

RE “versus” coal in India – A false framing as both have a role to play

Policy Brief by
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BROOKINGS INDIA

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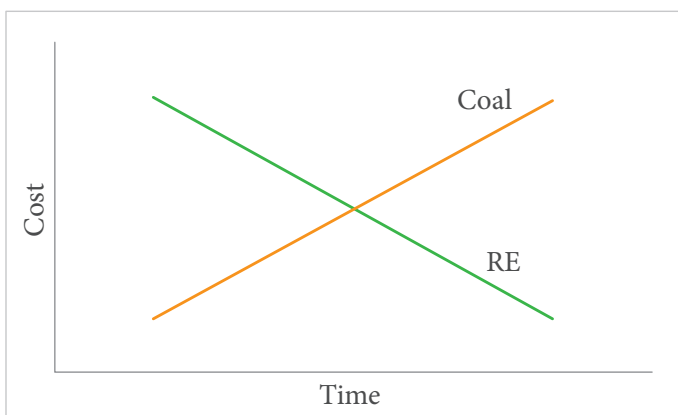
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Comparing Renewable Energy and Coal

A number of publications proclaim Renewable Energy (RE) is cheaper than coal. A newspaper will often show two cost curves, a rising one for coal, and a falling one for RE, especially solar (Figure 1). At some point they cross-over, an intersection dubbed “grid parity”. It’s a separate question whether this has already occurred, or is imminent. This framing falls short of capturing crucial aspects at play — it is unlikely there is a simple cross-over after which coal goes away. The reality is one that needs to factor in time of day, location, and share of RE, even before considering additional issues of contracting, technical constraints such as ramping capabilities, and frameworks for who will pay for the transition.

A simple claim that RE is already cheaper masks system-level costs as well as disproportional impact on selected states, generators, and stakeholders. This paper presents an alternative comparison model for RE and coal, and suggests a portfolio approach, with both playing a role in the near future, will lead to superior planning.

Figure 1: Generic (typical) cost comparison of Coal and RE



There are a few problems with simple curves crossing over at “grid parity”. First, what costs are these? More often than not, these are generation costs only, captured via a Levelised Cost of Energy (LCOE) calculation. These usually do not capture system level costs, or support mechanisms available to any particular generation type. While RE is no longer explicitly subsidised in India (except for residential end-user rooftop solar), there is a lot of support available to grid-scale RE,

including (now limited) accelerated depreciation. Some 90 percent of total solar deployment thus far has been large-scale solar parks, which feed in to the grid similar to other generators; wind has long been with megawatt scale turbines. These systems can benefit from one or more of the following: land (either free or at least made available), free transmission, waiver of a number of surcharges, etc.

Importantly, given RE has official or de-facto “must run” status, they displace other generation even if it were available. This could lower the plant load factor (PLF), also termed capacity utilisation factor (CUF), of other generation. India’s coal plants have seen a dramatic fall in PLFs in the last decade, from almost 75 percent to below 60 percent. Most of this hasn’t been due to RE but disproportional growth of coal capacity in recent years, at a rate double the growth of power demand. But, as RE’s share grows to perhaps almost 20 percent by 2022 (if the 175 GW target is met by then, and assuming reasonable overall demand growth), the impact on

¹ India classifies hydro as traditional power, and not RE, except small/mini hydro which are treated as RE.

PLFs will become measurable. This growth of coal capacity means comparing RE with coal isn't a "what should I build" question only – there is already a lot of coal capacity built, to the extent the banking sector is staring at stressed if not non-performing assets (NPAs).

A Central Electricity Authority (CEA) calculation for the burden of RE on the rest of the system in two RE-rich states (Gujarat and Tamil Nadu) showed a system-level cost of about Rs. 1.5/kWh. While this may be high given RE's costs are falling, a portion of these costs is due to the impact on thermal generators that have to reduce their output, lowering their efficiency and also resulting in lower capacity utilisation.

The second problem with a simple calculation is that RE is non-controllable, rather, it is opportunistic – take it when you can, i.e., when the wind blows or the sun shines. While improvements in weather prediction mean we can have a fair estimate of upcoming RE output, it has both random variation as well as inherent variation, for example, we know the solar output at night is zero. We still need something else to meet demand at times when RE output is low.

India's load profile today is relatively flat, and it often has peak demand in the evenings. A glance at the grid operator's portal showing RE output and demand for the last few days (post windy season) shows that at 7:30 PM, roughly the peak, the share of RE has been only between 1-2 percent.² Coal remains the baseload supply, and the peak is met, to a measurable extent, by higher output from hydropower. The bad news is we aren't adding as much hydropower as before – its share of generation has been falling, and slipped from 14.0 percent in FY 2011-12 to 9.6 percent in FY 2017-18.³ This is a case of lower growth for hydro capacity than an absolute decline in generation.

“Cheap RE” isn't enough

Comparing the economics of RE and coal is much more complicated than shown in Figure 1. Let's assume RE becomes, magically, free. This is variable RE (VRE), and it's difficult to absorb more than a certain level without storage. Consider solar. Even if we had unlimited, free solar power, what would we do at 8 PM? Storage is still expensive.

The corollary of this question is how much RE can we handle before needing storage. While not a law of physics, there is some evidence that, in practice, a VRE share much higher than its CUF becomes quite tough, and may require special effort if not storage, especially for solar.⁴ Stated another way, let's assume the peak national Indian demand in 2022 is 225 GW (load met at a national grid level); this is compared to some 170+ GW in 2018. For solar, we actually need the noon demand, which may be only about 200 GW on many days in 2022 at most. As and when we reach 200 GW of solar capacity (not by 2022, but some point later in the coming decade as per targets), then there is a chance on some days we have too much solar, and have to either throw it away (curtail it) or put it through a storage.

In reality, the limit won't be equal to the noon demand as there will also be some amount of wind that will periodically coincide with solar, not to mention some amount of other capacity will have to be online. Nuclear usually can't be switched off, and some hydro becomes "must run" depending on reservoir levels and competing needs. Importantly, a fraction of coal power must be operating to meet evening demand as it cannot be switched

² Seen online at the Government of India portal <http://meritindia.in> (accessed end of September, 2018).

³ CEA Executive Summary Reports (monthly), 2012-18.

⁴ A. Trembath and J. Jenkins (2015) "A Look at Wind and Solar, Part 2: Is There An Upper Limit To Intermittent Renewables?" available at <https://thebreakthrough.org/index.php/voices/energetics/a-look-at-wind-and-solar-part-2>

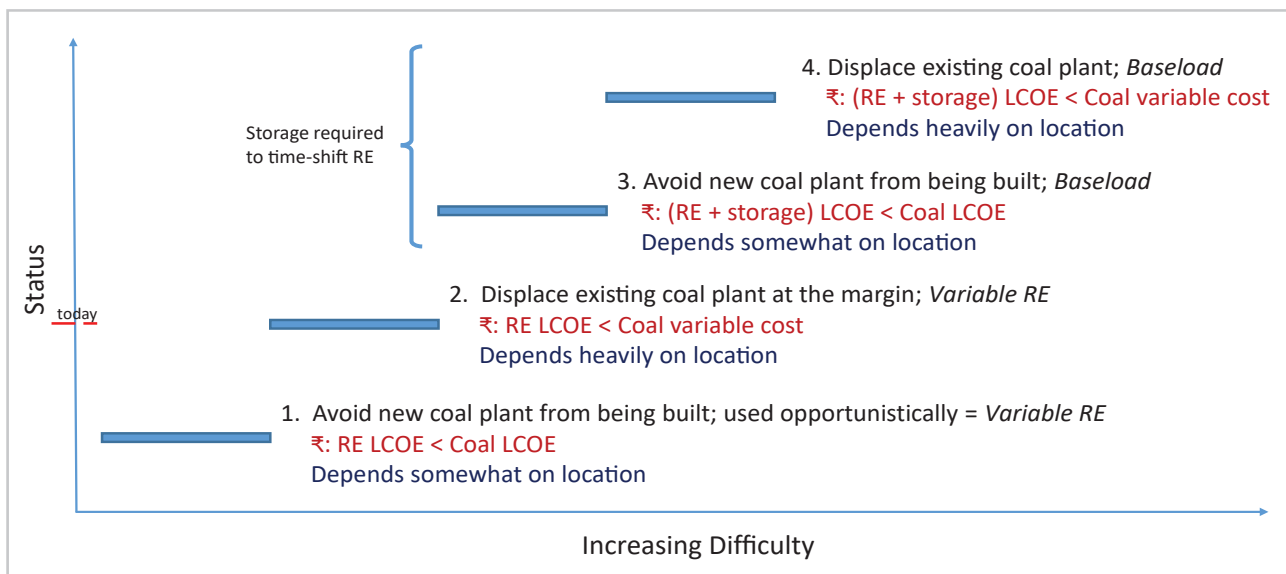
on and off rapidly. Running coal plants at part output is feasible, and will happen at noon – running plants in a two-shift mode (switching off in the middle of the day) is very disruptive and expensive. This note doesn't aim to calculate such a number – with effort and purposeful design it can be quite high – but there is a point after which RE requires storage.

Instead of the simple cross-over for RE's competitiveness versus coal, we believe its evolution will be like a ladder, with steps of competitiveness, changing not merely with time but with fraction of penetration by VRE. There will be four main steps for the competitiveness of RE, based on different cost components of coal – fixed (capital) and variable (fuel). Note that RE only has fixed costs (no fuel costs), and so, once built, should always operate. It is a distortion that load dispatchers who balance the grid in India today see only incremental variable costs of coal and compare these with the total (fixed) costs of RE. For coal, at present, fixed costs are paid regardless of usage under standard power purchase agreements (PPAs), based on plants being available. RE doesn't enjoy this same framework. It's worth emphasising that the steps of competitiveness listed below are based on just the fixed versus variable costs of coal, and are not reliant on the distortion of PPAs.

While not discrete, the four steps will be as per Figure 2. Note these economics are excluding the pollution or emissions externalities of coal. New emission norms by the Ministry of Environment, Forests, and Climate Change (MoEFCC) will entail a measurable but affordable cost on coal power plants.⁵

The first two steps are lower-hanging fruit, without storage required. The easiest step is when we compare what plant to build – VRE is cheaper than adding a new coal plant. The next step is when we compare building a new RE facility with running an existing coal plant, for which fixed costs are to be paid regardless. This isn't about PPAs – even without PPAs someone is on the hook for paying the banks. RE's costs can be lower than the fuel costs of coal, but this depends heavily on location.

Figure 2: Ladder of competitiveness for Renewable Energy vs. Coal



* Economic calculations without full values of externalities; LCOE=Levelised Cost Of Energy (combined capital and variables[fuel] costs)

Note: In addition to things changing over time, what the rest of the grid does all matters! The future may not be as discrete; this is illustrative.

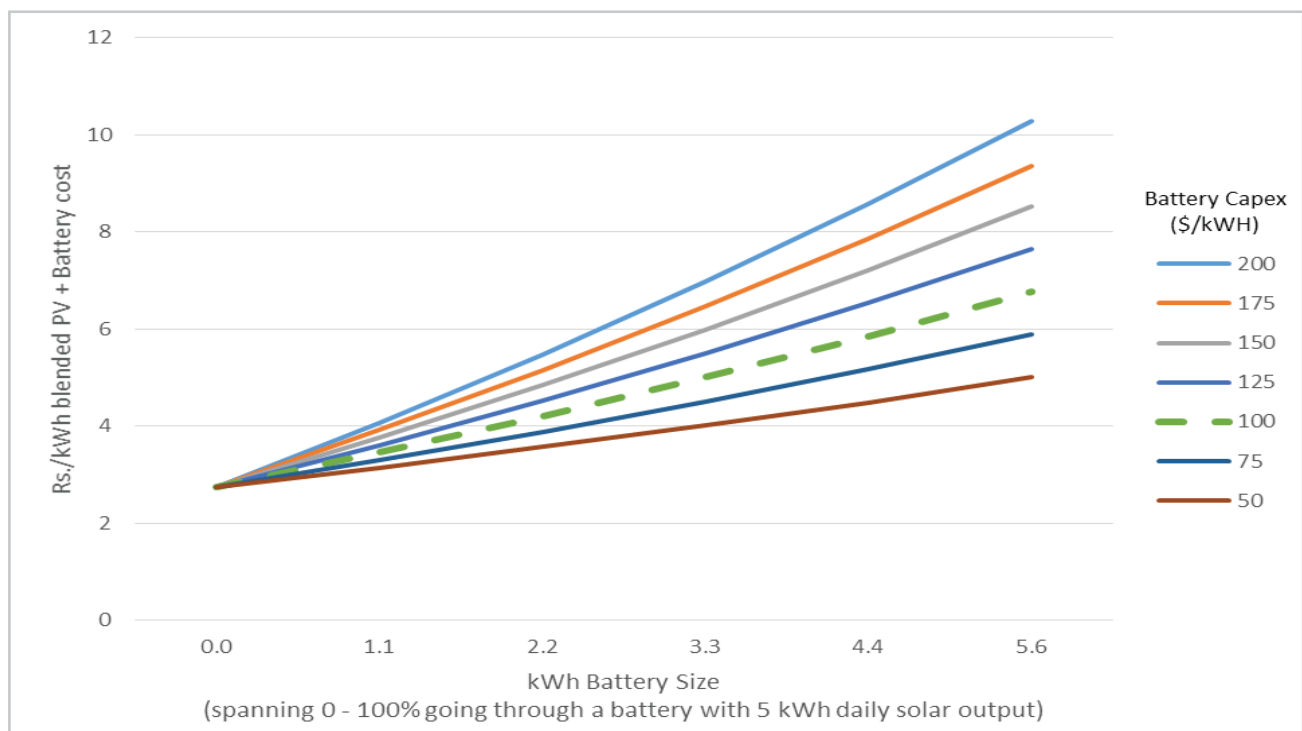
⁵ Measurable is not just based on consumers' willingness to pay but by the present health impacts of emissions, which are calculated to be much higher than the costs of compliance (CSTEP, 2018). "Benefit Cost Analysis of Emission Standards for Coal-Based Thermal Power Plants in India", available at http://cstep.in/uploads/default/files/publications/stuff/CSTEP_Report_BCA_of_Emission_Standards_for_TPPs.pdf

Coal has very high transportation costs, in part because Indian Railways relies on a cross-subsidy by freight to cover passenger costs, and coal is the single largest form of freight carried.⁶ This means that this step will show a spread by location — new super-critical pithead or mine-mouth coal plants can have variable fuel costs in the order of Rs. 1.25/kWh, this is inclusive of measurable taxes and levies on coal, not to mention profits of the public sector dominant miner, Coal India Limited (CIL), which is 78.34 percent owned by the government and is one of the highest dividend payers to the exchequer. It's worth noting that the RE potential is maximum in locations far from coal mines, especially South and West India.

The last two steps repeat this comparison with storage, for example, via batteries. Even here, it won't be a binary calculation of RE with versus without a battery — battery usage will be fractional and grow over time as RE's share rises. Even the other steps aren't just separated by the presence or absence of a battery - there will be a need for improved transmission, changes in pricing norms, operational parameters, etc.

A parametric analysis of the costs of battery plus RE is shown in Figure 3. These are based on two key parameters – cost of the battery and share of RE requiring a battery. These costs shown are for total battery costs including packaging, electronics, inverter, etc.⁷ Figure 3 shows the costs will be modest at first, but grow over time. It is a billion rupee question whether battery prices will fall faster than the rate at which battery usage will grow.

Figure 3: Battery costs with a solar panel



Note: Data based on Brookings India calculations. This chart shows RE plus battery costs with a 1 kW solar panel. This assumes base solar is 2.75 rupees/kWh without a battery (about 4 cents/kWh), a 15-year battery lifespan, and a 10 percent discount rate, for a high-efficiency battery system. A popular global benchmark price is \$100/kWh. The x-axis shows the size of battery required for a 5 kWh daily solar input to span the share of electricity stored in the battery from zero to 100 percent. E.g., a 40 percent share, or 2 kWh of solar generation, translates to about a 2.2 kWh battery size (higher because of battery depth of discharge limitations).

Source: Tongia and Gross (2018)⁸

⁶ P. Kamboj and R. Tongia (2018) "Indian Railways and coal: An unsustainable interdependency", available at <https://www.brookings.edu/research/indian-railways-and-coal/>

⁷ A number of reports claim approximately \$100/kWh battery costs today – but those are only cell level costs. Total system costs are multiple times higher.

⁸ "Working to turn ambition into reality: The politics and economics of India's turn to renewable power" available at <https://www.brookings.edu/research/working-to-turn-ambition-into-reality/>

Future steps, unknowns, and discussion

Minister for Power R. K. Singh recently lamented that states aren't buying RE even with record low bids.⁹ Analysts blame distortions in contracting between fixed and variable costs, as discussed earlier. This is only partially true since we actually have the case of choosing whether to build a new RE plant versus run an existing coal plant more, à la the overhang of under-utilised coal capacity. Second, we have the real issue of a time-of-day based surplus – states often see a peak in the evening, and hence, are anyway committed to other capacity. Ideally, they shouldn't be committing to plants, but rather to buying power, that too by time of day. This would enable the rise of peaking power, where one plans for energy at a portfolio level instead of capacity in static blocks. Time of day wholesale pricing and flexible markets would also spur storage solutions, smart grids (for both peak management and demand response), etc.

While this policy brief addresses national issues, the challenges are far sooner and more stark at the state level, especially given the concentration of RE potential in a handful of states who today bear costs and risks disproportionately. The rise of non-state bids, where power bypasses the state and directly connects to the interstate transmission system, reduces the concentration of RE upon a few states, but it has limits since ultimately the counter-party risks from other (further) states remains the bottleneck, any short-term benefits notwithstanding. Having solar power more accessible to other states helps us move up steps one and two of Figure 2, but it also makes it that much harder for RE-rich or RE-surplus states to offload RE to other states in a transactive manner – they are likely to be surplus or deficit at relatively similar times. Importantly, this model relies on extensive transmission, which today is chosen to be priced as free, but if the intent is wholesale transfer of power across India, then the cost of such transfers is not just non-zero, but it is higher than typical transmission because of the lower PLFs of RE.

As the path-breaking analysis for integrating 175 GW RE into the grid by the US National Renewable Energy Laboratory (NREL), India's central grid operator, Power Systems Operation Corporation (POSOCO), and the US Lawrence Berkeley National Laboratory (LBL) showed, we have to move to larger balancing areas than the states.¹⁰ We also need to increase the technical (and contractual) flexibility of coal generation plants. Ultimately, we need flexible systems best enabled by more liquid and competitive frameworks, that is, markets.

The future will be less discrete than Figure 2, with lots of variance and overlap. There are certainly many unknowns, such as how much demand will grow, or what shape the load curve will take. If air conditioning is an expected major growth in demand, will this grow faster for commercial users or residential users? The former means daytime demand, the latter evening. How fast will battery prices fall? What is the level of RE that can be absorbed before storage becomes important? More than just modeling and analysis, better data on what is happening today is critical for researchers and policymakers, e.g., what is the performance and operations of plants today, with time of day granularity?

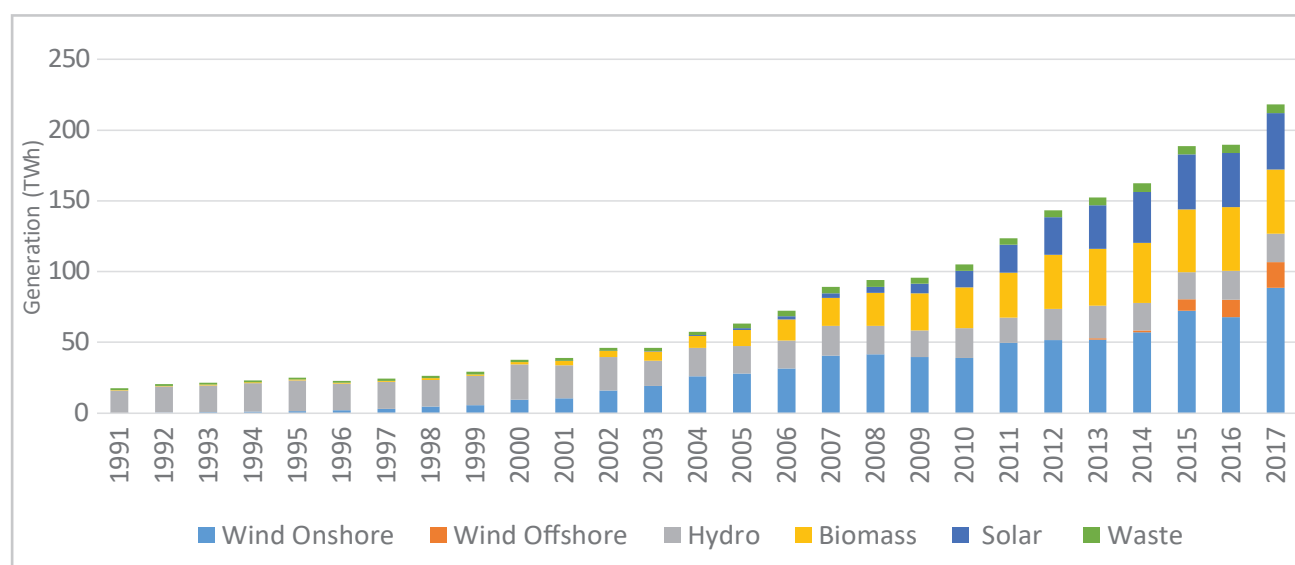
To expand on just one point to illustrate the complexity, figuring out when we need storage (and how much) needs deeper analysis. There is no single answer as each utility, region, and country is different, based on its load profiles, what alternatives it has, etc. India's grid is heavily coal-centric, and the demand profile is exceptionally flat, at least as of today, with an evening peak most of the time at a national level. Some utilities have found 30 percent or even 50 percent RE is feasible before requiring large storage.

⁹ <https://www.financialexpress.com/industry/no-takers-for-solar-power-power-minister-warns-that-states-are-not-buying-even-at-lowest-rates/1332407/>

¹⁰ "Greening the Grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid," (NREL, POSOCO, LBL 2017) <https://www.nrel.gov/analysis/india-renewable-integration-study.html>

Germany crossed 30 percent RE some time back, and the grid hasn't collapsed. Of course, the economics haven't been easy, with enormous surcharges (the EEG) to pay for the RE, set at 8.08 €-cents/kWh for 2018 (mostly for historical feed-in-tariff decisions).¹¹ At a technical level, out of the roughly 1/3 of total generation that was from renewables, some 1/3 of this RE share is actually hydro and biomass.¹² Variable RE was only a bit over 22 percent in 2017 (see Figure 4). Germany has also had relatively flat demand growth, only 0.41 percent annual electricity demand growth between 1991 and 2017, and -0.20 percent between 2005 to 2017, the period of high RE growth.¹³ Grid balance has been met by a reduction in coal production and by having net export of power grow to almost 10 percent of consumption, reflecting the importance of balancing across the continent. In fact, Germany benefits from pumped hydro storage in other countries to help its balancing.

Figure 4: Renewables generation by type in Germany. Germany includes hydro as renewable energy. During this period, demand growth has been nearly flat.



Data Source: Clean Energy Wire¹⁴

There are a lot of steps India can focus on to help manage the growth of RE, and minimise its risks and burdens. Many are listed in the Greening the Grid paper and also in Tongia and Gross (2018), and include larger balancing areas, signaling grid conditions (for example, time of day pricing), etc. But it would be incorrect to characterise state hesitation as recalcitrance, and policies should address state or DisCom concerns, even if some of these are more perception than reality.

The good news is that India is still at about 8 percent RE share. There is still a long way to go before India hits a wall for RE integration. But if the objective isn't just to have 20-25 percent RE share, but go for much higher, so we can move towards deep decarbonising, then it will take significant policy, regulatory, and technical changes to today's grid. Even the low-hanging fruit share of VRE that can be easily absorbed will have cost implications. A nuanced framework for the cost of RE is a step forward. India can even pay extra for greener power – but making all costs explicit will help allocate costs (and risks) to those best suited to handle them, with efficient micro-economic signaling. Ignoring such costs, or socialising in an implicit manner, may lead to unnecessary inefficiency, risk, or even resistance.

¹¹ Fraunhofer ISE (2018) "Recent Facts about Photovoltaics in Germany" compiled by Dr. Harry Wirth, January 2018. Available online at

<https://www.ise.fraunhofer.de/en/publications/studies/recent-facts-about-pv-in-germany.html>

¹² Germany classifies hydropower as renewable energy, unlike India

¹³ <https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts>

¹⁴ <https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts>

Further reading

- 1) **The politics and economics of India's turn to renewable power.**
Tongia, Rahul; Gross, Samantha. (2018, September).
<https://www.brookings.edu/research/working-to-turn-ambition-into-reality/>
- 2) **“Greening the Grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India’s Electric Grid”**
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<https://www.nrel.gov/analysis/india-renewable-integration-study.html>.
- 3) **“Report of the technical committee on study of optimal location of various types of balancing energy sources/energy storage devices to facilitate grid integration of renewable energy sources and associated issues,”**
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About the author



Rahul Tongia is a Fellow with Brookings India, and part of the Cross-Brookings Initiative on Energy and Climate. His work focuses on technology and policy, especially for sustainable development. He leads the energy and sustainability group at Brookings India, and also is active in broader issues of technology. Tongia’s work spans the entire gamut of electricity, with focuses on supply options including renewable energy (covering finance, grid integration, etc.); smart grids, which use innovative information and communications technology to improve management of the electric utility grid; issues of access and quality; and broader issues of access, reforms, and regulations, including electricity pricing

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