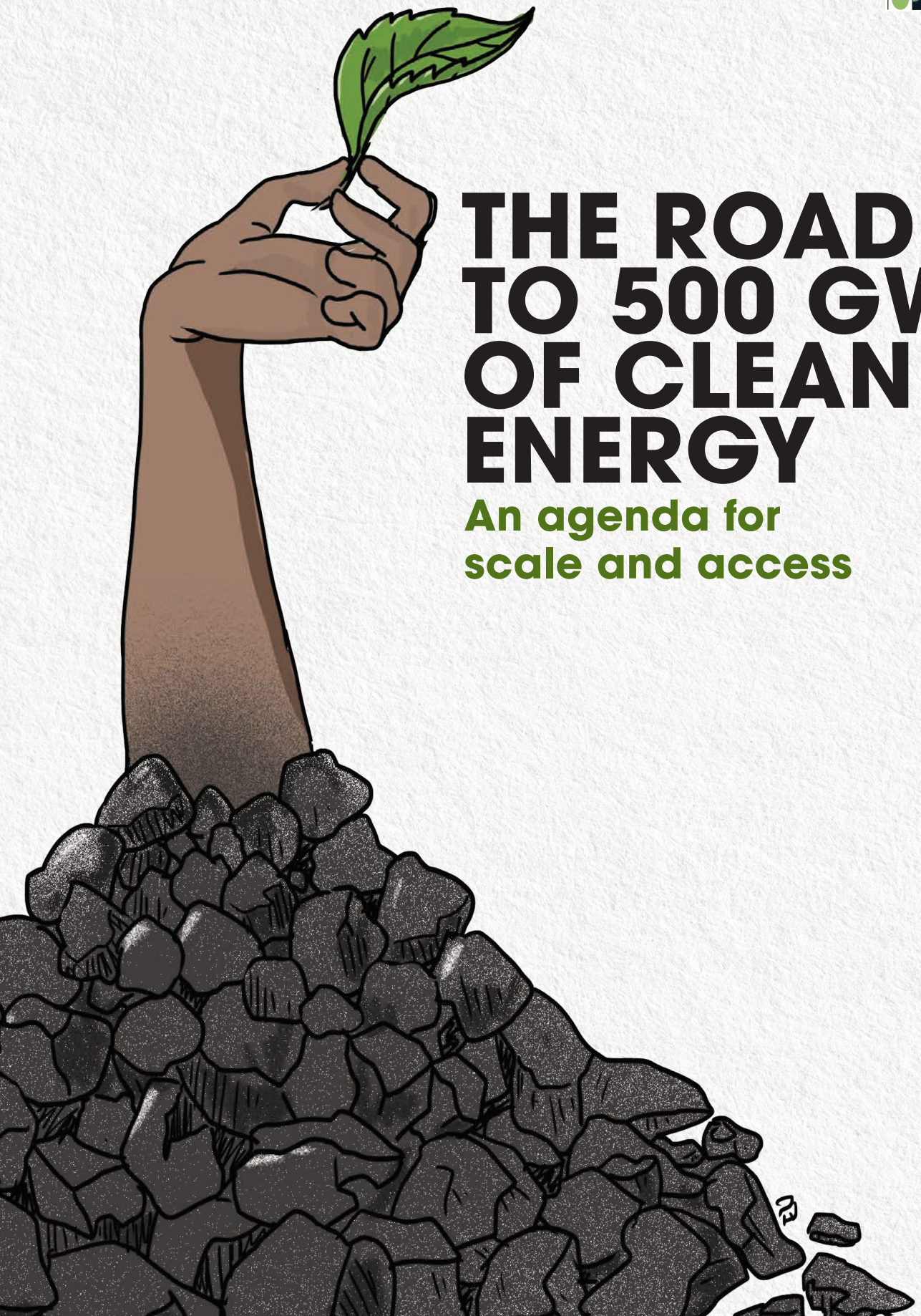


THE ROAD TO 500 GW OF CLEAN ENERGY

An agenda for scale and access

THE ROAD TO 500 GW OF CLEAN ENERGY

An agenda for scale and access

Authors: Sunita Narain, Nivit Kumar Yadav, Binit Das and Arvind Poswal

Research Support: Subhrajit Goswami and Santosh Kumar

Editor: Souparno Banerjee

Cover Design: Ajit Bajaj

Cover Illustration: Yogendra Anand

Layouts: Kirpal Singh

Production: Rakesh Shrivastava and Gundhar Das

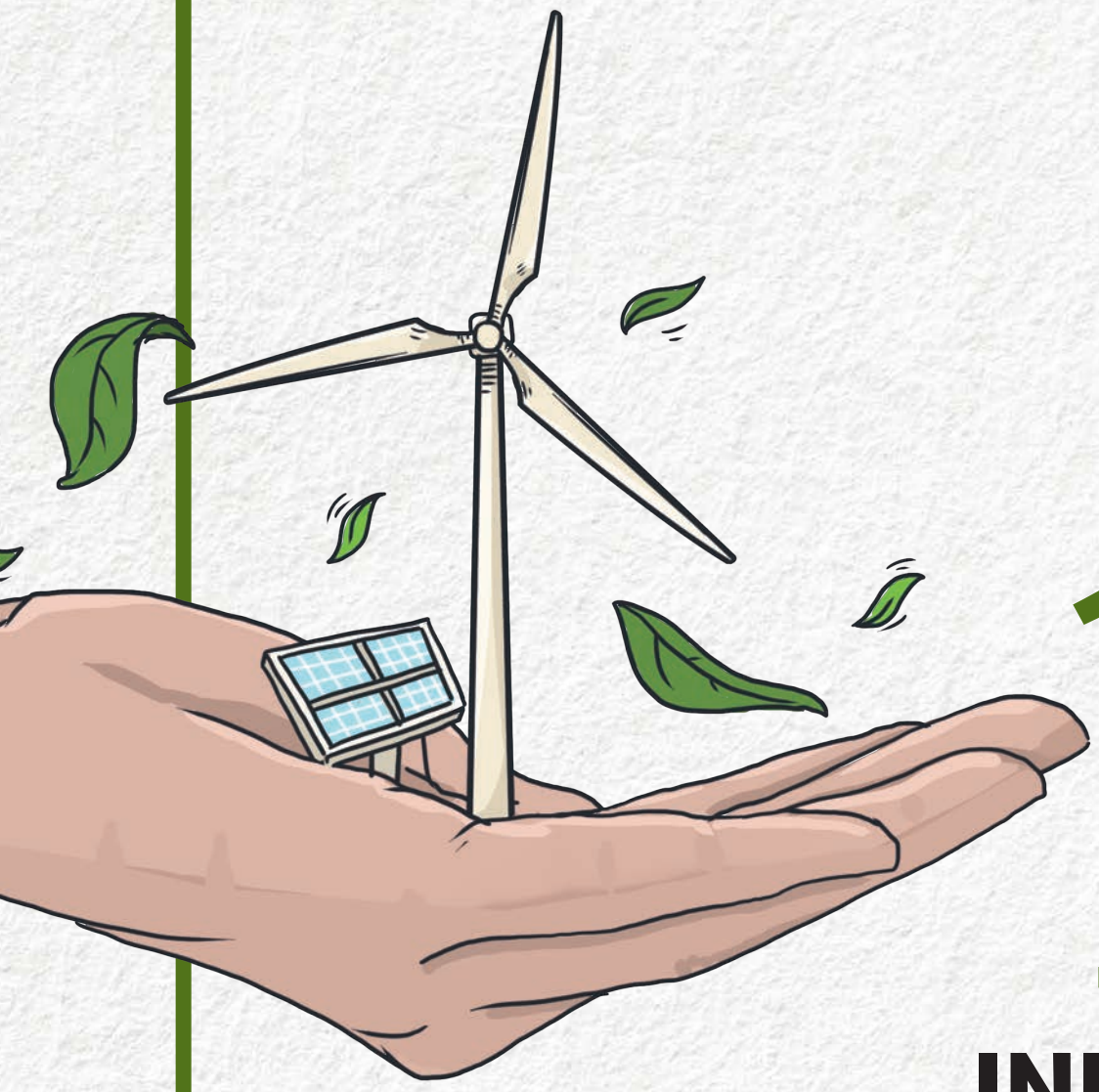
This publication captures CSE's research on the sector as well as the deliberations of the National Dialogue on Renewable Energy for an Equitable Green Transition, organised by CSE from December 9-10, 2024.

Centre for Science and Environment is grateful to the Swedish International Development Cooperation Agency (Sida) for their institutional support

Citation: Sunita Narain, Nivit Kumar Yadav, Binit Das and Arvind Poswal, 2025, *The Road to 500 GW of Clean Energy*, Centre for Science and Environment, New Delhi

Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110 062
Phone: 91-11-40616000
Fax: 91-11-29955879
E-mail: cse@cseindia.org
Website: www.cseindia.org

Contents



1

INDIA'S DECARBONISATION PLANS AND TARGETS FOR 2030

India's target for installed non-fossil energy capacity is 500 GW by 2030. It means that in terms of installed capacity, India aims to have 50 per cent 'clean' energy by the end of this decade.

The challenge for the country is to augment power infrastructure, make it clean, and supply reliable electricity at affordable rates – at a time when demand is set to surge by 2-2.5 times by 2047 even as millions do not have access to energy, let alone clean energy.

This report categorises the sector into two segments: new renewables which includes solar, wind, biomass and small hydel, and non-fossil energy, which includes new renewables along with large hydroelectric and nuclear power.

The Central Electricity Authority's estimation of an optimal energy mix India by 2030 says the country's energy demand will increase from 1,255 billion units (BU) in 2022 to 2,440 BU in 2030. To meet this demand, 777 GW of installed capacity would be needed by 2030 – and the growth will come primarily from new renewable sources.

By 2030, fossil (coal)-powered electricity will not disappear; it will still generate 56 per cent of the electricity. But what would change is that new renewable, which generates about 13 per cent today, would go up to 32 per cent.

Solar power would be the driver of India's clean energy future; it would supply 23 per cent of the total electricity generated in the country by 2030.

The 'question of coal' is not about replacement; instead, it is about displacement of coal through non-fossil energy sources.

In August 2022, India submitted to the United Nations Framework Convention on Climate Change its target to reduce its emissions intensity by 45 per cent by 2030 (compared to 2005 levels), and to achieve 50 per cent of cumulative electric power capacity from non-fossil fuel sources by 2030. This is a part of the country's Nationally Determined Contributions (NDCs) for achieving climate goals set out in the Paris Agreement.[1]

In addition, it has increased its target for installed renewable energy capacity from 175 GW by 2022, to non-fossil energy capacity of 500 GW by 2030. According to the Union ministry of power, this translates into 50 per cent non-fossil fuel electric power generation capacity by 2030.[2] In other words, in terms of installed capacity, India aims to have 50 per cent 'clean' energy by the end of this decade, displacing the current king of energy, coal-based power.

What is not clear is how the government defines 'clean energy'. The ministry of power uses the term 'non-fossil energy', which includes large hydropower and nuclear power. But this is often interchanged with renewable power[3], which would mean that solar, wind, biomass and small hydropower would need to add up to 500 GW by 2030. In March 2019, the Government of India included hydroelectric power in the category of renewable energy. However, for the purposes of this report, we have categorised the sector into **'new renewables'**, which includes solar, wind, biomass and small hydel, and **'non-fossil energy**', which includes new renewables along with large hydroelectric and nuclear power.

There is also the question of what this would mean in terms of generation of power: what percentage of the generated power – or the electricity we consume – is planned to be renewable or non-fossil-based?

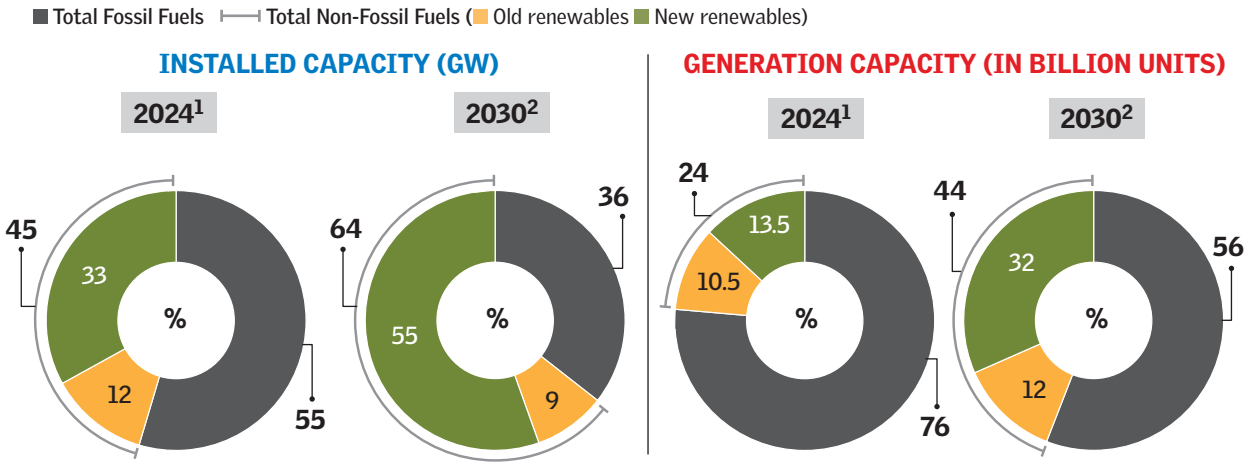
All this is important in terms of the country's energy future and its ability to transition out of fossil fuels. India's tryst with clean power will happen at a time when – as estimates from the 2024 Economic Survey show – demand is slated to surge by 2-2.5 times by 2047 to meet the growing economic needs of the country. We also know that currently, millions of households do not have access to energy, let alone clean energy. So, it is a challenge for the country to augment its power infrastructure, to make it clean, and to supply reliable electricity at affordable rates.

In 2023, the Central Electricity Authority (CEA) updated its scenario for optimal energy mix for the country by 2030 (*see Table 1*). According to this, the country's energy demand will increase from 1,255 billion units (BU) in 2022 to 2,440 BU in 2030 (CEA's report on *Optimal Generation Capacity Mix 2029-2030*). This will

Table 1 and Figure 1: The CEA's plan for India's clean energy scenario in 2030

	March 2024[1]				March 2030[2]			
	Installed capacity		Generation		Installed capacity		Generation	
	GW	% of the total installed capacity	Billion units (BU)	% of the total generation	GW	% of the total installed capacity	Billion units (BU)	% of the total generation
Coal and lignite	218	48.9	1292	74.6	252	32.4	1330	54.5
Oil and gas	25	5.6	31	1.8	25	3.2	34	1.4
Total fossil fuels	**243**	**55**	**1324**	**76**	**277**	**36**	**1364**	**56**
Hydro (large)	47	10.6	134	7.7	54	6.9	212	8.7
Nuclear	8	1.8	48	2.8	16	2.0	93	3.8
Total old renewables	**55**	**12**	**182**	**10**	**69**	**9**	**305**	**12**
Solar	82	18.4	116	6.7	293	37.6	554	22.7
Wind	46	10.3	83	4.8	100	12.9	207	8.5
Biomass/small hydro	15	3.5	26	1.5	20	2.6	4	0.1
Others	4	0.9	2	0.1	19	2.4	6	0.3
Total new renewables	**147**	**33**	**227**	**13**	**431**	**55**	**771**	**32**
Total non-fossil Fuels	**202**	**45**	**409**	**24**	**501**	**64**	**1077**	**44**
TOTAL	**445**	**100**	**1733**	**100**	**777**	**100**	**2441**	**100**

Note: The cumulative total has been rounded off.



Sources: 1 Central Electricity Authority of India, monthly generation reports; 2 Report on Optimal Generation Capacity Mix 2030, Version 2.0, April 2023, CEA

require 777 GW of installed capacity by 2030; but the growth will come primarily from new renewable sources. As per the report, the country will make a big switch in its modal share of energy generation by the end of this decade. The 500 GW of capacity of non-fossil energy will supply 44 per cent of the electricity demand of the country.[4]

PHOTO CREDIT: ISTOCK/PAVLOBALIUKH

According to the Central Electricity Authority of India (CEA), by 2030, 500 GW of non-fossil energy sources (like sun and wind) will meet 44 per cent of the country's total energy demand

By March 2024, fossils – coal, gas and lignite – had added up to 55 per cent of the installed capacity but were generating 76 per cent of the electricity; by 2030, there would be a transition. Fossil (coal)-powered electricity will not disappear under this plan – in fact, it will still generate 56 per cent of the electricity. But what would change, and drastically, is that new renewable, which generates roughly 13 per cent of the electricity today, would go up to 32 per cent.

To do this, as per the CEA, the country would need to install 426 GW of new renewables, including 293 GW of solar energy. If this is done, solar power would be the driver of this clean energy future; it would supply 23 per cent of the total electricity generated in the country by 2030. Clearly, this is ambitious and will provide the green energy transformation that the India desperately needs.

The 'coal question', therefore, is not really about coal, but about what the country will do to increase the installed capacity and generation of clean energy, so that future needs can make the transition out of fossil fuels. It is not about replacement, but displacement of coal through non-fossil energy sources.

2

THE SCENARIO IN 2024

India ranks fourth in the world in renewable energy capacity addition, with a total capacity exceeding 190 GW. It also has the fifth largest solar power capacity and the fourth largest wind power capacity.

Growth in non-fossil power capacity has been impressive: from 87 GW to about 198 GW between 2014 and 2024. Coal is losing its preeminent place – in terms of installed energy mix, coal power is now just below 50 per cent from 60 at the beginning of the decade.

Total electricity generated from all sources between 2014 and 2024 has increased by 1.6 times. In non-fossils, new RE has increased from 65 billion units (BU) to 226 BU – a 3.5 times jump, with solar driving this change.

New RE in the electricity generation mix in 2023-24 stood at 13 per cent, which is a jump from 2014-15, but still not close to where we need to be.

Generation from Central Public Sector Undertaking (CPSU) renewable energy plants suggests that capacity utilisation is satisfactory – solar energy CUF of these plants ranges from 25 to as high as 32 per cent, while wind energy CUF is from 16 to 28 per cent.

Growing: Installed capacity of clean power

By October 2024, India ranked fourth in the world for renewable energy capacity addition, with a total capacity exceeding 190 GW. Additionally, it has the fifth largest solar power capacity and the fourth largest wind power capacity globally.[5]

In the past decade – 2014 to 2024 – the share of non-fossil power India's total installed capacity has increased from 32 per cent to 45 per cent (*see Table 2*). Driven primarily by solar energy, non-fossil share has jumped from 87 GW to close to 198 GW. This is impressive, even though the share of fossil-based power (installed capacity) has also gone up from 187 GW to 243 GW during this period. Therefore, while coal is still the 'king' with an installed capacity of 218 GW (out of the total of 441 GW), it is losing its place. Share of coal power is now below 50 per cent in terms of the installed energy mix of the country, down from 60 per cent at the beginning of this decade. Conversely, the share of new renewables (primarily solar and wind energy) has gone from 14 per cent of the installed capacity to 32 per cent.

Generation: Needs scaling up

The question is how much of this installed power is leading to the great switch in terms of clean energy consumption. The objective is clearly to move consumers to use more clean energy – and this means that as a percentage of electricity generation, renewable and non-fossil sources like hydel and nuclear must increase and slowly displace coal. India does not have a stated target for the percentage of generation of non-fossil energy in the electricity mix, but going by the CEA projection for 2030, new renewables would generate 32 per cent of the total electricity in the country (with solar at 23 per cent). Therefore, there is an urgent need to scale up capacity and generation.

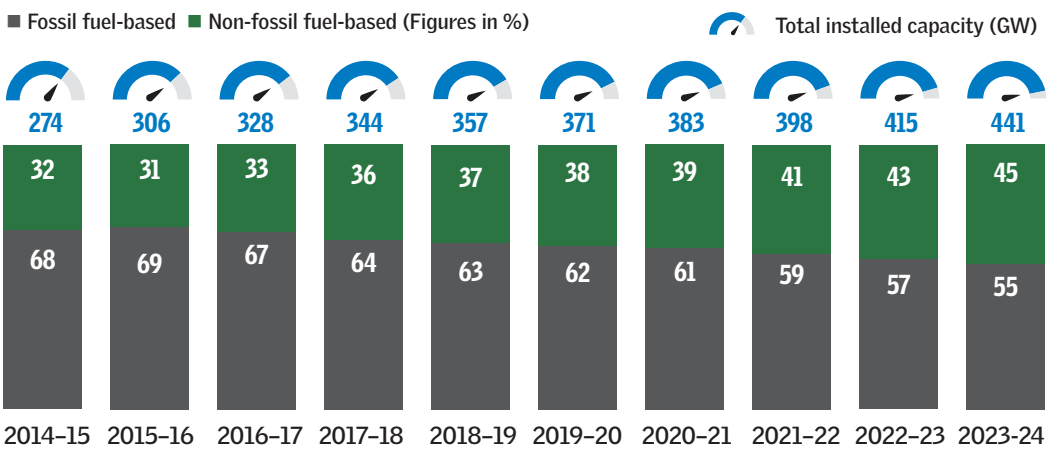
Between 2014-15 and 2023-24, the following energy trends have emerged:

- Total electricity generated from all sources has increased 1.6 times from 1,090 BU to 1,731 BU; in this, fossil fuel-based energy has kept pace, increasing also by 1.5 times (*see Table 3*).
- Old renewables – classified as large hydroelectric power plants and nuclear – which are also classified in the non-fossil fuel energy sources have slipped in their growth trajectory. The share of hydroelectric power has reduced in the mix in 2023-24 – this could be an aberration because of hydrological conditions, but trends show that this energy source is not growing in the mix. Nuclear energy generation has also stalled.
- What is leading the charge of the non-fossils is new renewables, which has increased by a huge 65 BU to 225 BU – a 3.5 times rise in this period. Solar

Table 2 and Figure 2: Installed capacity – 2014-15 to 2023-24 (GW)

	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023-24
Coal and lignite[1]	165	185	192	197	201	205	209	211	212	218
Gas and diesel[1]	23	26	26	25	25	25	25	25	25	25
Total fossil fuels	**187**	**211**	**218**	**222**	**226**	**230**	**234**	**236**	**237**	**243**
Large hydro – old RE[1]	41	43	44	45	45	46	46	47	47	47
Nuclear – old RE[1]	6	6	7	7	7	7	7	7	7	8
Total old RE	**47**	**49**	**51**	**52**	**52**	**52**	**53**	**54**	**54**	**55**
Solar – new RE[2]	4	7	13	22	29	36	41	54	67	82
Bio-energy – new RE[2]	8	9	9	9	10	10	10	10	10	10
Wind – new RE[2]	23	27	32	34	36	38	39	40	43	46
Small hydro – new RE[2]	4	4	4	4	5	5	5	5	5	5
Total new RE	**40**	**47**	**58**	**70**	**79**	**88**	**95**	**109**	**125**	**143**
Total non-fossil fuel-based	**87**	**96**	**110**	**122**	**131**	**140**	**148**	**163**	**178**	**198**
Total installed	**274**	**306**	**328**	**344**	**357**	**371**	**383**	**398**	**415**	**441**
% new RE	14%	15%	18%	20%	22%	24%	25%	27%	30%	32%
% non-fossil fuel-based	32%	31%	33%	36%	37%	38%	39%	41%	43%	45%
% fossil fuel-based	68%	69%	67%	64%	63%	62%	61%	59%	57%	55%

Share of non-fossil energy in installed electricity capacity surged from 32% to 45% in last 10 years; new renewables increased by 3.5 times



Sources: 1 Central Electricity Authority of India; 2 Ministry of New and Renewable Energy

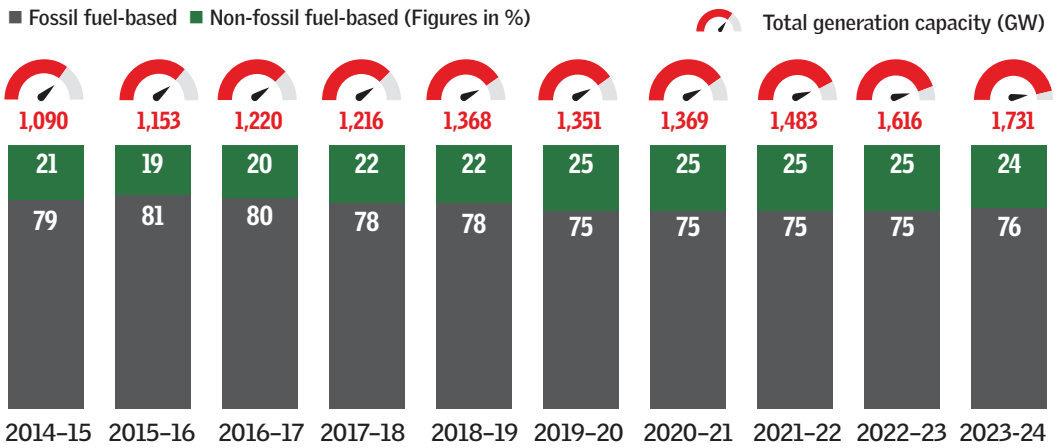
power has been the driver of this change, going from 7 to 116 BU. This is no mean achievement. It is important to note here that while the installed capacity of solar (82 GW in March 2024) includes ground and rooftop solar, no data is available for generation from rooftop systems, which account for roughly 17 per cent of the installed solar capacity in the country.

Table 3 and Figure 3: Electricity generation from different sources – 2014-15 to 2023-24 (in billion units)

	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023–24
Coal and lignite[1]	819	881	928	900	1019	963	978	1077	1181	1292
Gas and diesel[1]	41	47	49	50	50	48	51	36	24	31
Total fossil fuel	**860**	**929**	**977**	**950**	**1069**	**1011**	**1029**	**1113**	**1205**	**1324**
Large hydro – old RE[1]	129	121	122	126	135	156	150	152	162	134
Nuclear – old RE[1]	36	37	38	38	38	46	43	47	46	48
Total old RE	**165**	**159**	**160**	**164**	**173**	**202**	**193**	**199**	**208**	**182**
Solar – new RE[2]	7	7	13	26	39	50	60	73	102	116
Bio-energy – new RE[2]	16	17	14	16	17	14	16	18	19	17
Wind – new RE[2]	33	33	46	53	62	65	60	69	72	83
Small hydro – new RE[2]	8	8	8	8	9	9	10	10	11	9
Total new renewables	**65**	**66**	**82**	**102**	**126**	**138**	**147**	**171**	**204**	**226**
Total non-fossil fuel-based	**230**	**224**	**242**	**266**	**299**	**340**	**340**	**369**	**411**	**408**
Total generation	**1090**	**1153**	**1220**	**1216**	**1368**	**1351**	**1369**	**1483**	**1616**	**1731**
% new RE	6%	6%	7%	8%	9%	10%	11%	12%	13%	13%
% non-fossil fuel-based	21%	19%	20%	22%	22%	25%	25%	25%	25%	24%
% fossil fuel-based	79%	81%	80%	78%	78%	75%	75%	75%	75%	76%

Note: Generation data is for ground-mounted utility-scale solar as there is no data available for rooftop solar
Sources: 1 Central Electricity Authority of India; 2 India Climate & Energy dashboard, NITI Aayog

Share of non-fossil energy shows marginal rise in total electricity generation in the past decade. Electricity from fossil fuel, however, increased 1.5 times, from 860 BU in 2014 to 1,324 BU in 2024



Note: Generation data is for ground-mounted utility-scale solar as there is no data publically available for rooftop solar
Sources: Central Electricity Authority of India, Ministry of New and Renewable Energy, India Climate and Energy Dashboard of NITI Aayog

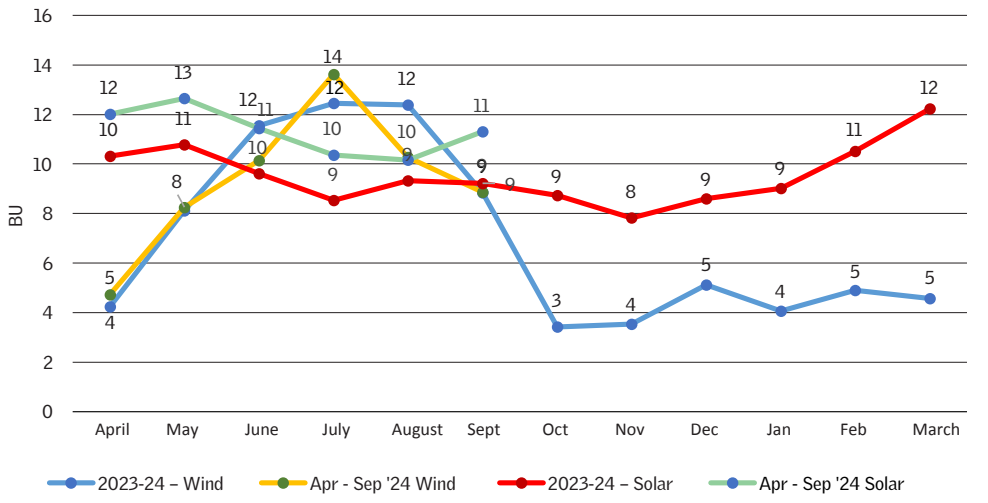
However, despite this:

- Coal is still king in terms of generation. In 2023-24, the percentage share of fossil-based energy in our electricity mix remained almost the same as in 2014-15, at 76 per cent.
- The percentage share of new renewables in the electricity generation mix in 2023-24 stood at 13 per cent, which is a doubling from 2014-15, but still not close to where we need to be.
- If we add hydroelectricity and nuclear power to this, the percentage share of non-fossil energy in the electricity mix becomes 24 per cent in 2023-24.
- At present, 143 GW of installed capacity of new renewables is generating 226 BU of energy, while 243 GW of fossil energy (coal, lignite and natural gas) capacity is generating 1,324 BU. The question is, is this the optimal capacity utilisation of the different sources?

Optimising the capacity utilisation factor

In all energy sources, the capacity utilisation factor (CUF) or plant load factor (PLF) is based on a variety of aspects, ranging from the limitations of the technology to the number of days a plant needs to be shut down for maintenance and breakdown. All sources are also limited by availability of raw materials – in the case of coal or gas projects, it is about the supply of domestic and imported raw materials or their price. For instance, India has stranded assets of gas-based power projects because the price of natural gas is high and that does not make the energy produced viable. In the case of renewable power, solar and wind, the limitation is increased because

Graph 1: Generation of solar and wind power (in billion units) – 2023-24



Source: Central Electricity Authority of India, Monthly generation reports

of the intermittent nature of raw materials; these are dependent on the days when the sun shines and when the wind blows.

For coal-based thermal power plants (TPPs), the PLF is typically in the range of 60-80 per cent, primarily driven by demand. It tends to be higher during summer when demand peaks and is lower just before winter as demand drops.

On the other hand, the CUF for renewable energy sources varies significantly with the seasons. There are technical limitations as well as seasonal variations. Solar CUF is higher during summers but decreases in winters and in rainy seasons. Wind energy faces a similar issue; wind speeds vary greatly throughout the day and across different months, leading to significant fluctuations in CUF, which is also low when averaged annually.

In its scenario for 2030, the CEA has assumed certain CUF/PLF of installed plants to calculate energy generation. According to this, the average PLF of coal-based plants is projected to be 60 per cent in 2030, which will require roughly one billion tonne of coal annually. The variable cost (mainly of coal and the running of the plants) would be between Rs 1.30-3.50 KWh, according to CSE's estimates.

However, it projects differently for different regions and technologies when it comes to renewable energy sources. The CEA estimates that currently, solar power CUF averages between 16.67 per cent in the northeastern region to 19.5-19.8 per cent in the western and southern regions of the country. It projects that this CUF must increase to over 22 per cent in all regions, going to 24 per cent in the South, either through technological improvements or due to location-related factors. For wind energy (onshore), it estimates the CUF to be highest in the western region – 27 per cent – and lowest in the southern states at 24 per cent.

The data available on RE capacity utilisation is limited. The CEA puts together monthly/annual generation data from different energy sources, but does not provide the comparable installed capacity in most cases. However, an analysis of the generation from Central Public Sector Undertaking (CPSU) renewable energy plants suggests that capacity utilisation is not a problem. According to this data, as provided by the CEA in its September 2024 RE generation report[6], and as per CSE's calculations, solar energy CUF of these plants ranges from 25 to as high as 32 per cent, while wind energy CUF is from 16 to 28 per cent. Clearly, this depends on the location of the plants, but what it does suggest is that CUF is being optimised at least for the installed capacity under CPSUs. It would be important

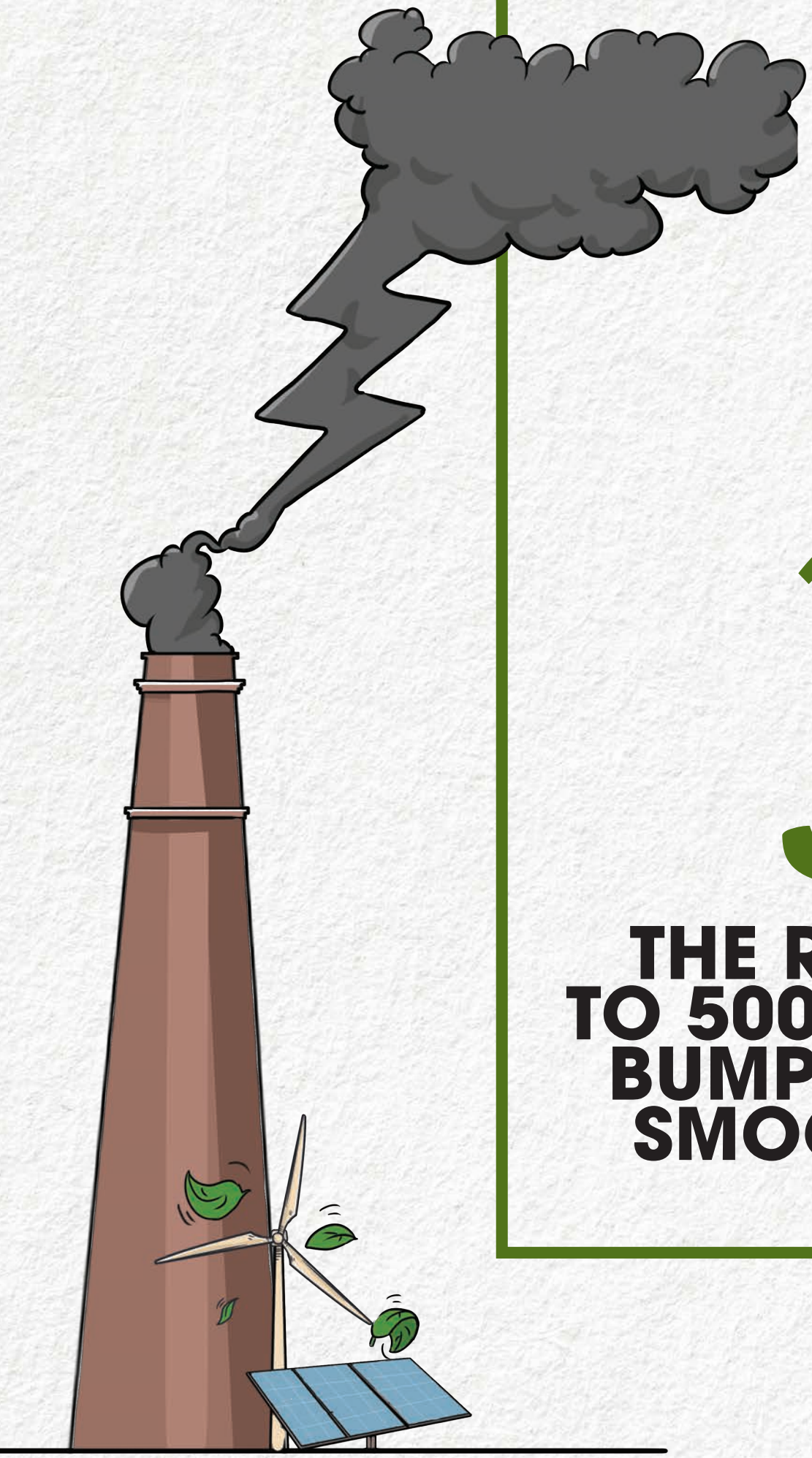
Table 4: Renewable energy generation by CPSU-owned stations

Projects	States	Source	Installed capacity (MW)	RE generation (MU) 2023-24	CUF in % 2023-24*
Shambu ki Burj-II	Rajasthan	Solar	150	385	32
Fatehgarh	Rajasthan	Solar	296	743	32
Shambu ki Burj-I	Rajasthan	Solar	250	611	31
Devikot	Rajasthan	Solar	240	569	30
Kayamkulam	Kerala	Solar	92	214	29
Nokhra	Rajasthan	Solar	300	684	29
Jetsar	Rajasthan	Solar	160	343	27
Ettayapuram	Tamil Nadu	Solar	230	490	27
Simhadri Floating Project	Andhra Pradesh	Solar	25	51	26
Parasan Solar Power	Uttar Pradesh	Solar	75	152	26
Solar_Bilhaur	Uttar Pradesh	Solar	225	443	25
Solar Kasaragod	Kerala	Solar	50	97	25
Devbhumi Dwarka Wind Power Project	Gujarat	Wind	63	140	28
Oil India Ltd	Gujarat	Wind	43	96	28
Sadla Wind Power	Gujarat	Wind	50	101	26
Rojmal	Gujarat	Wind	50	100	25
Oil India Ltd	Madhya Pradesh	Wind	63	106	21
Patan Wind Power Project	Gujarat	Wind	50	77	19
Wind Power Project	Rajasthan	Wind	50	62	16
Small Hydro Vindhyachal	Uttar Pradesh	Small hydro	8.00	37	59
Dhukwan SHEP Jhansi,UP	Uttar Pradesh	Small hydro	24.00	74.9	39
NEEPCO	Assam	Small hydro	25.00	127	64
DVC	Jharkhand	Small hydro	4.00	5.52	17

*Some of the solar generating stations display very high obtained CUFs, such as 32 per cent. This is as per standard calculations based on CEA's available data.
Note: CPSU = Central Public Sector Undertaking; MW = megawatt; MU = million units; CUF = capacity utilisation factor
Source: CEA

to monitor performance in all renewable energy installed plants of the country. Currently, there exists several data deficiencies in this sector.

Data transparency is important to track because even though renewable power has been notified to be 'must run' – in other words, it will get priority in all sources of power generation – this is often not the case. For instance, wind energy is often curtailed as units are required to back down from energy generation because of lack of transmission or even because utilities find the cost of the power to be too high – particularly in the case of old power purchase agreements.



3

THE ROAD TO 500 GW: BUMPY OR SMOOTH?

India is committed to expand its clean energy portfolio. It has set ambitious targets and improved the regulatory environment for scaling up the industry.

The most critical and game-changing governance innovation has been to create a mechanism to remove the uncertainty of payments and risks associated with renewable energy projects – the Solar Energy Corporation of India (SECI) is the key agency for doing this.

Why is solar installation and commissioning sluggish despite the fact that delivered solar energy costs are cheaper than coal-based thermal power?

Data from the SECI indicates that large capacities of RE projects – including those where the effective PPA date is way past -- have not been commissioned. Overall, a total of 34.5 GW of solar, wind and hybrid projects falls in this category. In addition, there is a sizable portfolio of projects, which do not have PPAs signed.

CSE's interactions with sector experts point to several reasons – volatility in prices, intermittency of the power supplied, land availability and transmission problems.

The fundamental flaw with the current policy regime of renewable projects is a lack of data and transparency. It is difficult to find data on finished projects – with projects being implemented by a variety of agencies, there is no consolidated accounting or monitoring of their progress.

Enabling the transition: Agencies and regulations

There is no doubt that India is committed to expand its clean energy portfolio. The government has set ambitious targets and much has been done to improve the regulatory environment for scaling up the industry. The Union ministry of new and renewable energy (MNRE) has plans to ensure annual bids of 50 GW of new renewable capacity until 2017-28 – it has designed agencies to implement the programme.

Initially, three Renewable Energy Implementation Agencies (REIAs) had been nominated: the National Thermal Power Corporation (NTPC), the Solar Energy Corporation of India (SECI) and the National Hydroelectric Power Corporation (NHPC). These agencies were to function as intermediaries in this business, to bid for projects, select developers and sell the energy to distribution companies. In April 2023, the SJVN – formerly known as Satluj Jal Vidyut Nigam – was added to this list of REIAs.

The sector had already been awarded the advantages of being in the 'Must-Run' category under the Electricity Act of 2003. This means that among all energy sources, RE will be given priority dispatch (electricity generated from RE gets priority compared to electricity generated by other sources). But often, this might not be the case. For instance, wind energy units are forced to go slow on energy generation due to lack of transmission infrastructure or because utilities find the cost of the power to be too high – particularly in the case of old power purchase agreements.

In 2021, the Union ministry of power notified the Electricity (Promotion of Generation of Electricity from Must-Run Power Plant) Rules, which set out the compensation that would be awarded to renewable energy plants if they were required to be curtailed.[7] This sector is also exempt from paying inter-state transmission charges for projects commissioned by June 30, 2025.[8] Furthermore, the Renewable Purchase Obligation (RPO) followed by the Renewable Consumption Obligation (RCO) has been notified till 2029-30 – this mandates all consumers to buy and consume a defined proportion of their energy from renewable sources and attracts penalties for non-compliance.

But perhaps the most critical and game-changing governance innovation was to create a mechanism to remove the uncertainty of payments and risk associated with renewable energy projects.

The Solar Energy Corporation of India (SECI) plays a key role as an implementor of renewable energy projects. SECI issues tenders for solar and wind projects and awards these to developers based on a tariff-ruled competitive process. It then issues a letter of intent to the developer, but this process does not end here. The SECI, to de-risk the sector, then takes on the work to find buyers for this successful bid. It signs 25-year power supply agreements (PSA) with state distribution companies (discoms) and other utilities. Once this is done, it awards the power purchase agreement (PPA) to the developer of the project. The SECI is thus the country's key power trader in the renewable sector. It buys power from the developer of solar and wind projects and then sells it to the state distribution company. According to its 2022-23 Annual Report, SECI has cumulatively signed PSAs of 48.352 GW capacity – which is roughly 34 per cent of the installed RE capacity in 2022-23 and 72 per cent of the installed solar capacity.[9]

By being an intermediary, the SECI takes on the risk of non-payment of dues by state electricity distribution companies – notorious as they are for this. This becomes even more cumbersome as SECI also takes on the burden of developer claims under the 'change of law' clause, which is invoked when there are additional charges of tax or other regulatory changes. The SECI is required to pay developers for the power purchased, regardless of the payments received from state discoms. This is beneficial for de-risking the projects of developers, but it does put a question on the financial health of SECI.

To de-risk SECI and other REIAs, the government has created a payment security fund, a capital reserve to provide interest-free payments to compensate for delays in these payments from distribution companies. In addition, there is the provision of tripartite agreements signed between the Central government, state government and the Reserve Bank, under which payments can be withheld if there are dues, or penalties imposed.

But there is little official information about whether this system is working or not. This is important, not just to understand the implementation of the renewable energy programme, but also to review the functioning of such a financial de-risking mechanism. For instance, the payment security fund has also been established for the electric bus programme in cities, with the provision that in the case of default by city bus companies, the private bus operators will be paid through this fund and recovery will be made through the tripartite arrangement with the Reserve Bank of India.

Commissioning of RE projects: The status

In India's clean energy transition, the most ambitious target is for solar power, which would need to install an additional 211 GW by 2030 – roughly 40 GW a year over the next five years.

The good news is that solar energy installations are increasing. According to the Bengaluru-based market intelligence form Mercom, in the first nine months of 2024, the country commissioned 16.4 GW of solar energy – which is a 16 per cent year-on-year increase that has brought India's installed capacity to 89.1 GW. Another 127.2 GW of utility scale solar energy projects have been tendered or are pending auction. In other words, if these fructify, then the country would have installed some 217 GW of solar capacity in the coming years, bringing it close to its target of 293 GW by 2030.[10]

However, this 'sunny' picture needs to be understood further. The November 20, 2024 chargesheet by the US Securities and Exchange Commission (SEC) against Gautam Adani and his nephew Sagar Adani, executives of Adani Green Energy Ltd, and Cyril Cabanes of Azure Power Global Ltd, has raised concerns about the renewable sector in the country.[11] The SEC has alleged that a bribery scheme "was orchestrated to enable the two renewable energy companies to capitalise on a multi-billion-dollar solar energy project that the companies had been awarded by the Indian government."

Without getting into the legal arguments or the merits of the case, the question that arises here is why should there be a need to 'bribe' officials to accept solar energy contracts? Delivered solar energy costs are cheaper than coal-based thermal power – it is estimated that new coal projects (without being greenfield and taking land into account) would deliver energy at Rs 5-5.50 per unit. In addition, this conventional energy source has to pay for inter-state transmission costs. In comparison, solar energy costs Rs 2.60-2.80 per unit. Given this cost advantage, there should be no reason why solar energy is not preferred.

There is clearly some problem as this data from the SECI website shows, and this needs to be understood so that the pathway ahead can be cleared. The data for June 2024 for projects being implemented by SECI shows that large capacities of solar, wind and hybrid projects have not been commissioned; what is of particular concern are the projects where the effective PPA date is way past.

Even assuming the projects that have effective PPA dates for 2023 and 2024 will be commissioned soon, there is a backlog of over 12.5 GW of solar projects which

have not been commissioned till date. In addition, there are another 5.9 GW of wind projects and 3.9 GW of hybrid projects with PPA dates of 2022 and earlier that have not been commissioned, as per the last data that was available for June 2024 (for solar), November 2024 (wind) and September 2024 (hybrid plants).[12]

Overall, there is 18.4 GW of solar, 9.6 GW of wind and 6.5 GW of hybrid projects – adding up to 34.5 GW – for which PPAs have been signed, but the projects have not yet been commissioned.

As per the information available, the 'effective PPA date' means the date on which the power purchase agreement begins. In this case, all these projects should have been commissioned on the date the PPA began – but about 34.5 GW is still pending commissioning and has missed the date on which it should have begun operating and selling power to the utility through SECI.

As per procedure, SECI and other implementing agencies sign the power supply agreement (PSA) with utilities before signing the PPA with the developer of the project. This means that the PSA has been signed, but power is not being sold and delivered to the utility. There is no public information that links the PSA and PPA – something which is required and will build confidence and transparency in this sector. This would have allowed for better understanding of the cost to the utility as agreed on in the project (PSA), and the link to the project and its developer (PPA) who would supply this electricity.

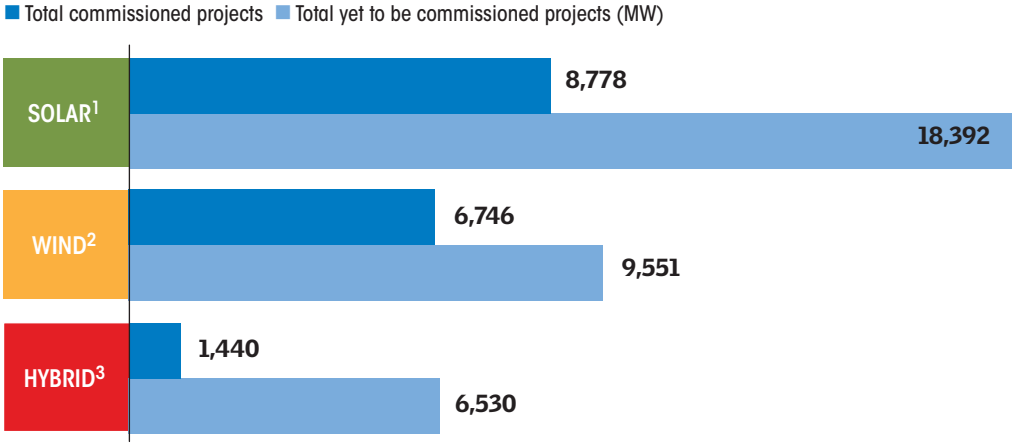
The not commissioned projects range from inter-state solar to hybrid and round-the-clock solar and wind. The category of solar plants linked to manufacturing makes up the biggest not-commissioned category. Most developers have projects that are delayed – Adani Power is at the top of the lot, but this could be because it is the largest in the country today and has ventures on manufacturing of solar components as well, which are now being developed as integrated projects (*see Tables 5 onwards*).

It is not only projects that are not being commissioned; there appears to be no or at least few takers for this cleaner and cheaper energy source. According to Mercom, SECI has released data that as of December 2024, "there are 9.2 GW of renewable energy capacity – solar, wind-solar hybrid, solar with battery energy storage and firm and dispatchable energy (FDRE) across 33 projects, which is stranded for want of off-takers." Adani Green Energy accounts for the highest inventory of unsold power at 1.799 GW, with a tariff of Rs 2.42 per kWh discovered in the reverse auction. Azure Power is next with 0.967 GW at a tariff range of Rs 2.42-Rs 2.54 per kWh.[13]

Table 5 and Figure 4: Project status – total commissioned and yet-to-be commissioned projects (as per SECI)

Effective year of PPA	Total commissioned projects (MW)			Total yet to be commissioned projects (MW)		
	Solar[1]	Wind[2]	Hybrid[3]	Solar[1]	Wind[2]	Hybrid[3]
2017	NA	1,280	–	NA	270	–
2018	1,150	2,152	–	1,450	2,348	–
2019	4,177	1,775	840	300	1,096	–
2020	2,404	246	600	400	195	–
2021	450	1,293	NA	7,387	877	1,510
2022	597	NA	NA	3,022	1,200	2,400
2023	–	–	–	3,799	2,390	1,170
2024	–	–	–	2,034	1,175	1,450
Total[4] (MW)	**8,778**	**6,746**	**1,440**	**18,392**	**9,551**	**6,530**

As many as 44 projects are yet to be commissioned despite effective power purchase agreements till 2024.



Notes: NA: Not available as of December 2024, while assuming a standard timeline of two years.

1 As of June 2024

2 As of November 2024

3 As of September 2024, bidding for hybrid (wind+ solar with or without storage) projects commenced from 2021 onwards.

4 Dash (-) represents data for projects from 2022-24 for which the effective PPA dates are available, while the commissioning status is yet to be updated.

There is another estimate that shows the bid-to-PPA ratio is only 16 per cent.[14]

Over and above this are the 'stuck' projects of other REIAs – data for this is not available. But Mercom data shows that as of June 2024, NTPC Green's pipeline of projects, for which there is no supply or purchase agreement, adds up to nearly

11 GW. Yet another report suggests that the unsigned contracts may add up to 30 GW, including the 9 GW of SECI.[15] This suggests a clear challenge as without PPAs, the future of renewable energy appears to be bleak.

The price of power is not the issue – at least, not in terms of the cost as compared to coal power – even with the SECI trading margin of Rs 0.07 per kWh added to it. According to Mercom's analysis of SECI data, the tariffs for the unsold capacity range from Rs 2.42/kWh to Rs 4.99/kWh – the higher end being for hybrid and FDRE projects.

But if these estimates are correct, then roughly 34 GW of projects of renewable energy have still not been commissioned after signing a PPA, and another 30 GW is in limbo because of lack of PPAs.

While there is little public information on what is going on in this crucial energy sector, CSE's interactions with sector experts has thrown up the following challenges:

- Power utilities (discoms) are hesitant to sign PSAs because the price of solar projects in particular has been volatile – in fact, it has been dropping. They do not want to be bound down with a higher price for the next 25 years.
- Discoms find that though the Levelised Cost of Electricity (LCOE) of renewables is lower than that of fossil fuel energy, its intermittency is a problem. The utility continues to purchase coal-based power for its night-time users and for other times when the sun-wind is not available. In addition, it has to pay for the fixed cost of this fossil energy even when there is supply from renewable sources, and this adds to the final bill.
- Developers find land availability to be a constraint. It is estimated that an additional 0.3 million hectare is needed for 500 GW.[16] This is a challenge as in a country like India, land is scarce: even lands termed as wastelands have habitations and users or are common resources critical for grazing or forestry. This is why resolving the land conundrum requires care to both compensate landowners; share benefits; and find other options for scaling up renewables, such as rooftop solar and canal-top solar.
- Transmission lines are required to evacuate the power generated. It is estimated that commissioning a transmission line takes three-four years on an average, compared to commissioning of a solar plant, which takes one-1.5 years.

Having said this, there are no obvious reasons why developers of projects should delay commissioning the projects with effective PPAs, as it would be assumed that the project viability, including its location and cost, had already been determined

and agreed upon. There is no more information available why these projects are delayed beyond the effective PPA date.

The fundamental flaw with the current policy regime of renewable projects is the lack of data and transparency. It is difficult to find data on the complete list of finished projects with capacity utilisation and the link to the power sale. This is also because projects are being implemented by a variety of agencies – both Central Public Sector Undertakings and state governments – through private developers. There is no consolidated accounting or monitoring of these projects and their progress.

Table 6: Not commissioned solar projects (as of June 2024)

Type of project	Total not commissioned (MW)
2,000-MW ISTS-connected solar PV projects (ISTS-I)	850
3,000-MW ISTS-connected solar PV projects (ISTS-II)	600
750-MW grid-connected in Rajasthan tranche-I (non-solar park)	0
150-MW (50 MW x 3) grid-connected floating solar power project to be installed at Rihand dam	150
1,200-MW ISTS-connected projects (ISTS-III)	150
1,200-MW ISTS-connected projects (ISTS-IV)	0
7,50-MW grid-connected in Rajasthan tranche-II (non-solar park)	0
1,200-MW ISTS-connected projects (ISTS-V)	30
1,200-MW ISTS-connected projects (ISTS-VI)	0
1,070-MW grid-connected solar PV power projects in Rajasthan tranche-III (non-solar park)	920
CPSU scheme (tranche-I, 2,000 MW)	55
CPSU scheme (tranche-II, 1,500 MW)	316
1,200-MW ISTS tranche-VIII	1100
2,000-MW ISTS tranche-IX	1103
ISTS solar PV plant linked with solar manufacturing plant	9234
1,785-MW Rajasthan (tranche-IV)	1785
2,000-MW ISTS-connected solar PV power projects (ISTS-XI)	1100
2,000-MW ISTS-connected solar PV power projects (ISTS-XII)	1000

Table 7: Not commissioned wind projects (as of November 2024)

Type of project	Total not commissioned (MW)
1,000-MW ISTS-connected wind power projects (tranche-I)	50
1,000-MW ISTS-connected wind power projects (tranche-II)	240
2,000-MW ISTS-connected wind power projects (tranche-III)	1050
2,000-MW ISTS-connected wind power projects (tranche-IV)	1278
1,200-MW ISTS-connected wind power projects (tranche-V)	569
1,200-MW ISTS-connected wind power projects (tranche-VI)	227
1,200-MW ISTS-connected wind power projects (tranche-VII)	300
1,800-MW ISTS-connected wind power projects (tranche-VIII)	195
2,500-MW ISTS-connected wind power projects (tranche-IX)	427
1,200-MW ISTS-connected wind power projects (tranche-X)	450
1,200-MW ISTS-connected wind power projects (tranche-XI)	1200
1,200-MW ISTS-connected wind power projects (tranche-XII)	1100
1,200-MW ISTS-connected wind power projects (tranche-XIII)	600
1,200-MW ISTS-connected wind power projects (tranche-XIV)	690
1,350-MW ISTS-connected wind power projects (tranche-XVI)	1175
500-MW ISTS-connected wind power projects (tranche-XVII)	100

Table 8: Not commissioned hybrid projects (as of September 2024)

Type of project	Total not commissioned (MW)
1,200-MW ISTS-connected solar-wind power projects (tranche-I)	0
1,200-MW ISTS-connected solar-wind hybrid power projects (tranche-II)	0
1,200 MW ISTS-connected solar-wind hybrid power projects (tranche-III)	1100
400-MW ISTS-connected RTC projects	400
1,200-MW ISTS-connected with assured peak power supply in India ISTS-VII	1200
1,200-MW ISTS-connected solar-wind hybrid power projects (tranche-IV)	1200
1,200-MW ISTS-connected solar-wind hybrid power projects (tranche-V)	1170
1,200-MW ISTS-connected solar-wind hybrid peak power projects (tranche-VI)	300
1,200-MW ISTS-connected solar-wind hybrid power projects (tranche-VII)	900
Battery energy storage system project of 250 MW/500 MWh	250

Source: Analysis from Solar Energy Corporation of India

Table 9: Not commissioned solar projects – major developers delayed (as of June 2024)

Major developers	Total not commissioned (MW)
ADANI Adani Green Energy Twenty Five A Ltd Adani Green Energy Twenty Five B Ltd Adani Green Energy Twenty Five C Ltd Adani Green Energy Twenty Five Ltd Adani Green Energy Twenty Four A Ltd Adani Green Energy Twenty Four B Ltd Adani Green Energy Twenty Four C Ltd Adani Green Energy Twenty Four Ltd Adani Green Energy Twenty Seven A Ltd Adani Green Energy Twenty Seven Ltd Adani Green Energy Twenty Six A Ltd Adani Green Energy Twenty Six B Ltd Adani Green Energy Twenty Six Ltd Adani Renewable Energy Fifty Eight Ltd Adani Renewable Energy Fifty Five Ltd Adani Renewable Energy Fifty Nine Ltd Adani Renewable Energy Fifty Seven Ltd Adani Renewable Energy Fifty Six Ltd Adani Solar Energy Jodhpur Six Pvt Ltd (earlier known as SBE Renewables Twenty Four Projects Pvt Ltd) Adani Solar Energy RJ Two Private Ltd (earlier known as SBE Renewables Sixteen Projects Pvt Ltd)	9149
RENEW Renew Hans Urja Pvt Ltd ReNew Solar Photovoltaic (earlier known as ACME Photovoltaic Solar Pvt Ltd) Renew Solar Piyush Pvt Ltd Renew Solar Stellar Pvt Ltd ReNew Sun Power Pvt Ltd ReNew Surya Vihaan Pvt Ltd	1825
ACME ACME Deoghar Solar Power Pvt Ltd ACME Dhaulpur Powertech Pvt Ltd ACME Phalodi Solar Energy Pvt Ltd ACME Raisar Solar Energy Pvt Ltd	1200
NTPC NTPC Ltd NTPC Renewable Energy Ltd	970
AZURE Azure Power Fifty One Pvt Ltd Azure Power Fifty one Pvt Ltd Azure Power Fifty Two Pvt Ltd	700

Table 10: Not commissioned wind projects – major developers delayed (as of November 2024)

Major developers	Total not commissioned (MW)
JSW JSW Neo Energy Ltd JSW Renew Energy Ltd JSW Renew Energy Three Ltd	1752
ADANI Adani Green Energy (MP) Ltd Adani Renewable Energy Four Ltd Adani Renewable Energy Seven Ltd Adani Wind Energy Kutchh Four Ltd Adani Wind Energy Kutchh Two Ltd	1600
TORRENT Torrent Power Limited Torrent Power Ltd Torrent Saurya Urja 2 Pvt Ltd	900
RENEW ReNew Naveen Urja Pvt Ltd ReNew Power Pvt Ltd ReNew Wind Energy (AP2) Pvt Ltd ReNew Wind Energy (TN) Pvt Ltd	685

Table 11: Not commissioned hybrid projects – major developers delayed (as of September 2024)

Major developers	Total not commissioned (MW)
NTPC Renewable Energy Ltd	1200
Greenko AP01 IREP Pvt Ltd	900
RENEW ReNew Surya Ojas Pvt Ltd Renew Surya Roshni Pvt Ltd	700
Adani Hybrid Energy Jaisalmer Five Ltd	600

Source: Analysis from Solar Energy Corporation of India

4

THE ROADMAP AHEAD

To surmount the problem of intermittency of new renewables, it is now proposed that India should move towards round-the-clock projects – add battery or pump storage to solar and wind projects. But will these projects, with higher costs, be viable for power purchase agreements?

The mechanism of Renewable Purchase Obligations (RPO), mandated by the 2003 Electricity Act, ensures that states with higher potential of renewables can sell this power to others. All states are required to meet 43.3 per cent of their total consumption of electricity from renewable sources by 2030. But there is a shortfall in nearly 25 out of 30 states in meeting their annual solar RPO targets.

Green energy states that supply to other states can be incentivised by offering green credits to industries that use clean power, or by giving grants to the states through the Finance Commission.

To encourage domestic production of solar cells and modules and step out of the Chinese shadow, India has taken recourse to imposing high customs duties on imported solar components; disincentivising use of imported materials; and introducing a Production-Linked Incentive scheme which provides finances to companies that wish to venture into manufacturing solar components.

Wing repowering offers an opportunity to increase the energy output of a wind farm, while utilising the same land footprint. But this has not had many takers in India.

Energy security for vast numbers of people requires an energy delivery system that is different – that delivers affordable and clean power. DRE, or decentralised renewable energy, has huge potential and works by putting energy generation in the hands of consumers.

India's solar rooftop system has an installed capacity of 14 GW, as per official figures. A perfect local-for-global solution, rooftop solar does not require land and can enhance RE capacity locally, reduce the users' electricity bills and bring down the need for transmission infrastructure.

Whither round-the-clock RE

Given the intermittency of new renewables, it is now proposed that the country should move towards round-the-clock projects. In other words, solar and wind projects would include battery or pump storage. The Economic Survey 2023-24 says the Union ministry of power has issued guidelines on tariffs for such projects, terming it as "firm and dispatchable power" from grid-connected renewable projects (FDRE). The question is, will these projects, with higher costs, be viable for power purchase agreements?

According to the Economic Survey 2023-24 (*see Table 12*), while inter-state transmission connected solar PV projects were bid out in the range of Rs 2.6-2.74/kWh, the cost of round-the-clock projects went up to close to Rs 6/kWh.[17]

As yet, little information is available about the commissioning of these projects. The round-the-clock (RTC) project listed under SECI's hybrid projects, with an effective PPA date of 2021, has not yet been commissioned. Industry insiders remain wary about the price of delivered power and whether this will be acceptable to fund-stretched discoms. But there is another view that this price of RTC projects should remain competitive with that of fossil fuels, which score because of their ability to supply power throughout the year and time of the day.

Table 12: The cost of RE projects

	Projects	Cost (Rs/kWh)	As per ministry of power (MoP) guidelines or actual tender
1	Inter-state connected solar PV	2.6-2.74	MoP guidelines
2	Inter-state wind and solar hybrid	3.43-3.54	MoP guidelines
3	Inter-state connected wind	3.18-3.49	MoP guidelines
4	Inter-state solar-wind round-the-clock	4.64-5.96	MoP guidelines
5	Railway Energy Management Company auction for round-the-clock	4.25-4.43	Actual tender
6	Satluj Jal Vidyut Nigam auction for round-the-clock	4.38	Actual tender

Source: Economic Survey 2023-24, SECI Tender Document

Implementing renewable purchase obligation targets by power procurers

The Electricity Act of 2003 had mandated the Renewable Purchase Obligations (RPO) as a mechanism to ensure that states with higher potential of renewables would be able to sell this to others; the mechanism makes it mandatory for all

discoms to purchase a certain percentage of their energy from renewable sources. As per this mandate, all states are required to meet 43.3 per cent of their total consumption of electricity from renewable sources by 2030.

The underlying idea behind setting RPO targets is two-fold: firstly, to significantly promote power procurement from expanding renewable sources, and secondly, to establish a viable market for clean energy technologies that are presently not cost-competitive, but do actively contribute to climate action goals.

In instances where targets are not met, states can utilise the tradable renewable energy certificate (REC) mechanism, which holds comparable equivalence to RE-based power. According to the initial notification in 2010, State Electricity Regulatory Commissions (SERCs) are required to determine incremental annual RPO targets based on factors such as RE resource potential, current and projected load-demand shapes and the impact of supplied power on the retail tariff.

The RPO trajectory witnessed periodic increases to nearly 23 per cent in 2023 from 2.75 per cent in 2016. In 2023, the ministry of power revised the RPO targets to reflect the increasing share of renewable energy in generation, aiming for 39 per cent by 2028. These revisions came into effect from April 1, 2024.

An analysis of states based on publicly available data (indiaredata.org and other online resources) reveals a shortfall in nearly 25 out of 30 states in meeting their annual solar RPO targets.[18]

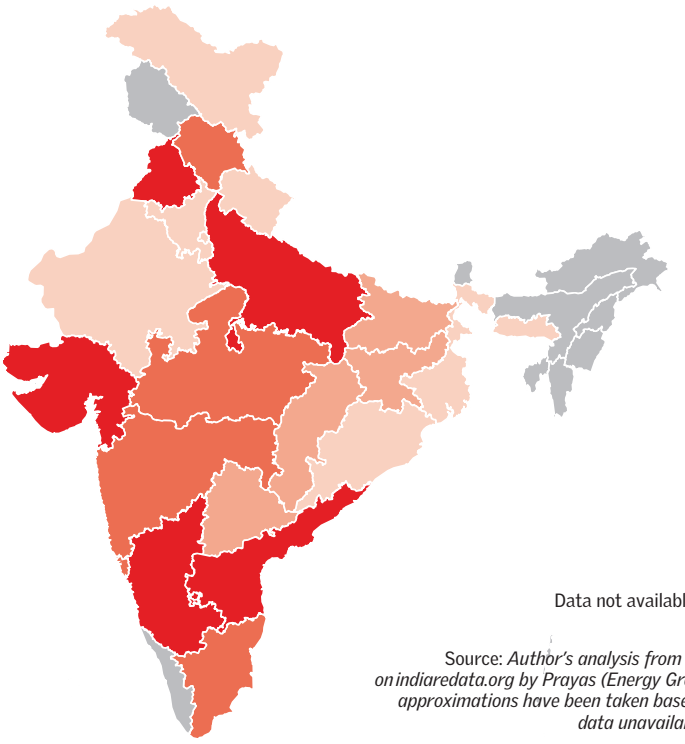
The rapid decline in solar power tariffs from 2015 to the present – dropping to around 2.5 per kWh from nearly Rs 6/kWh – has rendered solar tariffs cost-competitive with conventional thermal power. Ideally, the availability of competitive solar tariffs should encourage greater adoption of solar energy, thereby influencing clean energy investment decisions in the states.

However, since most discoms are bound by legacy PPAs for thermal power, their capacity to procure solar-based power gets reduced, thus affecting the overall RPO targets. *Map 1* categorises states based on their RPO compliance and shortfalls from 2014.

Only five states have consistently met their solar RPOs: Karnataka, Andhra Pradesh, Gujarat, Punjab and Uttar Pradesh. The eastern states have performed below 40 per cent since 2014, with several instances of unavailable data (West

Map 1: Deficits by states in meeting RPO targets

States consistently meeting RPO targets (100 per cent or more than 90 per cent)	Karnataka, Gujarat, Andhra Pradesh, Punjab and Uttar Pradesh with approximately 90 per cent compliance
States with more than 80 per cent compliance	Himachal Pradesh, Maharashtra, Goa, Tamil Nadu and Madhya Pradesh
States with less than 60 per cent compliance	Bihar, Chattisgarh, Jharkhand and Telangana.
States with less than 40 per cent compliance	Haryana, Rajasthan, Uttarakhand, Meghalaya, Jammu & Kashmir, Delhi, West Bengal and Odissa



Source: *Author's analysis from data on indiaredata.org by Prayas (Energy Group), approximations have been taken based on data unavailability*

Bengal and Odisha) and low levels of integration despite potential (Jharkhand, Chhattisgarh and Odisha). Northern states such as Rajasthan, despite having the highest installed solar capacity, have not met targets from 2014 to 2019, and thereafter have not publicly disclosed their performance. Some states in the region may still be relying heavily on costly thermal PPAs (Delhi and Haryana), which hinder cheaper solar power procurement.

It should be noted that several states such as Telangana, Bihar, Chhattisgarh, Odisha, West Bengal and Tamil Nadu have not consistently published their data.

Previously, the report of the Standing Committee on Energy of the 17th Lok Sabha in 2021 and a Comptroller and Auditor General report in 2015 have highlighted dismal performances by state discoms in meeting RPO targets, as well as the non-enforcement of penalties and the allowance of carry-forward deficits from previous years by respective SERCs. According to a Niti Aayog (India's national policy think tank) paper, *Resource Adequacy Planning to Meet RPO Targets by States – All India Roadmap 2024*, the current deficits in the targets are also attributed to inadequate generation of solar power. This is evident from the consistent shortfall in meeting RPO targets and the reluctance of utilities to purchase RECs for compensation.

A CEA report *20th Electric Power Survey of India*[19] – also highlighted this generation deficit.

The question is, how can this mechanism be further strengthened and enabled so that it can ensure scaling up of renewable energy projects in the country?

Incentivising green energy states

There are some states in India that have moved towards non-fossil fuel energy, and are enabling the clean energy transition in the country. These states are generators of green energy; for instance, non-fossil fuel energy as a percentage of total generation in the Himalayan states of Himachal Pradesh, Jammu and Kashmir and Sikkim is 100 per cent.

These states – with higher non-fossil energy generation than their total energy consumption – are also suppliers to other states. The question is, how can these states be rewarded for this energy transition. One way could be to qualify industries that use clean power for green credits; or transfer of grants to the states through the Finance Commission.

Ensuring domestic manufacturing/raw mineral supply for scaling up

India has an ambitious plan to raise the bar on domestic manufacturing of solar cells and modules. It has a three-pronged approach, much like in many other parts of the world, to wean itself out of the Chinese domination on solar components. One, it has imposed a customs duty of 40 per cent on imported solar modules and 25 per cent on imported solar cells. Two, it has created a system to disincentivise the use of imported materials through the requirement of all projects to use domestically produced materials. Three, there is the Production-Linked Incentive (PLI) scheme which provides finances to companies that wish to venture into manufacturing solar components. This scheme, for which the ministry of new and renewable energy had issued guidelines on April 28, 2021, targets manufacturing of high-efficiency solar PV modules in the country.

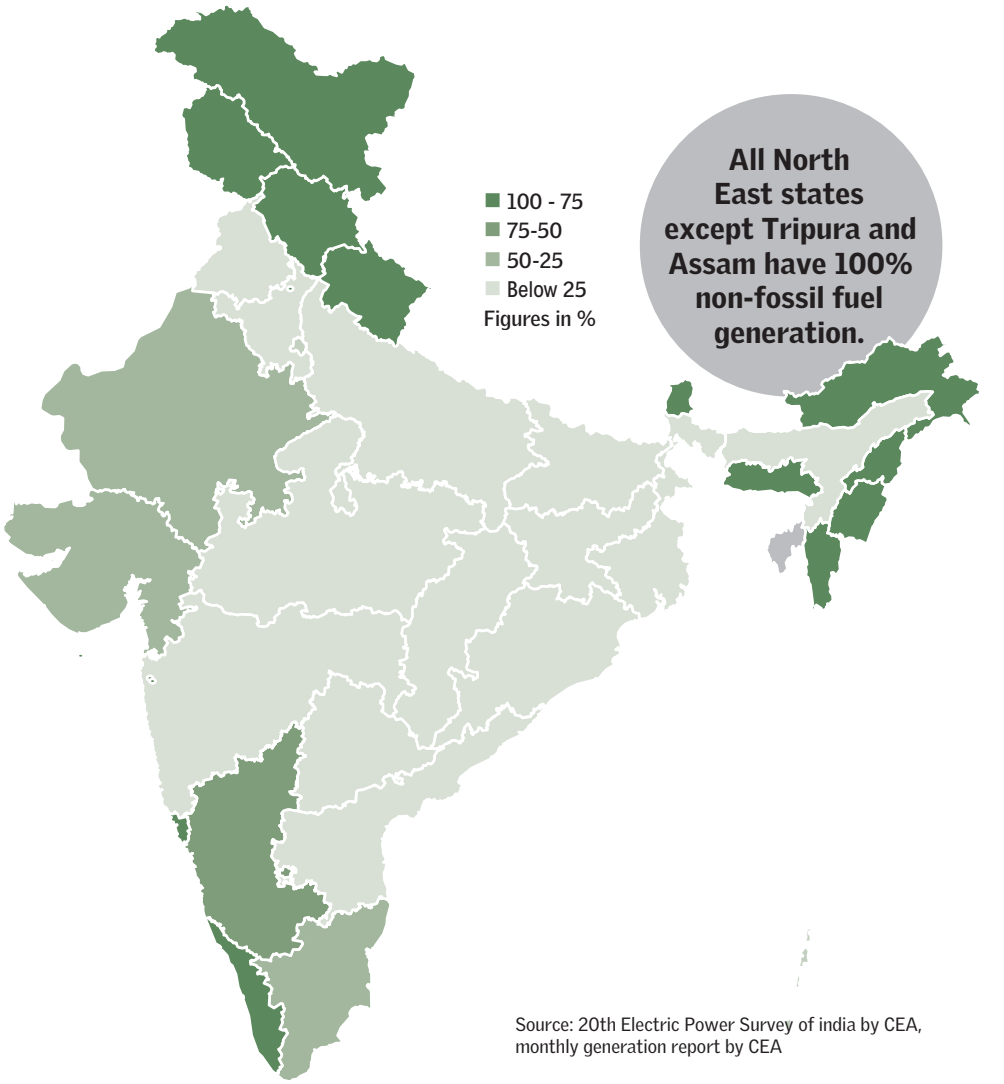
In April 2024, the country reissued the Approved List of Models and Manufacturers (ALMM), which requires that all government or government-assisted projects – that make up the bulk of the projects in the country – should source Indian-made modules. Mercom reports that after the ALMM, solar module imports into the country have dropped sharply. Currently, Indian companies are importing from Vietnam and Cambodia, which have a free trade agreement with India.[20]

Table 13 and Map 2: RE generation within states and RE generation as a percentage of total electricity consumption in the states – a comparison

State/UT	2022-2023 in MU					
	Fossil	Non-fossil		Non-fossil as % of total generation 2022-23	Non-fossil generation as % of total electricity consumption 2022-23	RE generation as % of total electricity consumption in state 2022-23
	Coal, lignite and gas	Nuclear and large hydro	Renewable (excluding large hydro)			
Chandigarh			13	100	0.8	0.8
Himachal Pradesh		38,667	2,913	100	374.7	26.3
J&K		16,777	393	100	175.7	4.0
Ladakh		403		100		
DNHDD			31	100	0.3	0.3
Goa			20	100	0.4	0.4
Kerala		7,989	1946	100	38.1	7.5
Sikkim		11,697	12	100	2384.8	2.5
Arunachal Pradesh		4,821	25	100	832.6	4.3
Manipur		478	9	100	57.6	1.0
Meghalaya		980	72	100	57.2	3.9
Mizoram		204	62	100	53.9	12.6
Nagaland		177	112	100	42.1	16.3
Uttarakhand		15,436	932	100	113.4	6.5
Karnataka	35,014	20,601	29,575	59	64.3	37.9
Rajasthan	57,419	7,555	40,990	46	55.8	47.1
Tamil Nadu	67083	21,978	27,626	43	44.6	24.8
Gujarat	55,482	9,773	29,763	42	27.3	20.6
Punjab	31,506	4,400	4,170	21	13.8	6.7
Andhra Pradesh	61,542	3,748	16,412	25	28.1	22.9
Maharashtra	126,907	14,880	17,207	20	19.2	10.3
Delhi	3784		530	12	1.6	1.6
Telangana	50,738	6,010	7,430	21	18.7	10.3
Assam	8,393	482	279	8	6.7	2.5
Andaman Nicobar	215		38	15	13.3	13.3
Odisha	64,532	5,463	2,761	11	10.3	1.5
Madhya Pradesh	135,838	7,309	8,873	11	21.5	11.8
Uttar Pradesh	152,063	4,167	7,217	7	9.0	5.7
Haryana	32,139		1,420	4	2.4	2.4
Puducherry	233		12	5	0.4	0.4
West Bengal	87,612	3424	329	4	6.1	3.2

State/UT	2022-2023 in MU					
	Fossil	Non-fossil		Non-fossil as % of total generation 2022-23	Non-fossil generation as % of total electricity consumption 2022-23	RE generation as % of total electricity consumption in state 2022-23
	Coal, lignite and gas	Nuclear and large hydro	Renewable (excluding large hydro)			
Chhattisgarh	142,599	237	2,003	2	4.8	4.3
Jharkhand	30,473	305	81	1	1.1	0.1
Bihar	55,200		289	1	0.9	0.9
Lakshadweep	15		0	1	0.2	0.2
Tripura	7,079		7	0	0.6	0.6

DNHDD: Dadra and Nagar Haveli and Daman and Diu



Source: 20th Electric Power Survey of india by CEA, monthly generation report by CEA

According to data presented to Parliament (Lok Sabha question no 338), India's capacity to manufacture high efficiency solar PV modules was 60.5 GW as on October 31, 2024. The Union minister of state for new and renewable energy said this capacity makes the country well positioned to meet the domestic demand and cater to the global market through exports.

But the question still is, as solar demand increases in the country, will there be a gap between the supply of these solar components; and does the price of domestically produced components keep the projects viable?

Industry observers point to another issue. India is now a growing exporter of solar components and has plans to take advantage of the world's disenchantment with China's supply chain. According to a 2024 report by the Institute of Energy Economics and Financial Analysis (IEEFA), the country's "export value of PV modules has increased by more than 23 times in just two years between FY 2022 and FY 2024". The exporters of these modules earn 40-60 per cent higher profits when their products are sold to countries like the US (as compared to India). This report says that the top solar component manufacturers including Waree Energies, Adani Solar and Vikram Solar exported more than half their annual module production in 2024.[21] Industry observers, however, say that this could be an underestimation as the bulk (close to 100 per cent) of the domestic production is bound for exports.

There is no doubt that we can add to economic growth, bring in foreign exchange, and even generate employment through the export of solar components, but will this lucrative export market end up constraining India's domestic solar ambition? Data from the Union ministry of commerce and industry's Export-Import Data Bank reveals a trend of declining imports, and also of increasing exports of solar modules.

The question also is if India can challenge the dominance of China through its manufacture of modules and even cells, given that the basic raw material is still not in its control. China has a complete stranglehold on polysilicon – the first step in the supply chain – as well as on the production of the ingot from the polysilicon and the wafer, which is cut from the ingot. India is now breaking into the cell and module market, but China still controls up to 80 per cent of the world's supply. As a 2024 paper from the Observer Research Foundation (ORF), a think tank, points out, while India is projected to become the largest module manufacturer after China by 2024, it will still need to source its components from China.[22]

Table 14: Import and export of solar modules between 2019-20 and 2022-23 (in millions of units)

Imports	2019-20	2020-21	2021-22	2022-23
Photovoltaic cells not assembled in modules or made up into panels	795.82	739.05	773.48	1233.81
Photovoltaic cells assembled in modules or made up into panels			99.83	7.95
Exports	**2019-20**	**2020-21**	**2021-22**	**2022-23**
Photovoltaic cells not assembled in modules or made up into panels	6.91	1.05	0.84	1.86
Photovoltaic cells assembled in modules or made up into panels			0.97	5.75

Source: Department of Commerce, Export Import Data Bank

Wind repowering: How to make it work

Wind energy – a critical source of clean power – seems to have peaked in the country. Its growth has been sluggish and new projects are not being commissioned, as seen from the data from SECI. The fact also is that this sector was India's leader in renewable power; the best wind sites (onshore) have all been used up.

But wind technology has vastly improved now and the same site can be repowered with a new turbine to generate more electricity. With newer turbines being significantly larger and more efficient than their predecessors, they can capture more wind and have greater electricity output. Repowering presents an opportunity to double or even triple the energy output of a wind farm while utilising the same land footprint. According to the *Indian Wind Power Directory 2021*, the bulk of wind turbines in the country are below 0.5 MW or between 0.5-1 MW. They are also of lower hub heights (25-30 m), which lowers the capacity to generate wind energy.

The Chennai-based National Institute of Wind Energy (NIWE) has assessed the repowering potential in the country to be 25.4 GW, specifically focusing on turbines below 2 MW. According to the Global Wind Energy Council, newly installed wind turbines are around 3.2 MW; in fact, Adani Wind has received certification for India's largest turbine, a 5.2 MW model with a 160-metre rotor diameter.

This figure underscores the untapped potential within India's wind energy sector. The Union ministry of new and renewable energy echoed this estimation in its December 2023 policy regarding national repowering and life extension. This is not a new idea. The question is why, despite the clear logic, wind repowering is still not taking off.

There is not much happening in repowering; data available from various sources indicates that very few old turbines have been replaced. It is only in Tamil Nadu that less than 30 MW has been replaced, with the same aggregate capacity of the farm. Other states are yet to see any development in this sector. The mismatch between policy guidelines and demand from the industry needs to be looked at closely.

The CSE report on Tamil Nadu,[23] the state that has the highest potential for repowering, finds that there are policy gaps in this area. The Tamil Nadu Generation and Distribution Corporation (TANGEDCO) has a draft policy for repowering and life extension, which aims to optimise on existing wind resources. But there are problems that still need to be addressed: the question of fragmented ownership of existing wind projects and most critically, the economic incentives for dismantling the existing turbines and their replacement. This is when the CUF of existing windmills and the few repowered projects is substantially higher – going from 6 to 17 per cent. Therefore, higher energy is generated and this increases viability.

The comparison of greenfield wind projects and repowering reveals – not surprisingly – that there is a cost attached to the dismantling and disposal of old turbines, which is not there in a new project. But this is not the issue: the reason for investing in repowering is the lack of new windy sites and the potential to optimise on current availability of land and other resources. The problem is that the old wind projects have been fully depreciated and there is no real incentive now for developers to repower. This is combined with bottlenecks in transmission infrastructure, which makes evacuation of power difficult.

But these barriers are not impossible to overcome – and the opportunity is huge. What needs to be discussed is the agenda moving ahead.

Decentralised renewable energy: Potential and prospects

The fact is renewable energy is about a different tomorrow – a tomorrow that is green and inclusive. The technology is also designed to be modular and decentralised. As of today, large-scale renewable transition across the world has been fitted into the grid-based system, which was designed for fossil fuels. In this way, utility-scale solar or wind feeds into the same grid and the power is supplied to households and industries through distribution companies.

The question is, how can this be differently planned and executed? Is it possible?

Firstly, there is the challenge of electricity supply. The government has an aggressive plan to reach every household with electricity. But the fact is that even as the grid reaches everywhere, the light does not. This is because people are either too poor to pay for the electricity, or the distribution company is too poor to supply it, or the market has no way of working with the cashless energy segment. Whatever the reason, millions in the country are still in darkness. Energy poverty is still crippling vast numbers of Indians, who cannot use this crucial enabler to progress – from education to employment.

Secondly, there is the challenge of clean energy for cooking. Women across the developing world – including in China and India – are exposed to toxic emissions because of the biomass they burn to fuel their cooking stoves. Globally, it is estimated that 2.6 billion people still rely on biomass for cooking, with 80 per cent of Sub-Saharan Africans and 66 per cent of Indian using this inefficient and polluting fuel.[24] This adds up to roughly half the developing world – which is about 40 per cent of the whole world. The International Energy Agency estimates that even by 2030, 43 per cent of the developing world (33 per cent of the world's people) will continue to cook using biomass.

Thirdly, there is the limitation of land for renewable projects – by optimising on available land (with farmers) or rooftops (with households and institutions), energy is generated, consumed and even supplied to the grid. It is the ultimate 'uber' solution as resources in the hands of people are used to build a new energy future which would be cheaper and easier to manage. But this is still a work in progress.

The fact is that energy security for vast numbers of the poor requires an energy delivery system that is different. It will require delivering energy which costs less but is advanced and cleaner, into households that cannot even afford to buy basic fuel or light. It will require cutting the length of supply lines, leakages and losses and everything else that makes energy cost more, so that it is affordable. There is no clear idea what will work. But what is clear is that we have to push the envelope so that RE becomes transformational – an agent of change for the society and environment.

On its dashboard, the Union ministry of new and renewable energy categorises decentralised renewable energy as one that is used for lighting (street and home lighting systems) and agriculture (off-grid solar pumps which are grid-interactive, and solar feeders). DRE can be a crucial cog in livelihood generation as well, in terms of developing clean energy applications for income generation purposes,

besides direct electricity use. In addition, small solar and other renewable energy power plants of up to 2 MW are included in the PM-KUSUM scheme.

It is clear that there is huge potential in this sector which puts energy generation in the hands of consumers – who then would be expected to improve demand-side management to optimise their energy. There are also new areas emerging which look at this source of power for livelihoods and agro-photovoltaics (Ag-PV). The question now is how this can be scaled up.

Rooftop solar: An idea whose time has come?

The domestic sector consumes roughly a quarter of the electricity in the country. Rooftop solar offers a solution to reduce the burden on distribution companies, as households would themselves produce the electricity. But the question of viability of this system remains: can it provide the electricity that is needed by the building owner – residential or institutional – both in terms of quantum and time of day?

In most solar rooftop systems, people use the distribution companies to supply excess day-time electricity and buy back electricity at night-time – or when the sun is not shining, or to meet larger demands. Therefore, the role and the health of the distribution company is critical for the growth and success of the distributed renewable system – this is, unless the entire system can be designed to disengage with the utility through stand-alone batteries for storage and supply.

The government of India has been incentivising the rooftop solar programme for some decades. It has also seen policy innovations as governments work to improve the programme to ensure that it can deliver to segments which are unable to pay for the capital cost of the system. The problem also lies in the fact that energy costs for households – particularly at the lower income levels – remain subsidised; this makes it difficult for the more expensive solar-based system to penetrate.

The rooftop solar system has been most preferred when consumers see an obvious cost advantage in producing their own electricity. The opportunity lies in how governments can use millions of roofs to put in place an energy system of the future – and this seems to be taking off now. The PM-Surya Ghar (solar house) scheme – also called the 'free electricity scheme' – is designed to reach a million rooftops in the country.

As per the MNRE dashboard as of October 2024, the country's solar rooftop system has an installed capacity of 14 GW – this is added to the combined installed solar energy capacity of 80 GW. In other words, solar rooftop constitutes some 17

per cent of the total installed capacity for solar. The problem is that while there is data for installation of solar rooftop, the generation from this system is not accounted for. This is because this information is in the hands of consumers or with distribution companies (which receive the energy that is supplied, but do not collate the data).

The India RE-Navigator, a project of Bridge to India, a subsidiary of the credit-rating agency CRISIL, estimates the total solar rooftop capacity to be close to 13 GW, of which roughly 10 GW is in the industrial-commercial segment and less than 3 GW in the residential segment. Interestingly, the data shows that the bulk of rooftop solar is in the CAPEX (capital-expenditure) model (roughly 9 GW out of 13) – in which consumers install the system at their own cost or with subsidies from the government. The rest is in the OPEX (operating expenditure) model, where solar companies put up the capital cost into the system and the 'owner' pays for the electricity generated.[25] According to India-RE Navigator, some 616,019 solar projects had been installed in the country till November 2024.

The case for rooftop solar emerges from its own characteristics: as land-based solar is very land-intensive, the use of decentralised solar resources can enhance RE capacity locally, reduce the users' electricity bills and bring down the need for transmission infrastructure. It is the perfect local-for-global solution. The government has provided schemes for upfront subsidies to underwrite the high capital investment, as well as payment for the solar energy fed into the grid through net metering.

Over the years, policies have innovated and evolved:

- In 2010, the Jawaharlal Nehru National Solar Mission (JNNSM) was launched with a target of 2,000 MW (2 GW) of RTS capacity by the year 2022. The focus was initially on generation-based incentives.
- In 2012, the government of India introduced a net metering policy which would credit the generators for each unit of energy distributed to the grid.
- In 2013-14, the OPEX (developer-led) model was introduced in addition to the CAPEX (consumer-led) model.
- In 2019, distribution companies (discoms) were made the nodal implementing agency for rooftop solar. During this phase, the central financial assistance (CFA) was also increased to 40 per cent for up to 3 kW and 20 per cent for 3-10 kW capacity for residential owners only. Additionally, incentives were introduced for discoms and developers to encourage more active participation.
- The installed capacity increased by 83 per cent between 2019 and 2023, up from 1.8 GW in 2019 to 10.4 GW in 2023.

- In 2024, an ambitious the PM-Surya Ghar Programme has been launched targeting the residential sector

The PM Surya Ghar (Muft Bijli) Yojana

The PM Surya Ghar (Muft Bijli) Yojana of 2024 targets the lower income residential segments. The objective is to leapfrog these households to cleaner energy, even as incomes increase and so does the demand for electricity. This ambitious scheme with an outlay of Rs 75,021 crore aims to reach 10 million households by 2027, and will provide upfront money to households with consumption of up to 300 units of electricity per month. The scheme has an online process, from registration to subsidy disbursal, which is sent directly to the bank account of the residential consumer through the national portal. It is estimated by the National Sample Survey Organisation (NSSO) that on an average, the bulk of Indian households use less than 100 units of electricity per month.

The scheme will provide an upfront capital cost of Rs 30,000 for a 2-kW solar rooftop system, which would generate roughly 230 units per month. The catch is that the capital cost is still not fully financed – this 2-kW system would cost between Rs 1-1.15 lakh or higher. This means that the household would need to self-finance and pay Rs 90,000-1 lakh – which is a barrier for poor households. The incentive for households is that they then become self-sufficient in energy, with a zero-bill for power consumption – as stated in the scheme's objective. This, of course, depends on the quality of the rooftop available to these households, as the poor – in most cases – live in unauthorised and slum areas.

The subsidy is capped at Rs 78,000 for systems of 3-kW and above. This system would provide roughly 350 units per month and cost about Rs 1.60-1.80 lakh, which means that the subsidy would pay for half the cost.

According to data provided by the government to the Parliament (Lok Sabha Unstarred Question No 422, answered on November 27, 2024) about 4.2 per cent of the total registrations on the national portal have led to installations of solar rooftops. Therefore, with 14.488 million people registering for the scheme on the portal, it led to applications from 2.5 million and final installation of 0.6 million.

Gujarat reported installation of 281,769 rooftop solar projects out of the 310,845 applications received; Maharashtra reported installation of 120,696, while Uttar Pradesh accounted for 51,313 installations out of 2.2 million registrations and some 0.5 million applicants. This also suggests a huge mismatch between the applications received and the installations.[26]

Table 16: PM Surya Ghar subsidy structure

Average monthly electricity consumption (units)	Suitable rooftop plant capacity	Subsidy provided
0-150	1-2 kW	Rs 30,000 per kW up to 2 kW
150-300	2-3 kW	
>300	Above 3 kW	Additional Rs 18,000 for capacity up to 3 kW, capped maximum at Rs 78,000 for 3 kW

Source: PM Surya Ghar-Muft Bijli Yojana, National Portal

However, it is not clear how much of the subsidy amount has been disbursed so that the systems can be installed. Replying to Rajya Sabha Question No 945 on December 3, 2024, the minister of state said that "subsidy has been released to 0.366 million applicants". It is also not clear how government is planning to monitor the implementation and the commissioning of these projects. This will be important to ensure that the subsidy is not misused.

Gujarat has been leading on rooftop solar for some years now and by early 2024, already had close to 2.9 GW installed on its roofs. Maharashtra, Karnataka, Rajasthan and Kerala follow, and these five states make up about 70 per cent of the rooftop solar installed in the country, according to the MNRE.

The other option being considered by many states of India is to aggregate the rooftops so that these become feasible for projects to the taken up in the RESCO (renewable energy service company) or private operator model. Madhya Pradesh is leading on this: its RESCO tenders 1 and 2 for rooftop have been over-subscribed and are being implemented in over 100 buildings across the state. Under this, for instance, all medical colleges in the state have taken to solar rooftop with a combined capacity of 2.9 GW. As a result of the combined tender, the price has also been reduced – IIM Indore, for instance, has a plant of just 460 kW, but at a price of Rs 1.38 per unit.[27]

It is clear the success of the rooftop programme is intrinsically linked to the health of the discoms. In recent years, substantial government effort has been made to address discom finances, particularly concerning their deficits and the necessity for continuing with the state subsidies. Following two significant bailout programmes funded by the Central government, states have worked to improve tariff structures and reduce subsidies to households. With rising electricity bills affecting everyone, including those who were previously cross-subsidised (such as low-income residential consumers who receive up to 200 unit free or nearly free

per month), rooftop solar is increasingly appealing to a broader range of consumer categories beyond commercial and industrial (C&I) users.

The key is to ensure that while rooftop solar is incentivised, it does not come at the cost of the discom. Currently, as 'paying' customers set up their rooftop generation units, the discoms get less money; this weakens their financial situation further. However, without the discoms, the household or institutional solar rooftop owner would not have access to supply of electricity during the night or at times when the sun is not shining. They would need to invest in storage systems, which as of now are still costly. Therefore, the discom is the storage back-up for rooftop owners – this needs to be understood so that both can grow together.

This then raises issues of what would be the best billing policy for discoms and individual roof owners. Currently, the preferred billing system is termed as net-metering, under which the discom adjusts the bill for the units of electricity exported. There is another option to move towards net-billing, which would allow the discoms to pay only for the units exported and at the lower price of day-time electricity.

The fact is the incentive system must be changed so that rooftop owners are benefitted if they maximise their consumption – they do not set up the system to 'sell' to grid, but to use the generated electricity during the day to its maximum. This lessens the load on the discom, which is then used as a 'storage' or back-up for night-time electricity purchase.

The PM-KUSUM scheme

The Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) was introduced in 2019 with the objectives of incorporating renewable energy for irrigation; helping farmers gain access to solar water pumps at subsidised rates; and giving farmers an avenue to utilise their barren land by setting up solar power plants for energy generation.

PM-KUSUM was divided into three components – A, B and C – with corresponding targets to be met by 2022. Under Component A, farmers or cooperatives can install renewable energy plants up to 2 MW on their lands with the objective of selling generated electricity to the discoms. Under this component, procurement-based incentive (PBI) is provided to the discom at Rs 0.40 per kWh to buy renewable power from the farmer or cooperative. In addition, there is a component for development of one village in each district of the country as a model solar village – a grant of Rs 1 crore is provided to transition to solar. The target for

this was set at 10,000 MW of decentralised ground/stilt-mounted grid-connected solar power plants.

Component B includes installation of off-grid solar water pumps on farmers' lands. The target was set at 1.75 million stand-alone solar agriculture pumps. Component C entails solarisation of grid-connected agricultural pumps by installing these pumps on farmers' lands.

Components A and C were supposed to be implemented initially on a pilot mode for 1,000 MW capacity and 0.1 million grid-connected agriculture pumps, respectively; component B was to be implemented in a full-fledged manner with a total Central government support of Rs 19,036.5 crore. The scheme was scaled up from its pilot stage in 2021; in August 2022, it was extended till 2026. The 2019 target: solarisation of one million grid-connected agriculture pumps.

In 2020, the MNRE introduced feeder-level solarisation (FLS) as a sub-component under component C. in addition to solarisation of existing electric pumps (to be referred to as individual pump solarisation or IPS).

The scheme also offers subsidies for components B and C to encourage its adoption. Under component B of the scheme, 30 per cent central financial assistance (CFA) is provided on the upfront costs in addition to at least 30 per cent subsidy through the state government. In total, farmers have to contribute some 40 per cent of the costs of their solar water pumping systems. The subsidy in the case of special states (northeastern states, Sikkim, Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Lakshadweep and Andaman and Nicobar Islands) is 50 per cent CFA. Under component C (FLS), developers receive 30 per cent CFA and no additional subsidy is provided from the state.

CSE's analysis of the scheme reveals that the three components of the scheme have been planned in a way to enable them to offer benefits to farmers of all categories – marginal, small, medium and large, divided on the basis of landholdings. Component A benefits farmers by giving them access to an extra source of income from their barren land. Farmers can start a solar power plant between capacities 500 kW and 2 MW and sell the electricity generated to the grid.

Component B targets small farmers who are currently dependent on diesel and off-grid based pumps. The farmers can opt for stand-alone solar water pumps replacing their electric/diesel pumps, which would lead to savings in terms of operational costs such as amount spent on purchasing diesel or paying electricity bills.

Component C is divided into two sub-components. The first is individual pump solarisation (IPS), which involves setting up grid-connected solar water pumps on farmers' lands. Under IPS, the capacity of the solar power plant can be twice the capacity of the farmers' existing water pumps (in kW), so that farmers can sell the excess electricity generated back to the grid. The second sub-component, feeder-level solarisation (FLS), entails farmers with land located at a five-km distance from the nearest substation to start a micro-grid – they can use this to sell electricity to the substation and power their agricultural feeders.[28]

According to the national portal on PM-KUSUM, the progress under this scheme is primarily in component B – where roughly 0.5 million solarised pump sets have been installed. Three states are in the lead: Haryana with 136,036 pumps, Maharashtra with 163,906 and Rajasthan with 82,553 solar pumps on their agricultural fields.

Table 17: Component-wise savings/income of farmers

Component	Purpose	Assumption	Savings/income
Component A	Introduced to incentivise farmers owning large areas of barren land to invest in solar power generation	A farmer with 14 acre of land would set up a plant of about 2.5 MW with an upfront cost of Rs 8 crore. The units generated in a day would be about 16,900 with a tariff of Rs 3.14/unit	Daily income: Rs 53,066 Monthly income: Rs 15,91,980 Breakeven period: Five years
Component B	Introduced to incentivise farmers to shift from electric/diesel pumps to solar pumps	A farmer with 6 acre of land shifts from a 12-horsepower (hp) diesel pump to a 7.5-hp solar water pump. The farmer uses the diesel motor for 150 days a year using five litre/day of diesel on an average. The cost of diesel is Rs 86.52/litre	Average annual savings: Rs 64,890
Component C	Introduced to incentivise farmers to replace their electric pumps with solar pumps and for farmers with large areas of barren land to invest in solar power generation	A farmer with 14 acre of land would set up a plant of about 2.5 MW with an upfront cost of Rs 8 crore. In a day, it would generate 16,900 units with a tariff of Rs 3.51/unit	Daily income: Rs 59,319 Monthly income: Rs 17,79,570 Breakeven period: Three-four years

Source: Farmer interviews by CSE team

Table 18: The progress of PM-KUSUM – as of September 2024

PM-KUSUM[29]	Total sanctioned capacity up to 2026	Total installed capacity/pump numbers (September 2024)
Component A: Solar plants up to 2 MW	9.1 GW	0.29 GW
Component B: Off-grid solar pumps	1.34 million	0.5
Component C (IPS)	1,71,640	4,759
Component C (FLS)	3,385,494	32,512

Source: PM KUSUM National Portal, available at https://pmkusum.mnre.gov.in/#/landing#state-wise-details

But even in this component, progress is impeded. CSE's 2024 study on the implementation challenges of the PM-KUSUM scheme identified that the cost was the key concern. Under the scheme, which provides subsidy, the solar pump system must be procured through manufacturers listed under the 'Approved List of Models and Manufacturers (ALMM)'. This list is to ensure that domestically manufactured solar modules are used. These are more expensive than the imported modules. This increase in solar PV module price has led to an increase in the cost of solar water pumps under PM-KUSUM and therefore, an increase in the farmers' upfront costs. The availability of free or nearly free electricity adds to this lack of interest. However, in states, where agricultural electricity is regulated, there is greater demand for solar pumps.

It is also clear that the as groundwater levels go down, farmers will need higher capacity pumps to withdraw water. Under PM-KUSUM pumps up to 15-hp are permissible, but subsidy is given only for pumps up to 7.5-hp. This adds to the cost of the system. However, in many cases, states are combining this programme with the incentives given for drip irrigation, which makes the system work to manage water demand.

The problem also is the lack of delivery in rural areas – the sector still lacks entrepreneurs who can do operations and maintenance in these regions. This needs to be improved.

References

1. India's updated first Nationally Determined Contributions, submitted under the Paris Agreement in August 2022 (India, 2022), https://unfccc.int/sites/default/files/NDC/2022-08/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf, as viewed on November 4, 2024
2. 500GW Nonfossil Fuel Target, https://powermin.gov.in/en/content/500gw-nonfossil-fuel-target, as viewed on November 4, 2024
3. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1913789, as viewed on December 5, 2024
4. Central Electricity Authority, Report on Optimal Generation Capacity Mix 2029-2030, 2023, https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf, as viewed on November 4, 2024
5. Year End Review 2023 of Ministry of New & Renewable Energy, https://pib.gov.in/PressReleasePage.aspx?PRID=1992732, as viewed on November 4, 2024
6. Renewable Generation Report, https://cea.nic.in/renewable-generation-report/?lang=en, as viewed on November 12, 2024
7. NOTIFICATION F. No. 23/18/2020–R&R, https://powermin.gov.in/sites/default/files/Electricity%20%28Promotion%20of%20generation%20of%20Electricity%20from%20Must-Run%20Power%20Plant%29%20Rules%2C%202021.pdf, as viewed on November 12, 2024.
8. CERC Notifies ISTS Charges Waiver for Renewable Energy Projects, https://www.mercomindia.com/cerc-inter-state-transmission-charges-regulations, as viewed on November 12, 2024.
9. Solar Energy Corporation of India, SECI, Annual Reports, https://www.seci.co.in/financial/annual-reports, as viewed on November 13, 2024.
10. Mercom India, Solar Market Update, https://www.mercomindia.com/product/q3-2024-india-solar-market-update, as viewed on November 3, 2024.
11. United States Securities and Exchange Commission, https://www.sec.gov/files/litigation/complaints/2024/comp-pr2024-181.pdf, as viewed on November 4, 2024
12. Solar Energy Corporation of India, Solar Monthly Progress Report, https://www.seci.co.in/ists/solar, as viewed on November 28, 2024

13. Mercom India, “Over 9.2 GW of solar power from SECI remains unsold due to lack of offtakers” https://www.mercomindia.com/solar-power-seci-remains-unsold, as viewed on December 6, 2024
14. P K Das, CMD IREDA, The road to 500 GW, presentation at Renewable Energy Conclave by CSE-AAETI, https://cdn.cseindia.org/attachments/0.11065400_1733727372_pradip-kumar-das.pdf, December 9, 2024
15. Money control, “Rise in green energy projects fuels surge in power purchase deals: Centre”, https://www.moneycontrol.com/news/business/companies/rise-in-green-energy-projects-fuels-surge-in-unsigned-power-purchase-deals-centre-12888580.html, as viewed on December 12, 2024
16. *Ibid*
17. Economic Survey 2023-24, Chapter 6, https://www.indiabudget.gov.in/economicsurvey/doc/eschapter/echap06.pdf, as viewed on December 6, 2024
18. Down to Earth, “How renewable energy purchase obligations targets can advance energy transition in India”, May 2024, https://www.downtoearth.org.in/renewable-energy/how-renewable-purchase-obligation-targets-can-advance-energy-transition-in-india-96101, as viewed on December 6, 2024.
19. Central Electricity Authority, Report on twentieth electric power survey of India (Volume 1), https://cea.nic.in/wp-content/uploads/ps___lf/2022/11/20th_EPS_____Report___Final___16.11.2022.pdf, as viewed on May 2, 2024.
20. Mercom India, “India’s solar cell and module imports drop sharply in 2024, https://www.mercomindia.com/indias-solar-cell-and-module-imports-drop-sharply-in-q2-2024, as viewed on December 5, 2024.
21. Institute for Energy Economics and Financial Analysis, “Indian Solar PV exports surging”, https://ieefa.org/resources/indian-solar-pv-exports-surging, as viewed on December 6, 2024.
22. Observer Research Foundation, America, “India: the rising power in global solar photovoltaic supply chains”, https://orfamerica.org/newresearch/solar-rising-india, as viewed on December 6, 2024.
23. Centre for Science and Environment, Report on Accelerating Wind Repowering in Tamil Nadu, https://www.cseindia.org/accelerating-wind-repowering-in-tamil-nadu-12306, as viewed on December 6, 2024.
24. International Energy Agency, Report A vision for clean cooking access for all, https://iea.blob.core.windows.net/assets/f63eebbc-a3df-4542-b2fb-364dd66a2199/AVisionforCleanCookingAccessforAll.pdf, as viewed on December 6, 2024.

25. India RE-Navigator, Rooftop Solar, https://www.india-re-navigator.com/rooftop, as viewed on December 6, 2024.

26. Saur Energy, "Gujarat and Maharashtra top beneficiaries of PM Surya Ghar scheme till Oct 24, https://www.saurenergy.com/solar-energy-news/gujarat-maharashtra-top-beneficiaries-of-pm-surya-scheme-till-oct-24, as viewed on December 6, 2024.

27. Manu Srivastava 2024, Sun Smiling, presentation at the RE Conclave CSE-AAETI, on Road to 500 GW, https://cdn.cseindia.org/attachments/0.02901600_1733729966_manu-srivastava.pdf, December 9, 2024

28. Centre for Science and Environment, Report on Implementation challenges of the PM Kusum scheme, available at https://www.cseindia.org/implementation-challenges-of-the-pm-kusum-scheme-12284, as viewed on December 6, 2024.

29. PM KUSUM National Portal, available at https://pmkusum.mnre.gov.in/#/landing#state-wise-details, as viewed on December 6, 2024.

India aims to ramp up its installed non-fossil fuel energy capacity to 500 GW by 2030. This will mean that by 2030, 50 per cent of India's installed capacity would be 'clean' energy. At a time when energy demand is set to soar and millions still don't have access to power, there is a three-fold challenge facing the country: to augment the power infrastructure, make it clean, and supply reliable electricity at affordable rates. Will the ambitious steps that India is taking on building up its renewable and non-fossil fuel energy systems help it surmount this challenge? This publication offers a bird's eye view of the sector, its promise and the perils and pitfalls that it confronts.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phone: 91-11-40616000 Fax: 91-11-29955879
E-mail: cse@cseindia.org Website: www.cseindia.org