that project risks, which are risks that can affect all procurement mechanisms, affected deployment more than risks specific to auctions (this is discussed more in Section 3.2). This indicates that auctions specifically were not entirely responsible for poor deployment.

This is evident in India as well, where other procurement mechanisms such as feed-in tariffs have experienced poor deployment. For example, Rajasthan's wind power feed-in tariff policy of 2004, which allotted a total of 12,435 MW of projects in 2004–2012, resulted in deployment of only 1790 MW, or 14% of the total capacity that was allotted [39]. Karnataka also recorded poor deployment effectiveness of 20% under their feed-in tariff policy [22]. On the other hand, auctions that managed risks well, such as India's JNNSM auctions, were successful in deployment. We discuss this further in Section 3.2.

3.1.3. Equity

We found that auctions led to fair allocation of projects in the majority of cases, when policy was designed to encourage high participation and limit allowed capacity per bidder. Among the 12 auctions we examined, around 2/3rds of the auctions were competitive or moderately concentrated, meaning that capacity was allocated to a large number of developers. Approximately 1/3rd

[16] This does not include - Karnataka Solar PV Phase 2 (Aug 2013), Madhya Pradesh Solar PV (Jan 2014), Brazil's Wind Phase 2, California's RAM 1&2, and South Africa's Phase 1&2 Wind and Solar auctions –as they are too recent and are yet to reach the deadline for commissioning.



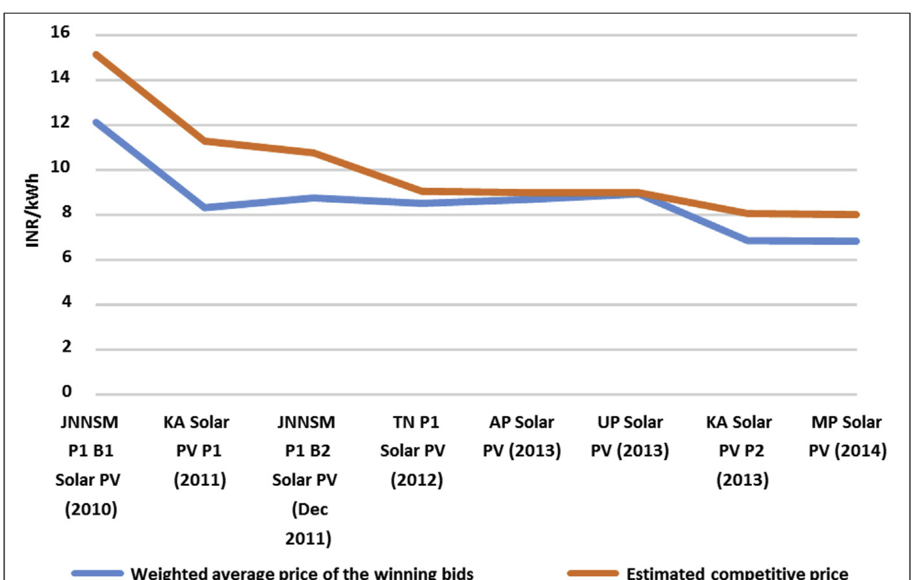
*Using the Gujarat feed-in tariff as the baseline, the tariff reduction achieved is 3.3%. Using CERC's benchmark tariff as the baseline, the tariff reduction is 32.3%.
Sources: World Bank, GERC, MNRE, Panchabuta, Economic Times, KREDL, Re-Solve, EfficientCarbon, IFC, IRENA, ANEEL, GWEC

Fig. 1. Cost-effectiveness of auctions.

of the auctions were highly concentrated, with a few dominant developers garnering the majority of the capacity auctioned (Table 3).

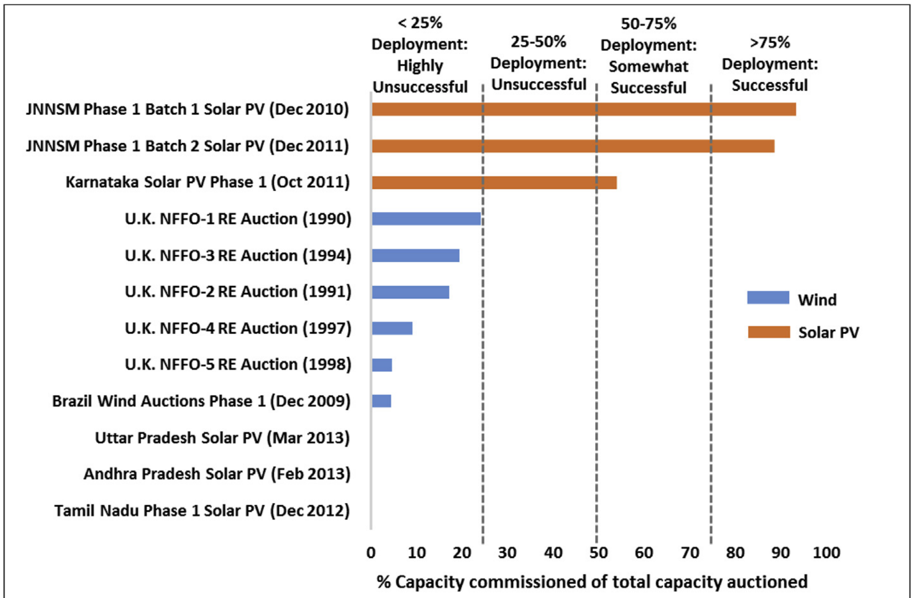
Auctions designed to allocate capacity to multiple players, such as through a limit on capacity per bidder, would likely improve cost-effectiveness by encouraging competition, as well as increase deployment effectiveness by diversifying developer-specific risks, such as bankruptcy of the developer, which can lead to delayed or abandoned projects.

Some of the auctions we examined included a limit on capacity per project instead of a limit per bidder and some both. A cap on capacity per project would ensure that high volume of capacity is not concentrated at any one geographic location, which could burden the transmission network. Auctions that included limit on capacity per bidder were successful in allocating capacity in a competitive manner, for example, the Indian Solar PV auctions of



Source: NVVN, KREDL, NEDA, CERC, Efficientcarbon, re-solve

Fig. 2. Auction tariffs vs. competitive tariffs.



Source: MNRE, KREDL, Re-Solve, NEDA, Efficientcarbon, Aneel, Windpowermonthly
Note: All capacity commissioned data is as on date (~Sept 2014), except for Brazil auctions for which data pertains to Aug 2012.

Fig. 3. Deployment effectiveness of auctions.

Table 3
Capacity allocations in auctions.

Auction	Total capacity auctioned (MW)	HHI score	Remarks	Limit per bidder (MW)	Limit per project (MW)
JNNSM Batch 1 Phase 1 Solar PV (Dec 2010)	150	333	Competitive	5	5
Karnataka Solar PV Phase 1 (Oct 2011)	50	1411	Moderately concentrated	10	10
JNNSM Batch 2 Phase 1 Solar PV (Dec 2011)	350	661	Competitive	50	20
Tamil Nadu Phase 1 Solar PV (Dec 2012)	1000	271	Competitive	No limit	No limit
Uttar Pradesh Solar PV (Mar 2013)	200	2189	Highly concentrated	50	50
Karnataka Solar PV Phase 2 (Aug 2013)	130	828	Competitive	10	10
Madhya Pradesh Solar PV (Jan 2014)	100	2050	Highly concentrated	No limit	No limit
Brazil Wind Auctions Phase 1 (Dec 2009)	13,341	2802	Highly concentrated	No info	No info
S. Africa Wind Auction Phase 1 (2011)	1850	1682	Moderately concentrated	No limit	140
S. Africa Wind Auction Phase 2 (2012)	650	1871	Highly concentrated	No limit	140
S. Africa Solar PV Auction Phase 1 (2011)	1450	1230	Moderately concentrated	No limit	75
S. Africa Solar PV Auction Phase 2 (2012)	450	1543	Moderately concentrated	No limit	75

Sources: MNRE, KREDL, Re-Solve, NEDA, EfficientCarbon, ANEEL, Eskom, Windpowermonthly.

National Solar Mission and Karnataka. Auctions such as Madhya Pradesh and South African solar and wind auctions, which did not include a limit on capacity per bidder, resulted in concentrated capacity allocations.

3.2. Diagnosis

We examined the impact of the seven identified risks (Table 1) on the cost- and deployment effectiveness of auctions both qualitatively and quantitatively. Our findings are categorized under high-level heads of total risk, auction-specific, and project risks. We have also presented the results from statistical analysis in Appendix B.

3.2.1. Total risk

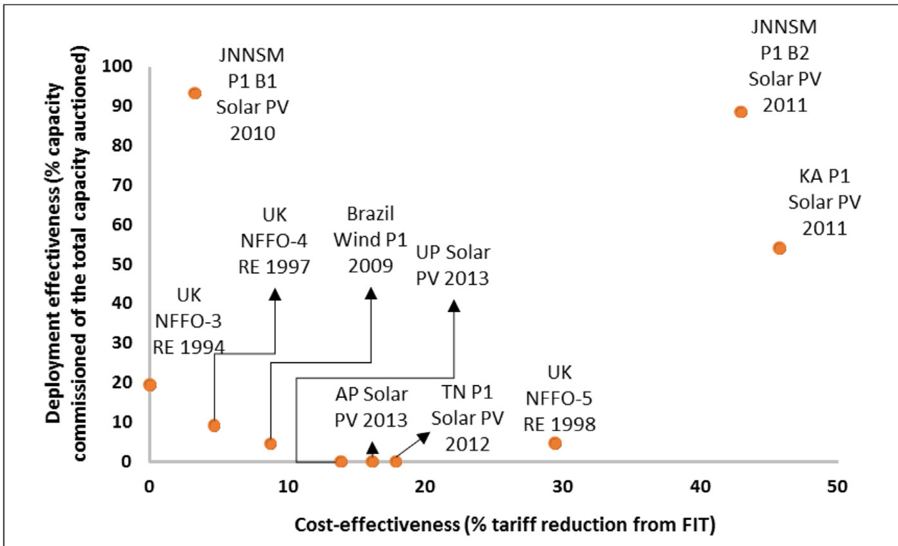
Total risk, which is the combination of all seven individual risks, has a negative impact on both cost and deployment effectiveness, as expected.[17] Although we found that an increase in total risk results in lower cost-effectiveness, we would need more data for statistically significant (i.e., more than 90% confidence) results. Our findings were more conclusive for deployment effectiveness. We found that, for a 20% increase in risk from its mid-value (i.e., 0.5 for the normalized total risk), deployment effectiveness decreased by 38% points; that is, for every 1% increase in total risk, deployment effectiveness decreased by nearly 2% points. This underscores the need for increased focus on risk reduction to ensure deployment.

3.2.2. Project risks vs. auction specific risks

Project risks had a higher impact on deployment effectiveness than auction-specific risks. Between the risks that affect all renewable energy projects (project risks) and risks that affect only auctions (auction-specific risks), we found that project risks had a greater effect.

We found that project risks did not significantly impact cost-effectiveness. On the other hand, we found that project risks have approximately 60% greater negative impact than auction-specific risks on deployment effectiveness. This indicates that

[17] Total risk is the sum of quantitative values assigned to individual risks based on intensity.



Sources: MNRE, KREDL, Re-Solve, NEDA, Efficientcarbon, Aneel, Windpowermonthly, World Bank, GERC, Panchabuta, Economic Times, IFC, IRENA, ANEEL, GWEC
P1 = Phase 1
B1, B2 = Batch 1 and 2 respectively

Fig. 4. Cost-effectiveness vs. deployment.

policymakers should focus more on project risks to ensure deployment.

3.2.3. Individual risks

Among all the risks that affected the cost-effectiveness of auctions, we found that auction design, and specifically when the design did not encourage enough competition for the capacity auctioned, was the only risk that had a statistically significant impact.[18] For example, in South Africa's solar power auctions, where the auction design risk was high, the tariff reduction was only 30%. In comparison, an auction with low auction design risk recorded a tariff reduction of 58%.

We found that this risk can be reduced if policymakers ensure more competition by auctioning a volume of capacity, which is well within the market's ability to supply. For example, in auctions in South Africa, this strategy resulted in an additional 28% point reduction in auction-discovered tariffs compared to the baseline feed-in tariff. In Phase 1 of South Africa's Wind and Solar Auctions, there was no cap on the volume of capacity auctioned, which led to less competition and a tariff reduction of 30%. In Phase 2, the volume of capacity auctioned was limited, which led to more competition and a greater tariff reduction of 58% [12].

Deployment effectiveness is most affected by auction design risk, completion risk, and financial risk. Auction design, specifically with respect to flawed tariff determination, has impacted deployment effectiveness. For example, in the Indian Solar PV auctions of Tamil Nadu Phase 1 (Dec 2012) and Andhra Pradesh (Feb 2013), under the auction design, selected bidders were asked to match the lowest bid in order to sign a contract [13,35]. This forced bidders with different cost structures to accept the lowest bid and commission the projects at a loss, which led to poor deployment.

3.3. Achieving both cost and deployment effectiveness

Policymakers have concerns on whether high tariff reductions achieved in auctions could lead to deployment failure, due to underbidding and, therefore, low returns to investors that ultimately make the projects financially unviable. This was evident in the U.K. NFFO auctions, in which many developers underbid and eventually failed to commission their projects.

We examined ten auctions, for which we have both cost and deployment data, to determine whether there is tension between cost and deployment effectiveness. As shown earlier, while almost all the auctions were cost-effective, only a few were effective in both cost and deployment (Fig. 4).

However, high cost-effectiveness need not be always a result of underbidding. Our analysis indicates that deployment failure in many of the auctions was independent of the tariff reductions.[19] As stated earlier, flawed auction design with respect to tariff determination method, lack of penalties, and payment security mechanisms (when off-taker risk was high), as well as lack of support policies for transmission infrastructure development led to poor deployment.

With proper risk management, both cost and deployment effectiveness can be achieved together. Auctions that are designed well with respect to managing risks have achieved success in both cost and deployment effectiveness; for example, JNNSM Solar Phase 1 Batch 1 and 2 and Karnataka Solar Phase 1. In Table 4, we highlighted how various risk factors were managed through specific design elements in some of the auctions.

Auctions that have been successful in both cost and deployment effectiveness used design elements such as penalties for failure to

[18] Another factor that likely played a role in cost-effectiveness is market timing. An example of market timing driving tariff reductions would be the Indian national solar auctions, which were introduced at a time (2010–11) when solar module prices in the global market were declining due to slowdown in demand in key economies [45]. Several state solar auctions quickly followed the national auctions to benefit from the slump in global module prices and the experience gained in the national auctions. However, we would not consider market timing as an auction design element as timing of auctions would be an extremely difficult exercise for policymakers.

[19] We did not find a statistically significant and negative relationship between cost and deployment effectiveness.

Table 4
Design elements to manage risks in renewable energy auctions.

Individual risks	Risk factors	Likely impact on auction effectiveness	Design elements to manage the risks	Examples of auctions which used these elements
Auction design	Flawed tariff determination (L1 process)	Impacts deployment effectiveness as L1 process will force developers other than the lowest bidder to commission projects at a loss	Pay-as-bid instead of L1 process of tariff determination	All the auctions except Tamil Nadu Phase 1 Solar PV and Andhra Pradesh Solar PV
	Lack of competition	Impacts cost-effectiveness of auctions	Limit on capacity auctioned	All auctions except South Africa Wind and Solar Phase 1
	Favoring a specific technology (technology neutral auctions)	Impacts the uptake of new technologies as matured technology would be more competitive	Technology-specific auctions	All auctions except Brazil Wind Phase 1&2 and California RAM 1&2
	Contract re-negotiations	Impacts cost- and deployment effectiveness as developers seek higher tariff and negotiate for new power purchase contracts	1) Non-negotiable power purchase contracts; 2) In-built flexibility in PPAs allowing surplus and shortfall in production to be set-off in 4-year block periods	1) South Africa Wind and Solar Phase 1&2; 2) Brazil Wind auctions Phase 1&2
Underbidding	Aggressive and unrealistic bids by non-serious bidders	Impacts deployment effectiveness due to financial unviability	Penalties for failure to commission projects	All the auctions except U.K. NFFO auctions
Collusion	Lack of tariff reduction	Impacts cost-effectiveness as bidders collude to keep tariffs higher	Ensure high competition and adopt sealed-bid auction	Most of the auctions used sealed-bid auctions except Brazil Wind Phase 1&2, which used descending clock auction.
Completion risk	Delay in environmental and other regulatory permits	Impacts deployment effectiveness	1) Pre-bid environmental license requirement; 2) Procurer/Govt. handles these risks	1) Brazil Wind Phase 1&2 and South Africa Wind and Solar Phase 1&2; 2) India's coal Ultra Mega Power Plant auctions
	Delay in transmission interconnection	Impacts deployment effectiveness	Pre-bid grid access studies	India JNNSM Phase 1, Brazil Wind Phase 1&2, South Africa Wind and Solar Phase 1&2
Technology risk	1) Lack of accurate resource data; 2) Resource variability	1) Impacts electricity production of already commissioned plants as developers lack prior knowledge of the resource; 2) Impacts revenues if quantity of resource falls short of the expected quantity stated in the contract.	1) Certified pre-bid ground resource studies; 2) Weather derivatives/insurance	1) Brazil Wind Phase 1&2, South Africa Wind and Solar Phase 1&2; 2) None of the auctions we examined had these as part of the auction design, but individual developers may have utilized these instruments.
Financial risk	Projects not able to achieve financial closure	Impacts deployment effectiveness due to financial unviability of projects	1) Pre-bid financial criteria, 2) Concessional finance, and 3) Financial underwriting of bids	1) Almost all auctions, 2) Brazil Wind Phase 1&2, and 3) South Africa Wind and Solar Phase 1&2
Off-taker/ counterparty risk	Payment default by procurer	Impacts the financial viability of the project	1) A sovereign guarantee providing payment security in case off-taker payment default; 2) Centralized procurement through a financially strong off-taker and re-sale to regional utilities	1) India JNNSM Phase 1 Batch 1 PV, South Africa Wind and Solar Phase 1&2; 2) India JNNSM Phase 1, Brazil Wind Phase 1&2, South Africa Wind and Solar Phase 1&2

Source: CPI Analysis.

commission projects to manage underbidding risk. These auctions also ensured the presence of high competition to drive cost-effectiveness. In addition, other project risks such as off-taker risk were addressed through a payment guarantee mechanism to ensure deployment. Managing both auction-specific and project risks effectively ensured that these auctions achieved both cost and deployment effectiveness together.

It is also important to note that despite the use of certain design elements, some auctions have failed to achieve cost and deployment effectiveness due to the inadequacy of those design elements. In the case of Brazil wind energy auctions; although the auctions included design elements to handle completion risks (Table 3), they were only designed to partially manage these risks. For instance, environmental permits in Brazil are obtained through a complex three-phase process, which can cause delays, and the auction design only required the first-phase permit as a prerequisite to bid [8].

Therefore, auctions should not only include risk mitigating design elements, but also ensure that those design elements are effective. Further research is required to determine how to improve the effectiveness of risk mitigating design elements.

3.4. Designing effective wind power auctions in India

Wind developers in India fear higher completion and technology risks under auctions. Given significant developer resistance to wind energy auctions in India, we gave special attention to assessing the feasibility of wind auctions. From our discussions with wind project developers in India, we learned that they were concerned that completion and technology risks, which are generally higher for wind power compared with solar power, would increase further under auctions. Our research indicates that these concerns are valid to a certain extent. Completion risk, specifically delays in land acquisition and lack of transmission interconnection, could affect commissioning projects on time. Land acquisition is a problem in India due to small landholdings and lack of land purchase options [27]. This means dealing with multiple small landowners and higher upfront land costs.

Another completion risk, transmission interconnection, may also be exacerbated under auctions, as wind resources are not as well dispersed as solar resources in India. Holding a nationwide wind auction would most likely lead to a concentration of wind farms in high wind zones. This may require building new transmission lines or increasing the capacity of existing network, which could lead to completion delays. In addition, technology risk, which in this context means high resource variability coupled with a lack of conclusive resource assessments for India can present a greater challenge to wind projects than solar projects [32].

Wind power auctions in the U.K., Brazil, and South Africa, as well as coal-power auctions in India, have shown that flawed auction design and high completion risk can lead to a failure in deployment. South Africa's wind power auctions, similar to the U.K. and Brazil wind power auctions, did not include comprehensive policy support for building a transmission network to connect the expected new wind capacity, which prevented completed projects from connecting to the grid on time [12].

In coal auctions, to mitigate the high completion risks associated with large power projects, India adopted Case-2 type bidding for coal Ultra Mega Power Projects (UMPP), where the government bears the risk of land acquisition and other regulatory permits [31]. However, even with Case-2 type bidding, the first round of coal UMPP projects have yet to witness success in terms of deployment. Out of the four projects that were allotted, only one project, Mundra, has been able to commission all the units so far, albeit with a delay. The delays in commissioning the projects were largely due to developers seeking contract re-negotiation, due to a change in imported coal prices from Indonesia, and to a government delay in procuring land and permits [3,13]. These problems could occur in potential wind power auctions as well.

Given these concerns and evidence from other countries that wind auctions can lead to inadequate deployment, wind project developers have opposed attempts to introduce auctions for procurement of wind power in India. However, due to the possibility of a higher cost of support under feed-in tariff mechanism, auctions are worth considering, but they should be introduced cautiously and in a controlled environment. We suggest the following steps:

First, to counter underbidding, an auction-specific risk, strong penalties for not commissioning projects should be included, and perhaps bids could be completely underwritten by debt and equity investors as a prerequisite, as in the case of the South African wind and solar auctions (Table 4).

Second, for handling project risks such as delays in land acquisition, transmission interconnection, and resource assessment (technology risk), as a transition path, the government can bear the risk of land acquisition and other regulatory permits. Given the problems being faced in the execution of the coal UMPP projects, which were auctioned under a similar model, we suggest land acquisition and other regulatory permits be obtained before auctions are held.

Third, the government could hold a location-specific auction once it identifies the land. Identifying the land prior to auctions would give adequate time for developers to undertake resource assessment studies. The government should also require that on-ground resource assessment studies by developers and certified production estimates by an independent evaluator be completed prior to bidding, as in the case of the Brazil Wind power auctions (Table 4).

Fourth, to reduce the risk of variability in wind power production (another technology risk),[20] a design feature that allows squaring off excess production with shortfalls over four-year blocks would likely reduce the burden of penalties for variation in power production, as in the Brazil wind power auctions (Table 4).

[20] Due to high variability in wind power production, developers may not be comfortable to place bids for tariffs that would be applicable for long-term (20–25 years), given the expected high penalties for variations in power production and reduced profit margins under highly competitive auctions.

Finally, to reduce the risk of contract re-negotiation owing to changes in fuel prices (for example, in the coal UMPP auctions), which is similar to what could happen for wind power due to poor wind resource assessment, prior identification of land and a prerequisite of resource assessment would likely help. This may be combined with other design features, such as contractual flexibility in carrying forward gains and losses in production and non-negotiable power purchase agreements (used in the South Africa wind and solar auctions).

It is important to note that the above suggestions are meant to apply to interim auctions, which would act as a transition mechanism from the current feed-in tariff based procurement to an auctions-based procurement for wind power in India. Further research is required for designing full-fledged auctions for wind power.

4. Conclusions

Auctions for renewable energy are gaining popularity around the world due to their potential as a more cost-effective mechanism for the government. In this context, we examined auctions in India and elsewhere to answer two questions. First, have auctions been effective as a project allocation mechanism? Second, how can they be designed to achieve India's renewable energy targets? We assessed whether auctions are desirable as a project selection mechanism by examining 20 renewable energy auctions around the world with respect to cost-effectiveness, deployment effectiveness, and equity in project allocation.

Our analysis indicated that, if auctions are designed appropriately to manage risks, they can deploy renewable energy capacity in a cost-effective and fair manner. We summarized the design features that would likely make auctions more successful below.

4.1. Cost-effectiveness

We defined cost-effectiveness as a reduction in tariffs due to auctions when compared with a baseline feed-in tariff. Given that government cost of support is directly proportional to these tariffs, this reduction directly relates to a reduction in government cost of support. In this context, we also examined whether auctions are discovering tariffs that are close to the rate of renewable electricity that a competitive market would discover,[21] and whether transaction costs impact cost-effectiveness.

First, we found that auction-discovered tariffs were almost always lower than the baseline feed-in tariffs for the auctions we studied, meaning they were almost always cost-effective. We observed savings of up to 58% from the baseline feed-in tariff. 47% of the auctions had savings of greater than 20%; 24% had savings of 10–20%; and 29% had savings of up to 10%.

Cost-effectiveness in auctions is affected most by auction design risk, which is risk related to the design of auctions such as the volume of capacity to be auctioned and type of bidding. In particular, an auction is not cost-effective when there is not enough competition for the capacity auctioned. Controlling the renewable capacity auctioned and encouraging participation from project developers can result in sufficient competition and increased cost-effectiveness.

Hence, to increase cost-effectiveness, which is affected most by auction design risk, policymakers should ensure high competition by setting the volume of capacity auctioned well within the

[21] A price from auctions that is too high means that the auction was not as cost-effective as it could have been, while a price from auctions that is too low increases the risk of non-deployment.

Table 5
Regression results showing relationship between total risk and deployment effectiveness.

	Coefficients	Standard error	t Stat	P-value
Intercept	56.13168	16.86562	3.328172	0.007641
Total risk	−73.7842	35.869	−2.05705	0.066717

Table 6
Regression results showing relationship between project risk, auction risk, and deployment effectiveness.

Source	Value	Standard error	t	Pr > |t|
Intercept	105.747	28.366	3.728	0.005
Project risk	−92.968	29.405	−3.162	0.012
Auction risk	−57.242	27.475	−2.083	0.067

market's ability to supply. For example, even if the market is capable of supporting multiple GW of capacity at any time, restricting an auction to below 1 GW would ensure that there is enough competition; a practice typically followed successful in the national level solar auctions in India.

Second, we found that auction-discovered tariffs for solar projects in India have moved closer to market tariffs. Auction-discovered tariffs moved from within 23–35% of competitive tariffs in 2010–2011 to within 1–6% by 2012–2013. This could be due to reasons such as – auctions dynamically tracking reductions in costs of solar power or because of improvements in Indian electricity market regulator's benchmark tariff estimates, on which our estimates of competitive tariffs relied upon.

Third, when we looked at whether auctions might lead to increased costs for project developers, we did not find any additional transaction costs when compared with feed-in tariffs. However, developers are concerned about the indirect financing costs due to uncertainty about auction outcomes. The intangible costs involved in auctions may push the project costs higher under auctions in the long term compared with projects under feed-in tariffs as noted by some studies [1,4]. This has to be investigated further.

4.2. Deployment effectiveness

We defined deployment effectiveness as the ability of auctions to deploy the capacity of renewable energy intended through these auctions. Among the auctions we studied, although some auctions were able to deploy capacity successfully, many were not able to deploy the full intended amount. Only 17% of the auctions had greater than 75% deployment of the capacity auctioned, while 8% had 50–75% deployment, and 75% had less than 25% deployment.

Deployment effectiveness is most affected by auction design risk, completion risk (which is the risk of all factors that could delay the commissioning of projects), and financial risk (which is the risk of projects not being able to raise finance due to low bid prices or high off-taker risk). We found that auction design risk to deployment effectiveness in terms of underbidding can be best managed by imposing strong penalties for not commissioning the projects. Addressing problems associated with delays in transmission interconnection through support policies for transmission infrastructure expansion, and problems associated with poor financial health of the off-taker through a payment security mechanism [9], can minimize completion and financial risks.[22]

We also found that it is important to consider both cost-effectiveness and deployment effectiveness together. Designing auctions with the sole objective of cost-effectiveness, as in the case of auctions in which all bidders were asked to match the lowest bid, could negatively affect deployment. Auctions that were balanced in their objectives and managed risks well have demonstrated that both cost and deployment effectiveness can be achieved together (Section 3.3).

Hence, to improve deployment effectiveness, which is most affected by completion and financial risks, policymakers should use support policies to improve transmission infrastructure, provide payment guarantees to reduce off-taker risk, and use a pay-*as*-bid type of tariff determination instead of forcing selected bidders to match the lowest bid. For further improvement of deployment effectiveness, which is also affected by underbidding risk, include stringent penalties for delays in commissioning of projects.

We also specifically examined the possibility of introducing auctions for wind power procurement in India considering the ongoing discussions on this issue between the Indian policymakers and the Indian wind power industry (Section 3.4). Given the concerns of project developers in India and our assessment of risks, we suggest that the Indian government develop an interim auctions mechanism, which would act as a transition mechanism from the current feed-in tariff regime. Policymakers should design the interim auctions program to include features such as strong penalties for delays in commissioning, a location-specific auction with the government bearing the land acquisition and transmission interconnection risk, and identification of land prior to bidding coupled with prior resource assessment.

4.3. Equity

We defined equity as whether the total planned capacity of renewable energy is allocated to project developers in a fair manner. Policymakers should note that auctions led to fair allocation of projects in the majority of cases, when policy was designed to encourage high participation and limited the allowed capacity per bidder. Among the auctions we examined, around 2/3^{rds} of the auctions were competitive or moderately concentrated, meaning that capacity was allocated to a large number of developers. Capacity allocations in approximately 1/3rd of the auctions were highly concentrated, with a few dominant developers garnering the majority of the capacity auctioned.

Appendix. A. Assumptions for competitive tariff calculation

We used our own levelized cost of electricity (LCOE) models to estimate the competitive prices for auctions studied based on the following assumptions:

- Most of the data points such as capacity utilization factor (19%), useful life (25 years), working capital requirements (payables: 45 days, receivables: 60 days), taxes, debt-equity ratio (70:30), and interest rate (in the range of 12.30–13.39%) were taken from CERC's benchmark tariff orders applicable for that year.
- We have taken capital cost (which is in the range of INR 6.91–13.70 Cr./MW (USD 1.1–2.2 million/MW) over the years) closer to the date of commissioning i.e., we considered one-year forward prices as solar PV projects typically take 12 months to be built. Developers also usually bid with one-year forward expected prices.
- CERC's return on equity (ROE) appeared to be high at 22% when compared with our primary research findings. We have taken ROE (in the range of 16.99–17.25%) based on primary research

[22] To see individual auctions and how they were affected by these risks, refer to Table 2 in Section 3.

Table 7
Association coefficients showing relationship between different risk types and deployment effectiveness.

Independent variable	Association coefficients with deployment		P-value (contingency table)
	Goodman and Kruskal Gamma	Kendall's tau	
Completion risk	−0.829	−0.587	0.078
Auction design risk	−1.000	−0.685	0.007
Financial risk	−0.600	−0.411	0.106
Off-taker risk	−0.130	−0.066	0.582
Underbidding	−0.016	−0.010	0.581
Collusion	0.207	0.124	0.099
Technology risk	0.429	0.231	0.581

Table 8
Association coefficients showing relationship between different risk types and cost effectiveness.

Independent variable	Association coefficients with auction success (% price reduction)		P-value (contingency table)
	Goodman and Kruskal Gamma	Kendall's tau	
Completion risk	−0.236	−0.139	0.283
Auction design risk	−0.529	−0.308	0.165
Financial risk	0.200	0.124	0.178
Off-taker risk	1.000	0.547	0.126
Underbidding	−0.655	−0.400	0.241
Collusion	0.536	0.321	0.364
Technology risk	0.891	0.562	0.044

and data from the PDD documents filed with the UNFCCC by the developers.

B. Regression results

We identified seven individual risks that impact outcomes of renewable energy auctions from a larger universe of risks that affect renewable energy projects under various procurement mechanisms. These independent variables were ordinal-ranked on a scale of 1–3, with 1 denoting least risk and 3 denoting maximum risk. For deployment effectiveness, the dependent variable was quantitatively represented as *percentage capacity commissioned of total capacity auctioned*; whereas for cost-effectiveness, the dependent variable was quantitatively represented as *percentage price reduction from feed-in tariff.*

Total risk

A cumulative score for risk was calculated by adding all seven risks for each of the 19 auctions. These cumulative risk scores were then normalized between 0 and 1. We excluded those auctions for which the deadline for commissioning did not lapse at the time of our research. For the remaining 12 observations, a linear regression was performed between deployment effectiveness and normalized risk score. We found that, for a 20% increase in risk from its mid value (i.e., 0.5), deployment effectiveness decreased by 38% points (Table 5). On the other hand, we did not find a statistically significant relationship between total risk and cost-effectiveness; therefore, we did not include those results.

Project risk vs. auction specific risk

For this analysis, we categorized individual risks into two independent variables - project risks and auction risks. These two independent variables were then regressed against the dependent variables for deployment effectiveness and cost-effectiveness. Again, the same 12 auctions (as above) were used as the sample for the linear regression.

We found that, project risks, which are common to all procurement mechanisms, had a 60% higher impact on deployment effectiveness than auction-specific risks (Table 6): for one unit change in project risk, deployment effectiveness changed by 92.97% points, while a similar change in auction specific risk changed deployment effectiveness by 57.24% points. We also found that project risks did not have a statistically significant impact on cost-effectiveness.

Individual risks

We created contingency tables for each dependent variable with each independent variable. We then generated association coefficients between dependent and independent variables in the range $[-1, 1]$, where -1 denotes perfect inversion (of independent variable with dependent variable) and 1 denotes perfect positive association.

We found that deployment effectiveness is most affected by auction design risk, completion risk, and financial risk (Table 7). Among all the risks that affected the cost-effectiveness of auctions, we found that auction design, and specifically when the design did not encourage enough competition for the capacity auctioned, was the only risk that had a statistically significant impact (Table 8).

References

[1] Bloomberg, Assessing the Effectiveness of Clean Energy Policy; Wind – Research Note, 2011. www.bnefsummit.com.
[2] B. Becker, D. Fischer, Promoting renewable electricity generation in emerging economies, Energy Policy 56 (2013) 446–455.
[3] Business Line, Solar Players Worried over TN Purchase Pact, 2013. http://www.thehindubusinessline.com/todays-paper/tp-others/tp-states/solar-players-worried-over-tn-purchase-pact/article4260121.ece.
[4] L. Butler, K. Neuhoff, Comparison of feed-in tariff, quota and auction mechanisms to support wind power development, Renew. Energy 33 (2008) 1854–1867.
[5] M. Conti, How Renewable Energy Reverse Auction Mechanisms Work in Practice, 2012. https://jmichaelconti.wordpress.com/2012/05/24/reverse-auctions-for-renewable-energy/.
[6] J. Contreras, Y. Rodriguez, Incentives for wind power investment in Columbia, Renew. Energy 87 (1) (2016) 279–288.
[7] P. Cozzi, Assessing Reverse Auctions as a Policy Tool for Renewable Energy Deployment, 2012. Working paper, http://fletcher.tufts.edu/~/media/Fletcher/Microsites/CIERP/Publications/2012/May12CozziReverseAuctions.pdf.

[8] G. Cunha, L.A. Barroso, F. Porrua, B. Bezerra, Fostering wind power through auctions: the Brazilian experience. Int. Assoc. Energy Econ, Second Quarter (2012) 25–27.
[9] CPI, Driving Foreign Investment to Renewable Energy in India: a Payment Security Mechanism to Address Off-taker Risk, 2016. http://climatepolicyinitiative.org/wp-content/uploads/2016/04/Driving-Foreign-Investment-to-Renewable-Energy-in-India_Technical-Report.pdf.
[10] R. Deshmukh, A. Gambhir, G. Sant, India's solar mission: procurement and auctions, Econ. Political Wkly. XLVI (28) (2011).
[11] C. Donovan, Discussion Paper Series on Asset Pricing: Renewable Energy in Growing Economies, 2011.
[12] A. Eberhard, J. Kolker, J. Leigland, South Africa's Renewable Energy IPP Procurement Program: Success Factors and Lessons, 2014. World Bank working paper, http://www.gsb.uct.ac.za/files/PPIAFReport.pdf.
[13] Economic Times, Tamil Nadu may Be Rushing Too Fast towards Solar Power, 2012. http://economictimes.indiatimes.com/industry/energy/power/tamil-nadu-may-be-rushing-too-fast-towards-solar-power/articleshow/17688469.cms.
[14] K. Eisenhardt, Building theories from case study research, Acad. Manag. Rev. 14 (4) (1989) 532–550.
[15] A. Farooquee, G. Shrimali, Making renewable energy competitive in India: reducing financing costs via a government-sponsored hedging facility, Energy Policy (2016) (in press), http://www.sciencedirect.com/science/article/pii/S0301421516300465.
[16] G. Ferruzzi, G. Cervone, L. Monache, G. Graditi, F. Jacobone, Optimal bidding in a Day-Ahead energy market for Micro Grid under uncertainty in renewable energy production, Energy 106 (2016) 194–202. http://www.sciencedirect.com/science/article/pii/S0360544216302432.
[17] J. Hoppmann, M. Peters, M. Schneider, V. Hoffmann, The two faces of market support – how deployment policies affect technological exploration and exploitation in the solar photovoltaic industry, Res. Policy 42 (4) (2013) 989–1003.
[18] IEA, Deploying Renewables – Best and Future Policy Practice, 2011. https://www.iea.org/publications/freepublications/publication/Deploying_Renewables2011.pdf.
[19] IRENA, Renewable Energy Auctions in Developing Countries, 2013. https://www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_energy_auctions_in_developing_countries.pdf.
[20] KREDL, Order of the Govt. of Karnataka, 2011. http://kredlinfo.in/GO/feestucture.pdf.
[21] KREDL, Request for Proposal for 50MW Solar PV, 2014.
[22] KREDL, 2015; Website accessed in March 2015; http://kredlinfo.in/projwind.aspx.
[23] C. Kreycik, T. Couture, K. Cory, Procurement Options for New Renewable Electricity Supply, 2011. NREL Technical Report 6A20–52983, http://www.nrel.gov/docs/fy12osti/52983.pdf.
[24] A. Kylili, P. Fokaides, Competitive Auction Mechanisms for the Promotion of Renewable Energy Technologies: the Case of the 50 MW Photovoltaics Projects in Cyprus, 2015. http://www.sciencedirect.com/science/article/pii/S1364032114008399.
[25] R. Likert, A technique for the measurement of attitudes, Arch. Psychol. 22 (140) (1932) 1–55.
[26] D. Malagueta, A. Szklo, R. Soria, R. Dutra, R. Schaeffer, B. Borba, Potential and impacts of Concentrated Solar Power (CSP) integration in the Brazilian Electric Power System, 2014. http://www.sciencedirect.com/science/article/pii/S0960148114000809.
[27] Market Line, Suzlon Energy Company Profile, 2014. http://store.marketline.com/Product/suzlon_energy_limited?productid=9D1C9B19-BF3C-4966-A435-60171560A1FA.
[28] L. Maurer, L. Barroso, Electricity Auctions: an Overview of Efficient Practices, 2011. IFC Working paper, http://www.ifc.org/wps/wcm/connect/8a92fa004aabaa73977bd79e0dc67fc6/Electricity+and+Demand+Side+Auctions.pdf?MOD=AJPERES.
[29] MNRE, Guidelines for Tariff Based Competitive Bidding Process for Grid Connected Power Projects Based on Renewable Energy Sources, 2012. http://mnre.gov.in/file-manager/UserFiles/guidelines_sbd_tariff_gridconnected_res/guidelines_tariff_grid_re.pdf.
[30] MNRE, Outcome Budget 2013-14, 2014. http://mnre.gov.in/file-manager/UserFiles/outcome-budget-mnre-2013-14.pdf.
[31] MoP, Ultra Mega Power Projects, Govt. of India, Ministry of Power, 2007. http://powermin.nic.in/upload/pdf/ultra_mega_project.pdf.
[32] A. Phadke, R. Bharvirkar, J. Khangura, Reassessing Wind Potential Estimates for India: Economic and Policy Implications, 2011. LBNL working paper, https://ies.lbl.gov/sites/all/files/lbnl-5077e_1.pdf.
[33] PVTECH, India Renewables Budget Takes Big Hit, 2014. http://www.pv-tech.org/news/india_slashes_renewables_budget_by_more_than_two_thirds_for_2014.
[34] RERC, In the Matter of RERC Regulation, 2012. http://www.rerc.rajasthan.gov.in/Orders/Order140.pdf.
[35] Re-Solve, Andhra Pradesh Solar – Developers to Put up a Total of 350MW, 2013. http://www.re-solve.in/perspectives-and-insights/andhra-pradesh-solar-developers-to-put-up-a-total-of-350-mw/.
[36] P. Rio, Analysing the interactions between renewable energy promotion and energy efficiency support schemes: the impact of different instruments and design elements, Energy Policy 38 (2010) 4978–4989. http://econpapers.repec.org/article/eeeenepol/v_3a38_3ay_3a2010_3ai_3a9_3ap_3a4978-4989.htm.
[37] P. Rio, E. Cerda, The policy implications of the different interpretations of the cost-effectiveness of renewable electricity support, Energy Policy 64 (2014) 364–372. http://www.sciencedirect.com/science/article/pii/S0301421513009002.
[38] N. Rohankar, A. Jain, O. Nangia, P. Dwivedi, A Study of Existing Solar Power Policy Framework in India for Viability of the Solar Projects Perspective, 2016. http://www.sciencedirect.com/science/article/pii/S1364032115013295.
[39] RRECL, Total Registrations of Wind Power Plants, 2014. Status of wind power projects commissioned: http://www.rrecl.com/PDF/Total%20Wind%20Power%20Projects%20Commissioned%20(Policy%20wise).pdf, http://www.rrecl.com/PDF/Total%20registration%20of%20Wind%20Power%20Plants%20in%20Rajasthan.pdf.
[40] P. Santana, Cost-effectiveness as Energy Policy Mechanisms: the Paradox of Technology-neutral and Technology-specific Policies in the Short and Long Term, 2016. http://www.sciencedirect.com/science/article/pii/S1364032115016834.
[41] S. Shah, Why is the Wind Power Industry in India Afraid of Reverse Auctions in Rajasthan, 2012.
[42] S&P, Key Credit Factors; Methodology and Assumptions on Risks for Utility-scale Solar Photovoltaic Projects, 2009. http://www.standardandpoors.com/en_US/web/guest/ratings/ratings-criteria/-/articles/criteria/corporates/filter/project-finance.
[43] U.S. Department of Justice, Horizontal Merger Guidelines, 1992. http://www.justice.gov/atr/public/guidelines/horiz_book/15.html.
[44] Wind Power Monthly, Connection Problems Start to Limit Growth, 2013. http://www.windpowermonthly.com/article/1209699/connection-problems-start-limit-growth.
[45] World Bank, Paving the Way for a Transformational Future; Lessons from Jawaharlal Nehru National Solar Mission Phase 1, 2013. https://www.esmap.org/sites/esmap.org/files/ESMAP-World%20Bank%20Publication%20-%20Paving%20the%20Way%20for%20a%20Transformational%20Future%20-%20Lessons%20from%20JNNSM%20Phase%20I.pdf.