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Policy Paper

Advancing MNRE's Renewable Energy, Livelihood, and Climate Objectives








Leveraging Clean Energy for Billion Livelihoods (LaBL 2.0) for Decentralized Renewable Energy and Carbon Futures

MESSAGE FROM THE DIRECTOR GENERAL, TERI

India stands at a pivotal moment in its clean energy journey, where rapid technological progress must be matched by strong institutions and people-centric approaches. As the country advances toward its Nationally Determined Contributions (NDCs) and a resilient, inclusive energy future, decentralized renewable energy (DRE) solutions will be critical in generating livelihoods, strengthening rural entrepreneurship, and enhancing climate resilience in underserved regions.

For over four decades, TERI has advanced decentralized energy models that place communities at the centre of transition efforts. Initiatives such as Leveraging Clean Energy for Billion Livelihoods (LaBL 2.0) demonstrate that when renewable energy access is combined with capacity building, institutional strengthening, and livelihood integration, the impact extends beyond electrification. It enhances agency, promotes productive energy use, stimulates micro-enterprises, and supports climate-adaptive local economies. Technology alone does not deliver transformation—systems, partnerships, and enabling structures do.

The Ministry of New and Renewable Energy (MNRE) has led India's clean energy expansion through flagship programmes spanning rooftop solar, PM KUSUM, and the Model Solar Village Programme. These initiatives have expanded rural opportunities while improving energy security. Yet challenges remain in last-mile delivery, financing, community engagement, monitoring, and technology adoption.

Mission-oriented partnerships between government, civil society, technical institutions, and local ecosystems are therefore essential. TERI's LaBL programme, with its evidence-based approach and strong field presence, can complement MNRE's efforts by strengthening research, improving technology deployment, enhancing local capacities, and advancing climate outcomes through systematic carbon measurement.

This paper serves as both reflection and roadmap. It underscores the importance of integrated delivery systems, livelihood-linked energy access, context-sensitive design, and stronger institutional coordination. A just and inclusive transition requires communities not only to access clean energy, but to actively participate in and benefit from it.

As India progresses toward its clean energy and climate goals, TERI remains committed to supporting MNRE through rigorous research, field-tested models, and partnerships grounded in trust and long-term impact. The insights presented here aim to strengthen India's decentralized renewable energy ecosystem and advance scalable, sustainable implementation pathways.

MESSAGE FROM MINISTRY OF NEW AND RENEWABLE ENERGY (MNRE)

India's clean energy transition is among the most ambitious globally, guided by the principles of sustainability, energy justice, and inclusive growth. As renewable capacity expands and the decentralised energy ecosystem strengthens, the Ministry of New and Renewable Energy (MNRE) remains committed to solutions that advance national climate goals while transforming livelihoods, fostering entrepreneurship, and building resilient rural economies.

Decentralized renewable energy (DRE) plays a critical role in ensuring equitable access to clean power. Through flagship initiatives such as PM Surya Ghar: Muft Bijli Yojana, PM KUSUM, and the Model Solar Village Programme, MNRE has worked to extend renewable energy to the last mile, generating socio-economic benefits including livelihood diversification, enhanced agricultural productivity, and growth of rural enterprises.

At the same time, the scale and pace of expansion demand strong and adaptive implementation systems. Challenges in financing access, demand aggregation, technical quality, supply chain coordination, and local capacity building persist. Strengthening the delivery ecosystem therefore requires collaborative models that complement MNRE's institutional efforts with field-based expertise and technical innovation.

In this context, Leveraging Clean Energy for Billion Livelihoods (LaBL 2.0) presents significant potential as a strategic partner. With its rural footprint, experience in community-centred implementation, and strengths in research, enterprise development, and carbon measurement, LaBL can help reinforce MNRE's implementation, monitoring, and impact assessment architecture.

This policy paper outlines how structured partnerships can enhance the effectiveness and reach of MNRE's schemes. It highlights the importance of integrating livelihood outcomes into renewable planning, strengthening community-based delivery mechanisms, and aligning carbon accounting with India's broader climate strategy.

MNRE welcomes evidence-based approaches and collaborative partnerships that accelerate progress toward a cleaner, more inclusive, and resilient energy future. The insights presented here contribute meaningfully to strengthening India's decentralized renewable energy ecosystem and advancing our collective climate commitments.

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EXECUTIVE SUMMARY

India's clean energy transition has entered a transformative phase, with non-fossil fuel capacity exceeding 50 percent of installed electricity capacity ahead of the 2030 target under its Nationally Determined Contributions (NDCs). The Ministry of New and Renewable Energy (MNRE) has advanced this ambition through flagship schemes such as PM Surya Ghar: Muft Bijli Yojana, PM-KUSUM, the Model Solar Village Programme, and Atal Jyoti Yojana, embedding renewable energy within households, agriculture, and village infrastructure.

As capacity expands, the next phase requires stronger implementation ecosystems to ensure decentralized renewable energy (DRE) delivers sustained livelihood and resilience gains. Financial access barriers for small farmers, uneven last-mile service, technical quality concerns, skill gaps, and coordination frictions continue to affect inclusiveness and long-term performance. These constraints reflect ecosystem capacity rather than policy ambition.

This paper argues that mission-oriented platforms such as TERI's Leveraging Clean Energy for Billion Livelihoods (LaBL 2.0) can serve as catalytic intermediaries within MNRE's architecture. By integrating research, capacity building, enterprise incubation, blended finance, and localized deployment, LaBL strengthens last-mile delivery and aligns renewable energy expansion with livelihood enhancement and just transition objectives.

The paper further proposes integrating professionally managed Pay-Per-Use (PPU) models, drawing lessons from enterprises such as Oorja, within decentralized solar irrigation and rural enterprise frameworks. PPU shifts emphasis from asset ownership to service provision, lowers upfront costs, embeds maintenance incentives, and enables performance monitoring. Integrated within PM-KUSUM and district-level renewable clusters through viability gap support and outcome-linked disbursement, PPU models can enhance inclusion, fiscal efficiency, and system reliability.

Strengthening MNRE's implementation ecosystem through structured partnerships, service-based delivery innovations, data-driven monitoring, and cross-ministerial convergence will help shift India's transition from capacity addition toward outcome-oriented, livelihood-centered climate action.

Introduction

India stands at a critical juncture in its clean energy transition, balancing sustained economic growth with the need to address climate change, energy security, and environmental pressures. As a Party to the UNFCCC and signatory to the Paris Agreement, India has committed under its updated Nationally Determined Contributions (NDCs) to reduce the emissions intensity of GDP by 45 percent from 2005 levels and to achieve around 50 percent cumulative installed electric power capacity from non-fossil sources by 2030 (Government of India, 2022[1]). By 2020, emissions intensity had declined by 36 percent from 2005 levels, and non-fossil capacity reached 47.1 percent of total installed capacity by December 2024. In mid-2025, India crossed the 50 percent non-fossil capacity milestone, five years ahead of schedule with 242.78 GW out of 484.82 GW installed capacity[2]. These trends underscore the strength of India's institutional framework and sustained commitment to a diversified, low-carbon energy system.

Over the past decade, India's renewable energy sector has made significant structural gains. Falling solar photovoltaic costs, supportive policies, competitive bidding, and stronger institutional coordination have

[1] Government of India (2022). India's Updated First Nationally Determined Contribution under the Paris Agreement (2021–2030). UNFCCC submission. https://unfccc.int/sites/default/files/NDC/2022-08/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf

[2] Press Release:Press Information Bureau

positioned India among the world's largest renewable energy markets (IEA, 2023[3]). Solar energy has become central to the country's low-carbon growth strategy, driving large-scale deployment. Beyond emissions mitigation, renewable expansion has reduced reliance on imported fossil fuels, strengthening macroeconomic stability and energy security (Shakti Foundation, 2022[4]).

Within this broader climate strategy, the Ministry of New and Renewable Energy (MNRE) has translated national targets into large-scale programmes across utility-scale, distributed, and decentralized renewable energy segments. The National Solar Mission (2010) laid the foundation for rapid solar deployment through phased expansion. Subsequent flagship schemes such as PM-KUSUM, focused on agricultural de-dieselisation and feeder solarisation, and PM Surya Ghar: Muft Bijli Yojana, the world's largest rooftop solar initiative, have accelerated adoption across socio-economic groups and strengthened the distributed renewable ecosystem.

As of January 2026, MNRE reports 212 GW of renewable energy capacity (excluding large hydro) and 272 GW of total non-fossil capacity, reflecting a 225 percent increase over the past decade[5]. Evidence indicates that renewable investments generate employment multipliers and stimulate local value chains, particularly in installation and maintenance (IRENA, 2022[6]). Renewable energy policy in India therefore increasingly aligns with broader development priorities, including SDGs 7, 8, and 13.

A significant shift in India's energy policy is the growing emphasis on decentralized renewable energy (DRE) as a pathway linking climate and development goals. Although universal village electrification was achieved in 2018, reliable and affordable power for productive use remains uneven, particularly in rural and peri-urban areas (World Bank, 2021[7]). Decentralized solar solutions such as rooftop systems, solar pumps, mini-grids, and productive-use appliances provide localized and demand-responsive energy services. Evidence from CEEW shows that DRE technologies improve incomes, employment, and resource efficiency, especially for women and micro-entrepreneurs[8]. These findings position DRE as a development accelerator that aligns climate mitigation with inclusive economic growth.

Despite technological maturity and policy support, large-scale and inclusive deployment of decentralized renewable energy continues to face implementation constraints. Renewable transitions are socio-technical processes requiring coordinated institutional ecosystems (Geels, 2002[9]). In India, barriers include limited user awareness, high upfront costs, weak last-mile financing, technical skill gaps, after-sales service deficiencies, and fragmented coordination among central and state agencies and DISCOMs. These challenges are especially acute in productive-use applications, where adoption depends on risk perceptions, income stability, and credit access. The International Energy Agency's draft policy framework for DRE livelihood applications highlights the need for market-oriented ecosystems, targeted financing, standardized quality protocols, and strong monitoring and evaluation to ensure long-term performance and equity[10].

In this context, civil society organizations, social enterprises, and ecosystem platforms serve as critical intermediaries. By reducing transaction costs, mobilizing blended finance (including CSR and philanthropic

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3 International Energy Agency (IEA). (2023). India energy outlook 2023. IEA.

4 Shakti Sustainable Energy Foundation. (2022). India's clean energy transition: Macroeconomic and energy security implications. New Delhi.

5 Physical Achievements | MINISTRY OF NEW AND RENEWABLE ENERGY | India

6 International Renewable Energy Agency (IRENA). (2022). Renewable energy and jobs: Annual review 2022. IRENA.

7 World Bank. (2021). Tracking SDG7: The energy progress report 2021. World Bank, IEA, IRENA, UNSD, WHO.

8 How Decentralised Renewable Energy Technologies Impact Livelihoods

9 Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case study. Research Policy, 31(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

10 Draft Policy Framework for developing and promoting Decentralized Renewable Energy (DRE) Livelihood Application – Policies - IEA

resources), providing technical support, and strengthening community engagement, they bridge gaps between policy and implementation (Koh, Karamchandani & Katz, 2012[11]). Integrating renewable energy with livelihood development and enterprise incubation aligns climate objectives with rural economic growth.

The Energy and Resources Institute (TERI), through its Leveraging Clean Energy for Billion Livelihoods (LaBL 2.0) initiative, exemplifies this mission-oriented approach. LaBL deploys solar solutions for entrepreneurs, artisans, and rural enterprises, leveraging CSR and grant-based funding to lower entry barriers and build local operational capacity. TERI and MNRE's 2026 strategic workshop recognized LaBL 2.0 as a partner platform aligned with national priorities such as PM-KUSUM and the Model Solar Village Programme, underscoring its role in strengthening last-mile delivery and enhancing the socio-economic returns of decentralized renewable energy[12].

This policy paper situates mission-oriented platforms within India's renewable energy governance architecture and argues that strengthening MNRE's delivery ecosystem through structured partnerships with civil society–led implementation platforms can accelerate decentralized renewable energy deployment, enhance livelihood outcomes, and advance national climate and development objectives. Specifically, it (i) examines MNRE's flagship schemes and their interface with decentralized deployment; (ii) identifies key institutional and financial constraints affecting productive-use applications; and (iii) assesses how ecosystem-based delivery models can complement public policy frameworks.

By foregrounding implementation ecosystems and collaborative governance, the paper shifts the focus from capacity addition toward outcome-oriented renewable energy deployment. Integrating livelihood-centric approaches within MNRE's framework can deepen climate mitigation impacts, improve rural incomes, and strengthen community resilience, positioning India's clean energy transition as a model of inclusive, development-aligned climate action.

MNRE's flagship schemes and their contribution to national goals

India's renewable energy transition has evolved from a capacity-expansion strategy to a development-oriented agenda. Under MNRE's leadership, flagship schemes now integrate climate mitigation, energy access, livelihood generation, and decentralized economic growth. Together, they advance four interlinked objectives: (i) achieving India's NDCs under the Paris Agreement, (ii) strengthening energy security, (iii) enhancing rural incomes and local enterprise development, and (iv) promoting inclusive green growth aligned with SDGs 7, 8, and 13.

PM Surya Ghar: Muft Bijli Yojana

Launched in February 2024, PM Surya Ghar: Muft Bijli Yojana (PMSG–MBY) is among the world's largest household-level distributed solar initiatives. With an outlay of ₹75,021 crore and a target of 1 crore households by 2027, the scheme aims to add around 40 GW of rooftop solar capacity[13].

Combining capital subsidies (up to 60% for systems up to 2 kW), concessional financing, and a unified digital portal for approvals and disbursement, the scheme has streamlined deployment. By early 2026, it had reached an estimated 24–28 lakh households, adding 8–10 GW of rooftop capacity. It also includes a skilling component targeting around one lakh solar technicians, marking a significant acceleration compared to earlier National Solar Mission phases[14].

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11 Koh, H., Karamchandani, A., & Katz, R. (2012). From blueprint to scale: The case for philanthropy in impact investing. Monitor Institute.

12 https://csrtimes.org/teri-mnre-strategic-workshop/

13 Ministry of New and Renewable Energy (MNRE), PM Surya Ghar: Muft Bijli Yojana – Scheme Guidelines (New Delhi: Government of India, 2024).

14 Ministry of New and Renewable Energy (MNRE), Jawaharlal Nehru National Solar Mission – Mission Document (New Delhi: Government of India, 2010).

From a policy perspective, PMSG–MBY advances household energy affordability, strengthens distributed generation and grid resilience, generates domestic employment, and promotes energy democratization by enabling households to become active participants in the transition. International Energy Agency analyses note that rooftop expansion enhances consumer benefits while reinforcing national energy security, aligning clean energy deployment with household-level economic empowerment[15].

Model Solar Village Programme

Embedded within PMSG–MBY, the Model Solar Village (MSV) Programme advances decentralized renewable energy at the village scale. With an allocation of ₹800 crore and a target of one model solar village per district, it aims to create self-reliant, solar-powered rural ecosystems.

Each selected village receives up to ₹1 crore in Central Financial Assistance to deploy rooftop solar, public lighting, agricultural pumps, community plants, and livelihood-oriented applications. By integrating multiple technologies within a defined geography, the programme demonstrates how clean energy can drive rural transformation. In 2025, MNRE refined the guidelines to prioritize distributed solar capacity and introduced flexibility (e.g., Model Solar Panchayat) for sparsely populated districts, improving implementability[16].

The MSV approach promotes localized energy self-sufficiency, village-level livelihood enhancement, replicable district-scale models, and institutional convergence across energy, rural development, and agriculture departments. Its demonstration-based design aligns with international evidence that localized pilots reduce information gaps and accelerate adoption (Barnes, 2014[17]).

PM-KUSUM (Components A, B, and C)

Launched in 2019, PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) is a structural intervention linking energy, agriculture, and climate policy. It comprises three components: (A) decentralized grid-connected renewable plants (up to 2 MW) by farmers, cooperatives, and FPOs; (B) stand-alone solar agricultural pumps; and (C) solarization of grid-connected pumps through individual and feeder-level models.

By December 2025, installed capacity under PM-KUSUM exceeded 10,900 MW, benefiting over 20 lakh stakeholders, including FPOs[18]. Component B has seen particularly strong uptake, reflecting farmer acceptance of solar irrigation.

PM-KUSUM advances agricultural decarbonization by reducing diesel use, enables income diversification through surplus power sales, improves irrigation reliability and productivity, and strengthens distributed generation near consumption points. By positioning farmers as renewable energy producers, the scheme integrates climate mitigation with rural economic development and supports India's NDC targets.

Atal Jyoti Yojana

Atal Jyoti Yojana (AJAY) supports solar street lighting in rural, semi-urban, and tribal areas. Though smaller in scale than PM-KUSUM or PMSG–MBY, it plays an important enabling role in strengthening public infrastructure. By March 2023, about 2.72 lakh solar street lights had been installed across two phases (2016–2020), covering multiple states and aspirational districts[19].

AJAY enhances safety and mobility, especially for women, extends productive hours for local enterprises, reduces reliance on kerosene and diesel lighting, and strengthens community infrastructure in underserved regions. These interventions generate socio-economic spillovers that support rural development and inclusive growth.

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15 International Energy Agency (IEA), Unlocking the Economic Potential of Rooftop Solar PV in India (Paris: IEA, 2023).

16 content

17 Douglas F. Barnes, The Challenge of Rural Electrification: Strategies for Developing Countries (London: Routledge, 2014).

18 Press Release:Press Information Bureau

19 Ministry of New and Renewable Energy (MNRE), Atal Jyoti Yojana (AJAY) Guidelines (New Delhi: Government of India).

Clean cooking integration and household energy transitions

Recent policy discussions under PMSG–MBY highlight integrating electric and solar cooking within rooftop solar systems, extending the renewable transition to comprehensive household energy solutions. Convergence with the Pradhan Mantri Ujjwala Yojana broadens the focus beyond electricity to clean cooking access.

Evidence from the Health Effects Institute's *State of Global Air 2025* and the Global Burden of Disease Study underscores the continued health impacts of household air pollution[20]. Integrating rooftop solar with electric cooking can reduce long-term fuel costs, ease LPG subsidy burdens, lower import dependence, improve health outcomes, and support women-led energy enterprises. This convergence signals MNRE's shift from sector-specific deployment toward holistic energy system transformation.

Achievements and developmental impact

MNRE's flagship schemes collectively advance India's goal of achieving 50 percent cumulative installed power capacity from non-fossil sources by 2030. By January 2026, renewable capacity (excluding large hydro) stood at about 212 GW, with total non-fossil capacity reaching 272 GW[21].

Deployment under PM-KUSUM, PMSG–MBY, and other DRE initiatives has stimulated local value chains in installation, maintenance, manufacturing, and service delivery. Evidence shows measurable gains when DRE is combined with skills and market linkages: mini-grid ecosystems report 15–28 jobs per site, while multi-state evaluations document income and productivity gains, particularly among women users. Case studies from states such as Jharkhand, Uttar Pradesh, Assam, and Karnataka demonstrate how decentralized solar supports productive-use value chains and micro-enterprise growth[22]. Farmer participation under PM-KUSUM, technician training under PMSG–MBY, and village-scale deployment under the MSV Programme together contribute to decentralized economic revitalization.

Strong implementation in states including Gujarat, Maharashtra, Kerala, Rajasthan, and Uttar Pradesh underscores the importance of institutional coordination, vendor networks, and proactive state engagement[23]. International experiences such as Germany's rooftop solar expansion and Bangladesh's solar home systems highlight how sustained policy support, digital governance, and community engagement drive distributed renewable growth.

Overall, MNRE's portfolio integrates climate ambition with rural transformation. By embedding decentralized renewable energy within agriculture, households, and village infrastructure, it strengthens progress toward India's NDCs, enhances energy security, generates green employment, and positions DRE as a pillar of inclusive economic growth.

Implementation challenges in achieving MNRE's targets

Despite robust policy design and progress under schemes such as PM-KUSUM and PM Surya Ghar: Muft Bijli Yojana, structural and operational constraints continue to affect the pace, inclusiveness, and long-term sustainability of decentralized renewable energy deployment.

Financial constraints

Although PM-KUSUM provides 30 percent Central Financial Assistance (up to 50 percent in select regions), the remaining capital burden remains significant. Under Component A, project costs range from ₹3–4 crore per MW, requiring substantial farmer contributions[24]. Under Components B and C, small and marginal farmers often struggle to mobilize equity or margin money despite available subsidies.

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[20] Health Effects Institute, State of Global Air 2025 (Boston: HEI, 2025), www.stateofglobalair.org. Institute for Health Metrics and Evaluation (IHME), Global Burden of Disease Study 2023 Results (Seattle: IHME, 2025).

[21] 2024080998431910.pdf

[22] Jawaharlal Nehru National Solar Mission (JNNSM) | India Science, Technology & Innovation - ISTI Portal

[23] "Impact of Pradhan Mantri Ujjwala Yojana," Economic and Political Weekly.

[24] https://www.ceew.in/blogs/how-will-pm-kusum-yojana-will-help-to-solarise-agriculture%3F
https://www.pib.gov.in/PressReleasePage.aspx?PRID=2042069&reg=3&lang=2

While lending under PM-KUSUM qualifies for Priority Sector Lending and the Agriculture Infrastructure Fund, access to affordable credit remains uneven. Financial institutions frequently view farmland-based solar projects as higher risk due to limited collateral and repayment uncertainties. Evidence from Odisha shows credit gaps of around 27 percent for landless and marginal farmers, 15 percent for small farmers, and below 10 percent for large farmers, who secure nearly 92 percent of requested credit[25]. Such disparities risk reinforcing existing agricultural inequalities.

Demand aggregation and last-mile delivery

The financial health and risk perception of DISCOMs influence renewable procurement and integration. Ongoing fiscal stress in several states can lead to cautious procurement, particularly where grid integration and payment security are uncertain (NITI Aayog, 2015[26]).

Under PM-KUSUM, State Implementation Agencies manage demand aggregation, application processing, and approvals. While essential for accountability, this multi-tiered structure can increase procedural complexity and delay implementation (Solar Energy Corporation of India, 2022).

Beyond administration, effective last-mile delivery requires robust service networks, community engagement, and institutional coordination. Infrastructure deployment alone is insufficient without sustained operational support and beneficiary confidence (Rao, 2014[27]).

Technical quality, operations, and maintenance

Operational sustainability is critical to long-term scheme success. Field evidence highlights challenges such as theft, wildlife damage, substandard components, and weak after-sales service that undermine system reliability.

A study in Nanded district (Marathwada) found that 31.7 percent of farmers reported theft, 41 percent animal damage, 20.8 percent inferior pump quality, and 16.7 percent dissatisfaction with maintenance (Singh et al., 2025[28]). This is notable given PM-KUSUM's mandate for a five-year Comprehensive Maintenance Contract and district-level service centers, indicating gaps in enforcement and monitoring. More broadly, intense price competition has at times prioritized low upfront CAPEX over durability, with documented cases of inverter failure, poor workmanship, inadequate earthing, and module microcracks in decentralized systems (Karandikar et al., 2023[29]; Millinger & Mårlind, 2011[30]). Such quality trade-offs risk weakening farmer confidence and system longevity.

Awareness and social acceptance

Limited awareness and information asymmetry constrain adoption of decentralized renewable technologies, especially in rural and low-income areas. Many beneficiaries lack clarity on economic returns, quality differences, and maintenance requirements (Jain et al., 2023). Information gaps between vendors and consumers may favor lower-cost systems over durable options, prioritizing short-term CAPEX over lifecycle performance (Karandikar et al.).

Behavioral factors, such as neglect of routine maintenance, further reduce system efficiency and lifespan. In states where grid electricity is free or heavily subsidized, the incentive to shift to solar pumps remains weak unless complemented by awareness of reliability gains, including assured daytime supply and improved energy security (Gangavelapalem et al. [31]).

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25 Sikha Madhulagna et al. "Constraint Analysis of Accessibility and Utilization of Agricultural Credit and Associated Socio-economic Traits in Puri District of Odisha, India." Asian Journal of Advances in Agricultural Research (2024). https://doi.org/10.9734/ajaar/2024/v24i5504.

26 NITI Aayog. Report on India's Renewable Electricity Roadmap 2030: Toward Accelerated Renewable Electricity Deployment. Government of India, Feb. 2015.

27 Rao, Sanjeev. "The Last Mile: Gateway to Rural Empowerment in India." Field Actions Science Reports, special issue 12, 2014.

28 Singh, Anjana, Ravi Shankar, and Amitesh Kumar. "A comprehensive review of load frequency control and solar energy integration: challenges & opportunities in Indian context." Energies 18.4 (2025): 843.

29 Karandikar, Arvind, et al. Distributed Solar Quality and Safety in India: Key Challenges and Potential Solutions. No. NREL/TP-7A40-74833. National Renewable Energy Laboratory (NREL), Golden, CO (United States), 2023.

30 Millinger, Markus, and Tina Mårlind. Factors Influencing the Success of Decentralised Solar Power Systems in Remote Villages: A Case Study in Chhattisgarh, India. Master's thesis, Chalmers University of Technology, 2011.

31 Gangavelapalem, Manoghna, et al. Comparative Analysis of Central and State-Level Solar Energy Policies and Implementations: A Case Study of Tamil Nadu and Gujarat. EC Working Paper WP 01, The Energy Consortium, IIT Madras, Nov. 2024.

Skill Gaps and Capacity Constraints

Shortages of trained technicians, inspectors, and installers affect installation quality and system durability, particularly in rural areas (Karandikar et al.). Although PM-KUSUM mandates vendor-led training and local capacity building, implementation varies across states (Solar Energy Corporation of India). Strengthening technical skill ecosystems is critical to sustaining decentralized deployment at scale.

Inter-Institutional Coordination

Electricity falls under the Concurrent List (Seventh Schedule, Entry 38), creating shared responsibilities between Union and State Governments. Variations in state policies, approvals, and tariff structures can slow harmonized renewable integration (Vikas & Kumar[32]). Institutional fragmentation across ministries and agencies further complicates land clearances, grid connectivity, and transmission approvals, increasing transaction costs and delays (NITI Aayog[33]).

These constraints reflect ecosystem capacity gaps rather than policy ambition. Financial access, quality assurance, coordination, and social acceptance ultimately determine whether decentralized renewable energy translates into sustained, development-oriented outcomes. Strengthening these dimensions is essential for MNRE's flagship schemes to deliver both quantitative expansion and qualitative transformation.

Strengthening MNRE's implementation ecosystem

India's renewable energy expansion is increasingly constrained by delivery capacity rather than regulatory design. According to MNRE's latest Annual Report[34], installed renewable capacity exceeds 180 GW (excluding large hydro), led by solar, followed by wind, bio-energy, and small hydro. With a target of 500 GW of non-fossil capacity by 2030, the current scale of deployment places significant pressure on existing systems. A persistent gap between projects planned, approved, and commissioned highlights the need to shift from project-level monitoring to system-wide delivery management.

MNRE employs multiple monitoring tools, including milestone-linked financial assistance, generation certificates, quarterly reporting, and committee oversight. However, performance across segments remains uneven. Utility-scale solar has expanded rapidly through competitive bidding by the Solar Energy Corporation of India, whereas rooftop solar under PM-Surya Ghar has lagged, largely due to coordination challenges with DISCOMs and state agencies. This divergence indicates that outcomes depend not only on policy design but also on institutional coordination, transaction costs, and state-level implementation capacity. The scale of current renewable investments further underscores the need for strengthened delivery mechanisms.

The Indian Renewable Energy Development Agency (IREDA) has sanctioned loans worth tens of thousands of crore rupees in recent years[35]. Yet delays in land acquisition, grid connectivity, and payment security often slow project execution, indicating that financial closure alone does not guarantee timely completion. Monitoring frameworks must therefore integrate financial progress with infrastructure readiness and statutory clearances. A unified digital platform linking transmission utilities, state agencies, MNRE, Solar Energy Corporation of India, and IREDA could enable end-to-end project tracking and early identification of bottlenecks.

International cooperation offers useful lessons for accelerating renewable deployment. Mission Innovation brings countries together around shared targets, linking public investment to measurable outcomes such as demonstration projects, cost reductions, and timely delivery[36]. Similarly, REN21 provides comparative data

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32 Vikas, P. N., and Sharad Kumar. "Policy and Regulatory Innovations for High-Renewable Grid Penetration: A Critical Assessment of India's Transition Strategies." National Journal of Multidisciplinary Research and Development, vol. 10, no. 3, 2025, pp. 14-21.

33 NITI Aayog. Report on India's Renewable Electricity Roadmap 2030: Toward Accelerated Renewable Electricity Deployment. Government of India, Feb. 2015

34 https://mnre.gov.in/en/annual-report/

35 https://www.ireda.in/images/HTMLfiles/IREDA%20Annual%20Report%2024-25.pdf

36 https://mi-india.in/

on renewable deployment, policy instruments, and market trends, enabling benchmarking and greater transparency[37]. Such platforms demonstrate how standardized metrics and disclosure can strengthen accountability and accelerate diffusion of best practices.

Domestically, Solar Energy Corporation of India's competitive bidding model has reduced solar tariffs and expanded installed capacity. However, undersubscription in some wind and hybrid tenders, along with instances of state-level renegotiation, indicates the importance of aligning policy signals, transmission planning, and payment security. Strengthening MNRE's implementation architecture therefore requires embedded risk-mitigation measures, including payment security mechanisms, coordinated grid planning, and robust contractual enforcement.

From an analytical perspective, three structural shifts are required.

- First, monitoring must move beyond expenditure tracking to performance measurement. Dashboards should capture project completion timelines, actual generation, grid losses, and beneficiary coverage under distributed schemes.
- Second, coordination must deepen across departments, particularly between renewable capacity targets and transmission expansion under national grid plans. Without synchronized infrastructure development, capacity additions risk delay or underutilization.
- Third, key partners - public agencies, international institutions, and technical bodies should be engaged early, with clearly defined, outcome-linked targets.

Given the scale of India's renewable ambitions, implementation is a strategic priority. With over 180 GW already installed and annual additions needing sharp acceleration to meet 2030 goals, incremental improvements are insufficient. System-level upgrades such as integrated data platforms, performance-linked finance, cross-sector coordination mechanisms, and mission-oriented partnerships are essential. Strengthening MNRE's implementation ecosystem in this manner can translate policy ambition into time-bound, measurable transition outcomes.

Leveraging Clean Energy for Billion Livelihoods (LaBL 2.0)

Overview of LaBL

Till about two decades ago, India faced severe energy access challenges that impacted almost 300 million people, mostly in rural and underserved parts of the country, where access to modern energy for lighting, cooking and productive uses was constrained[37]. There was also an alarmingly high dependence on solid biomass and kerosene for household cooking and lighting energy, impacting the quality of life of habitants. Recognizing the dire need for modern energy access and reducing the dependence on fossil fuels, The Energy and Resources Institute (TERI) formulated and launched the Lighting a Billion Lives (LaBL) campaign in 2008. LaBL emerged as a pioneering effort to address energy poverty through clean and decentralized energy solutions, facilitating the last mile delivery of energy services for basic and productive use. Operating through an entrepreneurial model of energy service delivery, LaBL accelerated market development for clean energy technologies through knowledge sharing, capacity building and market seeding. With the evolving energy needs of communities and businesses, LaBL adopted technical advancements and ecosystem development to enhance the utility and reach of its interventions. Since its inception, LABL evolved into a global campaign gaining recognition and support from individuals, governments, private sector, philanthropies, celebrities and various other stakeholders and well-wishers. Overall LaBL weaved a fabric of inclusive development, anchored on technology, and nurtured by compassion and commitment toward environmental conservation, impacting around 14 million people across India, South Asia and Africa.

At present, India has attained near-universal access to household electrification. With basic electricity requirements fulfilled, the focus shifts to energy sufficiency for productive applications through green energy technologies. As India's growth is intrinsically linked to the growth of its industries, especially Micro Small and Medium Enterprises (MSMEs), addressing its

[37] https://www.ren21.net/gsr-2025/

[38] https://doi.org/10.1016/j.energy.2011.07.017

energy challenges becomes critical for sustaining the growth trajectory. Current estimates show the sector leaving a significant carbon footprint, with around 3-4% of India's CO2 emissions attributed to MSMEs. Decarbonization of the sector through clean and energy efficient technologies thus provides opportunities for emission reduction and long-term management of energy costs, without compromising on the reliability of supply for production activities. Moreover, it serves the goals of India's energy transition, creating outcomes for inclusive livelihood enhancement.

Building on the success of the LaBL campaign, TERI is launching LaBL 2.0- Leveraging clean energy for a Billion Livelihoods, which aims to push the boundaries of energy access to energy for productive activities and builds the ecosystem for just energy transition. The programme envisages the following objectives-

- **Enable livelihood empowerment** by supporting rural energy entrepreneurs—especially women—with training and finance to run solar enterprises
- **Scale replicable delivery models** for decentralized clean energy through different packages for primary, secondary, and tertiary sector.
- **Build local capacity** through intensive training and support to sustain energy systems and enable ongoing aftersales services.

Alignment with MNRE's priorities

Since Independence, India's energy policies have evolved from building infrastructure and meeting growing industrial and domestic demand through thermal and hydro power, to liberalisation-driven private sector growth. In the last two decades, focus has shifted to green energy, with ambitious climate targets, the National Solar Mission, Net Zero by 2070, and commitments to NDCs and SDGs establishing India as a global climate leader.

Policy has driven India's energy progress, with MNRE pioneering the green energy transition. From implementing small household systems in remote areas to advancing technologies like green hydrogen, MNRE has addressed evolving energy demand and supply, fostering a market for clean energy. A key focus has been decentralized solutions, with solar emerging as the most affordable and adaptable technology.

The LaBL Mission of TERI, both in its first phase and its current phase is by design aligned to MNRE's policies, specially on Distributed Renewable Energy. For instance, several of the technology applications developed and implemented under LaBL in India and Africa like solar home lighting systems, solar street lights, micro-grids, solar pumps, and solar lanterns among others, concur with the objectives of prominent MNRE schemes like the Off-grid Solar PV Applications Programme, Off-grid and Decentralised Solar PV Applications Scheme, Atal Jyoti Yojana (solar street lights), and PM-KUSUM (solar pumps). Under LaBL 2.0 advancements in technologies and the changing aspirations of consumers would be prioritised. For instance, the LaBL 2.0 programme could be integrated with the flagship PM-Surya Ghar scheme to proliferate on-grid solar rooftop models and supplementary community energy systems in rural and peri-urban areas by engendering an ecosystem and suitable market conditions for technology adoption. In addition to solar pumps being promoted under PM-KUSUM component B, the concept of agri-photovoltaic plants is an innovative energy and food security approach being prioritised under LaBL 2.0, similar to the concept suggested in PM-KUSUM component A. The principles of energy justice and inclusivity, that anchor LabL 2.0 to the larger just transition movement, are reflected in the Pradhan Mantri Janjati Adivasi Nyaya Maha Abhiyan (PM JANMAN) which focusses on providing off-grid solar systems for Particularly Vulnerable Tribal Groups (PVTG) Habitations and Villages. The Labl 2.0 programme aims to symbiotically converge with the salient features of the Framework for Promoting Decentralized Renewable Energy Livelihood Applications, whose main objective is to develop an enabling ecosystem for widespread adoption of DRE for sustainable livelihoods.

With its holistic vision for sustainable energy, LaBL 2.0 could help coordinate line ministries with shared green economy goals, including MNRE, Environment, MSME, Rural Development, Power, Agriculture, and Commerce.

How LaBL 2.0 can support MNRE's goals across three functional verticals

LaBL 2.0 seeks to advance large-scale clean energy adoption by promoting awareness, conducting baseline and endline assessments, deploying context-specific renewable energy solutions for livelihoods, training

end users, and building last-mile clean energy value chains. It also facilitates knowledge sharing and policy learning to strengthen national and state programmes for sustainable development. In this context, LaBL 2.0 contributes to national clean energy goals through three key functional verticals outlined below.

Research and Knowledge Support - Evidence generation, impact evaluation, and policy feedback for MNRE schemes

LaBl 2.0, in association with MNRE and state agencies, can carry out joint research and documentation of existing clean energy programmes implemented by the government and other agencies through periodic field studies, stakeholder consultations, documentation of best practices, and policy inputs to further strengthen the programmes. The key outcomes lead to documenting key challenges, the effectiveness of initiatives, social and gender inclusion, areas of socio-economic and livelihood impacts, green jobs, carbon reduction, etc.

Supporting data-driven refinement of MNRE programs

laBL 2.0 can contribute to the development of a national or selective state-level database on clean energy for livelihoods initiatives, by providing key inputs on technology dissemination, performance, geographies covered, subsidy, financing released, productivity and income enhanced, etc. This can help both MNRE and State Agencies to monitor and strengthen the respective programmes.

Besides, it can contribute towards the development of a national-level database for the number of green jobs and enterprises created under various clean energy programmes in different geographies. This would help in large-scale awareness, skilling, and development of on-ground technical capacities for large-scale implementation.

Technology Deployment and Capacity Building - Supporting the last-mile deployment of MNRE-approved technologies

LaBL 2.0 can contribute to the development of innovative livelihoods and the enhancement of clean energy technologies by facilitating joint research and collaboration. The solution can be piloted for customisation, creation of a suitable business model, and development of an ecosystem before developing policies and programmes at the national and state levels. With the vision of large-scale deployment of clean energy for livelihoods, LaBL 2.0 can assist the national government in identifying key livelihood interventions, suitable technologies, sectoral interventions, and geographies for large-scale implementation covering millions of livelihoods.

Local capacity building, O&M support, and enterprise development aligned with MNRE guidelines

One of the key areas of LaBL 2.0 is to develop a large number of last-mile clean energy enterprises and technicians by engaging rural youths and women. LaBL 2.0 can assist the national government in the development of such energy value chains in the existing off-grid programmes, such as Solar Street Lights, biogas, etc. It can contribute to organising short-term and long-term training and handhold the local agencies for creating master trainers, techncians and enterprises so as to enhance the local capacities for after-sales and sustainability.

LaBL 2.0 also works with various local agencies, including local government, not-for-profit institutions, financial institutions, and enterprises, and can contribute to the enhancement of their knowledge and skills so as to manage the project or programmes effectively and efficiently in timeline manner. LaBL 2,0 can design specific stakeholder orientation and training programmes for their capacity building. This can further help in the convergence of programmes and resource mobilisation for the implementation of large-scale clean energy powered llivelhoods programmes.

Carbon Assessment & Climate Outcomes

MNRE-supported programs in solar, wind, bioenergy, and other decentralized systems are significantly reducing greenhouse gas emissions. As India advances its clean energy transition, systematic quantification and reporting of climate outcomes is increasingly important. LaBL 2.0 can help MNRE and partner ministries develop scheme-linked carbon accounting frameworks to support India's decarbonization and net-zero commitments.

Carbon Accounting, Reporting, and Monetization

Flagship initiatives like PM-Surya Ghar: Muft Bijli Yojana and the National Green Hydrogen Mission can be integrated with carbon accounting systems, positioning them in international carbon markets. LaBL 2.0 can aggregate small-scale projects to access carbon credits, generate revenue streams, and enhance project viability and investment appeal.

Enhancing Contribution to India's NDCs and Net-Zero Goals

India's decarbonization efforts, including achieving net-zero by 2070, require robust emissions tracking. LaBL 2.0 can help MNRE and other ministries quantify scheme-level emissions, strengthen evidence-based reporting, and demonstrate contributions to livelihoods and just transition outcomes.

Operationalizing Service-Based Renewable Energy Delivery: Integrating Pay-Per-Use (PPU) Models within LaBL 2.0

While LaBL 2.0 strengthens decentralized renewable energy (DRE) through aggregation, blended finance, and capacity building, long-term sustainability of agricultural solarization and rural enterprises also requires innovation in delivery models. Integrating professionally managed Pay-Per-Use (PPU) architectures offers a scalable pathway to enhance inclusion, operational reliability, and fiscal efficiency under schemes such as PM-KUSUM.

The prevailing model emphasizes farmer-owned assets supported by capital subsidies. Although effective for installation scale-up, it places upfront financial and maintenance burdens on smallholders. PPU shifts from asset transfer to service delivery: infrastructure is owned and operated by a specialized provider such as a rural enterprise, cooperative, or FPO-backed entity, while farmers pay per hour or per unit of water used. This reduces entry barriers and broadens participation. Within LaBL 2.0, such service providers can be incubated, technically supported, and aggregated at district level, aligning livelihood goals with DRE deployment.

Lessons from the Oorja Model

Experience from service-based enterprises such as Oorja Development Solutions offers key operational insights:

1. Cluster-Based Aggregation: One solar plant serving multiple farmers improves load factors, lowers transaction costs, and enhances financial viability consistent with LaBL's aggregation logic.
2. Embedded O&M Incentives: Enterprise revenue depends on uptime, incentivizing proactive maintenance supported by remote monitoring and standardized servicing. This addresses common service gaps in ownership-based systems.
3. Digital Metering and Transparency: Prepaid or digitally metered usage ensures transparent pricing and generates data on performance and demand, supporting policy refinement and carbon accounting.
4. Water-Energy Efficiency Signals: Usage-based pricing encourages optimized irrigation and resource efficiency, while reliability improvements can offset moderate service fees.
5. Value-Chain Integration: Linking irrigation to processing and market access strengthens income gains and enhances the economic case for renewable investment.

Policy Integration within MNRE's Framework

PPU can be piloted within PM-KUSUM Component A and feeder-level clusters without displacing existing subsidies. Central Financial Assistance may be structured as viability gap support to service providers, with phased disbursement linked to performance indicators such as uptime, beneficiary coverage, and efficiency metrics.

LaBL 2.0 can catalyze this integration by identifying pilot districts, mobilizing FPO participation, structuring blended finance, standardizing service agreements, and establishing monitoring frameworks. This positions PPU as an ecosystem innovation embedded within MNRE's architecture.

Fiscal and Environmental Co-Benefits

Service-based irrigation improves plant utilization, reduces over-sizing risks, and strengthens emissions mitigation per installed kilowatt. Aggregated carbon accounting within clusters may enable participation in voluntary carbon markets, layering user fees, subsidy support, and carbon revenues to enhance financial sustainability while safeguarding affordability.

Strategic Implications

Embedding PPU within LaBL 2.0 advances three objectives:

- Inclusion: Lower upfront barriers for small and marginal farmers.
- Sustainability: Align maintenance incentives with commercial viability.
- Efficiency: Improve asset utilization and subsidy effectiveness.

This approach shifts decentralized renewable energy from installation-driven expansion toward a professionally managed rural energy service ecosystem aligned with development outcomes.

Policy Recommendations

To consolidate gains under MNRE's flagship programmes and deepen the developmental impact of decentralized renewable energy (DRE), policy reform should prioritize ecosystem strengthening over incremental scheme redesign.

First, MNRE may institutionalize structured partnerships with mission-oriented platforms such as LaBL 2.0 through formal collaboration frameworks, embedding them within district-level implementation to support research, monitoring, capacity building, and enterprise incubation. This can reduce transaction costs, improve beneficiary targeting, and strengthen local ownership.

Second, the financial architecture of DRE—particularly under PM-KUSUM—should incorporate blended finance and service-based delivery. Piloting Pay-Per-Use (PPU) models within Component A and feeder-level clusters, with Central Financial Assistance structured as viability gap funding linked to uptime and service performance, would lower upfront barriers for smallholders while improving operational sustainability.

Third, MNRE may establish a unified digital project-tracking platform integrating State Implementation Agencies, DISCOMs, SECI, IREDA, and transmission utilities. Moving from expenditure tracking to performance-based metrics—such as generation, uptime, timelines, and livelihood outcomes—would strengthen accountability and enable early bottleneck identification.

Fourth, quality assurance should be reinforced through standardized protocols, digital commissioning records, third-party audits, and performance-linked vendor empanelment. Enforcing Comprehensive Maintenance Contracts and integrating remote monitoring can reduce service gaps and component failures.

Fifth, decentralized skill ecosystems require convergence between MNRE schemes and national skilling programmes. District-level technician pools, structured certification, refresher training, and women-focused enterprise incubation can sustain local technical capacity.

Sixth, inter-ministerial coordination—linking MNRE with Agriculture, Rural Development, MSME, Power, and Environment—should be formalized to align renewable deployment with transmission planning, groundwater management, and rural enterprise promotion.

Seventh, MNRE may integrate carbon accounting and results-based climate finance within decentralized clusters, aggregating mitigation outcomes to access voluntary carbon markets and enhance financial sustainability.

Finally, demonstration districts combining LaBL 2.0, PPU irrigation, rooftop solar, clean cooking, and enterprise incubation can serve as replicable models, with standardized implementation playbooks enabling scale across states.

Conclusion

India's renewable energy transition has reached a decisive inflection point. Under MNRE's leadership, rapid capacity expansion has strengthened energy security and reinforced India's position in climate-aligned development. The next phase, however, requires deepening institutional, financial, and service ecosystems to convert installations into sustained developmental outcomes.

Decentralized renewable energy (DRE) forms the closest link between climate ambition and rural livelihoods. When integrated with agriculture, MSMEs, and household energy systems, renewable energy becomes a driver of income, resilience, and inclusive growth. The durability of these gains depends on reliable maintenance, accessible finance, skilled local capacity, and coordinated governance.

Mission-oriented platforms such as LaBL 2.0 illustrate how partnerships between government, research institutions, and civil society can strengthen last-mile implementation. Integrating service-based Pay-Per-Use models further aligns commercial incentives with system performance, expands access for smallholders, and improves fiscal efficiency.

The strategic priority for MNRE is therefore not only scaling megawatts, but institutionalizing collaborative, data-driven, and service-oriented governance. By embedding livelihood-centric models within its renewable architecture, India can transform its clean energy transition into a replicable model of inclusive, development-aligned climate action. Top of Form

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