Flexing India's Energy System through Market Mechanisms

A recipe for India to achieve a least cost, low carbon electricity market twice today's size

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India has set exceptionally ambitious renewable energy (RE) targets including 175 gigawatts (GW) by 2022, rising to 523GW by 2030, which includes 73GW of large hydro capacity. Such targets invariably encounter various new headwinds and challenges. The last year has brought some of these to the fore, including centre-state policy inconsistencies and questions over the grid's capacity to incorporate a rapidly rising variable renewable energy (VRE) penetration so quickly.

India's electricity supply has historically been largely coal dominated, with 201GW currently operational, representing 56% of capacity and 74% of total generation in 2018/19 (Figure 1). In the last 2-3 years the share of solar and wind generation, although low, has increased rapidly to 22% of capacity and 9% of generation (19% including hydro).

IEEFA references the proposed transformation pathways of other leading countries like California, Germany and Australia to conclude that a combination of technologies will be needed to manage peak demand requirements whilst maintaining grid stability.

India's Central Electricity Authority (CEA) has put a very heavy emphasis on battery energy storage systems (BESS), modelling as much as 34GW/136GWh by 2030. While BESS is increasingly commercially viable, deployment at this speed and scale is unprecedented, bringing associated learning-by-doing costs and integration risks. IEEFA would recommend a lower risk, multi-technology solution, including interstate and international grid connectivity enhancements, pumped hydro storage, gas peaking plants, faster ramping coal-fired power, utility scale and distributed batteries, hybrid projects, demand response management (DRM), greater diversity of generation sources and even solar thermal with storage.

A Time-Of-Day Pricing (TOD) signal, on-demand peaking supply contracts-for-different with contractual longevity or similar mechanism is also needed to incentivise capital markets to open up investments in on-demand peaking capacity.

Figure 1: India's Electricity Capacity and Generation (2018/19)

	---- Capacity ----		-- Generation --		Capacity	Increase
	GW	%	TWh	%	Utilisation	GW yoy
Coal-fired	200.7	56.3%	1,022.3	74.3%	58.7%	3.5
Gas-fired	24.9	7.0%	49.8	3.6%	22.8%	0.0
Diesel-fired	0.6	0.2%	0.1	0.0%	1.9%	-0.2
Large Hydro	45.4	12.7%	134.9	9.8%	34.0%	0.1
Nuclear	6.8	1.9%	37.8	2.7%	63.7%	0.0
Renewables	77.8	21.8%	126.8	9.2%	19.7%	8.6
Bhutan (Import)	n.a	n.a	4.4	0.3%	n.a.	
Total	**356.3**	**100%**	**1,376.1**			**12.1**
Capitve power	51.4					
Total	**407.7**	114.4%				

Source: CEA, IEEFA Estimates

Peaking supply: technology alternatives

For grid balancing of the ambitious target of 523GW of RE by 2030, India's 2019 CEA paper[1] assumes 34GW/136GWh of BESS is needed. India's largest BESS currently operational is the Tata Power Delhi Distribution 10MWh facility commissioned in February 2019, showing there is a huge gap between what is likely to be commercially feasible over the coming decade and the small scale of facilities in operation so far. While the pace of change in BESS is staggering, the learning by doing and supporting scale of manufacturing and technical support infrastructure is simply not yet in place to facilitate this 34GW by 2030 target.

As highlighted by Bloomberg New Energy Finance (BNEF),[2] battery prices have fallen 85% since 2010. IEEFA expects a further halving over the coming decade. The convergence of electrification technologies in the power, transport and potentially industrial sectors are combining to drive innovation and scale ahead of most expectations globally.

As such, batteries, both distributed utility scale on-grid and small scale behind-the-meter, are expected to proliferate, and progressively replace expensive, polluting, noisy, import diesel generators. While a new technology in terms of stationary power and grid applications, the evidence to-date is overwhelmingly positive, and the pace of technology development means batteries are highly likely to pay a key balancing role as VRE penetration increases. The international experience over the last 2-3 years suggests exponential battery uptake for some time yet (refer below), but not sufficient to give high confidence that the CEA's ambitious new 34GW by 2030 target can be achieved at such speed.

The Tata Power July 2019 announcement for a US$600m to a lithium-ion battery plant in the Dholera Special Investment Region in Gujarat is an impressive commitment,[3] and is likely to be only the first of several initiatives to support the GoI "Make in India" strategy in key growth industries of the future to maximise vertical integration benefits.

However, given India's ambitious VRE targets, IEEFA would recommend implementing a time of day pricing to incentivise a multi-technology approach, including:

1. Interstate and international grid connectivity enhancements, noting a broader coverage somewhat smooths VRE supply, assisting on grid integration and balancing, opening up international BIMSTEC[4] grid connectivity options as well;[5]
2. Accelerating deployment and retrofits of pumped hydro storage ((PHS) both on existing hydro-electricity dams and closed loop off-river systems); [6]
3. Faster ramping coal-fired power plants;
4. Co-located wind-solar-battery hybrid projects;[7]
5. Gas peaking plants, given India has 25GW of stranded gas plants already built;
6. Utility scale and distributed batteries, demand response management (DRM)
7. Solar thermal with storage in the longer term as this technology cost declines.

[1] India's Central Electricity Authority (CEA), draft report on optimal generation capacity mix for 2029-30
[2] BNEF New Energy Outlook 2019
[3] Economic Times, Tata Group to set up Rs 4,000cr lithium-ion battery plant, 12 July 2019
[4] BIMSTEC: The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
[5] IEEFA India: Grid investment needs to match enormous growth in renewable energy investment, 21 Jan 2019
[6] IEEFA, Pumped Hydro Storage in India, March 2019
[7] Utility Drive, Solar + wind + storage developers 'gearing up' as hybrid projects edge to market, 9 July 2019

Given India has already made the investment in 201GW of coal-fired power plants operating at now sub-optimal plant load factors (PLFs) of ~60%, and with a further 85GW of new coal plant proposals in the pipeline, IEEFA also sees merit in expediting the introduction of faster ramping coal-fired power technologies as a balance to least cost but variable RE. AGL Energy has pioneered this at limited capital cost by dialling down expected average utilisation rates and introducing new operational procedures (including better communication with the grid operator) at its approaching end of life 2.0GW coal plant at Liddell, NSW Australia.[8]

A greater diversity of generation sources will also help manage VRE. The government of India (GoI) has looked to accelerate 10GW of long stalled hydro-electricity plans,[9] and the proposed gap-funding of US$900m for the first 1GW of offshore wind proposed for Gujarat[10] is likewise a bold move to progressively open up this potentially huge new, sustainable, zero emissions, zero pollution domestic energy resource for India over the coming decade.[11] IEEFA commends the GoI for hastening slowly. This technology will likely see costs halve over by 2025.

International experience shows that a more diverse, predominantly domestic sourced generation fleet will provide getter energy security and improve flexibility to manage time-of-day and seasonal supply and demand variability better.

International electricity sector case studies

IEEFA draws upon international case studies across other leading markets like California,[12] Germany and Australia to highlight the various new technologies and adaptive market structures designed to manage the increasing share of VRE in their electricity mix.

California: 60% renewables by 2030

California, the fifth-largest economy in the world, has become a global leader in renewable energy. With renewables supporting 34% of the state's total energy needs in 2018 (two years ahead of the 33% by 2020 mandate[13]), the business community is calling for an even greater commitment to clean energy as an essential benchmark for the economic success of the state.

In August 2018, California enacted Senate Bill 100, setting a target of 100% carbon-free electricity by 2045. Angelina Galiteva, vice chair of the California Independent System Operator, sees the task of reaching the 100% RE target as entirely achievable.[14]

The bill mandates a move to 60% renewables by 2030 and requires all new houses to have solar by 2020, and commercial buildings by 2025. We note distributed rooftop solar in California is also playing an increasingly important role in mitigating midday demand peaks.

In 2018, California's Pacific Gas and Electric Company (PG&E) launched construction of the world's two largest utility-scale battery projects to-date. They include a 300MW/1,200MWh

[8] AGL Energy, NSW Generation Plan, 18 July 2018
[9] Business Standard, Centre to move policy to promote hydro power with units of 10 GW capacity, 5 December 2018
[10] Recharge News, India lines up $900m 'gap funding' for first offshore wind farm, 28 June 2019
[11] Platts, Europe's offshore wind industry expanding into Asia: event, 25 June 2019
[12] IEEFA update: How California became a global leader in renewable energy, 11 April 2019
[13] California Energy Commission, California On Track With 2020 Renewable Energy Goal, 22 February 2019
[14] Renew Economy, Energy Insiders Podcast: 100 per cent renewables – Is California dreaming?, 20 February 2019

project by Vistra Energy and a 182.5MW/730MWh project (both to be supplied by Tesla),[15] nearly three times the size of the largest lithium battery-storage facility currently in operation in South Australia (Tesla's Hornsdale Power Reserve at 100MW/129MWh).

June 2019 saw the Los Angeles Department of Water and Power (LADWP) sign a power purchase agreement (PPA) with 8minute Energy for the proposed 400MW Eland solar project at US1.997c/kWh (zero escalator for 25 years) and 200MW/800MWh of energy storage at an additional US1.3¢/kWh.[16] This landmark transaction saw a 15% reduction on the previous record low set in June 2018 at US2.3c/kWh (again, with a zero escalator).

IEEFA notes the inevitable stranded asset nature of India's 25GW of baseload gas-fired power plants. Already in the world's lowest price gas market, VRE is combining with batteries to challenge baseload gas plant viability. June 2019 saw General Electric close its Californian gas-fired power plant only commissioned a decade earlier, one-third of the way through its engineering life,[17] taking an estimated US$700m writedown in the process. Given this, the ability of expensive imported liquid natural gas (LNG) to play anything other than a back-up peaking power role in India is rapidly diminishing into the non-economic realms of now obsolete technology ideas that sounded logical at the start of this decade.

Germany: Renewables reached a record 77% penetration day in May 2019

Year-to-date to July 2019, renewable energy has contributed a record 47.2% of net electricity generation across Germany (with VRE at 34.6% plus hydro of 4.1% and biomass at 8.6%). A new monthly record high of 54.6% of total generation was set in the month of March 2019[18] renewable energy contributed a record 77% of electricity demand in Germany for a day in May 2019 (and over 100% for the five hours of 11am to 4pm).

Germany is consistently setting new records. These 2019 highlights represent a significant increase vs the previous annual record set in 2018 at 40.6%. Germany is well on track to achieve its target of generating 65% of its electricity from renewable sources by 2030,[19] and on the right trajectory for the target of 100% by 2050 (that was set back in 2010).[20]

International grid connectivity is a key balancing facilitator of Germany's rapidly rising VRE share. For the 2018 year, Germany had a net export surplus of 49TWh (80TWh of exports net of 31TWh of imports) of electricity bringing in €1.8bn. France, the Netherlands, Sweden and the Czech Republic are the four primary markets.

Germany is also one of the leading battery storage markets globally. By the end of 2018, some 120,000 households and commercial operations had already invested in solar integrated battery systems, with this expected to accelerate as retail grid parity of solar plus storage was achieved by the end of 2018.[21] Cumulative installs of large scale batteries across Germany more than doubled in 2019 to reach 371MW (adding 199MW in 2018). Beyond just cost-reductions, technology breakthroughs continue, with the expectation that the energy density of battery packs should increase 50% between 2016-2025.

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[15] GTM, PG&E Proposes World's Biggest Batteries to Replace South Bay Gas Plants, 2 July 2018
[16] PV Magazine, Los Angeles seeks record setting solar power price under 2¢/kWh, 28 June 2019
[17] Reuters, General Electric to scrap California power plant 20 years early, 22 June 2019
[18] Fraunhofer ISE
[19] Reuters, Germany needs to ease rules to hit 2030 renewables target, 19 June 2019
[20] The Guardian, Germany targets switch to 100% renewables for its electricity by 2050, 8 July 2010
[21] Germany Trade & Investment, The Energy Storage Market in Germany, 2019

Germany is also exploring hydrogen and renewable energy-to-gas technology developments for longer term storage and demand-supply management. The German Government tracks corporate plans for over €2bn of hydrogen mobility investment by 2024.

Germany is also undertaking the world's first commercial scale deployment of demand response management (DRM) technologies in the aluminium smelting industry (which accounts for 5% of world electricity demand). A smelter in Essen has been retrofitted to allow energy demand to be increased or decreased by up to 25% for up to 48 hours at a time, the equivalent of a virtual battery of 2,000MWh.[22] Early days, but with increased VRE penetration to over 65% by 2030, DRM is going to need to play a critical demand side role.

Australia

Across the Australian national electricity market (NEM) in the twelve months to July 2019, renewable energy contributed 23.1% of total generation (including rooftop solar at 4.5% and hydro-electricity at 7.3%).

As the leading state in Australia, South Australia, VRE generated 48.9% of total generation in this same 12 month period.[23] And South Australia has a 10GW pipeline of new renewable energy projects underway, plus almost 4GW associated storage projects, putting it well on track for a net 100% renewables by 2030 target.[24]

The Australian Energy Market Operator (AEMO) is pro-actively managing the development of long term thinking with its electricity Integrated System Plan (ISP)[25] noting the end-of-life closure of most Australian coal-fired power plants over the coming two decades and hence the inevitable increase in least cost VRE.

Despite the low population density of Australia, inter-state grid connectivity plays an important role in balancing the grid. The ISP includes a more than doubling of grid capacity over the coming decade, to facilitate a trebling of VRE and to access significant new PHS capacity for balancing, particularly for medium and long term seasonal requirements. New links between South Australia-New South Wales (NSW), Victoria-NSW, Queensland-NSW and a second subsea link for Tasmania-Victoria have been put forward for accelerated evaluation.

Australia is evaluating a massive expansion in PHS. The largest of these are the US$4bn Snowy 2.0 proposal of 2,000MW/350GWh[26] and the Hydro Tasmania Battery of the Nation proposal of up to 2,500MW/30GWh.[27] In addition, there are numerous distributed PHS projects being developed by private industry. Most advanced of these is the Genex Power 250MW off-river PHS supported by 250MW of solar at the now closed Kidston gold mine in Queensland. Funding is now in place following completion of a A$610m (US$425m) debt

[22] Light Metal Age, Trimet Starts Trial Operation of its "Virtual Battery", 10 June 2019
[23] Opennem.org.au
[24] Renew Economy, South Australia has 10GW wind and solar in pipeline as it heads to 100% renewables, 23 July 2019
[25] Australian Energy Market Operator, Integrated System Plan, 2018
[26] Snowy Hydro, About Snowy 2.0
[27] ARENA, Battery of the Nation – Tasmanian pumped hydro in Australia's future electricity market, June 2018

facility in July 2019.[28] AEMO models 4.1GW of additional PHS to be operational across Australia by 2030, and 14GW of total storage required by 2040.[29]

Australia leads the world in distributed residential rooftop solar systems, and Australia is on track for a record 2GW of rooftop systems to be installed in 2019 alone, taking the cumulative total to 10GW. In contrast to the heavy commercial and industrial (C&I) emphasis in India, Australia is still overwhelmingly focussed on residential systems (at 10GW), reflecting a mirror reversal of the tariff pricing structure in India (Australian residential tariffs (at US$200/MWh) are double that paid by industry). From a small base, C&I installs almost doubled in 2018 to reach a cumulative 270MW.[30] Like Germany, Australia is rapidly enhancing the US$10bn investment to-date in rooftop solar with time-of-use pricing, supported by smart meters and behind-the-meter battery storage. In September 2018 Victoria launched a program to incentivise 10,000 residential storage systems,[31] building on a 50,000 solar and storage systems program in South Australia.[32]

In December 2017 South Australia commissioned Neoen/Tesla's Hornsdale Power Reserve at 100MW/129MWh, the largest BESS globally at the time. An initial system evaluation study concluded the project was very successful in delivering on the System Integrity Protection Scheme and in contributing to the Frequency Control Ancillary Services (FCAS).[33] The results from the first year highlighted the excellent savings in terms of the grid services costs paid by the South Australian consumer and also the above expectations financial results for the BESS owner, Neoen (generating a gross return on investment of 20-30%).[34]

Australia has subsequently commissioned grid scale BESS in Victoria at Ballarat (30MW/30MWh by Fluence) and at Ganawarra (25MW/50MWh).[35] Industry is now building BESS integrated into a number of new VRE developments. July 2019 saw the latest proposal, a 200MW solar project supported by a 100MW/300MWh battery in south Australia.[36]

Building upon the proposed NEM settlement period shortening from 30 to 5 minute intervals from 2022,[37] July 2019 saw the Australian Energy Market Commission release a draft proposal to allow for a much wider participation of demand response management (DRM) in the wholesale electricity market from 2022.[38] The new system allows C&I electricity customers that are willing to reduce their power use selling their demand reduction into the grid through a new third-party body that will bid it into the market as wholesale prices peak with grid priority over existing generators. In effect, the "negawatts" available from energy users – who are saving energy – would be competing against the megawatts able to be supplied by generators.[39] Given Australia operates a wholesale pricing market that can range from negative A$1000/MWh floor to a peak of A$14,000/MWh, the

[28] North Australia Infrastructure Facility (NAIF), NAIF FACILITY BOARD APPROVES INVESTMENT DECISION FOR UP TO $610M OF CONCESSIONAL DEBT FUNDING FOR THE KIDSTON PHS PROJECT, 11 July 2019
[29] AEMO, Building power system resilience with pumped hydro energy storage, July 2019
[30] The Australia Institute, National Energy Emissions Audit, May 2019
[31] Victorian Government, Cheaper Electricity With Solar Batteries For 10,000 Homes, 11 September 2018
[32] South Australian Government, Solar photovoltaic systems and battery storage, 2018
[33] AEMO, Initial Operation of the Hornsdale Power Reserve BESS, April 2018
[34] Renew Economy, Deep dive into first year of Tesla big battery at Hornsdale, 7 December 2018
[35] Victorian Government, Batteries and Energy Storage, 2018
[36] Renew Economy, Alinta signs up for huge solar and battery project in South Australia, 18 July 2019
[37] Renew Economy, Garnaut slams AEMC move to delay 5-minute settlement switch, 5 September 2017
[38] Renew Economy, New demand response rule to erode market power of generator cartel, 18 July 2019
[39] Australian Financial Review, How 'negawatts' could help businesses cut their power bills, 18 July 2019

introduction of DRM technologies is likely to play a key role in critical peak power management (especially for the most difficult 10-20 hours annually).[40]

A price signal to incentivise peaking supply

Building on the reverse auction success in VRE in India, IEEFA notes the need for creating an effective market signal via a Time-Of-Day (TOD) pricing structure to incentivise firming of flexible sources of generation[41] to provide bankable price signals for on-demand, flexible peaking power supply so as to balance peak power supply and peak demand.

At this juncture, with India procuring ever-more very low cost but variable RE, electricity production tariff (pricing) structures need to be better aligned to incentivise faster ramping and flexible power generation. This is important in delivering at least cost on intermediate and peaking power needs, while also providing grid stability with the increasing share of VRE. Suitable supply side pricing structures need to be evolved to better incentivise flexible generation solutions. Further, as a demand side response, time of day smart metering and pricing structures for consumers also needs to be evolved for peak load management.

Further, additional variables such as energy efficiency technologies, seasonal changes in temperature and the growing use of air conditioners infer that the shape/width/magnitude of India's load curve will likely undergo change into the future.

For instance, as per the International Energy Agency's (IEA) World Energy Outlook 2018, the number of households in India owning an air conditioner (AC) has increased by 50% in the last five years. By 2040, two-thirds of households in India are projected to own an AC unit, a staggering 15-fold increase from today. While the share of cooling in electricity system peak loads is ~10% in 2016, this share will likely increase to over 40% by 2040 under the IEA's New Policy Scenario, altering the shape/width/magnitude of load curve substantially.

The current pricing system in India is a largely flat tariff providing little incentive for network or consumer efficiency through load smoothing. If India took into account the different categories and types of energy demand, and the variations in supply and costs of service, it would likely bring efficiency gains from differential pricing at peak periods.

Better consumer price signals during peak periods will incentivise the use of energy during periods of low demand and reduce the burden on the grid, while a time-of-day (ToD) pricing signal would better incentivise variable generation 'kicking in' at times of peak demand.

We note the positive progress at India's Central Electricity Regulatory Commission (CERC) in working towards reforming the energy markets with the proposal to change the market design to shift towards a more centralised national production and economic dispatch of electricity in a day ahead market.[42] A real-time energy market with gate closure (one hour before the time of operation) to be introduced and the existing ancillary services framework to be further strengthened and graduated to a market based mechanism.[43] Furthermore, once the hourly market matures, India could think of reducing gate closure time to 15 minutes. This could generate significant cost savings for the national system as a whole and

[40] AEMO & Energy Networks Australia, Open Energy Networks, Required Capabilities, July 2019
[41] IEEFA India, Flexing India's Energy System: Making the Case for the Right Price Signals Through Time-Of-Day Pricing, 8 January 2019
[42] CERC, Discussion Paper on Market Based Economic Dispatch of Electricity: Re-designing of Day-ahead Market (DAM) in India, December 2018
[43] CERC, Discussion Paper On Re-designing Ancillary Services Mechanism in India, September 2018

further TOD pricing will provide the right price signals for the creation of balancing capacity to provide grid stability, subject also to sufficient interstate grid transmission capacity be established.

Capital Requirements

IEEFA has analysed the likely requirements for and sources of capital to fund such an ambitious 2030 vision for India. The expansion to 523GW of renewable energy including hydro-electricity means the installation of 400GW of new zero-emissions capacity. Over US$700 billion of new investment will need to deliver India's total new generating capacity as well as grid transmission and distribution capacity across India by 2030. This will require a dramatic upscaling of domestic and international debt and equity capacity.

While India currently has another 85GW of coal-fired power plants under construction or at various stages of planning,[44] current commissioning rates of coal have dropped by 80% from the 20GW net annual additions evident in the four years to 2015/16 to just 3GW in 2018/19. IEEFA emphasises capacity studies need to look at both new commissionings and end-of-life plant closures, given the CEA estimates 46GW of coal plant closures by 2026/27 (4-5GW pa).

As per Figure 2, the June 2019 quarter saw just 45MW of new thermal power plant additions (well below the CEA expectations of 1.2GW). VRE installs of 2.82GW in the June 2019 quarter are running at forty times this rate, albeit IEEFA notes this install rate needs to treble to put India on track for its 523GW by 2030 target.

Figure 2: India's Electricity Capacity and Generation (June 2019)

Source	Mar 2019	Jun 2019	Change (GW)
Renewables	77.6	80.5	**2.82**
Large Hydro	45.4	45.4	**0.00**
Nuclear	6.8	6.8	**0.00**
Thermal	226.3	226.3	**0.05**
Total Ongrid Capacity	**356.1**	**359.0**	**2.87**

Source: CEA, MNRE, IEEFA Estimates

Conclusion

India's electricity system transformation and concurrent move to accelerate and deepen the ambitious 100% electronification target is exceptionally ambitious. These plans for 523GW of renewable energy by 2030 and concurrent targets for 34GW of battery storage are ambitious and world leading. Pushed by the need to enhance energy security by reducing over-reliance on expensive imported fossil fuels, India is set to take on a global leadership role in building a low emissions, least cost electricity system of the future, leapfrogging now outdated technologies. But with this comes investment and implementation risks and the need to move rapidly to ensure market and regulatory structures keep pace with this rapid transformation.

[44] Global Energy Monitor, July 2019