JMK Research & Analytics

Institute for Energy Economics and Financial Analysis
IEEFA.org

Jyoti Gulia, Founder JMK Research

Vibhuti Garg, IEEFA Energy Economist

October 2020

Wind-Solar Hybrid: India's Next Wave of Renewable Energy Growth

An Analysis of Tariff Trends, Policy and Regulation, and Challenges in a New Market

Executive Summary

India's total renewable power installed capacity is 88 gigawatts (GW), with ~38GW of standalone wind energy capacity and 35GW of solar energy capacity as of August 2020.[1] India has plans to reach a total 175GW of renewable energy (including 100GW of solar and 60GW of wind) by 2022 and 450GW by 2030.

As this energy transition accelerates, we need to explore various options, technologies and business models – aside from plain vanilla contracts – to expedite the adoption of increasing amounts of low-cost but intermittent renewable energy (RE).

Wind-solar hybrid (WSH), which harnesses both solar and wind energy, is fast emerging as a viable new renewable energy structure in India due to the high potential of both wind and solar resources across various locations and the provision of enhanced grid stability and reliability.

Wind-solar hybrid is fast emerging as a viable new renewable energy system in India.

To promote the setting up of WSH power plants, the Ministry of New and Renewable Energy (MNRE) adopted the National Wind-Solar Hybrid Policy in 2018 which also provides certain waivers and incentives to developers. Various state governments have also come up with their own WSH policies including Gujarat, Andhra Pradesh and Rajasthan.

As per the tenders allotted under various central and state schemes, according to JMK Research estimates, about 11.6GW of WSH power is likely to come up over the next three years, riding on strong support from Solar Energy Corporation of India (SECI) and several state governments. Capacity addition will rise at a compound

[1] Government of India Ministry of Power. Power Sector at a Glance. August 2020.

annual growth rate (CAGR) of 223% from 2020-2023.

SECI tenders for WSH without storage have attracted low tariffs to the tune of Rs2.67/kWh (US¢3.7/kWh) which are comparable to solar tariffs. Adani Green Energy, SB Energy, Greenko and ReNew Power are the key active participants across WSH tenders.

To understand the tariff trends for WSH projects, we developed a financial model for a 250MW wind-solar hybrid project based on the various assumptions gathered from stakeholder consultations. Our analysis shows that for solar and wind blended at a ratio of 80:20 respectively for a 250MW WSH plant, the levelised tariff comes to Rs2.49/kWh (US¢3.32/kWh), while blending solar and wind at a ratio of 50:50 results in a tariff of about Rs2.57/kWh (US¢3.43/kWh).

On analysing the impact of adding a storage component to the WSH project, for a 2-hour battery back-up, the levelised tariff increases substantially to Rs4.59/kWh (US¢6.12/kWh).

Clearly, adding battery storage is not a feasible option at present because it significantly increases project costs and hence the tariffs. However, the declining trend in the battery prices will make these projects viable within a few years and provide more stable power. The engineering, procurement and construction (EPC) cost of battery storage is expected to fall by 15-20% to US$250-270/kWh by 2021 from $300-320 per kWh at present.[2]

As part of this report, we have analysed in detail national and state policies and regulatory developments, tender activity, key players in the market, upcoming capacity addition, tariff analysis and the risks and challenges associated with WSH technology.

[2] JMK Research. Solar+Battery Storage: Assessing the Viability in India. January 2020.

Table of Contents

Executive Summary 1
Overview 4
Policy Analysis 7
National Wind-Solar Hybrid Policy 2018 7
State Policies 8
Wind-Solar Hybrid Tender Activity 11
Key Players 15
Likely Capacity Addition in Next 3 Years 17
Tariff Analysis 18
Risks and Challenges 21
Conclusion 22
About the Authors 24

Overview

India's long coastline is endowed with high-speed wind and is also rich in solar energy resources, thereby providing a great opportunity for the wind-solar hybrid industry to thrive.

Solar and wind power potential in India is concentrated mainly in Gujarat, Tamil Nadu, Karnataka, Maharashtra and Rajasthan. Hybridisation of the two technologies can happen either at the same location or at different locations depending upon the project requirement.

Hybrid systems are more likely to produce dependable power that meets demand.

Solar and wind are intermittent power generation sources that characteristically generate power at different intervals and during complementary seasons. Wind power is typically most productive during the night while solar only produces during the day. Whereas WSH plants produce both solar and wind power.

With the government's commitment to 100GW of solar by 2022 and 450GW of renewables by 2030, relying solely on wind or solar to achieve the target is a suboptimal option.

Demand curves in India usually have one morning peak and one evening peak, though the duration and time of peak may vary slightly from state to state. Daytime demand can be met with solar alone, but as the sun sets in the evening and the demand curve rises, ramping is required. The ramp rate will increase significantly with the integration of more solar into the grid. The higher the ramp rate, the higher the costs associated with maintaining grid stability.

Capacity utilisation factor (CUF) for standalone solar and standalone wind are also low. Combining the two will result in better CUF and hence enhanced efficiency of the plant. It can also address the pertinent land issues related to standalone solar and wind, as co-location optimises land use.

As we set out to achieve ambitious renewable targets, the underlying issues discussed above need to be addressed.

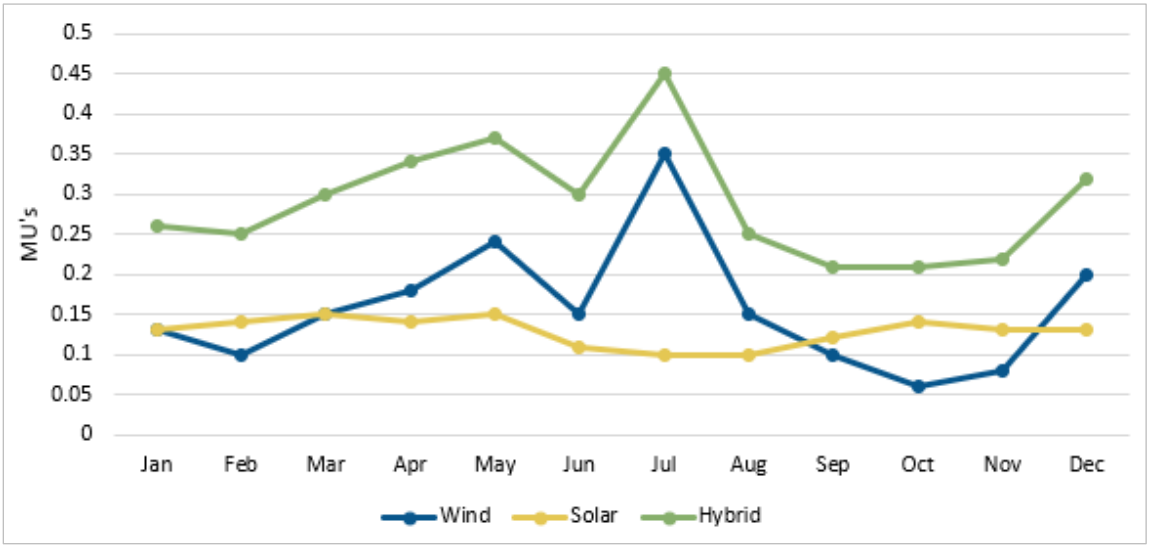
WSH can be an effective solution to address some of these issues. As the peak operating times of wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce dependable power that meets demand. Wind power plants integrated with solar power plants can take care of the morning and evening peaks in the demand curve.

These hybrid plants are designed to act as a single supply of clean megawatt-hours, with average capacity factors far higher than individual solar or wind plants.

Key advantages associated with hybrid projects include:

- Better utilisation of transmission infrastructure and maintaining grid stability;
- Lower generation variability due to hybridisation;
- Better utilisation of land resources;
- Reduced possibility of undesirable power peaks;
- Complementary generation profiles.

Figure 1: India's Monthly Wind, Solar and Hybrid Generation Profile



Source: National Institute of Wind Energy.

WSH systems gained traction in India following the announcement of the National Wind-Solar Hybrid Policy 2018. To be deemed a hybrid project, the policy mandated that the rated power capacity of either solar or wind should be at least 25% of the rated power capacity of the other resource.

Various state governments have come up with their own policies to provide an effective regulatory landscape for the developers. Gujarat came up with its policy first, in June 2018, followed by Andhra Pradesh and Rajasthan. Karnataka and Kerala have also issued draft versions of the policy and more states are expected to follow suit.

Table 1: Comparison of Hybrid vs. Standalone Solar and Wind Plants

Parameters	Wind-Solar Hybrid	Standalone Solar	Standalone Wind
Definition	Combining wind and solar power plants to achieve maximum output.	Power plants harnessing energy solely from solar.	Power plants harnessing energy solely from wind.
Energy Generated	Round the clock as solar and wind are complementary in nature. It reduces daily and seasonal fluctuations.	High during daytime hours when the sky is clear. Highest generation is from 11am to 4pm.	High during late night and early morning hours, and during rainy seasons.
Capacity Utilisation Factor (AC)	35-50%	16-20%	20-26%
Project Cost (AC)	Rs46-48 million/MW	Rs35-40 million/MW	Rs55-65 million/MW
Renewable Purchase Obligations (RPO)	Easier RPO achievements as it contains both solar and non-solar RPO.	Only solar RPO is fulfilled.	Only non-solar RPO is fulfilled.
Transmission Capacity Utilisation	More efficient utilisation	Remains underutilised	Remains underutilised
Energy Demand Met	Can fulfill 75-80% of energy demand even with time of day-based energy restrictions.	Can fulfill only 40-50% of energy requirements, with time of day restrictions and wheeling adjustments.	Can fulfill up to 50% of energy demand with changing wind patterns and banking period restrictions.

Source: JMK Research.

Adding battery storage systems is the key to effectively integrating high shares of solar and wind renewables in power systems. When neither the wind nor the solar systems are producing, most hybrid systems provide power through energy stored in batteries.

While storage costs have gone down by 80% in the last 5 years, a further decline in cost will play a pivotal role in the success of WSH projects in meeting demand reliably.[3]

SECI plans to bring out different types of hybrid renewable tenders with the aim of making renewables more dispatchable rather than just available. The objective is to utilise energy storage in such tenders to elevate the Capacity Utilisation Factor (CUF) of renewables to higher levels. The recently closed 400MW round-the-clock

[3] NREL. Declining Renewable Costs Drive Focus on Energy Storage. 2 January 2020.

(RTC) tender has set requirements of 80% annual CUF with minimum monthly CUF of 70%.

SECI has issued a total of 12,860MW hybrid capacity tenders (with and without storage), of which 4,290MW has been auctioned. According to estimates by JMK Research, about 11.6GW of WSH projects will be operational by 2023.

Policy Analysis

The Ministry of New and Renewable Energy (MNRE) adopted the National Wind-Solar Hybrid Policy on 14 May 2018. The objective of the policy is to provide a framework for the promotion of large grid-connected wind-solar PV hybrid systems for efficient utilisation of transmission infrastructure and land. It also aims to reduce renewable power generation variability and achieve better grid stability.

National Wind-Solar Hybrid Policy 2018

The policy seeks to promote new hybrid projects as well as hybridisation of existing wind/solar projects. The existing wind/solar projects can be hybridised with higher transmission capacity than the sanctioned transmission capacity, subject to availability of margin in the existing transmission capacity.

- **Rated capacity**: To be recognised as a hybrid power plant, the rated power capacity of one resource should be at least 25% of the rated power capacity of the other resource in a wind-solar plant. In terms of system size, in areas where wind power density is high, the size of the wind power system should be significantly higher than the size of the solar power system installed and vice versa.

- **Integration**: On the technology front, the policy provides for integration of both the energy sources i.e. wind and solar at alternating current (AC) as well as direct current (DC) level.

- **RPO fulfilment**: Power purchased from hybrid projects is eligible for fulfilment of RPO obligations depending on the proportion of wind and solar rated capacity.

- **Incentives**: All fiscal and financial incentives available to wind and solar power projects will also be made available to hybrid projects.

- **Transmission Charges**: No additional connectivity/transmission capacity charges shall be levied for already existing plants; however, transmission charges will be applicable for additional transmission capacity.

With significant renewable energy capacity additions in recent years and with the hybrid policy aimed at better utilisation of resources, it is envisaged that this policy will open a new avenue for availability of renewable power at competitive prices along with reduced variability.

State Policies

Various state governments have come up with their own policies to provide an effective regulatory landscape for the developers. Gujarat came up its policy first, in June 2018, followed by Andhra Pradesh and Rajasthan. Karnataka and Kerala have also issued draft versions of the policy and more states are expected to follow suit. These policies mention various waivers and incentives provided to developers including deferred payment of transmission charges and electricity duty among many others.

Table 2: Details of Wind-Solar Hybrid Policies at Central and State Level

Parameter	Gujarat	Rajasthan	Andhra Pradesh	MNRE
Date of Issue	June 2018	December 2019	January 2019	May 2018
Targets	-	3,500MW by 2024-25	5,000MW	-
Operative Period	2018-2023	-	2018-2023	-
Hybrid Definition	-	25:75	25:75	25:75
CUF	-	-	Minimum 40% CUF to be achieved for each 1MW of solar-wind hybrid system.	-
Types Defined	**Type A**: Existing/under construction projects (brownfield) **Type B**: New projects (greenfield)	Type A: Hybridisation of existing wind/solar projects Type B: New projects	-	-
Integration/ Configuration	**Type A**: AC integration only **Type B**: AC integration only in case of separate RPO and tariff. AC/DC integration in case of common RPO and tariff.	-	Either as AC or DC integration based on type of technology being used.	Either as AC or DC integration based on type of technology being used.
RPO Obligation from Hybrid	RPO can be fulfilled. **Type A**: Separately for solar and non-solar. **Type B**: Separate/common RPO allowed.	Mandatory for discoms to purchase power equivalent to 5% of their RPO targets under this policy.	RPO can be fulfilled separately for solar and non-solar.	RPO can be fulfilled separately for solar and non-solar.
Banking	-	Banking charges shall be adjusted in kind at 10% of the energy delivered at the point of drawl.	100% banking allowed during all 12 months of the year. Banking charges are adjusted in kind at 5% of the energy delivered at the point of drawl.	-
Waivers				
Cross Subsidy Surcharge (CSS)	**Captive**: No waivers **Third party sale**: 50% concession	-	50% waived for third party sale projects set up within the state.	-
Additional Surcharge	**Captive**: No waivers **Third party sale**: 50% concession	-	-	-

Transmission and Wheeling Charges	**Captive consumers**: 50% concession to captive consumers on wheeling charges and losses. **Third party sale**: No waivers	**Hybrid**: 50% concession for captive/third party sale for 7 years from project commissioning. **Hybrid + storage**: 75% concession for captive/third party for a period of 7 years from project commissioning.	50% exemption in transmission and wheeling charges for new projects developed within the state.	No additional connectivity/transmission capacity charges shall be levied for already existing plants; however, transmission charges will be applicable for additional transmission capacity.
Electricity Duty	Waived for intrastate consumption.	Waived for intrastate consumption.	50% exemption for intrastate consumption.	-
Others	-	-	Exemption from obtaining NOC/consent from AP pollution control board. Unutilised banked energy will be considered as deemed purchase by discoms at 75% of APPC.	All fiscal and financial incentives available to wind and solar power projects will also be made available to hybrid projects.
Restrictions				
Sanctioned Load	For captive and third-party model, power contracted shall be 50% of the sanctioned load of the consumer for solar and wind respectively. However, the consumer can set up a hybrid project to meet RPO without limit on sanctioned load.	-	-	-
Secondhand WTG/ Modules	Not allowed	-	-	-

Source: JMK Research.

Wind-Solar Hybrid Tender Activity

Tender Issued vs. Capacity Allocation

Since the introduction of the National Wind-Solar Hybrid Policy in May 2018, SECI, the nodal agency, has issued various tenders for wind-solar hybrid (with and without storage).

The first tender, issued by SECI in June 2018, was undersubscribed due to a tariff cap on the lower side. Adani Green Energy and SB Energy emerged as the winners with 390MW and 450MW allocated capacity, respectively.

The next 1,200MW tender, issued in March 2019, also remained largely undersubscribed due to a poor tariff ceiling of Rs2.7/kWh (US¢3.7/kWh). However, Adani Green Energy and ReNew Power emerged as winners for 600MW and 120MW capacity, respectively.

SECI issued the first tender with a mandatory storage component in August 2019. Greenko and ReNew Power emerged as the winners with allotted capacity of 900MW and 300MW, respectively.

It stipulated that the hybrid power developer must maintain an annual CUF of 35% – and a failure to do so would result in the developer being penalised. The minimum energy storage system (ESS) rated energy capacity installed must be equal to "X/2" MWh, where X is the contracted capacity of the project as per PPA. ReNew Power is using battery storage and Greenko pumped hydro storage. Therefore, for ReNew Power, the battery energy storage system (BESS) rated capacity would be 150MWh, while Greenko's pumped hydro storage capacity would be 450MWh.

The industry is optimistic about these tenders which have something new to offer.

SECI introduced the first round-the-clock (RTC) tender in October 2019, signalling a move towards assured, scheduled and affordable supply of RE power. The tender was fully subscribed, with ReNew Power winning the entire 400MW capacity. The developer is mandated to fulfil an annual minimum CUF requirement of 80% and a monthly CUF requirement of 70%.

SECI also introduced 2500MW interstate transmission system (ISTS) blended wind-power projects (Tranche-IX) in March 2020 for blended power (at least 80% wind component and 20% solar).

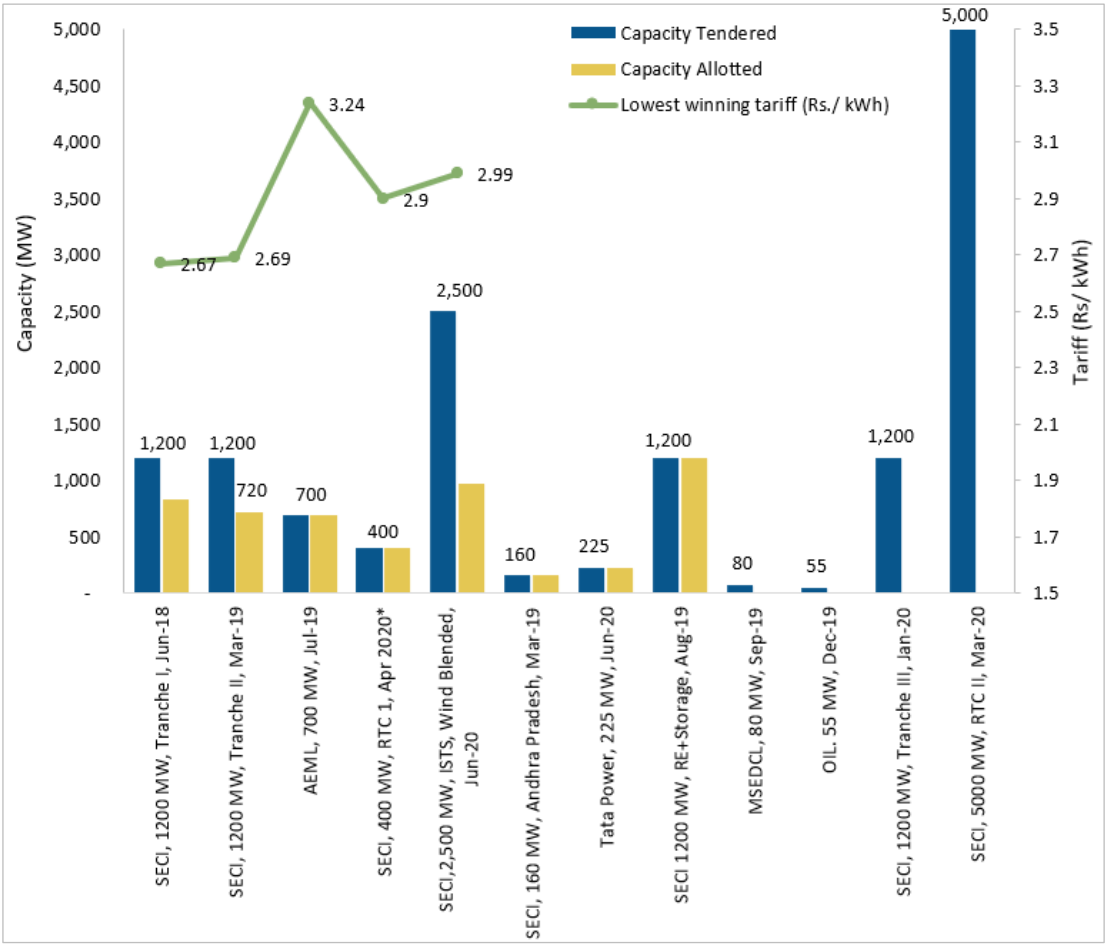
Global Infrastructure Partners' Vena Energy and JSW Solar emerged as the winners with 160MW and 810MW of allotted capacity, at a tariff of Rs2.99/kWh (US¢4.1/kWh) and Rs3/kWh (US¢4.1/kWh) respectively. With this win, JSW Solar

became a new key independent power producer (IPP) to enter the renewable energy sector.

Private players are also taking an interest in the issue of tenders for wind-solar hybrid projects. Adani Electricity Mumbai Ltd. (AEML) floated a 700MW tender which is fully subscribed. Rosepetal Solar Energy Private Ltd. (a wholly owned subsidiary of Adani Green Energy Ltd.) won the tender at a tariff of Rs3.24/kWh (US¢4.4/kWh).

Recently, Tata Power Company Ltd. also issued a letter of award (LoA) to Tata Green Power for 225MW hybrid capacity.

Figure 2: Capacity Allocation for Different Tenders



Source: JMK Research.
** First year tariff is Rs.2.9/kWh with an escalation of 3% until the end of 15th year.*
Note: Awarded tariffs in India have zero inflation indexation over the 25-year power purchase agreement, meaning the real tariff is contractually set to decline annually, driving electricity system deflation.

The rates quoted in these auctions are competitive and the industry is optimistic about these tenders which have something new to offer. SECI's Tranche-I and Tranche-II saw an under-subscription because the tariff ceilings were set extremely low. Tranche-I and Tranche-II saw the lowest bidding tariffs of Rs2.67/kWh (US¢3.70/kWh) and Rs2.69/kWh (US¢3.73/kWh), respectively. AEML secured a fixed PPA tariff of Rs3.24/kWh (US¢4.50/kWh) for a period of 25 years.

The RE with storage projects saw a slight tariff increase of Rs0.19/kWh (off-peak) over the previous tender. The storage tender has two components – flat tariff (off-peak) and peak tariff. The off-peak tariff was Rs2.88/kWh (US¢4/kWh) and the price discovered for the peak tariff for Greenko and ReNew Power was Rs6.12/kWh(US¢8.50/kWh) and Rs6.85/kWh (US¢9.51/kWh), respectively.

Further, the RTC tender by SECI is the first of its kind in the RE space globally. However, the price discovered in the RTC tender is overly aggressive at Rs2.90/kWh (US¢4/kWh). It remains to be seen how the company will be able to maintain a minimum annual CUF of 80% at such a low tariff.

Table 3: Status of Tenders Issued in Hybrid + Storage Market in India

Tender	Status	Date of Issue	Capacity Tendered (MW)	Capacity Allotted (MW)	Winners	Annual CUF (%)	Location	Storage Component
SECI Tranche-I	Under construction	Jun-18	1,200	840	Adani Green (390MW Rs2.69/kWh) SB Energy (450MW Rs2.67/kWh)	40%	Pan India	75:25 ratio of solar to wind or vice versa
SECI Tranche-II	Auction completed	Mar-19	1,200	720	Adani Green (600MW Rs2.69/kWh) ReNew Power (120MW Rs2.7/kWh)	30%	Pan India	75:25 ratio of solar to wind or vice versa
Adani Electricity Mumbai Limited (AEML)	Auction completed	Jul-19	700	700	Adani Green (Rs3.24/kWh)	50%	Maharashtra	Optional
SECI RE with Storage	Auction completed	Aug-19	1,200	1200	Greenko (900MW off-peak tariff Rs2.88/kWh. Peak tariff Rs. 6.12/kWh) ReNew Power (300MW off-peak tariff Rs2.88/kWh. Peak tariff Rs6.85/kWh)	35%	Pan India	Mandatory
SECI RTC-I	Auction completed	Oct-19	400	400	ReNew Power (Rs2.9/kWh with escalation of 3% for 15 years)	80% (annual) 70% (monthly)	Pan India	Optional
SECI RTC-II (Thermal + RE)	RFS issued	Mar-20	5,000	-	-	80%	Pan India	Optional
Oil India Ltd. (EPC)	RFS issued	Dec-19	55	-	-	-	Gujarat	75:25 ratio of solar to wind or vice versa

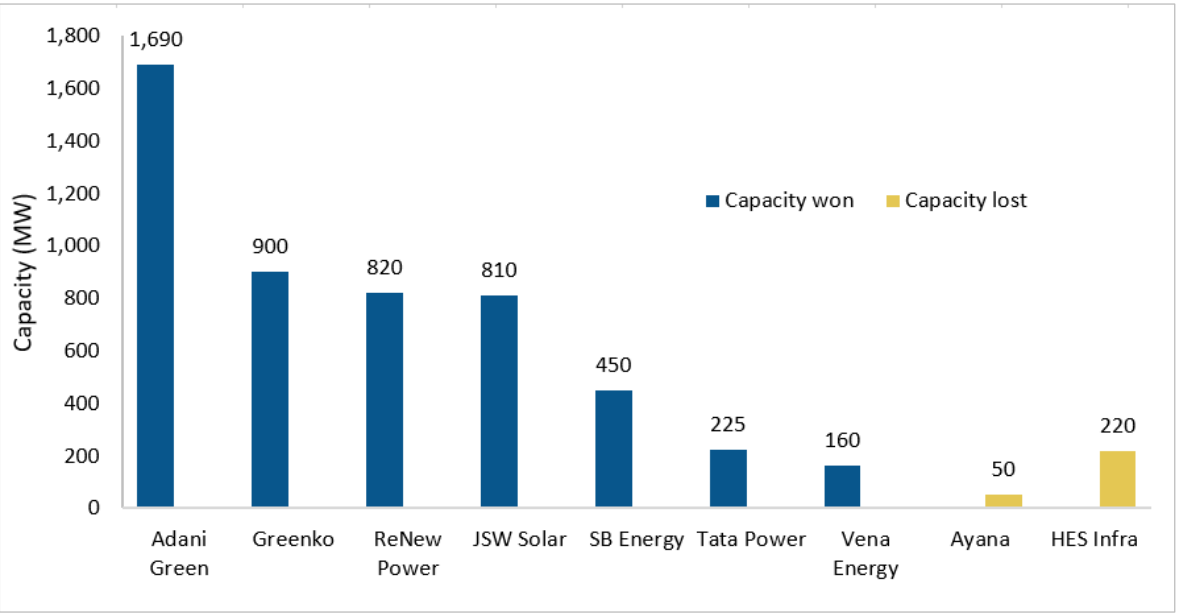
SECI and World Bank	Under construction	Mar-19	160	160	-	-	Andhra Pradesh	20MWh battery storage
SECI Tranche-III	RFS issued	Jan-20	1,200	-	-	30%	Pan India	75:25 ratio of solar to wind or vice versa
Tata Power Company Ltd.	RFS issued	Jun-20	225	225	Tata Power	35%	Maharashtra	Rated capacity of solar or wind should be more than 25% of the other. Wind component capped at 50% of the project capacity.
Maharashtra State Electricity Distribution Company Ltd. (MSEDCL)	RFS issued	Sep-19	80	-	-	20.5%	Maharashtra	75:25 ratio of solar to wind or vice versa
SECI, ISTS (Tranche IX)	Auction completed	Mar-20	2,500	970	Vena Energy Renewables (160MW Rs2.99/kWh) JSW Solar (810MW Rs3/kWh)	30%	Pan India	Hybrid with 80% wind and 20% solar

Source: JMK Research.

Key Players

Adani Green is the forerunner in wind-solar hybrid with a total capacity allocation of 1,690MW, followed by Greenko (900MW), Renew Power (820MW), JSW Solar (810MW) and SB Energy (450MW). There are also other active participants, such as Ayana Renewable Power and HES Infra Pvt Ltd, that have unsuccessfully bid for the tenders and have yet to make their presence felt in this market segment.

Figure 3: WSH Capacity Allocation to Various Players



Source: JMK Research.

Apart from long-term PPA projects with discoms, some project developers, such as CleanMax and Continuum Wind Energy, have recently started building wind-solar hybrid portfolios through the third-party sale/open-access model for corporate consumers.

Most of these players are exploring brownfield projects with good windy sites to build private RE farms to cater to growing demand from corporate consumers to reach their RE100[4] targets. Given the waivers that are available for hybrid projects under various state policies, this market presents a lucrative opportunity to cater to corporate consumer demand in the long run.

The hybrid market presents a lucrative opportunity to cater to corporate consumer demand in the long run.

[4] RE100.

Likely Capacity Addition in Next 3 Years

A total of 148.8MW of wind-solar hybrid capacity has been commissioned to date.

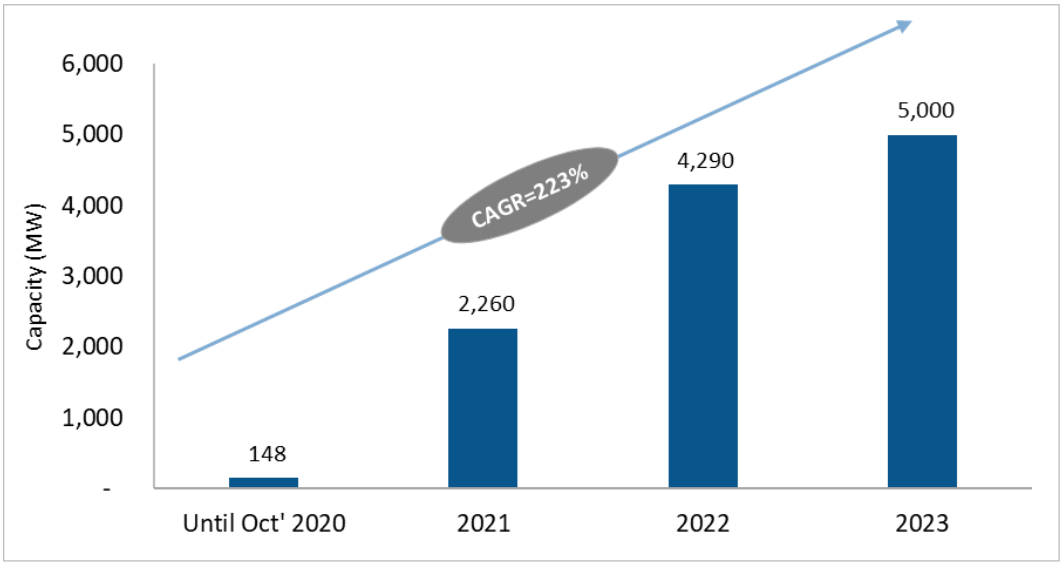
In April 2018, India's first wind-solar hybrid project including 50MW of wind and 28.8MW of solar was developed on a pilot scale by Hero Future Energies.

In July 2020, CleanMax developed a 15MW wind-solar hybrid captive power plant for US food giant, Cargill.

In June 2020, Continuum Wind Energy installed a 55MW hybrid plant in Periyapatti, Tamil Nadu.

As per the tenders allotted under various central and state schemes, the capacity addition of such projects is expected to grow at a CAGR of 223% to reach about 11.6GW in the next three years. The likely capacity addition is provided in the figure below.

Figure 4: Expected Wind-Solar Hybrid Annual Capacity Addition 2020-2023



Source: JMK Research.

Tariff Analysis

To understand tariff trends in the WSH market in India, we developed a financial model for a 250MW wind-solar hybrid co-located project based on the various assumptions.

The cost of a co-located system is 7-8% lower than the cost of a standalone solar system.[5] Co-locating the WSH and storage subsystems produces cost savings by reducing costs related to site preparation, land acquisition, interconnection, hardware (via sharing of hardware such as switchgears, transformers, and controls) and other installation overheads.

Four different scenarios have been considered for evaluation. Across all of these scenarios, a solar overloading factor of 40% is considered.

Key project costs across the various scenarios include solar PV module and wind turbine costs (60%) and balance-of-system (BOS) cost (25%). The project is considered as part of the solar park, so upfront charges must be paid for land on a lease basis. Land cost about is 3-4% of the total project cost. Other costs, including transmission cost, preliminary and preoperative expenses, contingency cost and interest during construction (IDC), constitute the remaining 9% of the total project cost.

The four scenarios are:

- **Scenario 1: 250MW co-located hybrid project with 80:20 split between solar and wind without a battery backup.**

  The levelised tariff comes to around Rs2.49/kWh (US¢3.32/kWh).

- **Scenario 2: 250MW co-located hybrid project with 50:50 split between solar and wind without a battery backup.**

  The levelised tariff comes to around Rs2.57/kWh (US¢3.43/kWh).

- **Scenario 3: 250MW co-located hybrid project with 50:50 split between solar and wind with a 2-hour battery backup.**

  The levelised tariff comes to about Rs4.59/kWh (US¢6.12/kWh). If the battery backup is used only for 1 hour in this scenario instead of 2 hours, the effective tariff comes down significantly to Rs3.59/kWh (US¢4.8/kWh).

- **Scenario 4: 250MW co-located hybrid project with 80:20 split between solar and wind with a 2-hour battery backup.**

  The levelised tariff comes to about Rs4.76/kWh (US¢6.35/kWh). If the battery backup is used only for 1 hour in this scenario instead of 2 hours,

[5] NREL. 2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark. November 2018.

the effective tariff comes significantly down to Rs.3.65/kWh (US¢4.9/kWh).

Based on this analysis, tariffs are lowest in Scenario 1, where solar capacity is 80% of the total hybrid project capacity with a DC overloading factor of 40%. Some developers are even considering a DC overloading factor of as high as 50%, in which case the tariffs come down to about Rs2.47/kWh (US¢3.29/kWh).

It is also clear that adding battery storage is not a feasible option at present, because it significantly increases project costs and hence the tariffs.

Further, due to aggressive tariff trends in recent solar auctions in India, at Rs2.36/kWh (US¢3.14/kWh) with zero inflation indexation over the 25-year PPA, the discoms are tariff-shopping[6] and are reluctant to ink power supply agreements (PSAs) for relatively higher tariff projects.

The COVID-19-induced collapse in demand has made this even more problematic as discoms have contracted excess supply, with thermal power plant contracts often incorporating capacity payments due even if they don't take the generation.

This is likely to create issues with the newly auctioned RTC and RE + storage projects.

Table 4: Assumptions for Analysing Tariffs for Hybrid Projects in India

	WSH Without Storage		WSH With Storage	
Parameters	**Scenario 1**	**Scenario 2**	**Scenario 3***	**Scenario 4***
Solar to Wind Ratio	80:20	50:50	50:50	80:20
Project AC Capacity	250	250	250	250
Battery usage	-	-	2 hours	2 hours
DC Overloading Ratio[7]	40%	40%	40%	40%
Project Cost AC (Rs Million/MW)	48	54	74	68
Project Cost AC (US$ Million/MW)	0.64	0.72	0.99	0.91
Capacity Utilisation Factor – PV Solar	19.5% DC CUF 27.3% AC CUF	19.5% DC CUF 27.3% AC CUF	19.5% DC CUF 27.3% AC CUF	19.5% DC CUF 27.3% AC CUF
Capacity Utilisation Factor – Wind	36%	36%	36%	36%

[6] Livemint. Discoms Leave 16.8GW Solar and Wind Projects in a Bind. 20 August 2020.

[7] A solar power plant rarely produces nameplate capacity power as solar modules operate at their maximum efficiency only during limited peak hours. It has, therefore, become routine industry practice to over-size DC module capacity to generate more power – a concept commonly known as DC overloading.

Solar PV Modules	Mono PERC	Mono PERC	Mono PERC	Mono PERC
WTG Size	2MW	2MW	2MW	2MW
Degradation Factor for Modules	2.5% for first year and then 0.6%	2.5% for first year and then 0.6%	2.5% for first year and then 0.6%	2.5% for first year and then 0.6%
Depreciation	3.6% (straight line method) for 25 years	3.6% (straight line method) for 25 years	• 3.6% (straight line method) for 25 years for wind and solar • 9% for first battery life and 6% for second battery life	• 3.6% (straight line method) for 25 years for wind and solar • 9% for first battery life and 6% for second battery life
Useful Life of Asset	25 years	25 years	25 years	25 years
Loan Tenor	18 years	18 years	18 years	18 years
Interest on Loan	9.5%	9.5%	9.5%	9.5%
Return on Equity	13%	13%	13%	13%
Debt to Equity Ratio	75:25	75:25	75:25	75:25
Levelised Tariff (Rs/kWh)	2.49	2.57	4.59	4.76
Levelised Tariff (US¢/kWh)	3.32	3.43	6.12	6.35

Source: JMK Research.

Note: 1 USD is considered equivalent to 75 Indian Rupees.

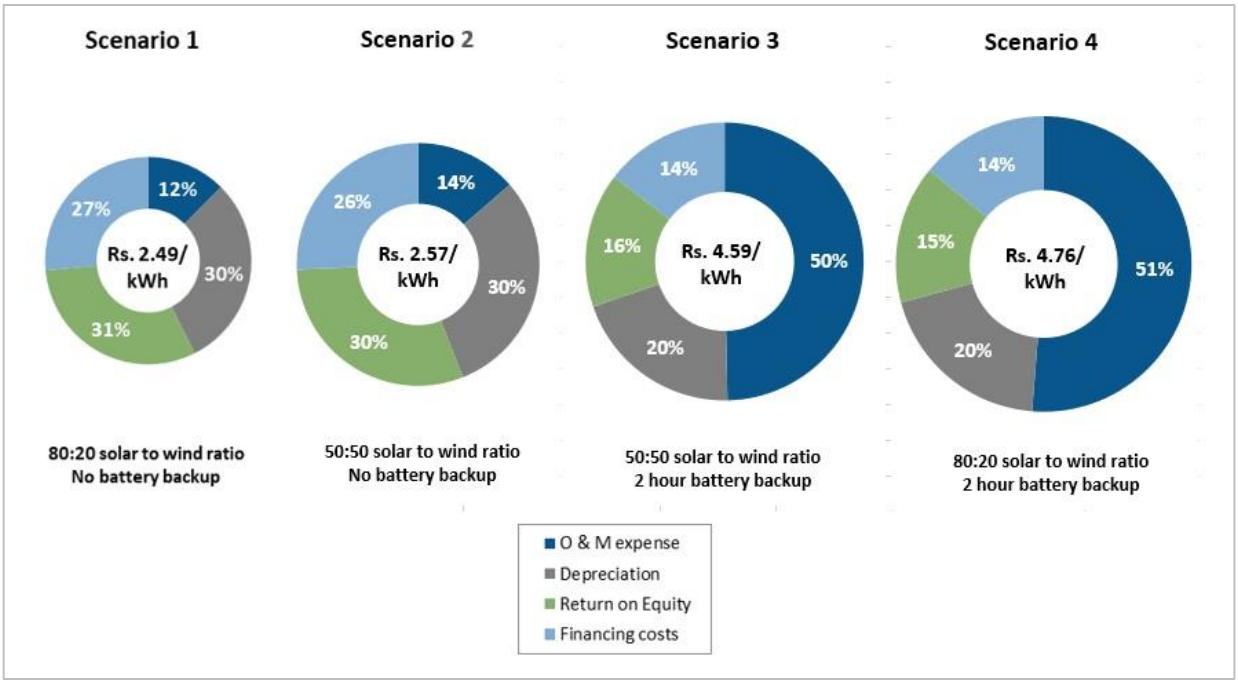
**Battery specification considered for analysis:*

- *EPC prices for storage: US$270/kWh (assuming storage component will be added after 2 years)*
- *Depth of discharge: 80%*
- *Round trip efficiency: 81%*
- *Charge discharge per day: 1 cycle*
- *Lithium-ion battery*
- *250MWh battery capacity (125MW used for 2 hours for peak supply)*

- *Life cycle of 10 years (Replacement considered after 10 years)*
- *15 years for 2nd battery (considering technological advancements)*

The addition of storage with RE plants is still a way off – it might take 2-3 years for adoption in the case of distributed/rooftop solar and 4-5 years for utility-scale plants. This will materialise when battery prices fall substantially alongside an increasing share of progressively lower-cost renewables in the total generation portfolio, resulting in storage becoming imperative.

Figure 5: Component-Wise Breakdown of Tariffs for Hybrid Projects



Source: JMK Research.
Note: O&M expense is higher in case of RE + storage plants as new battery will be replaced after 10 years for which additional cost will be incurred which is included as part of O&M expenses only. Battery prices after 10 years are estimated to reduce to US$120/kWh.

As per the above analysis, return on equity contributes highest chunk of the tariff of pure wind-solar hybrid projects. Since expected return on equity is higher in India (13%) compared to foreign countries, overall cost of financing in India is also on higher side and hence interest on debt is a major contributor to the overall tariff.

For hybrid projects with storage, the biggest component of tariffs is O&M expenses, followed by depreciation costs. O&M expenses are higher in the case of RE + storage plants as new batteries will be replaced after 10 years for which an additional cost will be incurred, which is included as part of O&M expenses only.

Risks and Challenges

Wind-solar hybrid has merit over standalone wind and solar. However, developers in this market are grappling with certain issues such as lower tariffs, policy uncertainty and technical challenges. Key issues and challenges include:

- **Land constraints**: Minimum CUF of 32-38% is expected in the tenders, which means that most of the capacity must be wind-based. However, installing new wind capacity is a challenge as most of the good, high wind potential sites with grid access are already saturated. Land constraints have always been a key issue in the Indian renewable energy sector. Implementation of a 'co-location' clause in certain tenders can be

dismal to the developers who are looking forward to a more flexible policy. India also has a significant opportunity to 'repower' end-of-life wind farms in prime locations, particularly in Tamil Nadu.

- **Integration challenges**: Technical challenges in integrating both wind and solar with the grid on the DC side. As per the MNRE policy, till the time the DC metering framework is not in place, only AC integration is permitted. This reduces the cost benefits associated with DC integration in terms of utilisation of the balance-of-system (BOS).

- **Lack of experience**: Presently, there is a lack of experience in executing hybrid plants due to a shortage of skilled resource availability.

- **System sizing**: Sizing of the plant to optimise the generation portfolio differs from site to site based on the potential available for wind and solar resources. The most optimal sizing of storage is also a key question. A high capacity installation can result in an underutilisation risk during high RE generation days when there will be almost no utilisation of storage.

As the sector matures, most of these issues can be addressed by having a more coherent policy and standards in place. The technical issues can be taken care of by having proper design, advanced fast response control facilities, and good optimisation of the hybrid systems. Policy corrections coupled with phasing out technical inefficiencies will ensure that WSH gains the requisite traction.

Conclusion

India is well suited to wind-solar hybrid projects as the potential of both wind and solar resources is vast across various locations. Given the inherent complementary nature of both wind and solar resources, the plant load factor (PLF) can be increased to about 50% vis a vis 20-35% PLF for standalone solar or wind plants.

The government has also tendered out some large-scale investments in this area that will drive this market. To further increase the share of WSH in the overall energy mix, some policy-related changes must be explored.

More states should follow suit to come up with coherent and comprehensive policy in alignment with the National Wind Solar Policy 2018. States can reserve a certain percentage of their renewable targets for WSH, along with providing impetus in the form of waivers and incentives designed to help grow the market. Criteria of co-location should be made optional for the developers, so that they can find ideal locations to set up the plants.

SECI has taken the lead by regularly coming up with large tenders to scale up market growth. The government is now also planning to hold renewable energy auctions for RTC and hybrid projects instead of plain solar or wind tenders.[8] The

[8] *Economic Times*. MNRE May Now Hold Auctions Only for RTC and Hybrid Projects. May 2020.

objective is to reduce the problem of intermittent supply and make clean power more competitive against traditional thermal plants.

Moreover, the government should also plan to structure hybrid-plus-storage tenders with CUF in a range that will not demand oversizing. This is likely to be the case for RTC tenders with a condition in place of 80% annual CUF.

In addition, battery storage is likely to make sense for commercial and industrial (C&I) consumers for onsite rooftop solar plants. It is expected that in the next 2 years, battery storage will take up about 20% of all C&I installations in India. Although for utility-scale renewable plants, battery storage is unlikely to be an economically feasible option for 4-5 years.

Falling battery prices alongside an increasing share of renewables in the total generation portfolio will drive the adoption of battery storage which will become an important element in the total power generation mix.

About JMK Research & Analytics

JMK Research & Analytics provides research and advisory services to Indian and International clients across Renewables, Electric mobility, and the Battery storage market. www.jmkresearch.com

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

About the Authors

Jyoti Gulia

Jyoti Gulia is the Founder of JMK Research. Jyoti has about 14 years of rich experience in the Indian Renewable sector. Her core expertise includes policy and regulatory advocacy, assessing market trends, and advising companies on their business strategy. She has worked with leading management consulting companies in the renewable sector including Bridge To India, Tecnova, Infraline and CRISIL.

Vibhuti Garg

Energy Economist Vibhuti Garg has advised private and public sector clients on commercial and market entry strategies, investment diligence on power projects and the impact of power sector performance on state finances. She also works on international energy governance, energy transition, energy access, reallocation of fossil fuel subsidy expenditure to clean energy, energy pricing and tariff reforms.