The Economics of Renewable Power: "It Depends"

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Remarkable. That is the only sentiment that can describe India's success with solar power, with pricing falling from the Regulator (CERC) indicated almost 18 Rs./kWh before the 2010 Jawaharlal Nehru National Solar Mission to perhaps under 7 Rs./kWh as seen in the 2014 2nd Phase of the Mission, Round 1 (adding the notified tariff plus the Viability Gap Funding, and levelizing). This is competitive with global costs (except for comparisons with wide interest rate differentials), and highlights the likelihood of "grid parity" sooner rather than later, which analysts have forecast for 2017.

However, as we've seen in the chapter on grid integration, a simple number for the cost of power isn't always sufficient since renewables are treated as "must run" and many forms/locations don't provide power coincident to the peak demand in India, requiring additional capacity for meeting the peak. Even if no new alternative plant is required, any displaced plant reduces its output, raising its per-unit cost. (Of course, India's shortfalls become a hidden blessing, economically speaking, since RE would then not be displacing other generation, but meeting a shortfall).

Ultimately, the economics of renewable power (rather, all power) needs more nuance, based on time, location, despatchability (controllability), etc. These are just from a grid and operations point of view – adding in societal metrics would require thinking about broader impacts such as the environment, foreign exchange, land use, jobs, etc.

To explore such issues, this chapter presents an analysis on the economics of power for utility procurement. Importantly, it compares grid-scale renewables (without a battery) with coal power, to what extent such a comparison can be made. These economics excludes low hanging fruit of displacing diesel based pumpsets with solar pumpsets, where viability is already strong today, especially given such generation can, for the most part, be opportunistic (harnessed and designed for only when the sun shines). This chapter is only for illustrating the issues and sensitivity analysis, and should not be used to pick a number for the cost of power. Better analyses would look at the grid and impacts at a system level, which can be done with more time, computing resources etc. – probably the biggest need for undertaking such studies is access to granular data.

From a retail consumer perspective, renewables appear far more cost-effective given (a) retail rates are inherently much higher than bulk procurement costs, often 33-50% higher in the US and Europe, and (b) Indian retail tariffs have enormous elements of cross-subsidy, both within categories based on tiered consumption (slabs where larger consumers pay more) as well as across categories, e.g., Commercial and Industrial paying much more than their cost to serve. This highlights the need for comparing apples to apples when considering "grid parity." One could compare "grid parity" at the edge (after removing pricing distortions) but one question remains, what value and services does the grid still provide (such as back-up, reliability, uncertainty mitigation, etc.), and how is it compensated for the same?

ECONOMICS OF ELECTRICITY

How are Generator Prices Set?

There are typically two options for setting prices for generation (and we assume prices are inherently linked to costs, plus a "reasonable" profit) – market-based, and regulated. A good market requires competition and a level playing field, while regulated systems are mostly costs-plus rate-of-return, and common in much of the world.[1] In reality, one could have hybrid systems as well. As the focus is on generation (utility procurement), we can ignore retail tariffs, which have slabs, and cross-subsidies.

From an equilibrium point of view, even if a supplier is paid a fixed (contracted) price, the value to the consumer (rather, utility) varies by time of day, location, etc. Probably the best description of differentiation of power is the analogy to fruit.[2] We (today) think of electricity like selling fruit (Rs./kWh) but the basket we sell is actually a mix of apples, oranges, lychees, mangoes, etc. each with different cost and other characteristics. Blending the supply as per their respective shares may work from an accounting perspective, but it masks important signaling about marginal costs as well as other characteristics of the power. The same is true of blending or pooling "expensive" power – this helps liquidity (payments) but not solvency (financial viability).

Down the road, including through eventual deployment of Smart Grids (which harness advanced digital communications and control to make the grid real-time aware of flows, more robust, etc.), consumer tariffs will become time of day if not real-time. In the short run, we need improved Time of Day characteristics of bulk supply (generation procurement) to better reflect grid conditions and needs.

Some Cost Number Calculations: A Model to Compare Solar PV and Coal

To better understand the nuances involved in pricing, we examine the levelized cost of energy from coal and solar PV for 2014. Levelizing is the process of converting cash flows (and generation) that vary over time into a time-value consistent figure, based on discounting.[3] This should hint at the first issue – what discount rate is to be used? Solar is capital cost heavy (and has no fuel costs, let alone fuel uncertainty or risks), while coal is operating cost heavy, especially in future years as fuel costs are likely to go up with inflation.

The below figures are based on a model made publicly available[4] so one can vary the assumptions of prices, discount rates, interest rates, efficiency, etc., and the model uses median or conservative numbers as a baseline for a new coal plant on domestic versus imported fuel, and solar photovoltaics (PV) from Phase 2 of the National Solar Mission, both open and domestic content categories. For coal, capital costs (Rs./MW) and weighted average cost of capital (WACC) both matter, while for solar, since this was effectively a reverse subsidy auction, the capital costs and WACC don't directly matter (they would be internalized by the bidder).

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Another fundamental differentiator is whether we take the total cost of coal power including capital costs, or whether we choose, for comparison, to only think of

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[1] A Regulator is still an important part of a market-based system, and not just a purely regulated system (with responsibilities in both cases spanning setting fair rules to checking market power to enforcement).

[2] See the book Smart Power (2010, Island Press) by Peter Fox-Penner for more on this concept.

[3] For more details on Levelized Cost of Energy (LCOE) calculations, and their limitations, see "Assessing the Economic Value of New Utility-Scale Renewable Generation Projects", Chris Namovicz, presented at EIA Energy Conference, June 17, 2013 (http://www.eia.gov/conference/2013/pdf/presentations/namovicz.pdf), or an India-centric discussion on power pricing, "Electricity Prices in India: Comparing Apples, Oranges, and Lychees", R. Tongia, Yojana Magazine, vol. 57, Planning Commission, December 2013.

[4] The model is available online at the Brookings India website at http://brookings.in/a-public-model-on-pricing-solar-pv-versus-coal/

solar power as negative demand, in which case only the incremental cost of coal power (mostly fuel) will be the benchmark. While at one level academic, this could actually mirror some utility decisions where the power plant is already built, and there might even be a take-or-pay clause for the power, or, in the case of Central coal plants, the capital costs are covered based on a minimum availability under the Availability Based Tariff schema, and so cutting down on output of a coal plant doesn't save the capital costs (as seen in many two-part tariffs, capital and operating expenses).[5]

Note that this calculation is purely for the output, and doesn't factor in grid externalities or variabilities, or other risks, except, as a choice for calculations, we could include the impact on the grid for stability, which is estimated to be at 30 paise/kWh (based on US numbers of half a cent/kWh for increased costs of ancillary services).[6] While some variables are flexible, other inputs are chosen based on standard published data, and all calculations are normalized to 1 MW size, i.e., per MW). The Viability Gap Funding mechanism is used for the price of Solar PV, which includes a flat charge by the utility plus bid VGF levels.

Coal costs and assumptions can be compared to CERC's Tariff Order for 2009-2014,[7] which specifies a 15.5% equity return (pre-tax), and nominal (estimated) debt rate of 10%. Instead of using overnight construction costs plus working capital, interest during construction capitalization, depreciation schedules, etc., a single (loaded) cost of capital per MW is used, combined with a weighted average cost of capital (WACC). Capital costs embed land and all other costs, and so these aren't explicit variables.

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[5] From a load despatch perspective, how contracts are set up, especially how capital (fixed) costs are to be paid matters a lot. Solar and wind have virtually zero marginal costs, so even "cheap coal" is more expensive, but asking RE to back down could make it cheaper for the Load Despatch Center (rather, utility) if the contracts were set up only to pay for units delivered, and if the fixed costs of coal were already covered.

[6] One Indian study also showed costs of increased cycling in the Southern Grid to be in a comparable range, varying by size of RE penetration and chosen balancing area ("Integrating Variable Renewable Energy.
with the Grid: Lessons from the Southern Region" AF-Mercados EMI, supported by the Shakti Sustainable Energy Foundation, November 2012, available at http://shaktifoundation.in/wp-content/uploads/2014/02/variable%20re%20grid%20integration.pdf).

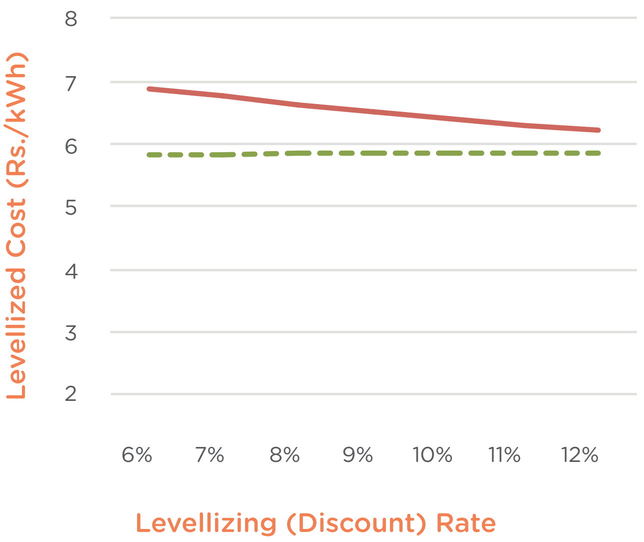
[7] These are taken from the Ministry of Power's National Power Training Institute (NTPI) note on "Tariff Determination Methodology for Thermal Power Plant".

MODEL RESULTS

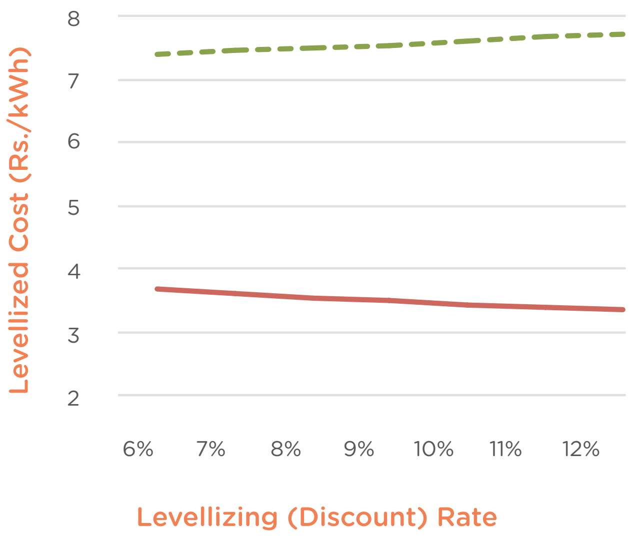
While there are literally millions of options in the output of the simple model (which is parametric, with ranges of feasible values for the inputs), to help ease calculations we examine four possible if not quite plausible scenarios, ranging from exceptionally favorable to solar to favorable to coal. More details on the rest of the assumptions (and the entire model) are available for download online at the Brookings India website.

FIGURE 1: Solar Photovoltaics versus Coal Comparisons (4 Scenarios, 2014) Coal Solar

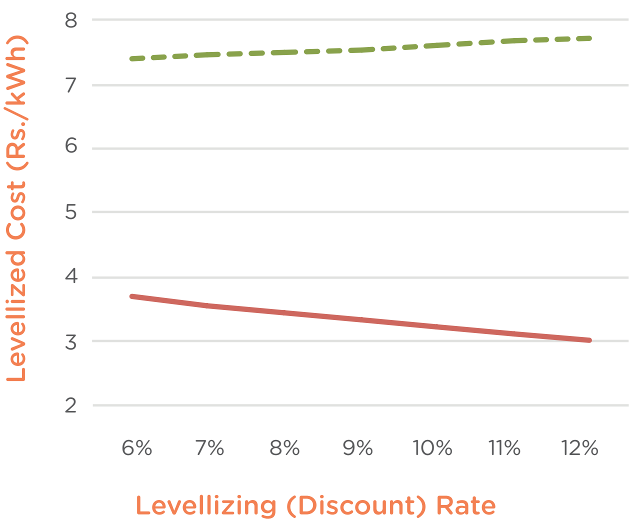
Scenario 1:
- Expensive Imported Coal
- Full coal costs (incl. Capex)
- Single Best Open Solar



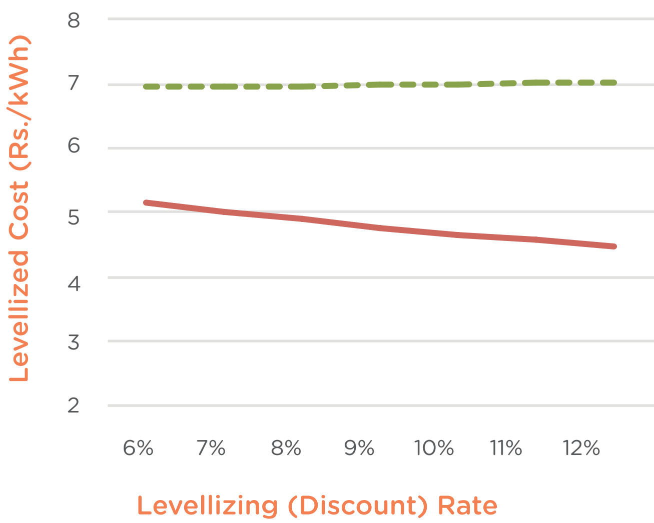
Scenario 2:
- Imported Coal
- Marginal Coal costs
- Avg. Domestic Solar Category



Scenario 3:
- Domestic Coal
- Marginal Coal Costs
- Avg. Domestic Solar Category



Scenario 4:
- Domestic Coal
- Full coal costs (incl. Capex)
- Avg. Open Solar Category



DISCUSSION & RECOMMENDATIONS

Depending on how you slice it, solar is already cheaper than coal (Scenario 1: expensive imported coal, low discount rate, open solar, no ancillary costs, factoring full coal capital costs, etc. for the single best solar bid, which was an outlier in terms of the Viability Gap Funding bid), or 2.5 times more expensive (Scenario 2: examining domestic coal at the margin, i.e., treating solar as negative demand, domestic requirement solar, 12% discount rate, etc.). Each of these scenarios is meant to convey insights – it would be simplistic to say the truth lies somewhere in between. If you're considering national policy, full costs of coal (Scenarios 1 and 4) matter. From a state utility perspective, Scenarios 2 and 3 (marginal coal costs) offer some insights. Using Scenario 4, solar is still 50% more expensive than coal-based power, even without factoring in the fact that solar does not contribute to the peak demand in India.

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The intent is not to suggest that coal can be viewed at only the marginal cost when viewed vis-à-vis solar. That is only the extreme example. The real calculation, beyond the scope of this piece but worth undertaking, will be what does or should solar power displace? Diesel? Wonderful, then the fuel savings are dramatically higher, but how many utilities buy so much diesel? (Of course, end-users use a lot of diesel, but that's a more sophisticated analysis, adding this stakeholder, as well as adding a cost for load-shedding.) Should one use the average marginal cost of the displaced power? For a hydro-rich state, that number can actually be very low. But if one displaces gas or a liquid fuel, that number becomes much higher. However, the generation from natural gas, especially as procured by utilities during the non-peak hours, is very low in India, especially after increases in the price of natural gas.

Isn't the learning curve of solar PV technology quite fast, perhaps as high as 20% (or, in recent years, closer to 40%)? This indicates that this same calculation a few years hence would lead to different results. The question remains that if India saw far greater improvements recently, how much of those were one-off benefits that won't continue for 5-10 years continuously? If JNNSM or other factors pushed costs downwards, more so than the long-term learning curve rate, would a regression to the mean learning curve rate be expected in the near future?

To play devil's advocate, if, say, solar is 5 (or 10, or however many) years away from true (utility perspective, completely unsubsidized) viability, shouldn't India just wait? An important question would be how much of price reductions are simply riding a global wave, and how much are driven by the Indian market, especially learning and innovation for installation, engineering/procurement/construction (EPC), etc.? Of course, worries about import risks and energy security are far less than for fossil fuels, since there is only a one-time cost calculation with most RE. Detailed analysis on the breakdowns of the cost improvements of PV (instead of headline numbers of Rs./kWh) will help us learn where to focus.

Ultimately, as recent renewable energy contracts in the US have shown, wind power can be just a few US cents per kWh (2.1 cents/kWh on average for a long-term contract in North Dakota, or about Rs. 1.3/kWh)[8]. While some of the differences are due to lower windspeeds in India, financing and other issues are major factors. This is seen in comparing solar PV tariffs, where India's resources aren't lacking, but the costs are still about double (post subsidies in the US).[9] As discussed in the chapter on Institutional Issues, interest rates and loan tenures matter. US interest rates are often in the range of 6%, or ~half of Indian rates. In other coun-

[8] *"Solar and Wind Energy Start to Win on Price vs. Conventional Fuels" New York Times, Diane Cardwell, November 23, 2014.*
[9] *ibid.*

tries, far lower interest rates have been seen for RE projects.

FUTURE OF THE GRID

Per many estimates, in the West increase in renewables brings down the wholesale price for electricity, meaning much if not all the extra investments for increased renewables can be done at no extra cost to consumers. It's a separate issue that this has negative implications for traditional suppliers (witness the three-quarter reduction in market value for traditional grid suppliers in Germany) – does this even hold in India? Because India does not have mark-to-market pricing (where the pricing is the value of electricity or any other good, like a share in a company, set by the last price, regardless of the actual prices paid for different/previous units), such savings are mostly not available. In India, generation is mostly set on bilateral contracts, instead of wholesale markets (power exchanges are very niche and limited, and already have relatively low prices for various reasons, including transmission and utility financial liquidity bottlenecks.) In addition, because the Indian system is so far out of equilibrium (shortfall), adding supply from renewables isn't likely to lower prices like it has in the West.

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Indian utilities already have enormous pressure, and have become, so-to-speak, the worst of both world. They neither are profitable commercial entities, nor are they fulfilling the purported social contract through quality, low-cost service. Costs to serve (fully loaded, including losses) are already above 5 or 6 Rs./kWh in many states, while average revenues are far, far lower.

Because there is no mark-to-market pricing, the average cost of procurement is still lower than otherwise, in part because of older generators that are very cheap (because they are already amortized, i.e., paid off). This means the Long Run Marginal Cost (LRMC) will necessarily be higher than average, which also implies that average generator costs could rise higher than inflation. On top of this, distribution utilities under-invest in capital expenditure, with many of them already citing 80-90% of revenues going to power procurement. This is unsustainable, and leaves very little scope for additional generation procurement, especially for peak pricing (or renewables pricing or innovation, like Smart Grids).

RECOMMENDATIONS FOR RENEWABLES PRICING

Beyond the recommendations to improve financing and techno-economics of renewable power from a supply side, there are two recommendations for better pricing at a systems level:

- Transparency
- Dynamic Pricing, Smarter Pricing

Transparency in assumptions and methodology is only the start. The first step should be credible procurement plans by utilities, which minimize if not end load-shedding. This would then allow greater optimization of various supply options, as well as grid management. There should be greater examination of grid impacts (see Chapter 3) and also the incentives for renewables that other energy sources don't get (but in fairness, fossil fuels also have major externalities, see the Chapter on Renewables and the Environment). As an example, support mechanisms for one State's solar power include:

- "100% banking facility
- No wheeling & transmission charges
- No cross subsidy surcharge
- PPA for 20 years & payment security for bankable proposals

- Electricity Duty exemption
- VAT refund for all the inputs required
- Refund of Stamp Duty & Registration charges
- REC eligibility"[10]

Dynamics and improved pricing has already been discussed, but from a pricing perspective, a simple starting point is Time of Day (ToD). More than Time of Day, the concept of State of Grid might be useful. More than simply real-time pricing, it factors in grid conditions (which range from predictable to unpredictable), alternatives (like spinning reserves), etc. One mechanism for this is the use of Ancillary Services, which keep the grid stable instead of providing simple kilowatt-hour services. To give perspective, depending on which set of numbers you use, the US Ancillary Services market is between $4 - 7.2 Billion. This implies the hidden Indian Ancillary Services market is already on the order of $1 Billion.[11]

Once we get pricing signals right by ToD if not State of Grid, this will enable a host of complementary efforts that will help manage the variability of renewable power, including peaker plants, storage technologies, and Smart Grids (especially in the form of Demand Response, which varies demand in response to signals, as opposed to the more static Demand Side Management, or DSM). In the longer run, more efficient and dynamic markets (which also signal marginal costs) will incentivize new energy saving services, without which efficiency (saving energy) reduces utility revenues, especially from the so-called "paying customers" (commercial and industrial) (see Chapter 8 for more on efficiency).

It is worth exploring the issue of peaking, given wind and solar don't provide despatchable power at the Indian peak demand period(s). Coal is actually a baseload provider, like nuclear power, and so regardless of whether renewables are 15% or 50% of the capacity, India will need more peaking power. The main options supply side options, technologically, short of storage, are hydro, liquid fossil fuels, and natural gas. Hydro is attractive at some levels (low marginal costs) but its despatch isn't just based on the grid but also on irrigation needs. More importantly, a new hydro plant built just for peaking would be expensive, let alone the environmental/social challenges in adding new capacity. Liquid fuels are imported and expensive. This leaves natural gas. India must build open cycle gas turbine (also called combustion turbine) plants to operate for a limited number of hours per year, as peakers. Depending on the usage pattern (load-factor, say, 15%) and input costs of fuel (say, $8/MMBTU delivered), gas-based peakers could cost in the vicinity of Rs. 8.4/kWh (bulk procurement). While higher than the average, with blending it could be manageable.

ECONOMICS FROM VARIOUS STAKEHOLDER PERSPECTIVES: IMPLICATIONS FOR THE FUTURE GRID

A very fundamental question, difficult to answer, is whether there is a cross-over point after which renewables such as solar should displace new plants based on coal, and if so, when will that happen? If people state grid parity by 2020 (if not earlier), should India be lining up contracts today for coal plants to come online by 2020 (perhaps 100,000+ MW of such capacity)? Of course, given the immense need for power in India and also the differences in time of day output, it's not an either-or proposition – India will need both baseload and renewable power.

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[10] *Andhra Pradesh Solar Power Policy, as referenced in http://mnre.gov.in/file-manager/UserFiles/presentations-23052013/APCPDCL.pdf.*
[11] *This is not to imply that no such services are undertaken today, but they are often undertaken by the default (state-owned) provider, often coal, which can be inefficient. To use an analogy, a marathon runner (coal) is often asked to run sprints (cycle up/down).*

Proponents of renewables point out that these deployments are able to be more rapid and draw private participation, unlike large (thermal) projects which are much more reliant on the government and utilities. On the other hand, large grid-scale renewables today also rely on the government and utilities. The question remains is there a future of the grid where renewables can, for the most part, bypass the government, and where either there is edge-based generation and consumption locally, or it goes through the grid to other consumers? In such a world, distinctions between "grid-scale" and "edge-based" become blurred.

We need analyses for the Future Grid which captures not just supplier versus supplier, but also edge based producer-consumers (termed "prosumers") as well as the nuances of dynamics, tariff slabs, subsidies, and cross-subsidies

If that future becomes a reality, this raises a fundamental question about the role of the utility and "the grid" – are these just a wires entity, or a provider of last resort? Keeping the grid stable with increased renewables will be increasingly expensive. The only reason we don't see major grid-level costs of renewables in India today is that the share is relatively small (except in some states) and we have an unstable grid which is kept far from equilibrium, where load-shedding is the low-cost balancing mechanism.

Costs of renewable generation are falling, and without worrying about reliability, redundancy, and predictability, simply on a use-it-when-you-can mode (opportunistically), renewables are only a little more expensive than typical utility procurement costs at the margin (even though utilities have a mix of generation suppliers, some cheaper than others). From an end-consumer perspective, especially larger commercial and industrial (C&I) users, their retail tariffs are already higher than solar power. In fact, per some calculations, 50% of units consumed in Maharashtra are already above the end-user solar price proposed by SECI (Solar Energy Corporation of India) for FY 2014-15.[12]

The economics in this chapter was meant to focus on utility procurement, itself complicated but still easier than factoring in end-user retail tariffs (which have a tiered pattern of slabs, based on consumption, for many users). It's time analysts, regulators and policy-makers undertook analyses for the Future Grid which captures not just supplier versus supplier, but also edge based producer-consumers (termed "prosumers") as well as the nuances of dynamics, tariff slabs, subsidies, and cross-subsidies. One cannot change one part of this complex web in isolation, without direct and indirect implications on all other players.

The nuances of electricity pricing are far more than the complexities hinted in this chapter as externalities, foreign exchange, employment, land-use, etc. are all major issues, dealt with in part in other chapters. Richard Nixon famously asked for a one-armed policy advisor, who thus couldn't say "On the other hand." This space isn't just dealing with another hand, but a multitude of nuances, trade-offs, and choices. However, with transparency in assumptions and accounting, we could get all the hands to at least stop pulling in separate directions, if not align.

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[12] *This excludes electricity duty and other surcharges. Ashwin Gambir and Shantanu Dixit, "Future of the Grid: India perspectives – trends, implications and challenges" presented at the Future of the Grid Workshop, organized by World Resources Institute (WRI), Bangalore, November 19, 2014.*