

# Decentralization to decarbonize the Indian economy

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**Keywords:** net zero; decarbonization; decentralization; economy; renewable energy.

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**Abstract.** *Renewable Energy (RE) plays an important role in India's energy security and reducing greenhouse gas emissions. Energy generated at the*

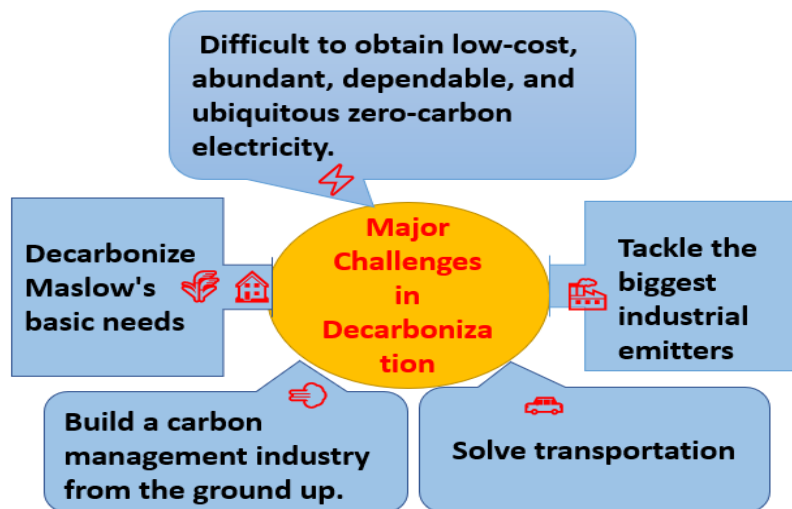
*centralized level has significant shortcomings, and environmental concerns drive a shift to decentralized energy. India is a developing country. Renewable energy power generation promotion is very important to create awareness among consumers and retailers. India's energy transition and decarbonization agenda aim to build a new clean energy system that is reliable, affordable, sustainable, and energy independent. The Indian government has taken several initiatives to increase domestic manufacturing capacity, particularly solar Photovoltaic (PV), Electric Vehicles (EV), and batteries. This paper aims to present significant achievements through different RE schemes, consider projections, and analyse India's ambition of net zero through the current policy concerning the decentralized use of renewable technologies prospects.*

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## **1. Introduction**

The electricity demand of a nation reflects its social conditions, the pace of economic growth, geographical variations, and the demography of the population at large. Electrical energy consumption rises year after year as people become wealthier and populations grow. Electrical energy generation and distribution are of vital importance. Currently, the majority of power generation, transmission, and distribution in India is through a centralised system. Centralized power means few power plants produce most of the power we use. Most of this power is generated in centralised locations and then sent via the power grid to homes and businesses. When transmission and distribution are centralized, the losses are high, so to reduce the losses and maximise the utilisation of renewable energy, a decentralised system is required. Decentralized energy is electricity that is generated not on the main grid but near where it will be utilized, instead of at a large plant elsewhere and sent through the national grid. The rapidly rising levels of global energy consumption are prompting increasing concern about the depletion of natural resources and the growing effects of environmental pollution, such as ozone depletion, climate change, and global warming. As economic stability and population growth increase, nations contribute to greater global energy consumption (Hassanein et al., 2019, Saleh et al., 2021, Momete, 2018, UNNATEE, 2019, CEA India, 2020).

Decarbonization is key to combatting global warming. It is the process of reducing or eliminating greenhouse gas (GHG) emissions by phasing out fossil fuels and moving to renewable energy sources such as the sun, wind, and geothermal heat. Developing decentralized renewable energy systems is critical for the global decarbonization of energy generation. Figure 1 lists the major challenges for decarbonizing.



**Figure 1.** Major challenges in decarbonization

India's long-term vision of decarbonizing its economy and reaching net zero by 2070 requires a holistic approach to integrating sustainable solutions at various levels (Shankar et al., 2022, Sheoran et al., 2022a). These changes also challenge traditional electricity demands and, thereby, the tariffs that must be revised to architect an effective policy in developing nations like India. The nation must significantly reduce emissions to accomplish its net-zero targets. This is because 2070 is less than 50 years away, and there are numerous uncertainties regarding developing new technologies and financing schemes for sustainable development (Sheoran et al., 2022b, Chopda et al., 2021). The government must take several crucial initiatives to solve the net zero equation. Companies too must enter the net zero space quickly. Five industries, including power (which accounts for more

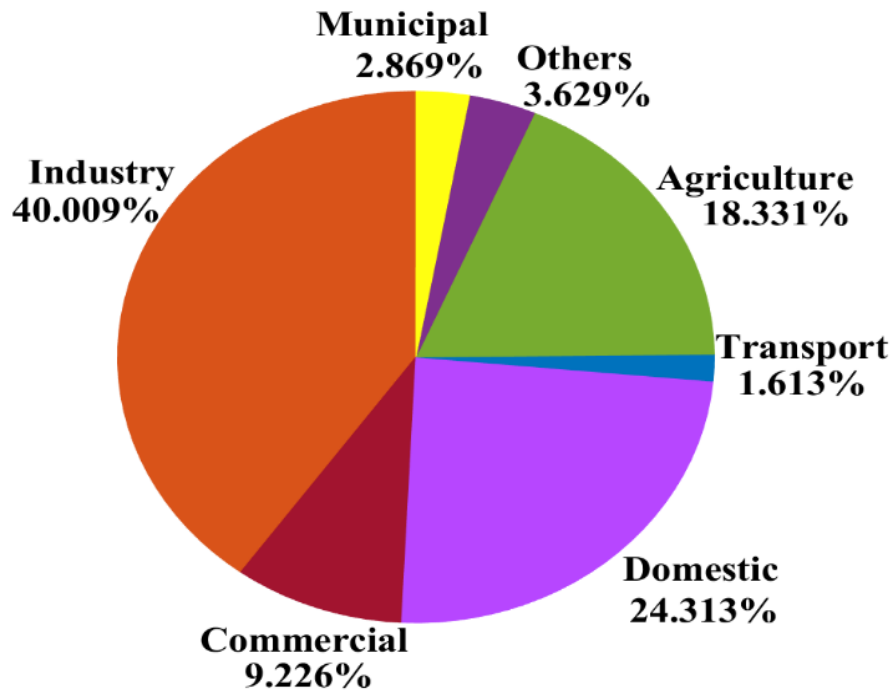
than 40%), iron and steel, cement, transportation, and agricultural, are responsible for most of our emissions. Other sectors, including those in refining and chemicals, come after these. These sectors will require significant expenditure to meet our net zero targets over the coming years. India's energy sector is evolving quickly, supported by decarbonization, with 50% RE capacity by 2030, decentralization by moving from centralized to distributed generation, democratization giving customers economic choice, digitization through use of technology to optimize grid power consumption and captive power consumption and its role in future demand requirements.

The role of on-grid and captive power consumption is in helping to advance the Nation's Energy System (NES). The most common type of solar PV system is on-grid, also known as utility-interactive. Grid-tied systems are linked to the electrical grid and allow building residents to use solar energy and grid electricity. Grid-connected systems do not have to meet a home's or business's electricity demand. When there is no demand for energy, the solar panels discharge excess energy into the grid for use elsewhere. A captive power plant is a facility that provides an energy user with a localized source of power. These are usually industrial plants, large offices, or data centres. The plants can operate in grid parallel mode and export excess power to the local power distribution network. They may also be able to operate in island mode, that is, outside of the local electricity network.

Figure 2 shows sector demand for electricity consumption. Renewable energy sources are most important for any country's development, and the advantages of renewable energy are numerous and affect the economy, environment, national security, and human health. This paper analyses discussions around the current policy concerning the decentralised use of renewable technologies, their prospects, and the policy push.

## **2. Policies in place and their progress**

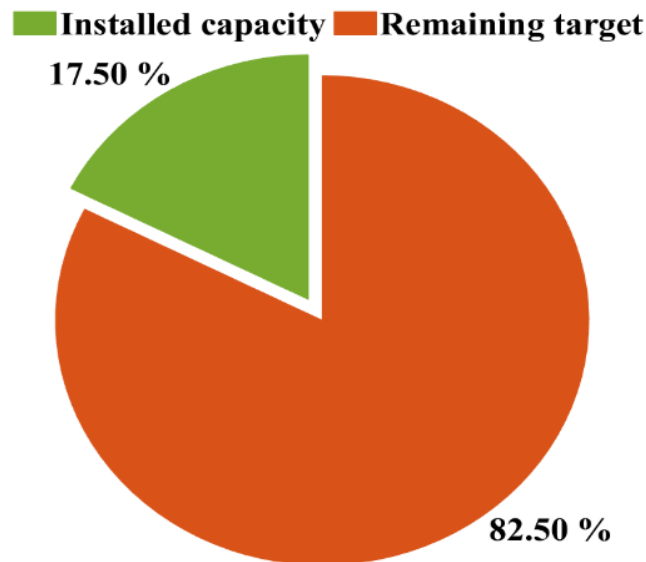
Conventional energy sources, such as oil, coal, and natural gas, are highly effective in driving economic growth, but they are harmful to both the environment and human health. Alternative energy sources have the potential to mitigate these risks. The potential of renewable energy sources is enormous, since they have the potential to meet many times the world's energy demands. Renewable energy sources such as biomass, wind, solar, hydropower, and geothermal can provide sustainable energy services using routinely available indigenous resources. A transition to a renewables-intensive energy future is con-



**Figure 2.** Sectoral demand for electricity consumption (UNNATEE, 2019).

sidered as increasingly likely (Shankar et al., 2022, Sheoran et al., 2022a, Sheoran et al., 2022b, Chopda et al., 2021).

The Indian government has set out an ambitious target of achieving a RE capacity of 175 Gigawatts (GW) by 2022 and 500 GW by 2030 to boost the Indian energy infrastructure and decarbonize the environment. Furthermore, the country is committed to fulfilling 50% of its energy requirement through Renewable Energy System (RES) by 2030. Several RE-based grid-connected and off-grid projects have been enabled by a range of union and state-level policies to facilitate energy transition goals and combat global climate change in a decentralized fashion. Figure 3 shows the progress in the grid-connected solar rooftop program. This section examines the existing policies of RE addition in various sections of the economy and their progress.



**Figure 3.** Progress on grid-connected solar rooftop program (Murthy, 2022, pv-roof, 2021).

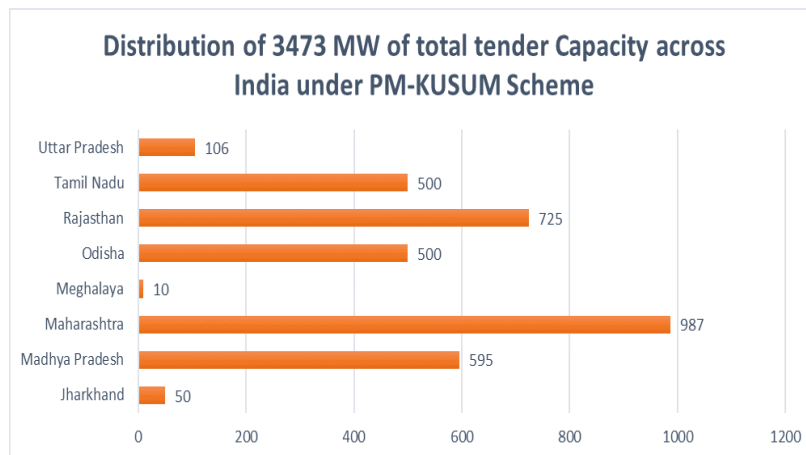
### 2.1 Residential Sector

A grid-connected rooftop PV program has been launched to decarbonize the building sector and achieve a cumulative capacity of 40 GW by 2022 through a project conducted with the Central Financial Assistantship (CFA) (Solar Rooftop, n.d., Adithya, 2016). The regulation of net metering has also been approved for this scheme by the government so that customers can earn extra credits when they generate more surplus energy than they need. As of December 2021, 7 GW of rooftop solar PV modules have been installed under the umbrella of this program (Murthy, 2022, pv-roof, 2021). The government had planned to invest 756 billion rupees through Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) to enable the much-awaited reforms of electrifying rural India. With this scheme, the government has approved the electrification of an additional 11.83 lakhs connections, including 1.35 lakhs connections through solar PV-based standalone systems. A Central Public Sector Undertaking (CPSU) scheme Phase-II has been designed to set up a 12000 MW grid-connected solar PV project by the government producers with Viability Gap Funding (VGF) support for self-use or use by the government entities through Distribution Companies (DISCOMS) or directly. The government has extended a VGF of up to 70 lakhs/MW on the CPSU scheme to the eligible organization for this project. To

electrify every household in this country, the saubhagya yojna project was launched in September 2017. As of 31 March 2021, as many as 2.817 crore houses had been electrified through saubhagya yojana including 4.16 lakh households through solar PV-based standalone systems.

## 2.2 Agriculture/Farming Sector

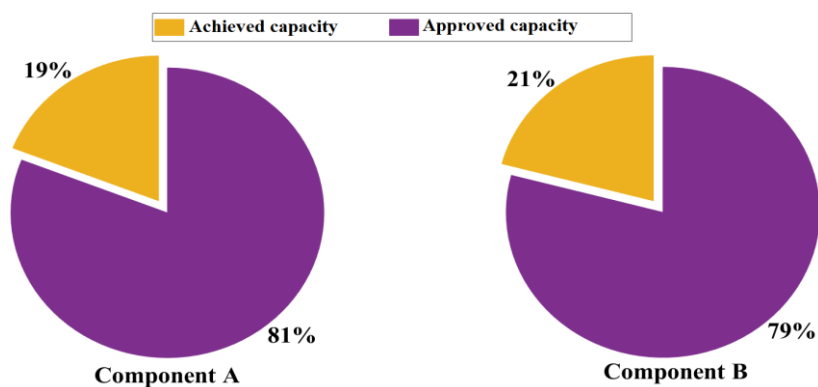
To decarbonize the farming sector, the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) scheme was launched with a target of adding RE capacity of 25750 MW by 2022 with a CFA of 34,422 crores. Pan India tender capacity under the PM KUSUM scheme shown in Figure 4 reflects that 3473 Megawatts (MW) of solar capacity is distributed among the states. As of December 2021, the solar PV modules with a total capacity of 4909 MW have been approved through component A of this scheme. A total of 3.59 lakh standalone solar pumps are provided for under component B, out of which more than 75000 pumps have been installed. In addition to components A and B, more than 9 lakh existing water irrigation pumps are planned to be solarized through component C of this scheme. The progress of the PM-KUSUM scheme shown in Figure 5 indicates that its execution needs to be increased to decarbonize the agriculture sector.



**Figure 4.** Progress on PM-KUSUM scheme (Vasudha\_power, 2022)

The “Development of Solar Parks and Ultra-Mega Solar Power Projects” initiative was launched in December 2014 to make it easier for solar project

developers to set up projects using a plug-and-play paradigm. Through this scheme, the Ministry of New & Renewable Energy (MNRE) has approved setting up 25 solar parks targeting over 40000 MW. The MNRE provides a CFA of 25 lakh per solar park for the composition of a Detailed Project Report (DPR) and an additional CFA of 20 lakh/MW, including grid connectivity cost. Off-grid and decentralized solar PV applications program Phase III was launched by the MNRE to set up an additional off-grid solar capacity of 118 Megawatts plant (MWp) by 2021 through 2.500.000 solar study lamps, 300.000 solar street lights, and 100 MWp of off-grid solar power plants. Furthermore, the electrification of several public institutions in rural regions, including health centres, anganwadis, offices, schools, panchayats, railways, and bus stations, is also planned through this scheme. As of 31 Dec 2021, 216.88 MW of RE installation has been completed through this scheme in various applications. In addition to the above-mentioned schemes, several other schemes such as “AICTE Training And Learning (ATAL) Jyoti yojana,” “scale up of access of clean energy for rural productive uses,” and “seven million solar study lamp scheme for school-attending children,” and others, have been launched by central and state governments in a decentralized fashion to decarbonize the environment.



**Figure 5.** Progress on PM-KUSUM scheme (Vasudha\_power, 2022).

### 2.3. Future key areas enabling decentralized RE addition: progress and future scope

#### 2.3.1. Agriculture



Being one of the most important sectors of the Indian economy, agriculture consumes 20-22% of the entire electricity demand, which accounts for 240 terawatt hours (TWh) annually. Furthermore, this sector is expected to demand 300-330 TWh of electrical energy by 2030 (IEA, 2021). Managing the agricultural load is increasingly becoming a challenge for electrical utilities. In the light of this, the government has launched the PM-KUSUM scheme to decarbonize the agriculture sector and supply clean energy using decentralized RES. With a growing scattered electricity demand, this sector provides a greater potential to enable decentralized RE addition and is expected to need 172-188 GW of solar PV deployment to fulfil its electricity demand. Solarizing the irrigation sector by enabling decentralized RE addition also holds great potential for reducing the Transmission and Distribution (T&D) losses to a considerable extent.

### 2.3.2. Commercial/Residential

In 2018, the urban population comprised 55% of the world population and is likely to cross 65% by 2050 (Hassanein et al., 2019, Saleh et al., 2021, Momete, 2018), resulting in an expected rise in the global energy demand by 52% from 2018 to 2040 (IEA\_US, 2018). India is expected to add a built area of 35 billion m<sup>2</sup> by 2050 (Shankar et al., 2021b), which would demand extra energy to cater for its needs. Currently, buildings account for 30-40% of the total energy demand of the globe and are expected to grow by an average of 8% per year for developing nations like India (Shankar et al., 2020). Supplying electricity to widely scattered buildings from remotely located energy centres adds T&D losses, which have been recorded as 20.66% at the national level (R\_CEA). Therefore, satisfying the required energy demand of the buildings by employing on-site environmentally friendly RES is key to turning an energy-hungry building into a Zero-Energy Building (ZEB). Moreover, decentralized RES is the most likely factor that can contribute to reducing T&D losses significantly.

India has a remarkable potential of 1.7 petawatt hours per annum through rooftop solar PV installation against India's existing electricity demand of 1.3 petawatt hour per year (R\_IEA, USAID, Shrestha et al., 2019, Bukya, et. al., 2019). In 2015 the Indian government set an ambitious target of achieving 175 GW of grid-connected RE capacity by March 2022. The national target for rooftop PV installation was fixed at 40 GW (IEA, 2022, Bhanja, & Roychowdhury, 2021). However, the installed rooftop capacity up to Q3 of 2021 was recorded as 6.7 GW (R\_rooftop, 2021, Anupama Khare Saxena et., al 2020). Therefore, the deployment of rooftop PV needs to be increased to realize the

concept of ZEBs and to reach the mark of 40 GW of decentralized RE for decarbonizing the environment.

Rooftop PV modules often fall short of catering for the electricity demand of high-rise buildings in an urban environment, which is growing at a rate of 2.7% annually. Therefore, deploying PV on the vertical surface of the buildings becomes imperative for decentralized clean energy generation. Semi-transparent building integrated-photovoltaic (BIPV) modules placed at the facade of the high-rise buildings also allow daylight harvesting in the buildings that further reduce the electricity demand across artificial lighting systems and strengthens the energy efficiency (Shankar et al., 2021a). BIPV modules are less efficient than rooftop PV due to their sub-optimal placement and semi-transparent nature. However, they do not require any functional space in the building for their deployment in an urban environment. Therefore, the deployment of BIPV modules must be increased in urban environments to enable decentralized RE addition and enhanced energy efficiency.

### 2.3.3. Industry

The industrial sector in India consumes the largest share of electricity, which accounts for 40-42% of total electricity demand. As of 31 March 2021, the installed capacity of industry-owned captive power generation (above 1 MW) was recorded as 70000 MW, generating energy of 200000 GWh in the fiscal year 2020-21(IEA\_US, 2018). Coal-based power plants account for 64% of total installed capacity, followed by 20.27% for oil, 11.46% for natural gas, and 5% for RES. In addition to the 70000 MW of captive power generation capacity, diesel generators of 75000 MW (excluding sets of size below 100 kVA and above 1 MW) have also been installed in the country (Deisel\_gen, 2014). Furthermore, catering for emergency energy needs during power outages, many diesel generators with a capacity of less than 100 kVA have also been installed, giving rise to a large amount of carbon emissions. Therefore, deploying decentralized RES is the most suitable option to cater to the industrial energy demand and decarbonize the environment.

### 2.3.4. Green Hydrogen

Low-carbon hydrogen has the potential to be a valuable source of clean energy in the fight against poor air quality and climate change. Generating green hydrogen on a large scale by utilizing electricity from the utility grid is unconstructive, expensive, and economically non-viable. However, utilizing captive power generation using RES in a decentralized fashion for generating

green hydrogen is a viable solution that decarbonizes the environment and reduces the growing burden from transmission and distribution systems. The National Hydrogen Mission launched by the Indian government aims to generate 5 million tonnes of green hydrogen by 2030. The policy promotes the utilization of RE as the basic ingredient in producing green hydrogen that will help meet the international commitments of clean energy and climate change.

### 2.3.5. *Mini-grid*

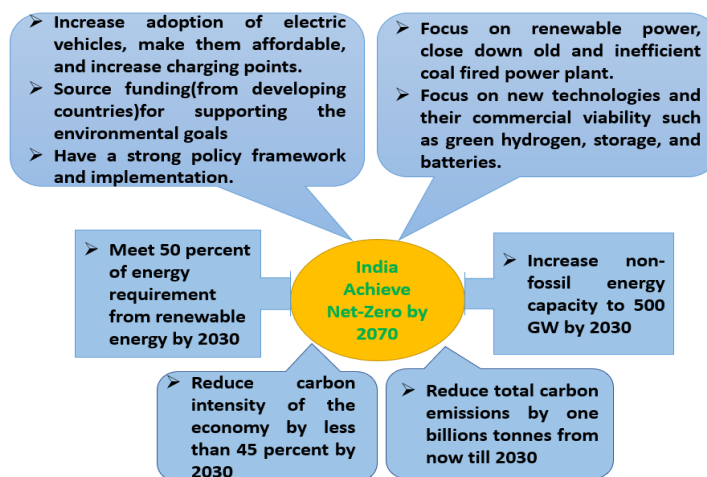
Decentralized RE sources such as mini-grids/microgrids offer a considerable opportunity for energy access in remote and unprivileged areas. The primary goal of rural electrification was to extend the central grid across the nation. However, the plan lacked serious efforts to promote productive uses and deliver an uninterrupted power supply. While the central grid remains the favoured source of electricity among the rural population, rural enterprises are taking up mini-grid as an additional source of electricity in the absence of electricity from the central grid. Mini-grids are successfully implemented in parts of India, Afghanistan, Nepal, and Tanzania as pilot projects (Shrestha et al., 2019, Bukya, et. al., 2019). Different RE technologies, such as solar, hydropower, biomass, wind, and energy storage systems are used by mini-grids in different ownership models varying from government, private, to non-profit organizations. Mini-grids have been popular in meeting basic needs such as lighting and irrigation due to affordability issues in the rural environment. However, with advancements in technology and decreasing battery prices, mini-grids could be a potential candidate for delivering uninterrupted electricity to less privileged areas and decarbonizing the environment.

An example of mini-grids as an alternative way to electrify rural India is provided by the state of Bihar. Although India achieved 100% household electrification in 2019, 37% of rural households in Bihar still do not have access to dependable electricity. Mini-grids are viewed as stable alternate sources of power in the state, which has about 8% of the country's mini-grids. The state's program plans to build on this momentum by installing another 100MW of renewable-based mini-grids with a capacity of less than 500 kilowatts(KW). Husk Power and other private energy service companies (ESCOs) have led the way in the state. Tariffs of Husk Power are cost-reflective and do not include subsidies, allowing the developer and consumers to determine their tariffs. Despite the higher prices relative to centralized grids (now available where mini-grids operate), most customers are willing to pay the extra price for a reliable energy supply.

### 3. Discussion and required policy push

Achieving India's 2070 net zero goal while supporting strong economic growth is highly challenging. There are multiple paths to choose from renewable sources such as wind and solar, while these need to be complemented with other sources like gas and supported by storage systems. Therefore, policy measures on decarbonization must adhere to the parameters of reliability, affordability, and energy independence.

Thus far, we have presented the existing schemes and policies pertaining to the decentralized usage of RE technologies to meet international commitments on climate change and clean energy. However, implementing these schemes does not seem to meet the commitments to decarbonize the environment. Therefore, we add some recommendations for consideration in terms of the necessary action to achieve India's ambition of net zero. Figure 6 shows India's foreseen net zero achievements by 2070.



**Figure 6.** Net-Zero Plan Implementation (IEA\_2021).

#### 3.1 Accounting – registration

If it can be said that knowledge equals power, knowledge about power is immensely valuable for utilities. The registration of connections through smart meters provides a deep understanding of the consumer's energy profile, i.e., when, how, and where energy is consumed across the network. Utilities can

utilize the historical data of energy consumption in power procurement cost, future energy planning, power quality monitoring, thereby avoiding revenue losses due to power quality events, and avoiding blackouts. Further, Discoms can use historical energy consumption data to implement the time of the day (ToD) tariff to incentivize changes in demand patterns. In addition to registering customers, utilities should improve their billing and collection efficiency through enhanced metering. They should fully use the restructured central government reform strategy to accomplish 100% metering with prepaid/smart meters while also being wary of cybersecurity dangers.

### *3.2 Subsidies/Tariff relief/financial schemes (CFA)*

The central and state governments provide subsidies for schemes like solar rooftops, PM-KUSUM, etc., for decentralized RE addition. However, the higher initial investment in such projects discourages a huge portion of the population from opting for such schemes. Therefore, the agencies must extend incentives to the customers through subsidies/tariff relief/financial assistantship to tempt them.

### *3.3. Open access*

The schemes on decentralized RE must be free from red tape and customer friendly. In addition, the schemes should be open access in the market with the help of private players with straightforward processes.

### *3.3. Target based governance*

Poor implementation of projects often results in falling short of reaching the stipulated targets. The number of approved and installed capacities in projects like PM-KUSUM indicates a lethargic implementation process that detrimentally affects the fight against climate change. Therefore, target-based governance is recommended for completing the projects within the designed time interval.

## **4. Conclusion**

India has been actively promoting renewable energy in a decentralised fashion, electrifying transportation systems, and improving energy efficiency in the wake of attaining the ambitious net zero emissions target by 2070. This paper considers an overview of the most innovative developments in relation to power system developments and trends. In particular, decarbonization and decentralisation are the main drivers of big transformations, and we have discussed the Indian

government's schemes, policies in place, and their progress in detail. According to our study's findings, for India to achieve net zero emissions by 2070, it must maximise renewable energy output and storage solutions, including carbon capture technologies for coal, the country's primary energy source. There is a need to promote and frame new policies for green energy through demand-side incentives and policies to reduce costs, notably through production-linked incentives for renewable energy generation at the domestic and industrial levels. Further research will have a significant role to play in facilitating these developments.

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