Scaling Rural Distributed Renewable Energy in India

A framework for planning and implementation

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Scaling Rural Distributed Renewable Energy in India:
A framework for planning and implementation

June 2026

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Photo: Dropka Films

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Executive Summary

India has significantly expanded rural electricity access over the past decade. However, many villages still face persistent challenges related to affordability, reliability, and voltage quality, especially during evening hours and for productive uses. In parallel, India's target of 500 GW of non-fossil electricity capacity by 2030 will add large volumes of renewable generation, but much of this growth is expected to come from centralized, utility-scale projects that strengthen bulk supply. These projects remain essential, but they may not always resolve the last-mile constraints that shape the quality of supply due to losses, local grid stability, and service delivery costs in villages.

Distributed renewable energy (DRE) can complement centralized expansion by generating power closer to demand, reducing effective network losses, easing local congestion, and improving supply quality at the feeder and village level. However, this potential depends on how DRE is planned and integrated.

In India, DRE deployment has largely progressed through scheme-driven programs targeting specific segments, such as rooftop solar for households under the Pradhan Mantri–Surya Ghar Muft Bijli Yojana scheme or solarization of irrigation demand under Pradhan Mantri Kisan Urja Suraksha evam Utthaan Abhiyaan. While these initiatives have accelerated DRE adoption, they typically focus on individual demand segments rather than whole-village electricity needs. As a result, demand assessment, system sizing, surplus management, grid operations, institutional roles, and financing are rarely addressed together within a single planning framework.

The Ministry of New and Renewable Energy has recognized the need for a clearer, more structured approach to decentralized energy, including stronger institutional and regulatory clarity to support durable rural deployment. This study responds by addressing the missing "system layer" for DREs by developing an evidence-based, utility-relevant framework to help states translate national ambition into practical, implementable DRE deployment strategies across diverse rural contexts.

The study combines (a) a review of India's DRE policy landscape; (b) field-based learning from two operational DRE-enabled villages, Manyachiwadi (Maharashtra) and Odanthurai (Tamil Nadu), to identify enabling conditions, risks, and constraints; and (c) a structured techno-economic assessment using a modelling tool, applied in depth to two villages selected for detailed analysis: Hiware Bazar (Maharashtra) and Bamun Sualkuchi (Assam).

The modelling estimates levelized cost of electricity (LCOE), indicative payback for utility-led, grid-connected configurations with and without battery storage, based on observed load profiles, scheme support assumptions, and system sizing exercises. Building on these results, the study proposes a planning framework for "model DRE villages" that governments and utilities can use as a playbook to implement a comprehensive approach to DRE deployment that works with—not around—existing schemes.

Key Findings From the Policy Review and Village Studies

1) Local success is possible but is often fragile without formalized roles and performance systems.

Village-level DRE initiatives can operate effectively when supported by local leadership, community trust, and stakeholder coordination. However, the case studies show that performance and continuity can remain fragile when projects depend heavily on individual champions, informal arrangements, or weak payment collection and operation and maintenance (O&M) systems. Establishing clear institutional roles, accountability mechanisms, and structured performance and maintenance processes is, therefore, essential for durable and scalable deployment.

2) Load typology[1] is the biggest driver of system design, grid impacts, and storage needs.

Load typology has design implications for the sequencing of DRE interventions. In agriculture-heavy villages, planners could start by solarizing the agricultural power supply and maximizing daytime self-consumption. In evening-peaking villages, planners could build grid interaction and storage solutions into the design, rather than treating balancing as an add-on.

3) Incorporating surplus and network readiness, including storage siting, improves system performance as DRE scales

Villages with seasonal or time-concentrated demand can experience periods when solar generation exceeds local consumption, creating surplus injections and reverse power flows that stress local networks. Utilities and states can manage these risks better by treating export management as a standard design element alongside sizing and finance. Village-level storage can reduce peak imports and cut the number of surplus days, but it does not eliminate sustained reverse flows in seasonal agricultural settings. Storage deployed at higher network levels (such as substations) can pool more diverse loads, improve utilization, and complement village-level solutions.

Village-wide DRE should therefore be treated as part of distribution planning, not only as a deployment target. Integrating DRE into distribution planning helps align system sizing, grid readiness, and operational responsibilities from the outset.

4) A practical planning bridge can strengthen delivery across existing schemes.

India already has multiple programs that support different parts of the rural DRE ecosystem, each with its own eligibility rules and implementation pathways. States can achieve more consistent outcomes by using a single planning instrument to align these pathways at the village or feeder level. We propose a Village Energy Plan to bring together typology, load assessment, demand projections, system configuration, techno-economic results, financing

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[1] "Load typology" refers to the dominant composition and time pattern of a village's electricity demand (e.g., agriculture-led daytime demand versus residential-led evening peaks), which determines how DRE should be sized, sequenced, and balanced (including storage and grid interaction).

convergence, and implementation roles into one coordinated plan that utilities and state agencies can apply systematically.

5) Policy and program alignment determines the scalability of technically viable solutions.

Metering rules, compensation mechanisms, and scheme design strongly influence whether technically feasible DRE configurations can be implemented at scale. Clear policy alignment can enable distribution companies (DISCOMs) to aggregate distributed consumers, manage shared solar assets, and integrate grid-interactive DRE more effectively. For example, Maharashtra limits virtual net metering to apartments and housing societies, whereas Assam allows wider residential use. Aggregation models for scattered rural rooftops and shared solar assets may thus be feasible in Assam but difficult in Maharashtra.

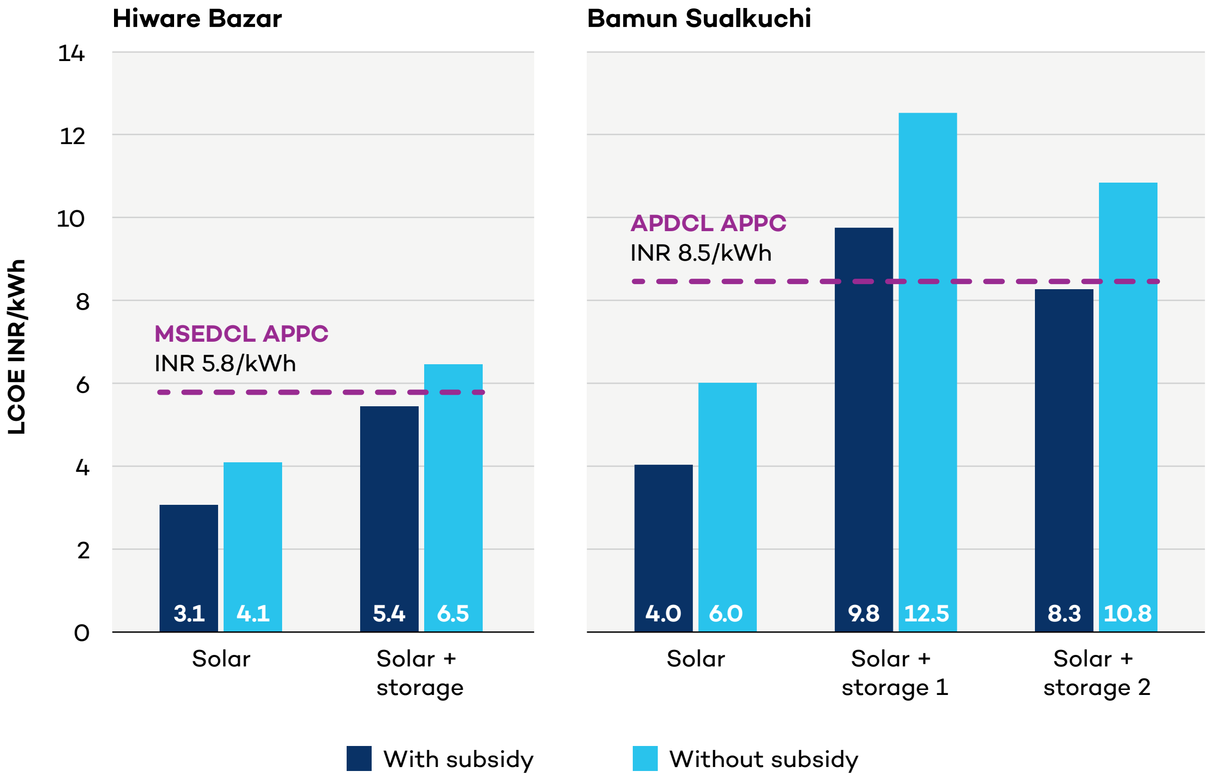
6) Techno-economic modelling shows solarization is cost-competitive, while storage requires staged deployment and system-value recognition.

Solarizing village demand, whether agricultural or residential, would deliver cheaper electricity than the benchmark average power purchase cost (APPC). Adding storage to manage surplus or peak demand increased the cost of the systems, but small battery systems were still found to be cost-effective relative to the benchmark.

In Hiware Bazar, a 980 kW ground-mounted solar (which would meet most of the electricity demands of the village) yielded an estimated LCOE of INR 3.06/kWh with subsidy (INR 4.09/kWh without), both below the state APPC (Figure ES1). However, surplus electricity generation would be frequent outside irrigation months, creating reverse power flow that must be managed. Adding a 350 kW/1,400 kWh (4-hour) battery energy storage system (BESS) would support peak demand during non-solar hours, significantly reduce (but not eliminate) reverse flow, and raise the blended LCOE to INR 5.44/kWh (with subsidy)—broadly comparable to APPC.

In Bamun Sualkuchi, a 1,318 kW on-grid configuration (70% ground-mounted, 30% rooftop) was estimated at INR 4.03/kWh with subsidy (INR 6.01/kWh without), well below the state APPC (Figure ES1). Adding a 500 kW/2,000 kWh BESS raised blended cost above APPC, while a smaller 400-kW/1,600-kWh BESS kept costs below APPC. This suggests the need for BESS pricing to reflect the system services it provides (peak demand reduction, avoided peak procurement, reduced curtailment, and improved feeder reliability), and the need for staged storage solutions that are affordable at the village level.

Figure ES1. Comparison of LCOE for solar, storage, and subsidy scenarios in Hiware Bazar and Bamun Sualkuchi



Note: In Bamun Sualkuchi, Storage 1 denotes the 500 kW/2,000 kWh BESS configuration, and Storage 2 denotes the 400 kW/1,600 kWh BESS configuration; both are paired with a 1,318 kW solar system.

Source: Authors.

Model DRE Village Framework

The study proposes a Model DRE Village Framework, building on the existing "**Model Solar Village**," component of PMSGMBY, to provide states and DISCOMs with a practical playbook to design and scale system-integrated, grid-interactive DRE ecosystems. The key features of the framework are

- village selection and categorization using typology-based diagnostics (including surplus/export profiles, feeder/distribution transformer readiness);
- standardized load analysis and sizing;
- coherent institutional roles across the Ministry of New and Renewable Energy, state nodal agencies, DISCOMs, district administration, and village Panchayats;
- financing pathways that converge schemes while assigning O&M responsibility clearly; and
- performance monitoring through data systems and periodic review.

All planning outputs could be consolidated into a Village Energy Plan, which would serve as the core implementation document. This single document could enable coordinated execution at the village level while supporting aggregation and learning at the state level.

The framework provides a practical starting point, but scaling it confidently across states will require a stronger, shared evidence base on rural distribution conditions and performance. A natural next step is to implement a small set of typology-based pilots that apply the Village Energy Plan and generate comparable data on reliability improvements, surplus and reverse-flow incidence, O&M performance, and consumer experience.

In parallel, states and utilities can strengthen transparency by making feeder- and DT-level load and export profiles available for pilot geographies, enabling more rigorous assessment of surplus management needs and the operational value of storage and flexibility. Further research can then translate these learnings into clearer design benchmarks and decision tools that make planning faster and more consistent.

DRE offers a critical bridge between national clean energy ambitions and the distribution-level realities of rural power supply. We provide a practical, system-oriented framework for DRE deployment that aligns village-level design with distribution realities. The next step is to convert this planning logic into a stronger national evidence base through larger data sets, transparent pilots, and rigorous valuation of storage and network impacts. With these additions, DRE can scale in ways that strengthen rural reliability, support the 500 GW target, and contribute credibly to India’s longer-term net-zero pathway.

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Abbreviations and Acronyms

ACOS	average cost of supply
AERC	Assam Electricity Regulatory Commission
AMC	annual maintenance contract
APDCL	Assam Power Distribution Company Ltd
APPC	average power purchase cost
ARR	Aggregate Revenue Requirement
BESS	battery energy storage system
CAGR	Compound annual growth rate
CapEx	capital expenditure
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CFA	central financial assistance
CMSPGHS	Chief Minister solar powered green house scheme
CSR	corporate social responsibility
CUF	capacity utilization factor
DISCOM	distribution company
DLC	district-level committees
DRE	distributed renewable energy
DT	distribution transformer
EPC	engineering, procurement, and construction
FLS	Feeder-Level Solarization
FPO	farmer producer organizations
KVK	Krishi Vigyan Kendra
LCOE	levelized cost of electricity
MERC	Maharashtra Electricity Regulatory Commission
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MoRD	Ministry of Rural Development
MSEDCL	Maharashtra State Electricity Distribution Company Limited

MSKVY	Mukhyamantri Saur Krushi Vahini Yojana
MSME	micro small and medium enterprises
MSV	Model Solar Village
MU	million units
NABARD	National Bank for Agriculture and Rural Development
O&M	operation and maintenance
PPA	power purchase agreement
RESCO	renewable energy service company
RPO	renewable purchase obligation
SERC	State Electricity Regulatory Commissions
SHG	self-help groups
SIDBI	Small Industries Development Bank of India
SNA	state nodal agencies
T&C	terms & conditions
T&D	transmission and distribution
VEC	village energy committee
VEP	Village Energy Plan
VNM	virtual net metering
WEG	wind energy generator

1.0 Introduction

India has significantly expanded rural electricity access over the past decade. However, persistent challenges remain in delivering reliable, affordable, and clean power to households, agriculture, public institutions, and rural enterprises. Many villages continue to experience evening supply shortages, voltage instability, and a heavy reliance on subsidized agricultural electricity, limiting the availability of dependable power for productive uses. The next phase of rural electrification must, therefore, move beyond universal access to focus on improving reliability, quality, and system performance across all segments of rural demand.

Centralized, utility-scale projects are essential for meeting aggregate capacity goals, such as India's goal of 500 GW of non-fossil electricity capacity by 2030 (Ministry of Environment, Forest and Climate Change, 2021), but they do not fully address distribution-level constraints that shape service quality, costs, and grid stability at the village level. This creates a critical need for solutions that can simultaneously expand renewable generation in ways that strengthen local electricity networks, improve last-mile electricity outcomes, and support national decarbonization goals.

The Ministry of New and Renewable Energy (MNRE) has acknowledged the lack of a dedicated policy framework for off-grid and decentralized renewable energy and called for a structured approach to support sustainable rural deployment and regulatory clarity aligned with national clean energy objectives (Koshy, 2026). This report responds to this gap by examining how distributed renewable energy (DRE) can be planned and deployed as a system-level solution, one that supports reliable rural electricity supply, aligns with DISCOM operations, and contributes meaningfully to India's clean energy and net-zero objectives.

This study responds to that gap by offering a replicable framework for village-scale DRE that connects demand profiles, system sizing, storage needs, and utility economics within existing policy and institutional settings. By grounding the analysis in distribution-level constraints and DISCOM decision making, the study informs states seeking to translate national renewable and net-zero targets into practical and scalable DRE strategies.

Research Questions

The development of an implementable DRE framework is guided by the following research questions:

1. What lessons do existing DRE initiatives in India offer on the conditions required for durable, scalable deployment across diverse rural contexts?
2. How can village- and feeder-level DRE systems be planned and integrated with distribution networks to improve reliability, quality of supply, and system performance in rural areas?
3. What factors shape the economic and operational viability of grid-interactive DRE systems from a distribution utility perspective, including the role of storage and surplus management?

4. What institutional arrangements and business models are best suited to enable coordinated DRE deployment while ensuring financial sustainability and alignment with DISCOM operations?
5. How can a practical, criteria-based framework guide states and utilities in translating national renewable energy and net-zero goals into implementable, village-level DRE strategies?

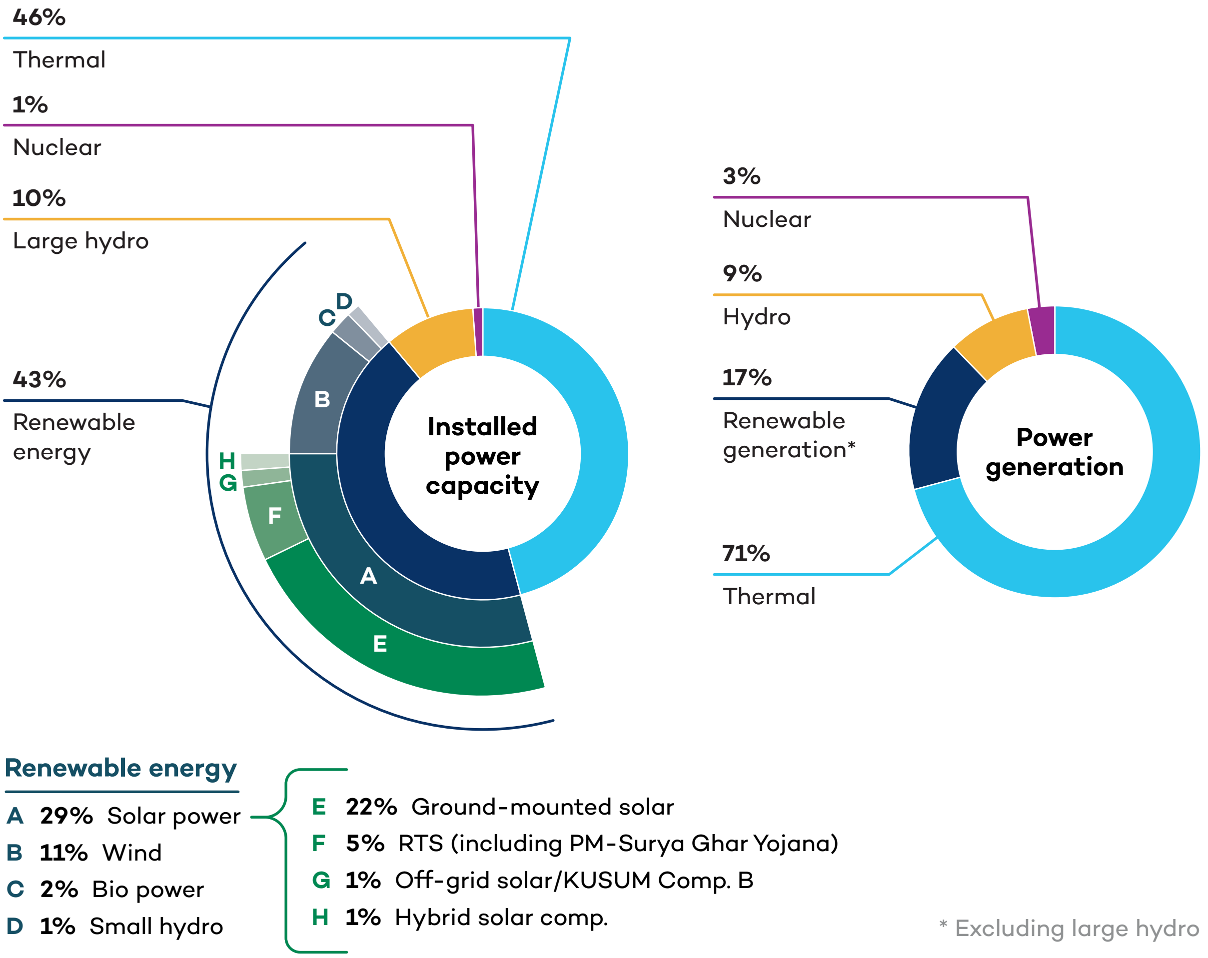
2.0 Context

This chapter situates DRE within India's evolving power sector. It briefly outlines the country's current energy mix and renewable trajectory, highlighting why distribution-level solutions are increasingly relevant as India scales clean energy while addressing reliability and system constraints, particularly in rural areas.

2.1 DRE Within India's Current Energy Mix

India's electricity generation capacity mix has been expanding, with renewable energy emerging as a central component of new capacity additions. As of May 31, 2026, the country's total installed capacity stood at about 542 GW, of which renewable energy (excluding large hydro) accounted for nearly 283 GW (Central Electricity Authority, 2026). All together, DRE technologies, such as rooftop solar (RTS), off-grid systems, small hydro, biomass, and waste-to-energy, account for 55 GW, or around 24%, of total renewable energy capacity (MNRE, 2026) (see Box 1 for more details on DRE in India).

Figure 1. Composition of India's installed power capacity and generation mix for fiscal year (FY) 26



Source: Authors, compiled from Central Electricity Authority, 2026; MNRE, 2026.

Box 1. DRE in India—Definition

DRE does not have a single universally accepted definition and is generally understood as small-scale renewable energy solutions deployed closer to the point of consumption. These systems commonly include solar photovoltaic (PV), solar thermal, solar lights, biomass, small hydro, etc. They are typically used for household services and productive applications such as water pumping, milling, and institutional RTS. DRE solutions can operate in stand-alone, mini- or microgrid, and grid-interactive configurations (Khalid et al., 2023).

In the Indian policy context, the Ministry of Power (MoP) defines DRE for the purpose of renewable consumption obligations as renewable energy projects not exceeding 10 MW in size, including solar installations under multiple metering configurations and other renewable energy sources notified by the central government (MNRE, 2022a).

2.2 The Role of DRE in India's Energy Transition and Net-Zero Pathway

Globally, DRE has scaled considerably in the past years, providing electricity access to an estimated 179 million people in 2021, up from 35 million in 2012, underscoring its growing role in bridging energy access gaps across rural and remote regions (Khalid et al., 2023). As costs decline and grid connectivity expands, DRE is increasingly relevant not only for access, but also for improving system performance, supporting local economic activity, and delivering wider socio-economic benefits.

In India, DRE offers a critical bridge between national clean energy ambitions and the distribution-level realities of rural power supply. The concentration of large-scale renewable capacity places increasing pressure on transmission networks (including long-distance power evacuation, grid balancing, and voltage challenges), constraints, and geographic concentration of generation. Localized renewable generation offers a complementary pathway by enabling electricity generation closer to consumption, reducing transmission and distribution (T&D) losses, and improving reliability at feeder and village levels when appropriately integrated with distribution planning (Climate Policy Initiative & Power Foundation of India, 2024). It can also support productive energy uses such as solar-powered irrigation, chillers, and dryers, while reducing reliance on costly peak procurement and fossil-based backup, contributing to emissions reduction and climate resilience.

Emerging evidence signals also highlight DRE's growing role in distribution planning. The MoP has introduced a DRE-renewable consumption obligation, mandating that distribution utilities procure nearly 5% of their electricity consumption from DRE sources by 2030, equivalent to roughly 63 GW of capacity (Ningthoujam et al., 2024). This requirement signals a shift in how DRE is positioned within the power sector, from a primarily consumer-level intervention to a resource that distribution utilities must actively integrate into planning, procurement, and system operations.

Despite these strong policy signals, DRE deployment in India has largely emerged in the form of fragmented, scheme-driven interventions, which often focus on individual consumers or specific sectors, without a coherent framework that links system sizing, grid integration, institutional roles, and financial viability at the village or feeder level (Khalid et al., 2023). As DRE becomes a mandated resource for distribution utilities, this gap between policy ambition and implementation frameworks becomes increasingly significant.

Within this evolving landscape, grid-interactive DRE configurations currently represent the most scalable and operationally viable pathway for rural energy transition. Compared to stand-alone systems, grid-connected DRE can improve system efficiency by reducing dependence on battery storage, avoiding associated replacement and maintenance costs, and enabling closer integration with existing distribution infrastructure (Jayachandran et al., 2023). The opportunities, economics, and implementation challenges associated with grid-connected systems differ significantly from those of off-grid and mini-grid models, warranting a distinct analytical and policy approach (Palit, 2024).

Accordingly, this study focuses exclusively on grid-connected systems to assess how DRE can complement existing grid infrastructure, improve the quality and reliability of rural power supply, and support scalable deployment aligned with current national and state policy priorities, utility-led planning, and regulatory frameworks.

2.3 Constraints

DRE uptake, especially in rural settings, remains constrained by upfront costs, challenges in integrating variable generation into distribution networks, and limited local technical capacity, which continue to slow its adoption. Understanding these constraints within the broader structure of India’s power sector is essential for assessing how grid-interactive DRE can be deployed in a financially viable and operationally effective manner.

The ability of DRE to function as a system-level solution is also shaped by how it is currently owned, financed, and regulated. While coordination challenges may exist for large-scale renewable energy projects as well, they become more immediate at the distribution level where generation, demand, and grid operations interact directly. Emerging business models—such as utility-led aggregation and renewable energy service company (RESCO) arrangements (MNRE, 2024c)—are being deployed across states, although their application remains uneven and context specific. Further, regulatory provisions governing tariffs, metering, grid interaction, and cost recovery have also evolved inconsistently, often without explicit consideration of village- or feeder-level system design, which limits their replicability and scale.

Most current interventions focus primarily on technology deployment on the supply side, with limited integration of village-specific demand profiles, feeder conditions, and distribution network constraints. Individual DRE solutions also face challenges in scaling in the absence of supportive distribution network conditions, such as feeder capacity and voltage stability.

2.4 Building on Flagship Programs: From deployment to system design

The government of India has introduced a range of policies, schemes, financial incentives, and regulatory measures to promote DRE at the consumer level to address persistent challenges related to rural energy access, dependence on fossil fuels and rising electricity costs. Key flagship schemes include Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyaan (PM-KUSUM) for solarizing agricultural production and Pradhan Mantri–Surya Ghar: Muft Bijli Yojana (PMSGMBY) for solar rooftop installations. See Appendix A for a longer list of key programs.

These flagship decentralized solar programs have successfully accelerated DRE adoption in India. For instance, PMSGMBY alone accounted for over 2.4 million RTS installations as of December 2025, demonstrating strong demand for decentralized clean energy when supported by a strong policy push and financial incentives (Press Information Bureau, 2025a). The Model Solar Village (MSV) component also reflects an emerging recognition of the need to move beyond individual households by targeting the solarization of village-level infrastructure. However, practical guidance on how to plan and implement integrated, grid-interactive village-scale systems remains limited.

2.4.1 Implementation Evidence From Ongoing Schemes: Coordination and equity constraints

Early implementation data of PMSGMBY highlights several structural challenges that limit the transformative potential of the existing DRE schemes:

Application-Realization Mismatch

As of December 3, 2024, while over 1.45 crore registrations under PMSGMBY were recorded, only about 26.38 lakh applications materialized, hinting at gaps between digital onboarding and project realization (Press Information Bureau, 2024).

Socio-Economic Skew in Adoption

Subsidy disbursements of INR 13,926 crore to 24.35 lakh beneficiaries as of December 2025 imply an average subsidy of ~INR 78,000, corresponding to installations of roughly 3 kW systems[2] (Press Information Bureau, 2025b). This may indicate lower participation among economically weaker households.

Cost Gaps and Associated Affordability Concerns

Field evidence indicates that even after MNRE's subsidy support, the remaining upfront contribution required to adopt RTS systems remains substantial (given the system costs range from INR 60,000 to 90,000 per kW). Similar affordability concerns are observed for PM-

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[2] As of December 9, 2025, under PMSGMBY, Central Financial Assistance (CFA) amounting to INR 13,926 crore was disbursed across 1,774,131 RTS installations (Press Information Bureau, 2025b) implying an average subsidy of ~INR 78,500 per installation, and indicating a concentration of higher-capacity systems, as the scheme's maximum subsidy is INR 78,000 for 3 kW systems.

KUSUM as well, where beneficiary contributions for solar pumps can still range up to several lakhs, depending on system size and state subsidy support (Yadav & Khanna, 2024). These residual costs disproportionately affect adoption among low-income households and small farmers, limiting wider adoption despite subsidies.

Consumer-Financed, Ownership-Driven Rollout

The RTS adoption under PMSGMBY is predominantly consumer financed either through self or supplementary loans, and the consumers eventually own these systems. Although MNRE issued operational guidelines in December 2024 to enable RESCO- and utility-led aggregation models (MNRE, 2024c) for improving affordability and scale, on-the-ground implementation remains limited. Moreover, since subsidies are disbursed only after system installation, consumers must mobilize the full upfront capital by themselves. The financing risk, system ownership, and operational responsibility, therefore, continue to rest primarily with individual consumers, constraining access for rural and low-income consumers. Similarly, financing was cited as a key barrier for small developers under PM-KUSUM, where low credit-worthiness and non-payment of bills by DISCOMs were perceived as risks, affecting access to finance and leaving projects constrained (Rahman et al., 2026).

Subsidized Electricity Reduces the Motivation for Adoption.

Some state policies offer free electricity up to defined consumption limits,[3] which may further dampen demand for RTS systems, as households may perceive little marginal benefit from self-generation beyond these thresholds. Similar trends have also been observed in the agricultural sector, where farmers with access to long-duration or free electricity supply for irrigation[4] often show limited motivation to shift toward solar-based systems, despite the availability of subsidies, since existing grid-based electricity already meets their operational needs at minimal cost (Yadav & Khanna, 2024).

Limitations of the PMSGMBY's MSV Component

Lack of information and clarity about the competition-based selection process of the potential MSVs, delays in implementation timelines, fragmented state-level coordination, and the absence of a robust framework for community-owned, bundled DRE solutions to integrate RTS, agriculture, livelihoods, and community services hinder the realization of MSVs as holistic energy systems.

2.5 The Case for a System-Level Approach

India's DRE programs have demonstrated strong proof of concept: millions of installations, growing policy commitment, and an expanding evidence base on what works. The next step

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[3] Several states provide free or heavily subsidized electricity up to a certain unit limit (units per month), primarily aiming at domestic households and farmers. Some prominent examples are Punjab (300 units), Karnataka (200 units), Telangana (200 units), Jharkhand (200 units), Delhi (200 units), Rajasthan (150 units), Bihar (125 units), Himachal Pradesh (125 units), and Tamil Nadu (100 units).

[4] The states of Andhra Pradesh, Tamil Nadu, Karnataka, Telangana, and Punjab provide free electricity to farmers.

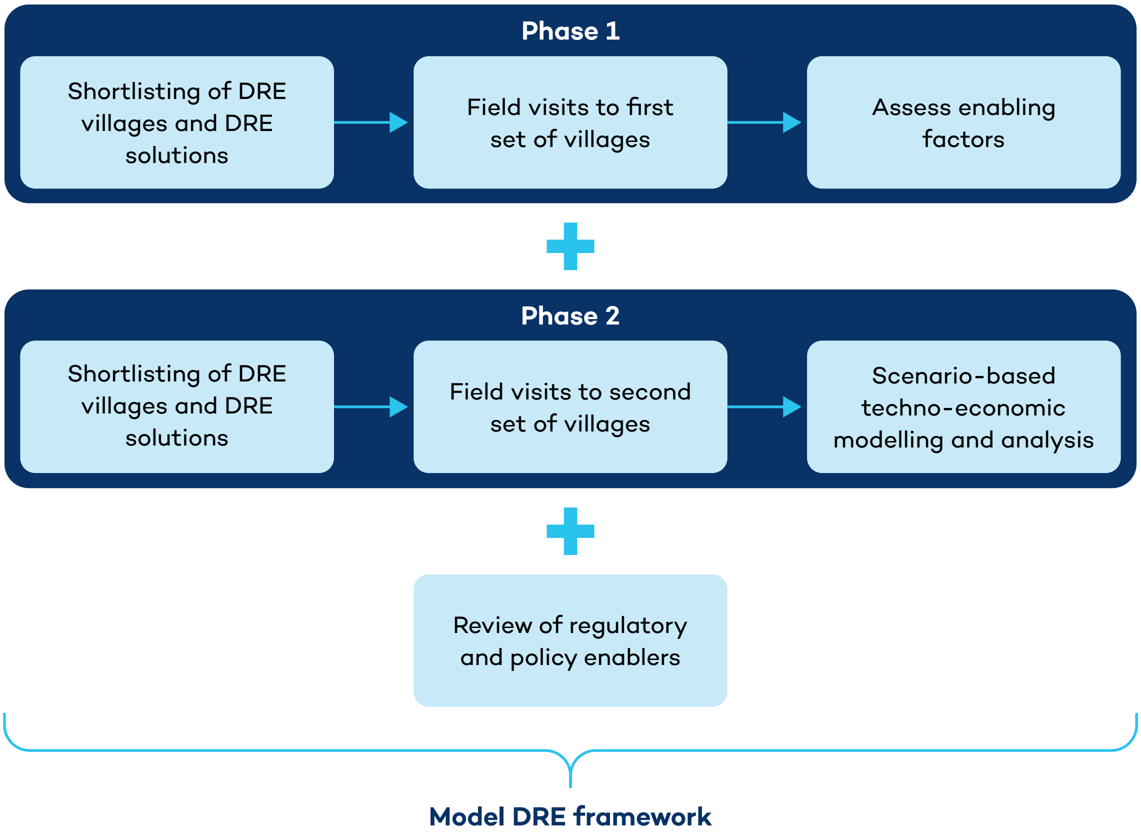
is to build on this foundation by moving from scheme-led deployment toward integrated planning that links demand, grid conditions, institutional roles, and financial viability at the village level. This shift from individual installations to coordinated, feeder-level system design is what would allow DRE to function as a reliable rural energy solution aligned with DISCOM operations and national clean energy goals.

3.0 Methodology

This chapter sets out the study's approach, describing how field insights, modelling, and policy review were brought together to develop a practical framework for planning and deploying model DRE villages.

The study adopted a two-stage approach combining field-based learning with techno-economic analysis. In the first stage, villages with established DRE practices were examined to identify key enabling factors, implementation challenges, and institutional lessons. In the second stage, a separate set of identified "model DRE villages" was visited and assessed through detailed techno-economic analysis to evaluate their DRE potential and deployment pathways. The visits combined stakeholder interactions, site observations, and review of project documentation. Insights from both stages, together with a review of existing policy and regulatory enablers, were synthesized to develop a scalable framework for planning and implementing model DRE villages.

Figure 2. Schematic of methodology adopted to create the Model DRE framework



Source: Authors.

3.1 Shortlisting the Existing DRE Villages and Field Visits

We adopted an evidence-based approach to identify Indian villages with established DRE practices, assessing 10 locations (Appendix B) through public data and an evaluation matrix. The screening considered factors like population, DRE system types, geography, project costs, and institutional and implementation aspects. This led us to shortlist Manyachiwadi (Maharashtra), Modhera (Gujarat), Kudgaon (Odisha), and Odanthurai (Tamil Nadu) for further study, ensuring diversity of contexts. Kudgaon was later excluded due to its microgrid focus, as the study concentrates on grid-connected systems. We also dropped Modhera due to limited responsiveness from the state-level stakeholders.

The field visits captured key project attributes, such as operational timelines, installed capacity, technology configurations, and financial structuring. The fieldwork also documented good practices related to energy access patterns, institutional arrangements, financing and O&M models, the role of government, and community engagement. These insights informed the qualitative understanding of how DRE projects are implemented and operated at the village level.

3.2 Shortlisting Potential Model DRE Villages and Techno-Economic Analysis

Following the initial field visits, additional engagements were undertaken, including in Assam, to identify villages suitable for detailed techno-economic assessment as potential model DRE villages. These engagements aimed to assess the willingness of village stakeholders and utilities to participate, share relevant data, and support field-level studies, which were critical for refining the methodology for developing MSVs. Based on recommendations from state stakeholders, Hiware Bazar and Anandvan in Maharashtra, and Jagiroad and Bamun Sualkuchi in Assam were shortlisted and ultimately consolidated around Hiware Bazar and Bamun Sualkuchi. Another round of field visits focused on collecting detailed feeder-level energy and load data, village demographics collection, and spatial inspection to inform the techno-economic analysis.

Based on the data collected through field visits and secondary research, we undertook an indicative techno-economic assessment comprising the following steps:

1. **Data Validation**
Checking data completeness and consistency, identifying gaps and risks

2. **Demand Assessment to Establish Baseline**
Analyzing feeder- and substation-level load profiles, reviewing category-wise energy sales, tariffs and subsidies, estimating feeder energy input and losses, and projecting category-wise demand using observed trends and village context. This step established a baseline of current consumption patterns and supply conditions for each village.

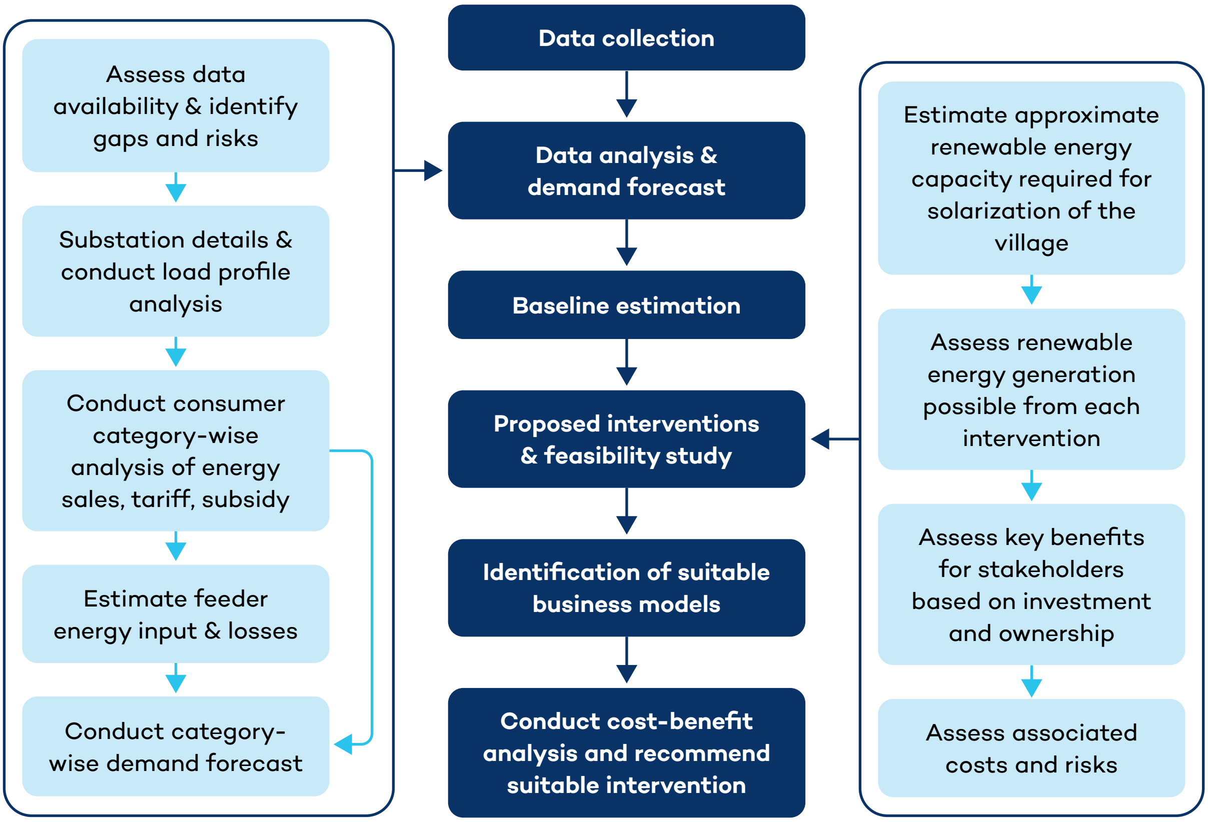
3. **Feasibility Assessment**
Based on the baseline, we assessed indicative DRE configurations for meeting village demand. This included estimating the required DRE capacity, expected annual generation under

different configurations, indicative storage requirements where relevant, the distribution of costs and benefits, and alternative implementation pathways.

The assessment was conducted using an Excel-based modelling tool developed for this study, which estimates village-level DRE system requirements and evaluates financial metrics across scenarios.

The model incorporates key parameters, such as technology capital costs, applicable subsidy provisions, APPC benchmarks, and battery integration costs (where applicable). We then computed scenario-level outputs such as levelized cost of electricity (LCOE) and indicative payback periods to compare alternative configurations aligned with the village's load profile and implementation context (Figure 3). A consolidated list of modelling assumptions and parameter values used for Bamun Sualkuchi and Hiware Bazar is provided in Appendix C (Table C1) to ensure transparency and replicability of results.

Figure 3. Methodological framework for assessing village-level DRE potential and feasibility



Source: Authors.

3.3 Review of Policy and Regulatory Enablers

We also undertook a review of DRE-related policies and regulatory frameworks in Maharashtra and Assam to identify key regulatory enablers and barriers influencing DRE deployment (Appendix D). The review covered incentive structures, DISCOM preparedness, financing mechanisms, net metering provisions, ownership models, and institutional coordination.

3.4 Scope and Limitations

The study focused only on the grid-connected DRE systems and does not assess off-grid or microgrid configurations. The techno-economic analysis was limited to two village case studies and was intended to provide insights rather than a blueprint for all villages. Further, the modelling relies on available feeder-level data and simplified assumptions and does not simulate detailed power system operations, balancing costs, or distribution network upgrades. The analysis focuses on solar PV and battery storage and does not assess other DRE technologies such as biomass, wind, or small hydro.

The study also does not quantify ownership models, financing structures, alternative subsidy allocation, or the full operational value of storage. Finally, the analytical tools developed in this study are intended to be adaptable to other contexts, but further analysis would be required before applying the results to additional villages or state-level planning.

4.0 Results

This chapter presents key findings from fieldwork, modelling, stakeholder consultations, and policy review.

4.1 Case Studies: Insights from successful DRE villages

This section presents qualitative insights from early adopters of DRE (Manyachiwadi and Odanthurai), highlighting leadership, governance, financing, O&M practices, and institutional conditions that shape the success of DRE projects.

The two villages represent mature examples of long-running DRE deployment shaped by strong local institutions, effective use of government schemes, and community participation. Manyachiwadi demonstrates how grid-connected RTS and shared infrastructure can accelerate village-level adoption, while Odanthurai illustrates how long-term experimentation with diverse DRE technologies can build institutional capability and energy self-reliance. Analysis suggests that successful DRE deployment depends not only on installing renewable energy assets but also on how projects are planned, financed, governed, and maintained over time. Table 1 summarizes the key characteristics of the two villages and provides context for the enabling factors and constraints discussed in the following section.

Table 1. Highlights from the field visits to the DRE villages in Manyachiwadi and Odanthurai

	Manyachiwadi, Maharashtra	**Odanthurai, Tamil Nadu**
Location	Satara district, Maharashtra	Coimbatore district, Tamil Nadu
Population	600 (~110 households)	~8,500 (1,500–2,000 households)
Recognition	First declared "Solar Village" of Maharashtra (Akashvani News, 2024)	Super Panchayat—India's first local body to set up a windmill (Saravanan M, 2016) Early adopter of DRE
DRE interventions since	2024	2000
DRE technologies	• RTS: 101 households with 1 kW systems (grid-connected under PMSGMBY) • 25 solar streetlights • 7 kW Solar pump for non-agricultural usage • 5 kW RTS for Gram Panchayat • 1 kW RTS for local school and temple • Biogas units for cooking • Upcoming: Solar water heating	• 2002–2003: 40 solar streetlamps • 2002: 9 kW biomass gasifier with woodchips as fuel • 2003-2004: Community-scale biogas plant using nightsoil • 2006–present: 350 kW wind energy generator (WEG). Power purchase agreement (PPA) with the DISCOM • 2011–2012: Household solar kits of 200 W panels for lighting

	Manyachiwadi, Maharashtra	**Odanthurai, Tamil Nadu**
Schemes utilized	PMSGMBY (MNRE, 2024d)	CM Solar Powered Green House scheme (Government of Tamil Nadu, 2011)
Financials	• Gram Panchayat savings to subsidize household RTS installations • Central subsidy of INR 30,000 from PMSGY	• Panchayat savings • Bank loan for WEG of INR 1.15 crore @8.5% interest rate per annum
Noteworthy	• O&M: 3-year annual maintenance contract (AMC) with solar installer *SunMitra* • Leadership and local governance demonstrated by Panchayat-driven initiatives • Strong community support: Households without viable rooftops were supported by neighbours who offered theirs	• DRE adoption was driven by rising electricity costs at the drinking water plant, prompting the Panchayat to invest in local energy solutions for long-term benefits. • Leadership and local governance demonstrated by Panchayat-driven initiatives • AMC for WEG • Community-based maintenance models for household solar kits and biogas systems
Challenges	• Land constraints • Relatively higher system costs from the vendor (INR 92,000/kW compared to a benchmark cost of INR 60,000 per kW) • Loss of RTS generation due to grid unavailability	• Tariff disbursement: Delays in payments from the DISCOM, leading to financial stress for the project • Governance gaps: Absence of formal leadership poses risks in decision making • Technical setbacks: Rising fuel costs and a lack of proper AMC led the projects to eventually fail.
Others	• EV adoption: Six to seven EVs, including solar-charged garbage collection vehicle • EV charging station	

Source: Authors.

4.1.1 Key Enabling Factors and Implementation Constraints

The two villages represent mature examples of long-running DRE deployment shaped by strong local institutions, effective use of government schemes, and community participation. Manyachiwadi demonstrates how grid-connected RTS and shared infrastructure can accelerate village-level adoption, while Odanthurai illustrates how long-term experimentation with diverse DRE technologies can build institutional capability and energy self-reliance.

These cases provide practical insights into enabling conditions, replicable practices, and systemic gaps relevant for scaling model DRE villages.

The two villages provide practical insights into enabling conditions, replicable practices, and systemic gaps relevant for scaling model DRE villages:

Elements That Worked for the Two Case Studies With Replication Potential

Shared Infrastructure and Community Trust

Land constraints remain a major challenge for both household and community-scale systems. Limited roof space and competing land uses often restrict project expansion.

In Manyachiwadi, households without viable rooftops were supported by neighbours, who offered theirs to host the panels, reflecting a strong sense of community. Odanthurai's biogas plant and Chief Minister's greenhouse solar kit installations promoted community-based maintenance models, where the onus for both utilization and maintenance lay with the user, fostering local responsibility and ownership.

Community-owned or shared infrastructure models, such as collective rooftops utilizing public village plots, can help overcome space limitations while ensuring inclusive access to clean energy.

✓ Inclusive models, such as shared community and institutional assets, encourage local participation, build strong peer support, and create a sense of ownership. This fosters collective responsibility and trust and helps sustain DRE initiatives.

Leveraging Enabling Policy Frameworks Through Awareness and Proactiveness

In Manyachiwadi, the implementation of grid-connected RTS systems was facilitated by the policy support and central financial assistance provided under the PMSGMBY (MNRE, 2024d). Similarly, Odanthurai leveraged state-led green initiatives, such as the Chief Minister's Green House Scheme (Government of TamilNadu, 2011), to promote household-level solar adoption. These cases highlight that effective alignment of local initiatives with existing policy and subsidy frameworks—coupled with the capacity to navigate and utilize them effectively—is critical to lay the ground for DRE successes.

✓ Awareness, institutional capacity, and proactive use of available schemes are key to advancing village welfare while simultaneously achieving renewable energy goals.

Localized Key Enablers in the Case Study Villages

Proactive Local-Level Leadership

At the core of both the villages' transformation is visionary local leadership. Over the past decade, Manyachiwadi's Sarpanch's focus on sustainability has earned the village multiple state and national awards, channelling INR 6–7 crore into green and inclusive development, whereas Odanthurai's progress in DRE owes much to the foresight of its former Panchayat President, Shanmugam Rangasamy, whose push for energy self-sufficiency began well before renewables became mainstream. His proactive governance attracted state collaboration and recognition, positioning the village as a model for innovation. Both cases highlight how transparent, future-focused leadership can drive momentum and lasting community-led transformation. However, scaling DRE initiatives across villages cannot rely solely on the presence of strong individual leaders, nor can it guarantee continuity beyond a leader's tenure. To ensure continuity beyond individual leaders, project implementation should be institutionalized.

✓ Establishing standardized operating procedures as a cornerstone for implementation, with village energy committees supporting execution through clearly defined roles and responsibilities, can help embed DRE initiatives more resiliently and make project implementation system leadership-independent and sustainable.

Financial Resources Available With the Gram Panchayat to Cover the High Upfront Cost of DRE

In both cases, the Gram Panchayat utilized its savings to subsidize DRE installations. In Manyachiwadi, it was reported that an RTS system cost INR 92,000/kW: with a central subsidy, it was only INR 30,000/kW, and the Manyachiwadi Panchayat provided INR 55,000 (out of its own past savings). This left villagers to pay only INR 7,000 of the rest. Odanthurai's Panchayat, despite its limited resources, managed funding wholly through its own savings and loans. For instance, the INR 1.55 crore wind energy project was funded via INR 40 lakh Panchayat contribution and an INR 1.15 crore bank loan at an 8.5% interest rate. All of the projects were provided to the beneficiaries without them having to bear any additional costs. These villages demonstrated how financial autonomy at the village level can bridge policy implementation gaps.

High upfront system costs remain a major barrier to scaling DRE adoption in rural areas. Transparent cost breakdowns and standardized procurement processes are essential to ensure cost efficiency and accountability.

✓ Establishing dedicated local funding mechanisms, such as village-level energy funds or revolving community accounts, underpinned with sound financial management, can help bridge last-mile financing gaps and reduce dependence on external subsidies.

As demonstrated by Odanthurai's experience, where generation revenues from the wind plant itself were sufficient to repay the loan.

✓ Concessional loans or interest subventions (which can be classified as additional subsidies) can make projects more attractive to both developers and local institutions. Well-structured financial models can ensure long-term viability even in the absence of state subsidies.

History of Implementing Innovative DRE Initiatives

Odanthurai's renewable energy journey took a phased, experimental approach. Beginning in the early 2000s, the village installed solar streetlights, biomass gasifiers, biogas plants, and later, a 350 kW WEG, which is one of the first Panchayat-owned projects of its kind. These initiatives were primarily funded through Panchayat savings, government support, and community participation, each addressing local energy needs while testing new technologies. Although some systems, like the biogas and biomass units, faced operational or financial hurdles, they provided valuable lessons for scaling DRE solutions.

✓ This history of experimentation, marked by both successes and setbacks, played a critical role in strengthening the Panchayat's ability to learn from earlier challenges, assess risks, and refine implementation strategies, building institutional confidence and progressively adopting novel DRE technologies over time.

Constraints to Solve That Are Beyond the Purview of Village-Level Control

Loss of RTS Generation When Grid Is Unavailable

Villages continue to face erratic supplies due to frequent outages and poor rural grid infrastructure. Produced solar power cannot always be exported to the grid, causing generation losses even during peak sunlight hours, translating to direct financial losses. Stable and reliable grid infrastructure is fundamental to realizing the full benefits of solarization.

✓ Strengthening rural feeders, ensuring daytime power availability to export excess solar generation, can enhance grid reliability and maximize utilization of DRE systems; additionally, integrating storage and incentivizing self-consumption can help address local reliability constraints and improve system resilience at the village level.

Low Tariff Lock-In and Disbursement Delays

Odanthurai Gram Panchayat's PPA with the DISCOM was fixed at INR 2.70/unit (valid up to 2026). Over time, although they were able to recover their initial investment through generation alone,[5] Panchayat representatives have described this locked-in tariff as inadequate compared to prevailing rates, noting that limited tariff advisory support at the time of signing constrained their ability to anticipate longer-term tariff trajectories and negotiate more favourable terms.

✓ Financial sustainability of village-owned DRE assets depends on a viable tariff design that protects routine O&M and operating cash flows.

Payment Issues

In Odanthurai, the more persistent challenge was delayed or irregular disbursements of funds by the DISCOM, which created cash-flow stress and also affected timely O&M spending even though the Panchayat had already recovered its initial investment. Delayed disbursement of funds or subsidies (for example, from the DISCOM) can strain the project finances and cash-flow stability, eroding stakeholder confidence and disrupting project implementation efficiency.

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[5] As per the Panchayat records, they received, the WEG generated 9.1 million units (MU) of energy over 18 years, receiving a total of INR 236.8 lakhs from the discom. Thus, the Panchayat earned roughly INR 13 lakhs every year from wind generation alone.

✓ Predictable and timely financial flows from central and state governments, DISCOMs to local bodies are crucial to sustain momentum and project viability. Introducing automatic payment mechanisms or escrow-based disbursement systems can reduce delays, ensure liquidity for maintenance, and improve trust among vendors, financiers, and communities.

Technical Setbacks

In Odanthurai, projects like biomass and biogas faced operational challenges and technical setbacks over time. Rising biomass fuel costs affected the financial viability of the biomass gasifier, while gas quality issues led to inconsistent performance and increased maintenance requirements for the biogas plant. In addition, the absence of O&M arrangements meant that system faults were not identified and addressed, ultimately leading to reduced utilization or shutdown.

✓ These experiences underscore the importance of robust AMC frameworks, clear accountability, and technical support for system upkeep, to ensure the long-term reliability and sustainability of DRE installations.

Limited Productive-Use Integration

The DRE systems primarily served lighting and basic household consumption, with minimal linkage to productive or income-generating uses that could enhance livelihood benefits.

✓ Integrating energy access facilitated by DRE with productive livelihood uses such as irrigation, agro-processing, cold storage, or water purification can create sustained economic and social benefits while improving system utilization and returns on investment.

4.2 Typologies of Village Load and Potential of DRE

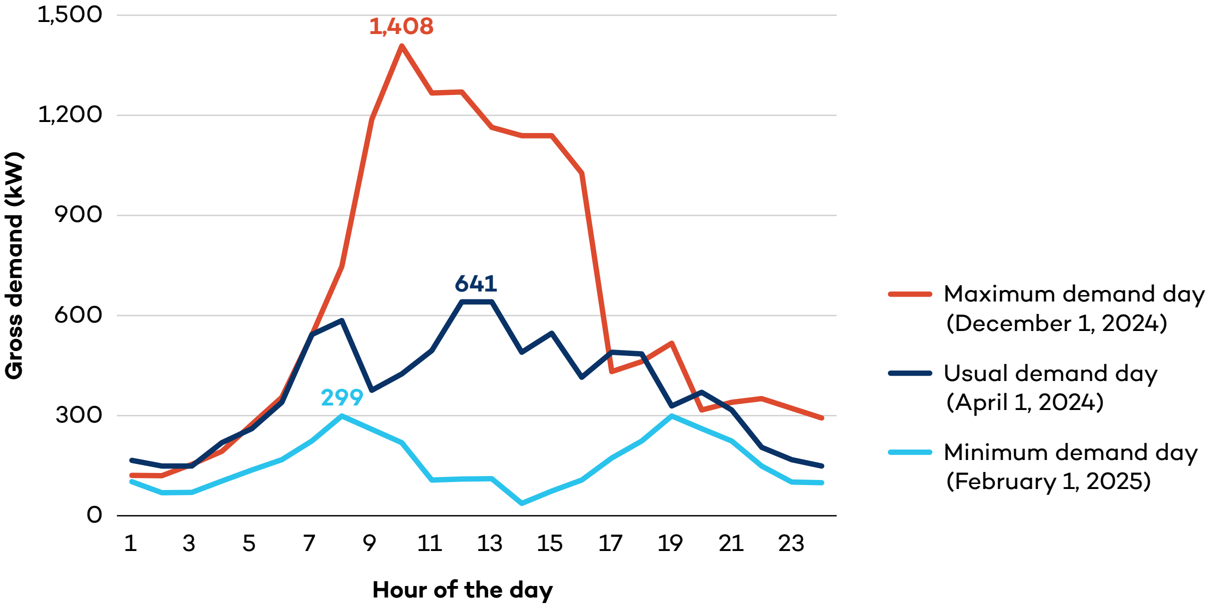
This section provides a technical and quantitative assessment of Hiware Bazar (in Maharashtra) and Bamun Sualkuchi (in Assam), to examine how village load typologies shape DRE system design and sizing. The analysis below focuses on how DRE systems can be planned and configured under different demand profiles. Demographic and socio-economic profiles of the two case study villages can be found in Appendix E.

Hiware Bazar's consumption is mostly agricultural and peaks during the day only in the irrigation seasons (primarily from September to January). Bamun Sualkuchi's demand is largely residential and peaks during the evening. Understanding these typologies is important for designing practical DRE systems that deliver reliable and affordable power while integrating smoothly with local distribution networks and strengthening grid stability.

4.2.1 Load Curve Analysis

We collected hourly load profile data across randomly selected days from each week of FY 2024–25 for both villages.[6] Figures 4 and 5 show the hourly demand on three representative days with minimum, average, and maximum demand as seen across the year. In Hiware Bazar, the hourly load ranges from about 37 kW during the lean irrigation months (February) to 1.4 MW during the peak irrigation season (December). In Bamun Sualkuchi, it varies between 112 kW (March) and 516 kW (October), with a yearly average of around 250 kW.

Figure 4. Daily load curves for Hiware Bazar for three days from different seasons



Note: The minimum, usual, and maximum load curves are derived from available sampled days only (120 days for Hiware Bazar). The “usual” demand curve for April 1, 2024, only reflects the average of sampled data set and may not be interpreted as the annual average daily demand. Same is applicable for the load curves shown in Figure 5 (for Bamun Sualkuchi) as well.

Source: Authors’ analysis based on load curve data received from the local DISCOM authorities.

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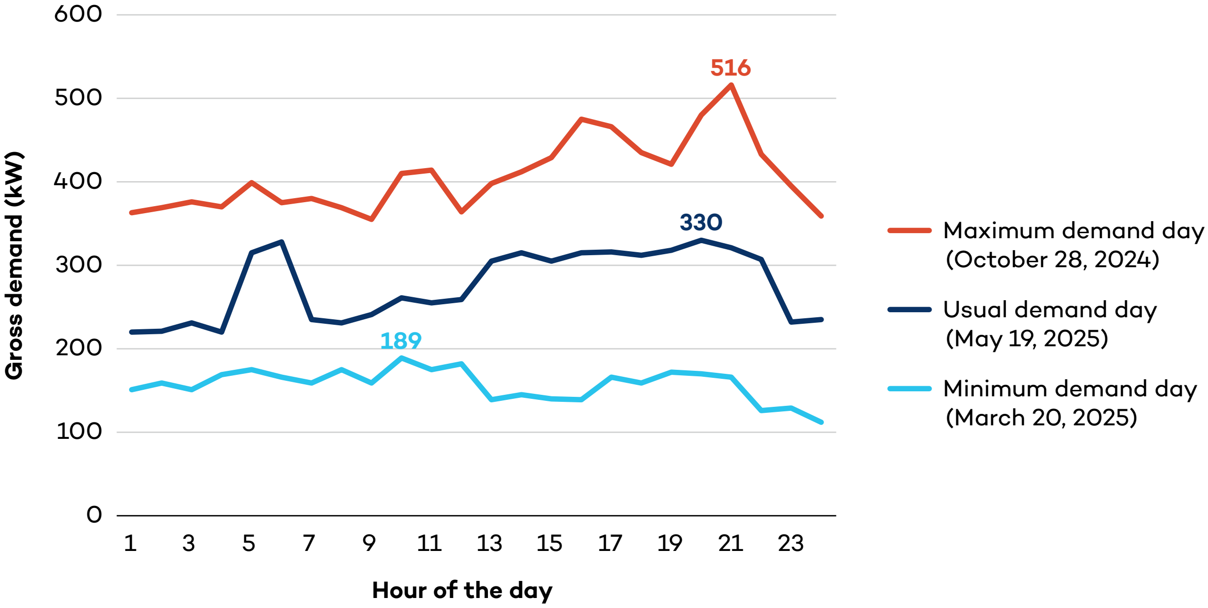
[6] We collected sample data for 120 days for Hiware Bazar and 84 days for Bamun Sualkuchi for the load curve analysis.

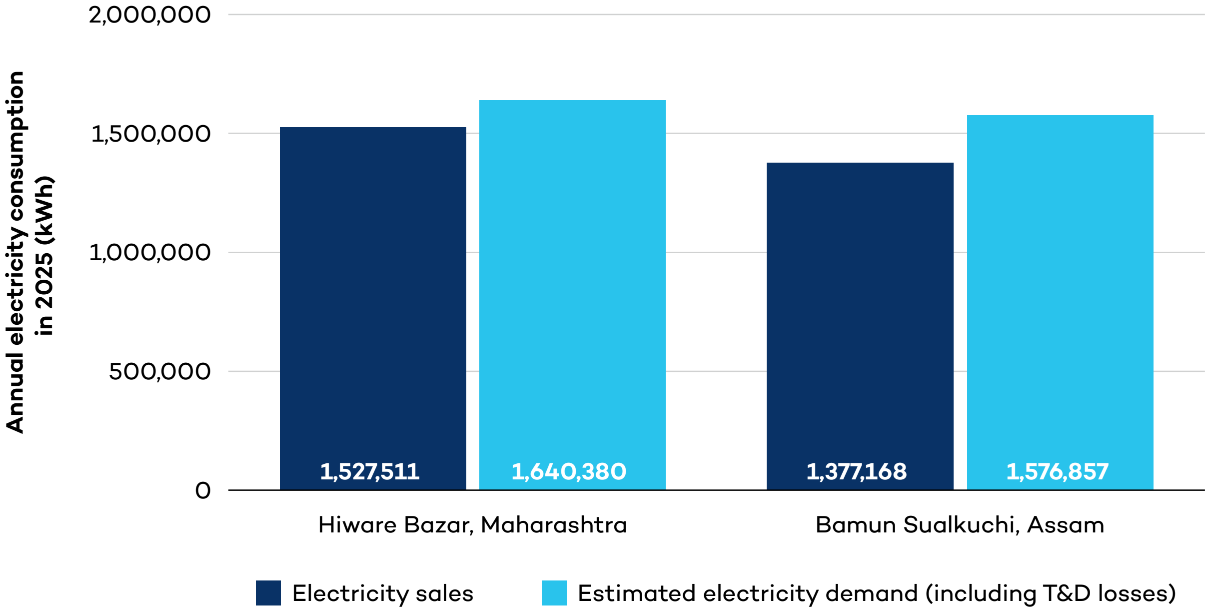
Figure 5. Daily load curves for Bamun Sualkuchi across three days from different seasons



Note: The minimum, usual, and maximum load curves are derived from available sampled days only (84 days for Bamun Sualkuchi). The "usual" demand curve for May 19, 2024, only reflects the average of sampled dataset and may not be interpreted as the annual average daily demand. In fact, total annual electricity sales in Hiware Bazar (1,527 MWh) was only 11% higher than Bamun Sualkuchi (1,377 MWh) in FY 2024-25, whereas the average demand curve shown above shows much higher difference.

Source: Authors' analysis based on load curve data received from the local DISCOM authorities.

Figure 6. Annual electricity demand for both Hiware Bazar and Bamun Sualkuchi



Source: Authors.

Apart from the load profile data, we also collected annual electricity sales data for FY 2024–25 for both villages and applied state-specific T&D loss factors (7.3% for Hiware Bazar in Maharashtra and 14.5% for Bamun Sualkuchi in Assam) to estimate the annual electricity requirement (i.e., the electricity that would need to be generated or procured to serve these villages). In FY 2024–25, Hiware Bazar consumed approximately 1,527 MWh of electricity, while Bamun Sualkuchi consumed about 1,377 MWh. After accounting for T&D losses, we estimate the annual electricity requirement at around 1,640 MWh for Hiware Bazar and 1,577 MWh for Bamun Sualkuchi (Figure 6).

4.2.2 Techno-Economic Analysis for Hiware Bazar Village

To assess the appropriate system size for Hiware Bazar, the analysis disaggregates village electricity demand into agricultural and non-agricultural components. Hiware Bazar's annual agricultural electricity use, estimated at 1,421,017 kWh in FY 2024-25, accounts for ~87% of its total demand (Table 2). The village has a dedicated 11 kV agricultural feeder (the Mumbadevi Gaothan feeder) supplying electricity exclusively to agricultural consumers.

Maharashtra plans to solarize dedicated agricultural feeders under its Mukhya Mantri Saur Krushi Vahini Yojana (MSKVY) 2.0 scheme,[7] in conjunction with the PM-KUSUM Component C (Feeder-Level Solarization [FLS]), which involves installing decentralized, ground-mounted solar power plants near substations to provide reliable daytime power to farmers. Under this scheme, the distribution utility undertakes competitive procurement, with private developers responsible for building, owning, and operating the plant under a PPA.

We project agricultural demand over the next 5-year period. Applying a conservative annual growth rate of 1% to agricultural consumption yields an estimated requirement of 1,493,503 kWh by 2029–30. After adjusting for deration,[8] the required installed capacity for the feeder-level ground-mounted solar plant is estimated to be approximately 980 kW, assuming a capacity utilization factor (CUF) of 18% for ground-mounted PV in Maharashtra (Table 2).

FLS ensures and improves the quality of the reliable power supply by aligning irrigation demand with daytime solar generation, thereby enabling farmers to receive more dependable daytime electricity for agricultural purposes. In addition, decentralized generation closer to consumption points also lowers T&D losses and defers network upgrades, leading to direct savings and reducing power subsidy burdens for both the DISCOMs and states (Rahman et al., 2026). Supporting this potential, the Gram Panchayat has identified approximately 10 acres of Panchayat-owned land within the village premises for the proposed ground-mounted solar installation, indicating that land availability is not expected to be a binding constraint for FLS.

The remaining non-agricultural demand (comprising households, shops, and public institutions) accounts for a relatively small share of total electricity consumption. This demand can be met either through RTS installations (on Panchayat buildings, households, and other

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[7] Launched in 2017, the Government of Maharashtra's MSKVY scheme promotes distributed renewable energy for the agriculture sector, with MSKVY 2.0 (approved in May 2023) now targeting 16,000 MW of solar capacity and 100% daytime electricity supply to agricultural pump consumers through feeder solarization across the state.

[8] A downward adjustment to expected solar PV output to reflect real-world performance losses over time.

public facilities), a small ground-mounted system, or a combination of both (along with storage solutions to cater to the evening demand), depending on village-specific considerations, such as land availability, institutional preferences, the desired degree of decentralization, and ease of grid integration. Using a medium-term planning horizon consistent with RTS deployment, the analysis estimates that meeting projected non-agricultural electricity demand by FY 2029–30 would require approximately 151 kW of solar capacity under a ground-mounted configuration, with the equivalent capacity increasing (to ~182 kW) if the same demand were to be met entirely through rooftop systems due to lower CUFs.[9]

Table 2. Projected agricultural electricity demand and required feeder-level solar PV capacity in Hiware Bazar

Estimated annual demand in FY 2024–25 (including T&D losses of 7.3%) (in kWh) (A)	1,421,017
Estimated annual demand in FY 2029-30 (assuming 1% annual growth) (in kWh) (B=A*(1.01^5))	1,493,503
Estimated annual solar generation loss in FY 2029–30 (assuming 0.7% Year on Year PV degradation) (in kWh) (C=B*0.007*5)	52,273
Estimated annual generation required from solar PV in 2029–30 (in kWh) (D=B+C)	1,545,776
CUF (for ground-mounted solar PV systems for irrigation) (E)	18%
Required PV capacity in 2029–30 (in kW) (F=D/(E*8760))	~980

Source: Authors.

However, designing the system to remain adequate over the next 5-year period also implies a degree of oversizing in the near term. The proposed 980 kW ground-mounted solar plant is expected to generate approximately 1.55 GWh of electricity in its first year. This exceeds Hiware Bazar's current total annual electricity demand of around 1.53 GWh. Even if we account for T&D losses (which would be significantly reduced if the village has its own

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[9] The sizing of solar PV capacity for non-agricultural consumers in Hiware Bazar also follows a medium-term planning horizon, consistent with RTS deployment under schemes such as PMSGMBY. Non-agricultural electricity consumption is estimated at 219,363 kWh in FY 2024–25 (including T&D losses). Applying a 1% annual growth rate yields a projected demand of 230,552 kWh by FY 2029–30. After accounting for a 0.7% annual PV degradation over the 5-year period, the corresponding annual solar generation requirement is estimated at approximately 238,621 kWh. If this demand were to be met entirely through RTS (a typical CUF of 15%), the required installed capacity would be ~182 kW (to be deployed across Panchayat buildings and other suitable rooftops). If instead the same demand were to be met entirely through a ground-mounted system with a higher utilization factor of 18%, the required installed capacity would fall to ~151 kW.

DRE setup), it would still be enough to meet 95% of the village's annual electricity demand. Additionally, the agricultural electricity demand in Hiware Bazar is highly seasonal. With a relatively low share of non-agricultural consumption, it is crucial to determine whether separate capacity is required.

We assessed the adequacy of the proposed system using high-frequency load curve data collected for 120 sampled days in FY 2024–25 (10 days per month, spanning at least 2–3 days across each week). As highlighted in the notes below Figures 4 and 5, these sampled days capture seasonal variation across the year but do not represent every day of operation. We compared these load profiles against the simulated generation profile of a 980 kW ground-mounted solar plant for Maharashtra using PVsyst.

The proposed 980 kW system is sized primarily to meet the village's projected annual agricultural electricity demand. While annual generation from the system is sufficient to meet most of Hiware Bazar's annual electricity requirement, this does not imply that generation exceeds demand during every hour of the year. In particular, winter months exhibit much higher peak demand, exceeding 1,400 kW, on December 1, 2024, and during this time, solar generation (from a 980 kW ground-mounted solar plant) would be insufficient to meet the village's demand, which would then require grid support or storage.

However, significant surplus generation was projected on 93 out of 120 days (~78% of the days) with an average daily surplus of about 1,926 kWh (median ~1,840 kWh).[10] Surplus occurs on all sampled days in 6 months when there is no irrigation (February to July), with the highest surplus observed in February and March (average ~3,600 kWh). These results indicate that adding further solar PV capacity for residential consumers would likely intensify surplus injections and reverse power flows during large parts of the year, increasing grid-management requirements and associated costs for the DISCOM.

4.2.2.1 Battery Energy Storage to Manage Surplus and Peak Demand in Hiware Bazar

Given the extent of surplus generation and the operational implications of sustained reverse power flows, the analysis examines whether limited battery storage could help manage intra-day imbalances, particularly by shifting excess daytime generation to morning and evening peak periods. In principle, if farmers shift irrigation demand further into daytime hours, evening demand would largely reflect residential consumption, and storage could both absorb part of the daytime surplus and reduce evening imports. Available load curves are not disaggregated by consumer category; therefore, our analysis used the consumption during the peak 4-hour periods (7–9 a.m. and 7–9 p.m.) in the non-irrigation season as a proxy for residential demand, during which average demand is around 350 kW.

We first tested a 350 kW/1,400 kWh (4-hour) battery configuration. The battery was assumed to store excess daytime solar generation and discharge it during evening peak-demand periods. This reduced average grid imports during the 4 peak hours from ~350 kW to ~130 kW (over

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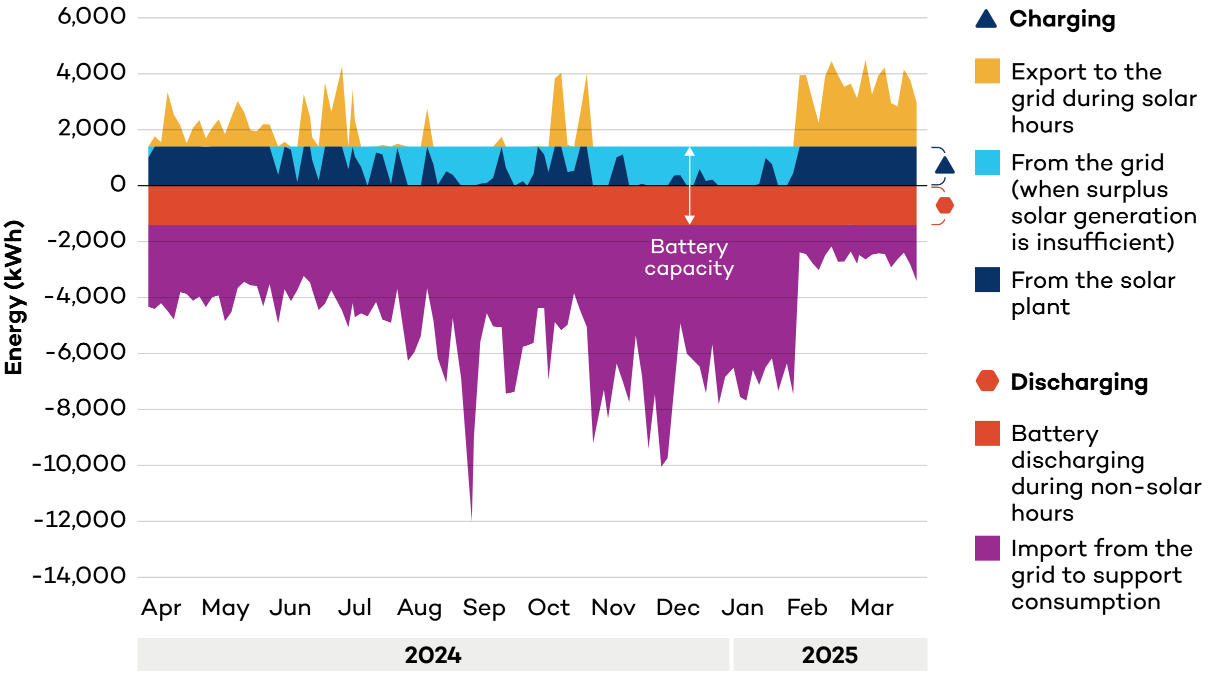
[10] For this entire techno-economic analysis presented in Section 4.2, "surplus generation" refers to the periods during which the instantaneous electricity generation from the solar plant(s) exceeds the village's electricity demand, resulting in net export to the grid during that particular time period.

60% reduction). Further, of the 93 sampled days with daytime solar surplus (in the no-storage case), the battery had sufficient capacity to absorb and later discharge all surplus energy on 33 days. Consequently, the number of days with net exports to the grid fell from 93 to 60. Nevertheless, significant surplus exports still remained on the other 60 days, averaging approximately 1,378 kWh/day, indicating that the battery only partially mitigates reverse power flows (Figure 7).

Figure 7. Exploring battery energy storage system (BESS) for the village of Hiware Bazar (350 kW/1,400 kWh)

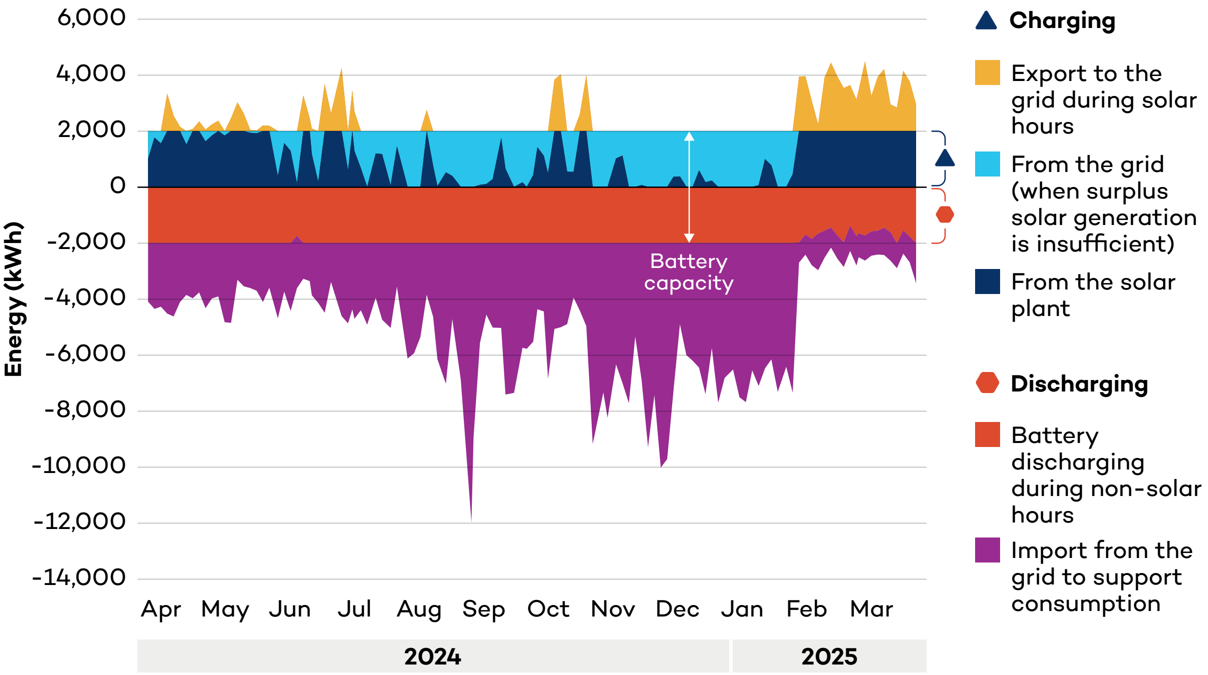


Source: Authors.

We then tested a larger 500 kW/2,000 kWh configuration, which further reduced peak-hour demand (to about 68 kW, over 80% reduction), and surplus days to 48 (from 78% to 40%). However, average reverse power flow remained high at about 1,113 kWh (around a 40% reduction relative to the no-storage case). In addition, seasonal dynamics constrain battery operation: during peak irrigation months (October to January), limited surplus availability reduces the ability to recharge from solar, while in February and March, lower demand increases the likelihood of incomplete discharge (Figure 8).

Therefore, the 350 kW/1,400 kWh configuration appears to be a more reasonable starting point for Hiware Bazar, while recognizing that the battery may still rely on grid charging during certain periods and that the system remains dependent on grid support.

Figure 8. Exploring BESS for the village of Hiware Bazar (500 kW/2,000 kWh)



Source: Authors.

Overall, the results indicate that for villages with a load typology similar to Hiware Bazar (which have highly seasonal agricultural demand and extended periods of surplus generation), distributed village-level batteries may not be the most efficient balancing solution across the year. Instead, it may be more appropriate to plan storage at a higher level in the network, such as at an upstream substation where the feeder is aggregated with a more diverse mix of loads (including commercial and industrial demand). Such aggregation can improve storage utilization, reduce seasonal mismatch risks, and support more efficient system operation than storage located at a village-serving distribution substation that primarily pools similar rural loads. Periodic reassessment of demand growth, storage requirements, and evolving grid conditions will also remain important to inform any future adjustments to system design.

4.2.3 Techno-Economic Analysis for Bamun Sualkuchi Village

Bamun Sualkuchi has a different energy profile, with no agricultural consumers. About 84% of electricity consumption comes from domestic users who also operate small weaving units from their homes. Energy use is thus linked to household routines, with low consumption during the day and a sharp rise after sunset when lighting, fans, and looms run simultaneously.

In this case, a configuration that relies on 70% ground-mounted capacity and 30% rooftop (both grid-connected) seems more feasible. As per the data from our field visit, there are a total of 2,706 consumers in Bamun Sualkuchi who belong to eight different categories (as shown in Table 3), and their overall connected load is 3,658 kVA, or 3,603 kW. Accounting for the T&D losses and annual growth rate of 1.83%, the annual electricity requirement for Bamun Sualkuchi would be 1,726,572 kWh in 2029–30.

Table 3. Annual consumption for categories of consumers and required generation in Bamun Sualkuchi village

Consumer categories	No. of consumers	Connected load (in kW)	Generation required in 2024–25 after accounting for T&D losses (kWh)	Annual generation required in 2029–30 (kWh)	Generation required from RTS (assuming 30% of it will be met by RTS) (in kWh)
	A	B	C	D	E=D×0.3
Jeevan Dhara	77	31	4,356	4,769	1,431
Domestic A	2,413	3048	1,328,301	1,454,416	436,325
Domestic B (5-30 kW)	28	192	89,983	98,527	29,558
Commercial load (0.5 to 30 kW)	99	160	107,433	117,633	35,290
General load up to 30 kW (non-commercial & non-domestic)	45	79	23,497	25,727	7,718
General load up to 30 kW (govt. schools)	20	28	1,924	2,106	632
Public lighting	12	13	19,277	21,107	6,332
Temporary	12	54	2,087	2,286	686
Total	**2,706**	**3603**	**1,576,857**	**1,726,572**	**517,971**

Source: Authors.

We first determine the system size that would meet 70% of their overall load from ground-mounted solar (1,208,600 kWh out of 1,726,572 kWh), and follow a methodology similar to that of Hiware Bazar in Table 2. The estimated capacity was 900 kW. Similarly, we estimate the RTS capacity at 418 kW, which will meet ~30% of the overall electricity requirement (details of the methodology are in Table 4). This gives us a total solar PV capacity of 1,318 kW, which will generate a total of 1.8 GWh of electricity, around 7% more than the village's requirements. Since the village has productive uses, it may see an increase in demand with the growing marketability of its products.

Table 4. Sizing of renewable energy capacity for different categories of consumers in Bamun Sualkuchi village

	Domestic A	Domestic B	Commercial	General load up to 30 kW	Public lighting
Estimated annual demand in FY 2029–30 (assuming 1.83% annual growth) (in kWh) (E) (Column E from Table 3)	436,325	29,558	35,290	7,718	6,332
Estimated annual solar generation loss in FY 2029-30 (assuming 0.7% year-on-year PV degradation) (in kWh) (F=G×0.007×5)	15,271	1,035	1,235	270	222
Estimated annual generation required from solar PV in 2029–30 (in kWh) (G=E+F)	451,596	30,593	36,525	7,988	6,554
No. of consumers (A) (Column A from Table 3)	2,413	28	99	45	12
Average annual consumption needed for every consumer (kWh) (H=G/A)	187	1,093	369	178	546
Average capacity of RTS required for every consumer, assuming 15% CUF (in kW) (I=H/(0.15×8,760))	0.14	0.83	0.28	0.14	0.42
RTS capacity (in kW) for each consumer (J)[11]	0.5	1	1	1	1
Total RTS (in kW) installed assuming 30% of all the consumers in each category will install RTS on their premises (K=J×A×0.3)	~362	~8	~30	~14	~4

Source: Authors.

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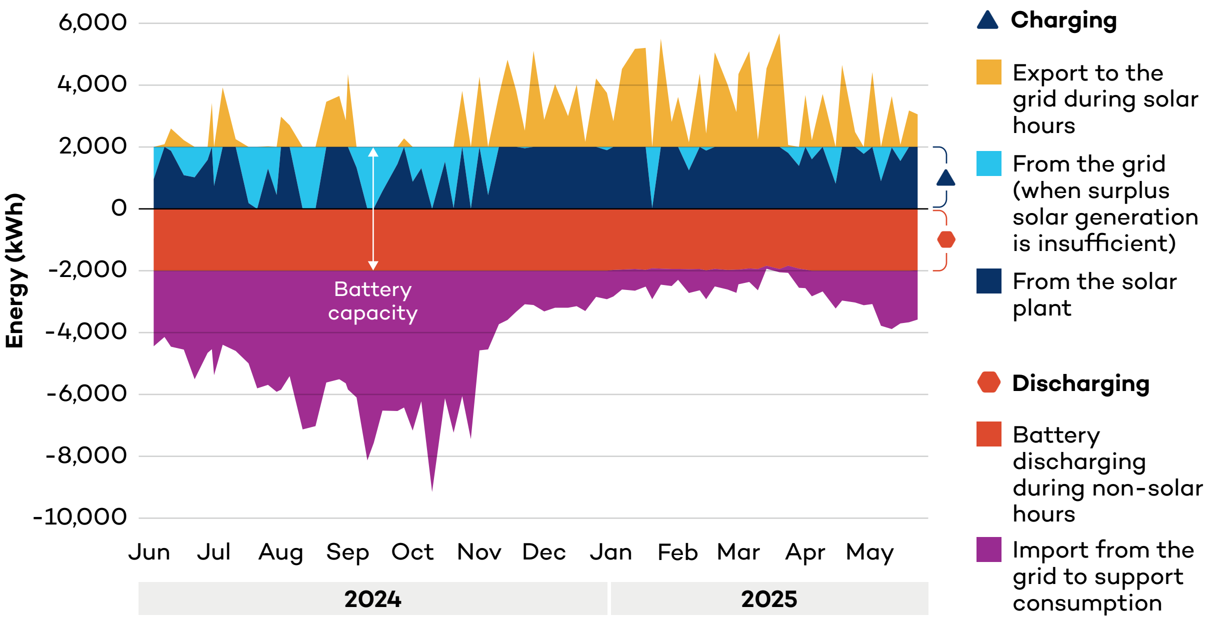
[11] While each consumer category had an average requirement of less than 1 kW, we rounded it off to 1 kW for them, except for the domestic A category, whose annual average consumption is extremely low, and they should be able to meet most of their annual electricity requirements even from a 0.5 kW system.

4.2.3.1 BESS to Manage Surplus and Peak Demand in Bamun Sualkuchi

Since solar generation coincides with daytime but not evening demand, we also assessed the BESS requirement to meet the peak demand for Bamun Sualkuchi (Figure 9). We again followed a similar methodology to that of Hiware Bazar. In Bamun Sualkuchi, the average peak demand (from 7 a.m. to 9 a.m. and 7 p.m. to 9 p.m.) is 440 kW, and the battery can be sized accordingly. However, we also found that peak demand in Bamun Sualkuchi is fairly consistent even during late evening and night hours. 500 kW/2,000 kWh was projected to be the optimal battery size for most seasons in Bamun Sualkuchi.

Figure 9. Exploring BESS for the village of Bamun Sualkuchi (500 kW/2,000 kWh)



Source: Authors.

Box 2. Why we did not explore a microgrid-based configuration

While the study also assessed fully islanded microgrid configurations as part of the analysis, these options are not presented in the report because they require substantial oversizing of both solar generation and battery storage to ensure a reliable supply during non-solar hours in the absence of grid support. This results in significantly higher capital costs and operational risks.

In Bamun Sualkuchi, for instance, meeting village demand under a fully islanded microgrid configuration would require a 1,588 kW ground-mounted solar plant supported by battery storage capable of delivering power for up to 12 hours, equivalent to approximately 4.57 MWh of storage, driven by peak nighttime demand of around 500 kW. The resulting capital cost is estimated at INR 14.82 crore, substantially higher than comparable grid-connected configurations (INR 11.06 crore for solar plus battery). In addition to the higher upfront costs, the absence of grid backup increases reliability risks and necessitates more complex and costly O&M arrangements.

In villages with Hiware Bazar typology, where electricity demand is dominated by agricultural loads and exhibits strong seasonality, the issue is compounded, as the system size will have to be very high during the irrigation season, but will be severely underutilized in the non-irrigation season. A microgrid configuration would duplicate grid-management functions, shift balancing and reliability responsibilities to local entities, and increase capital and operational costs without delivering commensurate system benefits.

4.3 Results From Scenario-Based Techno-Economic Modelling

Across the two configurations assessed for Bamun Sualkuchi, the analysis focused on utility-led implementation pathways, reflecting the need for coordinated system planning, grid integration, and operational control. Accordingly, Section 4.3 evaluates the LCOE and payback implications for a DISCOM-led on-grid solar configuration and a DISCOM-led solar-plus-storage configuration. For on-grid deployment, rooftop installations can be sequenced by initially prioritizing institutional and clustered rooftops, followed by household-level systems under net metering. This phased approach can reduce transaction costs, support smoother interconnection and monitoring, and enable the DISCOM to manage surplus generation and exports more effectively, particularly in periods when local demand is lower than solar output.

This section presents the scenario-based techno-economic results for Hiware Bazar and Bamun Sualkuchi, using the system and storage sizing from the previous section. We report solar-only LCOE for completeness but emphasize storage-enabled configurations because BESS serves primarily to manage intra-day imbalances, support peak demand, and reduce operational stress on the local network, not to increase annual electricity generation.

4.3.1 Baseline Utility-Led On-Grid Solar Configurations

In Hiware Bazar, the baseline configuration reflects FLS under MSKVY 2.0. Under this configuration, the Maharashtra State Electricity Distribution Company Limited (MSEDCL) installs a 980 kW ground-mounted solar plant to serve the dedicated agricultural feeder through a long-term PPA, with capital costs partially offset by scheme support.

The configuration is designed to align solar generation with daytime irrigation loads, thereby minimizing the need for storage for agricultural supply during solar hours. The resulting LCOE is INR 4.09/kWh (without any subsidy) and INR 3.06/kWh with MSKVY 2.0 subsidy, which is well below MSEDCL's APPC for FY 2023–24 (INR 5.78/kWh).[12] While this configuration achieves low energy costs and improves daytime voltage stability, it does

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[12] We use an effective APPC for Maharashtra of INR 5.78/kWh, derived from MSEDCL's FY 2023–24 true-up (Maharashtra Electricity Regulatory Commission, 2025). We follow a similar methodology to arrive at an APPC for Assam, which is explained in detail below.

not explicitly address the operational implications of seasonal surplus generation or evening demand for residential consumers.

In Bamun Sualkuchi, the baseline utility-led on-grid configuration assumes that the Assam Power Distribution Company Ltd (APDCL) invests in, owns, and operates a total solar capacity of 1,318 kW. The rooftop component benefits from subsidies under PMSGMBY (CFA of INR 30,000/kW plus an additional INR 15,000/kW from the state). Power flows are accounted for through a bi-directional export-import metering arrangement,[13] under which electricity drawn from the grid is billed at the applicable retail tariff, and solar electricity injected into the grid is measured separately and compensated at 100% of the APPC rate for Assam (8.46/kWh).[14]

The model also assumes an additional CFA of INR 1 crore under the village-level support available in Assam due to scheme eligibility thresholds.[15] The resulting LCOE is INR 4.03/kWh, substantially lower than APDCL's actual APPC (2023–24) of INR 8.46/kWh, with an indicative payback period of approximately 3 years and 3 months. Even without any subsidies, the LCOE only increases to INR 6.01/kWh, still lower than the APPC. Beyond energy cost savings, the configuration also reduces the effective impact of distribution losses by generating electricity near the point of use and can ease transmission congestion in a system that relies heavily on imports from outside the state.

Alternative ownership structures (such as Panchayat-led and cooperative society-owned models) were evaluated as part of the analysis but are not presented in this report. The focus here is on assessing the economic performance of utility-led configurations that align generation planning, grid operations, and long-term contractual arrangements, given the system-level coordination and incentive considerations associated with alternative models (Box 3).

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[13] Under export-import metering, the meter records electricity imported from the grid and electricity exported to the grid separately. Imports are billed at the applicable retail tariff, while exports are credited at the compensation rate specified in the applicable regulation or order (often benchmarked to 100% of APPC), enabling transparent settlement without netting imports and exports into a single quantity (Assam Electricity Regulatory Commission [AERC], 2019).

[14] We use an effective APPC for Assam of INR 8.46/kWh, derived from APDCL's FY 2023–24 true-up (Assam Electricity Regulatory Commission, 2025). The AERC-approved power purchase expenses for FY 2023–24 are INR 8,449.56 crore, and the AERC-approved energy input requirement is 13,237 MU. Dividing power purchase expenses by total procurement yields a procurement-only average of INR 6.38/kWh (INR 8,449.56 crore divided by 13,237 MU). However, the same AERC energy balance indicates that only 9,992 MU is ultimately available for sale to consumers, with the remainder attributed to losses (including distribution loss, interstate transmission loss, and pooled losses). Since village-level DRE generation is consumed close to the point of supply and therefore avoids a substantial share of these upstream and network losses, we compare DRE LCOE against the effective cost per unit sold, calculated as INR 8.46/kWh (INR 8,449.56 crore divided by 9,992 MU). Also, we use FY 2023–24 because it is the latest year with a completed true-up order available at the time of analysis; the FY 2024–25 true-up is not yet available, and FY 2025–26 is still ongoing.

[15] The village-level support under the PMSGMBY (MSV component) is available only for villages that meet the minimum population eligibility criteria: at least 5,000 population in general category states and at least 2,000 population in special category states (which includes Assam). In our case, Hiware Bazar does not meet this population threshold, while Bamun Sualkuchi does.

Box 3. Why we did not examine Panchayat-led DRE models as stand-alone options

Panchayat-led or community-owned models are often proposed as a pathway for decentralized renewable energy deployment, particularly for household and commercial loads. While these models were evaluated as part of the analysis, they are not presented as stand-alone options in this study because they raise important system-level coordination and incentive concerns.

A Panchayat-led generation model can lead to capacity planning and system sizing decisions that are optimized from a local perspective but do not adequately account for system-level constraints such as reverse power flows, feeder congestion, and balancing requirements. Particularly in villages like Hiware Bazar, with its stark seasonality of demand, this can introduce additional operational challenges for the distribution utility. Importantly, the costs associated with managing these impacts are borne by the DISCOMs and do not feature in Panchayat- or community-level cost–benefit analyses, creating a classic principal–agent problem in which local deployment decisions optimize for community-level returns while externalizing system-level costs to the utility.

Further, while a Panchayat-led on-grid configuration combining ground-mounted and RTS can appear highly attractive when layered with substantial central and state subsidies and grants, its financial viability is highly sensitive to continued public support. Without these subsidies, the LCOE rises sharply, and payback periods extend considerably.

Given the study's objective of identifying DRE configurations that are technically robust, fiscally sustainable, and scalable within existing utility and policy frameworks, the analysis therefore prioritizes DISCOM-led planning and ownership models. Panchayats remain important enabling actors for local coordination, site identification, and community engagement, but are not positioned as system owners or planners in the configurations.

4.3.2 Storage-Enabled Utility-Led Configurations and Interpretation

As estimated in the previous section, the storage scenario adds a 350 kW/1,400 kWh (4-hour) BESS in Hiware Bazar, and a 500 kW/2,000 kWh BESS in Bamun Sualkuchi. We assume a battery cost of USD 150/kWh. The storage-enabled configurations evaluate the techno-economic implications of adding BESS to the baseline on-grid solar systems. Since the modelling does not quantify time-varying procurement prices or the monetary value of avoided network investments, the analysis does not estimate net system savings from BESS. Instead, it reports how blended LCOE and indicative payback change when storage is added and discusses potential operational relevance qualitatively.

4.3.2.1 Hiware Bazar (Maharashtra): Solar + BESS for surplus management and peak support

Adding BESS in Hiware Bazar increases the blended cost of supply to approximately INR 5.44/kWh (with subsidy), with an indicative payback period of around 12 years, while still remaining below MSEDCL's APPC of INR 5.78/kWh (Table 5). These results show that the storage configuration can remain broadly competitive on an average-cost basis in Hiware Bazar while potentially improving operational performance by reducing reverse power flows and lowering reliance on upstream grid imports during peak hours.

4.3.2.2 Bamun Sualkuchi (Assam): Solar + BESS for evening peak support

Incorporating storage of 500kW/2,000-kWh in Bamun Sualkuchi increases the blended LCOE to INR 9.75/kWh (with subsidies), which is higher than APDCL's APPC of INR 8.46/kWh. In operational terms, storage could help displace peak-period purchases and improve evening supply adequacy. However, the study does not quantify the time-varying procurement costs, peak-period purchase prices, or avoided network costs, which are necessary to assess whether the incremental storage cost is offset by such system-level benefits. A more detailed system-level assessment would therefore be required to confirm the optimal storage capacity.

Given this uncertainty, APDCL could consider an initial deployment of a relatively smaller BESS size. For example, a BESS of 400 kW/1,600 kWh in Bamun Sualkuchi would reduce the blended LCOE to INR 8.27/kWh (with subsidy), slightly below APPC (Table 5). This smaller configuration can serve as a near-term option while the utility undertakes deeper analysis of peak-period costs, operational benefits, and evolving demand patterns to determine the appropriate scale of future storage deployment.

Table 5. LCOE of DRE configurations vs state APPC (Hiware Bazar and Bamun Sualkuchi)

Village	Scenario	Configuration	Applicable scheme support considered	LCOE (INR/ kWh)	Payback (indicative)	State APPC (after accounting for losses)	Key interpretation
Hiware Bazar (MH)	Solar-only (baseline)	980 kW ground-mounted PV (ag feeder solarization)	MSKVY 2.0 (capital expenditure [CapEx] support)	3.06 (with subsidy) to 4.09 (without)	3 years	MSEDCL APPC: INR 5.78 /kWh (FY 23–24)	Low energy cost; does not explicitly address seasonal surplus or evening peaks
	Solar + BESS	Baseline PV + 350 kW BESS, 4 hours	MSKVY 2.0 (BESS assumed unsubsidized)	5.44 (with subsidy) to 6.46 (without)	~12 years (with subsidy) to 17 years (without subsidy)		Higher blended LCOE; may support surplus management and peak support
Bamun Sualkuchi (AS)	Solar-only (baseline)	1,318 kW total PV (70% ground-mounted, 30% RTS)	PMSGMBY RTS subsidy + additional village-level CFA (eligible)	4.03 (with subsidy) to 6.01 (without subsidy)	3 years 3 months (with subsidy) to 3 years 4 months (without)	APDCL APPC: INR 8.46/ kWh (FY 23–24)	Low energy cost; reduces effective loss impact through local generation
	Solar + BESS	Baseline PV + 500 kW, 4-hour BESS	PV subsidies as above (BESS assumed unsubsidized)	9.75 (with subsidy) to 12.53 (without subsidy)	No payback as APPC is lower		Blended LCOE rises; potential peak support value is qualitative in this study; smaller BESS could be a staged option
		Baseline PV + 400 kW, 4-hour BESS	PV subsidies as above (BESS assumed unsubsidized)	8.27 (with subsidy) to 10.84 (without subsidy)	5 years 3 months (with subsidy) and no payback (without subsidy)		Due to reduced BESS size (from 500 kW to 400 kW), blended LCOE is below the state APPC (but only in "with subsidy" scenario)

Source: Authors.

While the techno-economic analysis presented above highlights technically feasible and financially viable DRE configurations, real-world implementation depends strongly on the policy and regulatory environment in which distribution utilities and consumers operate.

4.4 Policy and Regulatory Conditions Shaping Grid-Interactive DRE Deployment

To understand whether the technically feasible configurations identified in this study can be implemented at scale, we reviewed DRE-related policies, regulatory provisions, and subsidy frameworks in Maharashtra and Assam (Appendix D). The review focused on metering arrangements, subsidy design, ownership models, and institutional coordination, all of which influence how village-level DRE systems can be planned, financed, and integrated into distribution networks.

The policy review found that while many enabling provisions already exist, current programs remain oriented toward individual asset deployment rather than coordinated village-level system design. These gaps help explain several of the techno-economic and institutional findings that emerge from the case study analysis.

Box 4. DRE policy and regulatory review for Maharashtra and Assam

Observations for Maharashtra

- The state's non-conventional policy supports both grid-connected and off-grid projects, indicating a clear intent to bring renewable energy solutions directly to the point of consumption, especially in rural areas.
- The policy aimed to attract investments in the renewable energy sector, including distributed generation projects suitable for rural electrification and solarization.
- Regulatory framework allows multiple metering frameworks—net metering, net billing, behind the meter, VNM, group net metering, and gross metering—giving flexibility to stakeholders in terms of how they want to structure the RTS project.
- However, VNM remains a limited-use provision. It applies only to consumers in multistory buildings under a housing society or apartment owners' association that can jointly install a system at a common location. As a result, many rural households and other consumers cannot use VNM to overcome rooftop space constraints or participate in shared solar arrangements.
- Maharashtra's framework aligns with PMSGMBY, ensuring synergy between central and state initiatives. Agricultural feeder solarization by MSEDCL under PM-KUSUM and MSKVY 2.0 has accelerated in Maharashtra. State financial support is primarily focused on agricultural pumps and feeder solarization, with limited support for broader village-scale DRE configurations.

Observations for Assam

- Assam's renewable energy policy is aligned with national programs like PMSGMBY. An additional subsidy of INR 15,000 per kW of RTS (maximum up to INR 45,000 for 3 kW) under PMSGMBY can accelerate the deployment of RTS in the residential consumer category. Subsidy is released to the beneficiary's account after successful installation and commissioning of the RTS system. It also promotes the adoption of solar-powered irrigation and water-supply systems by designating institutional responsibilities, identifying priority deployment areas, and enabling subsidy-supported installation of both stand-alone and grid-connected solar water pumps.
- The Integrated Clean Energy Policy also supports integration of BESSs, which store electricity generated from solar power, allowing its distribution during peak hours or nighttime to enhance grid stability and reliability. The policy promotes farmer participation in the solar energy sector by enabling decentralized solar projects on unused agricultural land, supporting the solarization of grid-connected agricultural pumps, and encouraging stand-alone solar systems for electricity access in remote and underserved areas.
- AERC regulation allows multiple metering frameworks such as net metering, gross metering, VNM, and group net metering, which allows stakeholders to implement the RTS project by selecting the most suitable metering mechanism, resulting in accelerated deployment of the RTS. VNM is applicable to residential consumer categories, group housing societies, and government buildings to consider the development of centralized DRE plants, which can facilitate shared economic benefits from solar generation, fostering a community-centric approach to solarization.

4.5 Synthesis of Findings and Implications for a Model DRE Village Framework

This section consolidates the insights from the case studies, load typology analysis, and techno-economic modelling presented earlier in the chapter.

4.5.1 From Local Success Stories to System-Level Lessons

The experiences of Manyachiwadi and Odanthurai demonstrate that DRE initiatives can be enabled by strong local governance, institutional ownership, and community participation. In both cases, Panchayat-led decision making, access to financing, and coordination with external partners supported the adoption and operation of renewable energy systems. At the same time, these examples also highlight the limits of relying on context-specific leadership or informal arrangements, underscoring the need for more formalized planning processes, clearer institutional roles, and structured coordination mechanisms to improve replicability across locations.

These qualitative insights provide the institutional context for the techno-economic analysis presented in the chapter. While these case studies focus on governance and implementation conditions, the quantitative analysis of Hiware Bazar and Bamun Sualkuchi examines system sizing, costs, and operational considerations. Taken together, the two strands help link enabling conditions with practical system design considerations for future DRE deployment.

4.5.2 Load Typology as the Primary Driver of DRE Design, Economics, and Grid Integration

The comparative analysis of Hiware Bazar and Bamun Sualkuchi establishes that local load typology (particularly, the temporal alignment between demand and solar generation) plays a critical role in shaping DRE system design, storage needs, and operational feasibility. Hiware Bazar's agriculture-dominated, daytime-peaking demand exhibits a high coincidence with solar generation, enabling FLS to meet irrigation loads with relatively lower storage. In contrast, Bamun Sualkuchi's residential and livelihood-driven demand peaks in the evening, creating a structural mismatch with solar generation that necessitates higher battery storage and significant grid dependence.

These differences in load structure also directly shape sequencing and grid integration strategies. In agriculture-heavy villages, prioritizing solarization of agricultural demand before expanding rooftop or community systems maximizes self-consumption and limits surplus generation. In residential-dominant villages, phased rollouts, beginning with institutional or clustered rooftops, allow utilities to assess grid impacts before scaling household installations.

While this study does not quantify the full system-level balancing costs or assess them in consultation with utilities, the results highlight the importance of integrating granular load analysis into distribution planning and coordinating DRE deployment with DISCOM planning processes, rather than adopting purely technology- or capacity-driven approaches.

4.5.3 Ownership, Aggregation, and the Role of DISCOMs

Across both village typologies, the techno-economic modelling (focused on system sizing, storage needs, and cost comparisons) points to important planning implications for ownership and aggregation. The need to manage surplus generation, storage utilization, and interaction with the grid indicates that highly fragmented, consumer-led deployment may create additional coordination and operational challenges at the distribution level.

This implies that utilities need to remain central to system design, grid integration, and long-term operation of village-scale DRE systems. Panchayats and local institutions remain critical for community mobilization, governance, and accountability, but effective scale-up is likely to require stronger utility involvement in planning, aggregation, and operational integration.

4.5.4 Public Finance, Subsidies, and System Value

Public finance plays an important role in improving DRE viability, particularly for rooftop-led configurations that require battery storage. At the same time, the Hiware Bazar analysis shows that FLS aligned with daytime agricultural demand can be cost-competitive even without subsidy support, highlighting that the role of subsidies could be context specific. Central and state subsidies under schemes such as PMSGMBY, PM-KUSUM, and the MSV component materially reduce levelized costs and payback periods.

The analysis also suggests a broader policy implication: focusing subsidies solely on maximizing installed capacity may not always deliver the greatest system value. Supporting complementary investments such as storage, feeder strengthening, and monitoring systems could improve reliability and long-term performance. This finding has direct implications for how scheme guidelines and detailed project report templates are structured.

4.5.5 Storage: Divergent consumer and utility perspectives

The analysis highlights an important difference between consumer-level and system-level perspectives on battery storage. In the Bamun Sualkuchi case, adding storage increases the blended LCOE above the DISCOM's APPC, indicating that storage may not appear attractive when assessed purely on levelized cost.

However, storage is typically motivated by system-level objectives, such as managing evening peaks, improving supply adequacy, and reducing reliance on high-cost peak procurement. These benefits were not quantified in this study due to data limitations. Consideration of all uses for batteries, and their cost implications, is important for designing tariff structures, compensation mechanisms, and financing models that allocate costs and benefits appropriately across stakeholders, rather than evaluating storage solely through a consumer-level cost lens.

4.5.6 Policy and Regulatory Alignment as a Binding Constraint

Finally, state-level regulatory conditions strongly shape feasible DRE pathways. VNM restrictions, unclear compensation for stored energy, and limited integration between schemes constrain replication even where technical and financial conditions are favourable. For example, differences in VNM/group eligibility and settlement rules (as seen in the Maharashtra vs. Assam comparison) can determine whether a utility-led/shared RTS model is even implementable for dispersed rural households.

Results Summary

The results demonstrate that DRE can best support India's next phase of rural electrification if planned through a typology-based, DISCOM-integrated, and institutionally coordinated approach. Technical feasibility alone may be insufficient, and outcomes would depend equally on sequencing, ownership design, subsidy architecture, and regulatory alignment.

The empirical evidence from Hiware Bazar and Bamun Sualkuchi provides the analytical foundation for the Model DRE Village Framework presented in the following chapter, which translates these insights into a structured planning, institutional, and financing architecture that states and DISCOMs can apply at scale across diverse rural contexts.

5.0 Framework for Model DRE Villages in India

In India, there is no national framework guiding how villages should conduct load assessment, technology integration, institutional coordination, or financial design to become fully functional model DRE villages. This policy vacuum calls for a next-generation framework, one that complements MSV, strengthens its implementation architecture, and provides states with a practical playbook with options to design, finance, operate, and scale context-specific whole-village DRE systems.

This chapter proposes a new Model DRE Village Framework based on the analysis presented in this report. It provides states and DISCOMs with a planning blueprint and holistically integrates several technologies, along with system planning, institutional coordination, and village governance. While the MSV scheme provides an important starting point for village-level solar deployment, the proposed framework adopts a technology-agnostic and resource-led approach, encouraging villages to assess and utilize the full spectrum of locally viable renewable resources. These may include solar (RTS, ground-mounted and agricultural feeder solarization), storage solutions, biomass and biogas for community and productive loads, small hydro where feasible, and hybrid configurations. The framework, therefore, embeds village-level resource assessment and planning capacity, enabling local institutions to identify the most suitable mix of technologies based on demand patterns, resource availability, and system needs.

By placing equal emphasis on technical design, institutional coordination, and socio-economic integration, this framework aims to transform DRE from a collection of isolated installations into a cohesive, system-integrated driver of rural development, aligned with India's national clean energy objectives and climate commitments.

Finally, this framework is not intended as a substitute for the MSV guidelines; rather, it is designed to support and operationalize them further. It enables states to deliver high-quality, detailed project reports while building DRE villages that are technically sound, financially viable, socially inclusive, and scalable across India.

5.1 Objectives of the Model DRE Framework

The Model DRE Village Framework aims to develop:

- a planning and implementation architecture for states and DISCOMs to assess local renewable resource potential and design and implement DRE-based village systems;
- a coordination framework linking MNRE, state nodal agencies (SNAs), DISCOMs, Panchayats, and sectoral departments;
- standardized tools for load analysis, system sizing, financial modelling, and institutional design;

- guidelines for using existing scheme support (central financial assistance from MSV scheme component, PMSGMBY, PM-KUSUM, MSKVY 2.0) in a coordinated manner;
- a national blueprint that states can adapt based on local load patterns, institutional capacity, and resource availability.

5.2 Scope

The framework extends across all rural load segments, including agricultural, residential, public institutions and community infrastructure (such as schools, primary health centres, Panchayat offices, water supply systems, street lighting, and *Anganwadis*),[16] commercial and Ministry of Micro Small and Medium Enterprises (M/o MSME) (such as rural enterprises such as weaving clusters, flour mills, dairy chilling units, food processing, and local workshops that can integrate productive-use planning from DRE), and other emerging loads (such as electric vehicle charging, digital service centres, cold storage units, and livelihood hubs).

Further, the framework is applicable across all rural and peri-rural areas, irrespective of geographic region or state policy maturity. Planning follows a resource-led, technology-neutral approach: while solar is likely to play a major role, states are encouraged to incorporate other locally suitable resources—such as biomass and biogas in agri-residue-rich regions, micro and small hydro in hilly states, wind–solar hybrids where viable, and emerging storage solutions—based on local resource potential and demand patterns.

The scope explicitly includes the integration of DRE systems into grid operations, given the central role played by DISCOMs in ensuring voltage stability, balancing supply and demand, and managing financial flows. The framework, therefore, considers technical aspects such as load-flow management, peak- demand support, flexibility and ancillary services, and feeder-level planning. The framework reinforces that DRE systems must operate as part of the broader electricity system rather than in parallel to it, ensuring that decentralized assets enhance grid stability, promote efficient resource utilization, and support the long-term financial viability of distribution utilities.

While the framework is designed to be nationally applicable, its implementation is expected to follow a phased rollout. Initial adoption in a set of early-moving states and districts can help demonstrate operational pathways, strengthen institutional coordination, and generate implementation learnings. These early deployments are intended to inform iterative refinement and facilitate smoother scaling across diverse state contexts, rather than to test the validity of the framework itself.

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[16] *Anganwadis* are rural childcare centres in India that support mothers and children under six years of age by providing basic health care, nutrition, early childhood education, and services for holistic child development.

5.3 Guiding Principles

- **typology-based planning**: The design of a DRE system should arise from an understanding of the village's load curve, peak demand drivers, productive-use potential, and institutional strengths. One-size-fits-all technological templates generally may not be effective across India's diverse settlement patterns.
- **collaborative institutional model for planning, ownership, and governance**: DRE village systems require clearly defined and complementary roles across institutions. Distribution utilities are best positioned to anchor system planning, grid integration, asset ownership, and long-term technical operation given their statutory mandate, access to system data, and responsibility for reliability and financial management. At the same time, effective and durable deployment depends on strong participation from Panchayats and village-level institutions in shaping local demand, identifying priority loads, enabling community acceptance, and strengthening accountability. The framework, therefore, promotes a co-implementation model that combines utility-led technical delivery with community-anchored governance and oversight.
- **role of Panchayats and village energy committees in participatory decision making**: Gram Panchayats and village energy committees play a central role in ensuring that DRE systems reflect local needs and enable equitable access. Their responsibilities include facilitating consultations, supporting demand aggregation and household onboarding, identifying productive-use opportunities, monitoring service quality, and addressing grievances. This participatory role ensures that DRE deployment is locally owned and socially embedded, while technical O&M, tariff management, and system performance remain aligned with utility-led operations.
- **financial viability and long-term sustainability**: System design and planning should prioritize life-cycle performance rather than short-term installation targets. This includes attention to reliability, maintenance, replacement of storage assets, tariff alignment, and clear institutional responsibilities across the system lifetime. Ensuring that DRE assets remain affordable, operable, and financially sustainable over the long term is essential for avoiding stranded assets and ensuring continued service delivery.
- **convergence of central and state schemes**: DRE planning should overlay and combine financial support from multiple schemes rather than operate them in silos. This requires states to map, sequence, and converge PMSGMBY, PM-KUSUM, the Deendayal Antyodaya Yojana-National Rural Livelihoods Mission (DAY-NRLM), M/o MSME programs, and state solar missions into a coherent funding pathway for each village.
- **technology neutrality and system optimization**: Planning should begin with the optimal utilization of locally available renewable resources. Solar-storage-grid configurations are likely to play a central role in most contexts, but the framework encourages systematic assessment of biomass, micro-hydro, wind–solar hybrids and other locally appropriate solutions to ensure least-cost and most resilient system design.

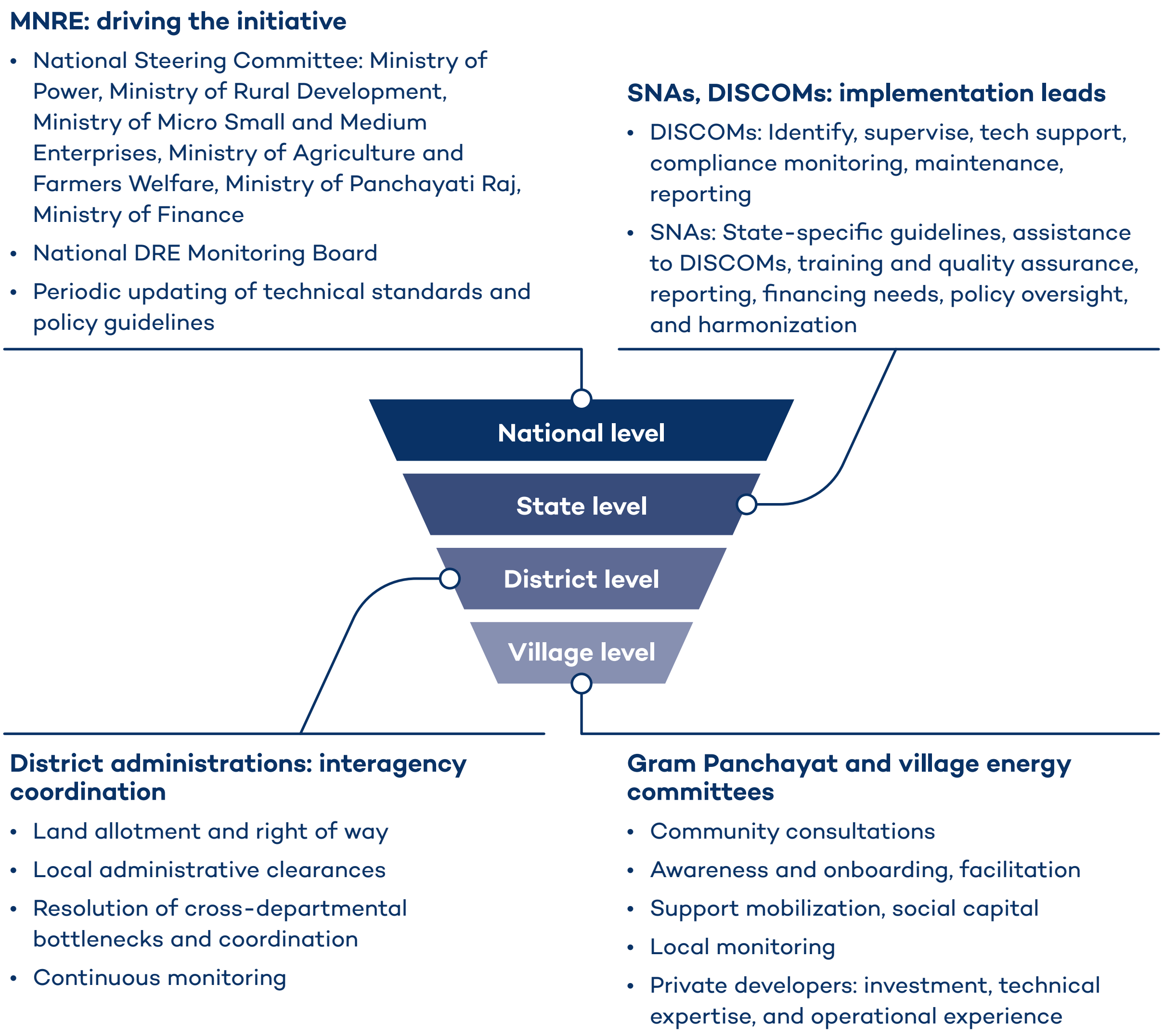
- **data-driven monitoring and long-term sustainability**: Implementation must be accompanied by transparent reporting systems, digital dashboards, real-time monitoring of generation and consumption, and structured mechanisms for annual review and course correction.

Together, these principles ensure that the Model DRE Village Framework is a comprehensive, institutionalized approach to rural clean energy development that is scalable across states and adaptable to diverse local contexts.

5.4 Institutional Architecture and Governance

The framework proposes a multi-tiered institutional architecture linking national, state, district, and village-level institutions in a coordinated but functionally differentiated manner. Each tier carries distinct responsibilities designed to be mutually reinforcing rather than hierarchically controlling.

Figure 10. Institutional architecture and governance for model DRE villages



MNRE: driving the initiative

- National Steering Committee: Ministry of Power, Ministry of Rural Development, Ministry of Micro Small and Medium Enterprises, Ministry of Agriculture and Farmers Welfare, Ministry of Panchayati Raj, Ministry of Finance
- National DRE Monitoring Board
- Periodic updating of technical standards and policy guidelines

SNAs, DISCOMs: implementation leads

- DISCOMs: Identify, supervise, tech support, compliance monitoring, maintenance, reporting
- SNAs: State-specific guidelines, assistance to DISCOMs, training and quality assurance, reporting, financing needs, policy oversight, and harmonization

District administrations: interagency coordination

- Land allotment and right of way
- Local administrative clearances
- Resolution of cross-departmental bottlenecks and coordination
- Continuous monitoring

Gram Panchayat and village energy committees

- Community consultations
- Awareness and onboarding, facilitation
- Support mobilization, social capital
- Local monitoring
- Private developers: investment, technical expertise, and operational experience

Source: Authors.

5.4.1 National Level (MNRE)

At the national level, the MNRE could serve as the policy and coordination anchor responsible for driving the model DRE village initiative. This designation would be consistent with MNRE's existing mandate as the nodal ministry for PMSGMBY (under which the MSV component already operates) and reflects the need for a single national anchor responsible for policy and strategic direction, standard-setting, interministerial coordination, and monitoring of implementation performance across states.

To support this, the framework proposes establishing a National Steering Committee on model DRE villages, chaired by MNRE and comprising representatives from the following:

- Ministry of Power (MoP)
- Ministry of Rural Development (MoRD)
- Ministry of Micro Small and Medium Enterprises (MSME)
- Ministry of Agriculture and Farmers Welfare
- Ministry of Panchayati Raj
- Ministry of Finance
- Ministry of Textiles
- Ministry of Health and Family Welfare
- Ministry of Tribal Affairs, and other relevant ministries as required.

Recognizing that interministerial convergence has historically been challenging, this committee would focus on resolving operational bottlenecks, harmonizing scheme guidelines, and providing states with a single coordination platform for DRE deployment. To enable consistent and transparent monitoring, cross-state learning, and data-driven policy improvements, MNRE could also integrate key DRE indicators into existing national scheme dashboards (for PMSGMBY, PM-KUSUM, etc.) and reporting systems. MNRE could also incorporate additional village-level metrics that are currently not tracked in a consolidated manner, including installations, generation performance, subsidy utilization, livelihood outcomes, and feeder-level impacts.

Finally, MNRE could periodically update technical standards related to grid integration, metering, interoperability, and safety, in close coordination with the MoP and the CEA, ensuring alignment with national power sector regulations and evolving national and international best practices.

5.4.2 State Level (SNAs, DISCOMs)

The framework proposes a joint implementation model anchored by SNAs and DISCOMs, building on existing SNA-led deployment under national solar programs while strengthening the operational role of distribution utilities for grid-integrated DRE systems.

DISCOMs

DISCOMs could play a central technical and operational role in ensuring that DRE assets integrate effectively into the electricity system. This role recognizes their statutory responsibility for electricity distribution and their critical function in maintaining grid stability and financial sustainability.

DISCOMs would be responsible for the following:

- co-identifying candidate villages jointly with SNAs and district-level committees (DLCs)[17] based on feeder-level performance data and local demand indicators;
- conducting or supervising load curve analysis, demand forecasting and grid impact assessments;
- leading technical system design in consultation with local institutions and district authorities;
- ensuring compliance with safety and technical standards;
- acting as technical anchors and aggregators for procurement, construction, metering, and commissioning activities, either directly or through engineering, procurement, and construction (EPC) contractors, developers, or RESCO models;
- maintaining and operating DRE systems, either directly or through service contracts;
- managing net-metering, gross-metering, or feed-in arrangements;
- integrating DRE assets with grid operations, demand response mechanisms, and digital monitoring platforms;
- supporting data reporting and coordination with SNAs, district administrations, and Panchayats.

Strengthening the role of DISCOMs could create tangible incentives, including improved feeder reliability, reduced peak procurement costs (if combined with storage solutions), deferment of network upgrades, improved visibility of distributed generation, and the opportunity to increase electricity use during daytime hours so that demand better matches local solar generation and reduces reliance on costly evening power purchases.

SNAs

SNAs could serve as technical coordinators and program managers, supporting implementation, capacity building, quality assurance, and convergence of central and state schemes.

Their responsibilities could include

- issuing state-specific guidelines that adapt the national framework to local conditions;
- providing technical assistance to DISCOMs in modelling, planning, and monitoring;

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[17] DLCs are existing district-level coordination bodies typically chaired by the district collector/deputy commissioner and comprising representatives from line departments, distribution utilities, and local government institutions. They are commonly used under centrally sponsored schemes to enable interdepartmental coordination and monitor implementation at the district level.

- managing training programs under Suryamitra or other skill development initiatives;
- facilitating convergence with state agriculture, MSME and rural development programs;
- conducting periodic inspections and quality audits;
- preparing annual progress reports and submitting them to MNRE;
- establishing state DRE Implementation Cells housed within SNAs, with dedicated coordination officers from DISCOMs, state rural livelihood missions, and state energy departments;
- preparing and periodically updating a State DRE Roadmap, identifying target villages/clusters and financing needs;
- reviewing project proposals and recommending them for MNRE support.

District Level

The DLCs could serve as the primary platform for translating the framework into district-level energy planning aligned with district development plans. Given their ability to coordinate across line departments, district administrations represent the operational hub of multi-sectoral implementation.

Primarily, district-level responsibilities could include the following:

- jointly overseeing village selection with SNAs and DISCOMs, and ensuring alignment with district development plans and priorities;
- facilitating land allocation, right-of-way approvals and local administrative clearances;
- supporting coordination of civil works, site preparation and verification;
- enabling linkages with livelihood missions, MSME clusters, Krishi Vigyan Kendras (KVKs) and skill development centres.

District-level coordination could be institutionalized through regular joint review meetings chaired by the district collector, bringing together DISCOM officials, SNAs, line departments, Panchayati Raj institutions, and implementing partners to ensure

- alignment of DRE activities with district development objectives,
- timely resolution of cross-departmental bottlenecks, and
- continuous monitoring of implementation progress.

State-level steering committees and digital coordination platforms can complement this process, but effective operational coordination may still remain anchored at the district level.

Panchayat and Village-Level Institutions

At the village level, Gram Panchayats serve as community-facing governance bodies that support mobilization, local consultations, and participatory decision making. While technical design, grid integration, and asset ownership could rest with distribution utilities and implementing agencies, Panchayats could play a central role in shaping locally appropriate energy pathways and ensuring that deployment reflects community priorities.

Each model DRE village could constitute a village energy committee (VEC) under the Panchayat, which could include representatives from self-help groups (SHGs) federations, farmer producer organizations (FPOs), school management committees, local enterprises, and marginalized groups. The VEC would act as a platform for participatory decision making and continuous engagement across the project life cycle.

The VEC's roles could include

- supporting village-level energy needs assessments and demand aggregation,
- contributing to the identification of productive-use opportunities and livelihood linkages,
- facilitating community consultations during system design and site selection,
- monitoring service quality and providing structured feedback to implementing agencies,
- supporting household onboarding and awareness activities,
- resolving local grievances and strengthening accountability.

Such institutional participation plays a particularly critical role in villages with strong social capital, as seen in Manyachiwadi and Odanthurai, where community involvement was essential for gaining trust and ensuring long-term sustainability. This approach enables participatory energy governance while ensuring that DRE assets remain technically robust, financially viable, and fully integrated into the formal electricity system.

Role of Private Developers, EPC Contractors, and RESCOs

Private developers bring investment, technical expertise, and operational experience into DRE deployment. So, their role would be encouraged within a structured public–private partnership or RESCO model led by DISCOMs. Developers may invest in rooftop or ground-mounted systems, operate storage facilities, or manage O&M services under performance-linked contracts. The framework emphasizes transparent and competitive procurement processes that ensure quality and cost-effectiveness.

5.5 Planning and Implementation Framework

Effective DRE deployment requires a structured planning process that links demand assessment, system design, financial analysis, and institutional coordination. Since villages differ widely in load composition, livelihood patterns, and network conditions, the framework adopts a typology-driven and evidence-based approach that remains adaptable while aligning with state regulations and MNRE guidelines (Table 6).

Table 6. Proposed institutional architecture of a standardized yet flexible planning approach for a model DRE village

Typology-based village identification	• Classify village type by load type and local conditions • Agri dominant/ residential dominant/mixed
Baseline survey and load assessment	• Conduct comprehensive surveys for consumer categories data, including DISCOM-level data • Analyze hourly and seasonal load curves to observe consumption patterns
Demand forecasting	• Project demand growth for a 5-year horizon • Use both historical and forward-looking parameters for demand projection • Conservative demand growth scenarios
System configuration and technology selection	• Integrated configuration of RTS, ground-mounted solar, Storage • Technology selection based on typology • Ensure technical feasibility, affordability, and operational reliability
Techno-economic modelling	• Inputs CapEx, OpEx, subsidies • Outputs for LCOE, payback periods, and optimal storage scenarios • Optimization of energy and financing costs, to inform phased deployment decisions
Village Energy Plan (VEP)	• Integrated implementation roadmap • Institutional roles, coordination, & financing • Monitoring, scale-up, and learning

Source: Authors.

5.5.1 Typology-Based Village Identification

Planning begins with classifying villages by dominant load type, seasonality, and local governance capacity. These parameters determine system configuration, storage needs, and implementation sequencing. It is also important to highlight that villages would rarely fit into rigid categories; therefore, the typology is intended as a planning heuristic based on the largest share of electricity demand (agriculture-dominant, residential-dominant, etc.), while recognizing that many settlements will be mixed or transitioning.

Agriculture-dominant villages offer a strong case for DRE because irrigation demand is largely daytime and aligns well with solar generation. Agricultural load is typically treated by DISCOMs as a "flexible" demand, since the timing of supply can be controlled through physical feeder segregation or virtual segregation (switching between three-phase and two-phase supply: while agricultural connections need three-phase connections, residential connections do not necessarily need that). Solarizing agricultural connections under PM-KUSUM or relevant state variants (such as MSKVY in Maharashtra) can therefore deliver reliable daytime power, reduce storage requirements, lower subsidy burdens, and improve feeder performance.

Within this typology, planners could also choose the appropriate agricultural solarization pathway. Individual pump solarization enables farmer-level incentives for energy and water conservation through surplus export but requires high levels of coordination and uptake across a feeder. It could thus be suitable in places where pumps are dispersed or far from the distribution lines. FLS aggregates agricultural demand into a single grid-connected plant, offering economies of scale and simpler implementation, but without automatic conservation incentives. Hybrid approaches can combine FLS with individualized crediting mechanisms, such as virtual allocation, where feasible.

Seasonality is a critical design parameter. Irrigation demand typically peaks only in certain months, and sizing solar capacity solely for peak irrigation loads can result in sustained surplus and reverse power flows during non-irrigation periods (as shown in the case of Hiware Bazar village). Typology-based identification should therefore flag surplus risks early, allowing system sizing to optimize for overall village consumption rather than peak seasonal demand.

Residential-dominant villages exhibit pronounced evening peaks and limited daytime demand, requiring explicit assessment of evening balancing strategies, including grid interaction and, where justified, storage. The analysis of Bamun Sualkuchi village presented in Section 4 is an example. They require careful assessment of storage, net metering, or hybrid RTS–groundmounted models.

Mixed or transitioning villages with growing non-farm loads (say, from small rural industries, weaving clusters, food processing units, or EV charging, etc.) require hybrid configurations that can adapt to evolving demand patterns over time.

Across all typologies, planners could design systems that anticipate changes in demand over time. The typology classification, therefore, acts as a diagnostic tool that guides system design while allowing flexibility as village economies evolve.

5.5.2 Baseline Survey and Load Assessment

A village-wide baseline assessment provides the analytical foundation for planning. This combines household, agricultural, commercial, and public infrastructure surveys with DISCOM feeder-, distribution transformer-, and meter-level data.

In addition to analyzing historical load curves, planners could also conduct ground-level assessments to identify

- latent and suppressed demand,
- opportunities for fuel switching from diesel or biomass to electricity,
- potential new productive uses and livelihood loads,
- seasonal livelihood and irrigation patterns,
- local network constraints and reliability issues.

At minimum, hourly load curves for representative periods across seasons could be constructed to identify peak demand windows, seasonal variation, demand–generation coincidence, flexible loads (especially irrigation) and local network constraints. This would ensure that the system design is grounded in and reflects both observed consumption and realistic future demand rather than relying solely on historical electricity use.

5.5.3 Demand Forecasting

System design could reflect a medium-term planning horizon, typically 5 years, to balance flexibility with investment certainty. Forecasts could translate baseline assessment results into forward-looking demand scenarios by accounting for

- expected household growth and new connections,
- likely expansion of local enterprises and public services, and
- gradual electrification of existing diesel-based or manual activities.

Given the uncertainty of rural demand evolution, planners could also develop low-, medium-, and high-demand scenarios rather than rely on a single growth assumption. Scenario-based forecasting allows system sizing and investment planning to remain robust under different demand trajectories, while enabling periodic reassessment during implementation.

5.5.4 System Configuration and Technology Selection

Using typology and load curve insights, DISCOMs could propose integrated configuration(s) combining RTS, ground-mounted solar and storage where required. In agriculture-dominant villages, agricultural solarization could anchor the system and be sized to meet daytime irrigation demand while managing surplus risks outside the irrigation season. However, an optimized system size could help ensure that most daytime irrigation demand is met without storage. In residential-dominant villages, planners could explicitly address evening peaks through appropriate balancing strategies, which may include storage or grid-based arrangements. The finalized configuration(s) should be able to ensure technical feasibility, affordability, and operational reliability.

5.5.5 Techno-Economic Modelling

The proposed configuration(s) could be assessed through a standard techno-economic model covering capital costs, operating costs, applicable subsidy schemes, and utility-side avoided costs or revenues. Outputs would include LCOE and payback periods, with a clear interpretation of the role of storage where included (as it adds significantly to the overall cost). This would help confirm financial feasibility, identify cost drivers, and inform phased deployment decisions, rather than optimize for energy-only costs. The techno-economic modelling should also consider state rules on metering/settlement, consumer eligibility, export compensation and aggregation options to determine the feasibility of all the proposed options and find out the best implementable model(s).

5.5.6 Village Energy Plan

Finally, all planning outputs could be consolidated into a VEP, which would serve as the core implementation document. The VEP captures the typology assessment, load analysis, demand projections, system configuration, techno-economic results, institutional roles, financing approach, implementation timeline, and monitoring framework, along with identified productive-use linkages. This single document could enable coordinated village-level execution while supporting state-level aggregation and learning.

5.6 Technology and System Design Guidelines

Model DRE villages would adhere to existing technical standards and program guidelines issued by MNRE, CEA, and Bureau of Indian Standards for RTS, ground-mounted solar, storage systems, metering, and safety. These national guidelines already provide detailed specifications on

- equipment certification and quality standards
- grid integration and safety requirements
- installation, metering, and monitoring protocols
- environmental and social safeguards.

We do not recommend duplicating engineering specifications; instead, we focus on how such technologies should be planned, sized, and integrated within the Model DRE Village Framework. Accordingly, technology selection and system design under this framework could

- comply with prevailing MNRE and CEA standards[18]
- be informed by the village typology and load assessment described in Section 5.5
- allow modular expansion as demand evolves
- prioritize reliability, maintainability, and life-cycle performance.

Detailed technical specifications could be adopted directly from MNRE program guidelines[19] and updated as national standards evolve.

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[18] CEA—Compendium of Regulations and Technical Standards for the construction of electrical plants and electric lines.

[19] Technical specifications for PMSGMBJ, including for inverter and communication devices.

Table 7. Recommended technologies and standards to ensure the safety, reliability, and long-term sustainability of model DRE villages

Rooftop solar systems	• Adoption of maximum power point tracking inverters • Adequate spacing, earthing, and lightning protection • Compliance with net-metering regulations • Encourage household RTS wherever structurally suitable
Ground-mounted solar systems	• Minimum 3–4.5 acres per MW land requirement • Proper cable routing and power evacuation infrastructure • Siting to minimize shadow or flooding risk • Environmental and social safeguards • Avoid compromising on agricultural land
BESS	• Minimum 4 hours storage (2 hours for morning and 2 hours for evening) for balancing • Lithium-ion or advanced chemistries with proven safety records • Proper enclosure, ventilation, and fire-safety mechanisms • Remote monitoring and predictive maintenance systems • Sizing must be derived through rigorous feasibility assessment
Smart metering and digital infrastructure	• Smart prepaid meters, remote monitoring dashboards • Device-level Internet of Things sensors for pumps, SME loads and BESS • To enable accurate billing, demand-side management, and real-time performance monitoring

Source: Authors.

5.7 Financing Framework

A sustainable financing structure must support both asset creation and long-term performance. The framework thus proposes a layered financing approach that enables convergence across schemes and aligns funding choices with clear ownership, O&M responsibility, and risk allocation (Table 8).

Table 8. Financing framework for DRE implementation

Sources of funds	• Government schemes (PMSGY, PMKUSUM, State renewable energy funds) • CSR contributions • Green financing (CSR, priority lending, concessional loans)
Utility-led models	**CapEx mode** • DISCOM finances, owns, operates assets • NABARD, SIDBI concessional loans **RESCO mode** • DISCOM planner, private RESCO operator • Leverage available CFA and state support • Plan optimally by assigning clear responsibility
Utility-led reinvestment	• Use system-level savings from DRE • Reinvest into public & livelihood assets (lighting, cold storage, e-mobility charging, livelihood centres, etc.)
Risk mitigation and bankability measures	• Payment security mechanisms, partial risk guarantees • Quality assurance protocols • Insurance coverage

Source: Authors.

5.7.1 Sources of Funds

Villages and implementing agencies could pool support from multiple channels rather than rely on a single scheme. This includes PMSGMBY subsidies for RTS, PM-KUSUM, and relevant state feeder-solarization variants for agriculture and other applicable grants. These can also be complemented by corporate social responsibility (CSR), priority-sector lending for productive uses and concessional finance from institutions such as the National Bank for Agriculture and Rural Development (NABARD) and the Small Industries Development Bank of India (SIDBI). The objective would be to match each demand segment with the most suitable funding source and improve overall affordability.

5.7.2 Utility-Led Models: CapEx versus DISCOM-led RESCO

Wherever the DISCOMs have adequate capacity, they can finance and own assets directly using available support to reduce their upfront costs. This can simplify planning and ensure technical standardization and grid integration. This can also help avoid the “principal–agent” problem, where local deployment decisions optimize for community-level returns while externalizing system-level costs to the utility. However, utilities may sometimes face constraints in financing the DRE projects and/or ensuring consistent O&M for dispersed assets over time.

To address this, the framework also emphasizes a DISCOM-led RESCO pathway in many contexts. Here, the DISCOM could remain the system planner and grid operator while a RESCO finances, installs, and maintains the assets under a long-term agreement. This structure preserves integration advantages while creating a built-in incentive for performance through service-level standards and performance-linked payments.

5.7.3 Utility-Led Reinvestment and Social Enterprise for Local Services

Where DRE deployment generates measurable system benefits, such as reduced procurement costs or improved billing and loss reduction, states could explore mechanisms to reinvest a portion of these benefits into village-level public and livelihood infrastructure. Naturally, any such reinvestment would need to be undertaken in consultation with state electricity regulatory commissions and aligned with prevailing regulatory frameworks. Potential applications could include public lighting, livelihood centres, cold storage, and e-mobility charging. The framework proposes that such reinvestment, where permitted and adopted, should follow transparent rules and be overseen jointly by the DISCOM and the Panchayat to ensure alignment with community priorities while maintaining system planning discipline.

5.7.4 Risk Mitigation and Bankability Measures

Across all financing pathways, the framework aims to introduce risk mitigation as a prerequisite for scaling investment. States can strengthen bankability through payment security mechanisms, partial risk guarantees, and well-defined quality assurance and verification protocols. Insurance coverage for equipment and public infrastructure can reduce exposure to climate and operational risks. Together, these measures improve confidence among developers and financiers and protect utilities and consumers from underperformance over the project's life.

5.9 Way Forward

- MNRE could revisit the Guidelines for Implementation of MSV component under the PMSGMBY and reflect emerging lessons from village energy planning, surplus management, storage siting, and institutional coordination. Implementation experience from current MSV villages could be systematically reviewed and used to refine the guidelines.
- MNRE could support small, typology-informed pilots that test the planning approach, phased deployment, surplus handling, and O&M accountability in real distribution contexts.
- MNRE could develop targeted training for DISCOMs, SNAs, and implementing agencies on VEP, load analysis, and system sizing. Strengthening the capacity of SNAs and related state institutions with tools, data access, and coordination mechanisms would be essential.

6.0 Conclusion

This report addresses a practical gap in India's DRE discourse. Much of the policy and program conversation still treats DRE as a set of deployable assets, while many binding constraints to scale sit in system design, distribution operations, and implementation coordination.

By combining lessons from existing DRE villages with village-level planning and techno-economic modelling across contrasting load typologies, the study shifts the focus from "how much DRE can be installed" to "how DRE can be planned and operated as part of the distribution system." In doing so, it addresses a gap in the literature between deployment assessments and scheme-level guidance, offering a planning logic that connects typology, load evidence, system configuration, institutional roles, and financing in a format that utilities and states can apply.

6.1 The Case for Integrated Village-Level DRE Planning

The study finds that village-scale DRE can be economically viable across diverse rural contexts, although outcomes depend strongly on local demand patterns and storage requirements. In Hiware Bazar village (state of Maharashtra), a 980 kW feeder-solarization configuration achieved an estimated LCOE of INR 3.06/kWh with subsidy, below state's APPC (INR 5.78/kWh), while adding a 350 kW/1,400 kWh battery system increased the blended LCOE to INR 5.44/kWh, still below the state level benchmark. In Bamun Sualkuchi village (state of Assam), a 1,318 kW solar configuration achieved an LCOE of INR 4.03/kWh with subsidy, below Assam's APPC. While a smaller 400 kW/1,600 kWh battery system also remained below the benchmark, larger storage configurations (500 kW/ 2,000 kWh) pushed costs above state's APPC.

These results suggest that solarization can provide cost-competitive electricity, while storage requires careful sizing and deployment to balance reliability and affordability. However, successful DRE scale-up depends not only on technology and economics, but also on how systems are planned, integrated, financed, and managed. The analysis shows that load typology shapes system sizing, storage requirements, surplus management, and grid impacts, while implementation outcomes depend on enabling regulations, appropriate ownership and financing models, and clear operational responsibilities. The experiences of Manyachiwadi and Odanthurai reinforce the importance of strong institutional arrangements for sustaining DRE systems over time. Together, these findings highlight that scaling DRE requires coordinated planning that links village demand, grid conditions, financing, and implementation responsibilities.

6.2 Recommendations for Government

The core recommendation is that the next phase of DRE scale-up should move from fragmented, scheme-led rollouts to a planning-led approach that can be replicated across states. Three near-term actions stand out:

- institutionalize a standard VEP template that links village selection and system design to feeder and DT data, seasonal load curves, and transparent sizing assumptions;
- explicitly treat surplus management and reverse power flows as first-order design constraints, especially in agriculture-dominant villages with strong seasonality, and encourage phased augmentation instead of upfront oversizing;
- design delivery models around long-term performance and not just commissioning targets.

Wherever DISCOM ownership is used, the program could specify O&M accountability, monitoring, and budget provisions. Where DISCOM capacity is constrained, DISCOM-led RESCO or performance-linked O&M models can embed maintenance incentives while retaining utility-led planning and grid integration. In addition, planning guidance could explicitly cover storage siting and aggregation. Beyond asking whether storage is needed, programs could also ask states and DISCOMs to assess where it should sit in the network. Evaluations could also explore upstream substation options that pool more diverse loads, improve utilization, and reduce mismatch risk.

6.3 Recommendations for Regulators

Regulators can complement the program design by strengthening performance-monitoring expectations and clarifying how grid support services such as peak reduction, surplus management, and network-stress reduction are recognized in planning and procurement. Where state rules narrowly restrict aggregation options (e.g., who can participate in VNM/group arrangements), regulators can consider broadening eligibility and standardizing settlement arrangements for rural contexts so that shared/utility-led RTS pathways can scale beyond a limited set of building types.

6.4 Future Research Priorities: Strengthening the evidence for scale

Further research is needed to quantify avoided peak procurement, deferred network upgrades and feeder-level operational benefits associated with storage deployment. Granular time-of-day procurement prices would be needed for this.

Second, research is needed to quantify how uncoordinated decentralized deployment can shift balancing and network costs to utilities across feeder types and states.

The next phase of research could focus on four areas:

- building a typology-and-metrics data set across states to test generalizability beyond a small set of villages and to identify recurring design and implementation failure modes;

- developing an applied valuation toolkit for feeder-level system costs and benefits, including peak procurement exposure, loss reduction, protection and voltage-management costs, and deferred CapEx so that storage and balancing choices can be evaluated more rigorously;
- comparing village-level versus upstream substation storage across typologies, and estimating not only blended costs but also avoided reverse-flow management costs, protection and voltage impacts, and how seasonal utilization affects the effective cost per "useful" kWh shifted;
- generating evidence on institutional performance by comparing delivery models, DISCOM CapEx, DISCOM-led RESCO, and third-party O&M, on uptime, life-cycle costs, and grievance handling.

6.5 A Practical Learning Agenda for Scale

Government, regulators, and research organizations can jointly accelerate learning through typology-based pilots that explicitly test phased deployment, surplus management approaches, and performance-linked O&M, paired with clear reporting requirements. Standardized monitoring and public reporting of results can help build the evidence base needed for wider replication.

6.6 Closing

In summary, our study contributes a practical, system-oriented framework for DRE deployment that aligns village-level design with distribution realities. The next step is to convert this planning logic into a stronger national evidence base through larger data sets, transparent pilots, and rigorous valuation of storage and network impacts. With these additions, DRE can scale in ways that strengthen rural reliability, support the 500 GW target, and contribute credibly to India's longer-term net-zero pathway.

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Appendix A. Past Experience With Distributed Renewable Energy Schemes: Achievements and learnings

Table A1. Overview of national DRE programs and policy frameworks in India

Name of program—launch year	Objective
National Solar Mission—2010	India's flagship solar development program aimed at scaling solar power deployment, initially targeting 20 GW of solar capacity by 2022, combining utility-scale deployment with approximately 2 GW of decentralized solar applications, thereby laying an early DRE foundation. The Rooftop Solar (RTS) program under the National Solar Mission evolved into the Grid-Connected Rooftop Solar Programme and eventually informed PMSGMBY.
Grid Connected Rooftop Solar Programme—2014 (Ministry of New and Renewable Energy [MNRE], 2014) and 2019 (MNRE, n.d.)	To achieve a cumulative installed capacity of 40,000 MW from grid-connected RTS projects.
Atal Jyoti Yojana—2016 (Press Information Bureau, 2023)	Installation of solar street lighting systems in the states with less than 50% of households covered with grid power, as per the 2011 census.
PM-KUSUM—2019 (MNRE, 2024a)	Defines subsidy structures, implementation models for solarizing agricultural power demand.
FOR (Grid-Interactive Distributed Renewable Energy [DRE]) Regulation—2019 (Forum of Regulators, 2019)	Model regulations for states guiding seamless grid integration of DRE systems. Sets standards for net metering, net billing, gross metering, etc.
Electricity Rights of Consumer Rules—2020	Outlines consumer rights related to electricity supply.
National Bio Energy program—2021 (MNRE, 2022b)	Supports biogas and biomass for clean cooking and power generation. This is a much older scheme that has seen many strengthening iterations.
Framework for promotion of DRE livelihood applications—2022 (MNRE, 2022a)	To create an enabling ecosystem for sustainable livelihoods using DRE sources like solar, wind, micro-hydro and biomass.

Name of program—launch year	Objective
Renewable Purchase Obligation—2022 (Ministry of Power, 2022)	Renewable purchase obligation (RPO) trajectory that progressively increases the share of renewable energy procurement required from obligated entities, including specific targets for different components of renewable energy. While the Electricity Act 2003 created the statutory basis for RPOs, empowering State Electricity Regulatory Commissions (SERCs) to set RPO targets, the evolution of state-specific RPO regulations and targets began in 2010 onwards.
New Solar Power Scheme (for PVTG Habitations/Villages) under PM JANMAN—2023 (MNRE, 2024b)	Electrification of remote Tribal households and community centres through off-grid solar systems and minigrids.
PM-Surya Ghar: Muft Bijli Yojana (PMSGMBY)—2024 (MNRE, 2024d)	Develop an ecosystem for RTS in residential and government buildings, a national application process, and a MSV component. • to provide RTS to 1 crore households across the country by 2026–27, with an outlay of INR 75,021 crore; • to potentially add 30 GW of decentralized RTS capacity and provide free electricity of up to 300 units per month to households by reducing or eliminating their electricity bills; • to provide central financial assistance (CFA) for residential grid-connected RTS systems, access to collateral-free loans up to INR 2 lakh at ~6.5%–7% interest, net metering benefits, and a centralized national portal for applications. The component of PMSGMBY allocates INR 800 crore (INR 1 crore per village) to establish one fully solar-powered model village in each district of India to serve as a replicable model for rural energy self-reliance.
Renewable Consumption Obligation—2025 (Ministry of Power, 2025)	The Central Electricity Regulatory Commission (CERC) expanded the traditional RPO framework under the renewable consumption obligation structure by introducing a specific DRE obligation, which shall be met from projects less than 10 MW in size, including solar installations under all configurations.

Source: Authors' compilation.

Appendix B. Shortlisted DRE Village Matrix

See Appendix B here: https://www.iisd.org/publications/report/scaling-rural-distributed-renewable-energy-india.

Appendix C. Techno-Economic Modelling: Assumptions and stepwise methodology

This section summarizes (i) the core assumptions used in the village-level techno-economic model for Bamun Sualkuchi and Hiware Bazar, and (ii) the stepwise methodology followed to translate load and sales data into system sizing, scenario design, and cost–benefit outputs (levelized cost of electricity [LCOE] and payback).

C.1.1 Key Modelling Assumptions

Table C1 provides the full set of input assumptions used in the Excel-based model, including demand growth, solar photovoltaic (PV) performance parameters, capacity utilization factors (CUFs), battery parameters, cost assumptions, escalation factors, and state-level cost benchmarks (average power purchase cost [APPC] and average cost of supply [ACOS]). The assumptions draw on a mix of tariff orders and regulatory references, stakeholder consultations (including EPC/vendors where relevant), and standard techno-economic parameters used in state renewable energy tariff regulations.

Table C1. Modelling assumptions for Bamun Sualkuchi and Hiware Bazar

Parameters	Units	Bamun Sualkuchi	Hiware Bazar
Compound annual growth rate (CAGR) in electricity consumption based on sales data collected for FY 2024-25	%	1.8%	1.0%
Annual PV degradation factor	%	0.7%	0.70%
CUF—Rooftop solar (RTS)	%	15.0%	15.0%
CUF—Ground-mounted solar	%	16.0%	18.0%
Round-trip efficiency—Battery energy storage system (BESS)	%	90.0%	90.0%
Depth of discharge—BESS	%	90.0%	90.0%
Discount factor	%	8.0%	8.00%
Deration factor (year on year)	%	0.7%	0.70%
Hour of discharge	Hours	4	4
Number of operation cycles in a year	Hours	300 (on-grid)	300 (on-grid)
Growth in energy charges	%	1.00%	1.00%
Growth in revenue from consumer	%	1.00%	1.00%

Parameters	Units	Bamun Sualkuchi	Hiware Bazar
Power purchase cost from solar PV (INR/kWh)	%	4.00	4.00
Escalation in power purchase cost	INR/ kWh	1%	1%
Escalation in ACOS	%	1%	1%
Price of Renewable Energy Certificate Purchase	INR/ kWh	0.37	0.37
Per kW system cost (ground-mounted)	INR/ kW	40,500	40,500
Per kW system cost (RTS)	INR/ kW	80,000	70,000
Cost of BESS for GM (USD/ kWh) up to 12th Year	USD/ kWh	150	150
USD to INR conversion rate	INR	86	86
Cost of BESS replacement (13th year onwards)	USD/ kWh	88	88
Annual decline in cost due to technology	%	5%	5%
Land requirement for 1 MW	Acres	5.00	-
Land lease rent per acre per year	INR	50,000	-
Annual increase in land lease rent	%	5	-
ACOS	INR/ kWh	9.55	9.25
APPC at energy sales (FY 2023–24)	INR/ kWh	8.46	5.94
Distribution losses (state)	%	14.50%	17.00%
Transmission losses (state)	%	3.23%	2.80%

Source: Authors.

How to read Table C1:

- **demand growth and degradation**: The model applies the village-specific energy sales growth rate and incorporates PV degradation (and deration, where applied) to reflect performance decline over time.
- **generation parameters**: Separate CUFs are used for rooftop systems and ground-mounted systems, consistent with their expected performance in each location.

- **battery parameters**: BESS sizing and dispatch are modelled using stated round-trip efficiency, depth of discharge, and a 4-hour discharge duration, alongside cost and replacement assumptions.
- **cost benchmarks**: APPC (at energy sales) and ACOS are included as reference benchmarks to interpret the modelled LCOE and payback results.

C.1.2 Stepwise Methodology Used For Village Techno-Economic Analysis

The study followed a structured sequence from data collection to scenario evaluation. The steps below mirror the modelling workflow used in the Excel tool and the supporting analytical checks, and the approach used to estimate LCOE and payback period.

Step 1. Data collection and structuring

We compiled (a) load curve data (hourly profiles, where available), and (b) consumer-category electricity sales/consumption data. We used load curves to characterize seasonal and intra-day variation and used historical sales data to inform future demand projections.

Step 2. Demand projection and typology identification

Using historical sales growth, we projected electricity requirements across the next 5 years up to FY 2029-30. We also identified the dominant demand segment in each village to guide system logic (for example, agriculture-dominant/daytime-peaking versus residential-dominant profiles/evening-peaking).

Step 3. Baseline system sizing for solar PV

For the target year, we estimated baseline annual energy requirements and translated these into required PV capacity using CUF assumptions and PV degradation factors. This step produced the first-cut PV capacity requirement for each village, differentiated by rooftop and ground-mounted configurations as relevant.

Step 4. Assumptions finalization for financial modelling

We populated the model with cost and policy inputs, including capital expenditure assumptions for rooftop and ground-mounted PV, applicable subsidy parameters, battery cost assumptions (including the replacement cost), operations and maintenance and other applicable escalation factors, and relevant state cost benchmarks (such as APPC). The full set of assumptions is reported in Table A1.

Step 5. Scenario definition and operational logic

We defined candidate village configurations and implementation pathways (for example, grid-connected PV, grid-connected PV plus storage, and other relevant configurations) and documented the operational rationale for each scenario. This included expected alignment with load shape, surplus/export implications, grid interaction requirements, and key advantages/limitations of each option.

Step 6. Load curve-based system refinement (solar and storage sizing) and option screening

Using load curve analysis, we refined system sizing and assessed operational feasibility. Where storage was considered, we identified peak periods and estimated indicative BESS requirements (power and energy rating) aligned to the system objective (e.g., peak shaving, surplus absorption, balancing). We then assessed implications such as surplus persistence, reverse power flows, seasonal charging/discharging constraints, and practical pros/cons of each solarization option.

Step 7. Techno-economic outputs (LCOE and payback)

For each scenario/business model, we estimated LCOE and indicative payback using standard project cost components and financial parameters aligned with applicable renewable energy tariff regulation approaches (CERC/SERC, as relevant). The LCOE computation uses the following inputs from Table A1: installed capacity, CUF, useful life, plant cost (INR/kW), debt–equity ratio, return on equity, interest rate/discount rate, depreciation, income tax treatment, operations and maintenance expenses, and interest on working capital.

Step 8. Option selection and interpretation for program relevance

Finally, we interpreted results with explicit attention to operational feasibility (surplus management, seasonal constraints, and grid interfacing) alongside LCOE and payback.

Appendix D. Comparative Analysis of Distributed Renewable Energy Policies and Regulatory Frameworks in Maharashtra and Assam

	Maharashtra	**Assam**
State-level policy	Non-Conventional Energy Policy 2020 sets clear targets for 12,930 MW of solar capacity by 2025, including specific goals for 2 GW rooftop solar (RTS), 500 MW solar for water supply, 250 MW for farmers, and electrification of 10,000 rural homes annually.	Assam Renewable Energy Policy, 2022, targets capacity addition of 1,200 MW by 2027, and actively encourages the adoption of grid-connected RTS installations in residential, commercial, industrial, and government sectors.
Renewable Energy Tariff Regulation	MERC[20] (Terms & Conditions (T&C) for determination of Renewable Energy Tariff) Regulations 2019 establishes terms for renewable energy tariff determination and applies to new renewable energy projects in Maharashtra selling to distribution licensees.	AERC (T&C for determination of Renewable Energy Tariff) Regulations 2017 establishes terms for tariff determination of RE projects subject to specified respective eligibility criteria.
Grid-Interactive Rooftop Renewable Energy Generation Regulations 2019 and amendments	• To promote renewable energy generation via grid-interactive RTS in Maharashtra. • The regulations talk about the various metering arrangements, including net metering, net billing, gross metering, behind the meter, and group net metering for all consumers in the area of supply of the distribution licensee. • Virtual net metering—Residential consumers living in multistory buildings of the same housing society or apartment owners' association, including their common connection within the same distribution licensee's area of supply.	• Provides mechanisms for consumers to sell surplus solar power back to the grid and receive credit, making individual household solar economically viable. • Group net metering and VNM for Renewable Energy Guideline, 2024 promotes solar energy adoption among various consumer categories and provides clear guidelines for metering and energy accounting. Sets standards for net metering, VNM, etc.

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[20] Maharashtra Electricity Regulatory Commission (MERC).

	Maharashtra	**Assam**
State subsidy	• Under the Mukhyamantri Saur Krishi Vahini Yojana (MSKVY) 2.0, the Maharashtra government provides a 90%–95% subsidy for stand-alone solar pumps (farmers pay only 5%–10%) and facilitates solar feeder projects to supply daytime electricity for agriculture under the MSKVY 2.0 scheme.	• The Assam Government provides a one-time upfront state-specific subsidy of INR 15,000 for a 1 kW RTS system, up to INR 45,000 for a 3 kW RTS system. • The subsidy is disbursed through Assam Power Distribution Company Ltd to the vendor, effectively reducing what the homeowner pays at the point of installation.

Appendix E. Demographic and Socio-Economic Profiles of Hiware Bazar (in Maharashtra) and Bamun Sualkuchi (in Assam)

	Hiware Bazar	**Bamun Sualkuchi**
District	Ahmednagar	Amingaon
Village area (ha)	976.84	5.28
Total population	1245	7,628
Male	625	3,746
Female	620	3,882
Farm families	205	NA
Farmless families	03	NA
Industrial workers	NA	3,388
Agricultural workers	NA	107
Rainfall (mm)	384	NA
Cultivable land (ha)	795.23	NA
Forest land (ha)	70.03	NA
Pasture land (ha)	6.75	NA
Total irrigated land (ha)	580.4	NA

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