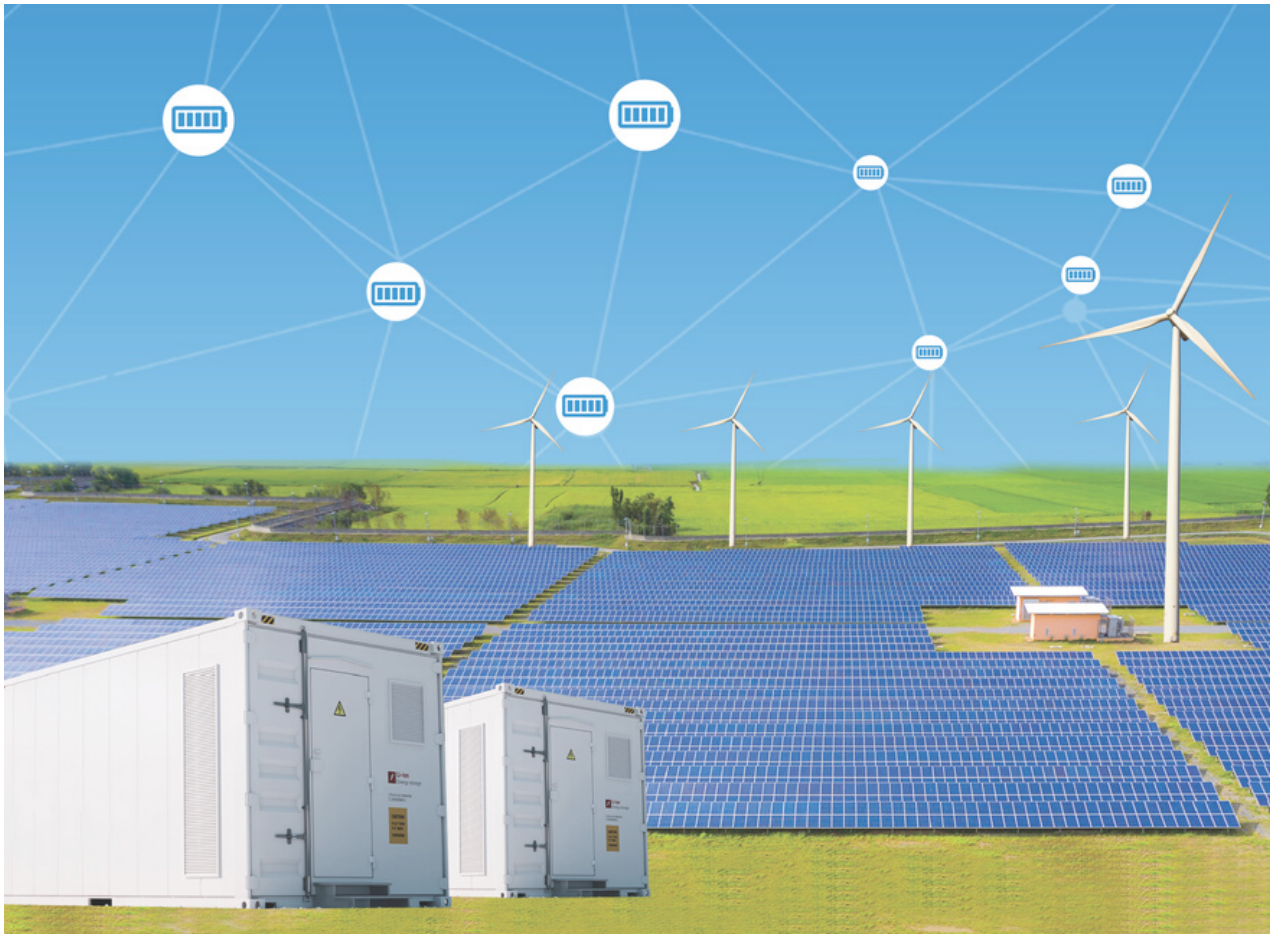
IESA
India Energy Storage Alliance



KNOWLEDGE PAPER ON THE NEED OF HYBRIDS IN RENEWABLES SECTOR

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10 YEARS
2010 2020
Customized Energy Solutions (India)

CONTENTS

Introduction

The Indian power sector has changed in many ways over the last one decade. The grid once dominated by conventional sources of energy has slowly been transforming to a more diversified grid. If we compare the capacity mix over the decade it shows that the percentage of coal in the Indian grid has not changed much, what has changed over time is the increase in the percentage of renewables in the grid and the decrease of other sources like diesel, gas, oil etc. In 2015, when the Government of India set itself the target of 175 GWs of renewables by 2022, it was seen as a very ambitious target. But when we see back today there has been considerable growth in the renewable sector over the last 5 years.

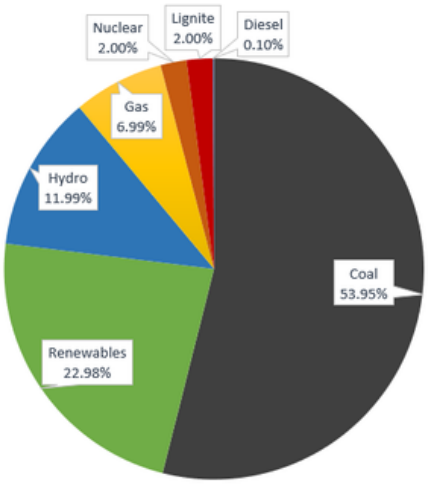


Figure 1: Generation Mix - 2020

In the starting of the decade (2010) renewables represented 10% of the generation mix, today it represents 23% of the capacity mix and around 14% in terms of generation mix. The government has promoted the growth equally with policies like must-run status for renewables and formalizing competitive bidding from the erstwhile Feed-in-Tariff regime. The industry has seen a growth of

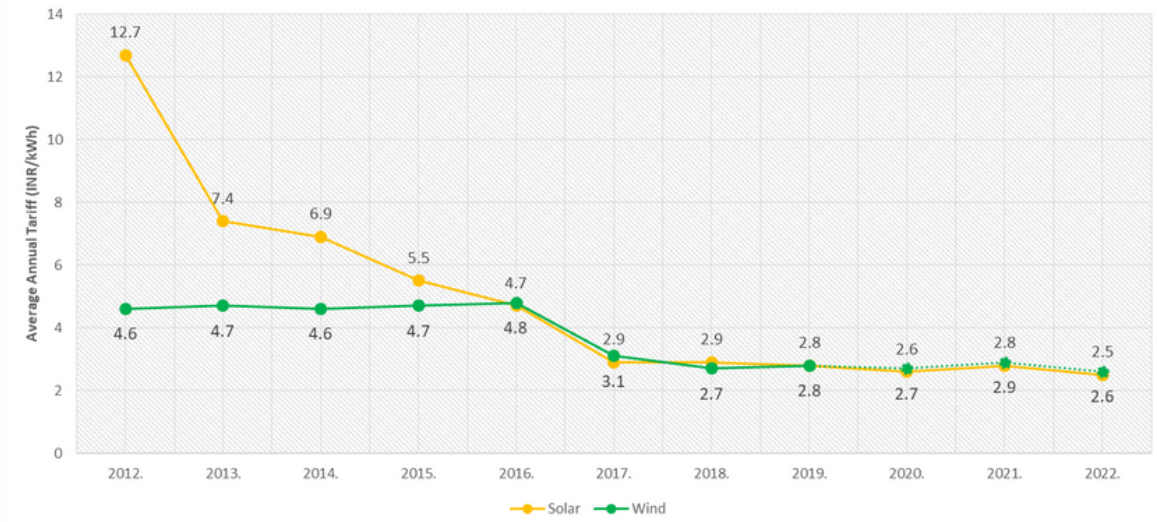


Figure 2: Tariff Trend in Renewables

more than 200% over the last decade. The tariffs also have reduced considerably from the ranges of ₹4 to 5/kWh to ₹2.8/kWh for wind and from ₹12.7 to 2.8/kWh for Solar. The tariffs are expected to further reduce to around ₹2/kWh by 2030. The renewables industry saw exemplary growth in 2016 and 2017 (22% and 37% respectively), but over the last two years the growth percentages have been low and the industry itself has been looking for the next inflection point. This to some extent is because both the industries are towards the end of their growth phase or in the early maturity stage and there-by we see the decrease in the growth percentages.

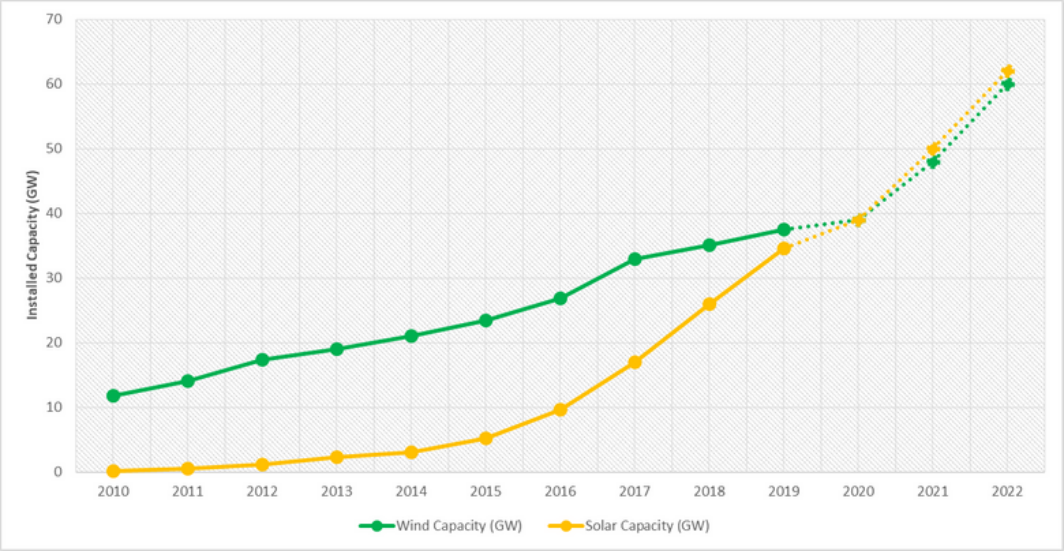


Figure 3: RE Growth 2010 - 2019

What will help here is an inflection, which will enablethe growth curve to sustain further. But with government commitments, push and targets of having 450 GW of renewables (300GW – solar, 140 GW-wind, 10 GW-biomass) in the grid by 2030 i.e. 54% of the grid generating capacity, much more than the estimated coal percentage in the grid at 2030 (32%). The total wind potential of India is calculated as 302 GW at 100-meter height and 600+GW at 120-meter height and for solar it is 794 GW. Today, we are just at 37.7GW for wind and 34 GW for solar, which means a lot more is to come in the renewables industry. With improvements in technology, there has been an increase in efficiency, life, capacity utilization and thus has further resulted in lower Levelized Cost of Energy (LCOE) numbers. As per report from BloombergNEF ('BNEF), LCOE for wind ranges from 37-to-50 $/MWh and for solar it ranges between 28 to 45 $/MWh as on today and will be seeing further reduction going forward.

The Growth of Renewables

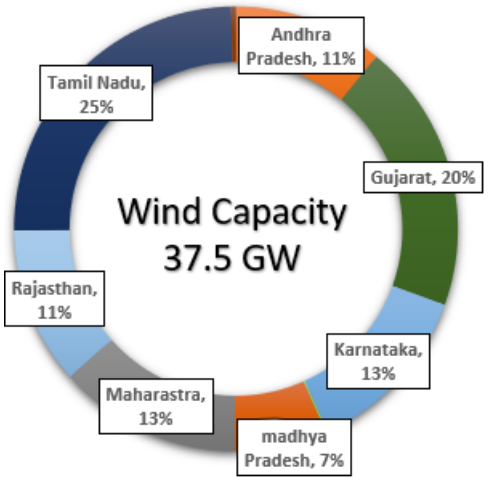


Figure 4: Top Wind Generating States

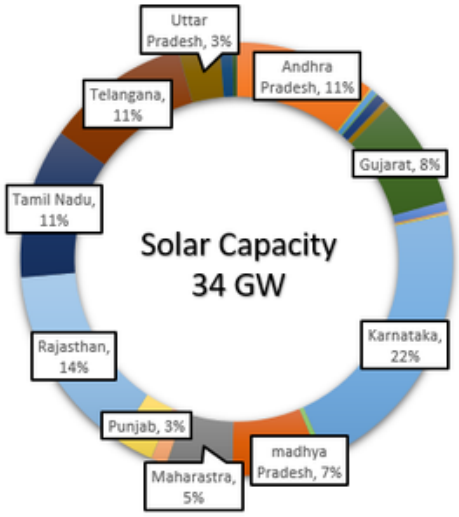


Figure 5: Top Solar Generating States

When we look into the wind generation spread across India, almost 96% of the total generation from wind is coming from 5 states, namely Tamil Nadu, Gujarat, Andhra Pradesh, Karnataka and Maharashtra. The wind capacity is projected to reach 140GW by 2030, representing 17% of the total generation capacity of the country. We are today at 37.7GW which is 62.5% of our 2022 target of 60 GW. India Energy Storage Alliance (IESA) analysis projects that in business as usual condition, India can achieve the target of 60GW by 2024, but with more proactive approaches and clarity in policy, the same is possible to be achieved by 2022.

When we analyze the spread of solar in the country it is much more spread out. Of the 34.5GW capacity that is installed, 22% comes from Karnataka,followed by Rajasthan, Tamil Nadu, Andhra Pradesh and Telangana at 11% each. But the overall demographic for wind is more spread across India. The same can be realized from the pie chart as depicted in Figure 5. The target for solar capacity by 2022 is set at 1100 GW, we are today at 37% of that target, which essentially means that the number of installations/ year and the number of tenders and its size being released has to increase a lot if we are to achieve the target of 100 GWs by 2022. As per analysis done by IESA, we estimate that under normal business conditions, India will be able to achieve the target of 100 GWs by late 2024, while with active focus and meeting of annual targets as set by MNRE, the same can be achieved by 2022.

Challenges in the Renewables Sector

As discussed above the renewable penetration in the Indian grid has been increasing year on year, from being 10% in 2010 to being 23% as on date and projected to be around 54% by 2030. The government has also ably supported this growth by giving renewables the status of 'must run'. But, with the increase penetration there has been challenges too, specially from the grid perspective. Over the last five years, the reserve margin in Indian grid alone has increased from 51% to 72%. What this also means is that conventional plants are being made to run at very low utilization factors and some of them are being shut down. This increases the variability in the grid as renewables itself is variable in nature. So, in effect we are increasing the vulnerability of the grid with increase of renewables in the grid. This is creating a huge concern for the state DISCOMs who are increasingly raising alarm on the grid dynamics. Projections show that by 2024, the Indian grid will have around 100 GWs of solar generation. This means that in early morning hours and late evenings, there will be a substantial ramping challenge that the grid will face. In early morning to cater to the solar generation and reduce the conventional load and in evening to cater for the fall in solar generation and increase the other generations. Our inhouse estimates show that ramping rate can increase to around 130% from today's level in 2030. This in figures comes to around 350 MW/min for a longer period of time (4 hours). Therefore, there is a worry on how robust as a grid are, to handle such dynamics. The DISCOMs also have their own renewable purchase obligation to meet which further causes concerns for them.

The 2012 Indian Grid Blackout has also given rise to many strict regulations to make grid responsible. This includes stricter DSM management protocols with high penalties for violating schedules, narrower frequency bands and more stringent rules for upgrades and maintenance cycles. Over and above this, the increase in rooftop solar in urban cities mainly has created problems of back feeding at the Distribution Transformer levels. The question which arises here is that is the existing infrastructure capable of handling this dynamic? One issue with DTs itself is its placement in cities. Which makes upgrades a very exhaustive and expensive task. One should also not forget about the captive power generation, which also ends up relying on the grid for reliability and in turn increases uncertainty of operations for the grid. There has been talks of making the load management blocks from 15 minutes at present to 5 minutes, which means the level of load management dynamic will only increase going forward.

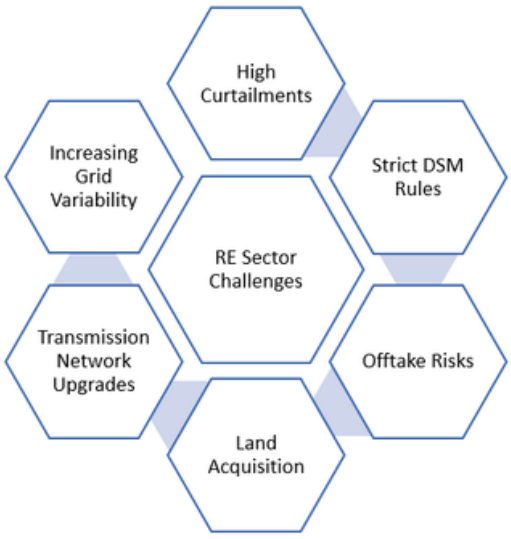


Figure 6: Industry Challenges

Talking of renewables expansion itself, the journey ahead will not be very smooth. The industry itself has been facing a number of hurdles starting from anti-dumping duties, not enough local manufacturing capacity, availability of land, DISCOM payment issues. Over and above this, one concern is that a lot of the potential of wind and solar that is estimated falls under agricultural and forest lands, where itbecomes very difficult to acquire land. Equipped with this is issues with reliability, which makes DISCOMs still consider this increased penetration a risk. Forecasting and Scheduling regulations has addressed a part of this risk but with the forecasting tools itself having inherent inaccuracies, the resulting forecasting compliance takes a hit, which also results in revenue losses. One more problem here is evacuation constraints. With the increase of renewables, the evacuation network has not been expanded in unison, which has now resulted in power curtailment concerns during high renewable resource months. Most of these wind or solar farms require transmission capacity additions or TL expansions as per the National Electricity Plan Vol II-Transmission. The report states 47 GVA of transmission addition is necessary by 2022 with RE target hits 175 GW. From Customized Energy Solutions analysis, it was observed that the peak RE generation crosses 100GW only 1.3% of the time (in 2022) for which transmission investment can be saved with the installation of a BESS for 5GW/15GWh. While several wind and solar farms are farther than 50kms away from the existing transmission structure. Nearly 50% of the projects are well within this range (of 50kms). By installing an ESS to store the peak generation, there can be significant savings on the transmission line investments. Hence by reducing 1.3% of the power from being transmitted across the lines, there can be savings on the transmission cost of constructing about 6 GVA of substations and transmission line capacities. These energy storage units can be also utilized for alternate application such as RE firming and RE output smoothening, thus the overall benefit is multiplied.

All these together makes the journey towards 2022 a more challenged one henceforth.

The Uniqueness of Wind and Solar Resources - Opportunity

Wind and solar resources are complimentary to each other. In the day times, when the solar irradiance is high, wind speed is relatively low, whereas during the early morning or late evening hours when due to non-availability of sun, solar generation plummets, the temperature difference created helps in wind speeding up during such times. This can be easily be observed in the monthly trends of solar and wind resources. Also,

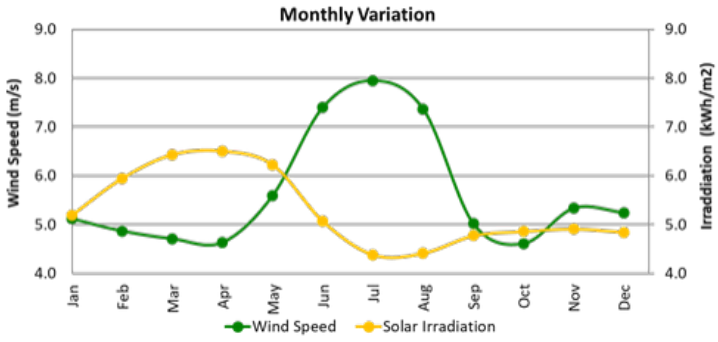


Figure 7: RE Monthly Variation

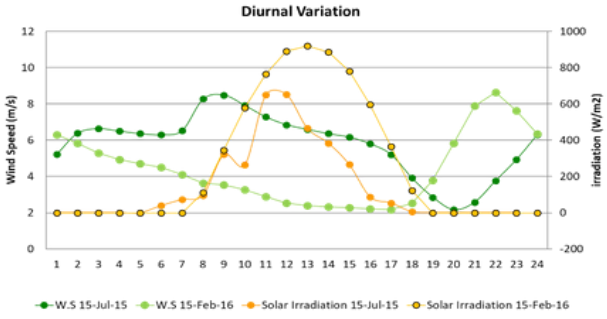


Figure 8: RE Diurnal Variation

the amount of irradiance and wind speed depends upon the month and based on the same, the pattern of both wind and solar resource changes considerably. The same can be seen in the diurnal chart. During monsoons, wind speed generally remains high throughout the day and reduces a bit towards evening, whereas solar is very fluctuating and low during the day time. Whereas during February and March when there are almost no cloud covers, solar is much less variant. This complimenting nature of wind and solar resources can be made utilized and this alone solves many raising issues in the renewables industry. If we combine wind and solar together then as a plant, they can address to issues like better land utilization, cost economics due to shared infrastructure and also address to some extent the issue of variability.

To address this concern, hybrids has been gaining importance over time. As on date, over 50 hybrid projects are announced worldwide. Australia and the US have been the leaders in this space. Simply put, a hybrid system can combine wind, solar with an additional resource of generation or storage. This in many ways solves the issue of intermittency and round the clock power for renewables. When added with storage it also helps renewables become reliable. The storage of energy can be through various forms, electrochemical, pumped hydro, gas peakers, gravity storage, flywheels, or others. Pumped storage is preferred for longer duration of storage, with electro-chemical, specially lithium-ion batteries (based on cost economics) are more helpful for shorter durations of 4-to-6 hours.

Indian National Wind Solar Hybrid Policy

The Ministry of New and Renewable Energy (MNRE) in India released a solar-wind hybrid policy in 2018. This provides a framework to promote grid-connected hybrid energy through set-ups that would use land and transmission infrastructure optimally and manage the variability of renewable resources to some extent. The policy aims to provide a framework for large-scale hybrids, while also encouraging new technologies and methods to carry out hybridization. It also encourages the procurement of hybrid power through transparent bidding processes, which could consider capacity delivered at grid interface point, effective capacity utilization factor (CUF), and the unit price of electricity. Existing projects wishing to go hybrid may do so under various conditions. These mainly relate to transmission charges and transmission capacity as well as separate rules for AC and DC integration of such projects.

The policy states: "In case of fixed speed wind turbines connected to the grid using an induction generator, the integration can be on the HT side at the AC output bus. However, in case of variable speed wind turbines deploying inverters for connecting the generator to the grid, the wind and the solar PV system can be connected to the intermediate DC bus of the AC-DC-AC converter."

The original draft policy first issued in June 2016 had targeted 10GW of hybrids by 2022, but no target has been set in the final policy. Some of the Indian States has also come out with state-specific hybrid policies. The states of Andhra Pradesh, Kerala and Rajasthan have released draft versions of the policy, while it is expected that more states will follow suit.

Salient Features of the Policy:

- The hybrid power injected to the grid cannot exceed the transmission capacity or grid connectivity sanctioned for the existing wind or solar project. It is to ensure that no augmentation of transmission capacity is required.

- No additional connectivity or transmission capacity charges will be levied by respective transmission entity for installing the solar PV or wind turbine generators considering that same transmission capacity is being used.

- Assessment of solar and wind power injected in to the grid through main meter from the hybrid project will be worked out on the basis of readings of AC meters installed on LT side of the WTG and solar PV plant in case of AC integration and in case of DC integration on the basis of readings of DC meters installed at the DC output of the wind and solar PV plant.

- The additional solar/wind power generated from the hybrid project may be used for captive purpose or may be sold: (a) to the respective distribution company at FIT determined by the respective state regulator or the latest lowest bid price discovered by SECI or any other government agency through transparent bidding process whichever is lower; or (b) to the respective distribution company at APPC under REC mechanism and avail RECs.

- The developer has the option to use the hybrid power for captive use or to a third party or DISCOMs at a price determined by the respective SERC for that hybrid power project.

- The hybrid power so purchased by DISCOM may be used to offset both solar and non-solar RPO.

- The hybrid power may be procured through a transparent bidding process under different mechanisms.

- Parameters that may be considered for bidding could be total capacity delivered at grid interface point, CUF and unit price of electricity.

Figure 9: Hero Future Energies Planned Wind-Solar-Storage Hybrid Project, Raichur

Figure 10: 100 MW / 129 MWh Tesla project, Australia (Wind with Storage)

RE Hybrid Projects Update

The concept of combining wind, solar, and storage in single projects is not new. However, recent hardware price declines now make large-scale projects economical. Some early examples of hybrid projects are early energy storage test sites built alongside solar and wind generation in Europe. For example, Siemens Gamesa has been testing the integration of a 400 kWh flow battery alongside solar and wind generation at its R&D site near Zaragoza, Spain. The real growth in these projects has occurred in the past two years, driven in part by new projects pioneered in India. In April 2018, General Electric announced a small hybrid plant with 41MW of wind and solar generation alongside a 10 MW/15 MWh battery. Several months later, another hybrid project was announced in the state of Andhra Pradesh. Developed by IL&FS Energy Development Company Limited and Black & Veatch the project combines 25 MW solar PV, 16 MW wind, and an undisclosed capacity battery system. Further growth in Indian hybrid projects will be driven by Andhra Pradesh's announcement to procure 5,000 MW of wind-solar hybrid projects through 2023.

Examples of Renewables Hybrid Projects across the Globe:

- Mongolia: In September 2018, the Asian Development Bank announced it is financing a 41 MW hybrid wind-solar plant with an onsite battery.

- Australia: The Kennedy Energy Center is expected to be online by the end of 2019, combining 43 MW wind, 15 MW solar PV, and 2 MW/4 MWh battery storage.

- Europe: The Swedish utility Vattenfall is building a hybrid plant in the Netherlands combining 22 MW wind, 38 MW solar PV, and 12 MWh battery.

- United States: The US is emerging as a leader in this market. In February 2019, utility Portland General Electric announced a hybrid plant combining 300 MW wind, 50 MW solar PV, and 30 MW/120 MWh battery storage. In July 2017, an even larger project was announced by Western Farmers Electric Cooperative in Oklahoma. The Skeleton Creek project will integrate 250 MW wind, 250 MW solar, and 200 MW battery storage.

Vendors and developers have noted this trend's acceleration. In 2018, Vestas announced it will be developing hybrid plants through partnerships with solar PV and energy storage suppliers. Vestas and other developers, such as NextEra Energy, will have to overcome barriers in the market including the lack of hybrid project accreditation and interconnection processes. As the economics of hybrid systems do approach lower price levels, our analysis indicates that they can potentially be competitive with 30-40 % of existing coal-fired stations in India. They can therefore become a viable solution to meeting future baseload power requirements, all at zero carbon emissions and future cost-inflation proof. Several leading Indian companies are also showing active interest in increasing their usage of clean power if round-the-clock solutions are available Since the release of the final policy, India has conducted two auctions for wind/solar hybrid projects. Both the auctions were under-subscribed, with bids totaling 1.56 gigawatts (GW) awarded to SB Energy, Adani Green Energy and ReNew Power, against a total of 2.4 GW on offer.

The discovered prices were marginally below the ceiling tariff of 2.70 Indian Rupees. Although the initial response from industry appears guarded, it is believed that renewable hybrids can play a key role in helping India accelerate the decarbonization of power generation and lowering the cost of electricity in the medium term with the cost of storage reducing and overall blended tariff of renewables + storage coming down as a result.

The recently concluded bid conducted by the Solar Energy Corporation of India (SECI) for 1.2 GW of solar, wind, and energy storage projects with guaranteed peak power supply showedhat energy sy67torage is now well competitive with other sources of fuel. While Greenko was awarded 900 MW, ReNew Power won 300 MW of projects. Greenko Group won the bid at a peak power tariff rate of ₹6.12 (~$0.086)/ kWh, and ReNew Power won at ₹6.85 (~$0.096)/ kWh. SECI has also announced a similar tender being released soon. With prices of batteries decreasing 87% over the last decade and continuing to fall, integration of storage with renewables hybrid becomes more and more economical. At present they are being more competitive than the newly built conventional units. Apart from the pure RE hybrid projects which till now were not many in number, there has been enough progress made in integration of storage with renewables. This space has been predominantly led by solar with storage projects but there are examples of wind with solar projects too. Some of the major projects are in Hawaii, Arizona, Australia to name a new.

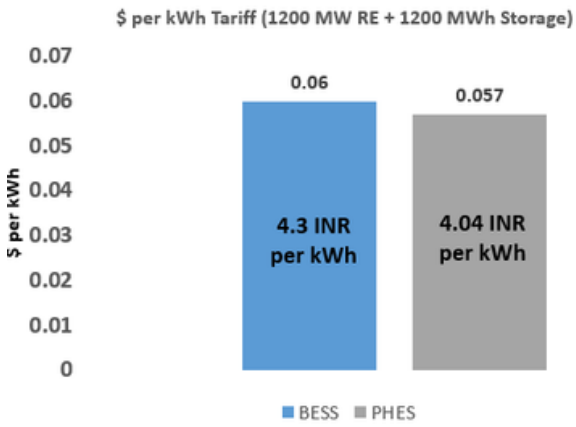


Figure 11: SECI VII Tender Result (RE + Storage)

Looking to some examples from USA Solar with Storage tenders it is observed that the ratio of battery capacity to PV capacity varies widely, reflecting specific circumstances. For example, Hawaiian projects—interconnected to isolated island grids with significant solar penetration—are at parity (1:1 or 100%) in order to capture and shift most or all mid-day generation into peak evening or night-time hours. Broadly speaking a 4-hour battery that is sized at roughly 25% of the PV capacity adds about $4/MWh to the overall PPA price. But as the battery capacity increases to 50% and 75% of the PV capacity, the levelized storage adder increases linearly to ~$10/MWh and ~$15/MWh, respectively.

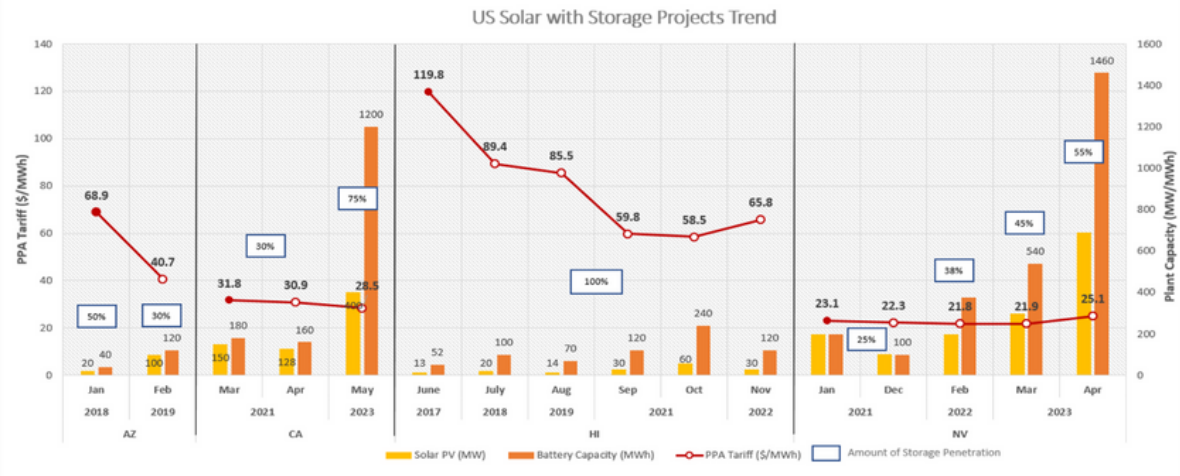


Figure 12: US Solar with Storage Tenders Trend

Energy Storage – The Enabler

The importance of energy storage to make renewables growth more sustainable over long term is well understood and appreciated at large in today's energy market. What therefore needs to be answered is: how. How do we bring about this integration and does the cost economics actually favor the same? Till two years back when such a model was worked upon for India, the cost economics did not work, mainly due to the high CAPEX requirement for inclusion of storage and the added cost of generation being incurred due to the storage component. The same is justified too, the battery costs in 2016 too were quite high which did not help in making such projects viable. The tariff adder to add storage component for a duration of 4-hours to effectively handle grid curtailments alone yielded to a tariff adder of ₹10/kWh. The bigger problem though is that storage deployment to address one concern does not yield economic results.

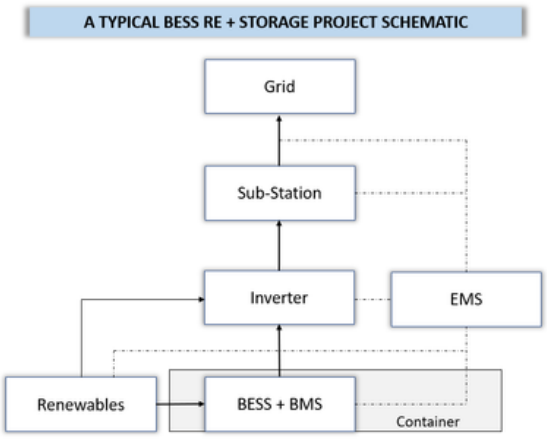
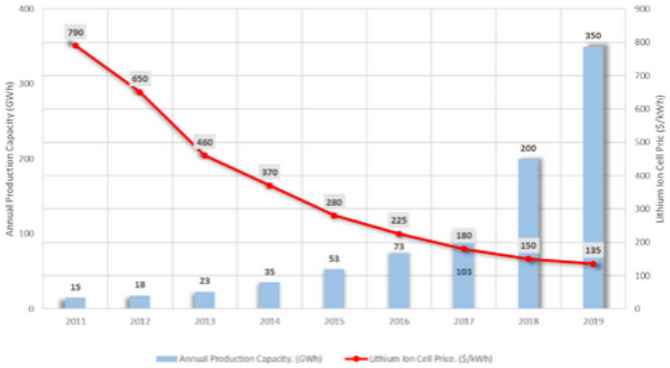


Figure 13: A Typical Hybrid Project Layout



This is mainly due to the fact of seasonality of renewables. Let's talk about wind curtailment. The high wind season in India predominantly ranges between June to October and it's not every day that the wind assets are curtailed, thus the application of batteries deployed for storage finds a very small window to act. The rest of the year the batteries remain unutilized. Therefore, it is much required to see that storage deployment finds multiple applications to cater at. For wind, these can be forecasting and scheduling management by minimization of Deviation Settlement Mechanism (DSM) penalties, curtailment minimization and catering to ancillary markets. This will make sure that the battery finds application to be utilized throughout the year and the revenue streams or savings continue on an annual basis rather than being seasonal. Battery storage finds more application with solar where, one the variability is less and also the duration of storage is more required due to non-solar hours. Also, integration of storage with solar is easier than the same with wind. Saying that it is worth to be mentioned that though at the beginning storage makes more economic sense with solar, wind will pick up pace too.

Over the last decade the price of batteries has dropped 87%, what started off at above $ 1000/kWh today ranges in $ 150/kWh. The trend is expected to reach a point when by 2027 the prices will be below 100/kWh. The system cost of a standalone battery project is much higher than when such projects are collocated with renewables. This is primarily because of the Balance of System (BoS) cost being shared between the two. Also, with increase in size of the project and duration the overall cost reduces. It has been seen that the BoS costs reduces by a significant margin for a 4-hour co-located storage system cost when compared to a 1-hour co-located system. The cost of the storage system depends on a number of factors like round trip efficiency, number of cycles that the battery runs in its lifetime, the depth to which the battery is discharged and also the surrounding temperature and conditions. If a battery is discharged fast or frequently, then the same has an effect on its life and also makes the battery more expensive, than when we go for a slow charge discharge cycle.

The Economics of Storage Integration

The overall project level breakup of a storage system cost has decreased a lot over the last few years. What has increased along is the percentage of storage integration and the hours of storage being considered. In the US alone, the tariffs for renewables with storage saw a decline of 15% in between PPA prices of 2018 and 2019.

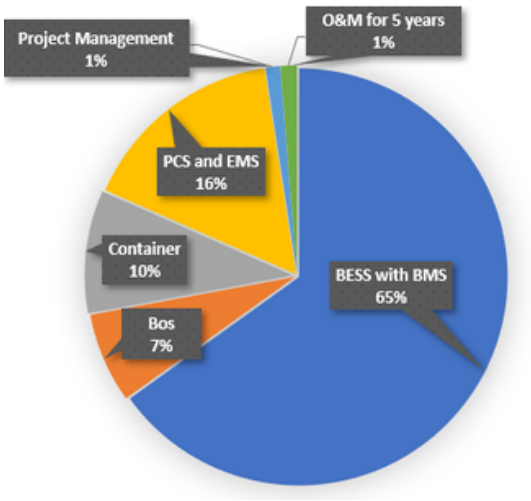


Figure 15: Storage Project - Cost Break-up

A typical cost breakup of a storage project is depicted in the pie-chart. The break-up is true for a 4-hour storage deployment project. For a 1-hour deployment, the cost of project is seen to increase. Also, when we consider a stand-alone storage project with a storage project which is co-located with renewables, there is a further decrease of costs due to a lot of common infrastructure related to BoS that gets shared. Based on today's costs the economics we find storage deployment over a period of 1-to-4 hours making more economic sense with solar than being wind.

As discussed above, battery storage integration with renewables comes in more beneficial for shorter duration of storage ranging from 1-to-4 hours. It is expected that initially in projects the percentage of storage will be around 10% which slowly will increase to 50% as the cost of batteries reduce. In a best-case scenario considering proactive policy support, tender authorities releasing more hybrid tenders with storage and the vision of 450 GW being realized by 2030, the storage capacity by 2027 can be around 12 GWh, on a conservative approach, it can be around 5 GWh. The tariff adder due to addition of storage will depend on the capacity of storage, depth of discharge, number of cycles and efficiency. As discussed before for a smaller duration of storage the tariff adder will be more than that for a longer duration of storage (4 hours). The range of this adder based on today's cost for a 4-hour storage is ₹7/kWh,this is expected to reduce to ₹3/kWh by 2027,whereas for a 1-hour storage, the present adder will be around ₹12/kWh, this is projected to be around ₹6/kWh by 2027.

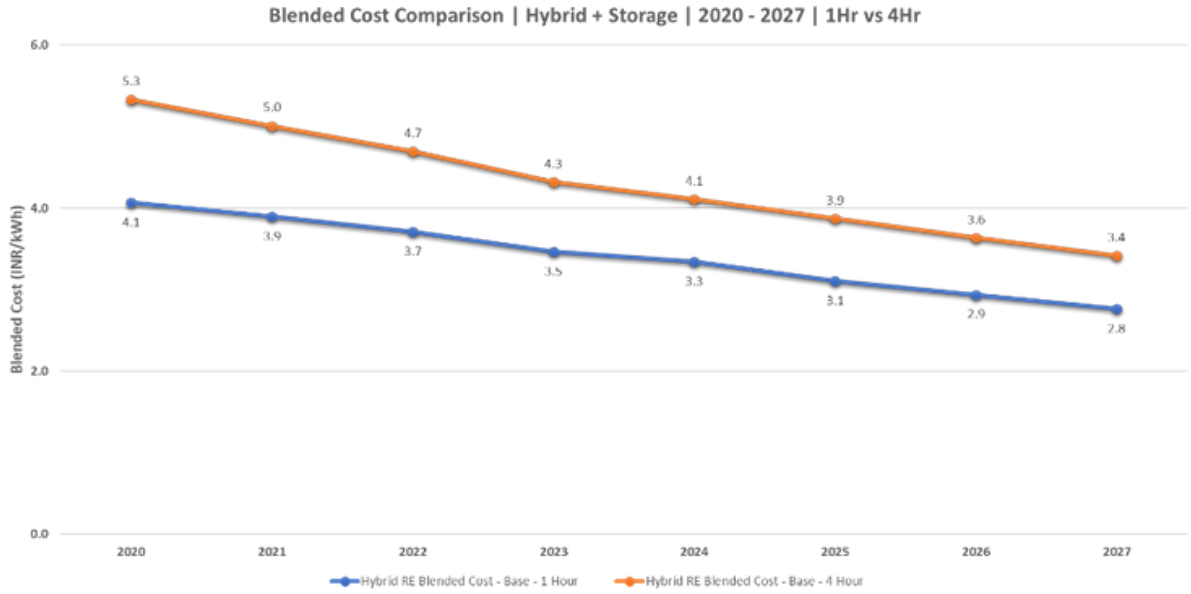
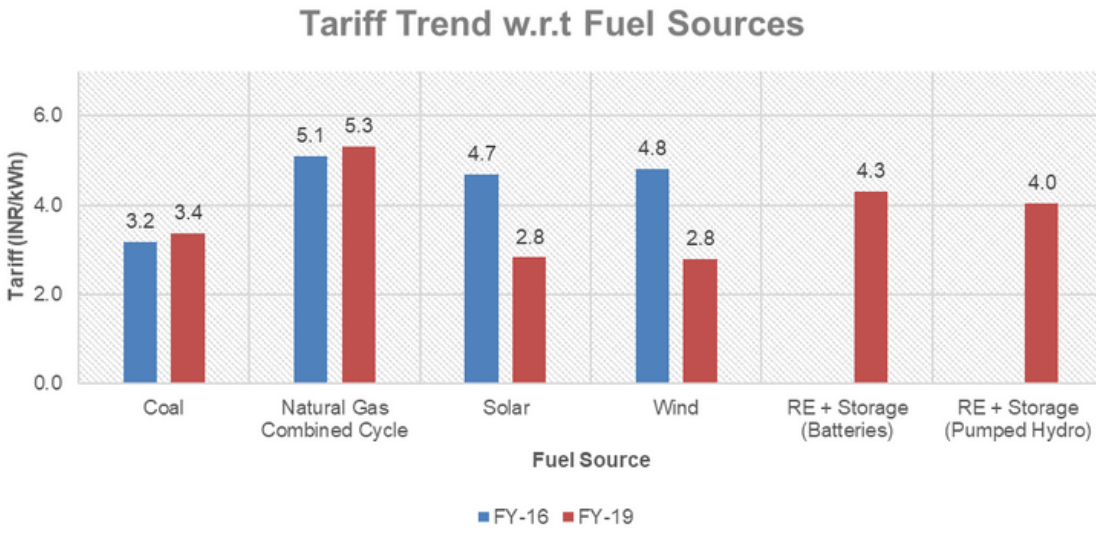


Figure 16: : Blended Cost Trend (RE + Storage)

The blended cost however is not a direct addition of the tariff of renewables and the tariff adder for storage. The blended cost changes depending upon the size of the storage, as based on the size the amount of charging energy required from RE will also vary. The more the energy required from wind/ solar to charge the battery the tariff will also change accordingly. Based on today's costs and considering technological advancements for both renewables and storage going forward, this cost is also expected to drop. At present for a 50% penetration, the blended cost for a 4-hour system can range between ₹5 to 8/kWh, this is expected to be around ₹2-4/kWh by 2027.

CONCLUSION

Overall, this looks to be the best way for renewables expansion in the future. With land availability and acquisition being a challenge, it makes more sense to utilize the land being available to the fullest and hybrids are a great solution to address this concern. With the government releasing the National Renewable Energy Hybrid policy and with the recent developments like National Renewable Energy Hybrid policy and with the recent developments like taking off tariff ceilings, reduction in cost of storage, advancements in efficiencies, the forecast for hybrid projects looks good for India. Such projects work much better with a two-part tariff like we saw in the SECIs 1.2 GW project of renewable energy with storage. This helps in attaining better project economics based on today's costs. This will also increase participation of developers and IPPs in such upcoming bids.



The tariff trends also help RE with storage projects, with more and more renewables penetrating the grid, thermal assets are slowly being run on part loads which ultimately is also increasing their per unit generation cost due to higher heat rate and lower efficiency of these units being operated at PLFs of 55%. Talks has also been started to lower this minimum set point of coal units which will further increase the per unit cost of generation. Further, is the cost of installing Fuel Gas Desulphurizer (FGD) and more improved emission control and monitoring equipment which is making new coal plants more expensive than RE hybrids. The story is same with gas peakers, therefore, on the per unit cost front, for RE hybrids the cost trend will only decrease going forward with increase in technological improvements and reduction in cost due to economies of scale and hence the future of hybrids is bright and is the right way to make renewables mainstream. The world around is ever changing and innovating, where the normal is now to change and improve every day to maintain one's competitive edge in the market and wind is no exception. Hybrids is that much required inflection point which the renewables industry needs to maintain its growth phase and have the sustainability edge.

About IESA

India Energy Storage Alliance (IESA) is the premier alliance focused on advancement of energy storage and e-mobility technologies in India. The alliance was founded in 2012 by Customized Energy Solutions (CES). IESA works to make India a global hub for R&D, manufacturing and adoption of advanced energy storage and e-mobility technologies. We have been at the forefront in development of enabling policy frameworks for adoption of energy storage and e-mobility technologies in India. We provide an ecosystem to our members to network and grow their business in India and around the world through in-depth analysis and active dialogue among the various key stakeholders. Our initiative 'IESA Academy' addresses the much-required skill development area through capability building programs and customized trainings with collaboration of industry and academia. Our members encompass all the vertices of the industry covering energy storage manufacturers, research institutes, renewable energy, power electronics, EV manufacturing companies.

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