A Present and Futuristic Perspective on Renewable Energy Integration in India

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Abstract— The Indian power sector is estimated to have approximately 76 GW of Renewable Sources Of energy, out of a total estimated production capacity of approximately 350 GW, as of the month of January 2019. Within the context of this plan for the journey ahead, additional research work has been carried out addressing consumption as it is anticipated to continue through the years 2022 and 2027. This confidence in one's competence to manage such a large and varied integrated power system served as the motivation for the research that was carried out. These assessments take into account the growing number of conventional generating stations that rely on fossil fuels as well as the growing number of typical power generators that rely on renewable energy sources. To meet the demand for electricity and energy, the competence of the system to function in an efficient and robust way with capacity based on non-fossil fuels has been built. This capacity will have a penetration of 49.3 percent in 2022 and 57.4 percent in 2027, respectively. Accordingly, taking into account the variable nature of the energy they provide as well as the total amount of energy they contain, it is predicted that India's Expected Naturally Determined Contribution from resources other than natural gas will amount to approximately 40 percent by the year 2030. This report outlines the various methods by which India might increase both the quantity and the value of energy generated by wind and solar sources for use in its electrical grid. It addresses alternatives for the short and medium term in the areas of policy, market, and regulatory frameworks, as well as requirement adaptability, power station versatility, reserve (pumped-storage hydro and batteries), and grid flexibility.

***Keywords*— Renewable Energy, Demand Side Management, Power Generation, Ancillary Services**

I. INTRODUCTION

The search for renewable forms of energy has become increasingly prevalent in recent decades due to the gradual depletion of fossil fuels, which were traditionally utilised as conventional natural sources for the producing electricity and energy to a significant level. Exploration has led towards the utilisation of wind, solar, biomass, and other forms of renewable energy as feasible sources of energy all over the world. This is important for maintaining sustainability. India is also at the forefront of the industry, ranking among the top four countries in terms of wind energy capacity and among the top five countries in terms of solar energy capacity and comes from sustainable resource capacity installed around the world.

The International Renewable Energy Agency (IRENA) concluded at the end of 2017 that the overall global capacity for RES was around 2,179 gigawatts [1]. It was anticipated that the capabilities for wind energy would be anywhere in the range of 514 GW, and the capacities for solar energy would be somewhere inside the range of 397 GW. China (15 GW), the United States (6 GW), Germany (6 GW), the United Kingdom (4 GW), and India account for around 75 percent of the world's newly installed wind energy capacity (4 GW). Additionally, more than 1 GW of capacity was installed in Brazil and France. In a similar vein, the increase of solar energy capacity around the world was led by just four countries: China (53 GW), India (9.6 GW), the United States of America (8.2 GW), and Japan (7 GW). In 2017, the growth of renewables was three times greater than the growth of the overall demand for electricity. However, this was not sufficient to prevent an increase in the overall emissions of carbon dioxide.

For the more developed economies, the focus is more or less entirely on the replacement of the conventional power plants described earlier, with just a negligible increase in energy demand. On the other hand, for developing countries and expanding economies like china And india, Brazil, and others like them, it is necessary to not only replace existing capacity but also significantly increase it. As a result, the overall requirement for additional funding is far higher than those of advanced countries as a whole. In recent years, China has seen a significant and rapid increase in capacity, and the country is now very close to fulfilling the target demand. Even India is making rapid strides toward meeting the growing demand for electricity and other forms of energy that the country's significant population necessitates.

Regarding the quantity of energy that it uses, India is the third largest country behind the United States and China. It has emerged as one of the primary methods of energy production that is driving demand growth all over the world and has made significant headway toward its objective of achieving universal electrification of residential users; in just the year 2018, 100 million additional people granted exposure to the electrical grid. In spite of the fact that the government has stated its choice to implement rigorous standards energy efficiency standards, such as LED lighting, effective cooling, and construction regulations. The average amount of electricity available for consumption per person across all 28 states and 8 federal territories of India still seems to be approximately a third of what it does in the rest of the world. This is due to the fact that India has a much larger population than the rest of the world combined. This growth is likely to continue increasing in the foreseeable future. After seeing a huge drop in 2020 because to Covid-19, the overall demand for energy in India has just started to increase again. The pandemic has had an influence on the profitability viability of the power distribution firms (DISCOMs), who were already grappling with increasing debts as well as a liquidity shortage before the pandemic struck.

India is confronted with three primary complexities:

(1) the expansion of access to and utilisation of reliable energy sources while preserving affordability for end users and sustaining the DISCOMs' financial viability;

(2) the best way to ensure the safety and dependability of the integration of a growing proportion of renewable energy sources at the same time;

(3) the best way to cut emissions in order to accomplish aggressive social and environmental commitments while still achieving economic objectives.

The percentage of electricity that comes from renewable sources varies greatly from state to state in India. The percentage of wind and solar energy generated in India's 10 places with the highest concentration of renewable energy sources is significantly higher than the national average of 8.2 percent for the country as a whole. In fact, the significant proportion of solar and wind energy produced in these states is significantly higher than in all of India. In the fiscal year 2020/21, solar and wind energy accounted for approximately 29 percent of the annual electricity production in the karnataka state, % in the rajasthan, 18 percent inside the state of Tamil Nadu, and 14 percent in the state of Gujarat. In the state of Gujarat, solar and wind energy also accounted for approximately 18 percent of annual electricity output. The states in India that are rich in renewable resources already have a larger share of variable renewable energy (VRE) than the majority of other countries around the world. As a direct consequence of this, a number of governments are already dealing with difficulties associated with system integration.

This paper contains two main parts. Initially, it discusses the current power picture in generation capacity in aggregate and also for alternatives, power usage and everyday power met, cross - functional and cross transmission rate, worldwide exchange, dealing in electricity sector, Extra High Voltage (EHV) transportation systems comprising High Voltage Direct Current (HVDC) systems spanning the entire geographic area of India for its vast population. In a word, this endeavour depicts current day-to-day system operation and achievements. Operational and commercial results of renewable energy integration have been reported.

Observations show the need for ancillary services in the integrated system's support mechanism to control frequency, voltage, and ramping or flexible capacity. Intra-state (inside the boundaries of geo-political states in an area) and cross - functional and cross (within each of India's five electrically delimited areas) actions must be performed to integrate renewables successfully. Some are in place, but others are not. Later in the article, renewables contribute a substantial amount of electricity and energy. Planning studies go through March 2027, with projections for 2030.

II. EXISTING SCENARIO OF POWER GENERATION

The dimensions of the Indian electricity grid and market are condensed into Table I [2] [3], which is shown in the following paragraphs.

Table I. Key Dimensions of Indian Power Generation Market

Dimension	Numbers
Area Footprint	3.2 Million km2
Population Served	> 1.3 Billion
Peak Demand Met	~ 176 GW
Daily Energy Met	~ 4 TWh
Installed Capacity	~ 350 GW
Renewable Energy Capacity	~ 76 GW
HVDC Transmission	11 Nos. HVDC Bi-pole/BtB, 1 MTDC
Transmission Network (EHV & HVDC)	~ 410,539 ckm
Inter-Regional Transmission Capacity	~ 99 GW
International Exchange with Neighbouring Countries	~ 3 GW
Electricity Market – Participants	~ 6,000 Nos.
Electricity Market – Transactions	~ 50,000 Nos.
Annual Trading Volume	~ 100 TWh
Power Exchange	2 Nos.

Indian Grid with a large footprint has already been tried to portray through to the ability to contribute of intermittent renewable power production under the renewable category to satisfy the conventional All India Load Curve, which can be seen in Fig. 1 below. This contribution can be seen as satisfying the conventional All India Load Curve. This was done in order to satisfy the usual All India Load Curve. The typical ramp rate has been reported to be 250 MW/min; but, on exceptional days (for example, because of celebrations), it can go as high as 500 MW/min [4].

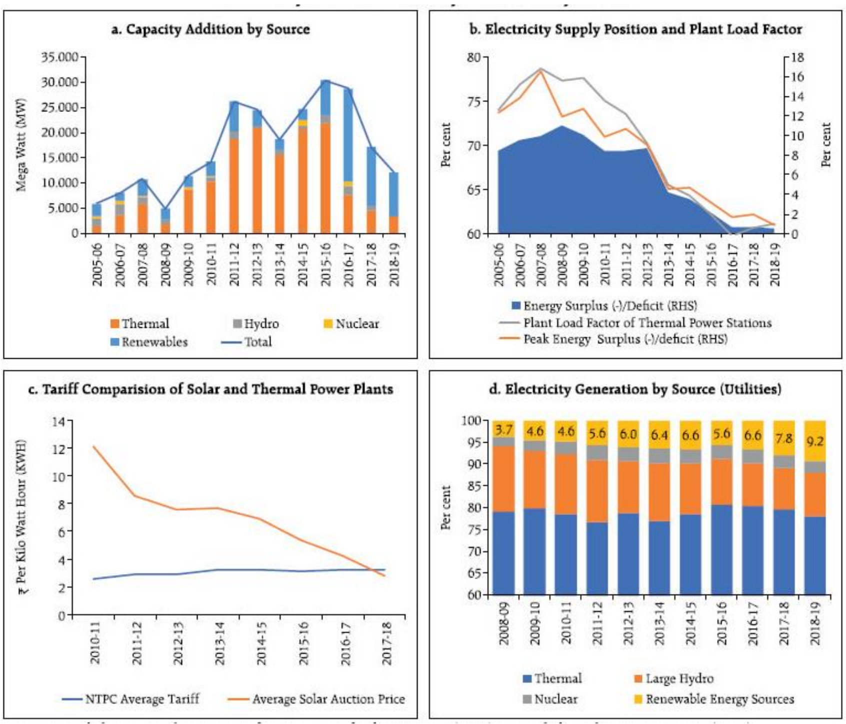

Figure 1. Dynamics of Electricity Generation by Source

Investment in renewable energy sources has benefited not just from increased competitiveness but also from the push provided by government policies. Renewable energy sources are important for India to accomplish its strategic energy policy goals, which include reducing its reliance on imported fossil energy and cutting carbon dioxide emissions in order to meet its climate change obligations set in the Paris Accord of 2015. Strengthened in future meetings of the Conference of Parties. India's strategic energy policy goals include reducing its dependence on imported fossil fuel and cutting carbon dioxide emissions in order to meet its climate change commitments (COP). Through what are known as Nationally Determined Contributions (NDC), the signatories of the Paris Agreement intend to keep the increase in the average world temperature to less than 2 degrees Celsius higher than it was before the industrial revolution.

India had also focused on decreasing the emission levels of its GDP by 33 to 35 percent (from the level in 2005), accomplishing a market share of non-fossil fuel sources in cumulative electricity installed capacity of 40 percent, and creating an addition of carbon sink of 2.5 to 3.0 billion tonnes of CO2 comparable by the year 2030. These goals are all in line with the Paris Agreement on Climate Change. These goals are all in line with the Paris Agreement. The goal of the Union Government to boost the capacity of renewable energy sources to 227 Gigawatts (GW) by 2022 was initially announced as an ambitious goal of 175 GW. With the formation of the International Solar Alliance, India has also assumed a leading role in international collaboration for the development of solar power through the utilisation of technology and the provision of financial resources (ISA).

The policy support for RES, which must have historically taken the form of government incentives (tax breaks, accelerated depreciation), shifted toward providing couple of generations incentives with the introduction of the Electricity act, 2003. The above fiscal incentives had traditionally taken the form of tax breaks and accelerated depreciation. In the past, financial incentives were the dominant form of policy support for renewable energy sources (RES). In general and especially, the Feed-in Tariff, or FIT, which seeks to regulate this same tariff at which utility companies gain entry into long-term power purchase agreement (PPAs) with generation assets, and the must-run status, which ensures the despatch of generation from RES regardless of whether or not there is demand, are the two policies that are currently being discussed. Both of these policies seek to control the import tax at which utility companies enter into long-term power purchase agreements (PPAs) with generating companies. Because the cost of renewable energy sources has fallen over time, the FIT system has been mainly replaced with auctions to establish tariff levels. It was common practise to fix FIT levels at cost-plus levels. Additionally, the Renewable Purchase Obligation, sometimes known as the RPO, came into effect in the year 2003.

This regulation requires DISCOMs and captive power consumers to source a minimum portion of their required power from renewable energy sources (RES), thereby ensuring that there is sufficient demand for generation from RES. RES refers to sources of energy that are derived from renewable resources such as solar, wind, and geothermal energy. An alternative to the FIT regime was made available in 2010 with the emergence of the Renewable Energy Certificate (REC), which required to be addressed the discrepancy among RE potential and RPO objectives throughout jurisdictions by successfully establishing a pricing mechanism for commercial transactions in credit for energy purchased for RES sources3. This was accomplished by providing a pricing mechanism for commercial transactions in credit for energy purchased for RES sources3. This was made possible through the implementation of a price system for trading activities in credit for energy that was bought for RES sources3. However, the REC route hasn't really gathered much momentum and only represented 5.7% of the overall RE capacity as of 2017-2018. This is a significant drop from the previous years. This may be due to insufficient compliance with the RPO mandate, which decreases the market for renewable energy certificates (RECs).

It is predicted that an increasing share of India's demand for power would be met by the increase of sources of renewable energy. However, in the medium term, when renewable energy begins to stabilise and strengthen, thermal power facilities will need to be harnessed in order to meet the growing demand that comes along with increased per capita consumption. This is because renewable energy will not be able to meet this demand alone. It is expected that the peak demand for power that is tied to the grid would increase from 161.8 GW in 2016–17 to 225.8 GW in 2021–22 and subsequently to 298.8 GW in 2026–27. This increase will take place over the course of four years. Although it is possible that current capacity and new additions that are already in the pipeline will be able to satisfy the predicted increase up to 2021-22, it is projected that by 2026-27, an additional thermal capacity of 46GW will be required to satisfy the growth in peak demand. This is based on projections made by the EIA (GOI, 2017).

III. GROWING RENEWABLES CHALLENGE POWER SYSTEM

The electricity infrastructure in India is scheduled to go through even more significant changes over the course of the next ten years. The government of the Union has plans to enhance the capacity of renewable energy sources to generate electricity by 450 GW in 2030, up from 175 GW in 2022. Some of the state's top officials have voiced their concern that their state will be forced to deal with an excess of VRE production and will need to:

- Increase the amount of power you export to other states dramatically.
- Allow some coal power facilities to be replaced with renewables locally or globally.
- Reduce the amount of energy generated by solar and wind sources to increase system reliability.

Recent trends that are at the root of the most significant difficulties associated with the integration of renewable energy sources include the growing hourly demand variability, the necessity to ramp up requirements as a result of the impact solar has on net demand, short-term frequency variations, and local voltage issues.

The transition of electricity demand in India, away from passive consumption and toward more full engagement by demand sectors, can provide support for the transformation of the power system there. Through unintentional load shifting caused by irrigation, agricultural users already play an essential role in maintaining a healthy equilibrium between power supply and demand.

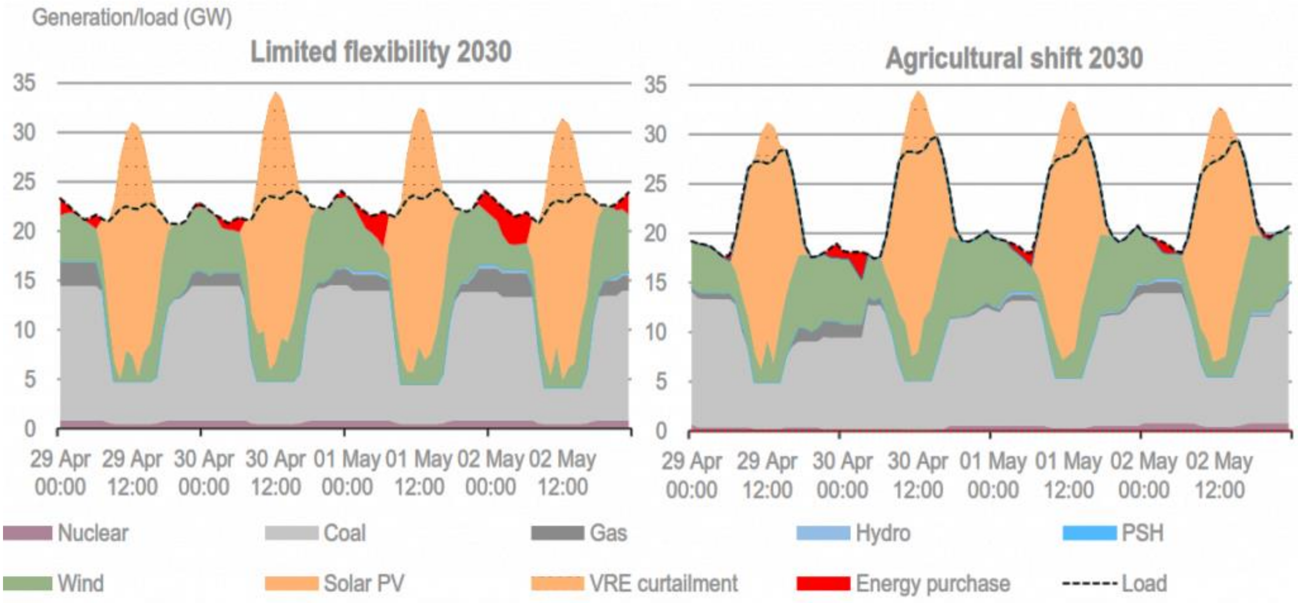

Figure 2. Agricultural demand shift affects overall demand and solar absorption

The current shift in agricultural demand, which occurs from high demand hours to low demand hours, already provides a significant source of minimum power system flexibility in India. This shift has aided and abetted a few really provinces in trying to reach increased rates of solar and wind invasion without major system events.

This change has been made possible in large part by the availability and utilisation of existing distribution networks devoted to agricultural users in specific states. These networks give the system operator the capacity to control irrigation loads without having an influence on other users of the grid.

As the foundation of the existing manufacturing demand response incentive, time-of-day charges for the industry are offered in the majority of states. These tariffs can also be referred to as time-of-use tariffs. For the triggering of predictive control capability from buildings and transport, it is recommended that, in the medium to longer term, a change toward time-of-use tariffs as the default choice be made, after the installation of advanced metering infrastructure (such as cooling and electric vehicle smart charging).

On the residential side, the transition to sophisticated digital metering, automation, and smart home products is a prerequisite. This transition must take place while maintaining privacy and avoiding proprietary standards, which could restrict compatibility and consumer choice.

A. Monitoring Of Rooftop Solar Systems

The proliferation of rooftop solar systems is causing concern among state system operators and local distribution companies (discoms) due to the potential impact these systems will have on the financial stability of discoms (due to a loss in revenue), issues for distribution systems (due to reactive power, voltage impacts, and reverse power flows), and uncertainty regarding demand forecasts.

The International Renewable Energy agency (IEA) and NITI Aayog collaborated on a report that highlighted professional experience, demonstrating how these might become framework assets as well as assistance the limited network with voltage regulation and reactive power. The report was published as a joint effort.

In order to increase the accessibility of solar energy assets in India, interconnection rules need to specify the registration of standalone devices, and registries of these assets should be maintained at both the state and the national level. It is recommended that states initiate construction of the residential solar database initially. In the long run, a consistent interface and data model at the national level can bring about more efficiencies and openness.

It is possible to reduce the income loss that DISCOMs experience by mandating that all customers with rooftop solar systems enrol in time-of-use pricing plans. This would also help to maintain cost parity between customers who have rooftop solar and customers who do not have rooftop solar. As the demand curves for the state are reshaped by solar energy installations and demand response, it will be necessary to reevaluate the time-of-use time slots on a regular basis.

B. New Policy Frameworks to Meet Stricter Emission Standards

The majority of states were aware of the important role that existing coal-fired power facilities will play in the future. It is anticipated that coal plants will operate less as alternative energies produce a greater amount of energy, which will result in decreased income.

At the same time, in order to maintain operational flexibility and conform to more stringent emission rules, certain coal facilities would need further investment. Such an investment needs to be evaluated against investments in flexible sources in other areas of the system (storage, demand, and grids), as well as investment in emission reduction targets.

According to the Stated Policies Scenario (STEPS) of the World Energy Outlook (WEO) published by the International Energy Agency (IEA), the capacity of the Indian power system to run on coal is projected to expand to 269 GW by the year 2030, up from 235 GW in 2019. According to the findings of the IEA's India Regional Power System Model analysis, the utilisation of coal power plants in India will undergo significant transitions by the year 2030.

The use will transition from the typical steady operation of the baseload to frequent operation close to the minimum and maximum output levels. In some jurisdictions, coal plants have the ability to better support the integration of significant percentages of variable renewable energy (VRE) by increasing their flexibility in ways such as faster ramp rates, lower technical minimum levels, and shorter start-up times.

The modification of existing hydroelectric power plants to enable operating in pumping system mode appears to be the storage solution of choice in many of the states that make up India. Batteries, on the other hand, are also set to play a significant part in the Indian economy.

In the morning peaks or evening ramps that require less than six hours of storage, an analysis conducted by the Lawrence Berkeley National Laboratory appears to suggest that battery storage combined with solar farms seems to be a more cost-effective remedy than pumped-storage hydro retrofits. This conclusion was reached as a result of the findings of the study.

The appropriate dimensions and position of energy storage will be different depending on the region, so in-depth research will be necessary in each state to determine these details.

C. Removing Barriers to Inter-State Trade

The contemporary regulatory and legislative frameworks create major gaps and impediments for power distribution flexibility resources, such as demand response, capacitors, pumped-storage hydro, and power plant flexibility. These resources include demand response, batteries, and power plant flexibility.

In the year 2020, significant advancements were made in the wholesale power trade of India. These advancements included improved trading throughout all of India's states as well as the establishment of traditional markets and sustainable markets.

Since the year 2020, the competitive economy has been able to fill an important void by giving corrections one hour in advance of the timeframe for generation that is changeable and uncertain, such as wind and solar. Clients, such as the discoms, are now able to fulfil the renewable purchase responsibilities of their respective states by making market purchases thanks to the recently established green market.

An assessment based upon that IEA India Regional Power Distribution System reveals that greater power exchange across states is an effective solution for the integration of renewable energy sources. This strategy has the potential to reduce curtailment in the STEPS by around 2.5 percent in 2030. However, this promise cannot be realised without overcoming considerable obstacles. These are the following:

- A deficit for capacity for intrastate commerce
- A lack of liquid assets available on the wholesale marketplaces
- Existing contractual frameworks that are rigid, specifically the long-term physical relative purchasing power agreements (PPA) that are in place between both the DISCOMs and the generators.

The majority of systems that have a high penetration of solar and wind energy also have some level of curtailment, often up to three percent of the annual output of solar and wind power. Although renewable energy sources are required to operate in India, sustainable generators may have their output reduced if there is a concern for the safety of the system. Solar and wind capacity has been reduced in recent years in the Indian states of Tamil Nadu and Karnataka, for example. There is a growing worry, particularly among investors, regarding the absence of associated mitigating regulations and the increasing curtailment of solar and wind output. The effects of the COVID-19 epidemic caused the electricity market direct investment to decrease by $10 billion, bringing the total investment in the power sector down to $39 billion in 2020. This fall included a decrease in investment in solar and wind energy.

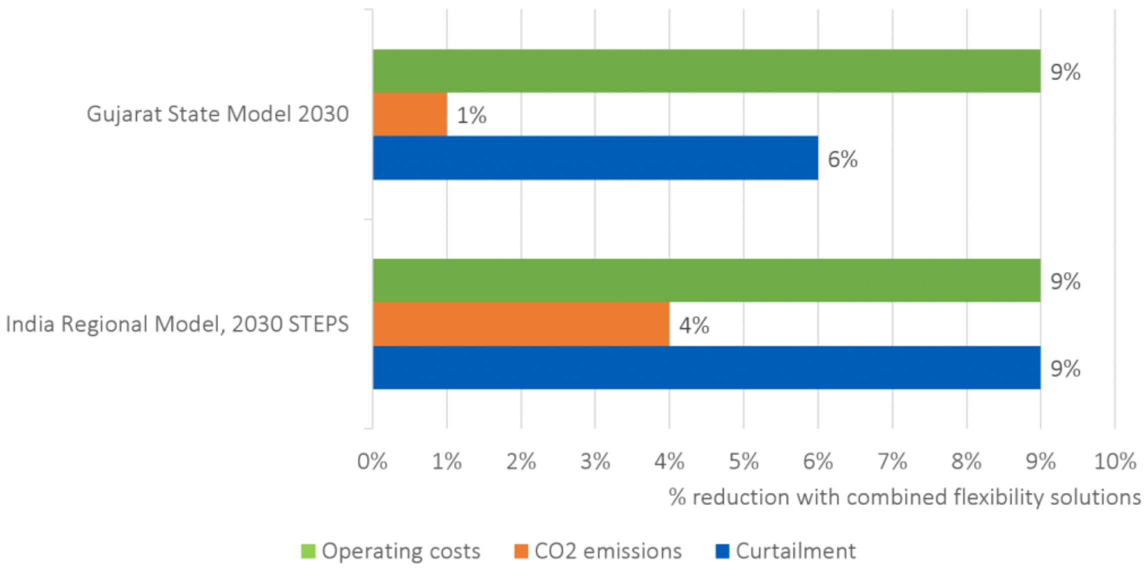

Figure 3. India and Gujarat's flexibility choices reduce curtail CO2 emissions, and operational costs.

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IV. CONCLUSIONS

Based on the findings of the study, it has been determined that the incorporation of 175 GW RE into the Indian power system by 2022 is feasible with minimum RE curtailment. The most significant influence on the integration of renewable energy sources in India will come from a decrease in the minimum generating level of thermal power. However, if certain adjustments are made to the operating methods that are already in place, it is possible that the nation will be able to achieve the RE objective in a manner that is more efficient financially. A careful planning process that is based on models could help reach an even larger proportion of renewable energy sources in the system.

It is essential to acknowledge that adaptability in the transmission system is the essential element for the integration of RE. In order to inform judgments about public policy that are evidence based, these investigations need to be carried out on a more regular basis, assessing a variety of situations across a range of time periods.

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