Title

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Publication Date
2024-01-21

Peer reviewed

Electricity Markets & Policy
Energy Analysis & Environmental Impacts Division
Lawrence Berkeley National Laboratory

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December 2021

The work described in this study was performed at Lawrence Berkeley National Laboratory under Contract No. DE-AC02-05CH11231 with the U.S. Department of Energy.

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Acknowledgements

We are thankful to the William and Flora Hewlett Foundation for funding this work. This work benefited from invaluable inputs from Mr. Alok Kumar, Secretary, and Mr. Ghanshyam Prasad, Joint Secretary, Ministry of Power, India.

We thank Ashwin Gambhir of Prayas Energy Group, Dr. Ashvini Kumar, Saloni Sachdeva, Akanksha Golchha, Manu Maudgal and Shubhashis Dey of Shakti Sustainable Energy Foundation for their helpful reviews of the report. We are indebted to Balawant Joshi and Ajit Pandit of Idam Infrastructure Advisory Pvt. Ltd. for their technical inputs and thoughtful feedback. We are also thankful to Andy Satchwell and Dr. Jiang Lin of Lawrence Berkeley National Laboratory for their review and suggestions.

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List of Abbreviations

BCD	Basic Customs Duty
BNEF	Bloomberg New Energy Finance
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
COD	commercial operation date
COP-21	21st Conference of the Parties
CUF	capacity utilization factor
EESL	Energy Efficiency Services Limited
EU	European Union
FY	fiscal year
GEC	Green Energy Corridors
GoI	Government of India
GW	gigawatt
GWh	gigawatt-hour
IEA	International Energy Agency
INR	Indian National Rupee
IRENA	International Renewable Energy Agency
ISTS	Interstate Transmission System
IWTMA	Indian Wind Turbine Manufacturers Association
KfW	Kreditanstalt für Wiederaufbau, Germany's state-owned investment and development bank
KREDL	Karnataka Renewable Energy Development Limited
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LCOE	levelized cost of energy
LCOS	levelized cost of storage
LED	light-emitting diode
MBED	market-based economic dispatch
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MW	megawatt
MWh	megawatt-hour
NBFCs	non-banking financial corporations
NDC	Nationally Determined Contribution
NPA	non-performing asset
NREL	National Renewable Energy Laboratory
PIB	Press Information Bureau
PLI	Production-Linked Incentive
PLF	plant load factor
PPA	power-purchase agreement
PV	photovoltaic
RBI	Reserve Bank of India
RE	renewable energy
REC	renewable energy certificate
SGD	Safeguard Duty
TBCB	tariff-based competitive bidding
TERI	The Energy and Resources Institute
TWh	terawatt-hour
UJALA	Unnat Jyoti by Affordable LEDs for All
USD	United States Dollar
WRI	World Resources Institute

Executive Summary

India is targeting 500 GW of installed non-fossil fuel capacity by 2030, as announced by Prime Minister Modi at the United Nations Climate Change Conference of the Parties (COP-26) in Glasgow in November 2021. Current nuclear and large hydropower capacity in India add up to ~50 GW, and hence 450 GW of installed renewable energy (RE) capacity by 2030 could help achieve this target. India reached 100 GW of RE capacity in August 2021 (with another 80 GW in the pipeline). Several studies have shown cost effectiveness and technical feasibility of deploying large quantum of renewable capacity (374 GW – 465 GW) to meet India's load in 2030. Specifically, a recent Lawrence Berkeley National Laboratory report [1], hereafter called the "2030 India Report"[1], concluded that the least-cost resource mix to meet India's load in 2030 consists primarily of a combination of RE and flexible resources as follows: 465 GW of RE (307 GW_{DC} solar, 142 GW wind, and 15 GW other RE), 63 GW (252 GWh) of battery storage, 60 GW of load shifting to solar hours (50 GW agricultural + 10 GW industrial), and flexible operation of the existing natural gas fleet of 25 GW. A coal power plant capacity of 229 GW (23 GW net addition over 2020) is found to be cost-effective.

In this policy brief, we assess the prerequisites for achieving this resource mix (450 GW of solar and wind capacity) by 2030, such as availability of land, new transmission buildout, financing and pace of deployment, as well as the impact on grid reliability and cost of generation. We also examine the impact of policies promoting domestic manufacturing. We find that meeting these requirements is challenging but plausible. Figure ES 1 summarizes the key insights on different considerations for achieving deployment of 450 GW of solar and wind capacity by 2030.

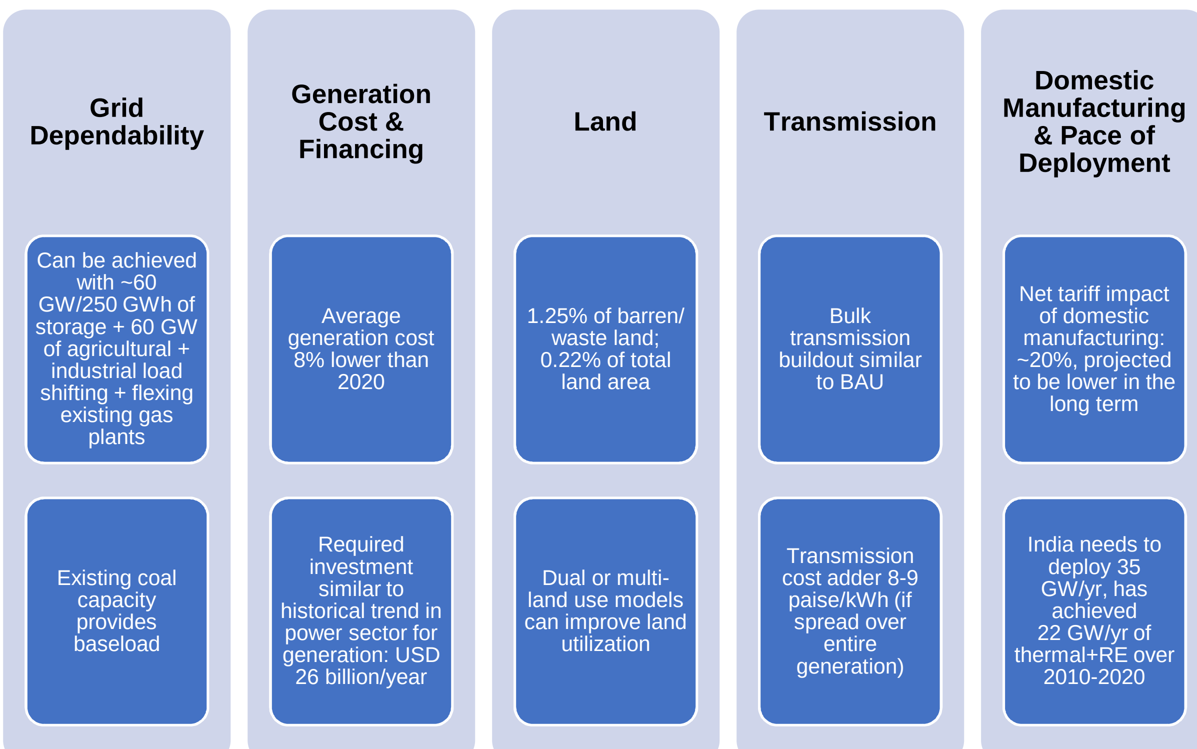

Figure ES - 1: Considerations for achieving 450 GW of solar and wind capacity by 2030

[1] This study was conducted under the Flexible Resources Initiative (FRI) of the U.S.-India Clean Energy Finance Task Force.

Grid Reliability and Integration: Battery storage costs have declined by 90% since 2010 [2], and these dramatic declines have created new possibilities for maintaining the grid reliability cost-effectively in renewable-heavy systems. Recent studies have shown how the Indian power system can meet demand in every hour by complementing large RE capacity with energy storage and load shifting, with limited addition of new coal capacity. The 2030 India Report shows that India can reliably meet its 2030 electrical load predominantly with 465 GW of RE (307 GW_{DC} solar, 142 GW wind, and 15 GW other RE), coupled with flexible resources and modest additions to thermal resources[2], as mentioned previously. Total non-fossil capacity by 2030 would be 545 GW. The modeling demonstrates that load is reliably met during every hour of the year, including during weeks of maximum load and highest net load. Therefore, in this policy brief, we focus our assessments and analysis specifically on installation of 450 GW of cumulative installed solar and wind capacity by 2030.

Cost of Generation: Owing to the recent steep reduction in RE and battery storage costs, the 2030 India Report shows that the most economical strategy to meet India's electricity demand involves 450 GW of solar and wind capacity combined with significant battery storage, and limited or no new investment in coal generation. Further, the 2030 India Report shows that the average cost of generation in 2030 (including new interstate transmission investments) would be Rs 3.6/kWh, which is 8% lower than today's generation cost, resulting in significant consumer savings. Note that the 2030 India Report assumes a modest decline in renewable energy costs (5-10% between 2020 and 2030) and a more pronounced decline in storage costs (30-40% between 2020 and 2030).

Land Availability: 450 GW of cumulative installed solar and wind capacity (307 GW_{DC} of solar and 142 GW of wind) would require 1.25% of the land that is categorized as barren or waste, which is equivalent to about 0.22% of the total land area in India. Because of the good solar resource across large swaths of India, the solar energy buildout—and thus the land use—potentially can be spread out. Options that enable dual use of land for installing wind turbines and agriculture as well as innovative land leasing models that share the benefits of RE revenues with existing land owners (such as farmers) can potentially address some of the concerns around land availability and livelihoods.

Transmission Buildout: The 2030 India Report shows that India would need to build about 280 GW of new interstate transmission capacity[3] by 2030. However, most of the new transmission buildout is driven by the near doubling of electricity demand between 2020 and 2030. The net additional investments in interstate transmission infrastructure for RE integration are found to be small. This is mainly because of three reasons: (a) solar resources are well spread out in the country and relatively close to load centers compared to coal resources; (b) energy storage obviates the need for significant new interstate transmission buildout for grid integration of RE capacity and, because of deep cost reductions, in most instances it is more economical than building new long-distance bulk transmission lines; and (c) wind and solar energy generation profiles are complementary. The Government of India has already announced plans to build 130 GW of new interstate transmission capacity through 2025. The investment required for the new transmission capacity (280 GW) at the interstate level is estimated to be about 21 billion U.S. dollars (USD), with about USD 1.5 billion required for spur lines and USD 1 billion for substations, totaling about USD 23.5 billion, or INR 172,300 crore, between 2020 and 2030. If spread over the entire electricity generation in 2030, the adder on the average generation cost would be about Rs. 0.08–0.09/kWh.

Financing: Deploying renewables at such a scale would require securing adequate financing. Deploying 450 GW of cumulative installed solar and wind capacity by 2030 requires that USD 266 billion be mobilized

[2] Net increase of 23 GW in coal capacity vs 2020 installed coal capacity. However, if adequate storage and renewable capacity are not deployed at scale, additional thermal capacity might be required.
[3] This does not include additional intra-state or spur line transmission capacity, albeit these investments would potentially be small

between 2021 and 2030 (for investment in an additional 365 GW of solar and wind capacity and 63 GW/250 GWh of battery storage), equivalent to USD 26.6 billion per year. This is 20% less than the annual investment that India's power sector saw on average between 2015 and 2019, across all generation resources. While annual investments specifically in renewables would need to increase significantly, a majority of investment in the power sector worldwide is already going to renewables. However, regulatory hurdles—such as banks hitting their lending limits in the power sector, along with prior bad debt—need to be addressed.

Domestic Manufacturing: India currently has 8 GW of solar module manufacturing capacity, along with 10 GW of wind turbine manufacturing capacity. For deploying about 36 GW of solar and wind capacity per year, about 50% of requisite production capacity already exists domestically. The potential increase in RE costs from policies that support domestic manufacturing is likely to be modest and is unlikely to affect the feasibility of meeting the RE targets. Based on the domestic manufacturing linked reverse auctions, the net increase in solar PPA prices due to domestic manufacturing appeared to be about 20% in 2020. As India expands its manufacturing capacity and solar deployment, this premium should shrink. The Government of India has enacted several measures to increase the share of domestic manufacturing in solar deployment, such as imposition of Basic Customs Duty on cells and panels imported from China, along with a Production-Linked Incentive for manufacturing in India. Additionally, recent announcements from industry point to significant growth in new solar manufacturing capacity, expected to come online over the next few years.

Pace of Deployment: India's power sector has deployed thermal and RE capacity rapidly—installing close to 22 GW/year between 2010 and 2020. Construction of coal power plants entails high ancillary costs to secure fuel linkages and water supply. Compared with coal power plants, solar and wind plants need less investment per MW and can be built three times faster. These precedents suggest that deploying 35–40 GW of solar and wind capacity per year would be challenging but potentially achievable.

States such as Karnataka, Tamil Nadu, Rajasthan, and Gujarat have led the installation of RE capacity to date, and distilling the lessons about which policies have worked is critical, for example, facilitating land acquisition and transmission connectivity as done in solar parks. Furthermore, India would need a new set of policy and regulatory measures to scale up deployment during this decade, including modifications to state level planning and procurement process and adjusting market rules for accommodating newer flexible resources like energy storage.


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1. Introduction

India has set a goal of reaching 500 GW of non-fossil fuel installed capacity by 2030. Several studies have shown the cost-effectiveness and/or technical feasibility of deploying large amounts of renewable energy (RE) capacity (374 GW – 465 GW) on the Indian grid by 2030, such as Lawrence Berkeley National Laboratory's (LBNL's) and the Central Electricity Authority's (CEA's) reports on the optimal generation mix for India in 2030 [1] [3], the National Renewable Energy Laboratory's (NREL's) study on cost-effective opportunities for grid-scale energy storage deployment in South Asia [4], and The Energy and Resources Institute's (TERI's) report on Renewable Power Pathways for 2030 [5].

However, concerns remain about deployment challenges such as land availability, transmission infrastructure, financing, imports and supply chain for solar and batteries, and the pace of deployment needed for the next decade. We use previous studies available in the literature as well as publicly available data to analyze these concerns. For example, we use Abhyankar et al. [1] to elucidate the technical feasibility, grid reliability, and economic benefits of achieving 450 GW of cumulative installed solar and wind capacity by 2030 as well as the transmission network requirements. We use Deshmukh et al. [6] for land assessment, Deorah et al. [7] for projections of Li-ion battery storage costs in India, CEA reports [8] [9] [10] for capacity additions over time and the construction time of coal plants, and so forth.

1.1 India's ambitious renewable energy targets

India had announced an ambitious RE target of 175 GW (100 GW of solar,[4] 60 GW of wind, 15 GW of biopower and small hydropower) by 2022. When this target was announced by Prime Minister Modi in 2015, India had 35 GW of RE capacity installed, of which solar constituted only 4 GW. As of August 2021, 100 GW of RE capacity was installed, including 44 GW of solar and 40 GW of wind.

India expanded its ambition of deploying renewables to a total RE capacity of 450 GW by 2030 [11] [12]. At the United Nations Climate Change Conference of the Parties (COP-26) in Glasgow in November 2021, Prime Minister Modi announced that India would deploy 500 GW of non-fossil fuel power generation capacity by 2030 [13]. Current nuclear and large hydropower capacity add up to ~50 GW, and hence 450 GW of installed RE capacity by 2030 could help achieve this target. In this policy brief, we assess the requirements for deployment of 450 GW of cumulative installed renewable capacity[5] by 2030.

Beginning with the launch of the Wind Mission and the Jawaharlal Nehru Solar Mission, India has deployed significant solar and wind capacity, while bringing down RE prices. Between 2010 and 2020, India saw the largest reduction in country-level solar levelized cost of energy (LCOE)—a decrease of 85%—and achieved some of the world's lowest costs for solar and wind power (Figure 1). For comparison, a solar tariff

[4] While our analysis focuses on utility (MW) scale renewable plants, we note that India has a target of installing 20 GW of distributed solar rooftop systems (by 2022), from a current installed capacity of 4.5 GW. Utility-scale solar has favorable economics and ubiquitous resource potential across the country, whereas rooftop solar faces significant barriers such as high transaction costs, metering, and limited roof space. Thus, the cumulative contribution of rooftop solar to achieving the 2030 target might be limited, and we focus our discussion on utility-scale systems only.

[5] Given low costs of solar and wind technologies, most studies show no further capacity additions for other renewable resources such as small hydro and biomass (15 GW existing capacity). Given 450 GW of solar and wind capacity would be cost effective for India in 2030, as shown by Abhyankar et al. [1], equivalent to 465 GW of total RE, we focus our assessment on this resource mix.

discovered in a recent auction by Solar Energy Corporation of India Limited in November 2020 [14] was Rs. 2/kWh, which is lower than the variable cost of close to 140 GW of existing coal capacity [1].

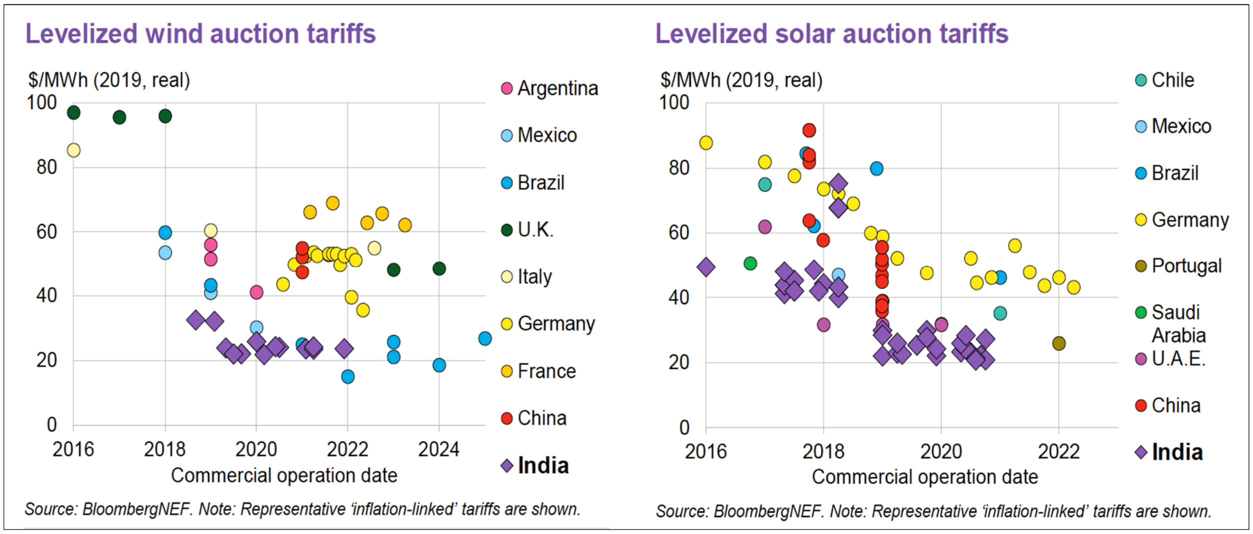

Figure 1: Solar and wind energy prices in key countries
Source: [15]

In addition, plummeting Li-ion battery costs have shifted the economic feasibility of grid-scale battery storage. With battery prices dropping by 90% over the last 10 years and expected to further halve by 2030 (Figure 2), RE projects with co-located storage are becoming the new norm in the United States. About 680 GW of new RE capacity is in the interconnection queue in the United States, along with 200 GW of battery storage, of which over 100 GW is co-located with RE [16]. The Los Angeles Department of Water and Power signed a power-purchase agreement (PPA) for a project with battery storage equivalent to over 50% of solar generation, at 40 U.S. dollars (USD) per MWh, expected to be commissioned by 2023 [17]. This is equivalent to about Rs. 2.92/kWh,[6] for extending the period during which solar power is supplied by 2.5–3 hours.

Using market trends from the United States and bottom-up estimates, a team from LBNL projected Li-ion battery prices (as levelized cost of storage) for India [7]. This report estimated that, by 2030, the additional cost of adding battery storage equivalent to about 30% of daily solar generation would be about Rs. 1/kWh.[7] Therefore, the cost of power from a solar-plus-storage plant that could extend solar generation to evening peak hours would be about Rs. 2.5/kWh (assuming the solar LCOE to be Rs. 1.5/kWh by 2030). As a comparison, over 100 GW of existing coal capacity has a current variable cost greater than Rs. 2.5/kWh [1].
Figure 3 shows the estimated cost per unit from a solar-plus-storage plant in 2030, for different levels of solar generation stored in the battery.

The impact of these cost trends is visible in RE installations in major countries as well as targets announced by the European Union (EU), the United States, and China. In the United States, the Biden Administration is targeting a 50%–52% reduction in carbon emissions by 2030, which entails 80% decarbonization of the power sector and requires about 1,150 GW of solar and wind capacity by 2030 [18]. Between 2020 and 2030, installed solar and wind capacity in the United States, EU, and China combined is expected to triple,

[6] At an exchange rate of 1 USD = Rs. 73.
[7] Termed as the "storage tariff adder," this is the cost of storage spread out over all solar generation.

from 1,080 GW to over 3,000 GW—more than six times larger than India's target (Figure 4). Solar manufacturing has a well-established supply chain, and the world is quickly catching up on battery manufacturing capacity and related supply chains to meet the demand surge expected from electric transportation and grid-scale batteries (Figure 5). New battery chemistries continue to be commercialized [19]. Thus, for the foreseeable future, concerns around the supply of lithium and other materials as a major constraint might not prove to be consequential.

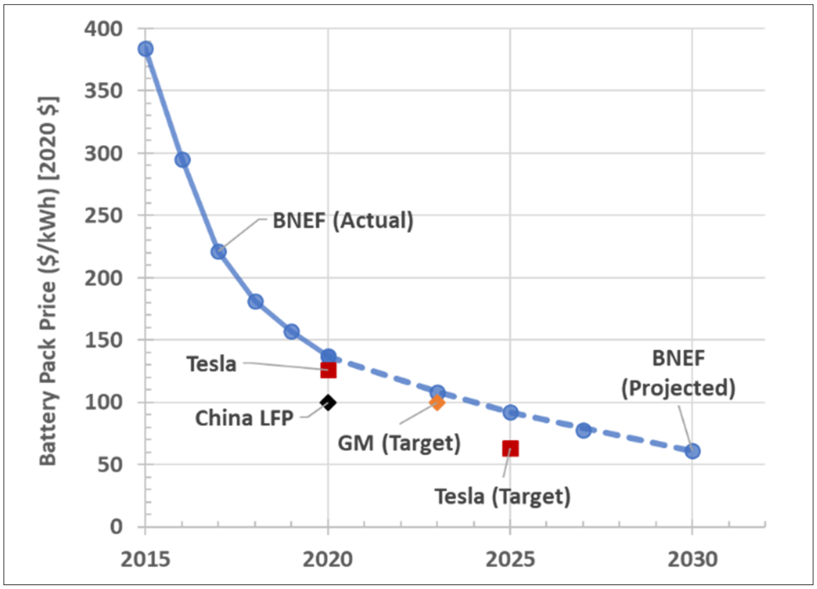

Figure 2: Global battery pack price trend
Source: [2] and author compilation

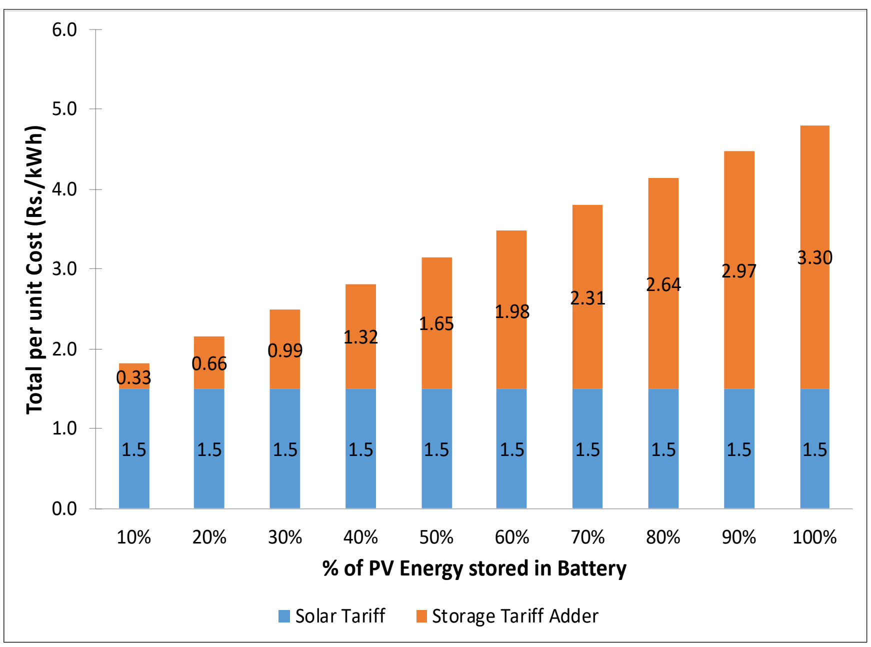

Figure 3: India solar tariff and storage tariff adder vs. percentage of photovoltaic (PV) energy stored in the battery for year 2030
Source: [7]

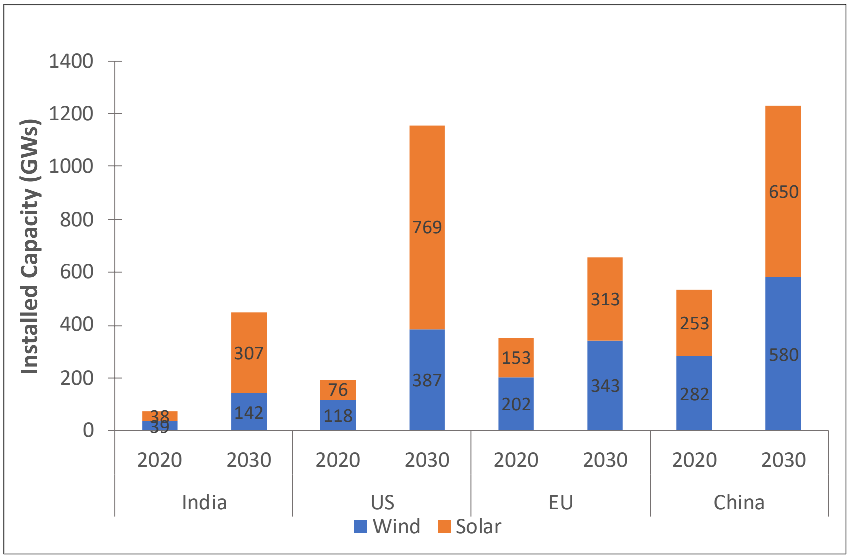

Figure 4: Solar and wind installed capacities for 2020 (actual) and 2030 (projected)

Sources: India 2020: [20]; 2030: [3]

United States 2020: [21]; 2030: projection based on 80% carbon-free electricity standard by 2030 (critical for achieving target of 50% emissions reduction by 2030) [18]

EU 2020: [21]; 2030: [22]

China 2020: [21]; 2030: [23]

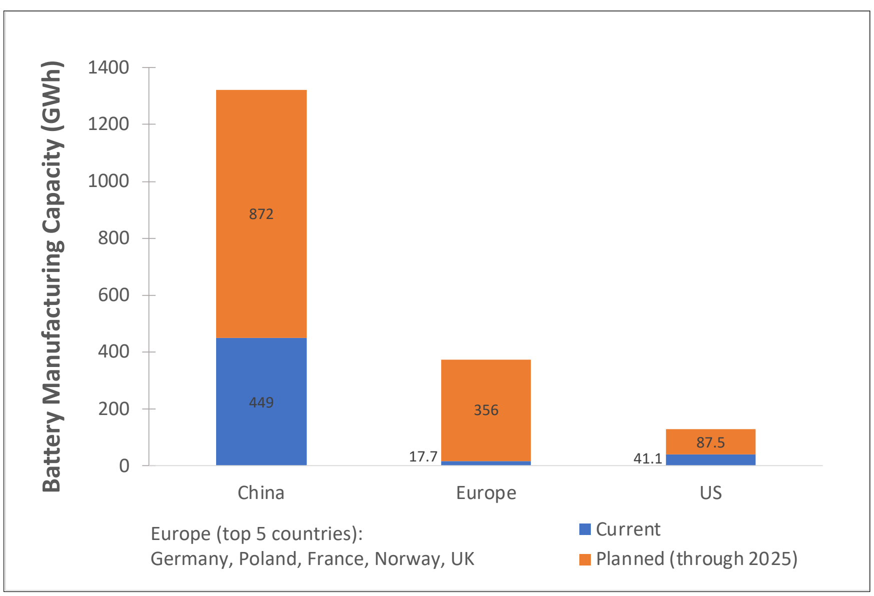

Figure 5: Battery manufacturing capacity, current and planned (through 2025) for different regions

Source: [24]

1.2 Installing 450–530 GW of solar and wind capacity by 2030 would be cost-effective

Several recent studies have demonstrated the cost-effectiveness and/or confirmed the operational feasibility of running the grid with large amounts of renewable capacity (375 GW – 465 GW) in 2030, most notably by CEA [3], NREL [4], and TERI [5]. CEA (2020) assessed a least-cost resource mix for 2030 (with 435 GW of RE) and validated the feasibility of this resource mix by simulating hourly dispatch for representative weeks of the year [3]. TERI (2020) focused on the operational strategies for achieving the target of 450 GW of renewable capacity by 2030, and demonstrated that the grid can be reliably run with some additional flexible resources on the grid, such as battery storage; however, they do not determine a least-cost mix [5]. BNEF used current RE prices, though the results were not spatially resolved, and it is unclear whether grid dispatch was modeled [15]. NREL (2021) conducted scenarios-based capacity expansion modeling to assess when, where and how much energy storage can be cost-effectively deployed in India through 2050, but the report does not take into account impact of demand side resources [4]. Additionally, Deshmukh et al. showed that various scenarios of renewable capacity (200 to 600 GW) are operationally feasible for the Indian grid, and minimize emissions [25].

In a separate report, we assessed a least-cost optimal mix of resources to meet India's projected demand in 2030 [1], henceforth called the ***"2030 India Report."*** The 2030 India Report[8] used 30-node, state-level optimal capacity-expansion modeling (including interstate transmission lines), with fiscal year (FY) 2022 as the base year.[9] The report used the latest available RE and storage cost estimates and trends, incorporated demand response, and modeled power plant level hourly economic dispatch to validate technical feasibility of the resource mix. We use the results from the 2030 India Report throughout this policy brief.
The 2030 India Report assumed the load projection from CEA's 19th Electric Power Survey [26], and it factored in the impending shift of 50 GW of agricultural load to daytime hours. This shift is already underway in states such as Maharashtra, Karnataka, Gujarat, and Madhya Pradesh. Shifting agricultural load to solar hours helps utilize solar generation and significantly reduces the need for baseload power at night. The report concluded that incremental demand through 2030 could largely be met by new investments in solar and wind capacity, plus storage and existing thermal assets, in both the "Primary Least Cost Case," which assumed a conservative drop in solar and wind energy prices going forward, and the "Low RE Cost Case," which assumed a historical rate of cost reductions.

The **Primary Least Cost Case** would consist of a combination of 465 GW of RE (307 GW_{DC} of solar, 142 GW of wind, and 15 GW of other RE) and flexible resources (63 GW/252 GWh of battery storage, 60 GW of load shifting to solar hours: 50 GW agricultural + 10 GW industrial), flexible operation of the existing 25-GW natural gas fleet, 140 GW of additional interstate power transfer capacity, and a national market such as the proposed market-based economic dispatch (MBED).[10] Small net addition to the existing coal fleet would be required—about 23 GW at pit-head locations in the eastern and western regions—beyond the coal capacity currently under construction. Total non-fossil capacity by 2030 would be 545 GW. The solar and wind share of total generation would increase from 10% in FY 2020 to about 36% in 2030, thereby driving the share of non-fossil generation to 50%. The average cost of generation in 2030 would be 8% lower than the cost in 2020, owing to the inflation-proof, low-cost renewable power and improved capacity factors for existing coal units.

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[8] This study was conducted under the Flexible Resources Initiative (FRI) of the U.S.-India Clean Energy Finance Task Force. U.S. Department of State and Federal Energy Regulatory Commission (FERC) co-led FRI from the United States, along with the Ministry of Power (MoP) on the Indian side.
[9] While we assume that 175 GW of RE is realized by 2022, we also run a scenario in which we optimize starting in 2021, with similar results for 2030. Please refer to [1] for details.
[10] MBED is expected to lower the barriers to interstate exchange of power and to enhance the flexibility of the system.

Under the **Low RE Cost Case**, which assumes that RE and battery costs continue to decline at historical rates (with solar LCOE at the best sites dropping to Rs 1.5/kWh by 2030), no new coal-fired buildout would be economic. The least-cost mix would include 547 GW of RE (385 GW_{DC} of solar, 147 GW of wind, and 15 GW of other RE), and 84 GW/336 GWh of battery storage. That is, the grid would reliably run with existing coal capacity of 206 GW in conjunction with renewable capacity and other flexible resources, and 56% of generation would be supplied by non-fossil sources, including large hydropower and nuclear. Table 1 summarizes the resource mix in the two scenarios.

Table 1: India's current installed capacity mix (2020) and projected mix (2030) for scenarios in the 2030 India Report

	Technology	Actual (2020)	Primary Least Cost (2030)	Low-RE Cost (2030)
Installed capacity (GW)	Coal	206	229	206
	Natural gas	25	25	25
	Nuclear	7	19	19
	Hydropower	43	67	67
	Wind	38	142	147
	Solar	35	307	385
	Other RE	15	15	15
	Storage	0	63	84
	Total	**369**	**867**	**948**
Share of coal-based generation		**73%**	**48%**	**43%**
Share of solar + wind generation		**10%**	**36%**	**42%**
Average cost of generation (Rs/kWh)	India	**3.90***	**3.59**	**3.50**

* Average cost of generation estimated by the model, close to the actual cost.

1.3 India's grid would be dependable with high renewable energy penetration

Using a dispatch model simulating India's grid operation during every hour in 2030, the 2030 India Report showed that the resource mix in both the Primary Least Cost and the Low RE Cost scenarios could meet the load reliably in 2030. Flexible resources would work in tandem to maintain grid dependability throughout the year including periods of high system stress such as peak load, high RE variability, and high net load.

Agricultural load shifting and energy storage together would be critical for diurnal balancing of the grid, while natural gas plants would provide seasonal balancing. Agricultural load shifting would increase the load during solar hours, while reducing the nighttime baseload requirement by about 30–50 GW. Energy storage, including batteries and pumped hydro, would charge during the day and discharge during evening (7–9 PM) and morning (6–8 AM) peak hours, while also providing the ramping support during the most critical ramp events. Natural gas plants would operate mostly during the low RE season (October through February), when the grid needs significant additional energy that the batteries are unable to supply owing to low RE generation. We found that the existing natural gas plants can fill this gap cost-effectively relative to building new coal power plants operating at low plant load factors (PLFs) to meet such seasonal loads. There would be sufficient buffer capacity on the grid even during days of high stress (highest load, highest net load, highest RE variability, etc.) to provide operating reserves to manage contingencies or errors in load/generation forecasts. The study also simulated hourly dispatch during the weeks of peak load and net

load peak by assuming solar and wind output to be 20% and 50% lower, respectively, and found that load is still met reliably.
However, if low-cost energy storage is not deployed at such scale, additional thermal investments beyond the 23 GW of net coal additions will be needed through 2030 to maintain grid reliability, but such assets will operate at low capacity factors.

Solar and wind plants also help manage unforeseen shifts in demand growth—such as lower-than-projected growth due to a pandemic or an economic downturn, or higher growth due to accelerated electric vehicle sales—because they can be constructed in 18–24 months. The shorter deployment time makes it easier for supply to track demand, especially when demand growth differs from projections.[11] This responsiveness helps avoid uneconomic investment in inflexible fossil assets, while making the grid more resilient to unanticipated disruptions in load or supply.

The 2030 India Report validated the cost-effectiveness and technical feasibility of deploying 450 GW of solar and wind capacity by 2030. Given higher costs of other RE technologies (such as small hydro and biomass), future additions to RE capacity are likely to be dominated by solar and wind plants, as concluded by the study. Hence, in this policy brief, we focus our assessments on the Primary Least Cost pathway suggested by the 2030 India Report, with 450 GW of solar and wind capacity by 2030. The following sections address additional concerns about achieving this goal.

2. Does India have the land to install 450 GW of solar and wind capacity?

India has 2.4% of the world's land area but close to 18% of the world's population. India's population density is about 460 people per km^2, compared with about 150 people per km^2 in China and about 35 people per km^2 in the United States. India uses over 60% of its land area for agriculture, compared with 56% in China and 44% in the United States [27]. Hence, land is a precious resource in India to support a growing population and a burgeoning economy.

Land requirements have been raised as a major criticism to installing hundreds of GW of solar and wind. Supercritical coal plants require less than an acre per MW, whereas solar PV plants need several times that amount. Averaging the five most recent plants commissioned[12] in India, new coal plants require about 0.78 acres/MW.[13] In contrast, the average land requirement for solar PV plants is about 5 acres/MW, and about 1 acre/MW for wind plants (actual footprint of wind turbines on the ground).

Deshmukh et al. [6] used satellite data to analyze the land requirements for solar and wind deployment in India. India has very good solar resources spread across the country, while wind resources are more concentrated in the southern and western regions. This analysis of land suitable for RE deployment excludes areas such as forests, orchard plantations, water bodies, urban areas, sensitive areas, and national parks, mapping the best resource areas for installing future solar and wind plants and supply curves for new capacity.[14] The capacity potential incorporating land availability as estimated in this report was over

[11] Our analysis does not include additional electric load that could come online due to electrification of transportation, buildings, and industry in the 2030 timeframe.
[12] Sasan, Lara, Khargone, Prayagraj, Uchpinda.
[13] This does not include land used for coal mining, which is a direct requirement for coal-based generation.
[14] See https://mapre.lbl.gov/rez/irez/.

3,300 GW for wind and over 5,000 GW for solar. The report recommends dual land-use strategies, for example, co-locating wind turbines with agricultural areas.

Based on the land requirement assumptions above, we estimate about 6,325 km^2 would be required to install 307 GW of solar and around 640 km^2 to install 142 GW of wind[15] in 2030. In total, these land requirements represent 0.22% of the total land area in India; hence land availability might not be a limiting factor for deployment.

Furthermore, land currently classified as “fallow,” “shrub,” “barren,” and “waste” constitutes about 558,220 km^2 in India [28]. If we consider these land categories as land available for installing RE plants, the land requirement for deploying total installed 450 GW of solar and wind capacity up to 2030 represents only 1.25% of this available land. Hence, at the national level, this seems achievable. However, more nuanced land-use and land-cover analysis and on-ground validation would be required. For instance, certain states have very low wasteland as a percentage of their geographic area and might need special consideration for RE installation [29]. Uttar Pradesh, Punjab, and West Bengal have less than 5% of land categorized as wasteland and might need to import power from other states in an RE-heavy scenario.

The 2030 India Report [1] also showed where solar and wind plants could be sited to install 450 GW of capacity by 2030 (Figure 6). The sites are chosen using multiple criteria such as resource quality, access to existing road and transmission infrastructure, and availability of land. This analysis could serve as a starting point for long-term transmission planning, but additional, more nuanced analysis is required for investment-grade assessment of individual site suitability.[16]

[15] This is the actual wind footprint on the ground. The total land area requirement is several times higher, but most of that additional land could be used for multiple applications including agriculture.
[16] RE projects should be planned with more awareness about local environmental and ecological impacts, even if they are small compared to coal or hydro projects, for example.

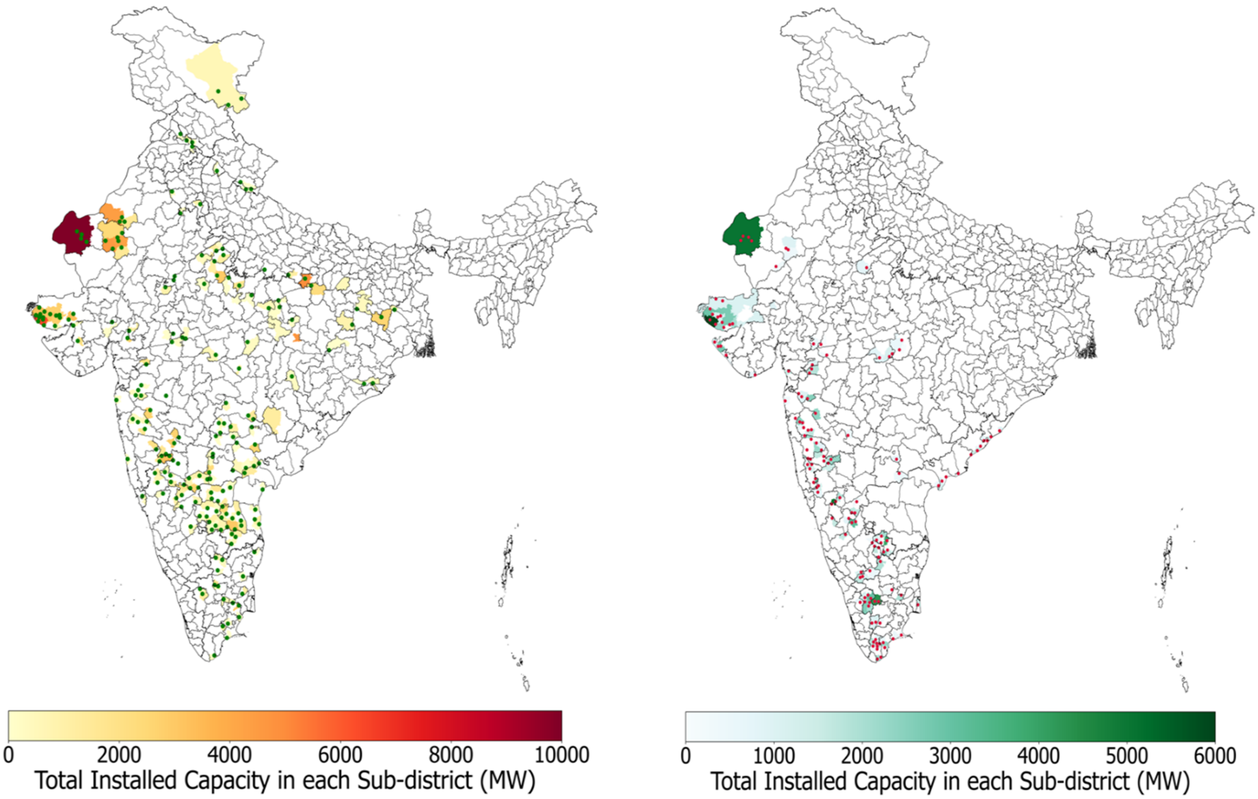

Figure 6: Sites and installed capacity by sub-district for 307 GW of solar capacity (left) and 142 GW of wind capacity (right) in 2030, as per the 2030 India Report model

In India, solar parks have been a major policy instrument for rapid deployment, because streamlining land acquisition has reduced developer costs and therefore tariffs. Various government agencies have also experimented with leasing land in arid regions. For example, for the 2,000-MW solar plant in Pavagada, Karnataka, Karnataka Renewable Energy Development Ltd. (KREDL) leased land from the farmers of a drought-prone village, assuring income of Rs. 21,000 per acre per year to the owners [30]. If scaled, this model would have the twin advantages of faster land procurement and income to rural landowners.

Policy and regulatory measures would be needed at the state level to address challenges related to fragmented land holdings and other barriers to land acquisition. Although the total land requirement for 450 GW of solar and wind capacity seems modest, more innovation in processes would be required as the scale of deployment grows dramatically.

3. How much additional transmission infrastructure is required?

Because India's peak load is expected to almost double over the decade, from 180 GW in FY 2020 to 340 GW in FY 2030, significant additional transmission investments would be required irrespective of the resource mix. The 2030 India Report investigated interstate transmission requirements and found that, regardless of the RE capacity addition, India would need 140–150 GW of new transfer capacity by 2030 to meet the rising load, which implies the required transmission capacity buildout to be approximately 280 GW.

The study found that, because of the deep reduction in solar and battery prices and generally good solar resource quality in most states, it is feasible to spread out solar and storage investments throughout the country, which may not be feasible with coal power plants that must be sited near coal mines to achieve low costs. Siting grid-scale storage near renewable plants also helps use the locational value of storage in maximizing transmission utilization. Thus, the study concluded that additional transmission investments required for an RE-heavy grid are minor.

Table 2 summarizes our estimate[17] of the incremental investments required for the interstate transmission network, spur lines, and substations up to 2030 in the Primary Least Cost scenario. This transmission network buildout takes into account siting of solar and wind plants in available land regions with the best resource quality, as detailed in the previous section. Because a large fraction of utility-scale RE projects is anticipated to be connected to the interstate transmission system (ISTS), we focus our estimate on that network.[18] This estimate includes the high-voltage lines, new substations, and the spur lines from the pooling stations to the substations. The investment in spur lines is a small fraction of the total investment, so the overall financial impact of underutilization due to the low capacity utilization factor (CUF)[19] of solar or wind plants is expected to be minor. The ISTS network would be used to transmit electricity from other generation sources as well, and it would need to expand as load grows. With an energy demand of about 2,300 terawatt-hour (TWh) per year by 2030, and an average 40-year lifetime of these assets, the per-unit cost of additional transmission comes out to about Rs. 0.08–0.09/kWh.

Table 2: Estimated investment required for interstate transmission network up to 2030 in the Primary Least Cost case

		Investment (rounded off to 100's of crore/USD billions)	
		INR crore	**USD billions**
Additional transmission capacity required	280 GW		
Estimated investment for new ISTS transmission		153,300	21.0
Estimated investment for spur lines		11,000	1.5
Estimated investment for substations		8,000	1.0
Total investment required		**172,300**	**23.5**

The Government of India (GoI) has undertaken comprehensive planning of the transmission network to ensure adequate transmission infrastructure under the Green Energy Corridors (GEC) scheme launched by the Ministry of New and Renewable Energy (MNRE) in 2015–2016. The National Committee on Transmission approved the Comprehensive Transmission Scheme for development of 66.5 GW of RE Zones by December 2022 [31]. These lines are being developed at the interstate levels under GEC Phase I and II. An additional 65.5 GW would be developed under Phase III by 2025. Hence, 130 GW of new ISTS

[17] This is a high-level assessment to arrive at a ballpark estimate. More detailed analysis is needed to determine a more accurate estimate.
[18] Connecting a plant to the nearest pooling station is the developer's responsibility, hence the cost is included in RE tariffs. Our understanding is that the high-voltage, intrastate network is not a major constraint at present.
[19] CUF is the ratio of the actual output (kWh generated) from a power plant to the maximum possible output over a year. Typical CUFs of solar and wind plants in India are 20% and 30%, respectively.

capacity is expected to be deployed by 2025. This pace of transmission network enhancement is in accordance with the transmission expansion required for deploying 450 GW of solar and wind capacity by 2030.

Our estimate above does not take into account future expansion of intrastate networks. However, an additional 20 GW of intrastate transmission capacity is being built at a cost of Rs. 10,000 crore [32]. The financing mechanism for the intrastate network combines 40% of the investment as a grant from the central government to the states, a subsidized 40% loan from KfW Germany, and 20% state equity. Furthermore, new projects are being awarded through tariff-based competitive bidding (TBCB), resulting in 30%–40% lower tariffs than without TBCB.[20] Therefore, the financial impact of transmission investment has been softened for RE-rich states, although additional regulatory changes might be required for equitable cost allocation.

4. Will financing constrain rapid renewable energy buildout?

While the availability of affordable capital has always been perceived as short in supply, as of April 2021, India had 80 GW of installed grid-interactive solar and wind capacity [33], 46 GW in the pipeline, and another 35 GW tendered [34]. Despite several real and perceived risks to investments, the number of commercial investors—domestic and international—has grown, and both greenfield and secondary activity in the RE market continue to increase in volume year on year. In the 2014–2018 period, interest rate spreads for utility-scale solar and wind power declined by 0.75% to 1.25%, which is significant because the cost of finance could contribute as much as 70% of the total cost of a unit of renewable electricity in 2015 [35]. This decline in debt costs could potentially be attributed to growing familiarity with the technologies and a decline in lenders' perception of risk. The total RE investment[21] in India in the 2015–2019 period was USD 77 billion (Figure 7), sixth highest in the world during that period and outpacing total investment in coal, gas and nuclear power every year since 2017 [36].

Looking forward to the deployment of 450 GW of solar and wind capacity by 2030, we estimate that the annual investment required for solar power is about USD 13 billion, totaling USD 130 billion for the additional 263 GW of installed capacity during the 2021–2030 period. With an additional USD 9.4 billion for wind power annually to reach 142 GW of capacity by 2030, the annual investment requirement is estimated to be about USD 22.5 billion.[22] Financing costs for energy storage might follow an initial learning curve, requiring another approximately USD 41 billion for 63 GW (252 GWh) of battery storage by 2030. While USD 26.5 billion per year is much greater than the average investment in renewables over the last few years, it is 20% lower than the average yearly total investment in India's power sector between 2015 and 2019 across different generation resources (Figure 7).

[20] Based on author conversations with industry representatives.

[21] IEA's *World Energy Investment* report uses the following accounting methodology: investment outlays are spread evenly from the year that an asset reaches financial close until the year it becomes operational.

[22] These estimates are based on current cost trajectory assumptions for solar, wind, and batteries in the 2030 India Report.

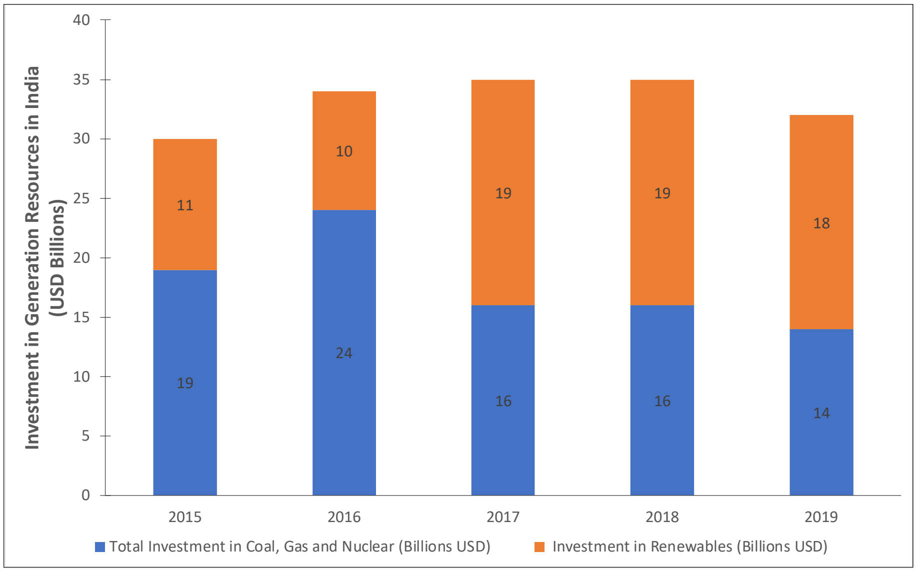

Figure 7: Total investment in different generation resources in India, from 2015 to 2019; majority of investment in conventional resources was made in coal-based power plants
Source: [36]

Our preliminary estimate of investment required for transmission network expansion and enhancement adds another USD 23.5 billion over the decade. Thus, deploying a cumulative installed 450 GW of solar and wind capacity by the end of the decade requires an investment of about USD 290 billion be mobilized between 2021 and 2030.

There is concern that the current investment flows into RE look far short of the annual investment required, even as every dollar invested continues to buy more RE owing to declining costs. This is because the funding capacity of domestic financial institutions is limited by several factors. The Reserve Bank of India's (RBI's) January 2021 *Financial Stability Report* indicates that gross non-performing assets (NPAs) of the banking system are set to rise from 7.5% of total advances in September 2020 to 13.5% by September 2021 [37], almost back to the peak of 14.5% reached in 2018. Coupled with the overreliance of India's RE sector on debts from banks and non-banking financial corporations (NBFCs), this makes the path to 450 GW seem challenging. The current cumulative bank and NBFC exposure to the power sector (including transmission, distribution, and generation across fuel types) is close to USD 160 billion. At a relatively stable 75:25 debt:equity ratio [38], India would need USD 72.5 billion in new equity investments and USD 217.5 billion in additional debt to be mobilized over the coming decade. The additional debt required would be 1.4 times the total existing investment in the power sector, thereby doubling the current debt exposure of banks and NBFCs to the power sector as a whole.

RBI regulation for banks requires their cumulative power-sector exposure to remain within 15% of total loan book, also called the "lending limit." Because of power-sector expansion in the past few years—along with legacy loans to thermal assets and lines of credit for transmission infrastructure and distribution companies—these limits are nearly exhausted [39]. As India added nearly 200 GW of power capacity during 2005–2015, much of it at costs higher than expected future costs, the financial sector was not challenged owing to limited exposure to the power sector in the past, which afforded banks greater flexibility to lend to new projects. In addition, a rapidly growing economy was accompanied by expansion in the size of loan books overall. Today, some long-term loans to thermal power plants and distribution companies are still held by the banks, thus limiting their ability to issue significant quantities of new loans without breaching the sectoral lending limits.

NPAs in the power sector account for about 40 GW of capacity [40], contributing to some of the bank exposure (especially for public-sector banks) because the debt is not being repaid, but also further constraining sector lending owing to the aggregate risk profile. The risk profile of solar and wind projects, with no fuel risk, could be considered as much more akin to the profile of other infrastructure classes. If the power-sector exposure of banks and NBFCs is unbundled into RE and all other power, RE has a much lower rate of default [41]. The rising risk profile of thermal assets raises the aggregate sector risk for lenders, which potentially impacts RE plants. Further, banks and NBFCs are facing an increase in NPAs as a result of the ongoing economic downturn caused by the COVID-19 pandemic, which might also limit their ability to lend and could further hamper the growing RE sector in India. Thus, sector-wide risk mitigation would be crucial for enabling cheap financing.

Nevertheless, annual investment of USD 25–30 billion seems well within reach when compared with global flows. Despite the pandemic, 2020 recorded a total USD 281 billion invested in renewables in the power sector [42], which is estimated to cross USD 350 billion annually by 2025 [43]. Total global investment in RE during this decade is expected to touch USD 3.4 trillion [44]. Combined with evidence suggesting that an overwhelming number of new power-sector transactions are entirely for RE assets [45], financing RE in India appears to be a function of total flows or constraints around power-sector limits rather than of perceived RE risk. Foreign capital continues to be interested in India's RE sector, both for debt and equity [46]. Interventions may be required to incentivize foreign and commercial capital to flow into the RE sector at scale and at affordable rates, particularly to respond to the sectoral challenges such as counterparty risk posed by the poor health of electric utilities. Evidence from transactions between 2014 and 2020 makes clear that RE is a strong asset class despite these risks [47].

Thus, the pathway to financing 450 GW of solar and wind capacity might require resolution of existing regulatory hurdles such as lending limits and the bundling of RE and power into a single asset class. Nevertheless, India's power sector has historically seen annual investment of the scale and pace needed for meeting this 2030 goal.

5. What impact could domestic manufacturing have on the cost of achieving 450 GW of solar and wind capacity by 2030?

India has about 10 GW of wind turbine manufacturing capacity, with models ranging in capacity from 250 kW to 2.5 MW and with hub heights up to 120 m [48]. Top global manufacturers, such as Vestas and Siemens Gamesa, have set up manufacturing facilities in India. The top three original equipment manufacturers (Gamesa, Vestas, and Suzlon) accounted for over 70% of installed wind capacity in India in 2019. India's wind technology exports add up to USD 600 million annually [49].

On the other hand, global solar cell and module manufacturing has been dominated by China. In 2019, China accounted for 97.4% of silicon PV wafers, 78.7% of cells, and 71.3% of modules produced globally [50]. Indian solar developers import cells and modules from China and Malaysia, meeting around 80%–

90% of the total annual requirement. At present, India has about 3 GW of cell manufacturing capacity and about 8.2 GW of module manufacturing capacity [51].

India's central government has taken several measures to increase the share of solar panels produced domestically in projects deployed on the ground. For example, GoI had imposed Safeguard Duty (SGD) on the import of cells and modules from China and Malaysia for the past several years (Table 3). In March 2021, MNRE imposed a Basic Customs Duty (BCD) of 25% and 40% on import of PV cells and modules, respectively, effective April 1, 2022. The imposition of BCD is expected to have a net impact of approximately 20% on solar tariffs in the short run [52].

Table 3: Solar cell and module SGD announced by GoI for different periods; BCD starting April 2022

GoI's Notification Date	Period	SGD/BCD Rate
30 July 2018	30 July 2018 - 29 July 2019	25%
	30 July 2019 - 29 January 2020	20%
	30 January 2020 - 29 July 2020	15%
29 July 2020*	30 July 2020 - 29 January 2021	14.90%
	30 January 2021 - 29 July 2021	14.50%
9 March 2021	Effective April 1, 2022	25% on cells
		40% on modules

* Included imports from Thailand and Vietnam.

To incentivize domestic manufacturing of PV cells and modules, GoI also announced the Production-Linked Incentive (PLI) scheme, funded with a total of Rs. 4,500 crore [53]. The PLI will be applied to sales of high-efficiency modules for 5 years once a PV manufacturing plant has been commissioned. On May 25, 2021, the Indian Renewable Energy Development Agency solicited bids to set up module manufacturing under the PLI program [54]. Similarly, in May 2021, GoI approved the "National Programme on Advanced Chemistry Cell (ACC) Battery Storage" for achieving manufacturing capacity of 50 GWh of battery storage with an outlay of Rs. 18,000 crore [55].

In light of recent incentives from GoI, several Indian manufacturers have announced expansion of manufacturing capacity. Announced expansion by companies such as Waaree, Adani, Vikram Solar, ReNew Power, and RenewSys account for 20 GW of new cell and module manufacturing capacity [56]. More recently, Reliance India Ltd. announced its ambition to establish manufacturing for PV cells, batteries, and hydrogen fuel cells over the next 10 years, with an investment of Rs. 75,000 crore [57].

In 2019, PV modules produced in India were about 28%–33% more expensive than those produced in China, primarily owing to higher bill-of-materials costs and lower manufacturing capacity utilization [58]. Other drivers of the price difference, especially at the same level of utilization, are labor, overhead, and financing costs. As domestic manufacturing scales up in India, the manufacturing costs are expected to decline gradually. Domestic manufacturing linked bids for solar power were about 15%–20% higher than other bids.[23] Interestingly, even after imposition of the SGD in 2019, PV auction prices in India concluded

[23] The Solar Energy Corporation of India Limited's domestic manufacturing linked tender discovered a tariff of Rs. 2.92/kWh in January 2020. The lowest bids in other tenders around that time were in the range of Rs. 2.50–2.64/kWh, a difference of 11%–17%.

after 2019 kept decreasing, dropping as low as Rs. 2/kWh in December 2020 for a commercial operation date (COD) in July–August 2022.

If India can address the key barriers to scaling domestic manufacturing, including tackling high input costs of electricity and land, the gap between pricing of Indian and imported modules should shrink significantly. In the medium to long run, it is plausible that the tariff impact due to domestic manufacturing could be closer to 10%–15% (about 15–20 paise/kWh). Even after accounting for this differential, PV would still be the cheapest generation technology in India, and solar plus storage would still be a cost-effective alternative to building new coal capacity.

6. Can India's power-sector ecosystem rapidly deploy sufficient renewable capacity?

In August 2021, India crossed the milestone of 100 GW of renewable capacity [59], of which close to 85 GW consisted of solar and wind capacity combined. To reach 450 GW of installed RE capacity in 2030, it would need to build about 35–40 GW of solar and wind capacity every year, a pace that appears to be challenging.

To meet India's growing load, generation capacity would have to grow significantly over this decade. Installing new coal power plants and other conventional plants is usually more complex than installing solar or wind plants; in addition to land and transmission, the conventional plants need fuel linkages and water supply. The average construction time for thermal plants worldwide is 4–5 years, compared with less than 2 years for solar and wind plants—and the time to build RE plants is decreasing as the industry and utilities gain experience [60]. India's construction times for coal plants have typically been higher than the world average owing to issues such as water supply[24] and coal linkage. Figure 8 plots the average number of months to COD from the date of financial closure and award of letter of intent for select thermal plants[25] built over the last decade.[26] On average, it took 5.5 years after financial closure for these plants to start commercial operations. In contrast, PV plants typically take 18–24 months for construction.[27] As per competitive bidding guidelines from MNRE for solar plants, a plant inside a solar park must be commissioned within 15 months of the PPA, or within 18 months otherwise [61]. Similarly, guidelines dictate 18 months for commissioning of wind power plants, once the PPA is signed [62]. The industry is able to achieve these timelines for the most part, with the exception of the past year and a half, during which projects have been delayed owing to disruptions caused by COVID-19.

[24] Coal plants account for fresh water consumption equivalent to a fifth of India's entire domestic consumption; 40% of existing coal plants are in water-stressed areas [69].
[25] Recent coal plants with data available for all units were selected. Several other plants have taken significantly longer to build.
[26] The figure shows the simple average of number of months to COD for different units at these plants.
[27] These values are from author conversations with industry; data from 10 projects totaling up to 1,750 MW were considered (capacity-weighted average commissioning time of 19.5 months), with commissioning dates between September 2018 and October 2020.

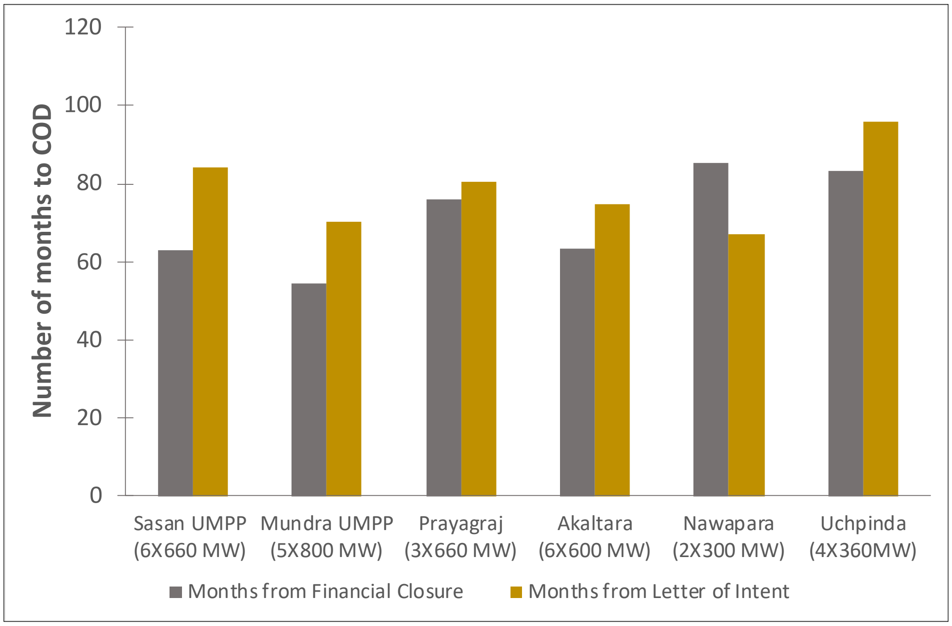

Figure 8: Construction time for coal plants in India
Source: data compiled from [8], [9]

Figure 9 shows electric generation capacity additions in India during 1990–2020. Between 2010 and 2020, India achieved the following:

- Total new capacity addition of 222.6 GW (about 22 GW/year), including conventional and RE assets and accounting for retirement of 10 GW of capacity.
- Thermal capacity addition of 14 GW/year.

India's power sector has added thermal capacity rapidly to address the country's chronic power shortage in the past, especially considering the relative complexity of constructing thermal plants. The annual pace of installation achieved was 22 GW/year for the previous decade, which is 60% of the pace required through 2030. Because the typical capital cost of a thermal plant is almost double the capital cost of a solar plant on a per-MW basis, and solar and wind plants can be built almost three times faster, we contend that India's power sector could likely install RE capacity at a faster pace.

Furthermore, India has some of the largest solar plants in the world [63]. The RE sector saw an average investment of USD 15.4 billion per year during 2015–2019. The pipeline of solar projects for the next 2–3 years (as of February 2021) adds up to 63 GW [34]. With some of the lowest solar tariffs in the world, the solar industry in India has continued to advance even during 2020, notwithstanding the disruptions due to COVID-19 [64]. Slower recent wind deployment could possibly be attributed to delayed adoption of competitive bidding in this sector, which has kept average tariffs higher.

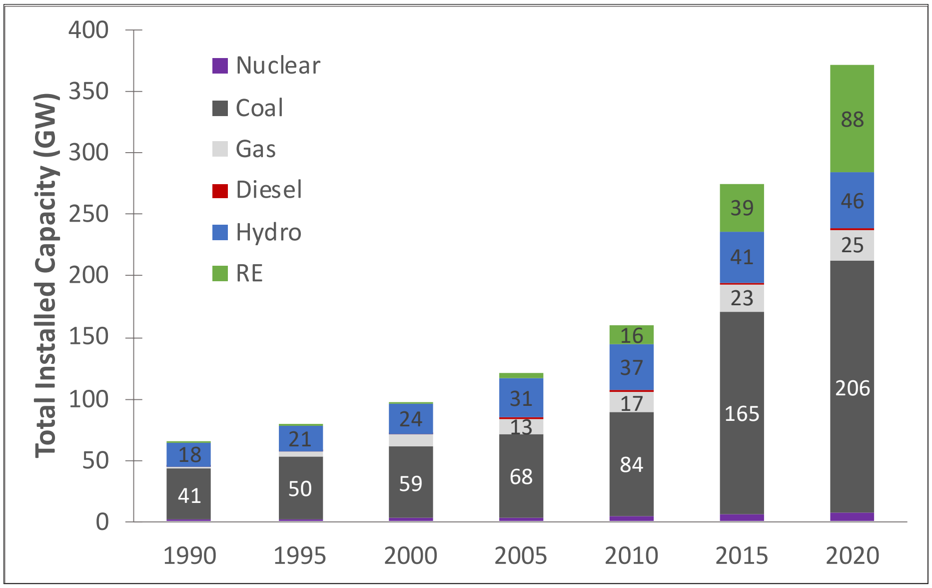

Figure 9: Cumulative installed electric generation capacity in India, 1990–2020
Source: compilation from CEA annual reports

States such as Karnataka, Tamil Nadu, and Gujarat have been successful at installing large amounts of renewable capacity over the past few years. With over 15 GW of renewable capacity installed as of June 2021, Karnataka plans to add another 20 GW over the next 5 years [65]. Several state-level incentives have been announced in the "Draft Karnataka Renewable Energy Policy 2021-2026," including facilitation of project development, a public-private-partnership model to develop transmission, solar and wind parks, and so forth. However, to further increase the scale of annual deployment, changes to current regulatory frameworks might be crucial. State-level planning and procurement processes would need to be modified to ensure procurement of least cost portfolio of resources to meet the demand, including renewables and battery storage. A Resource Adequacy framework that streamlines resource sharing among states would be key, along with market rules to compensate batteries for their full functionality. Additionally, learnings from states that are leading RE installation should be shared with other states.

India has also demonstrated other rapid interventions in the power sector over the past decade. The UJALA scheme, launched in January 2015, has procured and distributed 367 million light-emitting diode (LED) bulbs over the last 6 years [66]. Starting from a negligible base, the scheme has catalyzed a reduction in LED bulb prices to about a fifth of initial market price using aggregation of demand [67].

Furthermore, in October 2017, 88% of households in India were electrified, leaving close to 25 million households without an electricity connection, but by March 2019, 99.99% of all households were electrified [68]. Between July and December 2018, an average of 2,671,500 households were electrified monthly under the Ministry of Power SAUBHAGYA scheme. This is equivalent to 89,000 households daily, which demonstrates that India's power sector has achieved significant pace of infrastructure deployment in recent past.

The 2030 India Report concluded that, by the close of the decade, India's coal consumption from the power sector would be 750 MT/yr in the Primary Least Cost case and 667 MT/yr in the Low-RE Cost case—comparable to 2020 consumption levels (647 MT/yr). Thus, in the near to medium term, India's clean energy transition is unlikely to cause a loss of jobs in coal mining and transportation. This gives India sufficient time to prepare for a long-term transition. In fact, facilitating investment in the RE sector could create millions of jobs in manufacturing, installation, and ancillary supply chains, creating a ripple effect for India's economy.

7. Conclusion

In this policy brief, we examine issues related to cost of generation, grid reliability, land availability, investment in transmission, financing, impact of domestic manufacturing, and rate of deployment, for India to achieve 450 GW of cumulative installed solar and wind capacity by 2030.

LBNL's 2030 India Report concluded that adding 450 GW of combined solar and wind capacity would be cost-effective for meeting India's electricity demand in 2030 while maintaining the grid reliability. By deploying new flexible resources (such as battery storage and load shifting) and utilizing the existing ones (such as hydropower and natural gas plants), the load can be reliably met with a modest net addition of 23 GW in thermal assets between 2020 and 2030. Deployment of ~63 GW/250 GWh of battery storage would be critical, without which additional thermal investments would be required to meet the peak demand, although such power plants will run at very low capacity factors.

The average cost of generation in 2030 would be lower than today's cost if the least-cost resource mix is realized. India has sufficient fallow and waste land to support this buildout. Deploying 307 GW of solar and 142 GW of wind capacity would use only about 1.25% of the available fallow and waste land area.

The additional interstate transmission capacity needed for an RE-heavy grid is minor compared with the transmission needed to meet future load growth with thermal sources of power. The total new buildout required at bulk transmission level between 2020 and 2030 is a little over double the transmission expansion that has already been planned through 2025.

The total investment needed (in generation and storage resources) to realize this target is around USD 26.5 billion annually, which is 20% lower than the annual investment in India's power sector across all generation resources between 2015 and 2019. However, because public banks are hitting their lending limits and being hindered by NPAs, regulatory interventions might be needed to facilitate this scale of investment in the sector, including investments of foreign capital.

GoI has offered production-linked incentives for domestic manufacturing of solar cells and panels, and it has announced BCD on imports as well. We estimate that using domestically manufactured panels instead of imported panels may increase solar PPA prices by about 10%–15% in the medium term. Solar power would still be a cost-effective way to meet growing demand instead of building new fossil fuel-based plants.

To reach 450 GW of installed solar and wind capacity by 2030, India would need to build about 35–40 GW every year in this decade. India's power sector achieved a pace of capacity addition of 22 GW per year in the previous decade (including thermal and renewable). Policy and regulatory measures would be needed to increase the pace of deployment.

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