India's Electricity Sector Transformation

Momentum Is Building; Peak Coal In Sight

Institute for Energy Economics and Financial Analysis
IEEFA.org

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Tim Buckley, Director of Energy Finance Studies, Australasia (tbuckley@ieefa.org) and
Kashish Shah, Research Associate (kshah@ieefa.org)

Table of Contents

Executive Summary

This report examines the rapid electricity market transformation now taking place in India, showing how renewable energy and energy efficiency measures can help the country, soon to be the world's most populous, avoid the mistakes China made in its dash for coal-fired electric generation growth in the first years of this century, but also leverage the learnings from China's huge investment in renewables and grid capacity expansion.

Electricity demand in India is expected to double over the coming decade, and how this electricity will be generated is critically important for both India and the world. We present an electricity sector model out to 2027 in this report showing how India can meet its growing electricity needs via increasingly cost-competitive renewable energy resources and numerous energy efficiency measures, while at the same time keeping its coal use in check, at perhaps no more than 10% above current levels. IEEFA's forecast is far from consensus. In contrast, the International Energy Agency (IEA) forecasts India's coal consumption will more than double by 2040.

To say this clean energy transition is vital is an understatement. India already is the world's second-largest producer, consumer and importer of thermal coal and how it meets its rising electricity needs (it is now the third largest electricity user in the world behind only China and the U.S.) will have a major impact on global energy markets.

Indian leaders from the top down have embraced the need to transform the country's energy industry, pushed in particular by Prime Minister Narendra Modi's ambitious goals to make India a world leader in the adoption and deployment of low emissions energy efficiency and renewable energy infrastructure.

These government efforts have been strongly supported by the marketplace over the past couple of years. Prices for both wind and solar power have fallen significantly recently, with record low prices recorded in 2017. As a result, for the first time in India, installations of new renewable generation topped those of net thermal power additions in 2016/17. For the year, net thermal additions fell to just 7.7 gigawatts (well below the roughly 20 GW added annually in the prior four years), while renewable additions jumped to 15.7 GW.

The country's draft national electricity plan (NEP) calls for renewable energy installs to average 21-22 gigawatts (GW) annually going forward. The economics of renewables have improved dramatically — with both wind and solar costs down 50% in just two years, hovering at about US$0.038 per kilowatt-hour — IEEFA considers this an achievable target.

While renewable energy installations are expected to surge, IEEFA forecasts that net thermal power capacity additions are likely to contract to below 5 GW annually over the coming decade, held in check by the retirement of highly polluting, end-of-life subcritical coal-fired power plants. IEEFA expects retirements to average more than 2.5 GW. But with coal-fired power plant utilisation rates averaging just 56.7% in 2016/17 and little prospect of this improving over the coming decade, retirements could well accelerate to 4-5 GW annually. Retirement plans are likely to be pulled forward by the reality that solar and wind already are being deployed at scale at tariffs well below those of even existing domestic thermal power generation.

India's target to all but cease thermal coal imports by the end of this decade is now the logical economic outcome, especially since plants using expensive imported coal are increasingly the high-cost dispatch option. As the second largest importer of thermal coal globally, this is a materially adverse development for thermal coal-export nations.

In this report, we present IEEFA's model with our forecasts for the key parameters driving India's electricity sector transformation (Section 8). We place our model at the end of the report because it is informed by the preceding seven sections, which detail our thinking on key policy and market trends.

In Section 1, we describe how India currently relies on thermal power generation for 80% of its electricity, while hydro supplies a significant 10% and renewables currently just 7%. However, India has a national target of having 275 GW of renewable capacity installed by 2027 so changes are coming. Indeed, the tipping point may have been 2016/17, when net thermal capacity installs plummeted and renewable installs more than doubled.

These developments have continued into 2017, with costs of both falling by an unprecedented 50%, with recent tenders now pricing renewables at 20% below the average price on existing Indian thermal power generation. Section 2 details these developments and IEEFA's forecast of likely installations going forward. The rate of price deflation in renewables has surprised everyone, and this has caused some near-term turbulence, but we remain convinced renewables are clearly established as the low-cost source of new supply. Mexico's latest solar tender of November 2017 of just US$18 per megawatt hour (MWh) and Chile at just US$18/MWh (both down 50% since the start of 2016) shows there is still significant downward scope for renewables pricing longer term.

The challenges to integrating India's 40% renewable energy target by 2030 are not to be underestimated. However, the momentum over the past three years, gained through clear government policy and growing economic merit, give us confidence India will stay the course. Section 3 details the challenges relating to maintaining grid stability in the coming decade when demand is expected to double, and renewables' share will quadruple. State government distribution company (Discom) reform initiatives have made significant progress, but much more is needed for transformation to be locked in.

India's electricity demand is forecast to double over the coming decade. This is a significant challenge in any terms, but less than most forecast. Net of energy efficiency savings, IEEFA models an electricity elasticity of GDP growth of 1.0 times, materially lower than some emerging markets (China, Philippines) but consistent with India's trend of the last decade. Energy efficiency and construction of a more efficient smart grid will each play key roles in a cost effective sustainable electricity transformation (Section 4).

Section 5 examines the status of India's coal generation fleet, looking at forecast expansions in the latest draft NEP, projected retirements, and the performance of existing plants. IEEFA believes that continuing retirements of inefficient end-of-life plants and boosting performance at operating plants can help India in its efforts to deal with chronic air pollution and the resulting health issues as well as carbon emissions.

One of our key conclusions, detailed in Section 6, is that growth in thermal power generation is slowing significantly, which in turn means market expectations of India's thermal coal needs are excessive. Increased domestic coal production, at double the growth rate of the last decade, caused thermal coal imports to peaked in 2014/15, and means they are set to drop by two-thirds over this coming decade.

India has long debated the merits of building out nuclear and hydroelectric capacity. We review current government plans for these two resources in Section 7. IEEFA remains convinced that nuclear is not a commercially viable option because of the long lead times and the likely ongoing cost blowouts involved. At the same time, IEEFA sees the prudence in a careful buildout of hydro-electricity, which would provide cost-effective electricity, supply diversity, grid stability and peak demand management.

Introduction

As it has become increasingly clear that China has moved beyond peak demand for thermal coal, the focus and hopes of policymakers, financiers and energy industry officials (particularly those in the coal field) has shifted to India.

Coal export executives see growth potential, environmentalists worry that growth would undo other efforts to curb the worse impacts of climate change, and policymakers, particularly Indian government officials, see a chance to skip over the worst of past fossil-fueled development efforts and jump to a cleaner, greener electric grid.

The key question for all is whether India can manage a rapid expansion of its economy and provide the electricity needed to make that happen, while at the same time doing it in a manner that makes both environmental and commercial sense. Here, the focus has been on India's extremely ambitious renewable energy targets and what they mean for the nation's coal-fired generation fleet, which still accounts for the bulk of India's electricity. While most observers recognize that renewables are going to progressively reduce coal's share of Indian electricity generation, most still expect that the absolute volume of coal used in India will continue to rise materially as the economy expands. IEEFA challenges that assumption. The electric sector model presented in this report shows that peak thermal coal use is approaching much faster than has previously seemed possible, driven in large part by massive price declines in renewable energy generation as well as economy-wide efficiency efforts being undertaken across the country.

However, beyond India's achievements in renewables, the nation is working to increase efficiencies across its entire energy system. Such efficiency gains, which tend not receive as much attention, include:

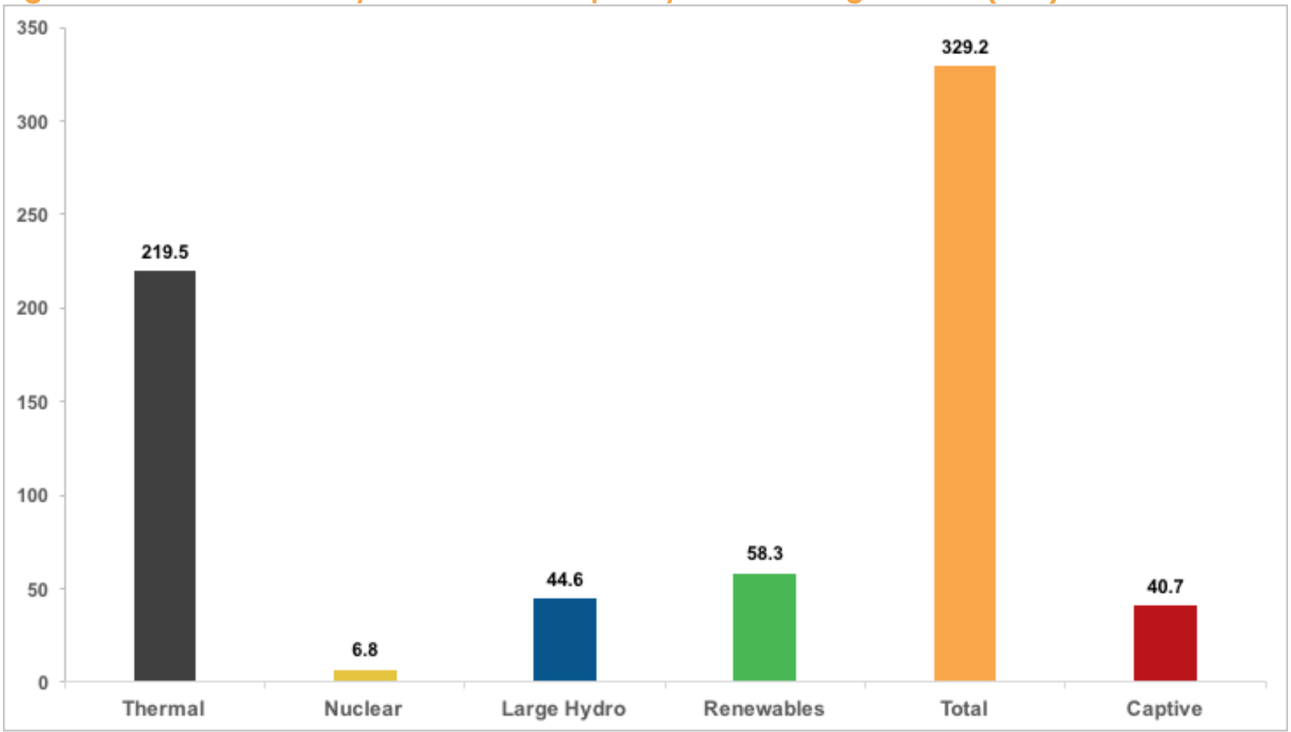
- Energy efficiency – the lowest cost electricity is that which is not used;
- Buying efficiency – India has lowered the cost of imported LEDs by 90% in three years;
- Grid efficiency – without reducing grid transmission and distribution (T&D) losses, any attempted electricity transformation is doomed;
- Distribution company (DISCOM) reforms are driving economic efficiency;
- Coal efficiency – Coal India Ltd has increased coal output in the last five years by 27% on an absolute 16% lower headcount;
- Rail efficiency – third party quality monitoring and reduced coal rail theft /substitution increases energy per tonne of coal moved;
- Thermal efficiency – coal washing improves coal plant efficiency;
- Capacity utilisation – increased operation of existing thermal power plants improves capital efficiency;
- Diversity of generation – improves grid balancing, energy security and system efficiency; and
- Capital market efficiency – improving transparency and regulation policies plus lowering inflation and hence interest rates drives down the cost of renewable energy.

These developments are going to have significant, permanent impacts on India's thermal coal use—with peak coal perhaps just around the corner. This idea, that India could be near peak coal demand, would have seemed laughable just a couple of years ago. But this is no longer the case: coal fired power plant utilisation are at record low levels, coal-related stranded asset concerns are rising, coal plant expansions are increasingly on hold and all the while the price and performance of renewable energy is improving.

1. India's Electricity Sector - Overview

The Indian electricity grid has installed system capacity of 329.2 GW (as of August 2017), plus 40.7 GW of off-grid self-generation (mostly thermal powered).

Figure 1.1: India Electricity Generation Capacity as of 31 August 2017 (GW)



Source: Central Electricity Authority (CEA)

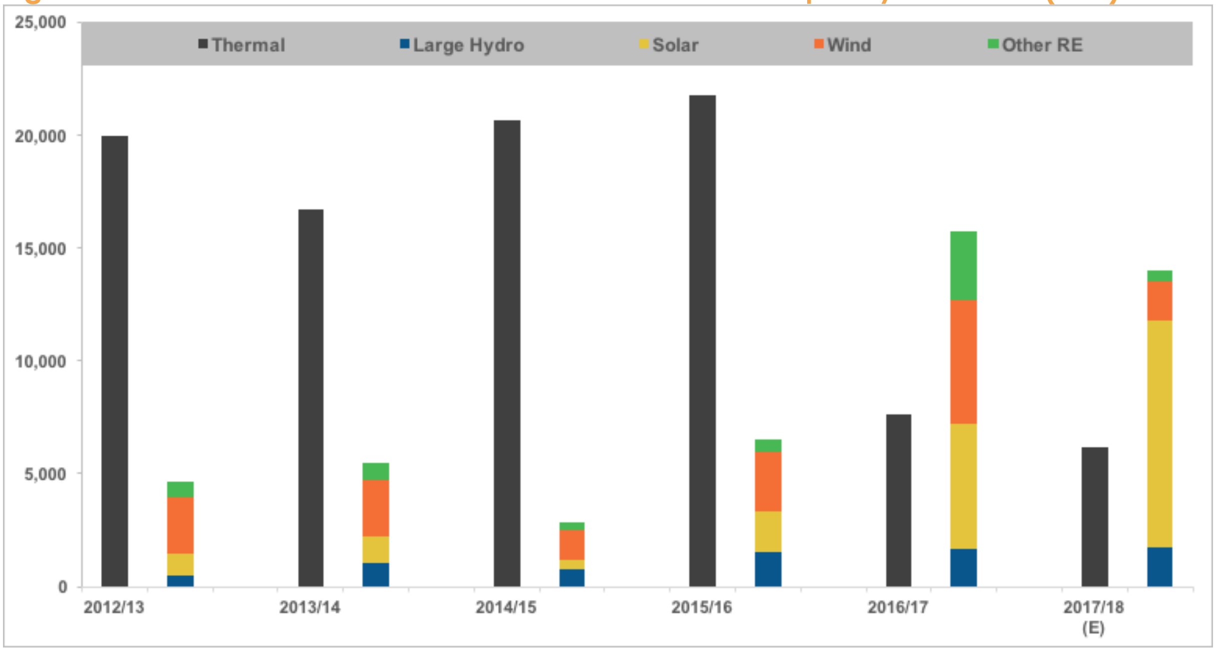
Thermal power capacity represented 66.8% of total installed capacity and 80.1% of electricity generation in 2016/17. Hydro electricity accounts for 44.5 GW or 13.6% of capacity (9.9% of generation) while non-hydro renewable energy accounts for 58.3 GW or 17.5% of capacity (and 6.6% of generation). Nuclear accounts for just 6.8 GW or 2.1% of capacity (3% of generation).

The Indian electricity grid has more than doubled its installed capacity over the past decade and has 30 GW annually in the last two years. Over 2012/13 to 2015/16 capacity expansion was overwhelmingly from thermal power—both coal- and gas-fired generation (see Figure 1.2).

However, in 2015/16 the Government of India announced an exceptionally ambitious plan to double installed capacity over the coming decade and to do so primarily through an accelerated deployment of renewable energy. As Figure 1.2 details, 2016/17 was the first year in Indian history in which renewable capacity installs (15.7 GW, 2.5 times the 6.5 GW of renewable installs in 2015/16) exceeded net thermal power installs (7.7 GW, down 65% year on year). While 11.5 GW of thermal power plants were commissioned, a record 3.9 GW of end-of-life thermal power plants were *decommissioned* in 2016/17.

IEEFA forecasts 14 GW of renewable capacity additions in 2017/18, a slight slowdown on 2016/17 but more than double the 5.8 GW of net thermal capacity additions.

Figure 1.2: India Renewable and Thermal Power – Net Capacity Additions (MW)

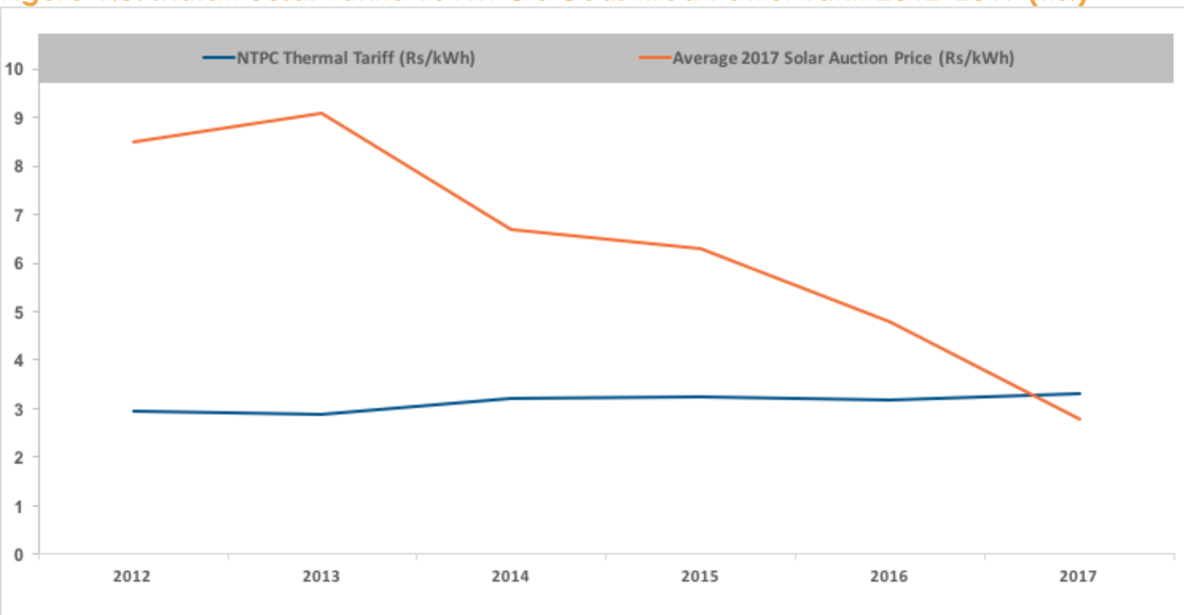


Source: Central Electricity Authority (CEA), MNRE, IEEFA Estimates
Note: The renewables estimates exclude large scale hydro

This has been a landmark year for Indian renewables, with record-breaking events that include new solar and wind infrastructure tariffs of well below Rs3 per kilowatt-hour (kWh), or roughly US$0.05 per kWh. These prices reflect a 50% decline over the past two years and put wind and solar tariffs below the cost of electricity generated by existing domestic thermal power plants (NTPC Ltd.'s average 2016/17 tariff was Rs3.20/kWh) as per Figure 1.3. Renewable energy tariffs are 30-50% less than what is required to justify more expensive imported coal or liquefied natural gas (LNG) capacity.

We explore these transformative developments in detail in Section 2.

Figure 1.3: Indian Solar Tariffs Vs NTPC's Coal-fired Power Tariff 2012-2017 (Rs.)



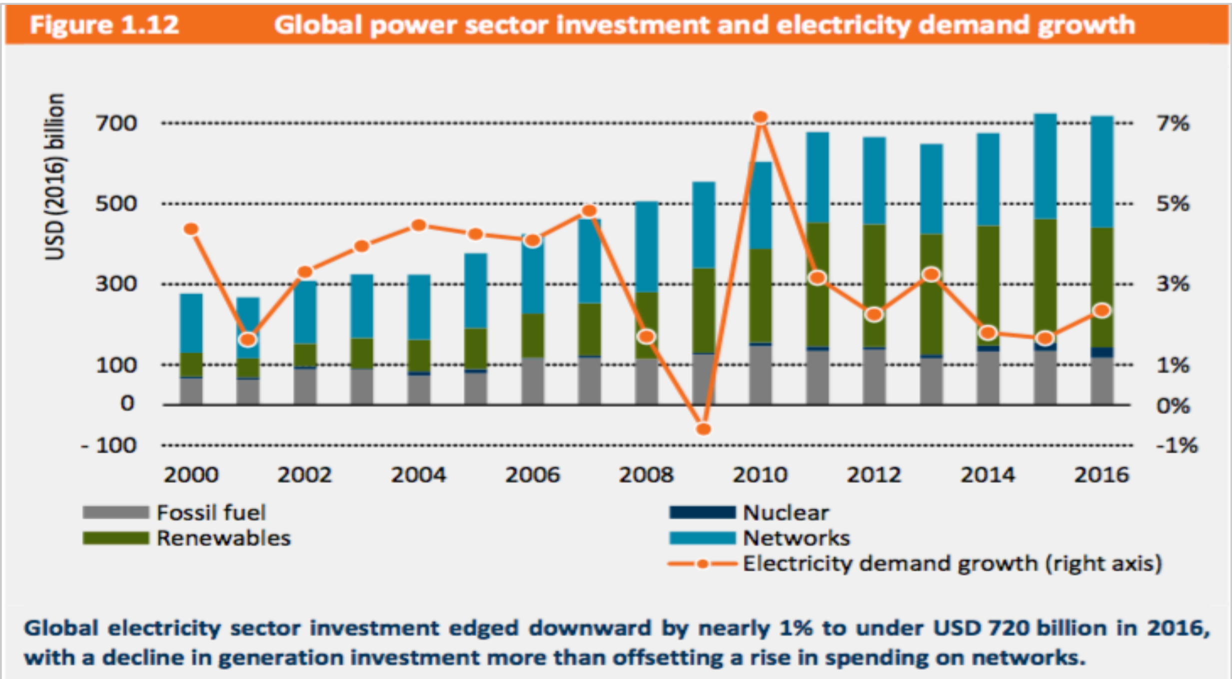
Source: NTPC, Bloomberg New Energy Finance, Livemint, Bloomberg Gadfly

While this report focuses on the Indian electricity sector transformation, Figure 1.4, taken from the International Energy Agency's July 2017 *World Energy Investment* report, shows a similar trend emerging globally.

Renewable energy infrastructure investment has been running at two to three times the level of new fossil fuel capacity investment since 2011. This has occurred as global electricity demand growth has slowed to half the rate seen in the previous decade.

The combined impact of slowing demand growth and accelerating deployment of ever-lower-cost renewable energy means the global electricity-generation transformation is gathering speed. With technology innovation and economies of scale driving down the cost of renewables, grid parity is being reached in more and markets every year. The technology-driven momentum of this trend appears unstoppable. While it is not yet possible to evaluate the full implications of the deflationary and environmental impacts of the global transition that is in progress, its effect on energy markets will be profound.

Figure 1.4: Global Electricity Sector Investment: 2000-2016 (US$bn)



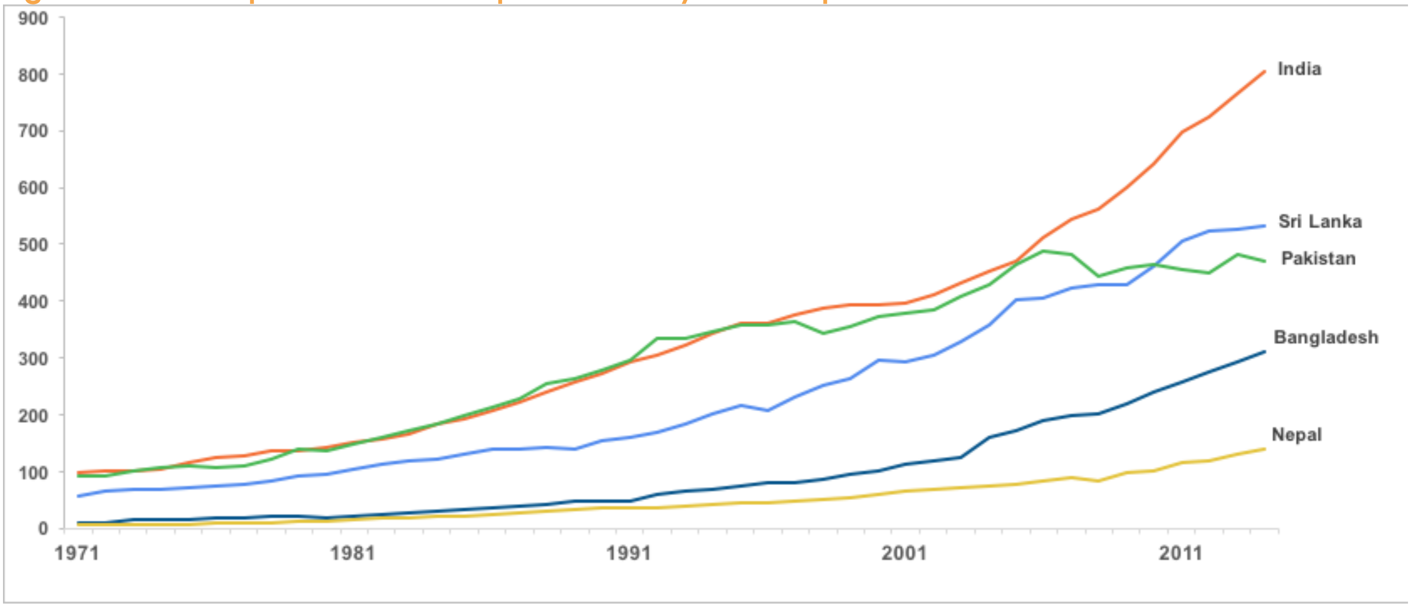
Source: IEA World Energy Investment, July 2017

Figure 1.5 details India's sustained growth in per capita electricity consumption over the past five decades. It has grown eight-fold to 806 kWh, more than double that of neighbouring Pakistan and Sri Lanka, and treble that of Bangladesh.

Nonetheless, India's annual per capita electricity consumption is still only one-eighth that of France or Germany (at 7,000 kWh each), and just one-fifteenth of per capita electricity consumption in the U.S. (at 12,000 kWh). Clearly, this differential has to be narrowed.

IEEFA expects India's gross domestic product (GDP) to double over the next 10 years, growing at 7% annually. Electricity demand is forecast to nearly double over this period. However, technology and grid-efficiency improvements combined with general energy efficiency gains should keep increases in demand to more manageable levels.

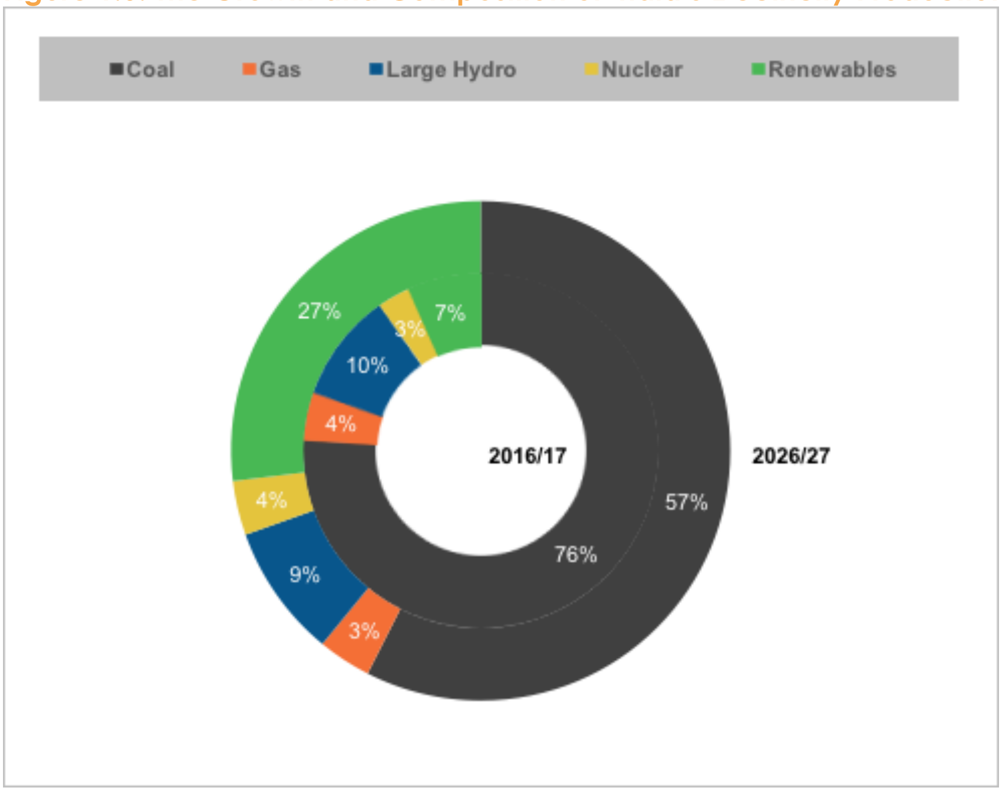
Figure 1.5: The Rapid Rise of Per Capita Electricity Consumption in India Since 1971



Source: World Bank

Figure 1.6 details IEEFA's forecast of total electricity production and the fuel mix in 2026/27 relative to 2016/17. It shows renewables' share of production trebling and thermal power generation's share shrinking, from 80% to a still dominant 60%. That said, a 20% share loss in just one decade highlights the magnitude of the transition now under way in India.

Figure 1.6: The Growth and Composition of India's Electricity Production: FY2017 vs FY2027



Source: Central Electricity Authority, IEEFA Estimates
Note: Excluding Diesel fired Generation & imports from Bhutan
RE includes solar, solar thermal, small hydro, biomass, onshore & offshore wind

Impact of Declining Capacity Factors

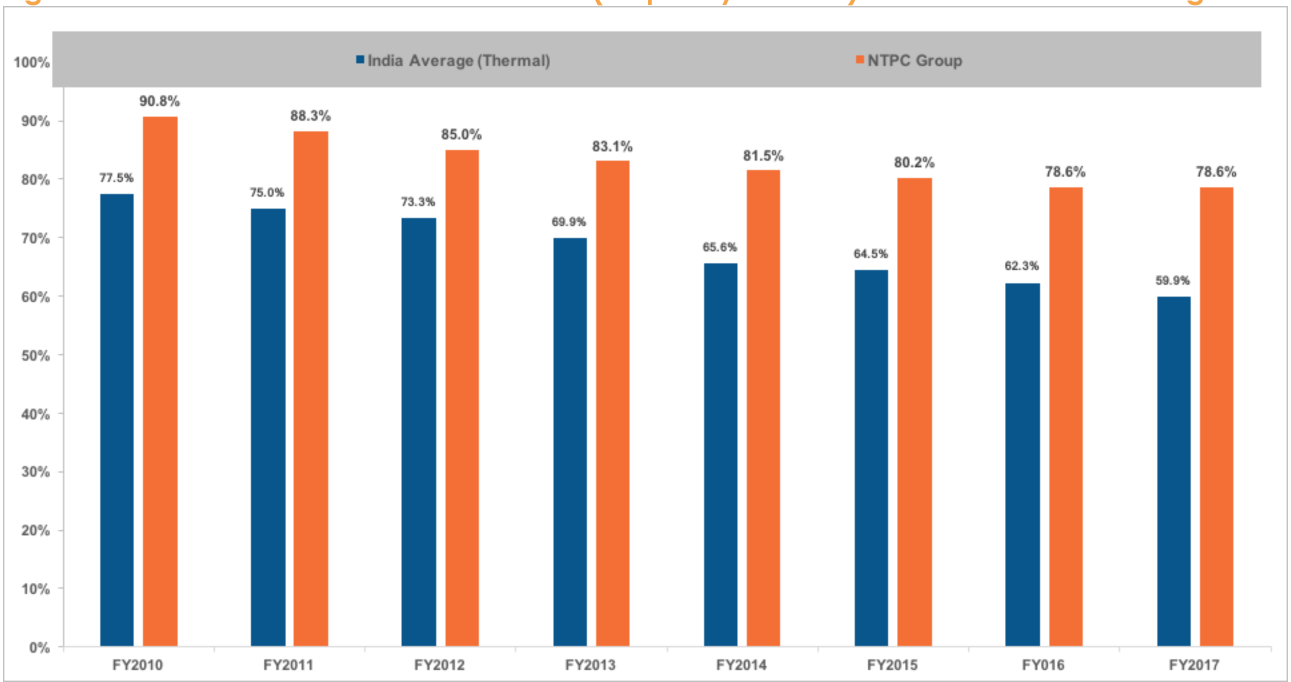
New thermal power plant capacity in India grew by a net 20 GW annually from 2012/13 to 2015/16. This trend saw capacity expansion running well ahead of electricity demand growth. The result: Declining Indian capacity utilisation rates across the thermal power sector this decade.

In 2016-17, thermal capacity expansions have slowed to a decade-low of just 7.7 GW (11.6 GW new adds less 3.9 GW of closures). Meanwhile, lower-than-expected demand growth, ongoing gains in grid and energy efficiency, and record renewable energy installations pushed thermal power sector utilisation rate in India to a decade low in 2016/17.[1]

Capacity factors at Indian coal-fired power plants have fallen, from 77.5% in 2010 to an average 62% in 2015/16 and less than 60% in 2016/17 (see Figure 1.7). IEEFA notes that capacity factors are higher than capacity-utilisation (as explained in Figure 5.5) rates.

NTPC's average plant load factor (PLF) has consistently run 15% better than the overall Indian figure, but even so, the average capacity factor in India dropped below 80% for the first time in 2015-16 and stayed at that level again in 2016/17, down from more than 90% in FY2009-10. NTPC, known formerly as the National Thermal Power Corporation, is owned by the central government. The private sector posted an average PLF of just 58.5% in 2016/17; many power plants cannot be operated profitably at such low utilisation rates.

Figure 1.7: Coal Power Plant Load Factors (Capacity Factors): NTPC and India Average



Source: NTPC, Indian Central Electricity Authority.

The Central Electricity Authority (CEA) is now forecasting that India's peak electricity demand by 2021/22 will be 235 GW, 17% lower than it had previously forecast. For 2026/27, 317 GW is forecast, 21% lower than the previous CEA forecast.

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[1] http://www.bridgetoindia.com/indias-problems-coal-sector-continue/

The lower-than-expected demand is now calling into question the viability of thermal power plants in parts of India.[2]

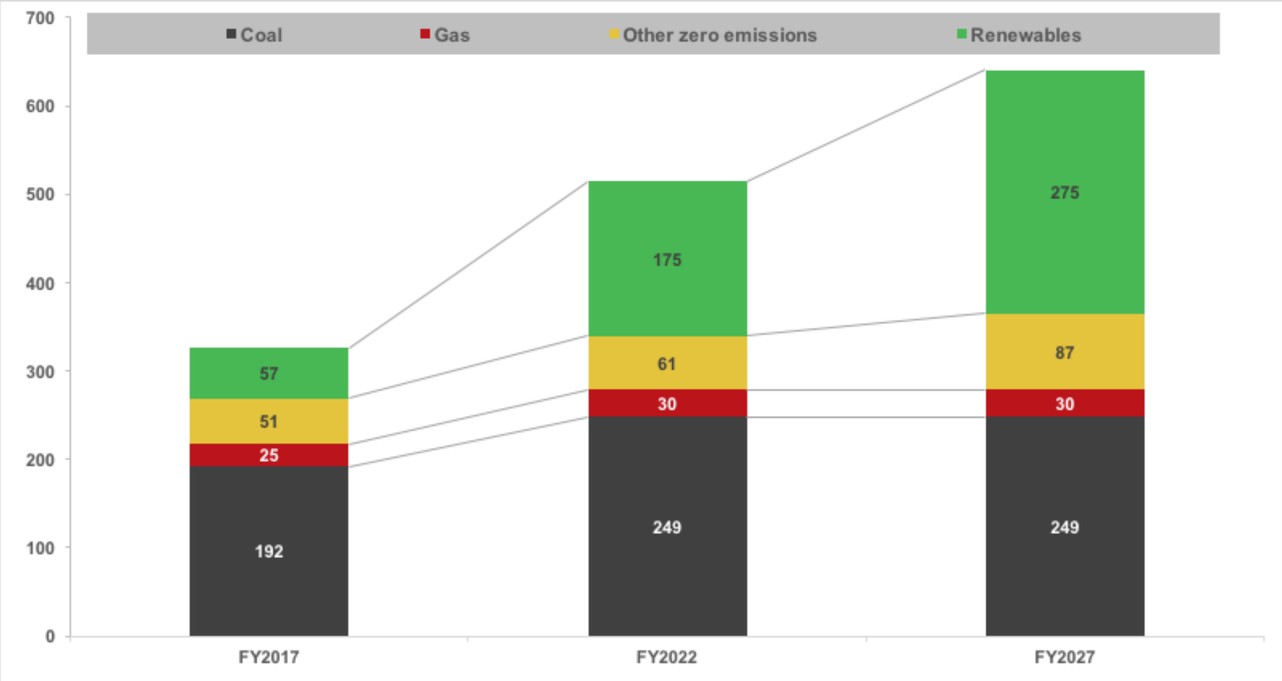
Water issues are also playing an increasingly important role in assessments of coal-fired power plant viability. Thermal power plants use 3.8 cubic metres of water per megawatt (MW), compared to 0.1 cubic metres/MW for solar and almost zero for wind power[3]. Adani Power was forced to temporarily shut down 2.6 GW of coal-fired power in 2016 due to water shortages—and water-related challenges will only grow more pronounced as the economy expands and the population increases.[4]

The growing penetration of renewable energy in India is also driving down coal-fired capacity factors. With renewables projected to reach 175 GW by 2021/22 and 275 GW by 2026/27, IEEFA expects the pressure on coal-fired plant capacity factors to grow. Absent a significant slowdown in thermal power expansions and/or an acceleration in end-of-life plant retirements, NTPC's capacity factors will continue to decline with the rest of India's coal-fired electricity industry, further eroding the economics of coal-fired generation.

Third Draft National Electricity Plan (NEP3)

India's draft third National Electricity Plan (NEP3), released in December 2016, covers the next two five-year periods to 2027, and concludes that beyond the half-built plants already under construction, India does not require any new coal-fired power stations over this period. IEEFA's electricity model supports the NEP3 conclusion.

Figure 1.8: Indian Electricity Capacity Additions and Totals to FY2027 (GW)



Source: Indian Central Electricity Authority, IEEFA estimates

2 http://energy.economictimes.indiatimes.com/news/power/wavering-power-demands-scare-upcoming-projects-in-andhra-telangana/58440497
3 http://www.livemint.com/Opinion/SZAi8vdmvddKR3N2NMANQJ/An-evolving-risk-paradigm-in-the-power-sector.html
4 http://indianexpress.com/article/business/companies/water-crisis-adani-power-shuts-2640-mw-units-at-tiroda-plant/

NEP3 calls for 57% of India's total electricity capacity to come from non-fossil fuels (362 GW of the projected 641 GW total) by 2027. By 2027, India aims to have 275 GW of total wind and solar capacity, plus 72 GW of hydro and 15 GW of nuclear. This expansion in renewables capacity will mean no new coal-fired capacity will be required until at least 2027.[5] Further, the 50 GW of coal power currently under construction will put the entire sector at just 50-60% of capacity utilisation through 2027. Where these new coal-firedl plants don't replace retiring capacity they will essentially become stranded assets retained as little more than reserve capacity.

The CEA says in its draft plan that expected peak demand at the end of 2021-22 will be 235 GW, some 17% lower than the agency projection in the 18th Electric Power Survey report. Peak demand at the end of 2026-27 is forecast to be 317 GW, which is 20.7% lower than the earlier projection.[6] When combined with excessive expansion of thermal power capacity over the last five years, lower-than-expected demand has resulted in India's thermal power fleet running at a decade-low utilisation rate (see figure 1.7).

National Energy Policy: NITY Aayog

India's draft national energy policy looks at the country's energy needs through 2040, based on a report and road map released in July 2017 by NITI Aayog, the Indian government's in-house think tank. That report focuses on renewable energy; drastic reductions in emery intensity; a doubling of per capita energy consumption and a tripling of per capita electricity consumption; 100% electrification; clean-cooking coverage by 2022; and reduced fossil fuel imports. The draft policy stresses efficiency, technology, regulatory oversight, effective engagements with overseas investors, air quality considerations, and human resource development across the energy domain.

This policy incorporates the 2022 targets with India's NDC (nationally determined contribution) for which the target year is 2030.[7]

The draft policy concludes that India will be largely self-sufficient in thermal coal supply through 2037, with domestic production forecast to peak at 1,200-1,300 million tonnes per annum, a forecast that IEEFA sees as flawed, given how wind and solar are already the low-cost source of new generation supply.

[5] http://energy.economictimes.indiatimes.com/news/renewable/in-10-years-half-of-indias-energy-capacity-will-be-from-non-fossil-fuel-sources/58258256

[6] http://energy.economictimes.indiatimes.com/news/power/wavering-power-demands-scare-upcoming-projects-in-andhra-telangana/58440497

[7] http://economictimes.indiatimes.com/industry/energy/power/government-to-form-panel-to-monitor-national-energy-policy/articleshow/59569281.cms

2. Renewable Energy: Capacity Building

By July 2017, India had cumulative installed solar energy capacity of 15.6 GW, including 1.7 GW of rooftop solar.[8] Solar installs in 2017/18 are set to nearly double for the third consecutive year, to 10 GW. India's wind installations had reached 32.3 GW by March 2017 after a record rate of installs of 5.5 GW in 2016/17, ranking India fourth globally in cumulative wind installs (behind China, the U.S. and Germany).

Solar and wind are gaining market share because they are cost competitive. An additional attribute—and one embraced by policymakers—is that they create jobs. As former Energy Minister Piyush Goyal highlighted recently, every new unit of renewable power creates five to seven times more jobs than a conventional thermal energy source.[9]

A key enabler of India's renewable energy expansion is the robust buy-in from leading corporates both across India and globally. NTPC Ltd has helped cut solar costs to less than Rs3/kWh in just two years and has a corporate strategy involving facilitating 15-25 GW of renewables investment.[10] IEEFA reviewed this activity in a May 2017 report, "NTPC as a Force in India's Electricity Transformation."[11]

IEEFA would note the significant scope for solar across India, with the growth in installation rates from 0.8 GW in 2014/15 to 3.0 GW in 2015/16 and 5.5 GW in 2016/17. IEEFA forecasts 10 GW of new solar for 2017/18, as India needs to continue the accelerated momentum in solar to meet its 100-GW-by-2021/22 target. IEEFA notes that progress toward this ambitious target is currently one year behind schedule, and that the unexpectedly dramatic rate of cost deflation has caused some contract reneging in both the wind and solar sectors.[12]

At this point, it is worth putting India's likely record 10 GW of new solar in 2017/18 into global context; while it would be a significant accomplishment, China is on track to set a new world record of 50 GW of new solar capacity in 2017, which would break the 34 GW record it set in 2016. All estimates of deployment rates are being broken, and India is perfectly positioned in the medium term to follow China's lead, given India's exceptionally low costs and clear policy framework.

In September 2017, Anand Kumar, the secretary of India's Ministry of New and Renewable Energy (MNRE), made a bold policy statement at the Renewable Energy India (REI):[13]

> *"Under Prime Minister Modi, we upscale our total renewable energy target to 175 GW by 2022. This, you will all agree, is a fairly ambitious target. With advancements in technology, and with price of solar and wind reducing, we are not only sure but confident that we will achieve the target, and exceed it. India has limited fossil fuels. We depend on imports for petroleum. If we have to support and meet the demand of 1.25 billion people, then renewables are the only way."*

India is set to tap into a global energy market transformation China has been leading for the last five years. Together, the two countries will create enough market momentum to make further transformation unstoppable. Rapid technology developments and cost

[8] http://www.bridgetoindia.com
[9] https://energyinfrapost.com/solar-wind-energy-powering-indias-power-sector/
[10] http://www.worldbank.org/en/news/immersive-story/2017/06/29/solar-powers-india-s-clean-energy-revolution
[11] http://ieefa.org/wp-content/uploads/2017/05/NTPC-as-a-Force-in-Indian-Electricity-Transition_May-20171.pdf
[12] https://energy.economictimes.indiatimes.com/news/renewable/ntpc-searches-for-buyer-for-kadapa-solar-parks-power/61194366
[13] https://www.pv-magazine.com/2017/09/20/rei-exhibition-india-will-surpass-175-gw-renewable-target-says-mnre/

reductions in battery storage, offshore wind, and solar thermal power will only serve to accelerate these trends.

Figure 2.1 highlights the potential for renewables across India in the 2017-2022 plan. An analysis of India's potential renewable energy shows this is just the start, with scope beyond this for cumulative renewables installs to rise sixfold in coming decades.

Indicative of this potential, R. K. Singh, the country's power and renewable energy minister predicted in October 2017 that renewable energy would deliver 40% of India's energy supply by 2030, up sharply from 16% in 2017, enabling strong economic growth whilst lowering India's carbon emissions.[14]

Figure 2.1: Indian Renewable Energy Capacity Potential (GW)

Sources	2022 Total (GW)	Potential	Potential (%)
Wind (onshore)	60	103	10%
Solar	100	749	73%
Small Hydro	7	20	2%
Biomass	11	23	2%
Wind (offshore)	2	127	12%
Grand Total	**180**	**1,022**	**100%**

Source: Ministry of New and Renewable Energy, Wind Energy Mission, Rural Electrification Corp. Ltd

Solar Energy Installations

Indian solar has grown spectacularly over the past three years. Installs trebled to 3.0 GW in 2015/16 and then nearly doubled to 5.5 GW in 2016/17. Installs are on track to nearly double again to 10 GW in 2017/18, taking cumulative installed solar to a projected 22 GW by March 2018.

While this rapid growth has caused teething problems, IEEFA notes the ongoing rapid incorporation of policy and rule changes that are designed to simplify, de-risk and encourage a sustained lift in solar infrastructure investing. This policy transparency, longevity and certainty has attracted both Indian corporate majors as well as leading global renewable infrastructure investors.

IEEFA sees India as largely on track to deliver on its target of 150 GW by 2026/27 as part of its larger, ambitious 275 GW renewables target set in the draft NEP3 (see Section 2.1 for more detail). This trend will entail direct infrastructure investment of more than US$150bn in addition to the US$200bn of grid modernisation and expansion capital required over the coming decade.

Figure 2.2 Indian Solar Capacity Additions to FY2027 (GW)

Year ended March	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
IEEFA's Installs for the year	3.2	5.5	10.0	10.0	13.0	13.0	14.0	14.0	14.0	14.0	14.0	14.0
Change in install rate (%)	318%	70%	81%	0%	30%	0%	8%	0%	0%	0%	0%	0%
Cummulative total (GW)	6.8	12.3	22.3	32.3	45.3	58.3	72.3	86.3	100.3	114.3	128.3	142.3
GoI Target												150.0

Source: Central Electricity Authority, IEEFA estimates
Note: The above numbers for installations include rooftop solar

[14] http://energy.economictimes.indiatimes.com/news/renewable/renewables-to-account-for-40-per-cent-of-indias-energy-mix-by-2030-power-minister-r-k-singh/61053064

A key underpinning of the rapid acceleration in deployments of solar infrastructure and associated capacity across India has been record low tariffs resulting from a series of very successful and well-attended reverse auction tenders.

With tariffs down 50% since the start of 2016, Indian solar is now cost competitive with existing thermal power plants. The strong growth forecast for Indian electricity demand over the coming decade, combined with proactive government policies to curtail excessive new thermal power capacity plans, provides a cushion that will facilitate India's rapid electricity sector transformation whilst avoiding the worst of thermal power stranded asset risks increasingly evident in China and Europe.

Solar Achievements: Records Set, Then Broken

Over the last two years, India has made enormous strides in developing domestic renewable energy capacity. Visionary stretch targets have been articulated only to then become formal government policy, with subsequent industry focus suggesting the impossible two years ago is now eminently achievable, underpinned by dramatic technology improvements, economies of scale as installs have doubled each year since 2015, and rapid price deflation – 50% in just two years for solar energy. India already has seen the benefits of its visionary long-term energy policy, which is providing transparency, longevity and certainty that is driving industry investment and learning-by-doing gains in India that are compounding the gains being made in China, America and Europe.

A 50% decline in solar tariffs in two years

February 2017 saw a landmark event in India's energy transition when the previous solar tariff record was broken in the Rewa solar project auction. The levelised tariff of the project is Rs2.97/kWh, more than a rupee below the previous lowest tariff.[15]

The first sub Rs 3/kWh record did not last long; in May 2017, the Bhadla, Rajasthan, solar project attracted a tariff bid of Rs2.62/kWh. Within a week, that record was broken with a Rs2.44/kWh bid at an auction in the same Bhadla solar park.[16]

Imported solar module panel costs have risen in the months since this May 2017 record-low tariff was set.[17] While this trend will require a stabilisation or even upward move in solar tariffs to support sustainable rates of return in the near term, India's cost of debt continues to decline, and this trend supports the long-term deflationary trends in solar.

In September 2017, Gujarat completed a 500 MW solar tender at a new record-low Rs2.65/kWh tariff for projects where developers must acquire their own land.[18] Renew Power won 260 MW of this heavily-contested tender, and many globally significant firms bid, including Tata Power and ReNew Power in India, Fortum (Finland), and Lightsource Renewable Energy (U.K.).[19]

November 2017 saw Chile award solar tariffs at a record US$21/MWh, down 50% in the last year, while Mexico awarded solar at a new global record low of just US$18/MWh, highlighting the scope for further price cuts for Indian solar medium term.

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15 http://www.livemint.com/Industry/zW5Lf1okn054cFug5yKGsL/Madhya-Pradesh-solar-bids-hovering-at-Rs3-per-unit-in-revers.html
16 https://www.pv-tech.org/news/yet-another-india-solar-tariff-record-of-2.44-rupees-in-rajasthan
17 https://www.bloombergquint.com/business/2017/08/20/rising-chinese-solar-panel-prices-may-put-projects-bid-at-record-low-tariff-at-risk
18 https://www.pv-tech.org/news/prices-in-gujarats-500mw-solar-auction-surprise
19 http://energy.economictimes.indiatimes.com/news/renewable/gujarat-solar-power-auction-sees-winning-tariff-of-rs-2-65-per-unit/60758818

The world's largest solar project in operation

As prices have dropped, project size has increased. In September 2016, Adani Green Power commissioned what was briefly the world's largest single site solar project, a 648MW project at Kamuthi, Tamil Nadu. By January 2017, China was reported to have commissioned an 850 MW solar project in Qinghai province.

But July 2017, India regained the mantle, at least temporarily, of having world's biggest single-site solar plant, with 1 GW commissioned in Kurnool in Andhra Pradesh.[20] Several solar project firms have a stake in this mega-solar project, with SB Energy at 350 MW and Greenko at 500 MW, which is funded by Abu Dhabi Investment Authority & GIC Singapore. Azure owns 100 MW of the Kurnool project and Adani Green Power 50 MW.

This highlights how some of the largest global power sector investors are actively building capacity in Indian solar infrastructure, a major endorsement of Prime Minister Modi's vision.

The world's largest solar projects in development

In 2015, Adani Green Energy signed a MoU with the Rajasthan state government for the development of a single industrial park with land and grid capacity for 10 GW of solar projects. By the end of 2018, this industrial park is expected to have more than 2 GW of solar operational, making it the largest solar project under development in the world.

In Karnataka, a 2-GW solar industrial park is scheduled to be commissioned by the end of 2018, backed by NTPC offtake agreements and with local landowners' involvement.[21]

The world's first solar-powered train

In July 2017, India commenced operation of a partially solar-powered train, with ancillary power generated by train rooftop solar with up to 72 hours of on-board battery backup.

More substantively in the near term, Indian Railways has lifted its solar capacity target fivefold, to 5 GW by 2025[22], with a plan to install solar on railway station rooftops as a way of permanently reducing power bills.

India's largest solar carport

Tata Solar in July 2017 commissioned 2.67 MW of solar carports at the Keralan airport.[23]

Floating solar

India is developing two 100 kW floating solar plants, one by the Surat Municipal Corp. in Gopi Talav and one by NTPC Ltd in Kerala.[24] These projects will boost floating-solar expertise in India, but they still pale in comparison to current Chinese projects, which include an operational 40-MW unit and an 80-MW facility now under construction.

Hybrid solar-wind development

In September 2017, Siemens Gamesa India won the rights to develop a 29 MW solar facility alongside a 50 MW wind farm to optimise site and grid connections.[25]

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[20] https://www.pv-tech.org/news/first-ever-1gw-solar-park-to-be-grid-connected-imminently

[21] http://www.thehindu.com/news/national/karnataka/1st-phase-of-pavagada-solar-park-to-be-ready-by-dec/article19779170.ece

[22] https://qz.com/1030696/india-is-rolling-out-trains-with-solar-powered-coaches-thatll-save-thousands-of-litres-of-diesel/

[23] https://www.pv-tech.org/news/tata-power-solar-completes-indias-largest-solar-carport-at-keralan-airport

[24] http://energy.economictimes.indiatimes.com/amp/news/renewable/floating-solar-power-plant-at-gopi-talav-in-surat-soon/59775675

[25] http://www.altenergymag.com/news/2017/09/26/siemens-gamesa-wins-first-order-for-a-hybrid-wind-solar-project-in-india/27184

Solar Irrigation Pumps

India has an estimated 26 million agricultural irrigation pumps, most of which are powered by either heavily subsidised or free electricity or heavily subsidised, imported diesel. A total of 135,545 solar pumps have been installed under the Solar Pump Program till 30th September 2017.[26]

IEEFA views this as a prime end-of-grid opportunity for solar power. This application can be optimised to operational times when solar is available at zero marginal cost, and expensive subsidies and/or grid connectivity can be avoided. Progress has been reported on this use case in states like Haryana,[27] but payment issues are reported to be holding up a program in Gujarat. Taking a whole-of-government perspective would suggest obvious economies of scale in moving to domestic renewable systems, aiding the "Make in India" initiative, with the added opportunity of export potential to Bangladesh and Africa.

Rooftop Solar: 40 GW by 2022

In 2016/17 India nearly doubled total rooftop solar installs to 1.4 GW with the addition of 678 MW in just 12 months. This is still well short of the run-rate required to achieve the ambitious 40 GW target that is part of India's 175-GW-of-renewables-by-2022 vision. However, it is strongly positive momentum and shows industry capacity is clearly building. October 2017 saw Renewable energy minister R K Singh detail that 2.36 GW of rooftop solar systems have been sanctioned to-date. [28]

Indian Railways has ambitious plans for its own rooftop solar initiative. By 2020, the state-run transportation network plans to put solar on 8,000 station roofs as part of a wider plan to generate 1,000 MW of renewable power (500 MW from rooftop installations, 500 MW in utility-scale solar projects, and 200 MW in wind-powered initiatives), which could be scaled up to 5,000 MW by 2025.[29] Indian Railways has made limited progress so far. Out of its 1 GW solar target, only 16 MW had been installed as of March 2017. However, as of July 2017, a reported 255 MW of rooftop and 250 MW of land-based solar projects are in the pipeline, with around 130 MW of capacity already awarded.[30] In August 2017, Indian Railways awarded 67 MW of rooftop solar capacity across India at tariffs ranging from Rs2.39 to Rs4.49 to firms that include Mytrah Energy and Azure.[31]

In July, Solar Energy Corporation of India (SECI) announced it had received rooftop solar bids to install more than 500 MW, including for a record low bid of Rs2.20/kWh (US$0.034) for an 11 MW project in the Andaman and Nicobar Islands, a special-category state, from developer Mundra Solar PV.[32] This tender should accelerate capacity building across India and alleviate grid congestion through the deployment of distributed generation.

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[26] https://energy.economictimes.indiatimes.com/news/power/india-must-encourage-hydro-power-projects-development-r-k-singh/61361775

[27] http://energy.economictimes.indiatimes.com/news/renewable/haryana-government-to-install-1-lakh-solar-pumps-for-irrigation/60494694

[28] https://energy.economictimes.indiatimes.com/news/power/india-must-encourage-hydro-power-projects-development-r-k-singh/61361775

[29] http://energy.economictimes.indiatimes.com/news/renewable/indian-railways-to-add-400-megawatt-solar-power-capacity-current-fiscal/59338507

[30] https://qz.com/1030696/india-is-rolling-out-trains-with-solar-powered-coaches-thatll-save-thousands-of-litres-of-diesel/

[31] https://www.pv-tech.org/news/67mw-of-rooftop-solar-awards-for-indian-railways-abb-to-supply-inverters-to

[32] https://www.pv-tech.org/news/indian-500mw-government-rooftop-auction-draws-lowest-price-of-2.20-rupees

The Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL) tender was awarded in August 2017; it calls for 30 MW of grid-connected rooftop solar to be installed across Madhya Pradesh. The lowest tariff awarded in the Madhya Pradesh section of the July 2017 SEIC auction was Rs3.14/kWh, suggesting that this 30 MW tender is likely to see very competitive rooftop solar development.[33]

In September 2017, Azure Power won a 50 MW allocation of a total of 360 MW tendered for Indian government building rooftop solar held by Solar Energy Corporation of India (SECI). Power will be sold at a tariff of Rs3.19 - 3.97/kWh (US$0.05-0.06) based on location across 10 states on GoI buildings. Including a capital incentive from SECI, the expected weighted average levelized tariff is Rs4.65/kWh (~US$0.07).[34]

Solar: At Risk From Anti-Dumping Investigation

India imported US$2.3bn of solar equipment in 2015/16, and 84% of that was procured from China. Indian solar cell and module manufacturing capacity is in the main using outdated technology and is not competitive. Domestic content requirement rules have been used by the Indian government to promote domestic upstream manufacturing, but there is a clear cost and quality differential versus cheaper Chinese imports.[35]

In July 2017, India commenced an anti-dumping investigation relating to solar cells and solar modules from China, Taiwan and Malaysia. While the Chinese authorities responded by labeling the investigation an "abuse of trade remedy measures," they more helpfully noted Indian solar is an emerging industry key to a future that will be materially hindered by anti-dumping surcharges.[36] Solar manufacturing remains a priority of the GoI.[37]

Here two Indian government priorities are in conflict. PM Modi is strongly committed to the "Make in India" initiative, which gives priority to developing India as a manufacturing hub, both for domestic and export markets. At the same time, solar is crucial to India's clean energy goals and the fact is China is in effect subsidising the global supply of ever-cheaper solar modules is accelerating the cost competitiveness of the solar power generation sector and enhancing solar infrastructure deployment. A swift resolution without import tariffs will help maintain Indian solar deployments.

Renewables: Sovereign Risk From Contract Scrapings

While the completion of new, low-cost, sustainable, domestic renewable energy investment is creating excitement across India, it poses a problem in that the rate of tariff declines has created a heightened risk that certain state governments will look to renege on now-expensive renewable energy contracts previously agreed to. This is causing legal uncertainty and sovereign risk on contract viability.[38]

In July 2017, for example, it was reported that SECI had scrapped 950 MW of solar tenders in Andhra Pradesh and Karnataka that were announced and awarded between June

[33] http://mercomcapital.com/mpuvnl-tenders-30-mw-of-grid-connected-rooftop-solar
[34] https://www.pv-tech.org/news/azure-power-wins-50mw-of-indian-government-building-rooftop-solar-projects
[35] http://energy.economictimes.indiatimes.com/news/renewable/solar-sector-unfazed-by-india-china-tensions/59954641
[36] https://www.pv-tech.org/news/china-warns-against-indian-abuse-of-trade-remedy-measures-on-solar#.WXd3Marh018.twitter
[37] https://www.pv-tech.org/news/mnre-secretary-reaffirms-indian-government-commitment-to-solar-manufacturin
[38] http://energy.economictimes.indiatimes.com/news/renewable/green-companies-may-slip-into-red-if-forced-to-cut-tariffs-banks/60051774

and August 2016. The benchmark tariff for those two projects was Rs 4.43/kWh (US$0.069/kWh), i.e. 80% more than the lowest solar tender (Rs 2.44/kWh).[39]

It has likewise been reported that Uttar Pradesh has renegotiated the tariff for a solar auction it conducted in September 2015, despite having already signed the necessary power purchase agreements (PPAs). The government of Jharkhand has delayed signing PPAs with the winners of an auction conducted 16 months ago, although it was reported in September 2017 that a compromise had been reached allowing for a 10-20% lower tariff and project downsizing in return for PPA confirmations. The government of Andhra Pradesh is even reported to have refused to sign a then-record-low solar tariff award of Rs3.15/kWh on 250MW by SolarDirect in April 2017.[40]

Similar developments are seeing wind project developments cancelled as well.[41]

However, with the run of record low renewable energy tariffs continuing, it is feasible that many existing thermal power tariffs will be challenged too as excessively costly, particularly if the proposed projects are stalled and unable to deliver on their contractual commitments.[42]

August 2017 saw the MNRE detail much-needed new guidelines for solar tenders to improve bankability and reduce sovereign counterparty risks.[43]

Solar: Contract Renegotiation

In a similar vein, reports are emerging that existing operating solar projects are being pressured via lost revenues from extended grid curtailments into accepting new, repriced PPAs in return for better protection and certainty on grid dispatch.

Renewable PPAs: At Risk of Payment Defaults

Reform of Indian distribution companies (Discoms) remains a key challenge, as discussed below in Section 3. Payment delays of three or even six to 12 months are an accepted business risk facing many electricity generators, whether thermal or renewable. Payment guarantees are increasingly being offered by the central government via SECI, NTPC or PTC India Ltd to provide bankable offtake agreements in the solar sector.

Prior to the first reverse auction 1 GW wind tender earlier in 2017, payment risk is a key concern for the bankability of wind infrastructure projects too.

In July 2017, Siemens Gamesa Renewable Power Chairman Ramesh Kymal said: "Payment security by Discoms is an area of major concern for independent power producers. There is enormous delay in payments by Discoms in certain states. Cutting down these delays and creation of an appropriate payment security mechanism will go a long way in enhancing the investor confidence and bankability of projects."[44]

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[39] http://asian-power.com/project/news/india-approves-550-mw-wind-ppas-cancels-950-mw-solar-tenders
[40] http://economictimes.indiatimes.com/industry/energy/power/distribution-companies-want-to-rework-pacts-as-solar-tariffs-hit-new-low/articleshow/59745228.cms
[41] https://www.bloomberg.com/news/articles/2017-07-27/wind-projects-in-peril-as-indian-states-rethink-purchase-pacts
[42] https://www.bloomberg.com/news/articles/2017-09-27/nlc-india-is-said-to-offer-lower-tariffs-to-save-power-plants-j82xdwtm
[43] http://energy.economictimes.indiatimes.com/news/renewable/new-solar-norms-to-stop-bullying-by-discoms/60202408
[44] http://timesofindia.indiatimes.com/city/chennai/solar-and-wind-projects-unviable-owing-to-low-tariffs/articleshow/59765886.cms

Renewable-Energy PPAs: Little Room for Error

In August 2017, India Ratings and Research warned of rising financial pressures on many relatively new renewable energy development companies. Startups that were built organically with limited equity capital have rapidly grown into industry leaders, but the aggressive reverse tender tariff bidding suggests limited room for error.

India Ratings estimates the tariff of Rs 2.44/kWh for the Rewa project means it could have an internal rate of return on equity of 10%. With debt costs of 8.5-9.5% and scope for further declines, this model could result in double-digit equity returns, but leaves little margin for error if Discom payments are delayed or disputed, or if curtailments rise.[45]

Renewable Capacity Building: Global Leaders Engage

In July 2017, Reliance Industries CEO Mukesh Ambani announced that the company was aiming to become a leading Indian renewables investor.[46] This decision followed earlier entry into the renewable infrastructure sector by many of India's other leading conglomerates, including Reliance Group, Tata Power, Adani Enterprises, Mahindra, and Aditya Birla.

India's renewables boom is also attracting a growing list of global investors, particularly to its solar sector.

From the international banking sector, investors include Japan's Softbank and Taiwan's Foxconn, which have together made a US$20bn commitment to Indian solar power, as well as Goldman Sachs, JP Morgan,[47] Morgan Stanley Infrastructure Partners and Macquarie Group.[48] Overseas electric utilities are also now active in the Indian renewables space, including Engie and EDF of France and Enel of Italy. Dutch asset manager APG, and Canada's largest pension fund managers are also participating in Indian renewable infrastructure transactions, including Canada Pension Plan Investment Board (CPPIB), Caisse de dépôt et placement du Québec (CDPQ), and Ontario Teacher's Pension Plan (OTPP).[49] Brookfield, Canada's largest asset manager, is actively seeking new renewable energy opportunities in India[50].

IEEFA anticipates a majority of the US$200-300bn likely to be invested in India's renewable capacity additions over the coming decade will be supported by overseas capital.

Global development banks also have been increasingly active in funding renewable energy, supporting infrastructure (e.g. solar industrial parks) and grid development programs, with significant new investments in India by the World Bank, the Asian Development Bank, the European Investment Bank[51] and KfW of Germany.

In May 2017, the Asian Infrastructure Investment Bank (AIIB) made its first Indian development loan, for US$160m, for grid infrastructure to support the "Andhra Pradesh – 24x7 Power for All" grid project. In July 2017, the World Bank was reported to have

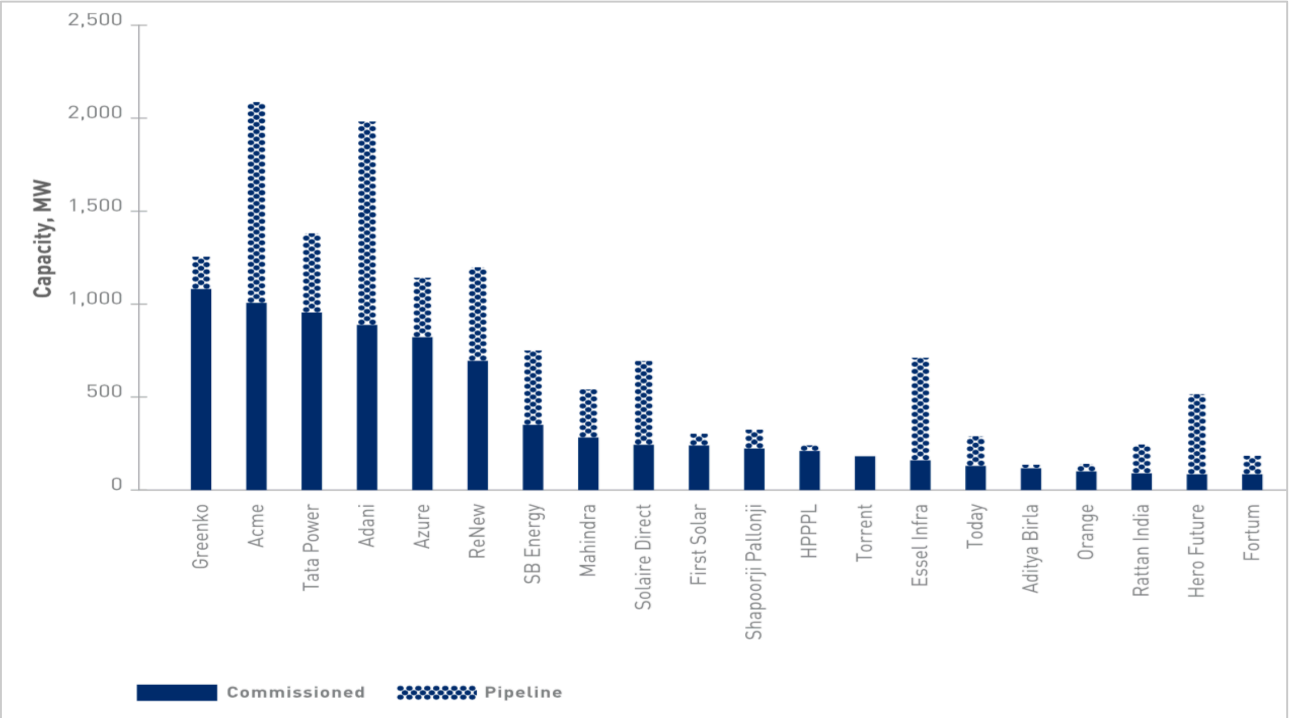
[45] http://energy.economictimes.indiatimes.com/news/renewable/aggressive-solar-power-bids-may-lead-to-capex-pressure-for-players/60089666
[46] http://www.businessworld.in/article/Reliance-Industries-To-Foray-Into-Renewable-Energy-Business/23-07-2017-122644/
[47] https://www.wsj.com/amp/articles/j-p-morgan-taps-renewable-energy-markets-1501236003
[48] https://www.pv-magazine.com/2017/04/12/macquarie-reported-to-have-acquired-330-mw-of-solar-pv-in-india/
[49] http://in.reuters.com/article/india-solar-global-pension-fund-idINKBN17W053
[50] https://www.bloomberg.com/news/articles/2017-05-03/brookfield-renewable-sees-opportunities-in-coal-fueled-india
[51] http://energy.economictimes.indiatimes.com/news/oil-and-gas/eib-makes-200-mn-euro-loan-to-sbi-for-mega-solar-projects/57955347

provided US$100m for development of solar park infrastructure, building on the US$625m of low-cost financing it provided for rooftop PV developers via a Program for Results (PforR) to be implemented by the State Bank of India.[52]

Indian renewables are also accessing the global capacity of the rapidly growing green bond market. To date in 2017, Indian renewable firms have raised US$3bn in green bonds,[53] doubling India's cumulative issuance to more than US$4bn.[54]

As an August 2017 Bridge to India report details, the top solar developers in India currently are Greenko, Acme, Tata Power, Adani, Azure and Renew. While two of these (Tata and Adani) are India's largest private power generation firms, the other four are relatively new Indian renewable energy startups. The fact that each has made investments of more than US$1bn in solar energy project development in the last three to four years shows the dynamic confidence in this rapid growth sector, but also provides a point of caution: With razor-thin EPC project development margins, there is little room for unanticipated delays, curtailment or Discom payment disputes (see Section 3 below).

Figure 2.3: India's Top 20 Solar Project Developers (MW)



Source: Bridge to India, 2Q2017 Indian Solar Compass

November 2017 saw yet another solar tariff record broken. In Chile, the third solar tender saw pricing cut to just US$21.48/MWh (a 20 year PPA requiring completion by end 2023), down more than 50% in just two years.[55] This phenomenal result illustrates that concerns that Indian solar tariffs of US$38/MWh are unsustainably low are misplaced. Price consolidation is likely near term, but medium term deflation is set to resume, further cementing renewable energy as the low cost Indian solution.

[52] https://www.pv-tech.org/news/indian-solar-park-off-taker-rules-and-world-bank-financing
[53] http://m.economictimes.com/markets/bonds/green-bond-sales-double-to-record-3-billion-this-year/amp_articleshow/60836663.cms
[54] http://www.bridgetoindia.com/greenko-azure-close-record-green-bond-issues/
[55] https://www.pv-magazine.com/2017/11/01/chile-lowest-bid-in-electric-auction-reaches-21-48mwh/

Wind Energy: Transformational, but Stalling in the Near Term

India has the fourth-largest fleet of wind farms operating globally, with 32 GW installed as of the end of March 2017. Installation rates have ranged from 1.5-3.0 GW annually over the past decade, with a significant increase to 5.5 GW in 2016/17.

The start of 2017 saw a major shift in India's wind energy tendering policy, moving from awarding wind power projects on a feed-in tariff basis to utilising the same reverse auction method that has proven possibly too successful in the solar sector.

A 20-30% decline in wind tariffs was achieved in February 2017

In February 2017, the same month in which the Rewa solar record was set, a new low tariff was set in the nation's first-ever auction for wind power, with 1,050 MW awarded at Rs3.46/kWh (US$52/MWh). Mytrah Energy, Inox Wind, Ostro Kutch Wind and Green Infra were awarded 250 MW each, while Adani was awarded 50 MW[56] against PPAs backed by the central government-owned PTC India Ltd, with completion due by September 2018.[57]

An additional 25% decline in wind tariffs was delivered in October 2017

October 2017 saw an additional 25% decline in wind tariffs in the second of two 1 GW tender results, with the winning bids coming in at Rs2.64-2.65/kWh (US$38/MWh) —with a strong range of domestic renewable energy developers taking the entire 1,000 MW (see Figure 2.4).[58] The rapid decline in tariffs is the result of lower profit margins, declining borrowing costs, improved offtake risk reduction (PTC India) and lower turbine costs.[59]

Figure 2.4: India's Latest Wind Auction Bids

Bidder's name	Tariff (Rs/kWh)	Bidder's qunatity (MW)
Renew Power Ventures Private Limited	2.64	250
Orange Sironj Wind Power Private Limited	2.64	200
Inox Wind Infrastructure Services Limited	2.65	250
Green Infra Wind Energy Limited	2.65	250
Adani Green Energy (MP) Limited	2.65	250
BLP Energy Private Limited	2.72	250
Sprng Energy Private Limited	2.77	192
Hero Wind Energy Private Limited	2.78	250
ReGen Power Tech Private Limited	2.80	250

Source: MNRE

However, the 45-50% cost reduction relative to the Rs4.00-5.00/kWh feed-in tariff available in previous years has caused an unexpected stalling in actual wind installation activity. Whereas 2016-17 saw India install a record 5.5 GW, many proposed feed-in tariff tenders have been cancelled and price expectations reset. So, while October 2017 saw the second aggressively priced 1 GW wind tender completed with an 18-month commissioning requirement, this investment will not reach completion until 2018/19 and there are few new wind projects currently due for commissioning.

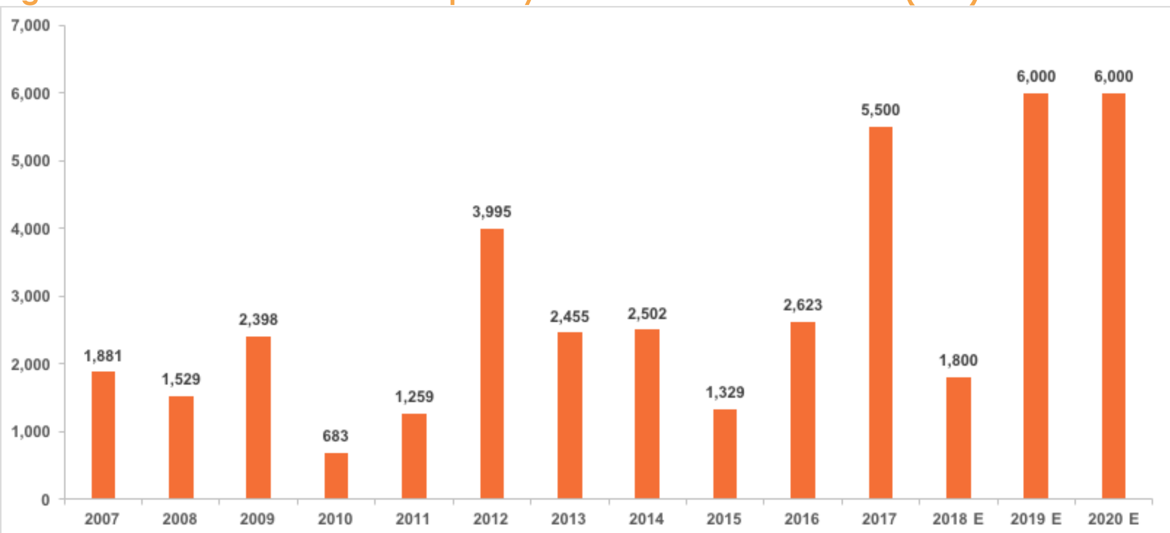
[56] http://asian-power.com/project/news/india-approves-550-mw-wind-ppas-cancels-950-mw-solar-tenders
[57] https://energyinfrapost.com/solar-wind-energy-powering-indias-power-sector/
[58] http://energy.economictimes.indiatimes.com/news/renewable/wind-power-tariff-falls-to-new-low-of-rs-2-64-per-unit-renew-inox-adani-among-winning-firms/60950586
[59] http://www.livemint.com/Money/565TBziwoPoiTdY9q5WL1I/Why-project-pipeline-not-falling-tariffs-is-a-bigger-conce.html

In another development of note, the Indian Wind Energy Association in August 2017 also moved for a high court challenge against a 500 MW wind auction in Tamil Nadu arguing the price limit of Rs3.46/kWh is contrary to a previous agreement to price tariffs at Rs4.16/kWh for the two years starting April 2016. All of this is contrary to India's national interests and creates uncertainty and delay to a much-needed acceleration in wind deployments.[60]

As such, wind project completions in 2017/18 could drop 60-80% to a decade low of just 1-2 GW.[61] This comes at a time when Finance Minister Arun Jaitley has capped the accelerated depreciation (AD) tax benefit at 40% effective from April 2017 and scrapping it altogether the next year. Additionally, the generation-based incentive (GBI) of 50 paise per unit to wind power producers ceased to exist in March 2017.[62] So while the strategic value of wind has never been greater, the underlying policy / tax support has taken a several steps backward, creating some near-term headwinds.

IEEFA is confident that with suitable national policy guidelines in place and on the back of the new competitive pricing norms of Rs2.64-3.46/kWh likely, India's national wind installations will recover to average at least 6 GW annually on the back of what has been described by leading wind developer Mytrah Energy as a "secular decline in costs".[63] India's energy ministry is working to modernise grid access and overcome stalled projects monopolizing / holding onto excess grid access allocations.

Figure 2.5: Indian Wind Farm Capacity Additions FY2007-FY2017 (MW)



Note 1: Capacity Addition figures are year to March estimates
Source: Central Electricity Authority, IEEFA estimates

July 2017 saw new bid submissions for 700 MW of new wind in Gujarat (since delayed) and a 500 MW Tamil Nadu tender, plus a 250 MW NTPC Ltd tender that closed in August 2017.[64]

However, September 2017 saw Indian wind turbine firms shut manufacturing capacity due to the prolonged downturn and excess capacity,[65] not a great endorsement of the Prime Minister's Make in India campaign to build domestic energy security capacity strategies.

[60] http://economictimes.indiatimes.com/articleshow/59946096.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
[61] http://www.financialexpress.com/industry/wind-capacity-addition-to-fall-to-1-5-gw-in-fy18-india-ratings/778857/
[62] http://indiaclimatedialogue.net/2017/08/11/wind-sector-hopes-regain-momentum/
[63] http://asian-power.com/ipp/exclusive/mytrah-energy-eyes-1000mw-additional-capacity
[64] https://mercomindia.com/advent-reverse-auctions-wind-player/

November 2017 saw Inox Wind state it's expectation that the Indian government and SECI were likely to undertake 6 GW of new wind auctions before fiscal year end, designed to kick-start industry activity and leverage record low wind tariffs of just US$38/MWh.[66]

Figure 2.6: Indian Wind Capacity Additions FY2017-FY2027 (GW)

Year ended March	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
IEEFA's Installs for the year	3.7	5.5	1.8	6.0	6.0	6.0	7.0	7.0	7.0	7.0	8.0	8.0
Change in install rate		48%	-67%	233%	0%	0%	17%	0%	0%	0%	14%	0%
Cummulative total (GW)	26.8	32.3	34.1	40.1	46.1	52.1	59.1	66.1	73.1	80.1	88.1	96.1
			GoI Target (Onshore wind)									**100.0**
			IEEFA Target (Onshore + Offshore Wind)									**98.5**

Source: Central Electricity Authority, IEEFA estimates

Offshore Wind Energy: A Decade Away for India

Offshore wind costs are plummeting, but are roughly a decade behind the development curve of solar.

That said, IEEFA expects offshore wind to emerge as a new cost competitive source of electricity generation for India by 2025. Providing grid diversification is a key advantage of offshore wind, as are its absence of land requirements and its proximity to heavily populated coastal cities.

Europe accounts for 90% of global offshore wind developments to date, but with Taiwan,[67] China, Japan and the U.S. all investing now in the next phase of growth, further technology and scale advantages are expected to combine with significant "learning by doing" effects to drive cost deflation, [68] a trend that will be assisted by utilisation rates of more than 50%, double Indian onshore wind rates.

In the first half of 2017, China completed 2,066 MW of offshore wind projects, on track for its target to have 10 GW of offshore wind under construction by 2020.[69]

India's 3,100-km coastline provides significant opportunity for further domestic electricity generation diversification as this technology becomes more cost competitive.[70] While trial deployments are being studied, commercial scale remains some time off.[71]

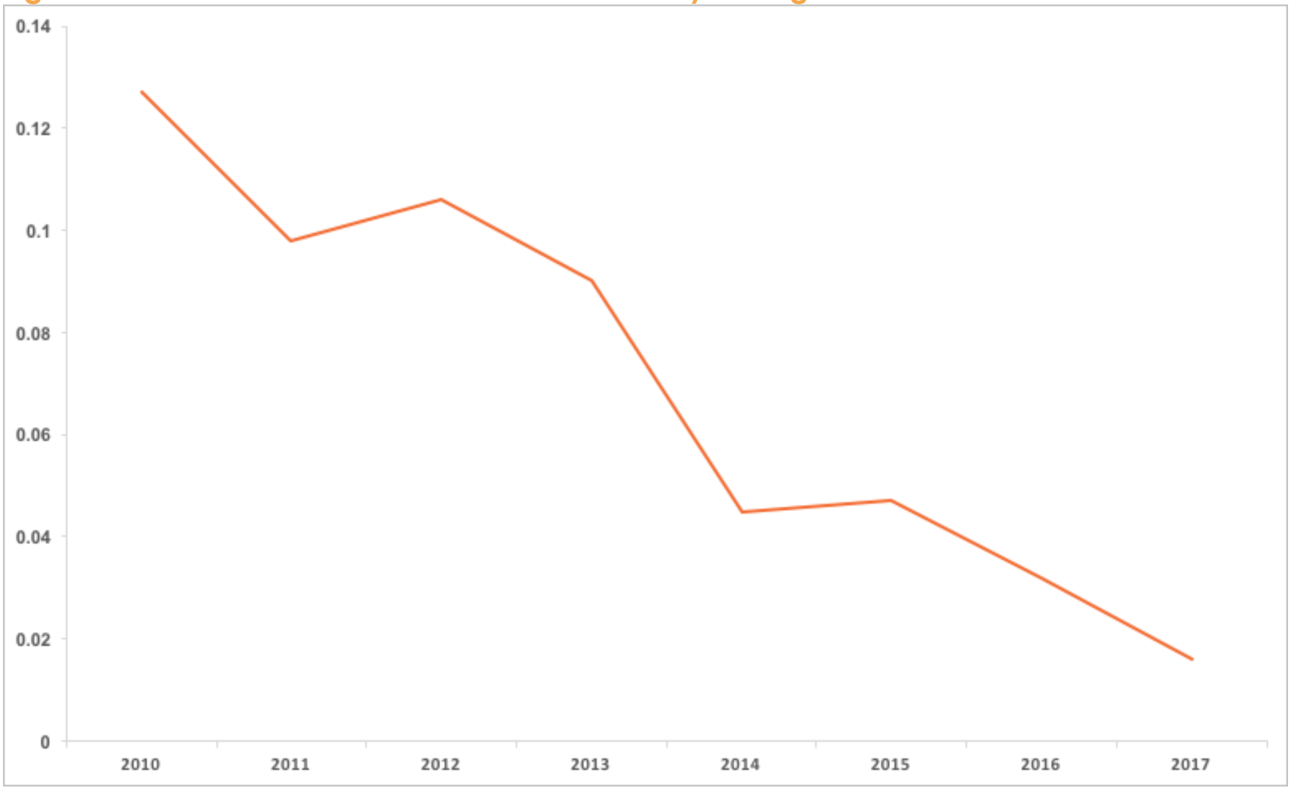
While it is uncertain as to when Indian deployments might begin, costs continue to fall quickly. In September 2017, the U.K. government awarded three offshore wind projects totaling 3.2 GW through a contracts for difference (CfD) with strike prices going as low as £57.50/MWh for projects scheduled for commissioning in 2022/23.[72]

[65] https://www.bloomberg.com/amp/news/articles/2017-09-14/india-s-wind-turbine-makers-mull-cuts-as-auction-pace-lags
[66] https://ultra.news/t-t/34494/india-see-6-gw-wind-power-auctioned-5-months
[67] https://www.bloomberg.com/news/articles/2017-06-18/taiwan-lays-plans-for-59-billion-in-renewable-energy-finance
[68] https://cleantechnica.com/2017/08/02/deepwater-wind-unveils-us-offshore-revolution-wind-farm-paired-tesla-energy-storage/
[69] http://www.hkexnews.hk/listedco/listconews/SEHK/2017/0825/LTN20170825878.pdf page 53
[70] http://energy.economictimes.indiatimes.com/news/renewable/offshore-wind-farms-can-be-potential-source-to-meet-energy-demand-scientists/60244562
[71] http://www.windpoweroffshore.com/article/1444224/two-offshore-sites-identified-india
[72] http://www.offshorewind.biz/2017/09/11/three-offshore-wind-projects-secure-contracts-for-difference-as-strike-prices-go-down/

3. Grid Stability, Transmission & Discoms

India has made substantial progress in improving its energy-system efficiency over the last three years. This is best illustrated by the reduction in the peak power deficit since 2009/10, from more than 12% to just 1-2% in 2016/17, with regular periods of surplus in the new year.

Figure 3.1: Indian Peak Power Deficit Falls Steadily Through FY2017



Source: Indian Ministry of Power, BNEF [73]

With the expected doubling of electricity demand over the coming decade, India's transmission and distribution system will require significant expansion. A $200bn investment program through 2030 would create the opportunity for India to establish an internationally connected smart grid capable of managing a doubling of power demand and incorporating much greater diversity in electricity generation, including distributed rooftop solar and battery storage. This would require India's distribution system reform program (Ujwal DISCOM Assurance Yojana, or UDAY) to be successfully carried through to completion, and in the process end the largely unfunded US$10bn annual distribution company (Discom) electricity subsidy.

[73] https://www.bloomberg.com/view/articles/2017-08-04/india-s-power-paradox

Grid Stability

India's draft 10-year National Electricity Plan has thermal power's share of total generation capacity falling from 67% as of March 2017 to 43% by March 2027. Renewable energy's share of installed capacity is forecast to rise from 18% in 2017 to 43% by 2027. This change will require India's grid transmission and distribution structure to not only have to deal with a significant increase in electricity demand in the coming decade, but will also have to accommodate greater distributed and renewable energy generation plus smart-grid requirements.

India's large existing hydroelectric generation fleet (44.5 GW as of March 2017) and 25 GW of gas-fired generation capacity provide existing peaking capacity. Greater reliance on pumped hydro storage and the expansion of concentrated solar thermal (CSP) (see Section 7, below) will be required.

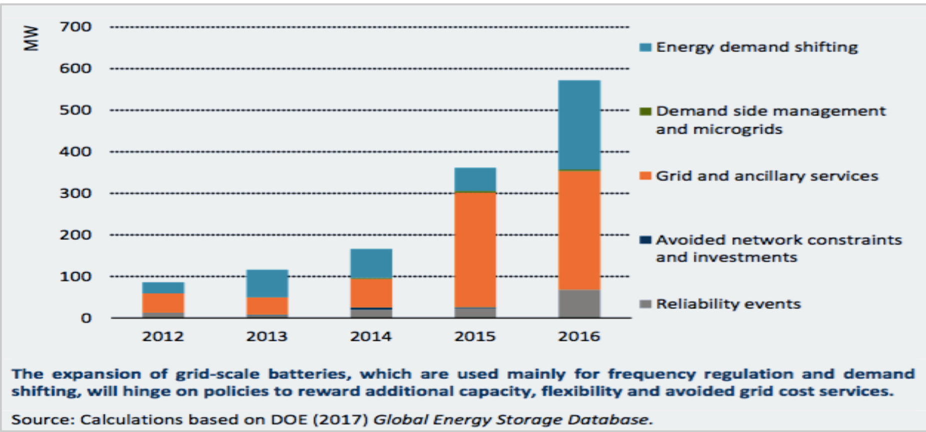
Strengthening the national grid in a country that has largely been separated into five regional grids since the 1990s is another key requirement, as are enhanced connections with neighbouring countries.

in addition, the development of a smart grid in the coming decade will facilitate demand-response management capacity, and enable the country to take full advantage of the rollout of electric vehicles and their associated collectively massive, distributed lithium ion battery storage.

IEEFA is certain that technology innovation and convergence across transport, building and electricity markets will create profound change by 2027. Over the coming decade, IEEFA expects battery storage to play a significantly greater role in India's electricity sector. The July 2017 announcement by the South Australian government that it will install a 100MW / 129MWh Tesla lithium ion battery storage facility (due online by December 2017) is a globally significant development,[74] building on similar progress in California. The IEA concurs, stating in its World Energy Investment 2017 outlook that "grid-scale storage is seen as an important potential source of reliability and flexibility, and batteries have received a lot of attention due to their modularity and recent rapid technology development."

As per Figure 3.2, time shifting peak demand is just one application of grid-scale storage.

Figure 3.2: Main Applications of World Battery Storage Investment



Source: IEA World Energy Investments Report, July 2017

74 http://www.abc.net.au/news/2017-07-07/what-is-tesla-big-sa-battery-and-how-will-it-work/8688992

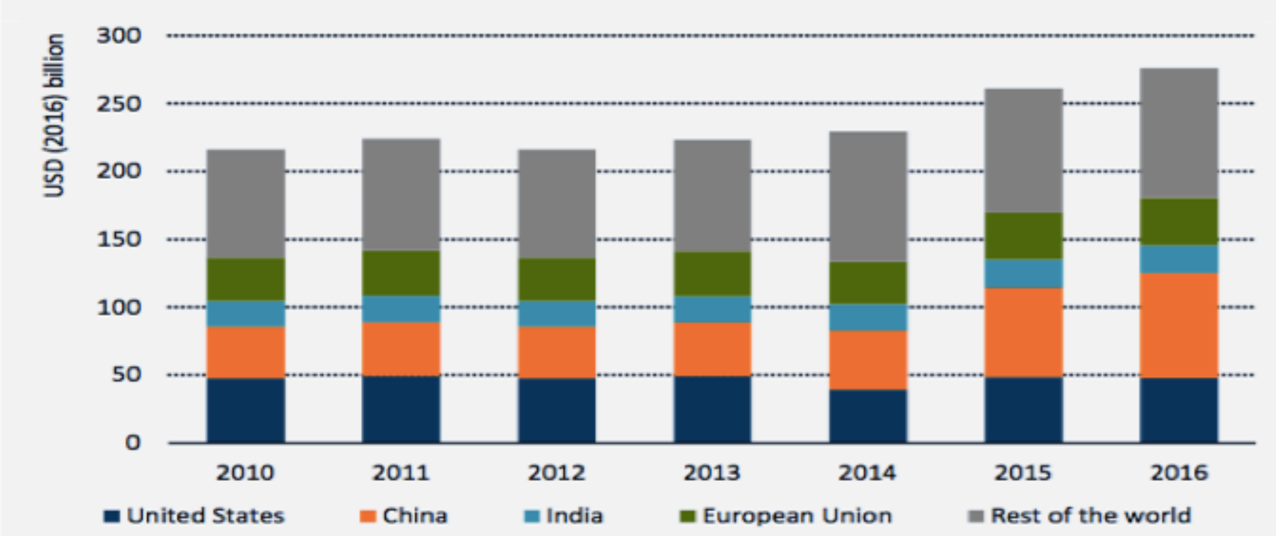
Grid Transmission

Given the expected growth of the Indian economy and hence the need for additional generation capacity, India would do well to continue its ongoing expansion and modernisation of its transmission network.

The value of projects commissioned between 2014-17 is 83% more than those commissioned between 2011-14, and there has been a 40% increase in India's transmission capacity between 2014-17 alone.[75]

India has invested US$15-20bn annually in network expansion since 2010 (See Figure 3.3). This investment has helped facilitate the transition from five independent regional grids in 1990 to a nationally connected structure today, along with a small but growing international connectivity. India is now linked to Bhutan and Bangladesh, and there are plans to expand international connectivity tenfold over the coming decade, potentially adding Nepal and Sri Lanka to better integrate renewables and enhance energy security.

Figure 3.3: India Has Invested US$15-20bn Annually in Grid Network Expansion (2010-2016)



Investment in electricity networks and storage has grown steadily in the last five years, driven by the need to integrate new renewables-based generation, improve system reliability and replace ageing assets.

Sources: Calculations based on NRG Expert (2016), *Electricity Transmission and Distribution Database*.

Source: IEA World Energy Investment July 2017

India is also in the process of commissioning two of the world's longest high voltage direct current (HVDC) grid transmission capacity facilities at Champa and North-East Agra to better integrate renewable energy capacity and strengthen the national grid (Figure 3.4).

[75] https://pibindia.wordpress.com/2017/08/13/digital-empowerment-delivering-on-rti-right-to-a-transformed-india/amp/

Figure 3.4: India Has Successfully Established National Grid Transmission Connectivity

Significant Large-scale electricity transmission projects outside China					
Project Name	Geography	Technology	Length (km)	Voltage (kV)	Status
Champa	India	UHVDC	1,365	800	Commissioned
North-East Agra	India	UHVDC	1,728	800	Under construction
Rio Maderia	Brazil	HVDC	2,375	600	Commissioned
Nordic Europe projects connecting to mainland	Europe	HVDC	1,598	Various	Different stages
North Sea Link	Europe	HVDC	720	525	Under construction
Plains and Eastern Clean Line	United States	HVDC	1,127	600	Under development
Rock Island Clean Line	United States	HVDC	805	600	Under development

Source: IEA World Energy Investment July 2017

Wind and solar power projects enjoy "must run" status under the Indian Electricity Grid Code (IEGC) and have to be scheduled for dispatch before any other source of power, but there have been instances in a few states, particularly Tamil Nadu and Rajasthan, where grid curtailments for renewables have been observed.[76]

Ongoing investment in boosting grid capacity and central planning are critical to minimising the disruptive influence of massive technology change, but the challenges are not insurmountable. In July 2017, for example, the U.S. Lawrence Berkeley National Lab published a landmark study, "GREENING THE GRID: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid"[77] that clearly illustrates the investment path and requirements and capacity for India to achieve its electricity sector transformation.

Similarly, Jim Robo, CEO of NextEra, which is the world's largest electric utility by market capitalization, stressed recently that grid stability and renewables can go hand in hand:

> *"I think the data is pretty clear: there [are] no reliability issues on the grid. There is plenty of capacity there, and the grid very resilient. Renewables and storage will make the grid more reliable."*[78]

IEEFA is equally certain that integrating renewables and maintaining grid stability can be done in a manageable and cost-effective manner.

Discom Reforms: UDAY

Two years in, the Modi government's Ujjwal Discom Assurance Yojana (UDAY) scheme for power distribution company reforms has started bearing fruit, with major improvements in both the financial and operational performance of India's debt-laden Discoms, as reported by India Ratings in July 2017.[79] UDAY has several key targets:

1. To remove the gap between average cost of supply and average revenue realisation, thereby creating a positive incentive for Discoms to sell electricity and creating positive retained earnings to fund investment in distribution networks.
2. To improve operational efficiency by reducing aggregate technical and commercial (AT&C) losses, that is, losses due to electricity theft, thereby lowering the cost of doing business for the distribution companies.

[76] http://energy.economictimes.indiatimes.com/news/renewable/new-bidding-guidelines-for-solar-power-projects-a-positive-for-the-sector-icra/60460728
[77] https://ies.lbl.gov/publications/greening-grid-pathways-integrate-0
[78] https://www.snl.com/web/client?auth=inherit#news/article?id=41437382&KeyProductLinkType=4 (paywalled)
[79] http://energy.economictimes.indiatimes.com/news/power/uday-scheme-turning-around-power-discoms-performance-india-ratings/59847355

3. To formally bring onto state government balance sheets previously undisclosed, off-balance sheet distribution company debts, improving transparency and accountability.
4. To lower the cost of servicing these companies' debts.

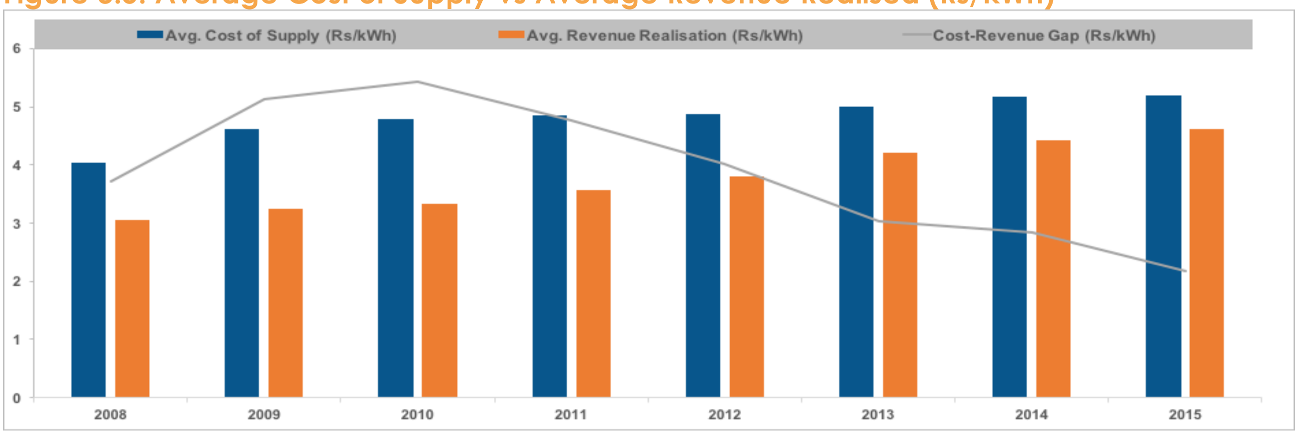
At the end of March 2017, 26 states and one union territory have joined UDAY; Nagaland, Odisha and West Bengal have not joined the scheme. Until FY17, Rs 2.69 lakh crore (US$42bn) of discoms' debt qualified for restructuring, and state governments and discoms together issued bonds worth Rs 2.33 lakh crore (86% of the total debt). As of fiscal year 2017, the value of pending bonds to be issued by Indian states are estimated to be Rs 36,278 crore (US$5.5bn); Issuance by state governments will be subject to the fiscal space of each state.

Some "green shoots" have emerged, with reduced interest costs and lower power purchase costs leading to improved financial performance by some distribution companies. For example, the discom Chhattisgarh turned profitable in the first quarter of 2016-17, while Gujarat discoms increased their profitability in Apr-Dec 2016-17. Similarly, Haryana discoms turned profitable in the second and third quarters of 2016-17.[80]

In a major positive announcement in July 2017, Vikram Kapur, Tamil Nadu's principal power secretary, noted the significant improvement at Tangedco discom, stating that "In recent years, the discom's financials have improved and [it] is likely to break even this year".[81] After a reported loss of Rs 72bn/US$1.1bn in 2015/16, this would be a dramatic turnaround and point to the success of the UDAY initiative.

As of October 2017, the UDAY website cites that the average cost of supply (ACS) less average revenue realised (ARR) gap has halved since 2015 from Rs0.58/kWh to Rs0.26/kWh.[82] In IEEFA's view, it is critical that the ARR exceed the ACS on a sustained basis in order to incentivise distribution companies to supply customers (a company losing money on every unit sold has no incentive to sell more of that product.). Once the India's discoms are profitable, they will not only have an incentive to increase supply, but also will have the financial capacity to reinvest in their distribution grid. This would produce a sustained reduction in AT&C losses, as well as incentivising energy efficiency and distributed rooftop solar with storage, creating a virtuous loop of efficiency and viability.

Figure 3.5: Average Cost of Supply vs Average Revenue Realised (Rs/kWh)



Source: Power Finance Corp – Performance report on state power utilities

80 http://energy.economictimes.indiatimes.com/news/power/uday-scheme-turning-around-power-discoms-performance-india-ratings/59847355

81 http://timesofindia.indiatimes.com/city/chennai/solar-and-wind-projects-unviable-owing-to-low-tariffs/articleshow/59765886.cms

82 https://www.uday.gov.in/home.php

4. Energy Efficiency: The Cheapest Capacity

The IEA estimates India is investing close to US$20bn annually in grid upgrades to rectify extreme aggregate technical and commercial (AT&C) losses and to accommodate a likely doubling of electricity demand in the coming decade.

One of the key initiatives undertaken by the Government of India is its sustained push to improve national energy efficiency.

Particularly in the face of extreme AT&C losses and largely unabated thermal power generation pollution, energy efficiency initiatives are one of the lowest-cost sources of electricity for India.

The very successful campaign that began in 2015 to drive the uptake in light-emitting diodes (LEDs) by cutting their price by more than 90% has shown the capacity of energy efficiency to play a leading role in the sustainable growth of the Indian electricity market. New standards for air-conditioner efficiency this year are likely to prove equally important in building India's capacity to sustain energy-efficiency initiatives.

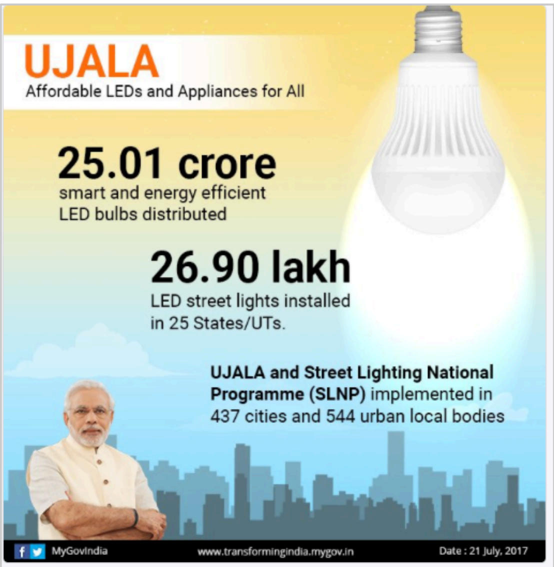
LEDs

The Indian government has been hugely successful in driving down the delivered cost of LEDs by as much as 90% over the last two years, leading to the installation of 250 million energy efficient LED light bulbs across the country, plus 2.7 million LED street lights.

This initiative has reduced annual electricity peak demand by more than 6 GW. India plans to replace all of its 770 million incandescent bulbs with LEDs by 2019, reducing peak demand by a cumulative 20 GW.

As part of this program, India is retrofitting 15,000 street lights daily with LEDs.[83]

Figure 4.1: The Indian Government's Success in Promoting LEDs and LED Street Lighting



Source: Indian Government, 23 July 2017

[83] https://energyinfrapost.com/gois-street-lighting-national-programme-illuminates-50000-km-indian-roads/

Air Conditioners

Having transformed the lighting sector, Piyush Goyal, then the Indian energy minister, began 2017 by targeting an enormous energy-efficiency opportunity in air conditioning.

The country's expanding economy is creating a broad middle class. Ass incomes rise, forecasters expect a huge increase in the deployment of air conditioners, adding stress to the Indian electricity grid during peak demand periods on increasingly common hot days.

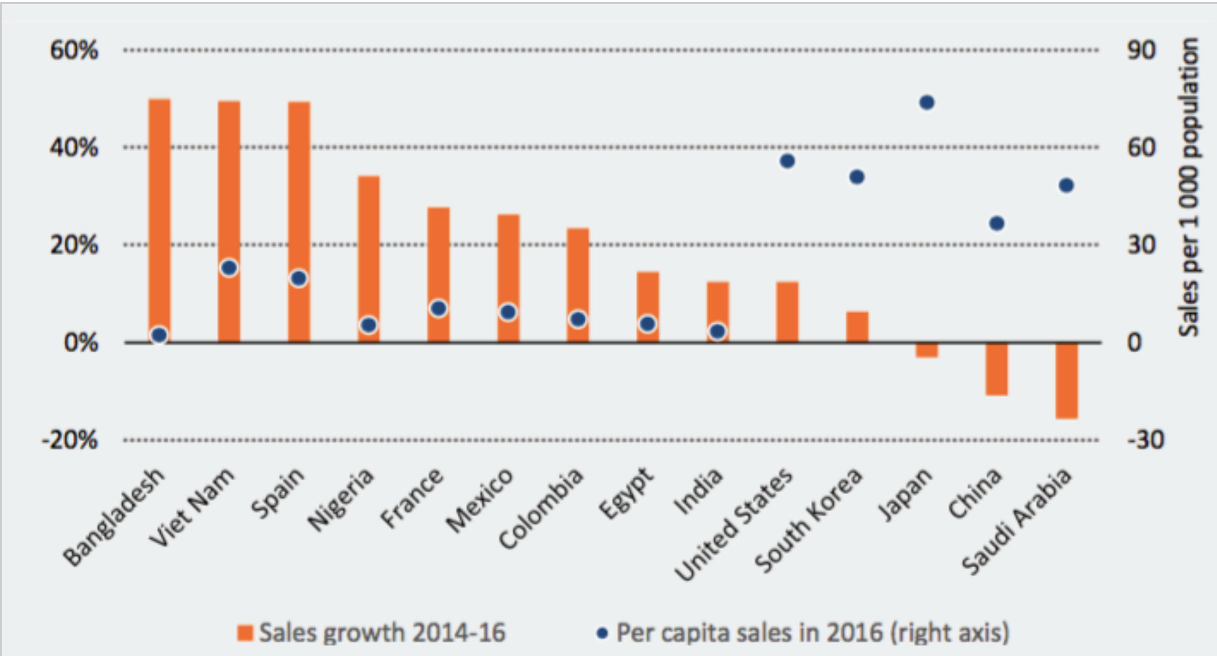
India already has tightened its air conditioner energy efficiency standards from a minimum EER (ratio of output to input energy) of 2.7 in 2016 to 3.1 by 2018. A significant focus has been on a new six-star rating system as well as improved labeling and information initiative to raise consumer awareness.

The IEA, in its "World Air Conditioning Overview 2016," estimated that a further tightening to best-practice standards could save India 2 terawatt-hours of electricity annually and avoid the need to add 1-2 GW of new peak load capacity each year.

The Government of India has commenced a bulk purchasing initiative of high-rated air conditioners to encourage manufacturers to gear up production of energy-efficient units plus service and installation capacity for replacing end-of-life clunkers.[84] However, the most efficient air conditioners can still be twice the cost of those meeting the minimum standards, which can stretch payback times for customers, slowing sales.

The IEA estimates also that 45% of the savings derived from this type of energy efficiency initiative would be realized at the grid level in terms of avoided peak period demand.

Figure 4.2: Air conditioner Sales Growth and Per Capita Sales in Selected Countries 2016



Source: BSRIA 2017, IEA World Air Conditioning Overview 2016

[84] https://www.theverge.com/platform/amp/2017/9/14/16290934/india-air-conditioner-cooler-design-climate-change-cept-symphony

Smart Meters

August 2017 saw Energy Efficiency Services Ltd. (EESL) launch of a US$500m tender to install 5 million smart meters in Uttar Pradesh and Haryana,[85] with a very strong initial response.[86] EESL will provide upfront capital and do the first decade's infrastructure maintenance to ease concerns about distribution company financial constraints. This is the first tangible move toward eventual universal smart meter coverage across India, which is a necessary precursor to a smart grid. Such a grid, with full two-way communications and interactivity, would:

- Encourage deployment of distributed rooftop solar and storage systems;
- reduce the AT&C (theft) losses that are crippling most distribution companies;
- facilitate real-time monitoring, helping to reduce peak power use;
- provide accurate bill reading and help address billing inefficiencies;
- allow the offering of pre-paid and remote connection of electricity services.

Battery Storage

Batteries will play a key role in the transition to a smart, interconnected, two-way Indian grid system to best manage peak demand and ever-greater share of variable generation. This will involve behind-the-meter distributed battery storage on rooftop solar plus distributed utility-scale battery systems to manage grid demand and supply variability.[87]

Storage is also playing a key role in accelerating development of electric vehicles (EV). Given India's aspirational target for 100% EV by 2030 and consistent with Prime Minister Modi's "Make in India" strategy, firms like Reliance Industries, Hero Motocorp, Adani, JSW Group, Suzuki, Toshiba and Tesla are readying to build battery manufacturing in India.[88]

With China likewise moving toward 100% electric vehicles by 2030 and cost deflation following a similar trajectory to solar—battery prices down some 80% in the last five years[89] —momentum is building rapidly.

The first step in this transition took place in October 2017, when NLC Ltd completed India's first utility scale solar with a storage project auction. This system, 20MW of solar and 28MWh of storage capacity, will be deployed in the Andaman & Nicobar Islands,[90] a perfect place to start since such a system offers both environmental and economic benefits. The new solar-plus-storage facility will replace a costly diesel generator costing US$0.23/kWh.

Knowing this second wave of technology innovation is pending is already causing significant financial distress to the thermal power sector, and IEEFA expects that this financial pressure will relentlessly build over time.[91]

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[85] https://www.bloomberg.com/news/articles/2017-08-16/india-enters-global-smart-meter-race-to-fight-utility-losses
[86] http://pib.nic.in/newsite/PrintRelease.aspx?relid=170237
[87] http://www.financialexpress.com/industry/renewable-energy-how-storage-capacity-has-become-critical-component-for-this-sector/878488/
[88] http://www.financialexpress.com/market/india-inc-charges-up-on-battery-manufacturing-reliance-suzuki-adani-to-set-up-multi-billion-dollar-battery-factories-among-others/861423/
[89] http://www.afr.com/business/energy/electricity/batteries-to-cement-place-of-renewables-as-lowrisk-investment-20170921-gylr2a#ixzz4tMLicZgp
[90] http://www.bridgetoindia.com/first-utility-scale-storage-project-india-takes-off/
[91] https://www.bloomberg.com/news/articles/2017-11-14/cheap-battery-forecasts-kill-india-s-25-year-coal-power-deals

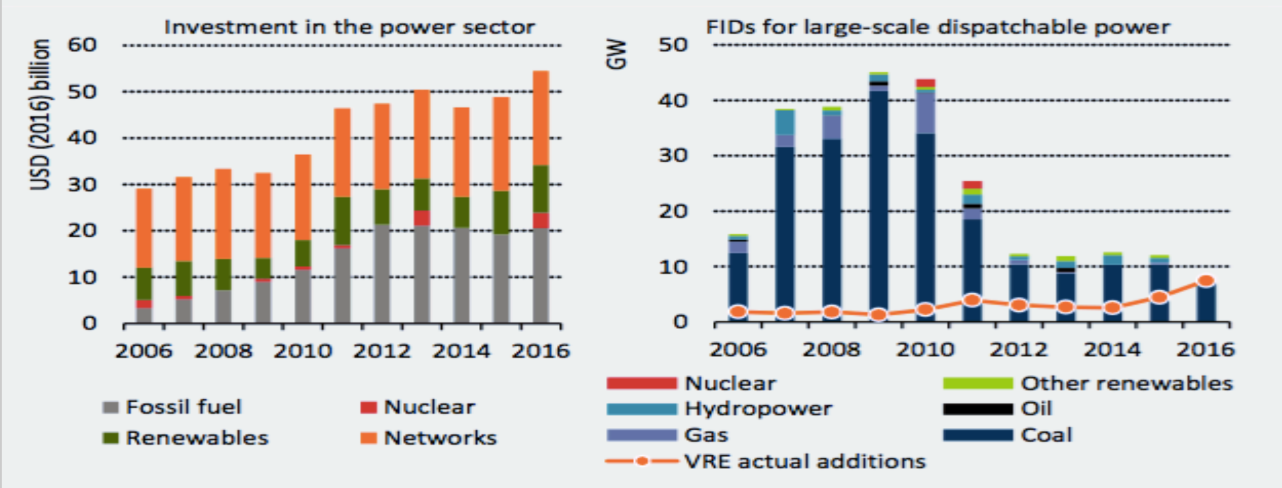
5. Indian Thermal Power Generation

India's third draft 10-year National Electricity Plan (NEP3) forecasts a net expansion of thermal power capacity of 57 GW over the decade to 2026/27. India's Ministry of Finance lowered this estimate, but only to 50 GW, in its mid-year macro-economic assessment released in August 2017[92].

IEEFA has forecast a similar 50 GW net expansion in thermal power capacity of, taking the total installed thermal fleet from 218 GW as of March 2017 to 268 GW by 2027. IEEFA has cross-referenced the current Central Electricity Authority (CEA) forecast against our estimate of capacity needed to cover forecast electricity demand growth net of zero-emissions capacity expansions and reviewed the current pipeline of proposed new plants. Against this, we have then assessed the net expansion given the combination of likely new Indian emissions controls and attrition through end-of-life plant closures. IEEFA see 7-8 GW of annual new thermal power plant additions over the coming decade, less 2-3 GW of annual beyond end-of-life thermal closures for a net annual expansion of 5 GW. Over the next 10 years, this equates to a net 48 GW of new coal plus 2 GW of new gas-fired capacity.

Figure 5.1 details the investment profile in the Indian electricity sector over the past decade, culminating in a record US$55bn in 2016, of which US$20bn was in networks, US$20bn in coal-fired power generation, and a record US$10bn in renewables infrastructure. However, changes are clearly in the offing. The IEA recently highlighted how new investment commitments (Financial Investment Decisions (FID)) into Indian coal power have dropped by two-thirds since 2012 relative to the 2007-10 peak period of 40 GW annually, suggesting a sustained step down from the 2012-15 coal commissioning peak.

Figure 5.1: Investment in India's Electricity Sector (US$bn, 2006-2016)



Power-generation investment in India reached nearly USD 55 billion in 2016, over half of which went to renewables and networks, with additions of variable renewables capacity equalling sanctioned new capacity of large-scale dispatchable plants for the first time.

Note: VRE = variable renewable energy (solar PV + wind); FIDs may not include plants <5 MW (below 10 MW for hydropower).
Source: Calculations for FIDs based on McCoy Power Reports (2017), dataset.

Source: IEA World Energy Investments 2017

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92 http://www.bridgetoindia.com/economic-surveys-bizarre-logic-social-cost-renewables-3-times-coal/

Thermal Additions

The Global Coal Power Plant Tracker database calculates that India's coal-fired power plant pipeline has been cut back dramatically over the last two years. This reflects both 20 GW per annum of new coal plants being commissioned but more materially through plants being cancelled entirely as surplus to need and/or stranded without adequate coal access, lack of land or water availability, developers that are now in financial distress and/or where financial close is elusive due to the absence of a power purchase agreement.

The database calculates a total 57.6 GW pipeline of coal-fired power plants in India, split between plants in pre-permitting (6.8 GW), permitted (7.5 GW) or under construction (43.4 GW) that are detailed as due for completion by 2023. The database also details 101 GW of Indian coal plants in pre-construction phases, plus 43 GW in construction with an undetermined completion date — so 144 GW in total. This 57.6GW subset just looks at those plants due for completion by 2023.

To bring that 57.6 GW of coal capacity online by 2023 would require an average annual completion rate of about 9 GW over the next six years. Whether that will happen is up for debate, as we detail below.

Across India, at least 24 GW of coal power plants classified as "under construction" are facing viability issues due to logistics,[93] exacerbated by lower-than-expected electricity demand growth and rising competition from ever-cheaper renewable energy.

Both IEEFA's electricity-sector model for India and the NEP3 reach the same conclusion: India will not need to build any more coal-fired power plants (beyond the 43 GW being constructed) until at least 2027. As a result, IEEFA expects that the number of coal-fired projects currently listed as under development will see progressive deferrals and continued cancellations.

To illustrate this trend, we note that NTPC's 1,600 MW Lara coal-fired power project was originally envisaged as a 4,000 MW plant (the 2,400 MW second stage on this project appears to have been set aside). In addition, the Darllipali project, originally intended as a 4,800 MW project to be constructed over three stages of 1,600 MW each, is hobbled by land acquisition issues, and the second two stages (3,200 MW total) are not even included on NTPC's current development list. NTPC also has two units of 800 MW each in operation at the Kudgi coal-fired plant with another 800 MW on the development list, but expectations that this would be expanded to 4,000 MW seem to have been abandoned[94] as the company looks toward expanding solar generation[95]. Finally, the proposed Bilhaur power plant, a 1,320 MW super-critical installation, no longer appears on NTPC's project development list.

Beyond these creeping retrenchments, NEP3 does not fully account for the number of plant closures that are planned over the coming decade. For example, NTPC alone is planning to close 11 GW of coal-fired power plants[96] As a result, the net thermal capacity added until 2027 could come in at less than 50 GW, not the 57 GW envisaged. But even at that lower level, the new capacity will put additional downward pressure capacity utilisation rates, further stressing coal-fired plant economics.

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[93] http://energy.economictimes.indiatimes.com/news/power/power-projects-of-24000-megawatt-capacity-facing-viability-issues/54957603

[94] http://economictimes.indiatimes.com/news/industry/energy/power/ntpc-may-drop-further-expansion-plans-of-kudgi-thermal-project-in-karnataka/articleshow/57859308.cms

[95] https://www.bloomberg.com/news/articles/2016-10-04/india-s-ntpc-to-expand-solar-goal-slow-thermal-power-bnef-says

[96] http://pib.nic.in/newsite/PrintRelease.aspx?relid=155395

Thermal Power Sector: Capacity Closures

India exited FY2017 with 218 GW of thermal power capacity in operation. Of this, 40 GW was built at least 25 years ago, equal to or exceeding its expected useful life (see Figure 5.2). By FY2027, this 40 GW will all be at least 35 years old, and overdue for retirement. Given pollution pressures and technological obsolescence, more ambitious market estimates suggest that up to 55 GW of thermal capacity could face closure in the next decade.[97]

These end-of-life thermal power plants in the main have very low capacity utilisation rates, lack even rudimentary pollution controls and operate at very low thermal efficiencies. All 40 GW are using outdated subcritical technology, and the resulting inefficiency is increasingly forcing closure of more costly end-of-life faculties.[98]

Of India's entire 218 GW thermal fleet, 75% uses subcritical technology and the balance is primarily supercritical. The Coal Plant Tracker Database shows that there currently are no operating Indian coal plants using modern ultra-supercritical (USC) technology.

Figure 5.2: India's Current Thermal Power Capacity – Pre-and Post-1993 (GW)

Combustion Type	Pre-1993 (MW)	Post-1993 (MW)	Total	% of Total
Subcritical	40,037	123,959	163,996	75.2%
Supercritical		54,045	54,045	24.8%
Ultra-supercritical		0	0	0.0%
Grand Total	**40,037**	**178,004**	**218,041**	**100.0%**

Source: Global Coal Plant Tracker Database, IEEFA Calculations

These inefficient, outdated plants actually give the Indian government a significant opportunity to sustainably improve its thermal power efficiency averages, provided the Environment Ministry pushes through with its proposed mandate for the progressive closure of outdated, end-of-life plants and their replacement with USC plants. Such a shift would cut pollution across India and reduce coal use per unit of electricity produced, saving money across the system.

In 2015 India adopted legislation with new emissions limits that is due to take effect at the end of 2017. The legislation is designed to both require minimum performance standards for new coal fired power plants and to require that existing plants either be retrofitted with emissions controls, or closed.

In October 2017, it was reported that 89% of India's entire thermal generation fleet is in breach of the pending emissions limits. Partly as a result, a staggered implementation date has been proposed by the Ministry of Power, with significant industry backing, to spread out the required capital costs of compliance. How this issue is resolved will say much about the country's commitment to a cleaner, less polluting generation sector.

[97] https://swarajyamag.com/infrastructure/revamping-old-thermal-power-infrastructure-power-sectors-newest-opportunity
[98] http://energy.economictimes.indiatimes.com/amp/news/power/punjab-shuts-down-its-oldest-thermal-power-plant-guru-nanak-dev/60864132

IEEFA assumes that of the 40 GW of coal-fired power plants built pre-1993, half will be closed by 2027. So, while 68 GW of new coal-fired power plants are expected to be commissioned by 2027, the net expansion in coal-fired power plants is just 48 GW.

IEEFA is confident that end-of-life coal plant closures will occur, rather than be consistently deferred, in light of very low utilisation rates and given India's increasing awareness of the growing health impacts of air particulates and water pollution,[99] particularly on the rural poor. While India currently has almost no regulatory limits to coal power plant pollution, IEEFA anticipates that, like Australia, India will move toward emissions-control laws more in line with the world's best practice. And then monitoring and enforcement will need to step-up to ensure compliance. As power producing utilities see the inevitability of expensive upgrade or closure decisions, more will take the cheaper option and close their aging plants.

Coal-Fired Power Plant Pipeline

The coal-fired power plants under construction in India now largely use older, more polluting technologies that mean the plants will be outdated before they are even commissioned. This will require expensive retrofitting, like the country-wide scheme undertaken by China over the last five years. Just 3% of coal plants currently under construction use modern ultra-supercritical (USC) technology, a process that boosts the plant's generation efficiency to about 40% compared to roughly 33% for a conventional unit, while 12.9% are being installed using decades-out-of-date subcritical equipment.

This will be a problem going forward, since these plants will have to comply with the new Minamata Convention, a United Nations treaty that entered into force in August 2017 and limits mercury emissions[100]. It would be fair to assume almost no Indian coal power plants have anything more than rudimentary mercury controls in place.

As per Figure 5.3, IEEFA estimates that 8.5 GW of new coal-fired power plants will be commissioned annually over FY2017-FY2020, but assuming 2.9 GW of annual end-of-life coal plant closures, this means India is likely to see net capacity expansions across the coal-fired power sector of just 6.1 GW annually, a dramatic two-thirds reduction from the rate of 20 GW annually from FY2013-FY2016. Retrofitting newly commissioned plants with modern emissions controls is an expensive addition far better incorporated in the new plant design to begin with.

Figure 5.3: Thermal Power Gross vs Net Capacity Additions in India (GW)

	2013	2014	2015	2016	2017	2018 (Est)	2019 (Est)	2020 (Est)
Gross Thermal capacity Additon (MW)	20,122	16,767	20,830	22,461	11,551	8,250	8,000	8,000
Closures (MW)	-194	-42	-188	-683	-3,896	-2,500	-2,500	-2,500
Net Thermal capacity Additions (MW)	19,927	16,725	20,643	21,777	7,655	5,750	5,500	5,500
			FY2013-FY2016				FY2017-FY2020	
Four year average				19,768				6,100

Source: CEA, IEEFA Calculations

99 http://energyinfrapost.com/coal-based-power-plants-set-miss-emission-norm-deadline/
100 http://reneweconomy.com.au/australias-coal-problem-also-mercury-problem-16626

Figure 5.4: India's Coal Power Plants Under Construction by Technology Type (MW)

Combustion Type	2017	2018	2019	2020	2021	Total	% of Total
Subcritical	4,970	650				5,620	12.9%
Supercritical	10,403	15,640	4,100	2,920	1,320	34,383	79.2%
Ultra-super			1,320			1,320	3.0%
Unknown	420	1,150	525			2,095	4.8%
Grand Total						**43,418**	**100.0%**

Source: Coal Plant Tracker Database, extracted August 2017,[101] IEEFA calculations
Note: This table only reviews coal plants under construction, not the 101GW announced but pre-construction.

Capacity Factors Versus Plant Load Factors (PLF)

One issue our analysis highlights is that the Central Electricity Authority's definition of plant load factor (PLF) differs materially from the international convention of using capacity utilisation factors (CF) — Figure 5.5. The CF is the percent of the time that the power plant is operating. In India for 2016/17 for all coal-fired power plants, the CF was 56.7%. However, the CEA quotes an average PLF for all coal-fired power plants in 2016/17 of 59.9%. The difference is that the CEA adjusts the PLF for "non-availability of fuel, maintenance shut-downs, unplanned break downs and no offtake (as consumption pattern fluctuates lower in nights)."[102] This results in a figure 300 basis points higher than actual utilisation rates.

Figure 5.5: Coal-Fired Power Plant Capacity Utilisation Rates vs PLFs

Coal	**2016/17**
Average coal fired power capacity	188.7
hours pa	8,760
TWh production at 100%	1,652.7
Estimated production (adj. (1))	937.6
Capacity utilisation rate	**56.7%**
All India PLF for coal - Avg for FY2017	59.9%
Source: CEA page 10 of March 2017 report	

Source: Indian Central Electricity Authority

Note 1: IEEFA has calculated coal fired power capacity utilisation rates by deducting oil and gas generation on an assumed 25% capacity utilisation rate.
Note 2: PLF overstates utilisation rate because it excludes when capacity is reduced by capex downtime, no coal availability, etc.

[101] https://endcoal.org/wp-content/uploads/2017/07/PDFs-for-GCPT-July-2017-Countries-MW.pdf
[102] http://powersectorindia.blogspot.com.au/2009/10/plant-load-factor-plf.html

High-Energy Low-Emissions Technology (HELE)

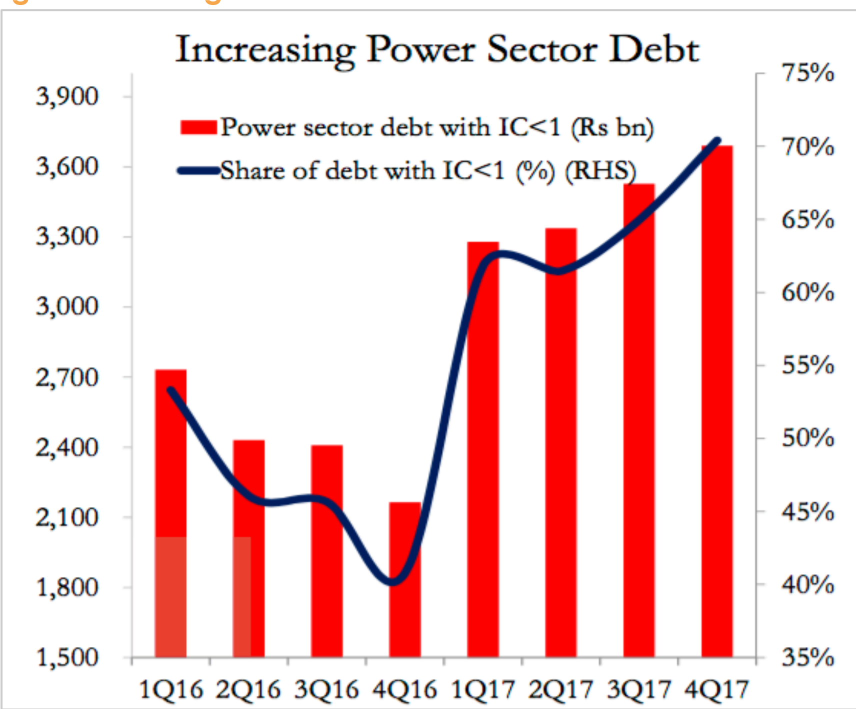
As per Figure 5.2, India does not have even a single ultra-supercritical power (USC) plant operational as of October 2017. Classified as high-energy low-emissions technology (HELE) power plants by the international coal industry lobby group, use of modern USC technology could justify the construction and investment in new coal-fired power plants in India, but to date the environmental legislation requiring HELE has been delayed by the Indian coal power lobby group.

Of the 43 GW of coal-fired plants under construction (Figure 5.4), none are known to be USC, and of the more than100 GW on the planning board across India, just 2.9 GW are USC. Western coal lobby groups constantly market HELE in justifying their continued investment in thermal coal in contradiction of the Paris Climate Agreement; this is little more than PR spin, however, particularly absent both formal rules and/or poor enforcement practices.

Stranded Assets and Non-Performing Loans

China Light & Power (CLP) of Hong Kong is a major thermal and renewable generation firm in India, but also owns one of the three large electricity generators in Australia, EnergyAustralia. In July 2017 the company's managing director, Catherine Tanna, stated that she thought "coal is a legacy technology" and that it could no longer serve as a low-cost, viable generation option for Australia.

Figure 5.6: Rising Financial Stress in the Indian Power Sector



Source: TERI, Dr Arvind Subramanian, CEA, 17 August 2017
Note: IC = Interest cover

Since India's energy system is on a strong growth trajectory for at least a decade to come, this Australian assessment may not seem applicable yet. But given that these plants are 40-year investments, IEEFA considers the stranded asset warning from one of Australia's largest thermal generation firms to be clear and pertinent.[103]

The Indian banking system already is being crippled by the failure to resolve stranded assets in the thermal power generation sector – Figure 5.6. Reports show well over 50 thermal power projects are stranded,[104] partly built but in the main massively over budget and behind schedule, often with inferior equipment, outdated technology and/or no access to coal.

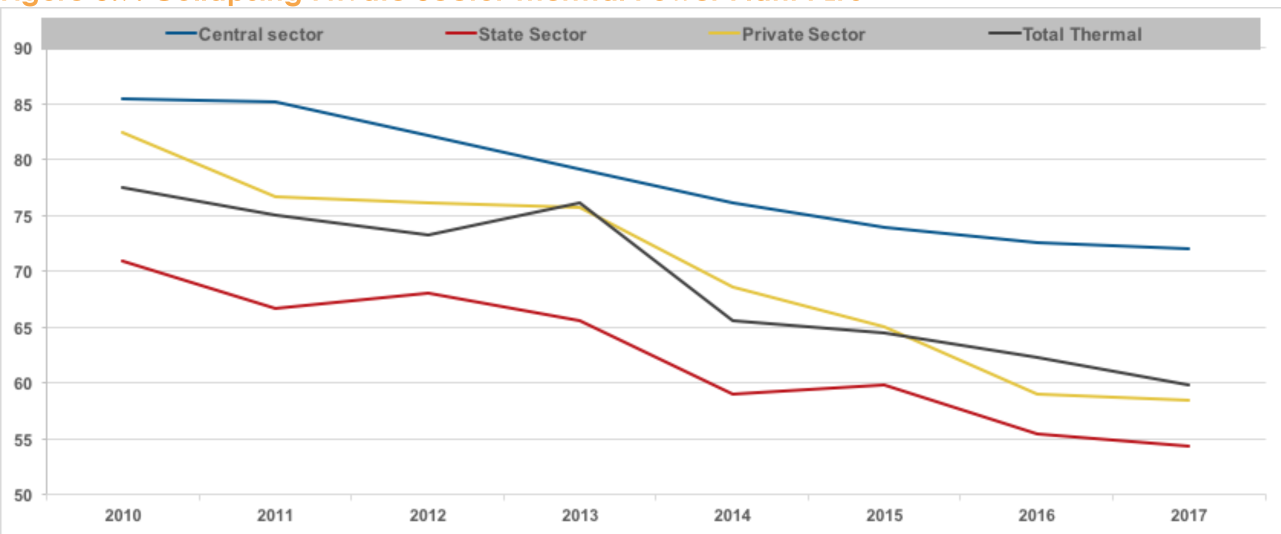
The result is that the power sector is the second largest cause of bad debt in the Indian banking sector, representing an estimated 12% of the US$150bn total, a problem that was identified as a key issue several years ago, but which has become much worse in recent quarters as thermal power plant utilisation rates continue to run at unsustainably low rates.

In July 2017, then Energy Minister Piyush Goyal told parliament[105] there were four key reasons for stalled thermal power projects across India:

- Non-availability of regular fuel supply arrangements;
- Lack of power purchase agreement (PPA) tie-ups;
- Inability of the promoter to infuse the equity and service excessive debts; and
- Regulatory and contractual issues.

IEEFA would add a fifth factor: the overbuild of thermal capacity and resulting collapsing in PLFs, particularly in the private sector — now below an average 55% — which has consistently run more than 20% lower than the PLF delivered by NTPC. A significant slowdown in the new build pipeline needs to be maintained to restore average PLFs to viable levels of 70-80%.

Figure 5.7: Collapsing Private Sector Thermal Power Plant PLFs



Source: CEA

[103] http://reneweconomy.com.au/energyaustralia-truth-coal-not-cheap-55748/
[104] http://in.reuters.com/article/us-india-power-debt-idINKBN1A6039
[105] http://pib.nic.in/newsite/erelease.aspx?relid=169142

The Government of India has made significant progress in trying to resolve fuel supply issues. In May 2017 the government announced a new policy for coal allocation, granting regular coal linkages, viz. SHAKTI (Scheme for Harnessing and Allocating Koyala Transparently in India) under which coal is to be made available to public sector undertakings of the central and state governments, and independent power producers (IPPs) against already concluded long-term PPAs.

To encourage the signing of bankable PPAs, the following measures have been taken:

- Ujwal DISCOM Assurance Yojana (UDAY) scheme for the financial and operational turnaround of power distribution utilities;
- Power For All (PFA) initiative with states for bringing uninterrupted quality of power to each household, industry, commercial business, plus small & medium enterprises;
- Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) for Rural Electrification, involving the strengthening of sub-transmission and distribution networks in the rural areas, plus the separation of agriculture and non-agriculture feeders and metering of distribution transformers/ feeders/consumers in the rural areas;
- Integrated Power Development Scheme (IPDS) for strengthening of sub-transmission and distribution networks in the urban areas; Metering of distribution transformers / feeders / consumers in the urban areas and IT enablement of distribution sector;
- Augmenting transmission capacity to remove transmission constraints; and
- Flexibility in utilization of domestic coal for reducing the cost of power generation.

Shri Goyal also informed that RBI has notified schemes such as (i) Scheme for Sustainable Structuring of Stressed Assets (S4A) and (ii) Strategic Debt Restructuring Scheme (SDR) for the revival of stressed assets. Due diligence and financial restructuring by banks to make projects viable would attract new promoters or states to purchase the stranded projects and bring in fresh equity investment. The issue of setting up a fund has been discussed among other options with stakeholders.

Doubling, to Rs400/t, the Coal Cess

India's Finance Minister Arun Jaitley in 2016 doubled the coal cess (tax) to Rs400/t (US$7/t) on all coal consumed, arguing this measure goes some way to pricing in all the externalities of mining and burning coal. Even with the move to close end of life outdated subcritical coal fired power plants, the externalities of burning coal are still very material in terms of water use, coal ash disposal, toxic heavy metals, plus carbon and particulate emissions. As Australia's shadow energy & environment minister stated in July 2017, even "ultra-supercritical coal, which sounds like something out of a Marvel comic, but even awesomely ultra-supercritical coal is still, by any stretch of the imagination, high polluting electricity".[106]

With already extreme air, particulate and water pollution evident across India, IEEFA expects upward pressure on the coal tax and / or an eventual carbon tax to further erode the marginal economics of coal fired power plants in India.

[106] https://amp.theguardian.com/australia-news/2017/jun/22/adani-mine-not-a-positive-thing-for-australia-labors-mark-butler-says

Stranded Assets: Import Coal Power at Mundra

Adani Power (4.6 GW), Tata Power (4.0 GW) and Essar Power (1.2 GW) have a collective 9.8 GW or US$10bn of modern but import coal fired power plant capacity all stranded because the proponents have bid 25-year fixed price electricity PPAs of Rs2-3/kWh, well below the cost they can generate electricity from, particularly given they are all based on expensive unhedged US$ denominated thermal coal imports into India.

The August 2017 move by the Gujarat state government to work with the State Bank of India to acquire the equity in these plants for Rs1 per plant would in IEEFA's view be a sensible move to protect Indian electricity consumers and lock in ownership of modern power generation capacity for the long term at relatively low cost. This would also prevent another US$6.2bn of bad debt from hitting the Indian banking system.[107]

Stranded Assets: Water Stress

Thermal power plants require significant water resources for cooling, a major issue in a country with frequent droughts and competing demands for limited water suppliers.

Indian thermal power plants suffered a record 14 TWh loss in 2016 due to droughts and water stress, with the Parli coal power plant in Maharashtra losing an estimated US$455m of operating revenues due to water-related generation outages.[108] IEEFA would note that India's water availability is finite and fully utilised already, so expanding coal-fired power generation capacity by even just the significantly downsized 50 GW by 2027 will compound an already acute problem, particularly as the water stress shutdowns are predominantly occurring during the peak demand periods of March to September.

Stranded Assets: Gas/LNG Power

India has 25 GW of gas-fired power generation capacity, which is understood to be operating at an average of just 22-25% capacity utilisation in 2016/17, and again so far in 2017/18.

In the April-August 2017 period, India imported 9.93 billion cubic metres of LNG, declining 4% year on year, [109] notwithstanding overall Indian electricity demand growth of 4.6% year on year, year to-date. The core issue remains the high marginal cost of electricity generation from imported LNG, particularly in competition with significant surplus coal-fired power capacity and a growing amount of zero-marginal cost renewables. Gas-fired power capacity is likely to remain marginalised to supply peak demand periods when all other generation sources are already in operation. India may need to introduce premium pricing signals in times of peak demand to incentivise LNG-fired power capacity to remain online and viable.

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[107] http://www.thehindubusinessline.com/news/national/consumer-interest-paramount-gujarat-official-on-beleaguered-power-plants/article9822841.ece

[108] http://www.wri.org/blog/2017/07/droughts-and-blackouts-how-water-shortages-cost-india-enough-energy-power-sri-lanka

[109] http://www.lngworldnews.com/indias-lng-imports-slide-in-august/?utm_source=emark&utm_medium=email&utm_campaign=daily-update-lng-world-news-2017-09-21&uid=51672

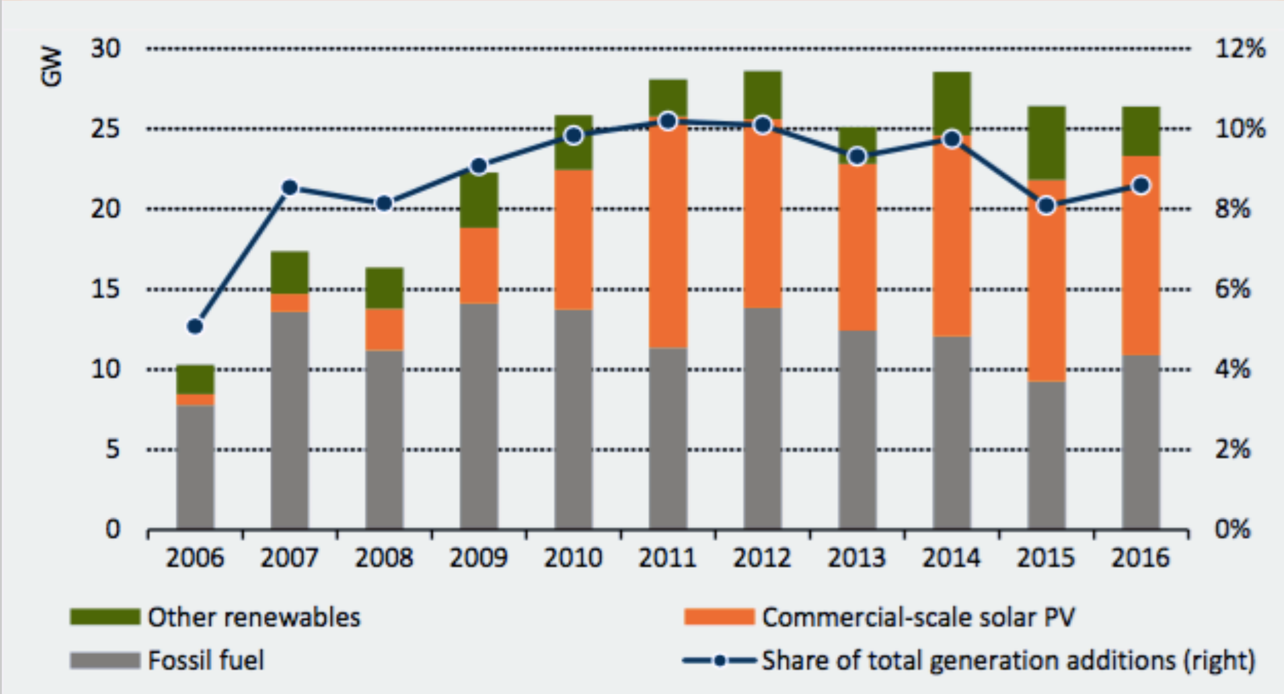
Thermal Power Sector: Captive Generation

India has 43 GW of captive or behind-the-meter thermal power generation as of March 2017, in addition to the 218 GW of grid thermal capacity (see Figure 1.1).

This generation has been predominantly thermal-fuel based, but the historic 80% accelerated depreciation tax allowance for wind projects has prompted significant investment in renewables capacity by Indian industry. As per the global trend — evident in Figure 5.8 — there is a sustained shift in corporate investment into renewables away from thermal power. With the commercial and industrial sector tariffs more than double residential tariffs in India, the development of the distributed rooftop solar sector for commercial applications is an obvious area for sustained growth in India.

Figure 5.8: Global Electricity Capacity Investment by Industry is Shifting to Renewables

Figure 2.22 Power generation capacity additions to directly serve commercial, industrial and public consumers



Generation directly serving companies and public entities was 10% of all new additions in 2016; it can be attractive for consumers with particular demand profiles or in places where grid power is unreliable.

Source: Calculations based on Platts (2017) *World Electric Power Plants Database*.

Source: IEA WEI July 2017

6. Indian Coal Self-Sufficiency

Because of the Modi government's plan to build domestic coal capacity sufficient to meet demand growth and cease thermal coal imports this decade, India this year overtook the U.S. to become the second largest coal producer and consumer globally. In 2016 the IEA estimates India expanded investment in its domestic coal mining capacity by 10% to US$3.7bn.[110]

IEEFA expects India's electricity sector to remain heavily dependent on domestic coal-fired power generation for decades to come, given power plants commissioned in 2020 will have the operating life to run through to 2060. However, with the policy focus on building grid efficiency and energy efficiency, and the improvement in energy security that will develop as India builds out wind, solar and hydro and to a much lesser degree LNG plus nuclear fueled capacity, coal fired power's share will likely decline significantly over the coming decade (see Figure 6.1).

Figure 6.1: Indian Thermal Coal Consumption in Power Generation (Mtpa)

Year ended March	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Coal fired power generation (TWh)	834	889	938	968	995	1,019	1,043	1,066	1,089	1,112	1,137	1,162	1,186
Coal-fired power - market share (%)	75.8%	75.7%	75.5%	75.1%	73.3%	71.2%	69.1%	67.1%	65.0%	63.0%	61.1%	59.2%	57.3%
Coal-fired power thermal efficiency (%)	32.0%	32.5%	32.9%	33.3%	33.6%	33.9%	34.3%	34.6%	34.9%	35.3%	35.6%	36.0%	36.3%
Tonnes per TWh	0.64	0.61	0.60	0.59	0.58	0.56	0.55	0.54	0.53	0.52	0.51	0.50	0.49
Thermal coal demand - for power (Mt)	530	546	562	569	573	575	577	578	579	579	581	582	582
Thermal coal demand - growth (% pa)	8.4%	2.9%	2.9%	1.2%	0.8%	0.4%	0.3%	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%

Source: CEA, IEEFA Calculations

India's 1,500Mtpa Domestic Coal Production Target Is Excessive

In 2015, Coal Minister Piyush Goyal articulated a plan for Coal India Ltd (CIL) to double its coal production to 1,000 Mtpa by 2020 as part of a wider plan for India to more than double national coal production to 1,500 Mtpa by 2022.

CIL has been successful in substantially growing production to meet demand growth and replace import capacity. Production volume growth of 9.0% in 2015/16 and another 2.8% to 554 Mtpa was reported for 2016/17. More recently CIL has been focused on reducing excessive in-house coal inventories, with the first five months of 2017/18 seeing shipments running at 117% of production, resulting in a 32 Mt inventory drawdown. However, with energy efficiency gains meaning Indian electricity demand growth is slower than some anticipated and renewable energy set to deliver much of the new incremental power demand, India is starting to evaluate the merits of a more sustainable, lower growth trajectory for domestic coal production.

A core component of India's energy market development is the premise that coal will remain a mainstay of electricity generation for decades to come. This is entirely consistent with IEEFA's electricity model for India, as is detailed in Section 8.

[110] IEA World Energy Investment July 2017

Excessive production expansion has also been curtailed by the inevitable conflict of coal mining with other significant land use needs in India. CIL reported in August 2017 that of 120 coal projects, half (62) were running behind schedule, mainly due to a delay in obtaining forest clearances, acquiring land, lack of railway infrastructure facilities and issues related to rehabilitation and resettlement.[111]

Figure 6.2: Coal India Ltd – Production and Dispatches (April-September 2017, Mtpa)

	Production	Dispatches	Ratio of Dispatches to Production
Sept 2017 (Mt)	38.8	43.6	112.4%
Sept 2016 (Mt)	35.2	37.7	107.1%
Change yoy	10.0%	15.5%	
Apr-Sept 2017 (Mt)	231.9	269.0	116.0%
Apr-Sept 2016 (Mt)	230.1	249.1	108.3%
Change YTD yoy	0.8%	8.0%	

Source: Coal India Ltd, IEEFA Calculations

However, having sourced a relatively steady 76% of electricity generation from coal over FY2014-FY2017, IEEFA forecasts coal's share of total generation will decline some 2% annually, falling to a record low of just 58% by FY2027.

Also, given the weak operating profile of CIL inherited by the Modi government, it is critical that India's coal system efficiency improve dramatically. To-date significant progress has been achieved. CIL has boosted coal production by 27% or 120 Mt in the last five years. Total employment at CIL has fallen 16% to 310,000 in the same time frame, leading to a 54% increase in labour productivity. Increased rail freight efficiency, greater washing of coal to improve energy content, third party testing of coal quality and improved coal linkages are all playing a key role in continuing this process.

In September 2017, Coal India Ltd announced a diversification strategy into other commodities in light of concerns over the approach of peak Indian coal demand.[112]

State-owned SCCL also has increased coal production by 6.3% pa to 61 Mt in the three years to 2016/17, with a now unnecessarily aggressive target of 100 Mtpa by 2020.

Captive mines owned and operated by power companies including NTPC, Adani Enterprises and Reliance Power are estimated to produce 40-45 Mtpa in 2017/18, and IEEFA forecasts this to double to over 100 Mtpa by 2026/27. However, in reflection of weaker than expected coal demand growth prospects, in October 2017 Coal Secretary Susheel Kumar was reported to be considering remedial action including possibly taking back unwanted and unviable coal deposits allocated in the last two years.[113]

NTPC Ltd has begun an upstream vertical integration strategy, commissioning its first mine at Pakri Barwadih in 2016, which produced 0.46 Mt through June 2017. This is part of an

[111] https://www.platts.com/latest-news/coal/newdelhi/indias-cil-says-62-mining-projects-behind-schedule-26789130
[112] http://www.livemint.com/Industry/87uGUm6aVWIHJBvRdY7HVK/Coal-India-plans-to-become-a-fullfledged-mining-company.html
[113] http://www.hellenicshippingnews.com/as-captive-coal-production-dwindles-centre-mulls-option-to-take-back-mines/

overall strategy to product 100 Mtpa by 2030.[114] [115] NTPC Ltd is also evaluating biomass co-firing of thermal power, which could materially erode coal demand, similar to moves by Drax UK.

Adani Enterprises Limited (AEL) commissioned its first coal mine at Parsa Kente in 2013 and plans to double production to 15 Mtpa. AEL plans to open the 5 Mtpa Parsa coal mine in 2018 and the 7 Mtpa Kente Extension mine in 2019 to reach 27 Mtpa by 2020. In August 2017 AEL announced it had been awarded the Gare Pelma Sector III coal block, giving it access to a fourth Chhattisgarh state-owned mine.

Reliance Power Ltd.'s Sasan Power operates one of the world's largest integrated mine-mouth coal-fired power plants. The three captive coal blocks Moher, Moher Almori & Chhatrasal located in Singrauli district of Madhya Pradesh are one of the largest in India, with production of 20 Mtpa.[116]

Tata Power produces 15Mtpa from its captive coal mine allocated to the Sasan UMPP.

In total, India has an ambitious domestic captive coal block target of 400 Mtpa by 2020,[117] one that looks decidedly off-target so far given consistent delays and cancellation of new coal block tenders, including the failed August 2017 auction of five coking coal deposits. However, one can also read into this growing industry reticence to invest in new coal capacity, considering emerging expectations about materially lower coal demand growth.

Cessation of Thermal Coal Imports

In 2015 Coal Minister Piyush Goyal put forward an ambitious target to virtually cease thermal coal imports within 2-3 years. At the time, Indian coal imports had been rising 20% annually for the preceding five years, reaching a record 217.8 million tonnes in 2014/15.

When the Indian goal was announced, both the IEA and the Australian Government's Office of the Chief Economist said this target was unachievable. However, recent developments show that Goyal's target was entirely directionally correct, with 2015 marking the peak of India's coal imports. Since then, imports declined 6% to 204 Mt in 2015/16 and another 6% to 191 Mt in 2016/17.

Looking at the fiscal year to-date (April to September 2017), data shows the trend has continued and Indian coal imports have fallen a further 7.5%,[118] and within this the rate of decline in thermal coal imports is even more dramatic.[119]

At the beginning of the current fiscal year, Goyal renewed his campaign, calling on all public sector undertakings (PSUs) to cease thermal coal imports into India in 2017/18. His efforts are having an impact, India's largest coal importing PSU, NTPC Ltd., has cut its coal imports 95% in the two years to 2016/17, to just 1 Mt.

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[114] http://www.livemint.com/Industry/9GfGTvx9onJKLKcMV0OfWL/NTPC-targets-3-million-tonnes-of-coal-production-in-201718.html
[115] http://energy.economictimes.indiatimes.com/amp/news/coal/-ntpc-to-secure-33-per-cent-of-coal-requirements-from-own-mines-by-2030/60160735
[116] http://www.sourcewatch.org/index.php/Sasan_Ultra_Mega_Power_Project
[117] http://profit.ndtv.com/news/corporates/article-niti-aayog-suggests-breakup-of-coal-india-1741871?amp=1&akamai-rum=off
[118] http://economictimes.indiatimes.com/news/economy/foreign-trade/coal-imports-up-10-in-september-as-power-plants-face-fuel-shortage/articleshow/60991698.cms
[119] http://energy.economictimes.indiatimes.com/news/coal/thermal-coal-imports-at-major-ports-dip-17-per-cent-to-30-mt-in-apr-jul/60071412

In July 2017 Goyal stated: "However, the gap between demand and supply of coal cannot be bridged completely as there is insufficient domestic availability of coking coal and power plants designed on imported coal will continue to import coal for their production."

IEEFA would note there remains scope for coastal coal-fired power plants to import high energy low ash thermal coal and blend with lower grade, lower cost Indian coal, but only if the cost is competitive. Absent blending, India's two largest coal-fired power plants operating on imported coal (Adani Power Mundra's 4.6 GW and Tata Mundra's 4.0 GW plants) are both running unsustainable losses and management have declared the plants unviable, offering the equity in both plants for sale for a token Rs1 each.

Figure 6.3: Indian Coal Production, Imports & Consumption (Mtpa)

Year Ended March	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
All Coal - Dispatches (MT)													
Coal India Ltd	490	535	543	576	608	638	670	697	721	739	750	761	773
SCCL	52	58	61	61	63	65	66	67	67	68	69	69	70
Private / Captive	45	32	36	47	57	65	72	78	84	90	96	100	104
Other	16	7	7	8	8	8	9	9	9	9	9	10	10
Total Lignite (NLC + other Producers)	47	42	46	47	47	48	48	49	49	49	50	50	50
Total Domestic Coal Dispatches	650	674	693	739	784	824	865	899	931	956	973	991	1,007
Less Domestic Coking Coal Dispatches	-57	-59	-58	-59	-60	-62	-63	-64	-65	-67	-68	-69	-71
Plus Thermal Coal Imports	174	156	149	134	100	80	63	50	38	29	22	16	12
Total Thermal Coal Consumption	767	771	784	814	824	843	865	885	904	918	927	937	948
Assumed growth rates (%)													
Coal India Ltd		9.2%	1.5%	4.5%	5.0%	5.0%	5.0%	4.0%	3.5%	2.5%	1.5%	1.5%	1.5%
Thermal Coal Imports		-8.5%	-3.8%	-10.0%	-25.0%	-20.0%	-21.0%	-22.0%	-23.0%	-24.0%	-25.0%	-26.0%	-27.0%
Coking Coal Imports		-1.1%	0.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Total Thermal coal consumption		0.5%	1.7%	3.8%	1.2%	2.4%	2.6%	2.2%	2.1%	1.6%	1.0%	1.1%	1.2%

Source: CEA, IEEFA Calculations

Given that India already is reliant on imports of iron ore and coking coal for steel production, uranium for nuclear power generation, thermal coal for coastal coal-fired power plants, LNG to cover for declining domestic gas production, as well as oil and diesel, strong economic growth will translate into greater fuel imports and a widening current account deficit with a resulting pressure on India's currency. A far greater reliance on domestic renewable energy generation could combine with a rapid move to electric vehicles to reduce this import energy dependence,[120] improve India's energy security, reduce pollution pressures, and create employment and investment opportunities.

[120] http://www.thehindu.com/profile/author/Rajnish--Wadehra--12997/

7. Zero Emissions Alternatives for India

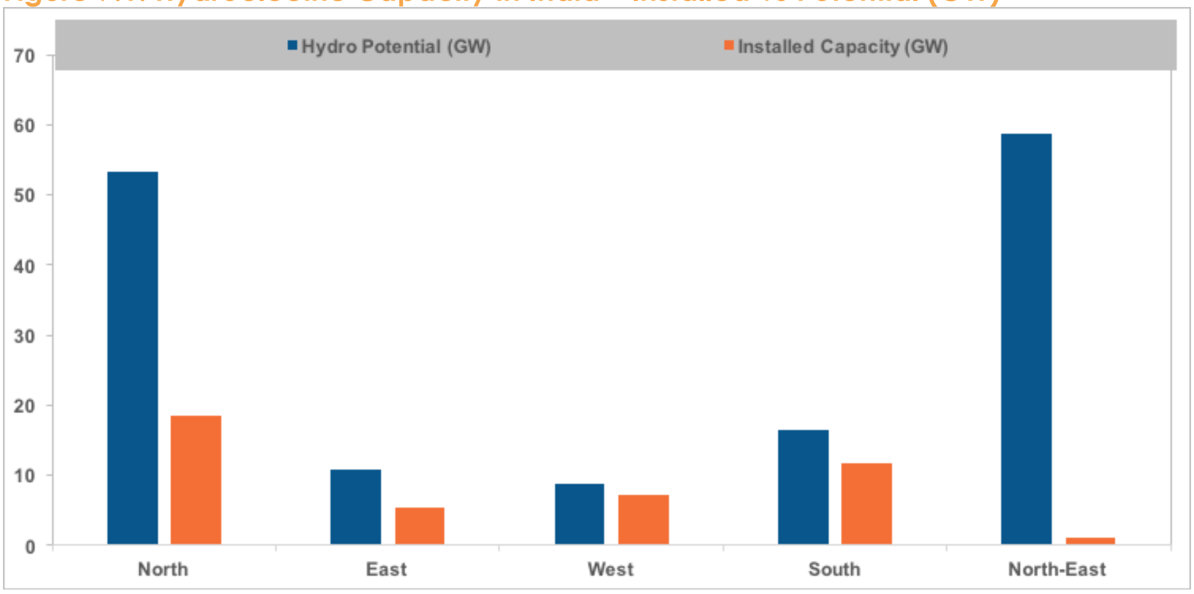
Hydro Additions

To strengthen India's energy and water security through greater system diversity and to support greater variable generation from wind and solar, the government is also driving hydro capacity expansions. With a renewable energy capacity target of 175 GW by 2022, adding targeted hydro capacity expansion takes the target to 225 GW.[121]

Having recently expanded into hydropower with the commissioning of the 800 MW Koldam hydroelectric plant, NTPC is currently developing three more projects to double its hydro capacity[122]. NTPC has two projects under development in the state of Uttarakhand; Tapovan Vishnugad (520 MW) and Lata Tapovan (171 MW). The Central Electricity Authority (CEA) report on hydro-development progress discloses commissioning dates for these projects of FY2019-20 and FY2020-21, respectively[123]. In addition, NTPC is developing the 120 MW Ramman in West Bengal, with a commissioning date of FY2019-20.

As per Figure 7.1, with installed hydro capacity currently at 41 GW, only 28% of India's reported 148 GW of hydroelectric capacity has been developed. As per CEA's data the total hydro capacity currently under construction amounts to 11 GW, which is only about 7% of total hydropower potential.[124] The slow pace of hydropower development can be attributed to complex clearance and approval procedures, land acquisition issues, insufficient market depth and scope, and limited availability of long-term financing. IEEFA notes that hydro plans will need to be reassessed considering changing weather and rainfall patterns on the Himalayas due to climate change.

Figure 7.1: Hydroelectric Capacity in India – Installed vs Potential (GW)



Source: Central Electricity Authority (CEA)

[121] http://economictimes.indiatimes.com/industry/energy/power/adding-hydro-can-take-indias-clean-power-to-225-gw-by-2022/articleshow/54332470.cms
[122] http://www.ntpc.co.in/en/power-generation/hydro-based-power-projects
[123] CEA, Monthly Hydro Reports, State wise note on Hydro Power Development, March 2017.
[124] CEA, Status of Hydro Electric Potential Development, March 2017

Hydro capacity of about 60 GW has been allotted for development, but it is still under various stages of approval. Additionally, 75% of the potential new capacity is in the relatively remote and low power demand region of the Northeast. Development of these resources will require significant new HVDC grid connectivity capacity with the west and south of India.[125]

In October 2016 the Ministry of Power announced the formation of a new committee to work in mission mode to get the 22 stalled large hydro power projects started and inject fresh investment to make them viable in the next three months. Further, it was decided to give hydropower status as a renewable energy, and that a separate renewable energy purchase obligation (RPO) should be set up for the hydro sector.[126]

In August 2017 the GoI was reported to be close to releasing its policy platform to revive this sector, with a focus on 14 stalled hydro projects worth US$4bn, with the proposal to establish a U$2.5bn hydroelectric development fund to revive the stalled projects.[127]

In October 2017 Power and renewable energy minister R K Singh reiterated the need for sustained development of hydro-electricity as a key part of the solution for peak demand management and affordable electricity for all.[128]

Demand Response Management

Another area of emerging opportunity for India is demand response management (DRM), which is a system designed to use technology to curtail electricity consumption for short durations at times of peak demand. Spread across a range of customers, this can provide voluntary load reduction without material economic disruption and thereby avoid involuntary load shedding and blackouts.

The move to introduce smart meters is a prerequisite to build a smart grid to better manage variable demand and variable generation. In October 2017 Australia completed its first 200 MW tender for DRM capacity for rollout from December 2017 onward.[129] DRM is a major peak demand management tool deployed and utilised in the U.S. over the last decade.

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125 http://mercomcapital.com/hydropower-projects-delayed-in-india-due-to-complex-clearance-procedures
126 http://pib.nic.in/newsite/PrintRelease.aspx?relid=151543
127 http://energy.economictimes.indiatimes.com/news/power/centre-to-finalise-hydropower-development-fund/60103997
128 https://energy.economictimes.indiatimes.com/news/power/india-must-encourage-hydro-power-projects-development-r-k-singh/61361775
129 http://reneweconomy.com.au/get-smart-aemo-unveils-200mw-virtual-power-plant-77632/

Nuclear Additions

India's draft NEP includes has a proposal for a tenfold increase, to 60 GW, in installed nuclear capacity by 2030, a clearly unachievable objective – both in terms of engineering capacity, financial cost to Indian ratepayers and the likelihood of continued, prolonged engineering and construction delays.

In a stark lesson India might do well to avoid, Southern Co.'s 2.2 GW Vogtle nuclear generating station in Georgia in the U.S. was cancelled in August 2017 after US$9bn already had been invested in this epic failure.[130] Capital costs for the plant, which is based on Westinghouse technology, are now estimated to be double the US$12bn expected in 2008 when this project was first proposed.[131]

Also in August 2017, SCANA Corp. and the Santee Cooper state utility announced cancellation of a similar nuclear project in South Carolina after wasting billions of dollars over nearly 30 years,[132] acknowledging four fundamental barriers to continuing this project:

- Higher than projected construction costs;
- Higher than projected operating costs;
- The fact that no reactor with the new design being used (the Westinghouse AP1000) has yet achieved commercial operation;
- General lack of nuclear industry economies and scale.

In August 2017 Duke Energy also announced it too was scraping plans for a 2,200 MW nuclear power plant in North Carolina, incurring a US$640m ratepayer funded loss. That plant was also designed with Westinghouse technology.[133]

Confirmation of these two Westinghouse nuclear debacles comes less than a month after Prime Minister Modi announced a deal with the Trump administration to use Westinghouse technology in India's renewed push into nuclear energy. The bankrupt Westinghouse is bizarrely reported to be planning to seek massive US EXIM Bank subsidised financing to fund six nuclear reactors in Andhra Pradesh.[134]

After this, and suggesting a more considered perspective, in August 2017 then Energy Minister Piyush Goyal confirmed the Indian government has more than halved its planned nuclear power plant expansion to just 7 GW (10 units of 700 MW each) using indigenously-manufactured equipment. This is a significant reduction on the March 2017 target for adding 15 GW by 2024. Goyal stated: "Nuclear power will never ever become the main source of energy for India because it is very expensive".[135]

In November 2017 it was reported that France's proposed Jaitapur Nuclear Power Project (JNPP) planned in Ratnagiri, Maharashtra was facing 25% capital cost blowout and further delays by the project proponent, Electricite De France (EDF). Just another disaster that highlights the financial risks and delays in any reliance on nuclear power.[136]

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[130] https://www.bizjournals.com/charlotte/news/2017/07/31/s-c-utility-votes-to-stop-building-16b-v-c-summer.html
[131] http://ieefa.org/ieefa-update-u-s-nuclear-project-cancellation-announcement-heard-round-world/
[132] http://www.foxbusiness.com/markets/2017/08/02/tab-swells-to-25-billion-for-nuclear-power-plant-in-georgia.html
[133] https://www.washingtonpost.com/business/duke-energy-scraps-sc-nuke-plant-seeks-higher-power-rates/2017/08/25/678ec176-89d7-11e7-96a7-d178cf3524eb_story.html?utm_term=.50f0f0fe6175
[134] http://energy.economictimes.indiatimes.com/news/power/nuclear-deal-between-india-and-japan-opens-up-new-vistas-of-cooperation/60472072
[135] https://ijglobal.com/articles/107722/india-scales-back-nuclear-power-plans
[136] http://www.newindianexpress.com/nation/2017/nov/15/india-pushing-for-jaitapur-nuclear-plant-despite-cost-escalation-1701709.html

Solar Thermal with Storage – IEEFA Assumes 2 GW by 2026/27

The dramatic increase in variable generation capacity due online over the coming decade, will also require India to build new flexible peaking capacity. In the U.S., record low natural gas prices means gas peakers provide this flexibility. In contrast, India's policy of setting domestic gas price caps well below import price parity means gas exploration and development is seriously constrained. The high cost of LNG-fired capacity limits the role of gas as a source of peaking capacity for India. In Australia, cheap domestic gas prior to 2015 meant gas peakers filled this role as well. However, a government energy policy failure has seen domestic gas production double while prices have trebled into 2017, such that Australia's previously low-cost gas peaking option is now redundant.

One option for meeting these new needs is solar thermal with storage. In August 2017, SolarReserve contracted to provide 135 MW net concentrated solar thermal power (CSP) with 1.1 GWh of storage capacity in South Australia at a record low price of A$75-85/MWh (US$60-68/MWh), a price the Australian government had only just forecast would not be reached till 2050.[137]

Then, in September 2017 Dubai awarded a US$4bn 700 MW CSP project that will deliver electricity in periods of peak demand for a record low US$73/MWh.[138] Paddy Padmanathan, CEO of ACWA Power, said: "This project is a game changer in our quest to decarbonise electricity generation by making available renewable energy at a price that competes with fossil fuel-generated electricity without subsidy not just when the sun is shining but at any time of the day and night."

IEEFA views CSP as an emerging technology highly likely to be well positioned to provide India much needed peaking electricity supply at very competitive time-of-use pricing by 2026/27, complementary to India's likely reliance on hydro, distributed batteries and gas for load balancing peak needs,

International Grid Interconnects & Imported Hydro

India is progressively building out grid interconnectivity with Bhutan and Bangladesh, and plans are under development for new grid capacity with Nepal as well as subsea cable connectivity with Sri Lanka. This will facilitate both importing and exporting of electricity, assisting with peak load balancing and new capacity management.

In June 2017 it was reported that India was again keen to revive the long planned, and long delayed US$4.7bn, 5.6 GW Pancheshwar hydroelectric power project on the Mahakali River that divides Nepal and India.[139]

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[137] http://reneweconomy.com.au/aurora-what-you-should-know-about-port-augustas-solar-power-tower-86715/

[138] http://reneweconomy.com.au/work-begins-on-worlds-biggest-solar-tower-and-storage-plant-31793/

[139] http://www.newindianexpress.com/nation/2017/jun/23/green-light-to-indo-nepal-pancheshwar-dam-project-1619842.html

8. IEEFA Model for India's Electricity Sector

India's electricity sector is dominated by an over-reliance on coal-fired power generation, which represents 58.8% of installed grid capacity. With significantly higher utilisation rates than renewables, coal represents 75.5% of total 2016/17 electricity generation. This picture is very similar to the position China was in five years ago, with all the threats and opportunities that entails, including: Rapidly escalating air pollution, water scarcity issues, current account deficit pressures from imported thermal coal, rising costs of thermal power generation and declining utilisation rates.

With declining production of domestic gas, India is faced with a fleet of 25.3 GW of largely stranded, underperforming gas-fired power plants increasingly reliant on high marginal cost LNG imports for fuel. Running at an average 25% capacity utilisation in 2016/17, this generation at least provides peak demand capacity, but a variable peak price signal would assist here.

Large scale hydro capacity stands at 44.5 GW or 13.6% of the installed total (9.9% of generation), with significant scope to double this in the coming decade or two, leveraging the significantly enhanced national grid system, at the same time providing peaking capacity to balance the development of greater regional interconnectivity.

At 6.8 GW of installed capacity, nuclear represents just 2.1% of India's system, and even with relatively high utilisation rates of 70-72%, just 3.0% of generation. Given the 10-20 years required to plan and build new nuclear plants, and the almost inevitable probability of capex cost blowouts, it is understandable why India has halved its nuclear ambitions this year.

Renewable capacity stands at 57.3 GW or 17.5% of India's total, but with utilisation rates of 18-20% for solar and 20-25% for wind the actual generation is a far less material 6.6% of India's total. Therein lies the opportunity, concerns over excessive reliance on variable generation is still 5-10 years away, and by then solutions can be relatively seamlessly integrated into the grid given US$20-30bn of annual grid upgrade spend.

The clear opportunity comes from the ability to build on this relatively one-dimensional over-reliance on thermal power and rapidly integrate cost competitive renewable energy generation to accommodate the vast majority of the system growth over the coming decade.

Figure 8.1: India's Electricity Capacity and Generation (2016/17)

	---- Capacity ----		-- Generation --		Capacity	Increase
	GW	%	TWh	%	Utilisation	GW yoy
Coal-fired	192.2	58.8%	937.6	75.5%	56.7%	7.0
Gas-fired	25.3	7.7%	54.6	4.4%	25.0%	0.8
Diesel-fired	0.8	0.3%	2.0	0.2%	25.0%	-0.2
Large Hydro	44.5	13.6%	122.3	9.9%	32.0%	1.7
Nuclear	6.8	2.1%	37.7	3.0%	68.5%	1.0
Renewables	57.3	17.5%	81.7	6.6%	19.4%	14.0
Bhutan	n.a	n.a.	5.6	0.5%	n.a.	
Total	**326.8**	**100%**	**1,241.5**	**100%**		**24.4**

Source: CEA, IEEFA calculations

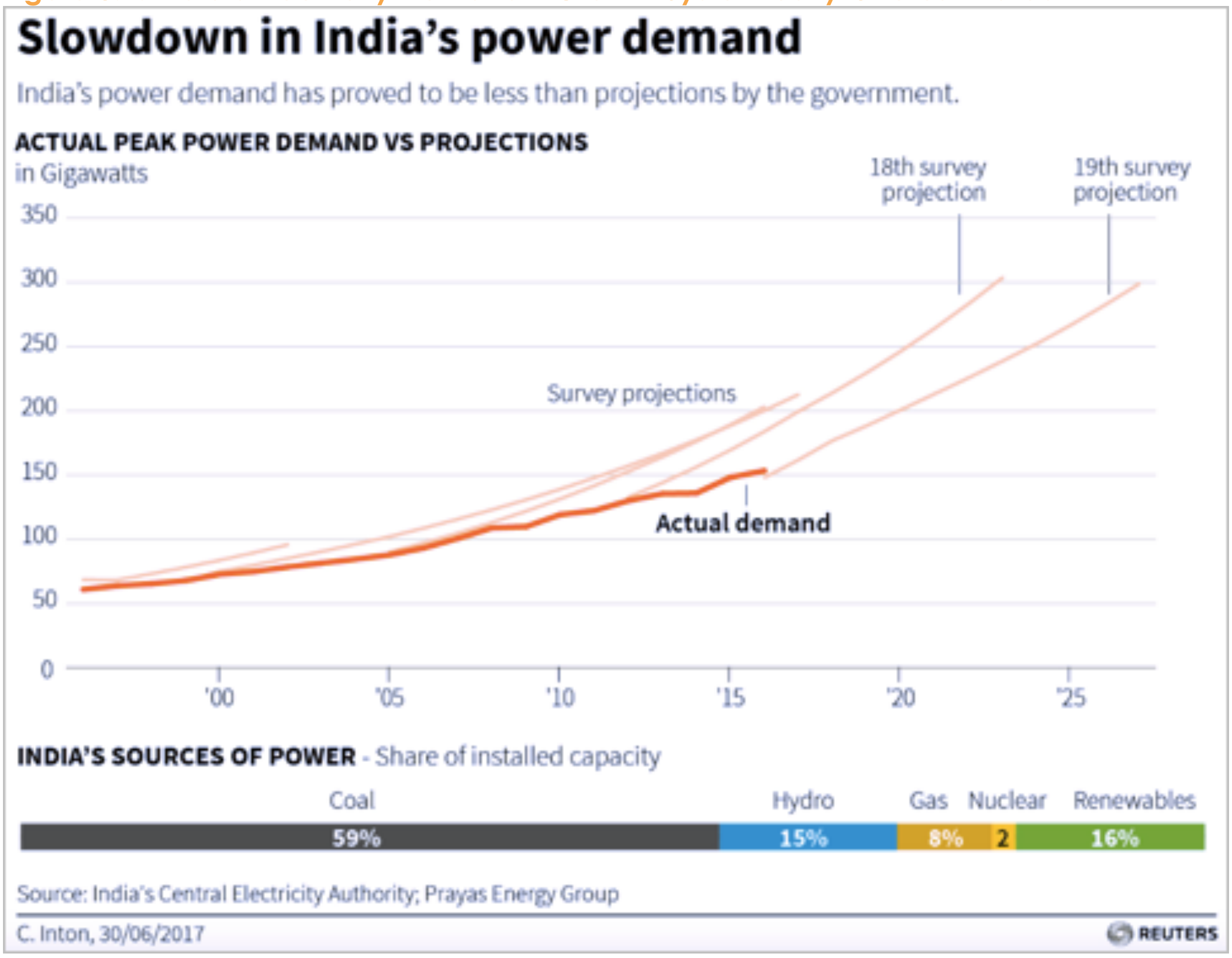
Electricity Demand Projections – 7% pa

Overestimation of global long-run electricity demand growth has been a standard lesson of the past decade, with possibly the exception of China in the 2000-2012 period of exceptional 10% annual economic growth coupled with electricity demand growth of 7.6% per annum. The consequences of unrestrained, unsustainable GDP growth are now clear to see, suggesting India should seek a more sustainable economic growth model. Given the now low cost and exceptionally scalable position of renewable energy, this is also the economically rational model, and one most likely to garner global inbound investment.

There is also no doubting the very strong sustained growth rate of electricity in India over the last decade. India witnessed 7.3% annual GDP growth over 2006-2017, and electricity production has risen 6.6% annually as a result – a multiplier of 0.9 times.

However, Figure 8.2 details a systematic overestimation of peak power demand in India. Even during a decade of exceptional growth, there are real economic costs of overbuilding electricity capacity due to excessive optimism on demand growth projections. This also highlights the very substantial benefits of pursuing a strategy to maximise energy efficiency efforts in order to moderate demand growth and lower the economic and environmental cost of India's electricity sector transformation.

Figure 8.2: India's Electricity Demand – Growth Systemically Overestimated



Source: Reuters

IEEFA forecasts 7.0% annual average GDP growth for India over the coming decade. Demonetorisation and GST have slowed growth near term in FY2018,[140] but in our view, this makes for a more sustainable base of growth. While we start with a gross electricity to GDP growth multiplier of 1.1 times (more than the net 0.9 times evident in the last decade), we do this to highlight that even a conservative energy efficiency saving of 1.0% annually would save 119 TWh of annual production growth over the coming decade (equivalent to 10% of India's current consumption).

So IEEFA forecasts net electricity demand to grow at 6.7% per annum (7.0% * 1.1 -1.0%) to 2026/27. Greater energy efficiency should offset any economic mix share shift to heavier reliance on energy intensive manufacturing and construction activity.

Figure 8.3: India's Net Electricity Consumption (FY2017-FY2027, TWh)

India's Waterfall Chart				
Net Electricity consumed in India in 2016/17 (TWh)			946	
Real GDP Growth	7.0%	pa		
Electricity to GDP multiplier	1.10	times		
Electricity Demand Growth	7.7%	pa	967	
Energy Efficiency	-1.00%	pa	-119	
Growth: gross production losses			197	
Reduced grid AT&C losses	-1.00%	pa grid efficiency gain	-207	
Net Electricity consumed in India in 2026/27 (TWh)			1,784	
Net expansion in Electricity Demand 2026/27 (TWh)			839	
Net expansion in electricity production required (TWh)			829	
The Increase in Net Electricity Demand is met by (TWh)			**TWh**	**Uplift**
Solar expansion			241	29%
Solar thermal expansion			5	1%
Onshore wind expansion			151	18%
Offshore wind expansion			9	1%
Increase in biomass generation			28	3%
Increase in hydro electricity			66	8%
Increase in hydro imports			31	4%
Increase in gas-fired electricity			17	2%
Increase in nuclear generation			32	4%
Change in Coal-fired power use			248	30%
Net expansion in Electricity Production by 2026/27 (TWh)			829	100%

Source: CEA, IEEFA calculations and forecasts

[140] https://www.bloombergquint.com/politics/2017/10/11/modi-facing-backlash-as-discontent-over-india-s-slowdown-deepens

Reduced AT&C Grid Losses Mean 5.4% pa Generation Growth

A second key assumption IEEFA makes is that aggregate technical and commercial (AT&C) losses on the grid will decline from the unsustainably high and exceptionally costly level of 23.8% in FY2015 to a more manageable 13.8% in 2026/27. This estimated 1.0% annual reduction would represent a huge savings, but still leave Indian grid losses more than triple the level posted in Germany, the world's most efficient grid. With the combined benefits of the major UDAY Discom reform, reduced theft aided by the progressive introduction of smart meters, decoupling of agricultural and residential grid connectivity and the smart grid benefits of India's planned US$20-25bn annual grid capital spend, this near halving of AT&C losses should be feasible.

IEEFA stresses that the combined benefits of energy efficiency and grid efficiency should cut electricity production growth by 119 TWh and 207 TWh respectively by the end of the forecast period. So gross electricity demand growth of 7.7% translates into 6.7% net demand growth net of energy efficiency. Factoring in AT&C loss reductions reduces the required growth in power generation to "just" 5.4% annually. This means that a doubling of India's economy by 2026/27 means a likely 90% rise in electricity consumption (to 1,784 TWh annually) but only a 67% increase in electricity generation (to 2,071 TWh). Grid and energy efficiency make the transformation far more cost effective and economically achievable. An accurate forward electricity plan also can help India avoid investing in excess capacity of the wrong type (baseload vs peaking), and accommodate more distributed capacity where most needed (e.g. C&I rooftop solar with storage) to optimise and mitigate some of the investment in grid capacity expansion.

Figure 8.4: IEEFA's Indian Electricity Model (FY2014-FY2027)

Year ended March	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Gross Production (TWh)	966	1,101	1,174	1,242	1,290	1,359	1,431	1,508	1,589	1,675	1,766	1,862	1,963	2,071
Gross Production growth (%)		13.9%	6.6%	5.8%	3.9%	5.3%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.5%
AT&C losses (TWh)	219	271	284	296	294	296	298	299	299	299	297	295	291	286
AT&C losses (%)	22.7%	24.6%	24.2%	23.8%	22.8%	21.8%	20.8%	19.8%	18.8%	17.8%	16.8%	15.8%	14.8%	13.8%
Reduced grid losses (%)		1.9%	-0.4%	-0.4%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
Real GDP Growth (%)	7.5%	8.0%	7.1%	7.1%	6.3%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
Electricity multiplier (x)	1.1	1.1	1.1	1.1	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1
Electricity growth (%)	8.3%	8.8%	7.8%	7.8%	6.3%	7.7%	7.7%	7.7%	7.7%	7.7%	7.7%	7.7%	7.7%	7.7%
Energy efficiency (%)	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
Net demand (TWh)	**747**	**830**	**889**	**946**	**995**	**1,062**	**1,133**	**1,209**	**1,290**	**1,377**	**1,469**	**1,567**	**1,672**	**1,784**
Net demand growth (%)		11.1%	7.2%	6.3%	5.2%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%

Source: CEA, IEEFA calculations and forecasts

Efficiency of Coal Use – Progressively Reducing Coal Use

NTPC Ltd over the last three years has demonstrated a 5% reduction in coal usage per unit of electricity output, as detailed in Figure 8.5. NTPC's coal use has increased by 2.7% in the last three years, while electricity output has risen 7.3%. So, coal use per unit of electricity has fallen 5% in three years to 0.683 kg/kWh even as Coal India Ltd has ceased all reliance on higher energy, lower ash content imported thermal coal. NTPC's latest initiative is to undertake co-firing using 10% biomass waste to reduce air and particulate pollution.[141]

This reflects the initial efficiency gains across India Railways and Coal India Ltd that include third party quality testing, monitoring of rail and truck movements and a greater focus on coal washing, all of which aim to reduce the excessive shipment costs involved in moving and then burning spoilage waste alongside coal.

Figure 8.5: NTPC – Coal Use Relative to Coal-Fired Power Generation (FY2014-FY17)

					FY15 vs FY2014	FY16 vs FY2015	FY17 vs FY16
NTPC Coal Volumes (Mt)	FY2014	FY2015	FY2016	FY2017	chg yoy	chg yoy	chg yoy
Domestic	149.8	151.1	151.8	159.4	0.9%	0.5%	5.0%
Imported	10.8	16.3	9.5	1.0	50.9%	-41.8%	-89.1%
Total Coal Sourced (Mt)	160.6	167.4	161.3	160.4	4.2%	-3.7%	-0.6%
Total Coal Consumed (Mt)	158.2	162.1	160.6	162.5	2.5%	-0.9%	1.2%
Coal as a % of total fuel	89%	89%	93%	95%			
Average Tarrif (Rp/kWh)	3.20	3.25	3.18	3.30	1.6%	-2.2%	3.8%
Electricity Dispatched (BU)	217.4	225.0	224.9	233.6	3.5%	0.0%	3.9%
Coal (kg/kWh)	0.718	0.707	0.700	0.683	-1.5%	-1.0%	-2.4%

Source: NTPC

Figure 8.6 details the overall national thermal coal use, which show an impressive 9.0% cumulative reduction in coal use from 0.66kg in 2013/14 to 0.60kg per kWh of electricity generated in 2016/17. Further gains are a key priority of Coal Secretary Susheel Kumar.[142]

Figure 8.6: Indian Coal Use Relative to Coal-Fired Power Generation (FY2015-FY17)

Year to March	2014	2015	2016	2017
Coal fired power generation (TWh)	740	834	889	938
Coal-fired power - market share (%)	76.6%	75.8%	75.7%	75.5%
Coal-fired power thermal efficiency (%)	30.8%	32.0%	32.5%	32.9%
Tonnes per TWh	0.66	0.64	0.61	0.60
Thermal coal demand - for power (Mt)	489	530	546	562
Thermal coal demand - growth (% pa)	7.7%	8.4%	2.9%	2.9%
% Change in Tonnes/TWh		-4.0%	-3.5%	-2.5%

Source: CEA

[141] http://www.businessinsider.com/r-india-tells-top-utility-to-mix-crop-residue-with-coal-to-reduce-new-delhi-smog-2017-11?IR=T

[142] http://energyinfrapost.com/coal-ministry-prioritises-turning-coal-india-clean-company/was

A second major area of thermal efficiency improvement can be achieved if the GoI follows through with its coal-fired power plant modernisation campaign. The obvious end goal is to enforce a requirement that only USC coal-fired power plants are built going forward (and existing but stranded half-built plants incorporating outdated subcritical and SC technologies be scrapped) to meet the growing public necessity to deal with escalating pollution pressures. Any new capacity to be approved should only occur concurrently with the enforcement of rules requiring the orderly closure of 40 GW of very inefficient, small, end-of-life subcritical plants across India (refer Annexure 1).

Figure 8.7: Coal-Fired Power Generation – Costs & Thermal Efficiency of Newer Technology

Technology Differences - New Investments 2016			
Technology	Capital Cost (2016 $ Billion/GW)	HHV Efficiency	Emission rate (T/MWh)
Subcritical	1.21	32%	1.04
Supercritical	1.46	37%	0.87
Ultra-Supercritical	1.70	40%	0.80

Source: World Coal Association 2017

While ex-Power Minister Piyush Goyal had discussed a proposal to research advanced USC technologies, Figure 8.7 highlights that even the move from subcritical plants at US$1.2bn/GW to USC at US$1.7bn/GW of capacity is fraught with a significant 40-50% capital cost escalation, and retains stranded asset risk as public pressures mount on coal-fired power pollution overall. Considering ongoing solar and wind cost deflation running at more than 10% annually, the stranded asset risk of investing in new HELE coal-fired power plants is already stark, with commercial viability highly questionable.

IEEFA notes that RWE, one of Europe's largest thermal power utilities, has just completed a US$11bn capex program in 2016 and yet Macquarie Group values the collective "assets" at just US$3bn, a 70% valuation loss – Figure 8.8.

Figure 8.8: Coal-Fired Power - RWE Europe: Write-Downs Even on Newly Commissioned Technology

RWE Europe	Thermal Efficiency	New Build cost (€/kW)	Macquarie valuation (€/kW)	Difference (€/kW)	Capacity (MW)	Implied replacement cost ((€m)	Macquarie valuation (€m)	Difference (€m)	Relative difference
New Gas	58%	800	287	513	3,903	3,122	1,120	2,002	-64%
New Hard Coal (Germany/Netherlands)	46%	1,600	590	1,010	2,142	3,428	1,264	2,164	-63%
New Lignite (Germany)	43%	1,650	347	1,303	3,044	5,023	1,057	3,966	-79%
Total			**379**	**895**	**9,089**	**11,573**	**3,442**	**8,131**	**-70%**

Source: Macquarie Group Equities Research, Peter Crampton et al, 12 September 2017

The ongoing scope for further energy efficiency in the mining, transportation and burning of coal is significant, with consequent benefits in terms of reduced per unit pollution, a lower delivered cost of coal and lower carbon emissions. IEEFA sees coal-fired power generation as being progressively less competitive, and the NEP3 clearly articulates a plan to progressively transition away from India's historic reliance on coal.

With India targeting significant ongoing improvements, and with China having delivered a 1.2% annual improvement to just 0.315 kg/kWh in 2016, IEEFA believes a 2.0% annual reduction can be sustained for some time. In turn, this plays a critical role is allowing India to approach peak thermal coal by the end of the decade.

Conclusion

Until very recently, India was viewed as the next China: Projected rapid economic growth was expected to lead to a similar surge in electricity demand, which in turn would result in continuing construction of new coal-fired power plants and steadily rising thermal coal imports.

It was a scenario that made the global thermal coal export industry optimistic. Those forecasts aren't playing out as expected, however.

The reality is that Indian coal imports likely peaked in 2015, and spectacular reductions in the cost of renewable energy in India over the past few years have brought a possibility, one unthinkable just a couple of years ago, into the conversation: India now may be approaching peak thermal coal consumption.

The year 2017 may well in hindsight be seen as the tipping point in India's electricity transition. A cascade of record lows in solar PV tariffs has pushed the price of solar below the tariff for NTPC's existing coal-fired generation fleet for the first time. In addition, reverse auctions for wind power have resulted in similarly rapid price reductions. And, perhaps most important, 2016/17 was the first year in which total clean energy capacity additions clearly outstripped new thermal generation. IEEFA expects this to be the new norm.

These new realities are also becoming evident in official government policies, with India's third draft national electricity plan forecasting no need for additional coal-fired capacity during for the next 10 years, beyond what is already being built. The expectation is that new electricity demand will be met with clean renewable energy.

Despite expected net annual thermal capacity additions of 5 GW/year to 2027, IEEFA's electricity model for India demonstrates how peak coal could be achieved within this time frame. Continuing energy efficiency drives and further cuts in grid transmission and distribution losses combined with achieving the nation's ambitious 175 GW renewable energy target may reduce coal-fired power demand growth to 2.5%.

Further, there is plenty of opportunity to boost efficiency at existing coal-fired plants, which also would cut overall demand. Taking these developments into account, it is possible that demand growth for thermal coal in India can be reduced close to zero (just 5-10% volume growth in aggregate this coming decade). And this is before the game-changing impact of new technologies such as distributed solar with battery storage come into play.

Although India will continue to use coal in its electricity system for decades to come, peak use is in sight. Beyond that, the prospect of supporting the energy needs of India's rapidly growing economy whilst simultaneously transitioning its electricity system is well within reach. In fact, India can become a global leader, since most of its electricity system needs of 2040 are yet to be built, giving the country a unique opportunity to skip a technology generation.

Annexure I

List of Indian Thermal Plants Commissioned before 1993

Plant	Year Commissioned	Capacity (MW)
Angul Smelter power station	1985-90	600
Anpara power station	1986-88	630
Badarpur power station	1973-81	705
BALCO Korba power station	1988	268
Bandel Thermal Power Station	1965-82	455
Bhusawal Thermal Power Station	1979-82	420
Bokaro B power station	1986-1990	420
Bokaro Steel City Thermal Power Station	1972-74	275
Chandrapur Thermal Power Station	1985-92	1,420
Chandrapura power station	1964-79	620
Dhuvaran power station	1972	220
Dr Narla Tata Rao power station	1979-90	840
Durgapur Projects Limited power station	1960-87	401
Ennore Thermal Power Station	1970-75	450
Farakka power station	1986-92	1,100
Feroze Gandhi Unchahar Power Station	1988-89	420
Gandhinagar power station	1977-91	640
Guru Nanak Dev power station	1974-79	450
Hasdeo Thermal Power Station	1983-86	840
Kahalgaon Super Thermal Power Plant	1992	210
Khaperkheda power station	1989-90	420
Kolaghat Thermal Power Station	1984-91	840
Koradi Thermal Power Station	1978-83	620
Korba Super Thermal Power Station	1983-89	2,100
Korba Thermal power station	1966-81	440
Kota power station	1983-89	640
Kothagudem Thermal Power Station	1966-78	720
Mettur Thermal Power Station	1987-90	840
MP Amarkantak power station	1977-78	240
Muzaffarpur power station	1985	220
Nasik MAHAGENCO Thermal Power Station	1970-81	910
National Capital Dadri Thermal Power Plant	1991-92	420
Neyveli Thermal Power Station I	1965-1970	600
Neyveli Thermal Power Station II	1986-92	1,260
Obra Thermal Power Station	1974-82	294
Panipat power station	1979-89	650
Panki Thermal Power Station	1976-77	210
Parichha power station	1984-85	220
Parli Thermal Power Station	1982-87	630
Patratu JSEB power station	1967-84	680
Raichur Thermal Power Station	1985-91	630
Ramagundam power station	1983-89	2,100
Renusagar power station	1967-89	350
Rihand power station	1988-89	1,000
Ropar power station	1984-92	1,050
Sabarmati power station	1962-88	390
Satpura Thermal Power Station	1979-84	830
Singrauli Super Thermal Power Station	1982-87	2,000
Talcher power station	1967-83	460
Tanda power station	1988-90	330
Titagarh power station	1983-85	240
Trombay power station	1984	500
Tuticorin Thermal Power Station	1979-92	1,050
Ukai Thermal Power Station	1976-85	850
Vindhyachal power station	1987-91	1,260
Vizag Steel Plant power station	1989-90	180
Wanakbori Thermal Power Station	1982-87	1,260
Others	-	1,219
Grand Total		**40,037**

Source: CEA, Coal Plant Tracker Database

Institute for Energy Economics and Financial Analysis

The Institute for Energy Economics and Financial Analysis (IEEFA) conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy and to reduce dependence on coal and other non-renewable energy resources.

More can be found at www.ieefa.org.

About the Authors

Tim Buckley

Tim Buckley, IEEFA's director of energy finance research, Australasia, has 30 years of financial market experience covering the Australian, Asian and global equity markets from both a buy and sell side perspective. Tim was a top-rated Equity Research Analyst and has covered most sectors of the Australian economy. Tim was a Managing Director, Head of Equity Research at Citigroup for many years, as well as co-Managing Director of Arkx Investment Management P/L, a global listed clean energy investment company that was jointly owned by management and Westpac Banking Group.

Kashish Shah

Kashish Shah, a Research Associate at IEEFA, has a master's degree in Economics from the University of Sydney and an engineering degree from NMIMS University in Mumbai. Kashish was working in the Global Analytics division for the Royal Bank of Scotland with a focus on regulatory policies. Kashish has research experiences in India's public sector by working for a member of Indian Parliament and a University of Sydney based research group.

Important Information