DIVECHA CENTRE FOR CLIMATE CHANGE

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Policy Brief
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Prospects for Renewable Energy in India[1]

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Highlights:

- India has committed to reduce its carbon emissions relative to economic output by 33-35% by 2030 from 2005 level.
- Renewable energy sector saw major expansion during the past decade. At the end of 2019, the total installed capacity of renewables stood at 86 GW, including 37.5 GW of wind power and 34 GW solar power.
- Electricity cost from solar photovoltaics experienced the steepest (82%) cost decline during the past decade, and costs of onshore wind and offshore wind power reduced by 40% and 29% respectively during the period.
- India is currently the cheapest place to build solar and wind power plants. Most solar projects since 2019 saw tariff costs in the Rs 2.50-2.87 per kWh range, which is 20-30% cheaper than electricity from existing coal plants and up to 50% cheaper than new coal plants.
- With the increasing share of renewable electricity generation, grid flexibility will be critical for the security and reliability of electricity supply. Grid flexibility will have to be complemented with storage, better connections between the regional grids, and demand side management.
- Effective tools for forecasting wind and solar generation will help grid operators to manage the variable nature of electricity supply and also prepare for events of very high and low output.
- Covid-19 and poor financial health of DISCOMs resulted in uncertainties in growth prospects for renewables. Several institutional reforms will be needed to consolidate the gains made in recent years to sustain the long-term future of renewable energy in India.

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Introduction

India has made a commitment at the 2015 Paris climate summit to reduce its carbon emissions relative to economic output by 33-35% by 2030 from 2005 level and have 40% of the total electric generation capacity from non-fossil energy sources by 2030. Renewable energy sources, especially solar and wind, are expected to play a greater role in achieving these goals. The plan to augment electricity production from non-fossil energy sources was announced by the present government in its first term when it set an ambitious renewable energy target of 175 GW by 2022 with 100 GW of solar, 60 GW of wind, and 15 MW of small hydel and biomass power plants.

India registered an impressive growth in the renewable energy sector during the past decade. At the end of 2019, the total installed capacity of renewables stood at 86 GW, including 37.5 GW of wind power and 34 GW solar power. The 2010 National Solar Mission had a target of 20 GW of solar power by 2022, which is one fifth of the present target. Solar generation capacity grew nearly five-fold since 2016. With 23 GW of additional capacity in the pipeline and another 30 GW in the bidding phase, the 100 GW solar target appeared within reach until the outbreak of the Covid-19 pandemic.

Aided by declining costs of renewable energy systems and a supportive policy environment, the sector witnessed dramatic growth and changes in the past five years. However, the industry displayed signs of fatigue even before the Covid-19 outbreak due to the peculiar power sector environment in which it operates. One of the impediments for further growth of renewables in India is the poor financial health of distribution companies (DISCOMs) of the States. Next, the policy uncertainty surrounding renewable auctions, bidding, and tariffs are not conducive for the long-term viability of renewable generation.

The share of renewables in global electricity supply increased to nearly 28% in the first quarter of this year, suggesting its "resilience" during the pandemic. But this is due to the reduced energy demand during the lockdown and priority dispatch given to renewable generators, forcing coal and nuclear plants to operate below their rated capacity and vary their power generation to accommodate the output from renewable power stations. This policy brief reviews the present status, trends, major challenges facing the renewable energy sector, and highlights areas for government support and policy intervention to sustain the growth momentum of the recent years.

II. Current Status and Trends

India's potential for electricity generation from renewable sources is enormous. According to recent[1] estimates provided by the government, the country's solar potential is 749 GW, wind potential 302 GW, small hydro 21 GW, biomass 17.5 GW, cogeneration bagasse 5 GW, and waste-to-energy potential of 2.5 GW. Although Karnataka and Tamil Nadu led renewable energy development in the initial years, Gujarat, Maharashtra, Andhra Pradesh, Rajasthan, and Telangana have become major players in the sector (See Fig 1 and Tables 2 and 3) in recent years.

The present policy attention for renewable electricity generation overlooks the larger role played by traditional renewable energy sources in India's total primary energy supply (See Fig 2). Renewable energy in India has long been dominated by biomass use in households lacking access to modern cooking fuels. Traditional biomass (firewood, animal dung, crop residue, etc) for cooking and heating is still the largest renewable energy source despite the steady decline of its relative importance. The relative share of biomass in India's primary energy supply declined from 43% in 1990 to 21% in 2017[3].

Hydropower has been the largest source of non-fossil electricity in India for many years and accounted for 40% of total electricity generation in the late 1970s[5]. Although hydropower generation has increased steadily, its relative share of electricity generation in 2019 declined to 10.4% while the share of renewable generation from solar and wind increased from below 1% in 2003 to 8.7% in 2019[6]. Coal accounted for the lion's share of India's electricity generation and has always been the main work horse of the power sector (See Fig 4 and 5), but saw its relative share significantly decline from a high of 76.6% in 2016 to 73% in 2019. However, the relative share of hydropower and renewable energy in the total

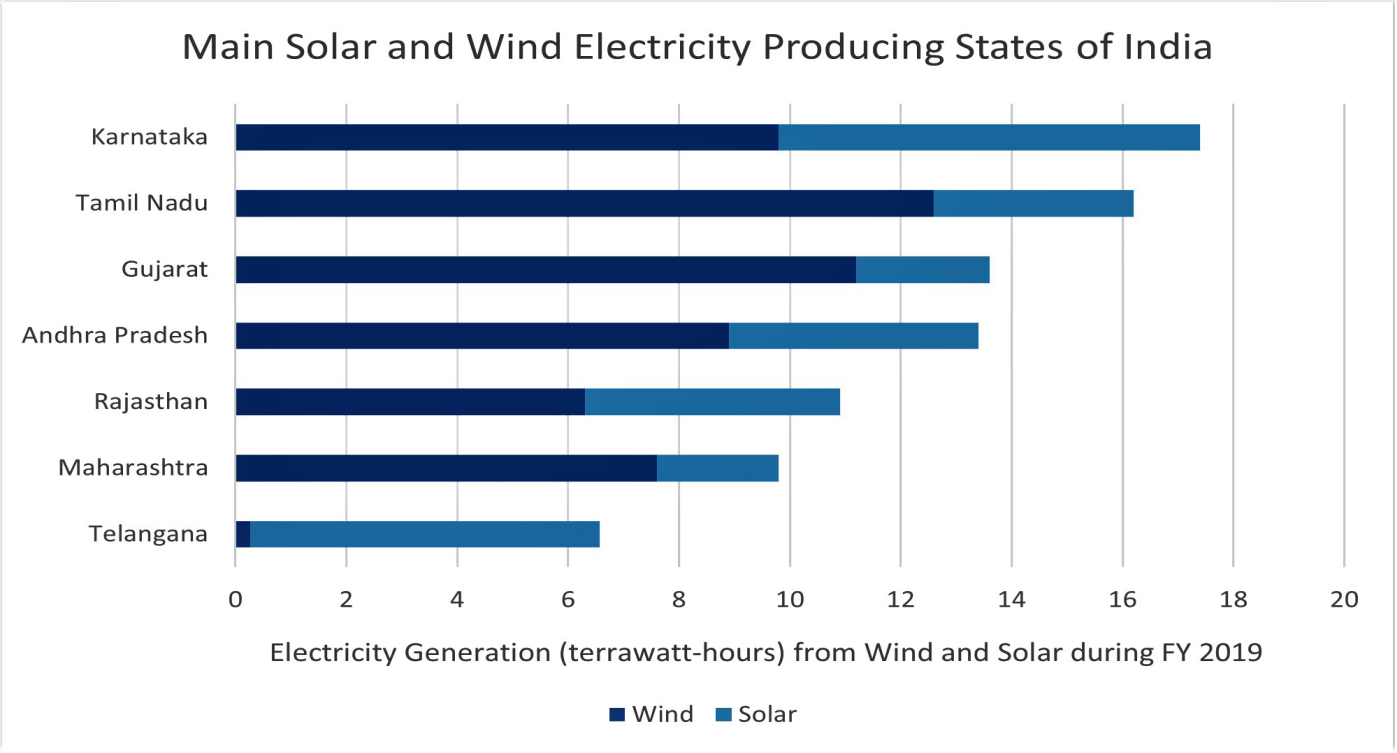

Figure 1: State-wise electricity generation (terawatt-hours) from renewables in 2019. Data extracted from Renewable Energy Data Portal Map, Prayas (Energy Group)[4].

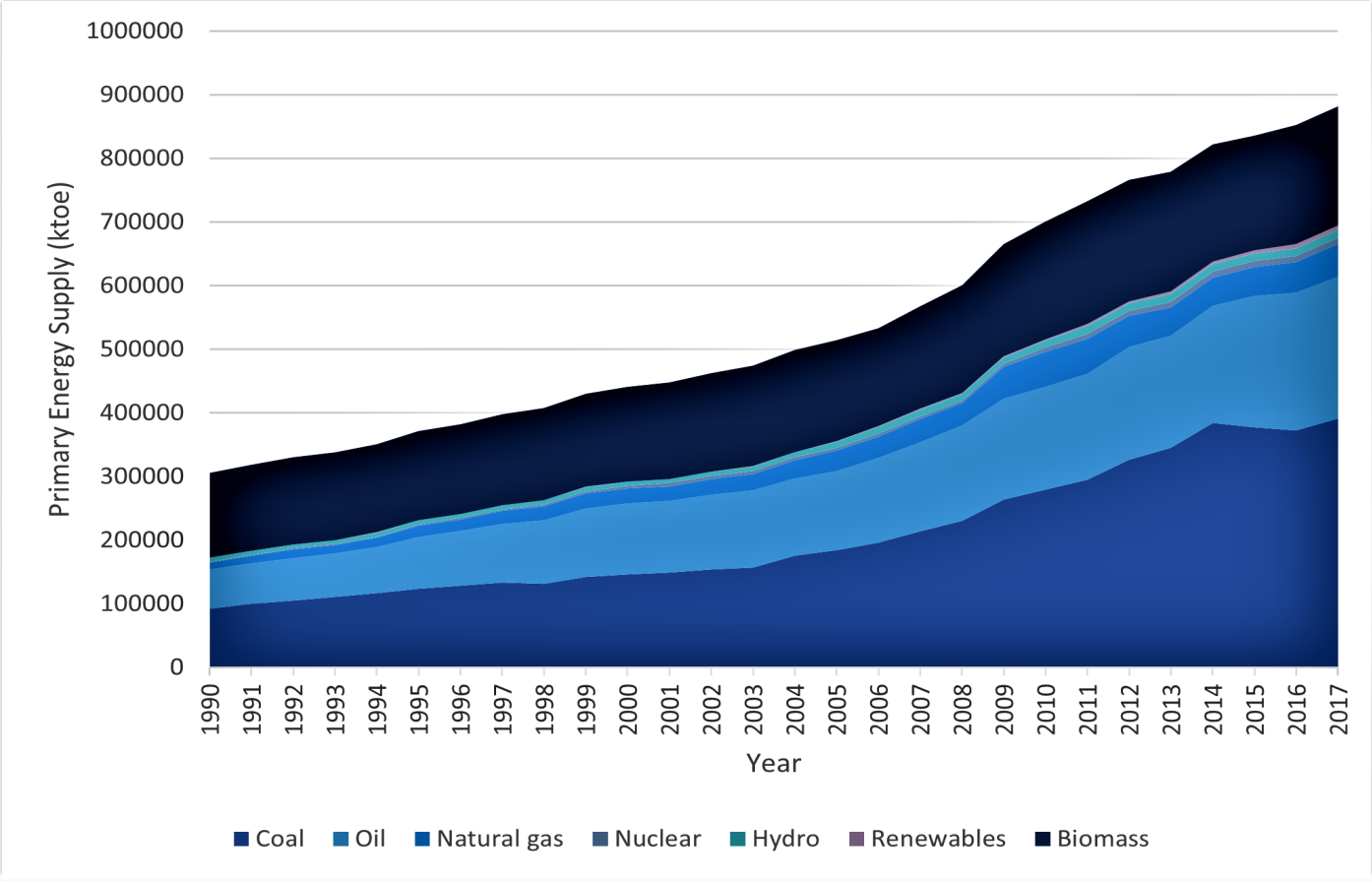

Figure 2: India's total primary energy supply (kiloton of oil equivalent) by source from 1990 to 2017. Graph made using annual data extracted from the International Energy Agency (IEA) website[4].

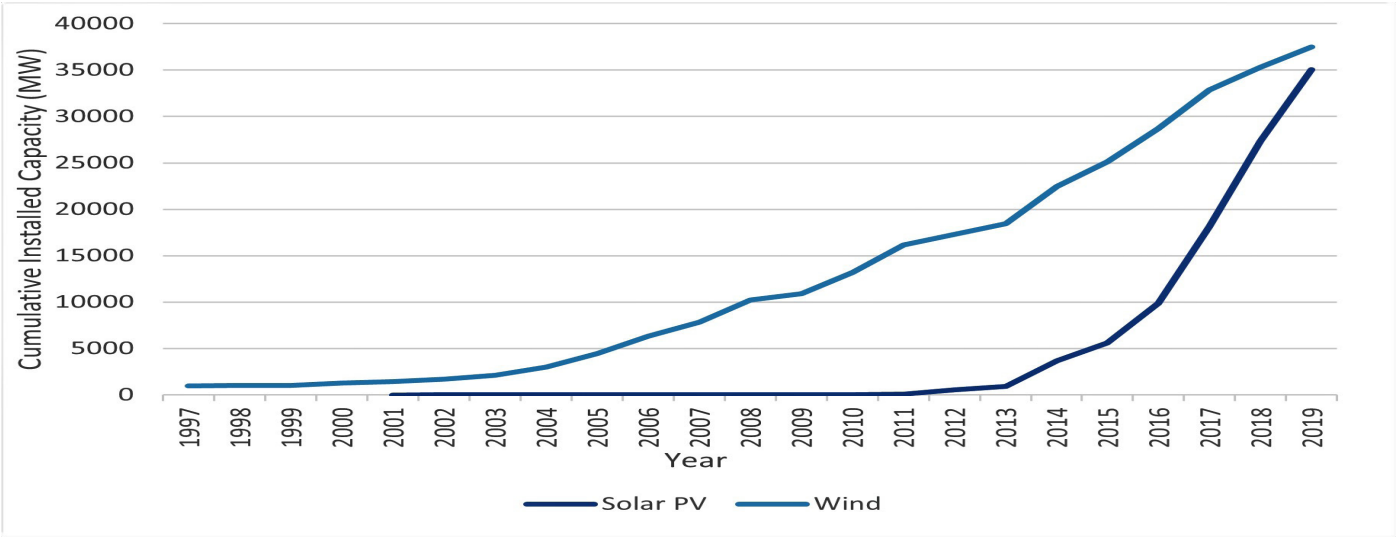

Figure 3: Growth of cumulative installed wind generation capacity (1997-2019) and cumulative installed solar photovoltaic generation capacity (2001-2019). Data for graph from BP Statistical Review of World Energy 2020.

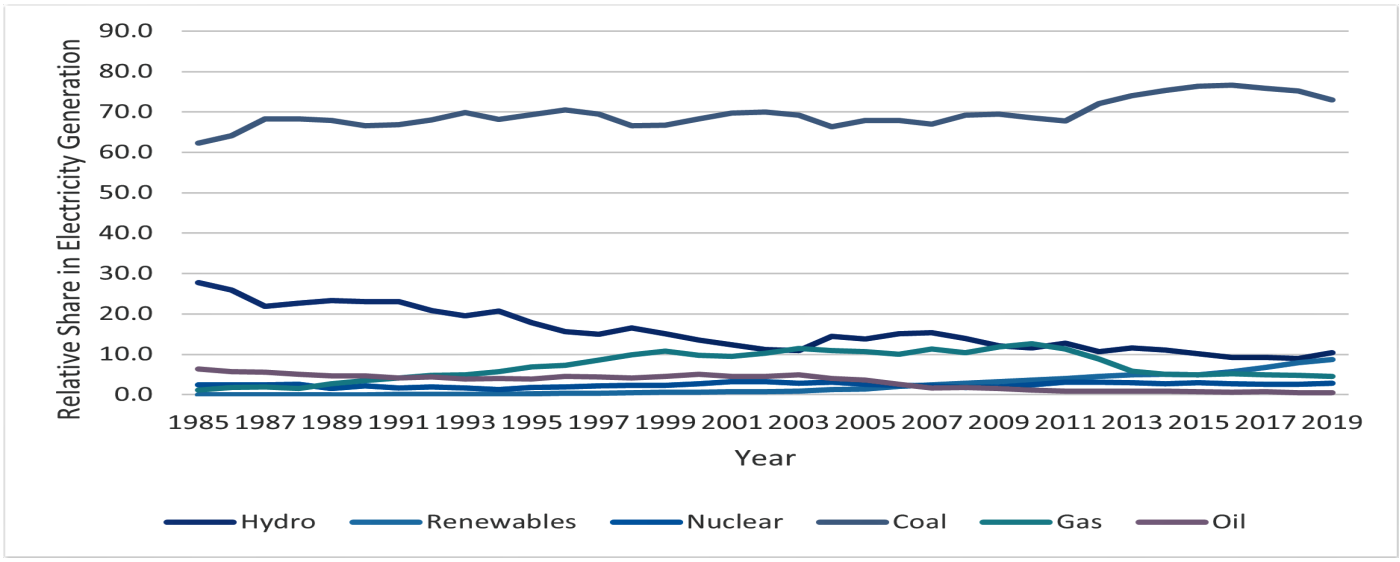

Figure 4: Relative share (percentage) of electricity generation by source in India from 1985 to 2018. Data for graph from BP Statistical Review of World Energy 2020.

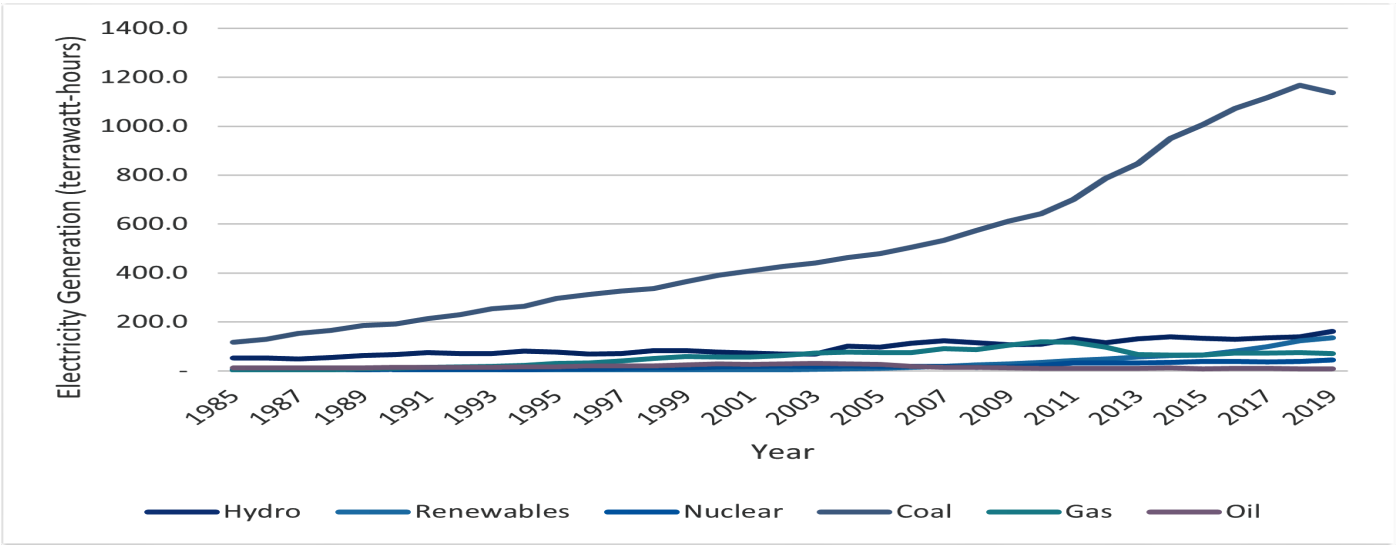

Figure 5: Electricity generation (in terawatt-hour) by source in India. Data for graph from BP Statistical Review of World Energy 2020.

primary energy supply is puny 1.4% and 0.9% respectively in 2017[7].

The summary of total installed generation capacity by source and ownership is provided in Table 1, and the relative share of various fuel sources (See Figure 6) indicates that we are just 2% short of our 2030 target of achieving 40% non-fossil generation capacity. At the end of 2019, the cumulative commissioned utility scale solar capacity was 30,982 MW, operational rooftop solar 5,440 MW, and about 20,220 MW solar projects in the pipeline. Table 2 provides a detailed breakdown of solar installations by state and the market penetration. The cumulative installed wind generation capacity at the end of 2019 was 37,505 MW, and Table 3 provides the cumulative installation in main states.

Electricity Generation Capacity (MW) in India								
Ownership	Coal	Lignite	Gas	Diesel	Nuclear	Hydro	Renewables	Total
State	65362	1290	7155	236	0	26959	2357	103358
Private	74173	1830	10599	274	0	3394	83395	173664
Central	58990	3490	7238	0	6780	15347	1632	93477
Total	198525	6610	24992	510	6780	45699	87384	370499

Table 1: Total installed electricity generation capacity (in MW) by source and ownership as on May 31, 2020. Data from Central Electricity Authority (CEA)[8].

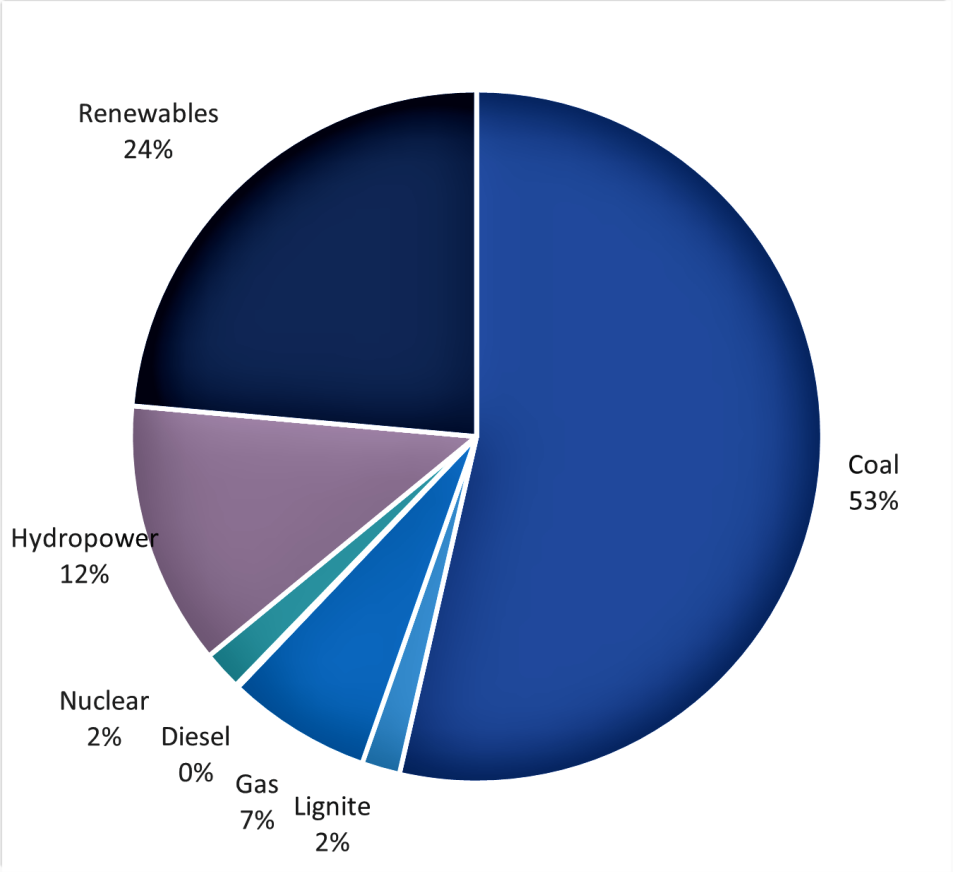

Figure 6: Relative share of installed electric generation capacity by source as on May 31, 2020. Data from Table 1.

Solar Power Projects (MW) in India			
State	Commissioned	Pipeline	Penetration
Haryana	156		1-2%
Punjab	851	150	4-6%
Uttarakhand	225		4-6%
Uttar Pradesh	953	1297	2-4%
Bihar	106	2	1-2%
West Bengal	91	10	1-2%
Assam	12	100	1-2%
Jharkhand	24		1-2%
Chhattisgarh	210		2-4%
Odisha	406	76	2-4%
Andaman and Nicobar	8	42	4-6%
Rajasthan	4501	10588	8-10%
Gujarat	2080	2435	4-6%
Madhya Pradesh	2324	336	6-8%
Maharashtra	1562	2554	2-4%
Karnataka	7295	378	>10%
Kerala	82	142	1-2%
Tamil Nadu	3462	685	6-8%
Andhra Pradesh	3587	1315	8-10%
Telangana	3517	252	8-10%

Table 2: Solar power projects in India as on December 31, 2019. Data Source: Bridge to India[9].

Wind Power Projects (MW) in India	
State	Installed Capacity
Andhra Pradesh	4092
Gujarat	7359
Karnataka	4753
Kerala	63
Madhya Pradesh	2520
Maharashtra	5000
Rajasthan	4300
Tamil Nadu	9285
Telangana	128
Others	4

Table 3: Wind power project in India as on December 31, 2019. Data Source: Ministry of New and Renewable Energy[10].

III. Renewable Energy Economics

Electricity generation from solar photovoltaics experienced the steepest (82%) cost decline during the past decade (2010-2019), followed by 47% reduction in concentrated solar. Costs of onshore wind and offshore wind power reduced by 40% and 29% respectively during the period[11]. Solar module costs in India have drastically come down from $5051 per kW in 2010 to $618 per kW in 2019, and the cost of solar electricity from 30 cents per kWh to 4.5 cents per kWh during the period[12]. The breakdown of solar photovoltaic installation costs in India is provided in Table 4. Installation cost for onshore wind plants in India declined from $3586 per kW in 1990 to $1054 per kW in 2019, and generation costs from 24 cents per kWh to 4.9 cents per kWh. India is currently the cheapest place in the world to build solar and wind power plants (See Figures 7 and 8). Solar electricity costs in India fell from Rs 7.49 per kWh in 2011 to Rs. 2.44 per kWh in 2018[13], making it the cheapest source of electricity. Average domestic renewable electricity costs are now two thirds of the domestic coal electricity tariffs, and half of imported coal electricity tariffs. Most of the new solar projects since 2019 saw costs in the Rs 2.50-2.87 per kWh range[14], and 70% of the winning tenders had tariffs below Rs 2.55 per kWh. This cost range is 20-30% cheaper than electricity from existing coal plants and up to 50% cheaper than new coal plants.

According to a report by the Energy Transitions Commission India[15], costs of solar and wind electricity could plummet further to Rs 1.9-2.3 per kWh and Rs 2.3-2.6 per kWh respectively by 2030. The report suggests that even pithead coal electricity will cost Rs 4.85 per kWh, and non-pithead coal electricity cost could go up to Rs 6.98 per kWh by 2030. If projections made in the report about stand-alone storage costs (Rs 11.9 per kWh by 2030) hold true, there will be no impediment for greater share of solar and wind electricity flowing in India's grid.

Breakdown of Utility Scale Solar PV Costs in India (US2019/kW)		
Category	Cost Component	
Module and inverter hardware	Modules	277.9
	Inverters	44.4
Balance of System Hardware	Racking and mounting	31.3
	Grid connection	29.4
	Cabling/ wiring	29.3
	Safety and security	21.3
	Monitoring and control	0.7
Installation	Mechanical installation	31.2
	Electrical installation	14.6
	Inspection	3.7
Soft costs	Margin	25.6
	Financing costs	40.6
	System design	19.9
	Permitting	14.2
	Incentive application	21.9
	Costumer acquisition	12.2
Total		**618.2**

Table 4: Breakdown of Utility Scale Solar PV Costs in India (US2019/kW). Data from IRENA[16].

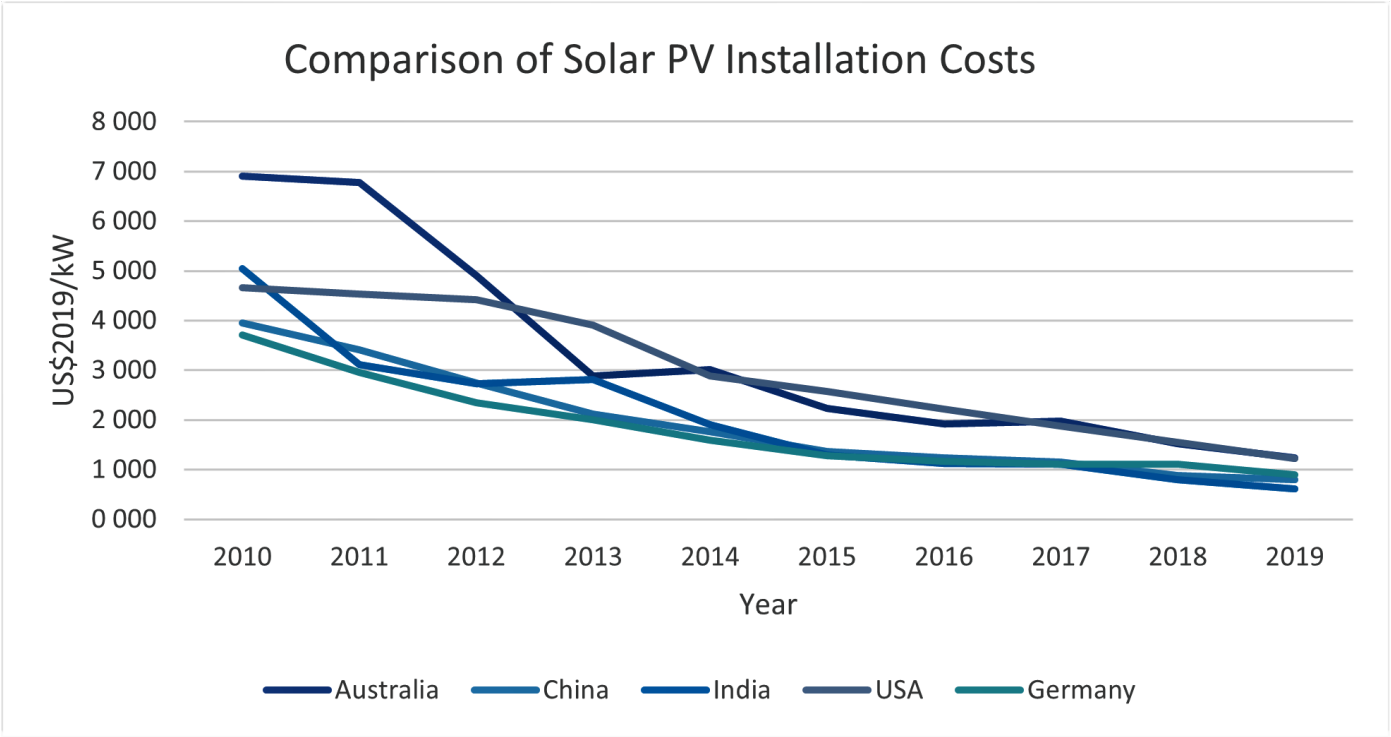

Figure 7: Comparison of Solar PV installation costs (US$2019/kW) from 2010 to 2019. Data from IRENA[17].

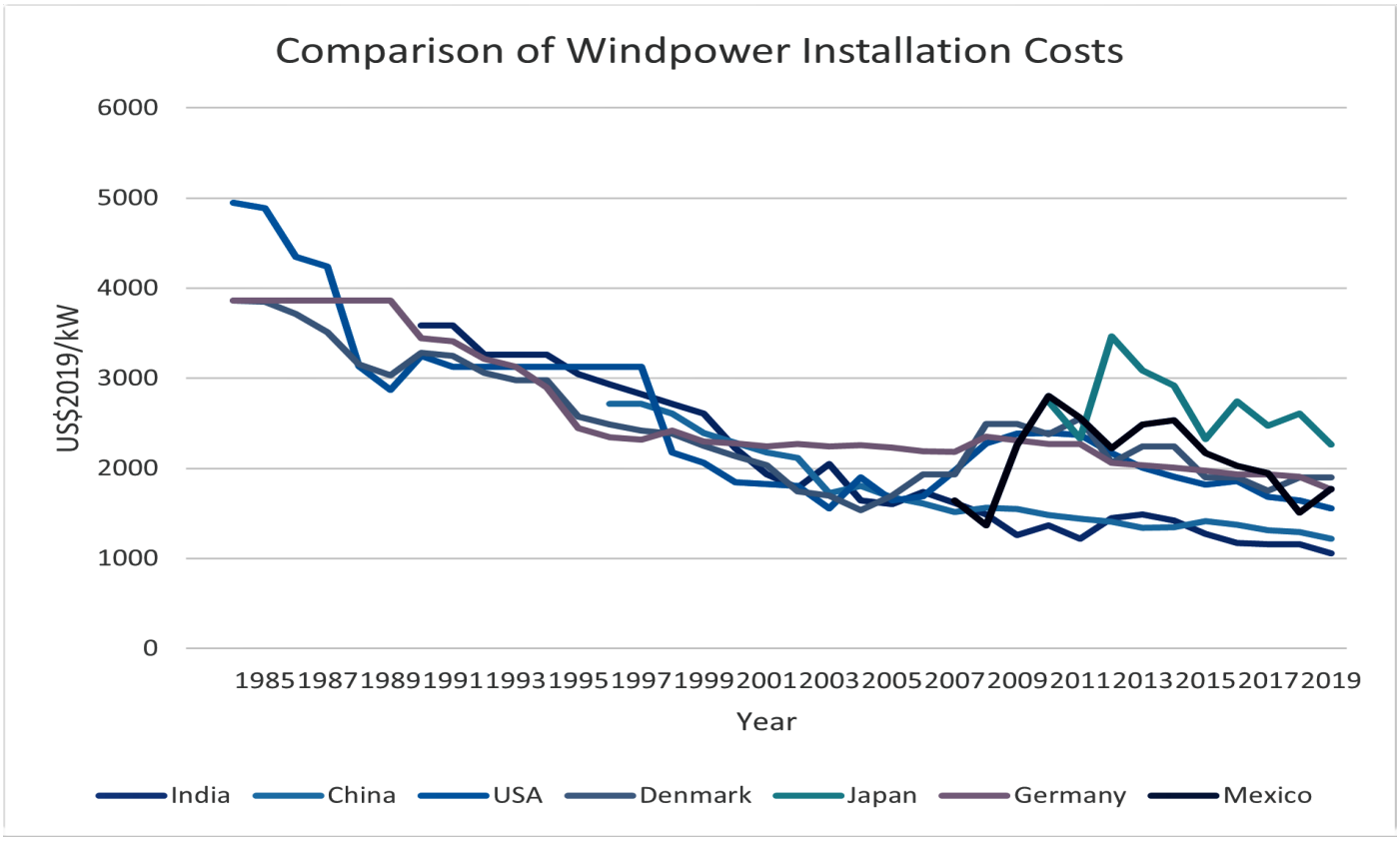

Figure 8: Comparison of wind power installation costs (US$2019/kW) from 1985 to 2019. Data from IRENA[18].

IV. Renewables Finance and Power Sector

While cost advantage rapidly increased the market share of renewables in recent years, it has also exposed the deeper malaise afflicting the power sector in India. Auctions for solar power projects were mostly held on the basis of tariff cap set by government agencies to ensure developers bid only lower than this limit. Wind power projects were based on fixed tariffs set by the electricity regulatory commissions of respective states. In 2017, the government auctioned wind capacities using the solar model that resulted in a significant decline in tariffs—dropping to Rs 3.46 per kWh in February 2017 when the cheapest wind tariff then was Rs 4.16 per kWh in Tamil Nadu[19]. Table 5 provides a sample of large-scale renewable tenders and tariff revisions during 2019 and 2020.

The Solar Energy Corporation of India (SECI) template for renewable energy auctions was also embraced by state utilities. In December 2017, solar electricity tariffs fell to the lowest (Rs 2.43 per kWh) in Gujarat[20]. Tariff caps in auctions have resulted in a highly competitive environment for renewable energy developers and investors. This became a challenge when the ceiling became too high and resulted in poor participation in recent tenders, which slowed the pace of renewable capacity addition. Tariff ceilings in auctions dampened the enthusiasm of the industry, which preferred doing away with tariff caps in favour of totally market driven auctions.

As a result, renewable energy generation growth declined to 5.2% in the first eight months of the previous financial year and lowest in the past four years since 2015[22]. The preference for solar generation also hurt the growth of wind power (See Fig 3), and a large amount of wind potential remains untapped and even existing capacities remains poorly utilized. Renewable capacity addition declined to 9 GW in 2019, compared to the 11-12 GW added every year during the preceding two years[23]. The growth prospects for renewables in 2020 look bleak due to the impact of Covid-19. The renewable energy industry remains a victim of system-wide crisis. There have been warnings that cost reductions cannot go downwards forever as developers will have to factor various risks to ensure reasonable returns from infrastructure projects. A recent analysis[24] suggests that sola tariffs below Rs 2.50 per kWh are financially unviable in future. International players having access to low-interest credit with longer tenure payment schedule have an advantage over their domestic counterparts. Since renewable energy sector is considered high risk, Indian banks lend at high interest rates and long payment delay translates to high costs for developers and in the worst case to non-performing assets[25].

The financial health of DISCOMs is important for the growth of renewable energy sector. Arbitrariness in policy implementation and non-compliance of contracts has a cascading effect that is felt across the power sector including the

Renewable Tenders and Tariffs in 2019 and 2020

Issued By	Type, Capacity	Tender Date	Original Tariff	Revised Tariff	Revised Date
MSEDCL	Solar, 1350 MW	31-08-2019	Rs 3.15	Rs 3.30	02-01-2020
NHPC	Solar, 2000 MW	03-09-2019	Rs 2.65	Rs 2.78	01-01-2020
BREDA	Solar, 250 MW	08-06-2019	NA	Rs 3.15	12-12-2019
SECI	Solar, 1200 MW	02-08-2019	Rs 2.70	Rs 2.88	03-12-2019
SECI	Wind, 1200 MW	20-09-2019	Rs 2.85	Rs 2.93	26-11-2019
SECI	Solar, 7000 MW	25-06-2019	Rs 2.75	Rs 2.93	12-11-2019
SECI	Solar, 500 MW	07-04-2019	Rs 2.85	Rs 2.93	30-10-2019
APGDCL	Solar, 70 MW	10-01-2019	Rs 3.50	Rs 4.00	06-09-2019

Table 5: Renewable Tenders and Tariff Revisions in 2019 and 2020. Data Source: MERCOM India[21].

renewable industry[26]. There are several instances of DISCOMs not honouring their contractual obligations to renewable generators. Given the rapid changes and development of the renewable sector, they add new financial or operational stress on already struggling DISCOMs. For example, allowing large commercial consumers to choose their power supplier robs DISCOMs of sizable revenue and high-value customers and leaves them with smaller consumers.

As part of the Covid-19 stimulus package to revive the economy, the Central government announced Rs 90,000 crore for DISCOMs[27] in May 2020. This fund will be used to pay their dues (estimated around Rs 94,000 crore) to various public and private thermal and renewable energy generators and transmission companies. If poor financial health of DISCOMs have impaired their ability to buy power from cheap renewable energy generators, the declining investment in the transmission and distribution infrastructure will affect the grid quality to support larger penetration of renewables in future. For every rupee spent in adding new generation capacity, about 50 paise should be ideally spent for upgrading transmission and distribution infrastructure.

V. Grid Integration

The recent increase in the relative share of renewable generation in India, which tripled[28] from 2.9% in 2009 to 8.7% in 2019, presents significant difficulties for grid integration and stability. Karnataka, Tamil Nadu, Rajasthan, and Andhra Pradesh—states with renewable generation share above 15%—are already facing problems with grid integration. In Gujarat, Telangana, Maharashtra and Madhya Pradesh, the renewable share of total electricity generation is between 5% and 15% (See Table 6)[29].

Most of wind generation in India is seasonal coinciding with the monsoons, but complements solar generation during non-monsoon period in daytime. The share of renewable generation is expected to increase to 28% by 2040[30]. In such a scenario, adequate grid flexibility will be critical for the security and reliability of electricity supply. Grid flexibility will also need to be complemented with storage, better connections between the regional grids, and demand side management. In this context, effective tools for forecasting wind and solar generation will help grid operators to manage the variable nature of electricity supply and also prepare for events of very high and low output. This will in turn reduce the amount of fast response spinning reserves, the need for which will increase as renewable generation increases. The recommended target of having adequate system reserve margin and spinning reserve of 5% at national level is yet to materialize due to technical difficulties at the plant level and reluctance on the part of generators[31]. Power producers in some

	Wind		Solar		
States	GW	TWh	GW	TWh	Relative Share
Karnataka	4.7	9.8	6.1	7.6	24.3
Tamil Nadu	9.0	12.6	2.6	3.6	16.1
Rajasthan	4.3	6.3	3.2	4.6	16.1
Andhra Pradesh	4.1	8.9	3.1	4.6	17.4
Gujarat	6.1	11.2	2.4	2.4	12.3
Telangana	0.1	0.3	3.6	6.3	11.5
Maharashtra	4.8	7.6	1.6	2.2	6.4
Madhya Pradesh	2.5	4.8	1.8	2.5	5.7
Punjab	0.0	0.0	0.9	1.5	4.6
Kerala	0.1	0.1	0.1	0.1	2.7

Table 6: VRE capacity, generation and percentage share, VRE-rich states, 2018. Data from IEA 2020.

countries are mandated[32] to maintain a certain level of their plant output (10-15%) as spinning reserves to maintain a high degree of reliability of power supply.

Integrating renewables on a large scale planned by India will require stronger and resilient electricity transmission and distribution infrastructure[33]. This will be in addition to the changes needed in market design, policy, and institutional framework to manage a large amount of variable electricity generation. Congested system and subsequent stagnation of transmission of generated power will discourage developers. Wind energy in Tamil Nadu is an example. Independent wind generators in the state face idling of their assets in certain periods due to lack of infrastructure to evacuate power. As other states add more renewable capacity, infrastructure for timely evacuation of power during surplus production will be critical. The Green Energy Corridor (GEC) was initiated in 2017 to connect states and solve this problem. Under this initiative, connecting 50 GW of solar and 16.5 GW of wind assets by the end of 2021 within the states is planned. Given India's federal structure, this system is expected to address resource inequalities across states, reduce involuntary curtailment of renewable output, manage intermittency and variations in quality of power. Technical balancing through strengthening of spot marketing and reserve control are other measures for renewable integration.

While enhancing grid flexibility and other policy measures will help renewable growth, the Achille's heel for the future of renewable generation is utility-scale storage. Even though battery storage, hydrogen production, and other means are available, pumped hydro storage (PHS) is the ideal storage currently available that can be deployed on gigawatt scale. India has 4.8% of installed global PHS capacity. About 2.6 GW capacity is operational now, and 2.2 GW capacity of conventional hydro storage (See Table7) is being converted to pumped storage with suitable plant retrofits and additional construction[34]. There is a large PHS potential in India that is estimated around 96.5 GW available in 63 sites. Most of this potential lies in the Western region that has favourable topography but ecologically sensitive.

VI. Policy Support for Renewables

The renewable energy sector is one of the major beneficiaries of the 1991 economic reforms, which increased the role of private players in electricity generation in India[35]. A new Ministry of Non-Conventional Energy Sources (the precursor to MNRE) was established in 1992 to promote the growth of renewable energy. The initial growth

Pumped Hydro Storage Facilities in India

Project Site	State	Capacity (MW)	Status
Kadamparai	Tamil Nadu	400	Operational
Bhira	Maharashtra	150	Operational
Srisailam	Andhra Pradesh	900	Operational
Ghatgar	Maharashtra	250	Operational
Purulia	West Bengal	900	Operational
Sardar Sarovar	Gujarat	1200	Construction
Panchet Hill	Jharkhand	40	Construction
Kadana St. 1&2	Gujarat	240	Construction
Nagarjuna Sagar	Telangana	705	Construction

Table 7: Pumped Hydro Storage Facilities in India. Data Source: Central Electricity Authority (CEA).

in renewable generation was led by the wind sector which benefitted from feed-in tariff and tax incentives in the form of accelerated depreciation. The 2003 Electricity Act provided the initial momentum for growth through the mandatory Renewable Purchase Obligations (RPO) for distribution companies. The next major policy support for renewables was the 2008 National Action for Plan for Climate Change (NAPCC), which recognized the role of renewable energy for climate mitigation and paved way for initiation of specific programmes. Table 8 provides a summary of key institutional support mechanisms that played an important role in promoting the renewable sector.

Recent difficulties faced by the sector requires changes not just in the policies pertaining to the industry but broader reforms in the power sector. These reforms will have to address the persisting complaints of the renewable energy industry, especially tariffs and payments. International investors would prefer policy certainty and assurances from the government to honour contractual obligations[36]. Several institutional reforms will be needed to consolidate the gains made in recent years to sustain the long-term future of renewable energy in India. Temporary fixes have failed to make much impact on DISCOMs. Without structural overhaul and comprehensive reforms, India's renewable energy sector will be afflicted by the problems of its ecosystem and limit its long-term growth.

Decentralized renewable generation is often overlooked in the renewable energy discourse and could address some of the technical, economical, and administrative burdens facing the power sector. Even though the 175 GW renewable energy mission included installing 40 GW of solar rooftop capacity by 2022, at the end of 2019 only 5.4 GW of rooftop capacity was achieved[37]. Decentralised generation will allow for larger number of players of varying sizes that will require different models for financing, subsidies, procurement, physical infrastructure, and policy support. To encourage more roof-top solar in residential areas while also reducing the resulting economical and administrative inconvenience to state DISCOMs, new institutional models could be explored. DISCOMs could partner with the Renewable Energy Service Companies (that are largely private entities) to install solar roof top systems and ensure regular payments on behalf of the customers, therefore reducing the transaction costs if the company have to directly deal with the customers[38].

Another area of concern is the large dependence on China for supporting renewable growth due to inadequate domestic manufacturing capacity. India's renewable energy boom, especially solar, is largely import driven because the domestic solar cell manufacturing capacity is only 3 GW per year against recent average requirement of 10-15 GW per year. Even ten years after the 2010 National Solar Mission, 90% of India's solar cell and panel[39] requirement is met through imports.

Component	Policies
State Fiscal and Financial	• Feed in Tariff (wind) • Host of Fiscal and Financial incentives- tax concessions, accelerated depreciation, generation-based incentives, viability gap fund
State Generating Demand	• Must-run status • Renewable Purchase Obligations (17% of electricity purchased ought to be REs)
State Building Infrastructure	• Transmission Infrastructure • Waiver of inter-state transmission charges • Reducing transaction costs by mitigating land acquisition and evacuation infrastructure risks

Table 8: Policy support for renewable energy in India.

VII. Policy Recommendations and Conclusion

With the rising number of Covid-19 cases in India, the government's priority will naturally be to deal with the health, economic, and security crisis it faces over the next several months and possibly for the next few years.

Policy instruments such as renewable purchase obligations are already in place to support the growth of renewable energy. Besides continuing them, the government could put in place incentives for encouraging new electricity capacity additions from the renewable sector. While this may come at the cost of thermal power plants forced to operate below their rated capacities in response to renewable generation, and accumulating further financial burden due to revenue losses and underutilization of existing capacity, the renewable generators should partly bear the costs for using dispatchable sources as backup. This will result in tariffs that will better reflect the costs renewable generators impose on the system. A useful pointer for fixing future renewable tariffs is the costs renewable generators are willing to pay for bids with storage options, and to pay that differential to compensate for the losses borne by dispatchable generators. This will result in better financial management across the power sector instead of depending on periodical government bailouts.

Financial support for new renewable capacity addition could be part of the economic stimulus packages announced by the Central government after the pandemic. The first tranche of the government's recent stimulus package went entirely for clearing the dues of DISCOMs to various energy producers including renewable generators. DISCOMs should be incentivized to honour their contractual obligations to renewable generators. The renewable energy industry in many countries have already emerged as a major source of employment. With further expansion of renewable industry in India, direct support to this sector such as strengthening the manufacturing base for renewable energy will aid economic recovery through new job creation and result in better utilization of stimulus funds.

Next, the issues in renewable energy auctions and procedures for setting tariffs need to be addressed to regain the trust and enthusiasm of developers. Policy uncertainty and confusion over these issues cause delays and mismanagement leading to cost overruns even in the renewable sector. This is partly due to the poor coordination between the Central and State governments on renewable energy projects. As long as the relative share of renewable energy in the system was small, these problems and system inefficiencies were less conspicuous.

Finally, as the share of solar and wind power increases in the system, investing in technology and infrastructure upgrades such as feeder separation, smart meters, data collection and data analytics will be critical for accommodating a large share of variable generation and improving the flexibility of the power system. The flexibility available in the power system will limit or help further deployment of renewable energy. Enhancing system flexibility requires better demand side management, accurate forecasting and scheduling tools, effective operation and management of various power generation, and timely deployment of efficient and economically viable utility scale storage solutions.

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