REVIEW OF SOLAR PV POLICY INCENTIVES AND REGULATIONS RELATED TO METERING AND BILLING OF GRID-CONNECTED ROOFTOP PV SYSTEMS IN INDIAN STATES

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Abstract

The share of rooftop photovoltaic (PV) capacity in India to total PV capacity has been marginal as the rooftop PV sector is falling short of its targeted capacity of 40 GW. This paper reviews solar PV policy incentives and contemporary regulations related to the metering and billing of grid-connected rooftop PV systems in Indian states and Union Territories (UTs) to understand their historical trend and present status. The policy incentive's deployment order and its effect on the PV capacity addition are presented using the National Renewable Energy Laboratory's (NREL) policy stacking framework. The review of policy documents shows that the states with the highest PV capacity published more policies between 2002 and 2022 than their counterparts. The Indian states and UTs significantly used market-expansion incentives over market-creation incentives to develop the domestic PV market. The prevailing metering and billing-related regulations in states and UTs are reviewed to understand the regulatory landscape of the country's grid-connected rooftop PV systems. It is observed that the choice of metering and billing mechanism employed differs across states and UTs, with net metering being the most commonly adopted mechanism.

Keywords: rooftop solar, policy incentives, policy stacking framework, solar energy, net metering,

1. Introduction

In 2015, India had targeted to install 100 GW of solar photovoltaic (PV) capacity by 2022 under the Jawaharlal Nehru National Solar Mission (JNNSM), comprising 60 GW for ground-mounted large-scale PV and 40 GW from rooftop solar. (Press Information Bureau, 2015) As of August 2023, India installed 71.61 GW of total solar PV, of which ground-mounted large-scale installations comprise 53.8 GW. The grid-connected rooftop PV contributes 11.08 GW of capacity (MNRE, 2023). The Prime Minister of India announced installing 500 GW of non-fossil energy capacity by 2030 at the 26th Conference of Parties (COP26) in Glasgow in November 2021. (Press Information Bureau, 2021) A policy document on a national program on high-efficiency solar PV modules published by the Ministry of New and Renewable Energy (MNRE) indicates that up to 280 GW of solar capacity is required for the optimum energy mix by 2029-30. (Production Linked Incentive Scheme "National Programme on High Efficiency Solar PV Modules," 2021)

It is evident that the PV installations are falling short of their targeted capacity despite having the potential to play a significant role in meeting India's electricity demand. Over the years, the PV sector has created a skilled workforce, thriving installation businesses, and a working supply chain in the domestic market. In order to promote the deployment, the Indian government has been supporting the installation of PV generation systems through various schemes under JNNSM. In addition, states and Union Territories (UTs) adopted numerous policy incentives to promote the uptake of PV systems. Despite government efforts, the share of PV generation in total electricity generation has been marginal and necessitates significant growth in the future.

The present status of deployment and future targets make it imperative to review the PV policies and regulations in the country. This paper reviews solar PV policy incentives and contemporary regulations related to metering and billing of grid-connected rooftop PV systems in Indian states and UTs to understand their historical trend and present status. The study aims to understand the state-specific policy strategies and their relationship with PV deployment to

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enhance and coordinate the country's deployment efforts in the grid-connected rooftop PV segment.

2. Methodology

The state and UT-level PV policy documents and PV-related metering and billing regulations were obtained from government department websites, state electricity regulatory commissions, and joint electricity regulatory commissions. The 25 Indian states and five UTs published 66 policies from 2002 till 2022. Of the 66 policies, 33 were related to solar PV from 21 states, and 23 were related to nonconventional and renewable energy from 15 states. Five states, namely Jharkhand, Manipur, Punjab, Sikkim, and Uttar Pradesh, and a union territory of Jammu and Kashmir, published dedicated policies for rooftop solar systems. In addition, Gujarat and Madhya Pradesh published dedicated policies for small-scale distributed solar and decentralized solar, respectively. The other two policies target solar–wind hybrid projects.

The policy incentive's deployment order and its effect on the PV capacity addition were studied using the National Renewable Energy Laboratory's (NREL) policy stacking framework (Doris, 2012). The framework was applied to study the solar market development in different state contexts in the USA. (Steward et al., 2014) The framework states that the solar PV market must undergo three stages of development: market preparation, market creation, and market expansion, to achieve responsible market saturation. It demonstrates how policy incentives should be deployed by focusing on the optimal deployment sequence. A study performed to understand the effectiveness of policy incentives in the US states using the policy stacking framework indicated that market expansion policies will be more successful once the market preparation policies are in place. (Ryan et al., 2019) The application of the policy stacking framework and grouping of policy incentives based on stages for the present study is shown in Fig. 1.

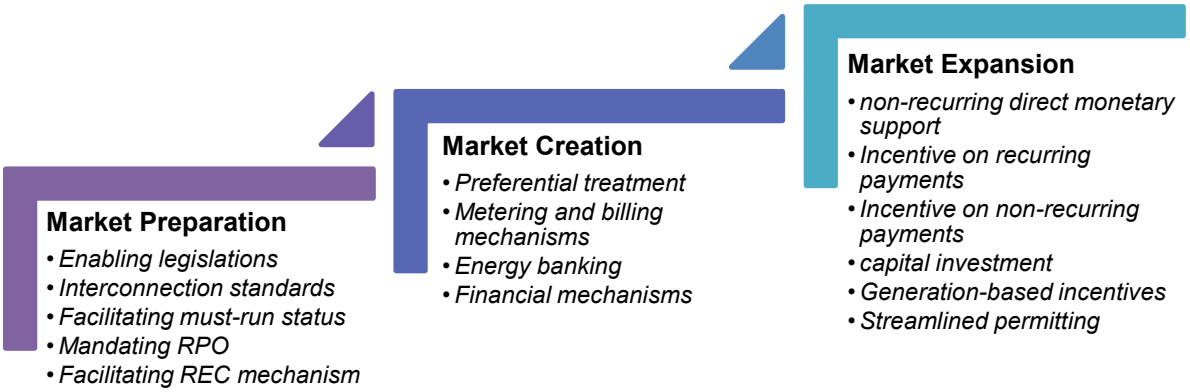


Figure 1 Application of policy stacking framework in Indian states and UTs (Author's work based on NREL's policy stacking framework)

The framework identifies incentives that remove legacy or institutional barriers to legally allow market players to use the technology as market preparation incentives. (Doris, 2012) The enabling legislation, interconnection standard, must-run status, Renewable Portfolio Obligation (RPO), and renewable energy certificate (REC) were labeled as market preparation incentives. The Electricity Act 2003 fulfills the requirement of market preparation incentives, as discussed in detail in the results section.

Market creation incentives are known as incentives that allow a motivated consumer to access the market and services and assure investors of long-term policy certainty without directly altering the project's economics. (Doris, 2012) The market creation incentives were grouped into preferential treatment (during grid access, project allotment, power dispatch, and land allocation), metering and billing mechanisms, energy banking, and financial mechanisms (interest subvention on loans).

A metering and billing mechanism facilitates the commercial settlement of the electricity bill the distribution utility raises to a prosumer with a grid-connected PV system. Five types of metering and billing mechanisms, namely net metering, group net metering, virtual net metering, net billing, and gross metering, were discussed in the present study. In the case of a net metering arrangement, solar units exported to the grid from a prosumer's grid-connected solar PV system are deducted from units (kWh) imported from the grid to arrive at the net imported or exported electricity. The net electricity import or export is billed, credited, or carried over by the distribution utility based on the applicable retail tariff (Tamil Nadu Electricity Regulatory Commission (Grid Interactive Solar PV Energy Generating Systems) Regulations, 2021). Group and virtual net metering are extended versions of net metering

arrangement, facilitating demand aggregation benefits. In group net metering, a prosumer can offset the import and export of units for multiple service connections against a single grid-connected PV plant. In virtual net metering, multiple prosumers can offset the import and export of units for their respective service connections against a single grid-connected PV plant (Delhi Electricity Regulatory Commission (Group Net Metering and Virtual Net Metering for Renewable Energy) Guidelines, 2019).

In net billing, the units imported by the prosumer from the grid and solar units exported are recorded independently at the interconnection point. The monetary value of units imported by the prosumer is calculated based on the retail tariff, and the monetary value of solar units exported is calculated using a feed-in tariff to arrive at the net billing amount. The criterion of offsetting the import and export of electricity differs in net metering and net billing. The units directly offset each other in net metering as their monetary value equals the applicable retail tariff. In net billing, offsetting is calculated based on the different monetary values of the imported and exported units.

In the case of gross metering arrangement, solar units (kWh) generated from a prosumer's grid-connected solar PV system and units (kWh) imported from the grid are measured. The monetary value of units imported by the prosumer is calculated based on the retail tariff, and the monetary value of solar units generated is calculated using a special tariff to arrive at the final billing amount.

Market expansion incentives target the development of individual projects by directly altering the project economics. (Doris, 2012) The market expansion incentives comprise non-recurring direct monetary support (grant/ capital subsidy/ viability gap funding), incentives on recurring payments (exemption/ deduction/ rebate/ credit/ abatement/ holiday/value-added tax), incentives on non-recurring payments (charge/ duty/ cess/ surcharge), capital investment, generation-based incentive, and streamlined permitting. The incentives were mapped over time to understand the state-specific policy strategies.

The regulatory landscape was examined with the help of 29 regulatory documents related to grid-interactive rooftop solar PV systems. The observations pertaining to the acceptance of metering and billing mechanism, permissible system size per consumer connection, and limit on utilization of distribution transformer capacity to integrate rooftop PV systems on the Low Tension (LT) side are discussed in the subsequent section with the help of maps.

3. Results

India's electricity sector is governed by the Electricity Act of 2003, which sets the foundation for the rules and regulations related to generation, transmission, distribution, trading, and electricity use. Section 9(2) of the Electricity Act 2003 empowers an individual or agency to set up a captive power generation plant and facilitates access to transmission facilities. Section 61(h) and section 86(1)(e) of the act entrust electricity regulatory commissions to promote cogeneration and generation of electricity from renewable energy sources. Section 86(1)(e) further suggests to adopt mechanisms such as renewable purchase obligation. Section 3(1) of the act directs the central government to prepare national electricity policy and tariff policy in consultation with state governments and the central electricity authority. (The Electricity Act, 2003) The act legislated fundamental prerequisites for completing the market preparation stage by removing the legacy barriers related to the uptake of solar PV systems.

The patterns in the use of policy incentives were assessed by splitting policies into three time periods: policies published before 2010 (before the announcement of Jawaharlal Nehru National Solar Mission), policies published between 2010 and 2015 (before the announcement of revised targets under the mission), and policies published after 2015 (after the announcement of revised targets under the mission).

Before 2010, nine states published policies promoting the use of renewable energy sources, whereas only one state published a policy promoting solar PV as an electricity source. Gujarat was the first Indian state to publish a dedicated policy for solar PV in 2009. (Gujarat Solar Power Policy 2009, 2009) With the announcement of the Jawaharlal Nehru National Solar Mission in 2010, fourteen more states published independent PV policy documents by 2015. Four states and two UTs announced dedicated policies for solar PV between 2016 and 2022.

The adoption of market-creation and market-expansion incentives in Indian states and union territories between 2002 and 2022 is shown in Fig. 2 and Fig.3, respectively. States and UTs are arranged in decreasing order of cumulative PV capacity as of August 2023. According to the data from the Ministry of New and Renewable Energy, Rajasthan installed the highest PV capacity, whereas Nagaland has the least capacity addition as of August 2023. (MNRE, 2023) It is evident from the graphs that the state with the most PV installations announced more PV incentives than that of the other states. The states with significant PV capacity were typically characterized by higher geographical areas and published more dedicated policies than their counterparts.

The number of state/UT policies published between 2002 and 2022 throws light on their outlook toward PV technology. The average number of policies published by the states with a geographical area above the national mean value was around 3, whereas the average number of policies published by the rest of the states and UTs was 1.4. The States with larger geographical areas envisaged PV as a potential solution for diversifying their energy needs. It was noted that states like Uttarakhand, Punjab, Haryana, Kerala, and UT of Delhi ranked better in terms of PV deployment despite having a geographical area below the national mean.

Among the ten states with the highest PV deployment as of 2023, Gujarat, Karnataka, and Punjab published their first policy before 2010. The policy document analysis indicated that two of the three states allowed a reduction in contract demand for consumers installing PV systems and provided a single window facility for project approval. The rest of the states and UTs published dedicated PV policies by 2015, except Maharashtra and Punjab, which announced PV incentives through renewable energy policies.

States with the highest PV capacity increasingly extended the benefits of state-level industrial policy to solar PV projects after 2010. Moreover, the exemption from paying electricity duty and relaxing the requirement of environmental clearance was widely mentioned in the policy documents of leading states. In addition, four out of ten leading states provided single window clearance facilities and authorized the use of government wasteland for PV projects. Many states and UTs revised their policies after 2015 as the capacity addition target of the Jawaharlal Nehru National Solar Mission, renamed National Solar Mission, increased from 20 GW to 100 GW. In addition to extending the benefits of state industrial policy, leading states exempted PV projects from paying the wheeling and transmission charges and cross-subsidy surcharge, and facilitated the banking of surplus energy into the grid.

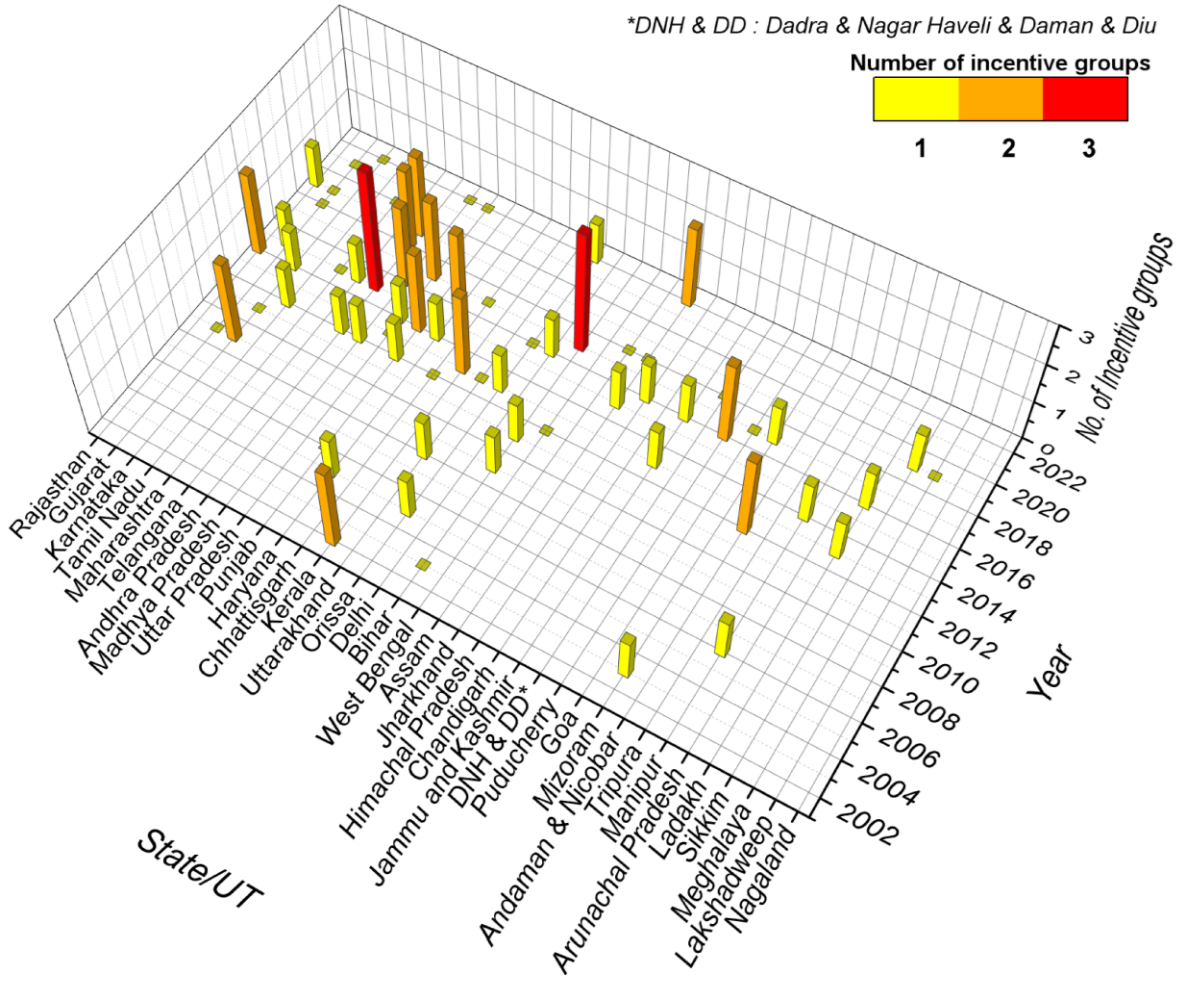


Fig. 2 Adoption of market-creation incentives in Indian states and UTs (Author's work based on the data from respective state/UT's policy documents)

The Indian states and UTs significantly used market-expansion incentives over market-creation incentives to develop the domestic PV market. Streamlined permitting and incentives on recurring and non-recurring payments were the most used market expansion incentives. Streamlined permitting comprises extending the benefits of state industrial policy, authorizing the use of government wasteland, relaxing the requirement of environmental clearance, relaxing the rules of using agricultural land to install PV systems, allowing a reduction in contract demand to consumers

installing PV systems, and providing single window clearance facility. The incentives on recurring payments include exemption from paying electricity duty, wheeling and transmission charge, cross subsidy surcharge, and electricity cess. The incentives on non-recurring payments include an exemption from entry tax, a refund of stamp duty, and a refund of the value-added tax (VAT). The widely used market-creation incentives include facilitating the banking of surplus energy and providing access to various metering and billing mechanisms.

Our analysis of Policy documents reveals that financing mechanisms (such as interest subvention on loans) and announcing preferential treatment to PV projects were the least-used market-creation incentives. The incentives related to preferential treatment include preference during offtake of power if a manufacturer develops a power plant within the state, preference for renewable energy-based manufacturing industry within the state in existing and upcoming special economic zones and industrial parks, priority to a PV manufacturer during a government land allotment process, and price preference for setting up the plant within the state in competitive bidding. The least used market-expansion incentives were generation-based incentives, capital investment by the state government and UTs, and extending non-recurring direct monetary support (such as additional capital subsidy from the state/UT). While the use of generation-based incentives was limited, the states and UTs implemented net and gross metering mechanisms. The central government extended non-recurring direct monetary support (such as viability gap funding, grants, and capital subsidy) through various schemes under the National Solar Mission.

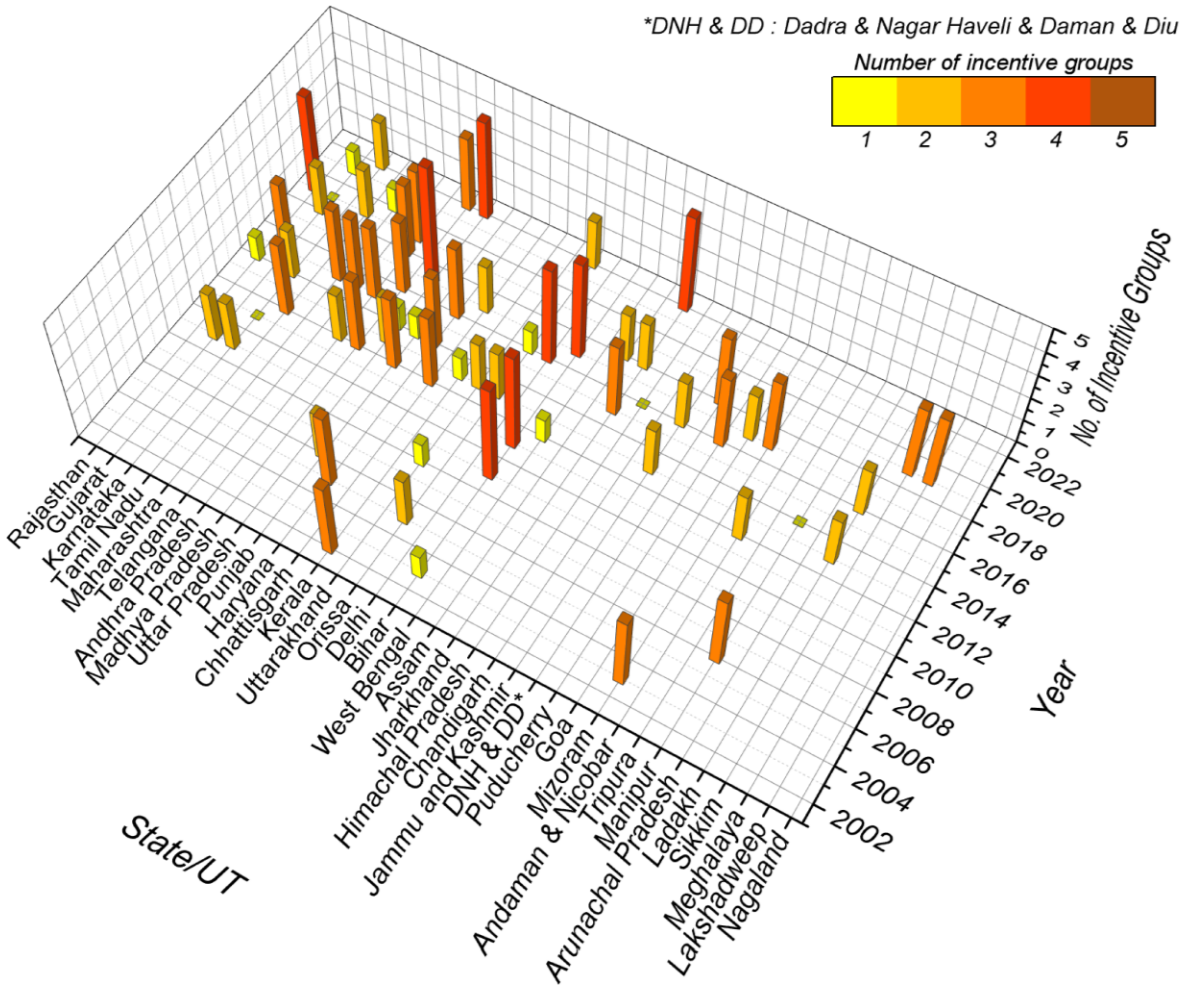


Fig. 3 Adoption of market-expansion incentives in Indian states and union territories (Author's work based on the data from respective state/UT's policy documents)

Indian states and UTs use metering and billing mechanisms such as net metering, net billing, and gross metering as critical public policy tools to increase the uptake of grid-connected rooftop PV systems. The acceptance of metering and billing mechanisms varied with the state. Fig. 4 shows the adoption of metering and billing mechanisms in Indian states and union territories. Net metering was adopted nationwide, whereas gross metering was adopted in 16 states and two union territories. Three states and two UTs published regulations related to the net billing mechanism. Three states and seven UTs adopted virtual net metering and group net metering.

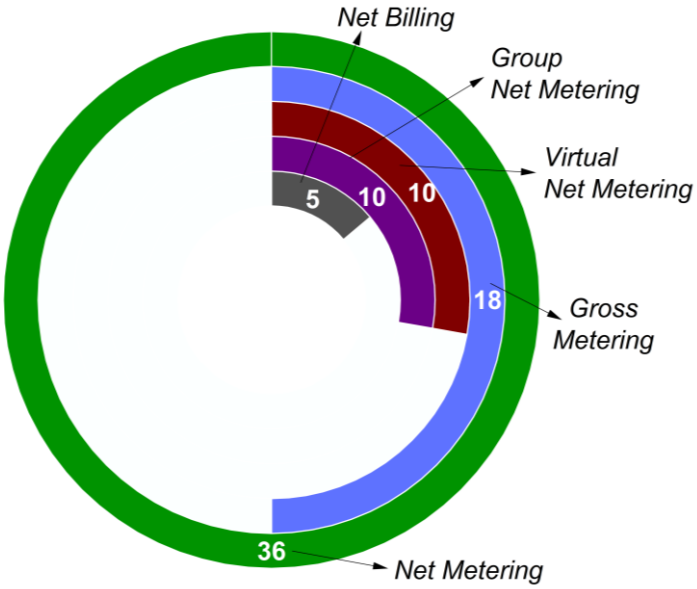
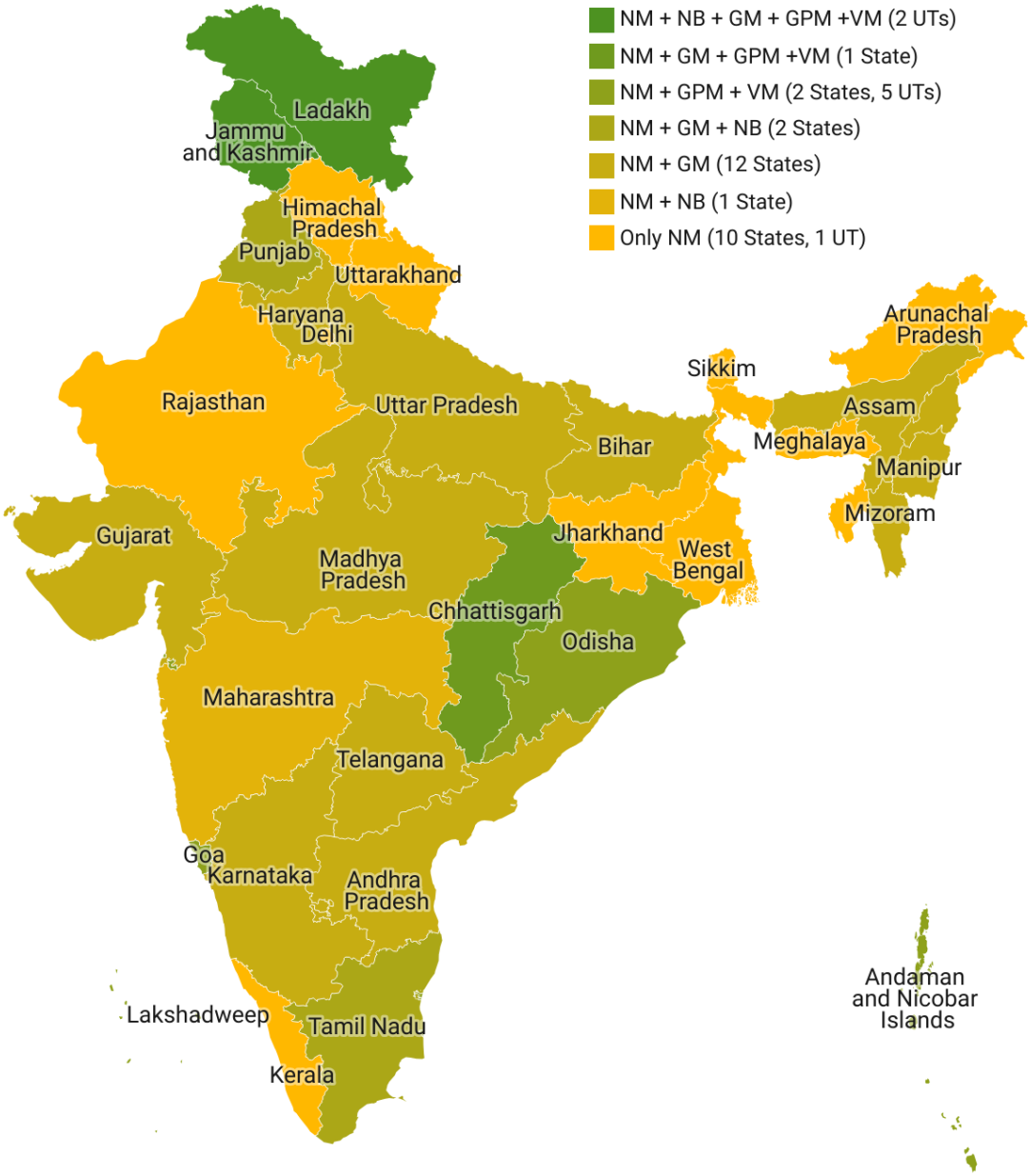


Fig. 4. Adoption of metering and billing mechanisms in Indian states and union territories (Author's work)

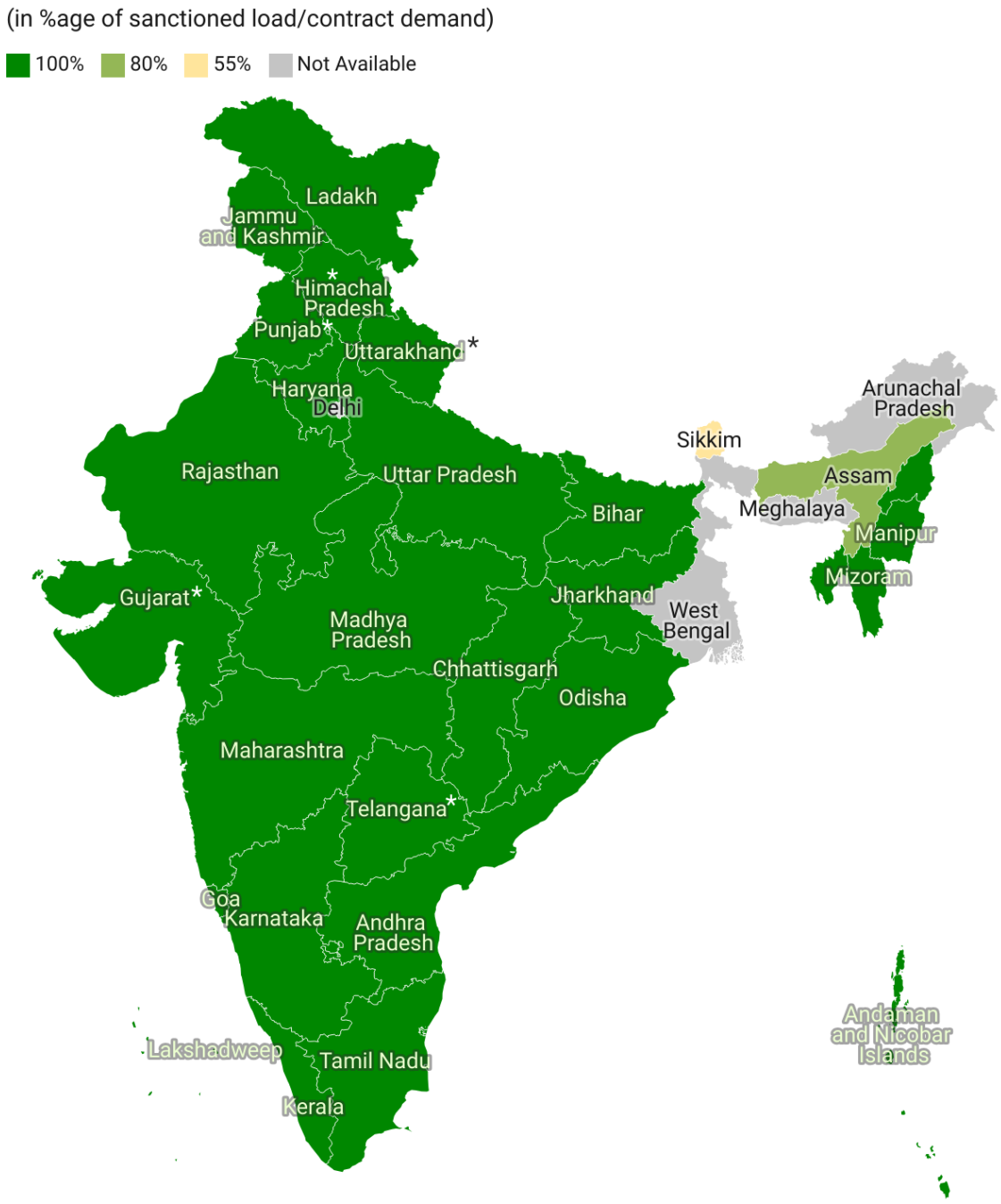
The acceptance of metering and billing mechanisms in Indian states and union territories as of August 2023, presented in Fig. 5, shows that the combination of net metering and gross metering was India's most widely used mechanism. The use of gross metering, in addition to net metering, has increased in the past five years. As of August 2023, 12 states published regulations allowing consumers to use net or gross metering for their grid-connected rooftop PV systems. Eight out of ten states that adopted only net metering mechanisms had cumulative rooftop PV installed capacity of less than 800 MW as of August 2023. The use of virtual net metering and group net metering increased after 2016. As of August 2023, three states and seven UTs adopted the regulation related to virtual net metering and group net metering. The adoption of virtual and group net metering regulations is anticipated to rise due to their demand aggregation benefits.



NM: Net Metering, NB: Net Billing, GM: Gross Metering, GPM: Group Metering, VM: Virtual Metering

Fig. 5. Acceptance of metering and billing mechanisms in Indian states and union territories (Author's work based on the data from respective SERC/JERC regulations on grid interactive rooftop PV systems)

Fig. 6 shows the limit on permissible system size per consumer connection in Indian states and union territories for residential net metering mechanisms. Most states and UTs granted permission to install a rooftop PV system having a capacity equal to the consumer's sanctioned load/contract demand. States like Gujarat and Uttarakhand adopted a liberal approach by imposing no limit for residential consumers. In the case of Gujarat, the provision of not capping the system size was further extended to Micro, Small, and Medium Enterprises (MSME) consumers and non-residential consumers with captive use.



NOTE:- Gujarat: Only for residential, MSME, and non-residential consumers with captive use | Himachal Pradesh: Up to 5kW of sanctioned load | Punjab, Telangana and Uttarakhand: Only for domestic consumers

Fig. 6. Limit on permissible system size per consumer connection in Indian states and union territories for residential net metering mechanism in % age of sanctioned load/contract demand (Author's work based on respective SERC/JERC regulations on grid interactive rooftop PV systems)

Fig 7 shows the limit on the hosting capacity of the distribution transformer (DT) in Indian states and union territories in terms of the percentage of DT capacity. The allocation of distribution transformer capacity exhibited significant interstate variation. Only six states and two UTs allowed 100% utilization of distribution transformer capacity to integrate rooftop PV systems on the LT side. Eight states and one UT prohibited consumers from installing more than 50% of the distribution transformer's hosting capacity, thereby limiting the penetration of rooftop PV systems in the distribution grid. The present scenario indicates the potential to improve provisions related to the hosting capacity and calls for further investigation.

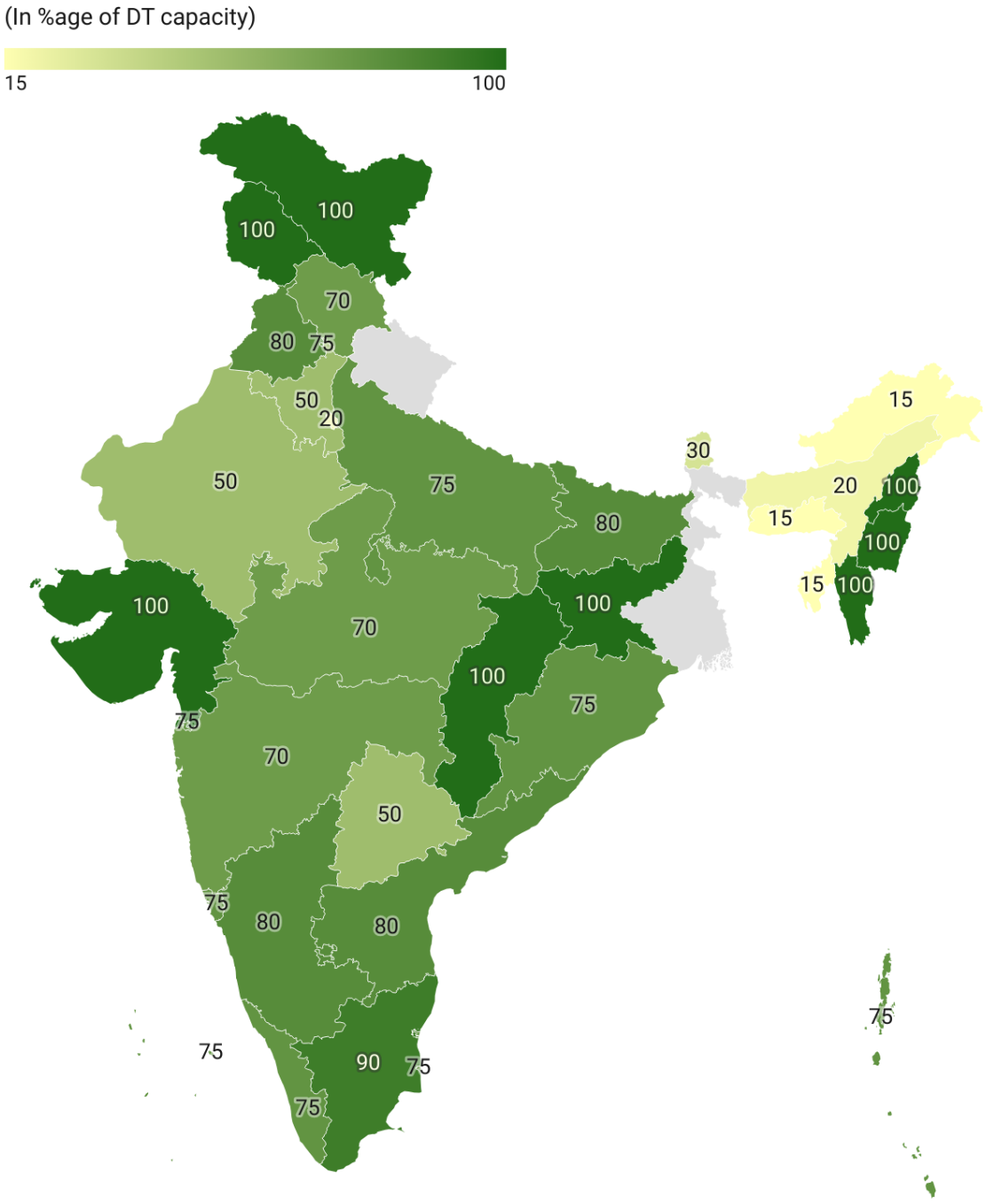


Fig. 7. Limit on hosting capacity of distribution transformer in Indian states and union territories in %age of DT capacity (Author's work based on the respective SERC/JERC regulations on grid interactive rooftop PV systems)

4. Conclusion

The solar PV policy incentives and contemporary regulations related to the metering and billing of grid-connected rooftop PV systems in Indian states and union territories are reviewed. The state-specific policy strategies and their relationship with PV deployment are presented to enhance and coordinate the country's efforts to accelerate the deployment. Applying policy stacking framework on data collected from 66 policy documents indicated that Indian states and UTs significantly used market-expansion incentives over market-creation incentives to develop the domestic PV market. The following are the noteworthy takeaways from the study:

- The states with significant PV capacity were typically characterized by higher geographical areas and published more policies than their counterparts.
- The state with the most PV installations announced more PV incentives than the other states.
- The least-used market-creation incentives were financing mechanisms (such as interest subvention on loans) and announcing preferential treatment to PV projects.

- The least-used market-expansion incentives were generation-based incentives, capital investment by the state government or UT, and provision of non-recurring direct monetary support (such as additional capital subsidy from the state/UT).

The central government used capital subsidy as a policy tool and offered non-recurring direct monetary support through grants, viability gap funding, and central finance assistance. The underutilization of these incentives by states and UTs indicates their commitment to avoiding redundancy in policy incentives.

The list of policy incentives offered by states and UTs with significant PV capacity is as follows;

- Before 2010: reduction in contract demand for consumers installing PV systems, and single window facility for project approval
- Between 2010 and 2015: exemption from paying electricity duty, and relaxing the requirement of environmental clearance
- After 2015: exemption for PV projects from paying the wheeling and transmission charge, cross-subsidy surcharge, and facility of banking of surplus energy into the grid

The study of 29 regulatory documents indicated that the number of metering and billing mechanisms offered by distribution utilities varied across states and UTs, highlighting the necessity of implementing additional mechanisms to expand the array of choices available to end consumers. The following are the noteworthy takeaways from the study;

- Net metering was adopted nationwide, whereas net and gross metering were the most widely used mechanisms by distribution utilities in India.
- Most states granted permission to install a rooftop PV system having a capacity equal to the consumer's sanctioned load/contract demand.
- The allocation of distribution transformer capacity exhibited significant interstate variation.

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