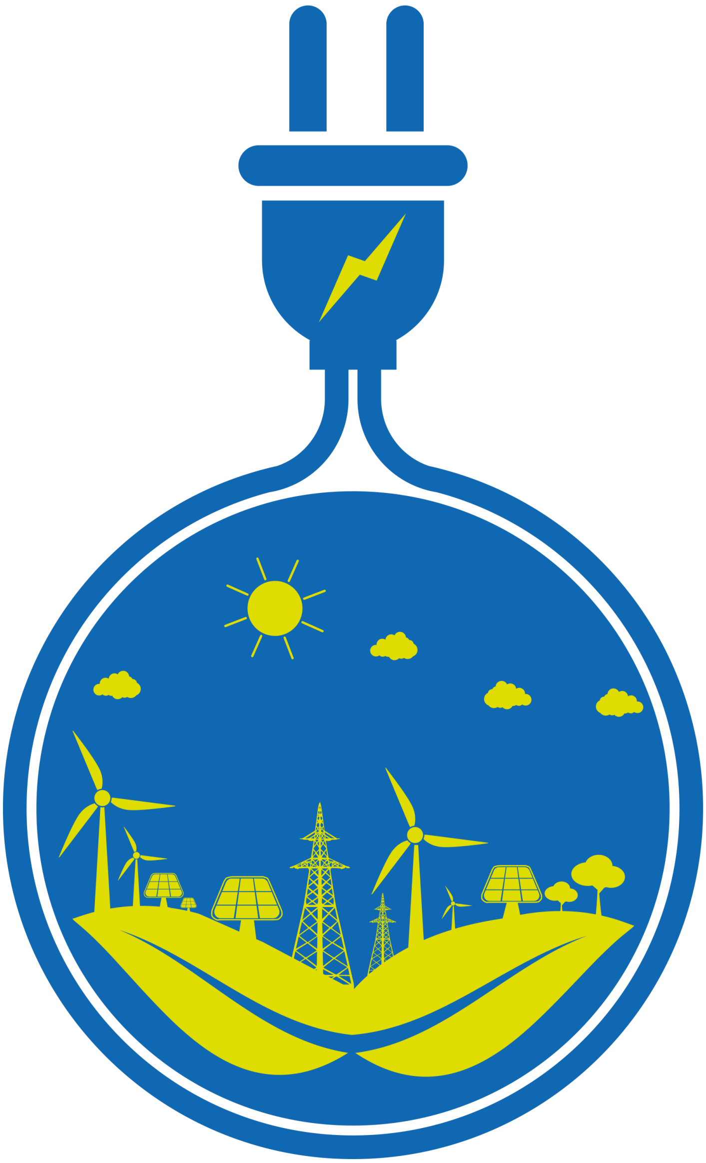
TATA CLEANTECH CAPITAL LIMITED

RENEWABLE INTEGRATION AND CURTAILMENT:

CAUSES, SOLUTIONS AND IMPACT ON PROJECT BANKABILITY



NOVEMBER 2020

~ 7.7 GW

Renewable capacity financed

>200

Projects financed

12.5 million tons

Annual carbon emission averted

About TCCL

TATA Cleantech Capital Ltd (TCCL) is a joint venture between TATA Capital Limited and International Finance Corporation, Washington D.C. (World Bank Group). TCCL is registered with the Reserve Bank of India ("RBI") as a Systemically Important Non-Deposit Accepting Non-Banking Financial Company and commenced its operations in 2013.

As India's only private sector financial institution focused solely on the green finance space, it offers end-to-end business solutions in the clean technology space. TCCL is engaged in the business of offering finance and advisory services across renewable energy, energy efficiency, waste management, power transmission, water, energy efficiency and electric mobility.

TCCL is the only Indian company and the first Private Sector Climate Finance Institution in the Green Bank Network thus far. It is also the first private sector company globally to partner with the Green Climate Fund ('GCF') to develop the solar rooftop market through a USD 100 million credit line. TCCL has played an instrumental role in expanding the pool of cleantech investors in India, by partnering with various classes of domestic and international investors that includes development finance institutions, multilateral banks, pension funds and wealth funds.

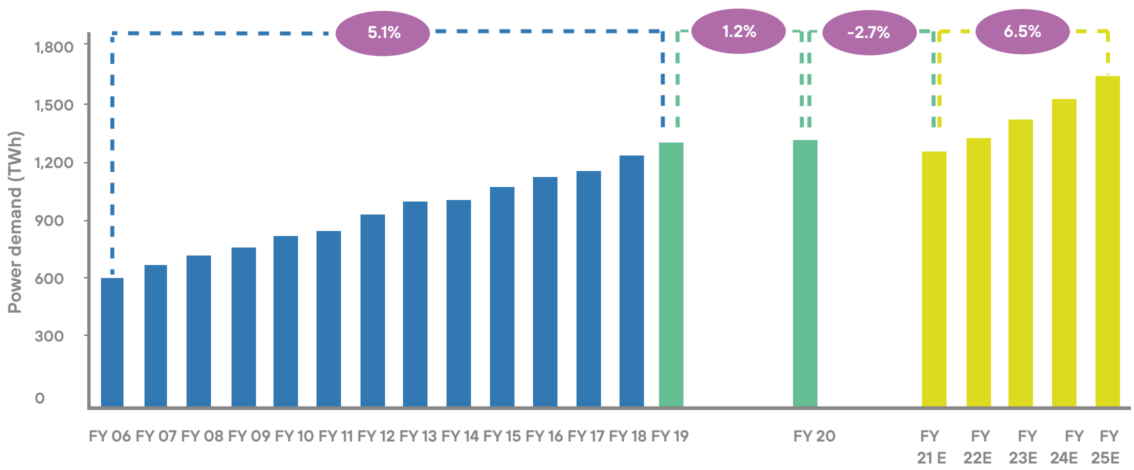
TCCL has delivered significantly higher ROE than industry while maintaining the best in class asset portfolio and is rated AAA by CRISIL.

For more information, please refer **www.tatacapital.com/tccl**

1. Sluggish growth in power demand

Electricity demand in India grew at a CAGR of 5.1% over the last decade from FY[1] 2011 to FY 2019. However, this fell to a mere 1.2% in FY 2020. India was already facing an economic slowdown, with industrial output declining to an 8-year low during the year. And given this sector is the largest consumer of electricity in India, the sectoral slowdown resultantly impacted the growth in power demand across the country in FY 2020.

Figure 1 : Indian power demand trend and projection



Source: TCCL Research and Central Electricity Authority (CEA)

The power demand fell sharply after the nationwide lock-down was imposed with the onset of COVID-19 induced pandemic. The month of April registered a reduction in demand of around 23% on a year-on-year basis. But with the lockdown restrictions easing from the latter part of 2020, power consumption has started to pick up. The shortfall vanished by September and October, in fact, witnessed a double-digit growth with a spurt attributed to consumption growth during the festive seasons. However, we need to wait and watch if this revival in power demand continues or whether a second wave of COVID-19 could slow down demand once again.

Even before COVID-19, India's power demand lagged expectations due to the economic slowdown.

At the same time, this uptake may still not suffice to compensate for the drop witnessed in the aftermath of the COVID-19[2]-related lockdown. Therefore, the outlook for the overall year still remains weak, with electricity demand expected to show a year-on-year decline of 2.7% during FY 2021. Nevertheless, some improvement is expected from FY 2022.

In the long-term, electricity demand is expected to grow steadily, albeit slowly, until FY 2025. Reforms that have been introduced by the government are expected to attract new manufacturing facilities over the coming years, which augurs well for the long-term growth prospects for power demand in India.

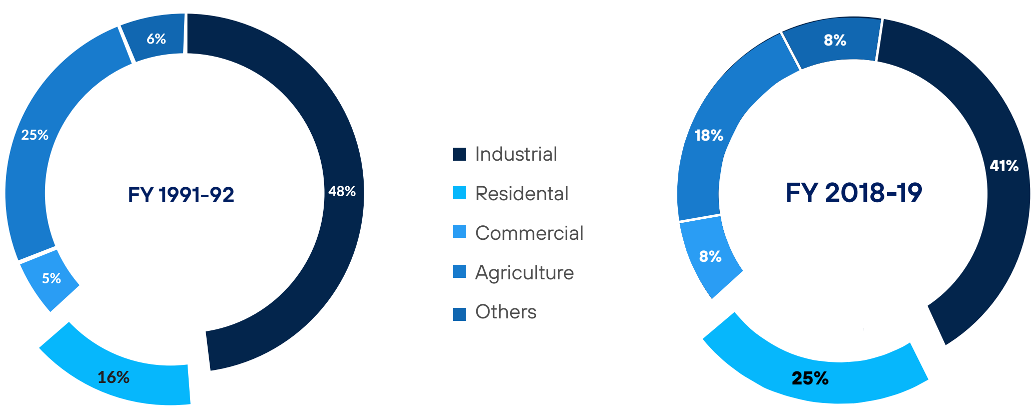
1. Financial year in India runs from April of the previous year to March of that year
2. The Energy Research Institute, "Bending the Curve: 2025 Forecasts for Electricity Demand by Sector and State in the Light of the COVID-19 Epidemic"

2. Power demand curve and renewables' curtailment

Share of industrial power usage dipped while residential rose, creating a twin peak demand curve in India.

Looking back at the era of globalization that commenced in India after the 1991 economic reforms, it is worth noting that industrial activity did not show an immediate pick-up contrary to expectations. This was primarily owing to the relatively slow growth in the manufacturing segment in the following years, which was hindered by a number of several structural and external factors at that time. Resultantly, the share of industrial consumption in the country's electricity demand mix fell from 48% in FY 1992 to 41% in FY 2019.

Figure 2: Sector-wise power consumption in India



Source: Ministry of Power

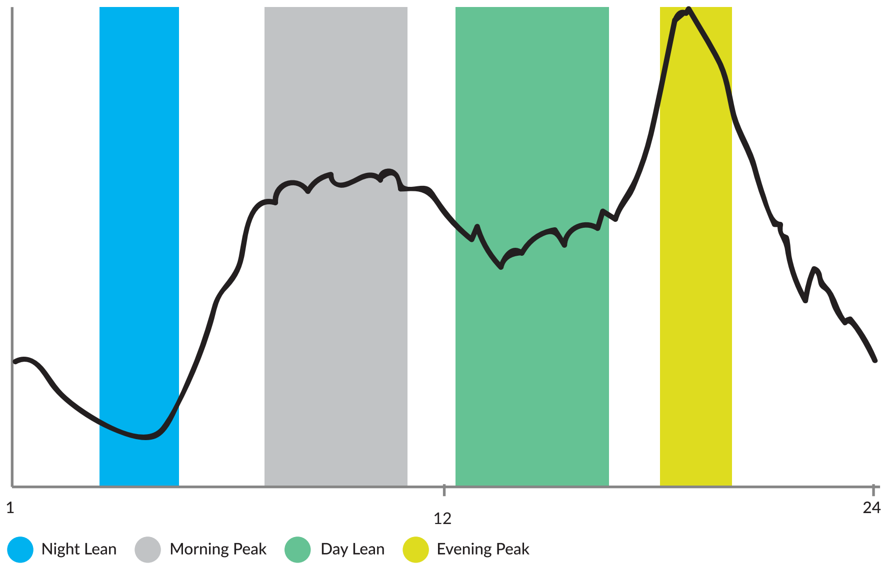
During the same period, the share of power consumption clocked by the residential segment spiked from 16% to 25%. This disproportionate growth was predominantly driven by increased electrification, enhanced lifestyles and aspirations, and an increasing dependence on air conditioners. In 2016, space cooling was estimated to account for around 8% of the total load, and around 10% of the peak load.[3]

With an increased share of residential demand, India's daily power demand curve observes twin peaks – one in the morning (8:00 to 10:30 AM) and the other in the evening (6:00 to 8:00 PM). Between the two, the evening peak is significantly more pronounced. This is because the evening period coincides with the time most people typically return home from their workplaces. At that time, the usage of air conditioning picks up sharply across the major cities.

Electricity generation from solar energy can help meet, to some extent, the demand during the morning peak. However, the challenge is that the inherent intermittent nature of both solar and wind sources implies that the bulk of the generation coincides with either the off-peak or normal day lean periods. The penetration of infirm solar and wind sources accentuates the requirements from other sources to meet the peak demand.

3. International Energy Agency (IEA), "The Future of Cooling Opportunities for Energy Efficient Air Conditioning"

Figure 3: Typical load profile of India

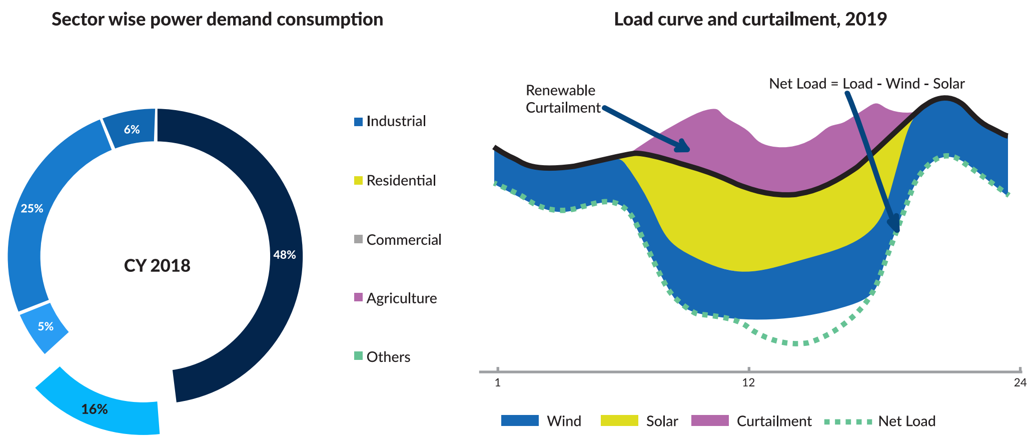


Source: Power System Operation Corporation (POSOCO)

With increasing renewable penetration India could also observe Duck-Curve similar to California.

A parallel for this scenario of peak demand management can be drawn from the state of California in the United States due to similarities in the demand breakup and the load curve. With increased penetration of solar power, California started witnessing the formation of famous "Duck-Curve".[4] That increased the stress on its conventional power sources to meet the accentuated peak requirement. To manage the grid, the operators in California had to resort to the curtailment of renewable power.

Figure 4: Demand break up and load profile in California



Source: California Independent System Operator (CAISO), National Renewable Energy Laboratory (NREL) and GE

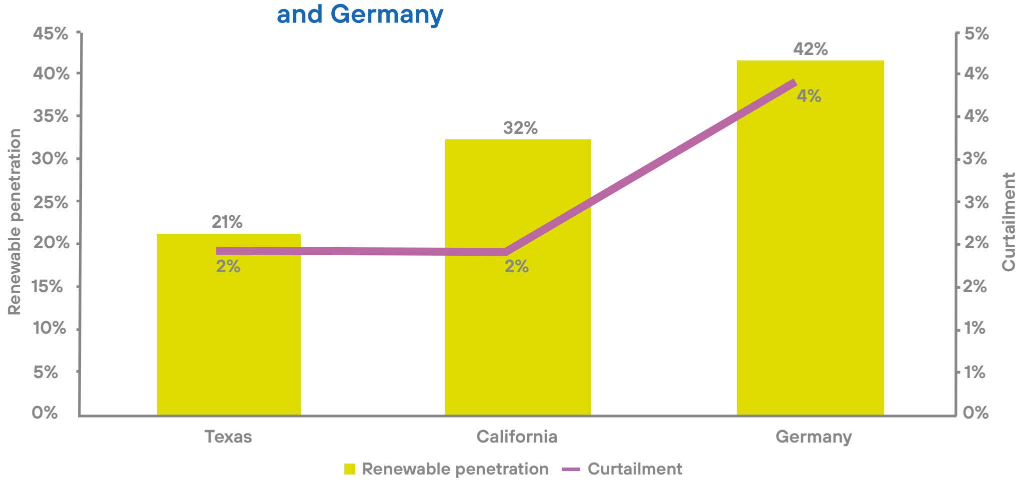
4. California experiences a daily spike in power demand in the evening, as generation from solar tapers off and residential demand increases. As a result, the evening net load ramp becomes steeper each year and start resembling the shape of a duck.

Grid management challenges lead to curtailment of renewable power, seen commonly across leading markets.

The challenges to grid management posed by the increasing penetration of renewable sources of energy vary across geographies. This is because a lot depends on the load profile and the renewable generation mix.

But the prevalence of such challenges creates a situation at times to curtail renewable power to maintain grid stability. Most countries who lead in renewables have also had to resort to such curtailment to maintain their grid stability.

Figure 5: Renewable penetration and curtailment in the USA and Germany



Source: CAISO, Electric Reliability Council of Texas (ERCOT), NREL, "Wind and Solar Energy Curtailment: Experience and Practices in the United States" and Tennet

Note: Data for Texas and Germany is for 2019 and data for California is for 2018

3. Issues related to grid management

Traditionally, electricity grid managers use a mix of conventional energy sources to match the demand profiles. Based on the demand schedule, the supply from the power plants are scheduled accordingly. The ability of the power plant to change the load is defined as its "ramp rate", i.e. the rate at which a generating unit can either ramp up or down the output. Further, the power plants are required to run at a minimum load to remain in an active condition before they can vary their outputs.

Table 1: Minimum load and ramp rates for different power sources

Technology / fuel	India's installed capacity, GW	Minimum load (of working capacity)	Ramp rate (ease of balancing)
Coal	200	25-60%	1-4% / minute
Gas (combined cycle)	25	40-50%	2-4% / minute
Gas (open cycle)		40-50%	8-12% / minute
Nuclear	7	55-60%	1-5% / minute
Pumped hydro storage	2	33%	50% / minute

Source: TCCL Research, POSOCO, CEA and International Renewable Energy Agency (IRENA)

Ideally, power plants that run either on coal or nuclear fuel are unsuitable for the purpose of grid balancing or meeting sudden changes in the demand pattern. These plants are typically used to meet the base load. Gas and hydro power plants are the best options available globally amongst conventional energy sources when it comes to grid balancing. This is owing to a relatively faster ramp rate and a comparatively lower requirement for the minimum load.

Grid managers also maintain Spinning Reserves. This refers to an extra generating capacity that is available by increasing the power output of the plants that are already connected to the grid, thus enabling grid balancing. The USA and Germany predominantly use gas plants while China uses hydro plants to manage the peak load.

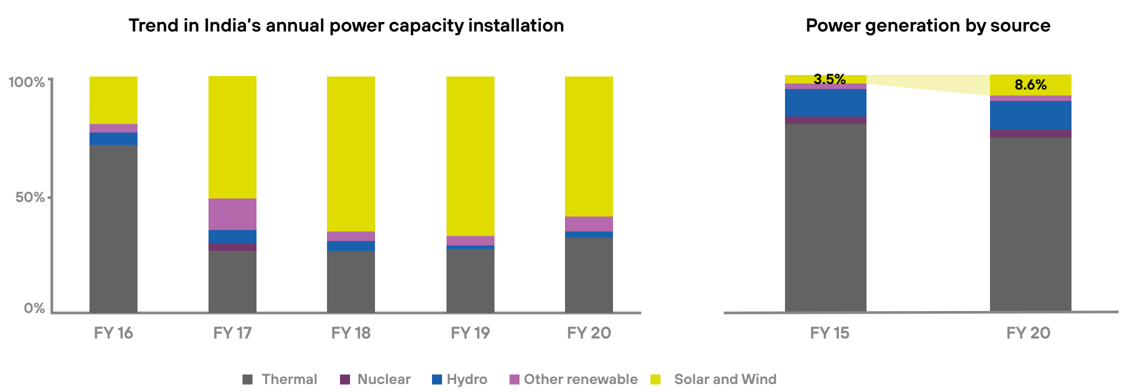
Lack of flexible power sources – gas and hydro – put further stress on coal plants to meet peak requirements.

However, due to limited availability of gas and a lower capacity addition through hydro sources, India has had to rely excessively on its coal power plants for its spinning reserve requirements. Technical constraints related to the operations of coal plants also make it difficult for grid managers in India to absorb a high quantum of infirm solar and wind plants. The problem exacerbates further due to the lack of advancements in the forecasting system. This puts an additional load on the coal plants to meet any unforeseen drop in the generation from solar or wind sources.

4. Increasing penetration of infirm solar and wind plants in India

India's electricity generation mix has seen a transition over the last decade with the mainstreaming of renewable energy projects. Solar and wind projects accounted for over 60% of the capacity addition in each of the last four fiscal years. As a result, the share of solar and wind power, technically referred to as penetration, in the Indian grid system has more than doubled from 3.5% in FY 2015 to 8.6% in FY 2020. On the other hand, electricity generation from thermal energy remained stagnant during the same period. At the same time, the rising penetration of infirm renewable sources and the falling Plant Load Factor (PLF) for the coal power plants is placing increased pressure on the grid managers.

Figure 6: Increasing penetration of solar and wind



Source: CEA

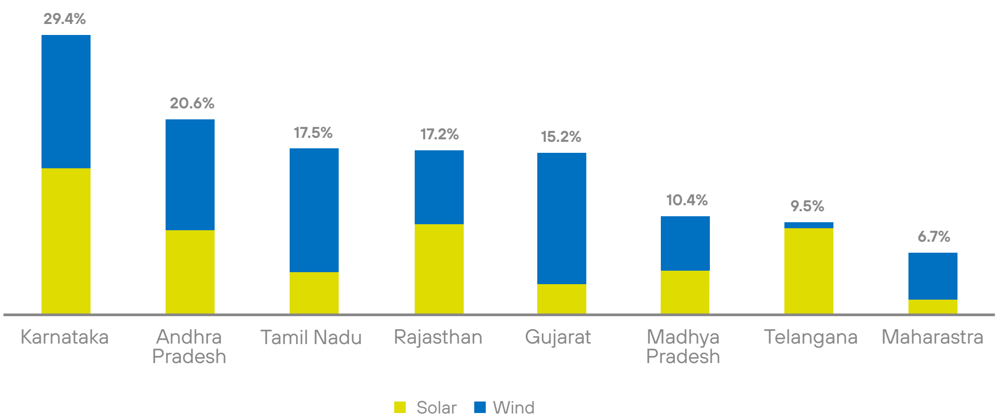
Significantly higher penetration at the state-level

The southern and the western states in India enjoy a higher capacity in solar energy owing to comparatively better irradiation, favourable policies and land availability. Coincidentally, the southern and western states possess better wind resources as well, although the resource availability of wind is more skewed than solar. Nevertheless, the bulk of the wind energy capacities are also installed in the southern and western regions of the country.

Although, solar and wind power generation was 8.6% in India, as of FY 2020, but it represents over 15% share in key states.

With both solar and wind projects coming up largely in the same states, the penetration levels have increased disproportionately in favour of these states. In essence, although the contribution of solar and wind power generation at the national level was 8.6% as of FY 2020, the number is significantly higher in these states. For instance, it is 29.4% in Karnataka and 20.6% in Andhra Pradesh. Even states like Tamil Nadu, Gujarat and Rajasthan have clocked shares of 15% plus from solar and wind projects within their total power consumption. The higher penetration in the leading states has placed pressure on their local electricity substations to ensure 100% offtake occurs throughout the year. The situation becomes more severe during the monsoon season when the generation from wind sources spikes up significantly.

Figure 7: Penetration of solar and wind energy in the leading states: FY 2020



Source: TCCL Research, CEA and POSOCO

Note:

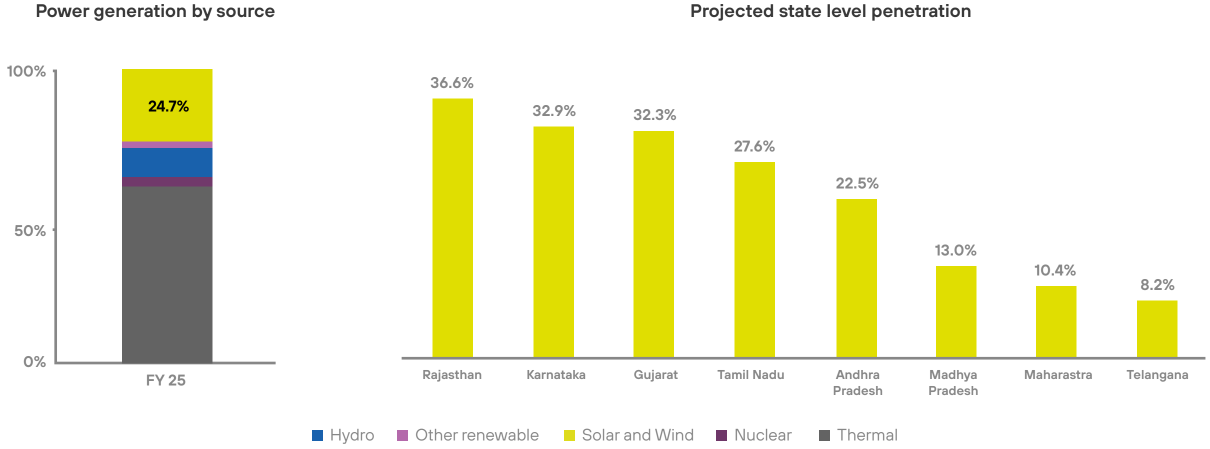
1. The analysis does not consider the rooftop installation

2. The power plants connected to the Inter-State Transmission Systems (ISTS) grid are also considered to contribute to the host states' requirement

3. The penetration of renewable power is calculated by taking the ratio of renewable generation and the host state's consumption

Further, the solar and wind sources are expected to account for 24.7% of the total power consumption in India by FY 2025. A bulk of this new power capacity is expected to come up in Rajasthan, Gujarat and Tamil Nadu, further increasing the penetration of infirm sources in these states going forward.

Figure 8: Projected penetration of renewable energy by FY 2025



Source: TCCL Research

5. Impact of curtailment on project bankability

While the conventional power plants also face some curtailment, they are protected by the "Two-Part" tariff structure. This is a separate tariff for the fixed and variable components. Under this, while offtakers must compulsorily pay for the fixed charges, they can pay for the variable charges only if the power is procured.

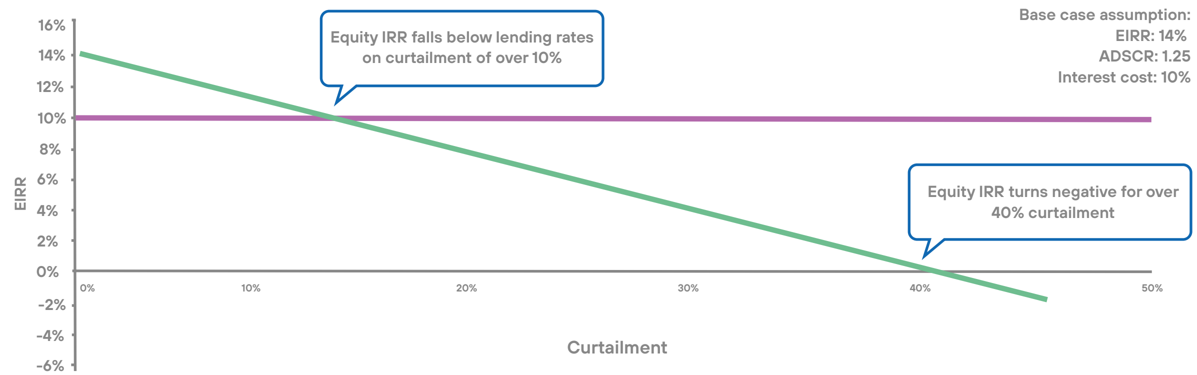
This two-part tariff structure is not applicable for the solar and wind plants because their operating cost is virtually nil, and the project's bankability revolves around 100% offtake. However, to safeguard the interests of the power generators, the government provides a "Must Run" status to the solar and wind projects. However, there remain loopholes that are being used to curtail solar and wind power by a few states in the purview of grid stability. The fact remains that a unit of power not generated from both solar and wind plants is effectively a unit lost forever.

Aggressive bidding seen in recent years in both solar and wind projects in India is based on the inherent assumption of 100% offtake for a period of 25 years. That assumption may be reasonable at the time of bidding. But it is highly likely that the project could face curtailment a few years down the line.

EIRR of project could fall below zero if curtailment exceeds 40%.

To showcase the impact of curtailment on the Equity IRR (EIRR), TCCL analysed a sample project with a comfortable projected EIRR of 14% at the time of bidding. Any curtailment of over 10% could result in the EIRR falling below the prevailing lending rates. Further, if the curtailment is over 40%, the EIRR would move into negative territory.

Figure 9: Impact on the EIRR due to curtailment

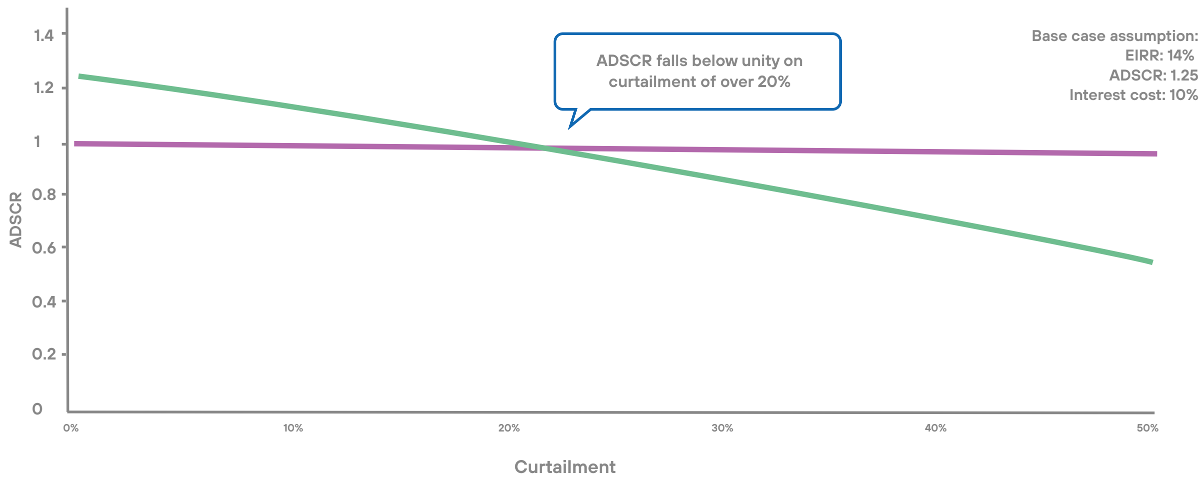


Source: TCCL Research

ADSCR would fall below unity if curtailment exceeds 20%, turning project into an NPA.

Further, the same project projected an Average Debt Service Coverage Ratio (ADSCR) of 1.25 at the time of bidding. This would fall below unity on the curtailment of 20% power, thus turning into a Non-Performing Asset (NPA).

Figure 10: Impact on ADSCR due to curtailment



Source: TCCL Research

6. Measuring curtailment

Any mismatch in the supply to and the demand from the grid results in frequency deviation. The permissible frequency band for Indian grids is 49.95 – 50.05 Hertz. A sudden mismatch between the supply and demand makes it difficult for the grid managers to maintain the frequency band within these limits. The scale-up in the volume and expanding geographical dispersion of infirm solar and wind power also increases temporal fluctuations. That can force grid managers to resort to curtailment.

In technical terms, curtailment is defined as the occurrence of either the following:

- **Grid unavailability:** Grid connected solar and wind plants cannot generate power if the grid is unavailable. The silver lining is the instances of grid unavailability have reduced significantly in India over the last decade.
- **Grid congestion:** This occurs due to capacity constraints around the transmission network. Congestion occurs when the transmission capacity is not adequate to transfer the entire power being generated on to the consumers. The real challenge for grid curtailment revolves around the congestion of the grid where renewable plants are injecting power.

India's regulatory structure on grid safety

The Central Electricity Authority (CEA) has issued "Grid Standards" and the Central Electricity Regulatory Commission (CERC) has issued the "Grid Code Regulations". These provide the necessary guidelines and standards to manage grid congestion.

Their key features include:

CEA's Grid Standards

- These standards do not mention the security or safety of the grid. They only talk about "grid disturbance" and "grid incident", which causes the tripping of one or more elements of the power system.
- The State Load Despatch Centres/Regional Load Despatch Centres (SLDC/RLDC) and Regional Power Committees (RPC) are responsible to maintain steady voltage and frequency within the limits.
- The RPCs review grid stability on a periodic basis. However, curtailment is allowed only with the concurrence of SLDCs and RLDCs, except in cases of imminent risk.

Despite "must run", solar and wind power could be curtailed on account of grid security, but the same is not properly defined.

CERC's Indian Electricity Grid Code Regulations

- SLDC and DISCOMs are mandated to maintain grid security. Unfortunately, grid security is not properly defined.
- Solar and wind power plants are accorded with a "must-run" status. However, the SLDC and DISCOMs are authorised to restrict over and under withdrawal of power by up to 250 MW in states which possess solar and wind capacities of over 3,000 MW and up to 200 MW in states which possess capacities between 1,000-3,000 MW. However, solar and wind power would be curtailed only after exhausting the technical flexibility available with the thermal power plants.
- Regulations require the SLDC to communicate about the curtailment to developers in writing. Developers have the right to seek information about grid standards violated by the plant, duration of grid incident and action taken report.

Curtailment is not recorded aptly in India as such requests are usually not backed by written communications.

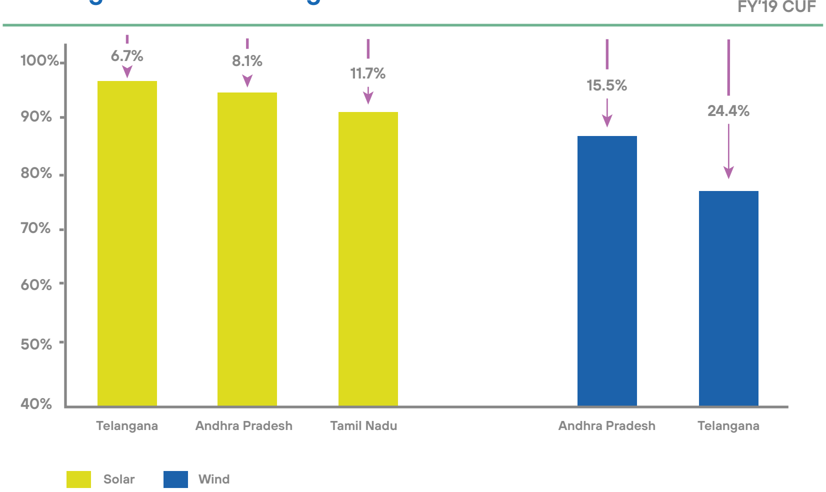
In practice however, the DISCOMs usually request the developers for the curtailment of a renewable plant without any written communication. In some cases, the request could be for purely commercial reasons that are masqueraded as technical incidents related to the grid. In essence, there are often no records of the actual curtailment of renewable projects in India.

In April 2020, India's Ministry of New and Renewable Energy issued an advisory on the deemed generation and "Must Run". According to this, in cases where curtailment was done for technical reasons. The developers would still require a communication from the SLDCs to get the benefit of deemed generation. But this is quite difficult in practice.

Although curtailment data is not available in India, several plants across key states have faced significant curtailments in the past. Notably, curtailment was estimated at over 35% in the peak season in Tamil Nadu during 2012 while Karnataka has faced curtailment each monsoon season since the last three years. The situation is similar in Andhra Pradesh, where the generation from renewable projects was arbitrarily pushed down in FY 2020. The National Solar Energy Federation of India wrote a letter to the Telangana state government reporting significant curtailment losses for the solar plants in that state.

To attempt the quantification of the curtailment, TCCL developed a metric by normalizing the monthly generation and arriving at the annual Capacity Utilization Factors (CUF) for each state. As per this analysis, the CUF of solar dipped by 8.1% and 11.7% in Andhra Pradesh and Tamil Nadu respectively during FY 2020. The same year, the CUF of wind declined by 15.5% and 24.4% in Andhra Pradesh and Telangana respectively. The normalized CUFs fell in the first quarter of FY 2021 for Andhra Pradesh, Telangana, Tamil Nadu and Maharashtra as well. While this reduction can be attributed to lower resources and other soft factors, the prevalence of instances of high levels curtailment cannot be ignored.

Figure 11: Reduced generation in FY 2020



Source: TCCL Research and POSOCO

Assumption:

1. CUF numbers were calculated based on normalized generation for each month

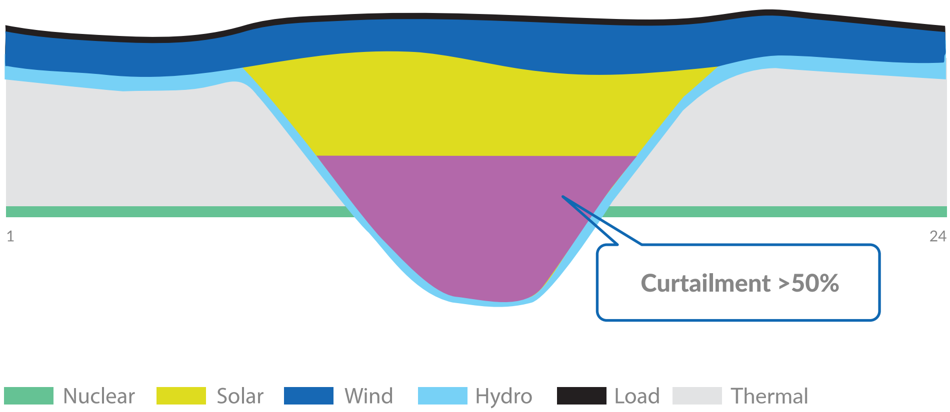
2. Generation from the projects commissioned in any month is taken from the subsequent month of achieving the commissioning

3. For the analysis, the CUF for FY 2019 was taken as 100% to show the reduced generation for FY 2020

SECI estimates curtailment of 50% by FY 2030 if demand profile remains unchanged and India meets the 450 GW target.

India has set a target to achieve 450 GW of renewable energy capacity by the year 2030. However, as per a study conducted by the Solar Energy Corporation of India (SECI), the installations could result in the curtailment of 50% of the solar generation by FY 2030 if the country's demand profile remains unchanged.

Figure 12: Projected load curve and possible curtailment in FY 2030



Source: SECI, "Concept paper: Firm & Flexible RE Projects with High PLF"

7. Solutions to address curtailment

In a nutshell, curtailment implies the inefficiency of the integration of renewable energy with the grid. Thus, larger is the flexibility of the system, the smaller will be the curtailment!

The solutions to make the system more flexible are two-folds: demand side management and supply side management.

Supply side management

1. Building and planning the transmission capacity

India needs an integrated transmission grid system to ensure the efficient channelizing of power from the resource rich southern and western areas to the other parts of the country. The Ministry of Power has launched a Green Corridor scheme for the evacuation and integration of 32.7 GW of renewable power by the year FY 2022. The total outlay planned for this activity was over INR 340 billion. In addition to the construction of new transmission grids, 11 Renewable Energy Management Centres were also being established to enable better coordination. The Indian government has already tied up financing channels from the German development bank, KfW, and the Asian Development Bank to develop the Green Corridor transmission network. The work on the inter state transmission is currently in its final stage of completion. The upgradation of the intra state transmission systems is expected to be completed by 2021.

The bidding agencies had also realized the challenge of increasing the penetration in select states. Resultantly, projects were designed to be connected to the Inter-State Transmission Systems (ISTS). The power from such projects is fed directly into the central transmission system. This reduces the probability of congestion. A key development in the context of power evacuation is the Renewable Energy Zone scheme. This was launched in 2019 to create 66.5 GW of substation capacity by 2022 in the renewable rich states. However, this is still in the bidding stage and significant progress is yet to be made.

Apart from this, India is also focussing on wind-solar hybrid projects for the better utilization of transmission infrastructure. Until now, over 3 GW of capacity has been allocated for solar and wind hybrid projects.

While this is a good start, India will require more concerted efforts to integrate the targeted 450 GW of renewable capacity by 2030. TCCL estimates that the investments required in this space would be to the tune of INR 4-5 trillion.

To integrate the targeted 450 GW RE capacity by 2030 India would require investments of INR 4-5 trillion.

2. Ancillary service/spinning reserve market

Ancillary services or creating spinning reserves from the private generators could provide the necessary headroom to the grid managers to integrate increased levels of renewable energy through a market-based approach. Under this, the private generators would be paid to maintain the frequency within the prescribed limit by:

- Maintaining load – generation balance (frequency control)
- Maintaining voltage and reactive power support
- Maintaining generation and transmission reserves

In 2015, the CERC had released the regulations for the ancillary services market in line with the regulations prevalent in Germany. It released the detailed procedures for the same a year later. However, this market is yet to become operational.

3. Forecasting mechanism

To manage the supply side dynamics, the grid operators require accurate information on the expected supply from the renewable sources. As of now, 15 states have already introduced these guidelines, and the penalty for forecasting and scheduling for the renewable plants are in line with that of the thermal plants. This penalty cost is estimated to be about 1-2% of the total revenue of the project.

However, the forecasting methodologies are yet to evolve such that they can better predict the generation on a "day-ahead basis". Thus, the penalty structure may not help until the forecasting system improves and integrates for a regional level assessment.

For smaller projects/developers, the impact is often higher. For instance, weather forecasting is mainly based on data received from the Indian Meteorological Department, AccuWeather and World Weather Online. The limited number of weather monitoring stations usually makes it difficult to forecast, with accuracy levels dropping below 70% during the monsoon months.

Demand side management

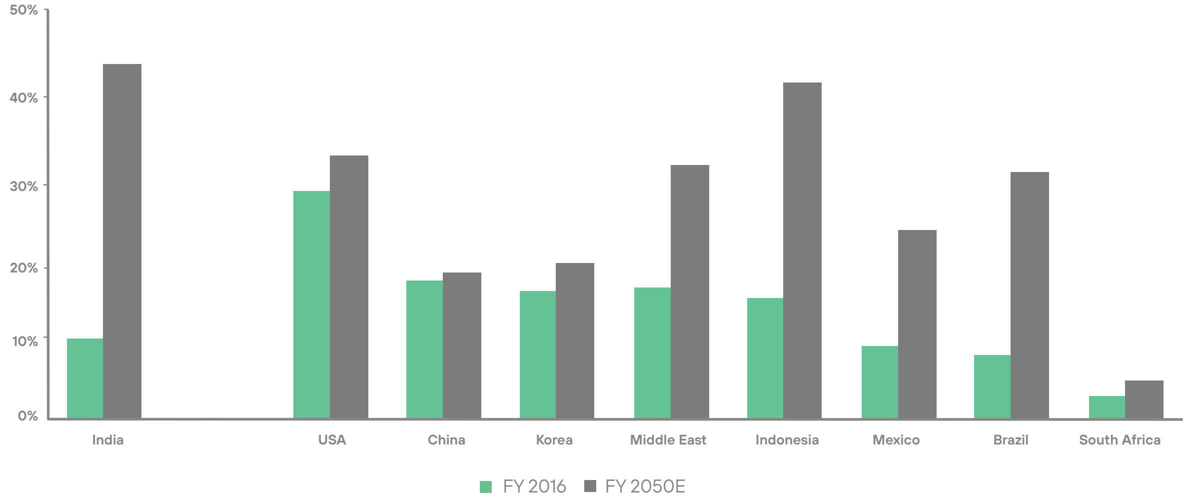
1. Demand forecasting

To effective plan the supply requirements, the grid operators also require an accurate forecasting of demand. The deployment of smart meters is an effective step taken by the country recently to source granular data. Energy Efficiency Services Limited (EESL) and various DISCOMs have already deployed over 1.5 million smart meters. However, given the total requirement across India is close to 250 million meters, the road ahead is still a long one indeed!

2. Demand shifting

The growth in power demand from the residential segment is expected to continue in India with improvements in prosperity and lifestyle. In the baseline scenario, the International Energy Agency (IEA) forecasts India may clock the highest cooling related demand globally. In fact, this demand could reach 1,350 TWh by 2050, which would be more than the total demand of the country in FY 2020. Further, in 2050, cooling demand could account for over 40% of the peak load.

Figure 13: Projected contribution of cooling load in India by FY 2050



Source: IEA, "The Future of Cooling Opportunities for Energy Efficient Air Conditioning"

A few Indian states have already implemented a differential Time of Day (ToD) tariff structure for commercial and industrial establishments. But the country needs to implement an effective ToD tariff schedule for all the consumer segments. This would incentivize all the consumers to shift their load patterns in line with the generation profiles.

Combination of demand and supply side measures have helped several countries to reduce curtailment significanly.

In the end, all countries that lead in renewable energy capacity have experienced enhanced levels of curtailments. A combination of the afore-mentioned solutions has ensured all these countries were able to keep their curtailment in check. For instance, Germany developed an ancillary services market and implemented the ToD tariffs to keep their curtailment levels in check despite the increasing penetration. The US state of Texas, on the other hand, faced wind curtailment of 17% in 2009. This was reduced to 4% by 2019 with the augmentation of transmission capacities, improved forecasting, ancillary market development and the deployment of smart meters[5]. China invested in the augmentation of its transmission capacity to reduce wind curtailment from 17% in 2016 to 7% in 2018 as well as solar curtailment from 11% in 2015 to 3% in 2018[6].

5. ERCOT and NREL, "Wind and Solar Energy Curtailment: Experience and Practices in the United States"

6. China National Renewable Energy Centre (CNREC)

8. Storage systems

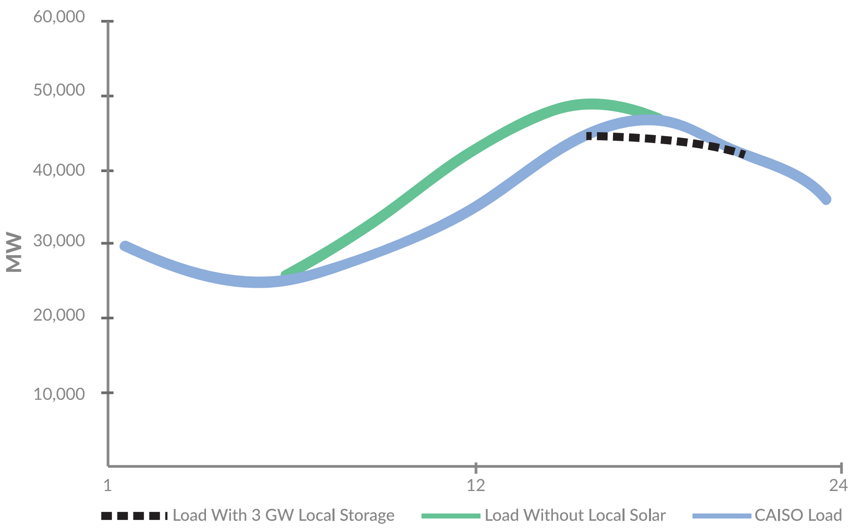
Storage systems are the most pragmatic solution for India to address grid integration and curtailment.

India can take a leaf out of the global experiences and work on both demand side and supply side management. However, despite all the efforts, curtailment would still occur if the generation from wind and solar represents the bulk of the instantaneous demand requirements.

The most sustainable solution to address curtailment is the adoption of storage systems. That would help ease out the stress on the generating sources to match demand profiles. There are a host of other applications too through which storage applications can support the grid:

1. Peak management and peak shaving: Storage is an ideal solution for peak management because there is virtually no minimum load requirement and a very high ramp rate. It can also act as a peak shaving solution by deferring the need to build the generation capacity to meet the peak demand. It also reduces the stress on the base load power plants to comply with the requirements of grid stability. As a case in point, California installed storage capacity of 3 GW to manage both peak shaving and peak management.

Figure 14: California load curve: With and without local storage



Source: California Solar & Storage Association (Load curve as of August 14th, 2020)

2. Frequency regulation: Balance out the momentary differences between electricity demand and supply within the transmission grid to maintain the interconnection frequencies close to 50 Hertz.

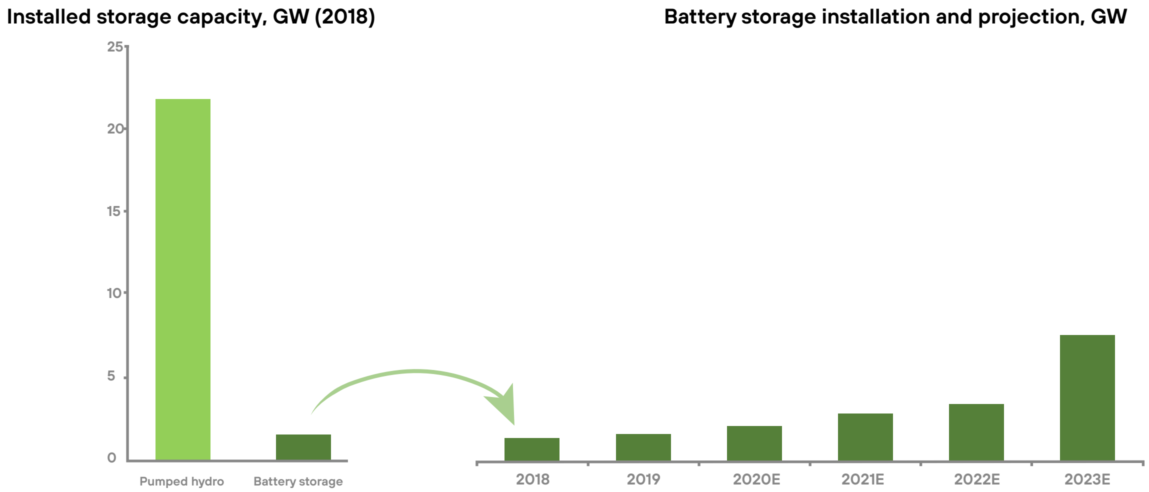
3. Spinning reserve: To serve as the reserve dispatchable capacity connected to the active grid to support unexpected events such as a sudden cloud cover.

4. Voltage or reactive power support: Reactive power arises due to phase differences between the voltage and current. These can be created by electric and magnetic fields in inductive and capacitive loads, such as motors or capacitor banks. Storage systems can help maintain the local voltage within the specified limits by serving as a source or sink of reactive power.

5. Arbitrage: The storage system can charge during the periods when the energy price moves south and discharge when the energy price moves north.

The two most common types of storage system available currently are the Pumped Hydro and Battery Storage. Traditionally, pumped hydro system was the main solution for storage. However, with rapid advancements in technology and reductions in costs, battery storage is also gaining traction globally. For instance, in the USA, pumped hydro capacity was over 20 times that of battery storage capacity by 2018. However, the latter represents the bulk of the new capacities planned and it is expected to increase by over 4 times by 2023.

Figure 15: Installed and projected storage solutions in the USA



Source: U.S. Energy Information Administration (EIA), "Battery Storage in the United States: An Update on Market Trends", July 2020

9. Way forward

India has already taken cognizance of the issues related to the increasing penetration of renewables and has proceeded with steps towards the right directions.

National Energy Storage Mission was launched in 2019 to boost battery manufacturing and deployment. Further, SECI released a concept paper on Firm and Flexible renewable energy projects with an aim to support the targeted 450 GW of renewable power by 2030. This paper aims to find solutions for designing projects with an improved firmness of renewable projects and enhanced flexibility. The solutions include the deployment of energy storage at the grid level and hybridizing with gas power plants.

The country has also started tendering out projects which would provide Round-the-Clock (RTC) power or power on demand by leveraging storage technologies.

Figure 16: RTC and power on demand projects in India

RTC projects

- SECI has allocated 400 MW RTC project in May 2020 with required minimum CUF of 70% (monthly) and 80% (annually)
- Ministry of Power has released guidelines for procurement of bundled renewable and thermal power under RTC mode - SECI has released tender for 5,000 MW under this scheme
- MNRE plans to introduce separate Renewable Purchase Obligation for RTC projects

Peak Power/ Power on Demand projects

- SECI has allocated 1,200 MW of solar, wind and storage projects
- The tender has different tariffs for supplying power during peak and non-peak slots
- Andhra Pradesh approved Greenko's 1,000 MW Solar, 550 MW Wind, and 1,200 MW Pumped Storage dispatchable power project

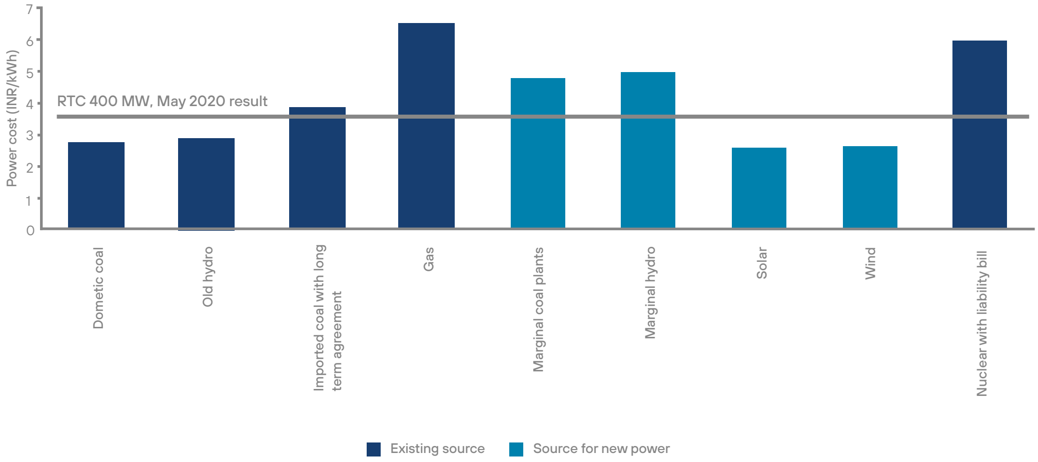
India has taken initiatives in the right direction but will require cost competitiveness of storage backed systems to scale up.

More importantly, the recently conducted RTC tender had the winning bid tariff of INR 2.92/kWh with a 3% annual escalation for the next 15 years. On a levelized basis, the tariff would be around INR 3.50/kWh, which is more economical than the marginal coal of large hydro power plants. Moreover, it would also be cost effective considering the grid balancing cost of solar and wind projects which is estimated by CEA to be around INR 1.11/kWh[7].

7. CEA, "Report of the Technical Committee on Study of Optimal Location of various types of balancing energy sources/energy storage devices to facilitate grid integration of renewable energy sources and associated issues", 2017

Figure 17: Competitiveness of RTC projects

Cost of power production (INR/kWh)



Source: TCCL Research

In this context, there is a tailwind for India. Following a sharp decline of 24% CAGR over the last decade, battery prices have reduced to USD 150/kWh. Going ahead, while the pace of the decline is expected to slow down, the prices are still slated to fall below USD 100/kWh by 2025. Moreover, possible technical developments using hydrogen fuel and flow-based batteries could unlock more economical solutions in the storage space.

CEA, the agency responsible for power planning in India, envisaged usage of storage solutions for grid integration in its report published in January 2020[8]. It indicates a combination of 27 GW of battery storage and 10 GW of pump hydro storage could address the renewable curtailment during the lean generation season by FY 2030. However, the curtailment could be up to 14.56% during peak generation season.

Capacity constraints around gas and hydro sources have ensured that renewable integration is primarily dependent on coal plants as of today in India. Therefore, scaling up of storage is essential to reduce dependence and possible replacements of coal in future. However, optimum utilization of storage solutions for economic viability would still require slight curtailment during peak season. Nevertheless, reducing it to acceptable limits is a necessity for making it feasible for all the stakeholders.

India seems to be on the right path of aggressively pursuing the adoption of storage technologies. All these efforts would not only help the country meet its ambitious intended nationally determined contribution (INDC) targets but also become a global case-study in the fight against climate change.

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8. CEA, "Report on Optimal Generation Capacity Mix for 2029-30", January 2020

Disclaimer

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