THE CASE FOR PROVING

BATTERY STORAGE VIABILITY FOR TAMIL NADU

A VIABILITY ASSESSMENT OF
HYBRID RE + BATTERY STORAGE SYSTEMS

A Report by

CLIMATE TRENDS

JMK Research & Analytics

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C O N T E N T

01 SUMMARY

1 Tamil Nadu leads the Indian states in renewable power generation, but it curtails a large percentage of this intermittent power due to reasons that include excessive generation and concerns around grid imbalancing. Since the lockdown was imposed in March 2020, it has curtailed ~50.8% of its solar power, while its average curtailment of wind power in 2019 went up to 3.52 hours per day from the 1.87 hours per day in 2018.

2 However, battery-based energy storage can address this issue, and the heavy losses to renewable power developers, by storing and releasing the power after peak solar and wind generation hours.

3 A hypothetical lithium-ion based battery energy storage system (BESS) that would store Tamil Nadu's solar and wind power was designed to model its contribution to offsetting the state's annual power demand. The system's capacity and discharge times were incremented step-wise over the 10 years, starting with two-hour battery backup in the initial years to 4 hours by 2030.

4 The system's LCOE was found to fall from Rs. 4.97/kWh in 2021 to Rs. 3.4/kWh in 2030, by which time it would meet 29% of Tamil Nadu's average annual power demand. It would do so at a tariff that was competitive with the cost of new coal power, @ Rs. 4.5-6/kWh (before thermal power plants' compliance with the new emission standards). If the power were to be wheeled to Delhi, even after accounting for ISTS charges post-H1 2023 and the state's rising power consumption, the solar and wind-powered BESS is able to cost-effectively meet 100% of Delhi's average annual power demand in 2030.

5 The system demonstrates that battery-based energy storage systems can be feasibly deployed as dispatchable power capacity in states with high renewable power potential to:

a. Throttle their wasteful curtailment of clean power generation

b. To work around the inherent intermittency of renewable power output

The system also proves to be a cheaper option than building new coal capacity to meet India's growing power consumption.

02 INTRODUCTION

India's electricity demand continues to grow at a significant pace and it was earlier projected to be around 2700 TWh by 2030, growing at a CAGR of 6% from 1500TWh in 2020[1] . However, considering the long-term effect of covid-19 on the economy, the power demand is expected, now, to be lower than the pre-Covid projection by about 7 – 17% (in 2025)[2] .

Yet, to cater to the ever-increasing demand for power, it is critical that India progresses steadily on its path of clean energy transition and make meaningful contributions towards global climate efforts. Around 75% of India's power output still comes from its 199GW of installed coal- and gas-fired capacity. The former is linked to heavy CO2, SOx, NOx and particulate matter (PM) emissions, and because of its increasingly uncompetitive tariffs, demand for coal and coal power is projected to decline steadily through to 2050.

In contrast, the national-level commitment of achieving installed RE capacity of 175 GW by 2022 and 450 GW by 2030 has provided a strong momentum to the green power revolution. The installed (wind and solar power) RE capacity increased over six times from FY2009-10 (11.8 GW) to FY2019-20 (72GW)[3] and their tariffs have fallen from as high as Rs. 15-18/kWh in 2009-10 to less than Rs. 3/kWh today. Thus, together, these variable renewable energy (VRE) systems contributed to 8% of the total electricity generation of the country in 2018 with 101 TWh[4] of generation (CEA, 2019).

Yet, despite the substantial rise in the share of VRE in the power generation mix, integration of this variable power has also brought certain limitations to the foreground. Due to the intermittent and inconsistent nature of the wind and solar power generation, there is a growing challenge of lack of power system flexibility, especially in states with higher share of RE installed capacity. Drawing on the advantage of complementary nature of the two renewable sources of generation, hybrid (integrated wind+solar) energy offers better capacity utilization than the standalone wind/ solar power generators. Adding Energy Storage Systems (ESS) also ensures better renewable energy integration and enhances power system flexibility.

Therefore, in order to boost clean and firm power capacity addition in the country, Hybrid RE+storage systems would prove to be one of the most important solutions. It acts as a single complete system to multiple contemporary needs – non-fossil fuel based energy generation, firm power supply and a mechanism for quick-responsiveness to load variations.

1 *BNEF, India's Clean Power Revolution, June 2020*

2 *TERI, Bending the Curve: 2025 Forecasts for Electricity Demand by Sector and State in the Light of the COVID-19 Epidemic, July 2020*

3 *IEA, India 2020 Energy Policy Review, Jan 2020*

4 *JMK Research, Tariffs for RE+storage tenders competing with thermal, Feb 2020*

This report shall focus on the VRE layout of the state of Tamil Nadu for a model study to understand the viability of such integrated system projects. Being a pioneer and one of the leading states in terms of VRE installation, Tamil Nadu is a good candidate for the viability assessment of a hybrid RE+Storage model.

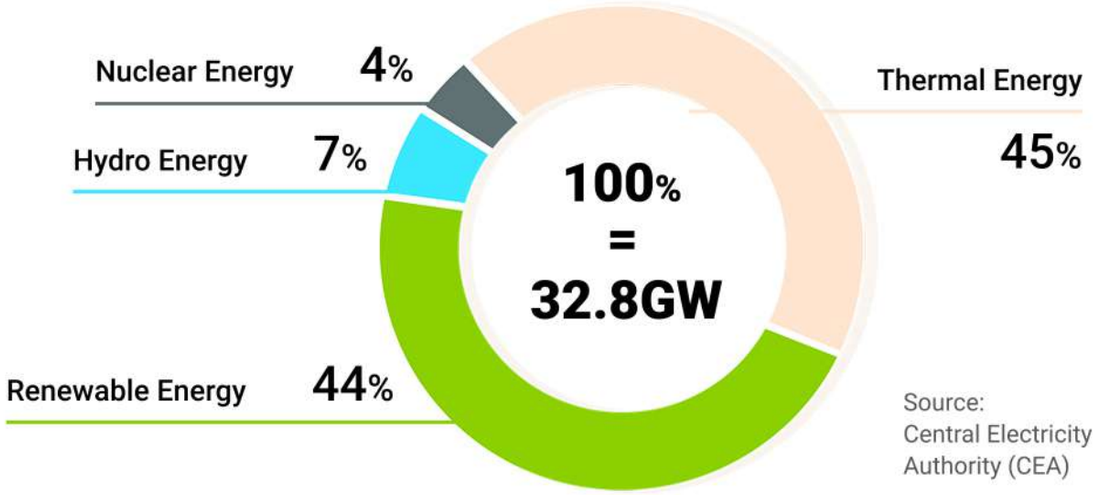
Apart from the benefits mentioned earlier, as part of our analysis, we will also evaluate the economic viability of such systems vis-a vis new thermal power plants, where tariffs are expected to be in the range of Rs. 4.5 - 6 /kWh . Specifically, in Tamil Nadu, in th¬e next three years, about 5 new thermal power projects with a combined capacity of 5.7 GW are likely to be operational in the state. One of the largest, the Cheyyur thermal power plant of 4,000 MW proposed near Chennai, is also likely to have a tariff of Rs. 5-6/ kWh[5] .

Henceforth, this report shall describe the background, trends and need for a clean source of generation along with battery storage and try to demonstrate, by applying techno-commercial analysis, the possible Levelized Cost of Energy (LCOEs) associated with such systems.

03 SNAPSHOT OF TAMIL NADU

Tamil Nadu is one of the most progressive and competitive states in India in terms of development and diversification of the state energy sector. It has the highest renewable energy installations, with about 14 GW of installed capacity (including wind, solar, biomass power) out of 33 GW of the state's total installed capacity (as of March 31, 2020). With the state's power demad typically varying between 13,500–16,000 MW across different seasons, renewable energy meets more than 15%[6] of this demand.

Fig 1.1 Source-wise installed capacity (as on 31st March 2020)

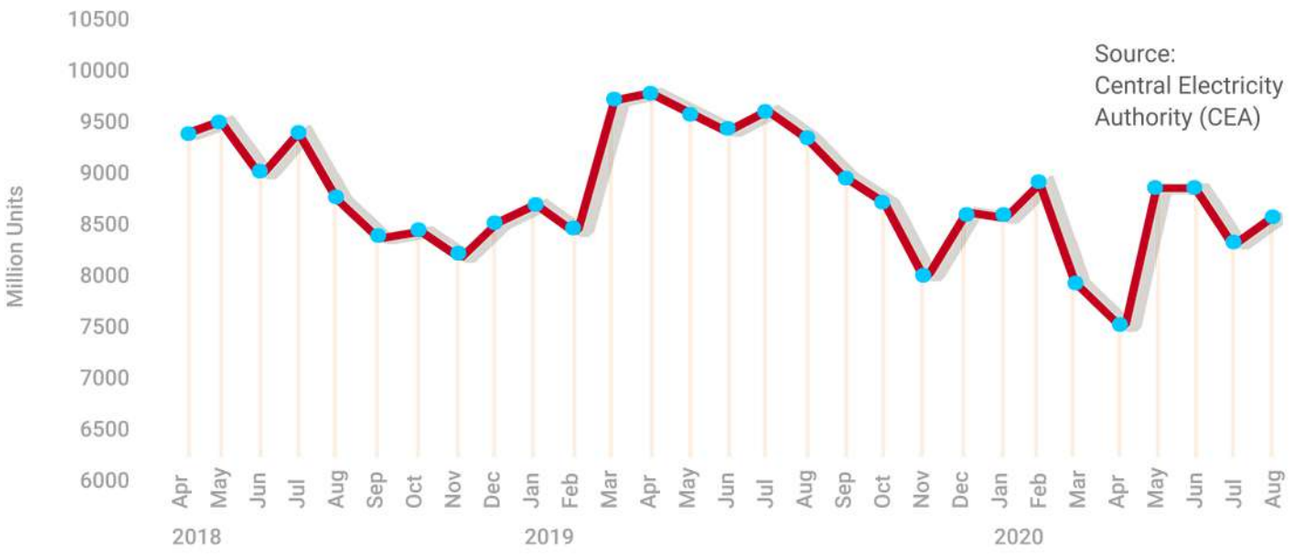


Source: Central Electricity Authority (CEA)

5 *IEEFA, Seriously Stressed and Stranded: The Burden of Non-Performing Assets in India's Thermal Power Sector, Dec 2019*

6 *IEA, India 2020 Energy Policy Review, Jan 2020*

Fig 1.2 Monthly energy demand trends of Tamil Nadu



On the basis of cumulative solar and wind installations, as of 30th June 2020, Tamil Nadu is the leading state with 13 GW of installed capacity [7]. Out of this, wind energy capacity constitutes the majority share of 71%. The state is also the best performing one in the wind energy sector, holding a significant share of over 25% of India's total wind capacity i.e. approx. 9.3 GW. In terms of state-wise cumulative solar power installations, the state ranks third with about 4 GW capacity. Cumulative wind and solar installations from 2014-2020 in the state have grown at a CAGR of 4.2% and 83.2% respectively, as per JMK Research.

04 ROLE OF STORAGE

Renewable energy has little to no operational emissions, which is a distinct advantage over fossil-power. However, it does not reflect the true costs of the systems because of:

1. Its intermittent power output and need for balancing
2. Its requirement for storage, without which it is unable to match the dispatchable power characteristics of fossil fuel alternatives, such as natural gas-fired plants which can be ramped up at rates of several MW/ min.

Therefore, even though solar and wind projects are presently awarded at around Rs.2.5/ kWh and the average cost of power procurement in India is at around Rs. 3.6/ kWh[8] - most of which comes from coal - renewables have not yet replaced coal or gas fired plants to meet sudden increase in demand, such as during peak loading.

7 *JMK Research, Q2 2020 India RE update (Apr-June 2020), July 2020*

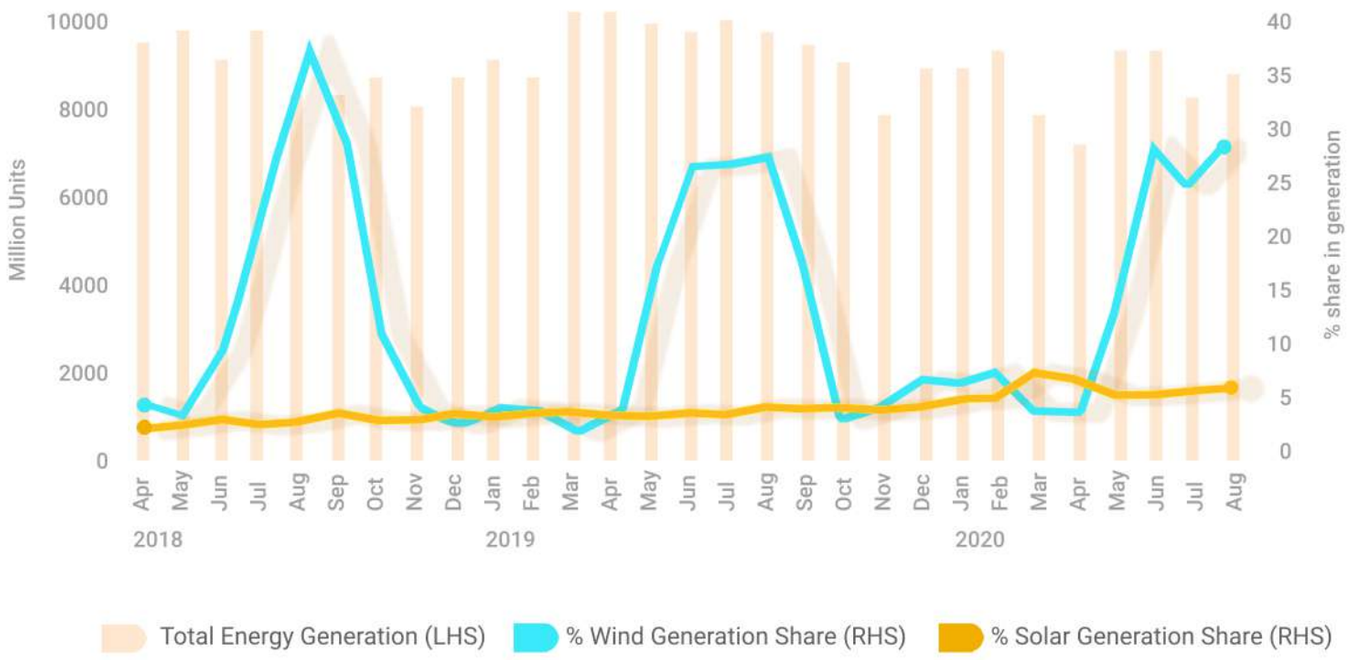
8 *Source: https://indianexpress.com/article/india/average-power-purchase-cost-rises-to-3-60-kwh-in-fy-19-5770442/*

4.1

Effective Solution to Intermittent RE Sources

Even though installed capacity (13 GW) is highest amongst all states in Tamil Nadu, the total estimated solar and wind power potential in the state is more than 51 GW. In terms of average monthly generation, wind and solar constitute about 14% and 4% respectively of the total monthly energy generation in Tamil Nadu.

Fig 2 **Wind & Solar generation share (in %) in Tamil Nadu for the period Apr 2018 – Aug 2020**



Source: CEA, JMK Research

However, adding more intermittent sources of solar and wind capacity to the total generation mix in the state can lead to grid imbalancing and frequency fluctuations. The problem of intermittent power generation due to the variation in wind speed and the solar irradiation intensity through the day leads to inconsistent power generation. Another constraint is the inability to 'control' the generation to match the demand, as can be done in a dispatchable fossil fuel power plant.

Effective energy storage solutions hold the key to overcoming these challenges. Storage technologies can provide the required backup power for intermittent renewable energy capacity without threatening grid stability or the ability to meet electricity demand.

4.1.1 RE Curtailment

Apart from managing the grid balancing issues, storage is also effective to manage the rising grid curtailment issues of solar and wind in the state. As discussed earlier, Tamil Nadu is one of the few states having relatively high share (>15%) of RE generation out of total electricity generation. Even though the installed capacity of renewable sources in Tamil Nadu is more than 40% of the total installed capacity, the share of actual generation through RE is much lower than what it can be.

Disregarding the factor of low CUF of wind and solar power plants, a major cause for this is RE curtailment. Despite the statutory provisions by IEGC (Indian Electricity Grid Code) and TNEGC (Tamil Nadu Electricity Grid Code) and orders of the Central Electricity Regulatory Commission (CERC) granting 'MUST RUN' status to RE generators, RE generation curtailment has been persisting in the renewable energy industry in many RE-rich states for many years. In case of Tamil Nadu, the wind and solar developers have been incurring severe losses due to backing down instructions from SLDC/ ALDC and curtailment of supply from the power plants by Tamil Nadu Generation and Distribution Corporation (TANGEDCO) or Tamil Nadu Transmission Corporation (TANTRANSCO).

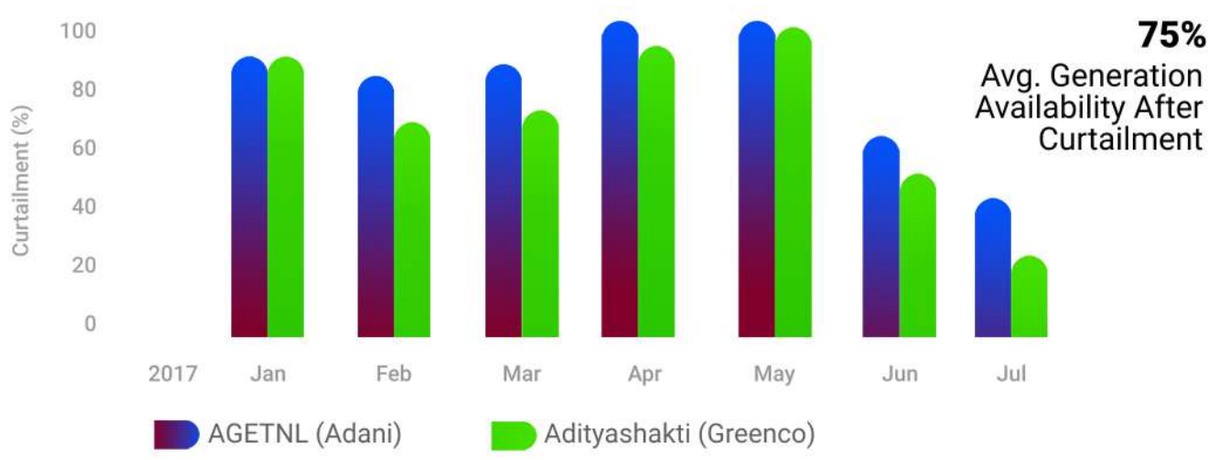
Table 1 Solar curtailment since lockdown (as on 1st Oct 2020)

Capacity curtailed	Total deemed generation	Average capacity curtailed
95.4 GW	15.6 Million Units (MU's)	50.8%

Source: NSEFI

Below chart represents generation availability after curtailment (GAAC) of Adani Green Energy (Tamil Nadu) Limited (AGETNL) & Adityashakti solar project by Greenko in Tamil Nadu during Jan 2017 – July 2017. The average generation availability after curtailment considering both the companies comes to about 75%.

Fig 3 Generation availability after curtailment (GAAC)



Source: JMK Research
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Also, Adani Green Energy along with four of its subsidiaries had reportedly accumulated a combined financial loss of Rs. 202.2 crores during April 2016 – July 2017, due to 18% average curtailment across these 5 companies over the 16-month period.

Wind power generators in Tamil Nadu also suffered critical losses on account of curtailment as instructed by the SLDC, particularly during the year 2019. In the state, average curtailment of wind power generation in 2019 was 3.52 hours per day whereas 2018 saw 1.87 hours of curtailment per day, as per IWPA (Indian Wind Power Association).

In general, for a conservative curtailment figure of 15%, the back down translates to an annual loss of 2,000 to 2,500 Million Units (MUs) [9].

The curtailment of RE generation can only be done in exceptional situations, bearing grid stability and transmission constraint issues. Therefore, to ensure safe and flexible operation of the state power system, Tamil Nadu is at a stage where it must be complemented with advanced flexible resources such as storage systems, along with improvements in RE forecasting and scheduling, cross-border trade etc. According to CEA [10], mandatory establishment of battery storage of 2.5% of daily energy generation at solar or wind plants can avoid the curtailment of RE power.

05 LCOE CALCULATION OF RE + BATTERY STORAGE SYSTEM

5.1 Intra State Supply In Tamil Nadu

The need for sustainable energy transition combined with the prevalent power sector scenario in Tamil Nadu necessitates installation of new clean generation+storage power plants. The share of stable power generated from such integrated plant systems can be progressively increased with y-o-y capacity additions. To evaluate the techno-commercial aspects of such clean energy projects, a detailed modelling was carried out with an integrated RE+Storage plant chosen as the system template.

Due to significant wind and solar potential in the state as well as due to the complementary nature of the two resources, the combination of wind and solar power for hybrid energy generation was deemed suitable. A lithium-ion based battery was taken as the battery energy storage system (BESS) for the model.

9 *Down To Earth, Renewable energy: Curtailment is a bane, Jan 2020*

10 *Source: CEA report on Flexible Operation of thermal power plant for integration of renewable generation: Jan'19*

Capacity additions of wind and solar systems were allocated each year with varying capacities during the period 2021-2030. The BESS capacity for each year was taken as 50% of the corresponding total AC capacity with the view of balancing the two sides – favourable project economics and maximum BESS capacity allocation. The discharge time of BESS additions assigned every year, through the 10-year project period, were incremented step-wise.

OTHER ASSUMPTIONS

Wind power cost	**Rs. 57 Million/ MW (US$0.76 Million/ MW)**
Solar power DC cost	**Rs. 27.3 Million/ MW (US$0.36 Million/ MW)**
Land cost	**Rs. 1.5 Million/ MW (US$0.02 Million/ MW)**
AC:DC overloading factor	**50%**
CUF Solar (From 2021 – 2025)	**19.5% (with high efficiency mono PERC modules)**
CUF Solar (From 2026 – 2030)	**20% (Assuming technological advancements)**
CUF Wind (From 2021 – 2025)	**36% (For 2 MW WTG's)**
CUF Wind (From 2026 – 2030)	**38% (Assuming technological advancements)**
Interest on fixed capital	**9.50%**
Repayment Period	**18 Years**
Return on Equity (ROE)	**13%**
Debt to Equity Ratio	**75:25**
Battery module cost (USD/ kWh)	**270**
Cost reduction due to battery co-location	**8% (only for first 2 years)**
Battery Efficiency	**80%**
Battery Discharge capacity	**80%**
Annual rate of decline of battery price	**9%**
USD to Rs. conversion factor	**75**

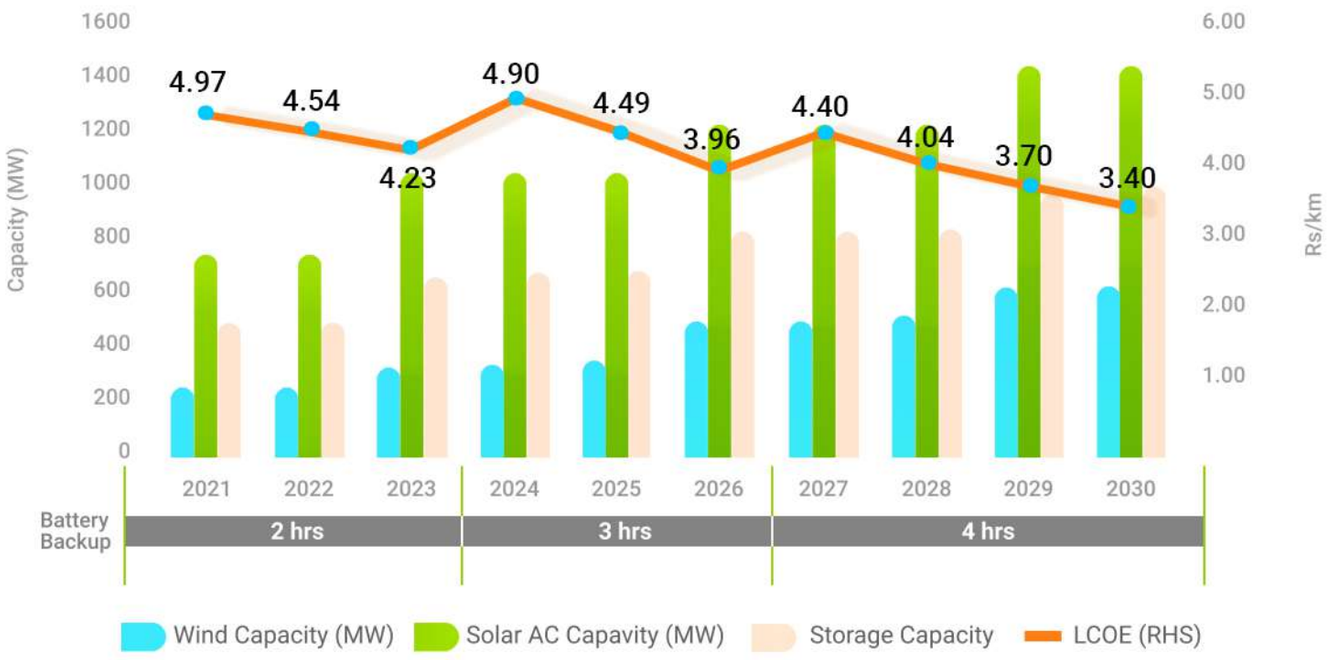
Different technical and economic aspects (net energy generation, ROE, etc.) of the hypothetical model were calculated for each year and for the entire project by consolidating all capacity additions.

RESULTS

The Levelized Cost of Energy (LCOE) determined in the integrated RE+storage system reflects the tariffs for the sum of stored energy supplied from the Battery Energy solution system (BESS) and the excess energy supplied directly from the wind-solar hybrid system as and when generated.

The LCOEs follow a general downward trend along the 10-year period but mark distinct surges in the 4th and the 7th years due to an increase in battery back-up hours in these years. Notably, the levelized tariffs for the 4th and 7th years do not climb higher than the previous peaks, i.e. the 1st year tariff and the 4th year tariff respectively because of the overall declining trend in expected battery prices.

Fig 4 **RE Hybrid+Storage System LCOE for Tamil Nadu for intra-state supply**

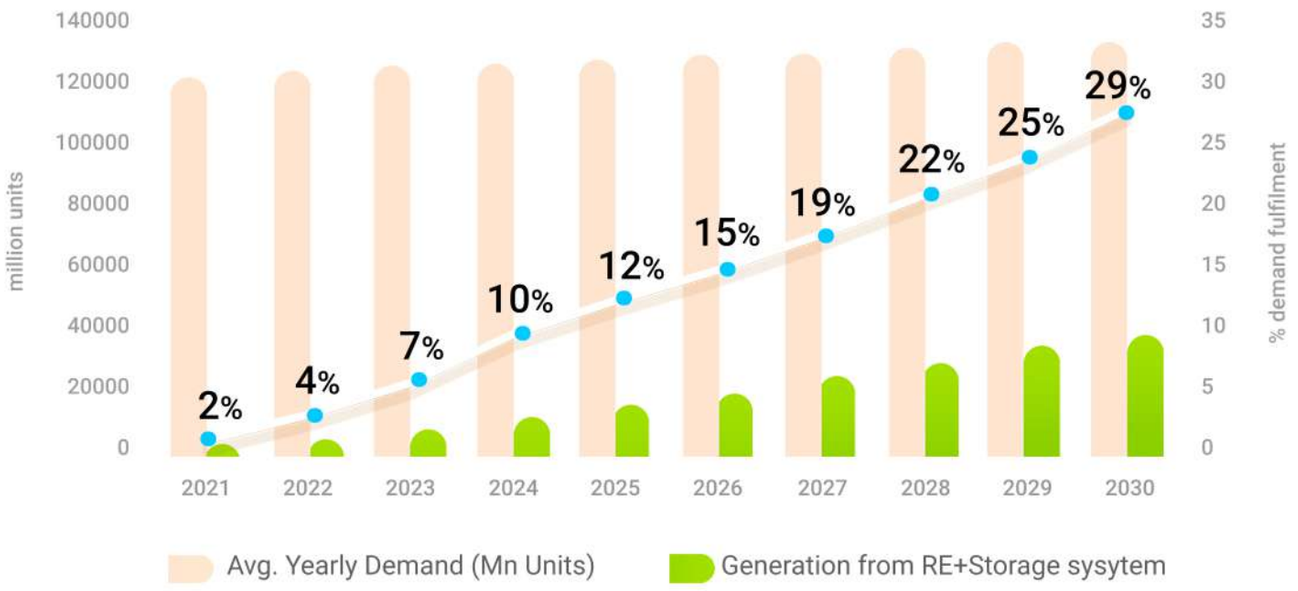


Source: JMK Research

Note: Battery storage backup is taken for evening peak period for 4 hours (when tariffs are the highest)

The generation+storage system capacities are step-wise incremented. With the gradual increase of annual power demand assumed for the state, the consolidated project is able to meet 29% of the average yearly electricity demand requirement of Tamil Nadu in the next 10 years.

Fig 5 **Requirement met of avg. yearly electricity demand inTamil Nadu from RE+storage system**



Source: JMK Research

Note: Average yearly power demand in Tamil Nadu is projected to increase by 1.5% till 2025 and 1% from 2026 onwards

5.2

Inter State Supply To Delhi

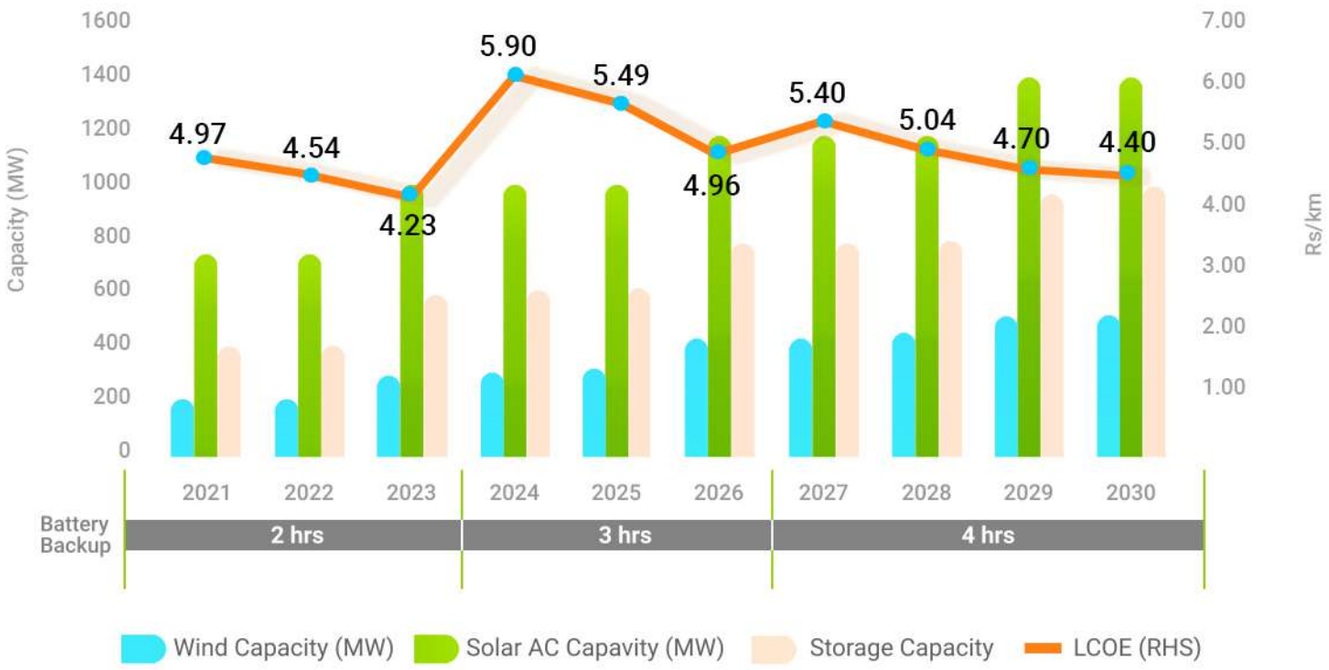
According to our hypothetical model, if the same RE+storage system set up in Tamil Nadu is used to supply power to Delhi via ISTS (Inter State Transmission Network), then 100% of Delhi's average yearly electricity demand will be met in next 10 years, i.e. by 2030. However, the DISCOM/ power offtaker would have to pay additional transmission charges of approximately ranging from Rs. 1-2/ kWh. Although, according to MNRE guidelines, the ISTS charges are completely waived off for the renewable capacity additions commissioned only until the end of H1 2023.

Thus, the LCOEs for the first three years would remain the same for pan-India supply. But, from 2024 onwards, additional transmission charges would be levied every year over the intra-state tariff rate.

In the case for RE+Storage power supply to Delhi, the 4th year, i.e. 2024 capacity addition is associated with the highest LCOE due to the combined effect of increase in battery back-up hour and levy of ISTS charges and transmission losses. In our analysis, from 2024 onwards, additional transmission charges of a minimum of Rs. 1/ kWh are included in the LCOEs (refer Fig 6).

The overall decline in LCOEs can be attributed to the decreasing costs of wind, solar power and li-ion based BESS along the 10-year timeline.

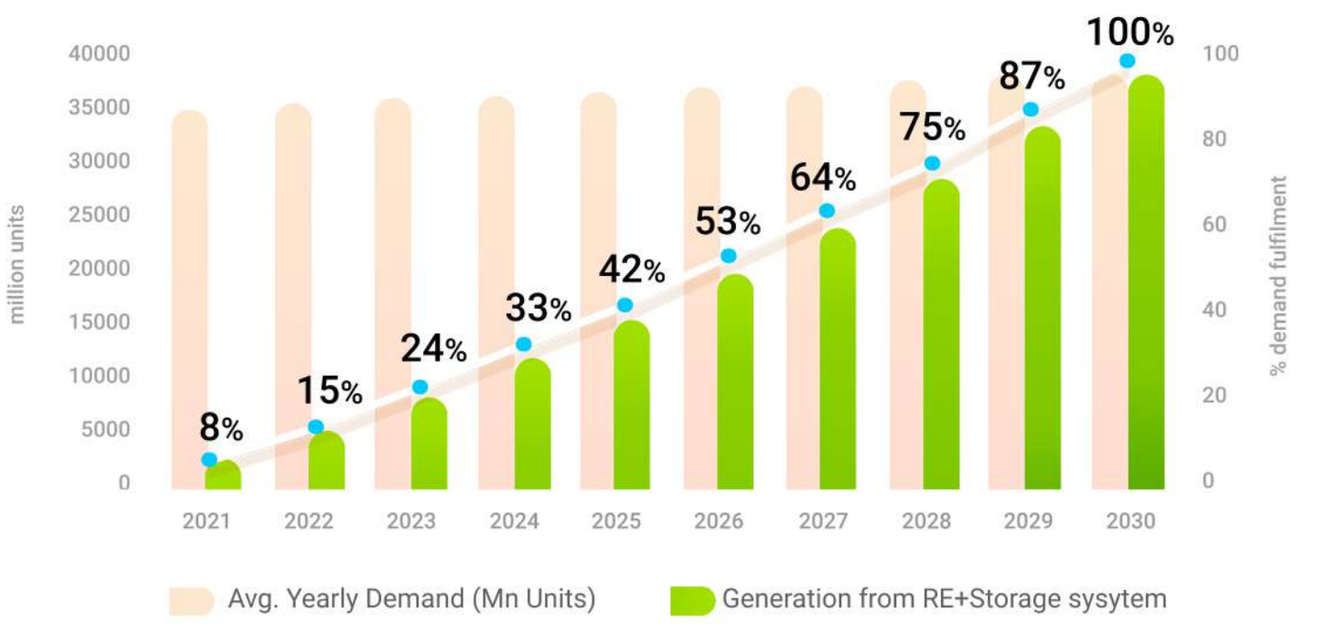
Fig 6 LCOEs for sale of power to Delhi (Inter-state supply)



Source: JMK Research

As can be seen below, utilizing the same system solely for sale of power to Delhi enables 100% fulfilment of its demand requirement by 2030.

Fig 7 Requirement met of average yearly electricity demand in Delhi from RE+storage system



Source: JMK Research

Note: Average yearly power demand in Delhi is projected to increase by 1% till 2030

06 CONCLUSION

The generation from the RE+Storage system, with the set capacities and other technical considerations, can fulfil nearly 29% of the annual average power demand of Tamil Nadu by 2030 and 100% of the power demand for Delhi. Thus, upon implementation of the integrated hybrid RE+storage system model and with the inter-state power supply of the stable renewable power generated from this consolidated project, the future annual average demand of Delhi can be offset with clean and firm electricity by 2030, and that too at favourable tariffs.

The LCOEs of such a system are competitive compared to tariffs of new coal plants in India, which are likely to be in the range of Rs. 4.5 – 6 / kWh in the near-future. Further, with ongoing fuel cost escalations and growing calls for tighter emission control, all coal plants would have to install pollution control technologies, such as flue gas de-sulphurisers (FGDs) and electrostatic precipitators (ESPs), which would further increase their tariffs. A 2019 study by CEEW and IISD[11] has also indicated that with the addition of FGDs and ESPs coal plants' tariffs would increase by Rs. 0.32-0.72/ kWh.

In this scenario, hybrid RE+storage systems carry a competitive edge as not only a cleaner and a firmer source of energy supply but also one that comes with competitive tariffs. This can be clearly vetted from our analysis as well, according to which the average LCOE rate, considering the 10-year tariff for Delhi (as shown in Fig.6), is about Rs. 4.96/ kWh. Therefore, it's clear that renewable energy systems in assistance with energy storage are ready to be deployed as cost-effective dispatchable power systems and a viable alternative to new coal power in the country.

11 *Source: https://iisd.org/gsi/news-events/indias-coal-power-sector-dragging-its-feet-address-avoidable-air-pollution*

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