Charging Change

Strengthening Kerala's Energy Security through Community Ownership

Exploring the Potential of Community-owned Battery Energy Storage Systems

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Charging Change: Strengthening Kerala's Energy Security through Community Ownership - Exploring the Potential of Community-owned Battery Energy Storage Systems

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Foreword

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FOREWORD

Kerala's energy transition is entering a phase that demands greater resilience, flexibility, and local responsiveness. As decentralised renewable energy, especially rooftop solar, expands, the State must strengthen the systems that underpin reliability, grid stability, and equitable access to power. The challenge before us is to ensure that new technical solutions are fiscally responsible, institutionally robust, and closely aligned with the everyday realities of households and communities. In parallel, our aspiration for energy-self-sufficient villages and panchayats calls for innovative models that can harness local resources while remaining firmly integrated with the wider grid.

Community Battery Energy Storage Systems (C-BESS) represents a promising pathway in this context. By enabling shared, local-scale storage, C-BESS can complement existing grid infrastructure, smooth demand fluctuations, and support communities during disruptions. At the panchayat level, such systems can become critical building blocks of energy-self sufficient localities, allowing villages to maximise the value of their renewable generation and enhance resilience during outages or extreme events. Equally, they invite important questions about institutional design, financial viability, and the role of local self-governments and community institutions in managing decentralised energy assets.

This report, prepared by Asar Social Impact Advisors Pvt. Ltd., brings together system-level analysis and panchayat-level evidence from Kerala to examine these questions in depth. It offers a grounded exploration of how community-scale storage might be integrated into the State's broader energy transition, while remaining attentive to public value, regulatory clarity, and the capacities of utilities and local bodies. In doing so, it also reflects on what it would take for Kerala's panchayats to move towards greater energy self-reliance, and how C-BESS and other decentralised solutions could enable village-scale energy planning and management.

As Kerala continues to balance energy security, sustainability, and affordability, such evidence-based work is both timely and necessary. I hope this publication serves as a useful reference for policymakers, practitioners, utilities, local self-governments, financial institutions, and civil society organisations as they reflect on the evolving contours of decentralised energy solutions in Kerala. It is my expectation that the insights presented here will inform thoughtful experimentation, structured pilots, and collaborative learning especially in pursuit of energy-iself reliant panchayats and resilient local electricity systems and that they will support Kerala's efforts to build a power system that is not only cleaner and more resilient, but also more responsive to the needs and aspirations of its people.

K. R. JYOTHILAL

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Foreword

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Kerala State Electricity Board Limited (KSEBL)

KSEB

MINHAJ ALAM IAS
Chairman & Managing Director
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Foreword

Kerala's power system is undergoing a structural shift. Rapid growth in rooftop solar and other decentralised resources is reshaping demand patterns across our distribution network, even as the State continues to depend heavily on imported power to meet evening peaks and periods of stress. For Kerala State Electricity Board Limited (KSEBL), this transition brings both opportunity and responsibility: we must integrate higher shares of renewable energy while maintaining reliability, protecting vulnerable consumers, and ensuring the financial sustainability of the utility.

In this context, Community Battery Energy Storage Systems (C-BESS) merit careful consideration as part of our medium to long-term strategy. Located at the level of distribution transformers or feeders, community-scale storage can help manage mid-day solar surplus, support evening peak management, and improve local voltage and power quality. Just as importantly, a community-anchored approach opens space to work with panchayats, cooperatives, and other local institutions in ways that reflect Kerala's strong traditions of decentralised governance and social inclusion.

This report, prepared by Asar Social Impacts Advisors Pvt Ltd in close dialogue with KSEBL, provides a grounded assessment of the technical, financial, and institutional feasibility of C-BESS in Kerala. For KSEBL, this kind of evidence is valuable in three ways: it helps us understand where and how distributed storage could add system value; it clarifies the conditions under which community participation is viable; and it highlights the regulatory and financial frameworks that would be needed for any future pilots.

As a utility, we view technologies such as community-scale storage not as end in themselves, but as potential tools in a broader effort to deliver affordable, reliable, and increasingly clean power to all our consumers. Any move towards piloting C-BESS will need to be phased, carefully targeted, and aligned with our planning, safety standards, and regulatory guidance. This report is an important input into that process of reflection and structured experimentation.
I trust that this study will be useful not only to KSEBL, but also to policymakers, regulators, local self-governments, financial institutions, and community organisations as we collectively explore the role that community-anchored storage can play in Kerala's energy future.

Minhaj Alam, IAS
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Executive Summary

Kerala's energy transition is at a critical juncture. The state has committed to achieving 100% renewable electricity by 2040 and carbon neutrality by 2050, positioning itself as a frontrunner among Indian states in climate ambition. Yet, its structural energy profile presents significant challenges. Nearly 75–80% of Kerala's electricity is imported from outside the state, making it vulnerable to peak-demand volatility, price fluctuations in external power markets, and transmission constraints. At the same time, rapid growth in decentralised rooftop solar installations particularly in residential and commercial sectors—has reshaped local load curves. While rooftop solar contributes substantially to mid-day generation, it does little to alleviate evening peak demand, resulting in growing imbalances between supply and demand within the state's distribution network. These dynamics underscore the urgent need for flexible, distributed storage solutions capable of enhancing renewable utilisation, grid stability, and energy security.

This report examines the techno-economic, institutional, and social feasibility of Community-Owned Battery Energy Storage Systems (C-BESS) as a strategic intervention within Kerala's evolving energy landscape. Unlike centralised storage infrastructure, C-BESS are conceptualised as decentralised systems installed at the distribution-transformer or feeder level. Moreover, these are collectively owned by community institutions such as panchayats, cooperatives, or community trusts. This report advances the argument that storage, when embedded within Kerala's strong decentralised governance framework, can function as a technical grid asset and as a democratic and developmental instrument. Such decentralised storage systems can strengthen local resilience, enhance equitable access, and reinforce community participation in energy transition.

A survey was conducted in Perinjanam Panchayat, Thrissur district, to examine the viability of C-BESS on ground. A comprehensive methodology combining policy and regulatory review, technical assessment of state-level load and rooftop solar data, financial modelling of storage deployment scenarios, stakeholder consultations, and primary household surveys was used. Perinjanam was selected as a pilot site because of its relatively high rooftop-solar penetration, compact settlement pattern, and strong local institutional presence. Surveys of solar prosumers and non-prosumers

were conducted to assess awareness levels, trust in governance actors, willingness to participate in community storage initiatives, and preferences regarding ownership and management structures.

Strong institutional trust in panchayats and cooperative bodies was observed, even though awareness of battery storage technologies was limited. Households prioritised reliability, affordability, transparency, and clear governance over environmental motivations. Respondents showed a clear preference for collectively managed systems over individually owned battery solutions, provided that financial risks are moderated and accountability mechanisms are in place. These findings highlight the importance of communication strategies focused on tangible economic and reliability benefits, alongside pilot demonstrations that build familiarity and confidence.

Kerala's load profile—characterised by pronounced evening peaks and significant mid-day solar surplus—creates favourable technical conditions for distributed storage. A substantial share of rooftop solar generation is currently exported to the grid during surplus hours, representing untapped potential for time-shifting through local batteries. Deployment of community-scale storage systems can capture this surplus electricity and discharge it during evening peaks, thereby reducing peak-time power procurement from external markets, mitigating reverse power flow issues, improving voltage stability, and deferring investments in network upgrades. Scenario modelling suggests that even limited deployment across a small proportion of distribution transformers can create meaningful distributed storage capacity, contribute flexible discharge potential, and enhance local grid resilience. At higher levels of adoption, community batteries could function as a distributed extension of the state's broader storage strategy.

From a financial perspective, declining battery costs and the potential for revenue stacking improve the viability of C-BESS. The report identifies multiple ownership and financing pathways, including public–community partnerships supported by viability gap funding and concessional loans, cooperative shareholding structures enabling local equity participation, utility-linked service models where storage provides peak-shaving services under contractual arrangements, and diversified revenue approaches combining time-of-day arbitrage, subscription-based services, and grid-support payments. While pure arbitrage may not always ensure strong

returns, system-wide benefits—such as avoided peak procurement costs, deferred infrastructure upgrades, and enhanced resilience—significantly strengthen the economic case.

Beyond grid stability, C-BESS offers significant equity and developmental co-benefits. Community ownership models can mitigate emerging disparities between solar-owning households and non-solar consumers by broadening access to storage-enabled advantages. Localised systems can create employment opportunities in installation and maintenance, strengthen women's participation in energy governance structures, and retain financial value within local economies. Moreover, batteries can provide critical backup support for essential services—such as schools, health centres, and emergency facilities—enhancing disaster preparedness.

C-BESS represents a technically feasible, economically promising, and socially aligned pathway for Kerala's clean energy transition. Scaling such systems will require regulatory frameworks, tariff mechanisms that recognise storage services, targeted viability gap support during early phases, clear safety and lifecycle standards, and structured pilot programmes with robust monitoring. A phased rollout—beginning with selected panchayats and municipalities and expanding to high solar-density regions—would allow institutional learning and financial optimisation. By integrating decentralised storage with democratic governance and cooperative ownership, Kerala has the opportunity to strengthen energy security, reduce import dependence, enhance renewable utilisation, and ensure that the benefits of the transition are equitably distributed. Community-owned storage can thus serve as a cornerstone of a resilient, inclusive, and people-centred energy future for the state.

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01 Introduction

Reliable and clean energy access is central to building resilient communities, especially against the backdrop of growing climate risks, rising electricity demand, and the global transition toward carbon neutrality. India has committed to achieving carbon neutrality by 2070. Building on this national vision, Kerala has charted a more ambitious pathway toward energy independence and climate leadership—targeting 100% renewable energy by 2040 and carbon neutrality by 2050[1]. These goals place the state at the forefront of India's energy transition, demonstrating a commitment that significantly advances national timelines. However, Kerala continues to import more than 70% of its electricity from outside the state[2], and any disruption in imported power has immediate and widespread consequences for households, public services, and the economy. This structural dependence on external power, combined with rising demand and intensifying climate impacts, makes the security of Kerala's energy future urgent and foundational for its development.

Kerala is renowned for its distinctive geography, natural resources, decentralised governance, and cooperative traditions, which shape development strategies at every level. The state's approximately 590-kilometre coastline, mountainous terrain, and intricate backwaters define its physical character and constrain the scope for large, centralised energy projects, making distributed and community-level solutions particularly relevant.

The unique energy context of the state creates a fertile ground for community-led energy transitions. Kerala's Panchayati Raj system empowers village-level administrations (panchayats)—backed by cooperative societies and active local participation—to steer social welfare, local businesses, and increasingly, energy innovation. High literacy, robust public institutions, and strong community mobilisation position the state as a frontrunner for scalable, publicly owned energy initiatives. Successful local models in housing, sanitation, and water management already demonstrate how panchayats can plan, own, and manage shared infrastructure in ways that are accountable and inclusive.

This report builds on the above context and institutional foundation to explore the potential of Community-owned Battery Energy Storage Systems (C-BESS) as a strategic tool for Kerala's energy future. It examines the potential of C-BESS in addressing the state's energy security challenges, supporting higher renewable-energy integration, and deepening decentralisation by embedding critical energy assets within panchayats, cooperatives, and local institutions. By analysing Kerala's current energy landscape, drawing lessons from international practice, and grounding insights in field research and stakeholder engagement, the report sets out pathways through which C-BESS can help the state move toward a more secure, resilient, and democratic energy system.

ENERGY SECURITY

On an annual average, internal generation contributes 22% of total electricity demand, while external sources supply 78% (Central Generating Stations 34%, Independent Power Producers/Captive Power Plant/Cogeneration 5%, Contracts 27%, Power Exchange 12%) of power. The heavy contractual and power exchange dependence implies significant financial exposure for Kerala State Electricity Board Limited (KSEBL) to contracted capacity charges and variable fuel costs. These can erode utility finances when demand or market prices deviate from projections, during national peak demand, and fuel supply disruptions.

Additionally, Kerala's energy reality presents significant security concerns. The state's total installed capacity, including allocated shares in joint and central sector utilities, stood at 7.82 GW as of 31st December 2025[3], with a major portion heavily dependent on external sources. Thermal power accounted for 39% of contracted capacity, renewable energy contributed 30% (including solar, small hydro, wind, and biopower), large hydro provided 26%, and nuclear supplied the remaining 5% (Figure 1). This capacity mix underscores Kerala's continued reliance on fossil fuel-based generation, accessed primarily through power-purchase agreements rather than indigenous resources.

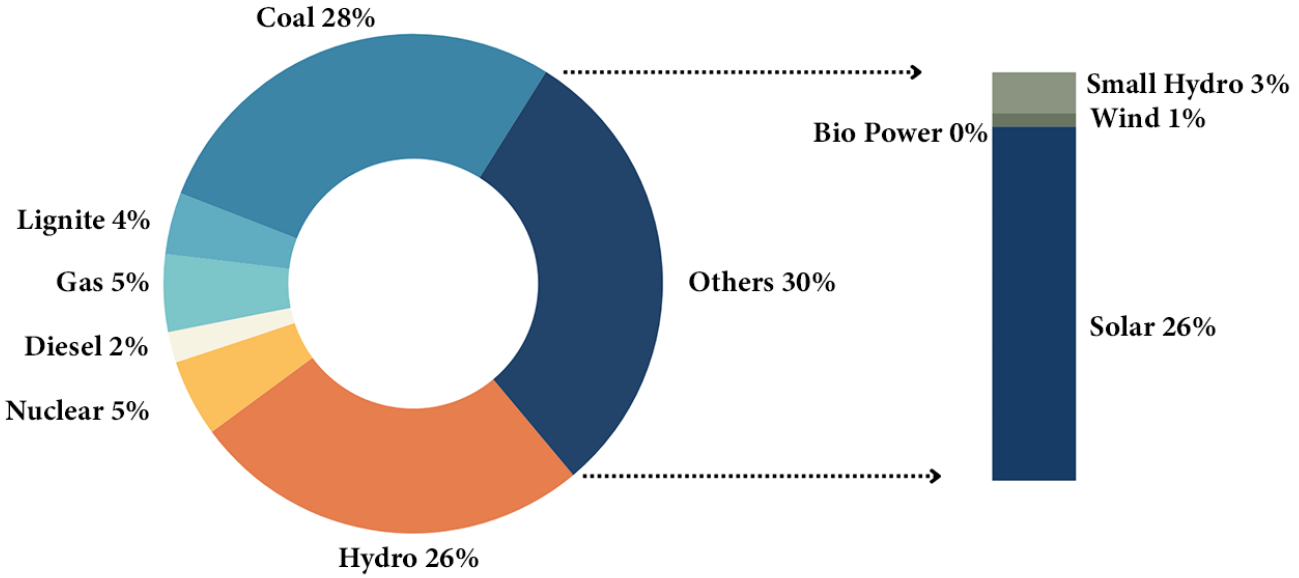

Figure 1: Contracted capacity of power in Kerala as on 31st December 2025

Kerala's electricity demand is on a steep upward trajectory: while the 20th Electric Power Survey of India anticipates a compound annual growth rate of 5.12% between 2023–24 and 2029–30[4]. The state recorded its highest-ever peak demand of 5,797 MW on May 2, 2024[5] which overshot the level projected for 2028, suggesting that demand could touch 10,000 MW by around 2031 if current trends persist[6].

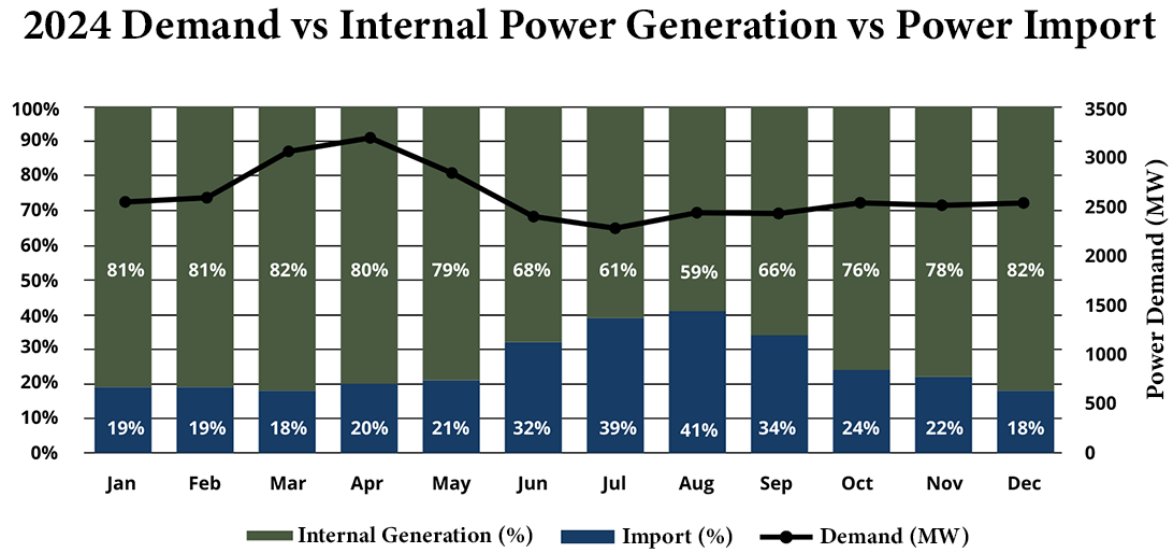

Figure 2. Kerala's power demand for 2024 met by internal generation and imported electricity[8]

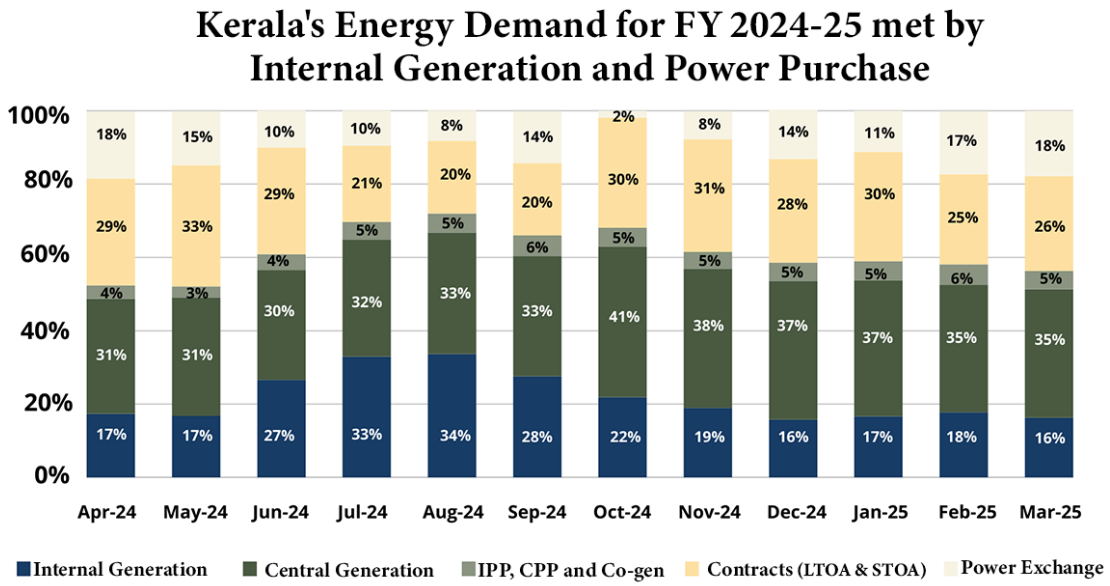

Figure 3. Kerala's energy demand for FY 2024-25 met by internal generation and power purchase

The dominance of domestic consumers who account for almost three-quarters of total electricity use combined with strong seasonal effects drive pronounced seasonal and daily fluctuations in demand[7]. Loads typically begin to climb from January and reach

their highest levels in March–April (Figure 2), with the grid routinely experiencing intense pressure between 18:00 and 22:00. In the summer months, this evening peak often stretches past midnight, further straining system reliability and reinforcing the case for distributed storage and demand management.

Accelerated investment in renewable energy diversification can help overcome these limitations. Solar energy, particularly through rooftop installations, has witnessed exponential growth and now forms the backbone of the state's renewable expansion strategy. Small hydropower optimisation and emerging wind energy projects complement this solar-centric approach, collectively aiming to reduce external dependency while building a more resilient and sustainable energy portfolio.

DISTRIBUTED RENEWABLE ENERGY (DRE) SYSTEMS

Kerala's acute land scarcity has necessitated a strategic shift toward distributed renewable energy (DRE). This has spurred remarkable innovation in rooftop solar systems, floating solar technologies, and optimised small hydro projects, all of which enable clean-energy expansion without competing for scarce land resources. The results have been transformative: installed renewable energy capacity has more than quadrupled from 572.42 MW in 2020-21 to 2,382.34 MW in December 2025[10], reflecting sustained infrastructure investment and strong policy commitment. DRE has yielded impressive outcomes, particularly in rooftop solar deployment with new capacity being added at an average rate exceeding 30 MW per month in recent years[11]. Rooftop solar systems account for 82.8% of the state's total installed Solar Photovoltaics (PV) capacity, and solar energy contributes around 85% of Kerala's overall installed renewable energy capacity[12]. The cumulative energy demand for April and May 2025 was 5,616 Million Units (MU) (Table 1). Solar energy contributed 34.8% of the installed capacity within the state. Despite such a significant number, it met only 1.45% of the bimonthly demand especially during the peak summer months when the generation was relatively high.

Energy Producer	Source	Installed capacity (MW)	Energy Generate during April and May 2025 (MU)	State share of Installed capacity (%)	State share of Energy Generated (%)
KSEBL	Hydro	2243.6	1287.3	47.49%	22.92%
	Thermal	159.96	0	3.39%	0.00%
	Wind	2.03	0.72	0.04%	0.01%
	Solar	12.5	1.93	0.26%	0.03%
Independent Power Producer	Hydro	76.5	28.89	1.62%	0.51%
	Thermal	526.58	0	11.15%	0.00%
	Wind	71.53	17.87	1.51%	0.32%
	Solar	1631.56	79.93	34.54%	1.42%

Table 1. Share of locally produced energy for the months of April and May 2025 (13) (14)

In the past five years, the state's renewable energy generation has more than doubled from 1,046 MU in 2020-21 to 2,646 MU in 2024-25 (Figure 4). Solar energy has emerged as the dominant force in this expansion, climbing from just cts accelerated rooftop deployments and supportive state policies. This solar surge contrasts with the more volatile performance of other renewable sources: small hydro generation peaked at 932 MU in 2021-22 but subsequently declined to 716 MU in 2023-24 before recovering to 814 MU in 2024-25, reflecting the inherent variability of monsoon-dependent generation. Wind energy has shown modest growth potential, rising to 215 MU in 2023-24 before declining to 120 MU in 2024-25, indicating both opportunity and challenges in wind resource development.

While the growing dominance of solar power demonstrates Kerala's success in harnessing distributed solar potential, the modest and inconsistent contributions from small hydro and wind highlight substantial opportunities for diversifying the renewable portfolio.

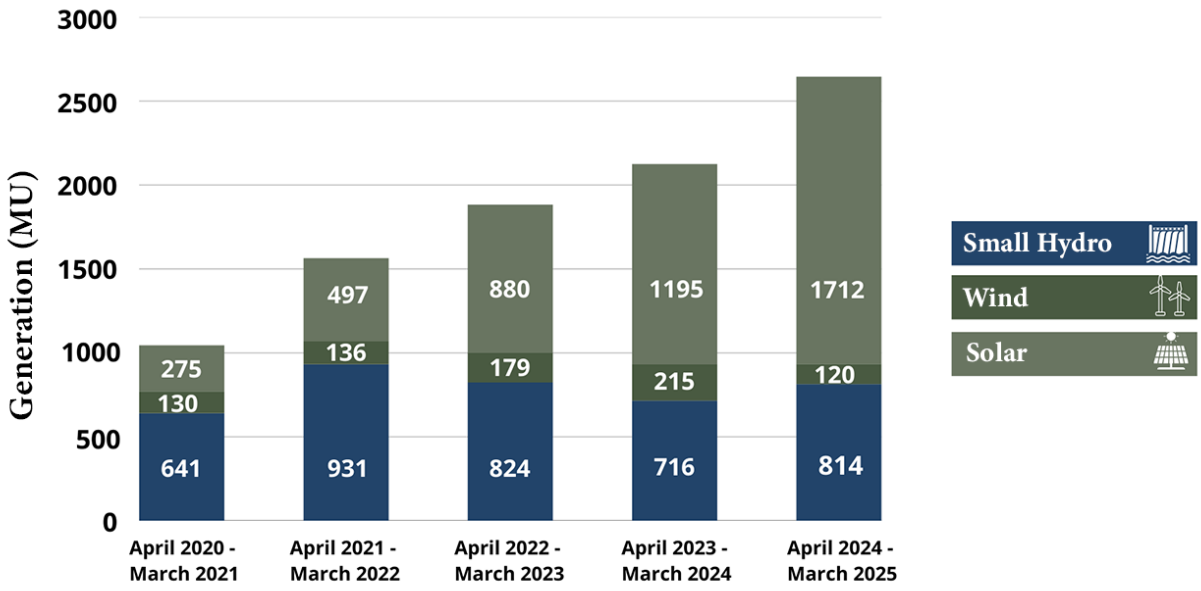

Figure 4: Renewable energy generation in Kerala (2020-2024) in Million Units (MU)[15]

Kerala's total electricity demand for FY 2024–25 amounted to 33,606.49 MU, with a significant reliance on non-renewable sources. The temporal mismatch between solar generation and peak demand underscores the urgent need for energy storage solutions to maximise the value of distributed renewable investments and to maintain grid stability.

ENERGY STORAGE IN KERALA'S RENEWABLE ENERGY TRANSITION

As Kerala moves toward a higher share of renewable energy, managing the intermittent and variable nature of these sources becomes critical for grid stability. Solar resources, for example, generate power during daylight hours, while the state's electricity demand peaks at night, precisely when solar output falls to zero. This misalignment intensifies the challenge of balancing supply and demand and increases stress on the grid, especially during evening hours when reliance on imports is high.

Strategic deployment of energy storage systems offers an effective pathway to address these dynamics. Recent studies estimate that, to reliably support a renewable-rich grid and meet future needs, Kerala will require an optimal installed storage capacity of around 3.8–4.1 GW by fiscal year 2039–40[16]. By charging storage systems with abundant daytime solar energy and dispatching the stored power during evening and nighttime peak periods, the state can maintain reliable supply while reducing dependence on external sources and costly market purchases.

Kerala can strengthen grid reliability and resilience by building a diversified storage portfolio rather than relying on a single technology. Pumped-Hydro Energy Storage (PHES) is well suited for large-scale, long-duration and seasonal balancing, while Battery Energy Storage Systems (BESS) excel at fast response, short-duration services such as frequency control, peak shaving, and local voltage support. PHES in Kerala tends to be large, centralised, and utility-driven, whereas BESS can be deployed at feeder, ward, or village level, coupled with rooftop solar and local demand profiles. This report focuses on BESS rather than PHES because the core focus pertains to communities—panchayats, cooperatives, and prosumers—directly owning and governing storage assets. This approach is far more feasible with modular, distributed batteries than with capital-intensive, site-specific pumped-hydro projects.

02 Community Battery Energy Storage System

BESS operates at three main scales: individual household batteries, community batteries, and utility-scale storage. Individual household batteries are grid-tied units paired with rooftop solar and installed within a single home. They store excess solar energy generated during the day and release it when the household needs power, helping reduce electricity bills, increase self-consumption of solar energy, and lower dependence on the grid. However, these grid-tied hybrid systems remain relatively expensive on a per-unit basis and currently have lower levels of acceptance and uptake. Perceptions around maintenance requirements and associated risks also shape adoption decisions.

Contrarily, utility-scale batteries are large installations, typically located at transmission grid substations, capable of storing hundreds of MWh of energy. These assets play a pivotal role in integrating large quantities of renewable energy into the grid, providing system-level services such as peak-shaving, frequency regulation, and backup during outages. For example, in Kerala, KSEBL has commissioned a 125 MW/500 MWh BESS project at the Mylatti substation in Kasaragod and four more are in the pipeline, capable of supplying electricity to thousands of consumers during periods of high demand or supply disruption. While crucial for grid operations, these systems are typically owned and operated by utilities or private developers, with communities benefiting indirectly.

C-BESS is situated between these two scales. A community battery is a centrally located energy-storage system shared by

an entire neighbourhood, feeder area, or panchayat rather than being installed in individual homes (Figure 5). It connects directly to the local electricity distribution network, allowing multiple households and prosumers to collectively benefit from stored renewable energy. C-BESS functions as a collective buffer that smooths the mismatch between variable renewable generation and local demand. By storing surplus solar energy when generation is high and demand is low, and releasing it during peak periods, community batteries help lower energy bills, stabilise the grid, reduce carbon emissions, and extend the benefits of clean energy even to those who do not have rooftop solar. That is, the surplus is absorbed by the community battery instead of being curtailed or exported inefficiently. This arrangement offers more equitable access to clean energy services while stabilising power flows for the entire community. Acting as a local balancing node within the distribution network, C-BESS ensures that excess energy produced in one part of the feeder can efficiently support surrounding users without overburdening upstream infrastructure. Installed at the distribution-transformer level, community batteries also reduce transmission and distribution losses compared with distant generation and storage and the larger scale plus collective ownership can bring down costs per kWh relative to individual household batteries.

Ownership and management can rest with panchayats, cooperatives, community trusts, or energy societies, transforming storage into a shared public resource that enhances reliability, savings, and resilience. C-BESS enables more renewable energy integration into the decentralised grid and strengthens local reliability, reduces system costs, and broadens access to clean power. It serves as a technical backbone for a people-centred, resilient, and community-owned energy future.

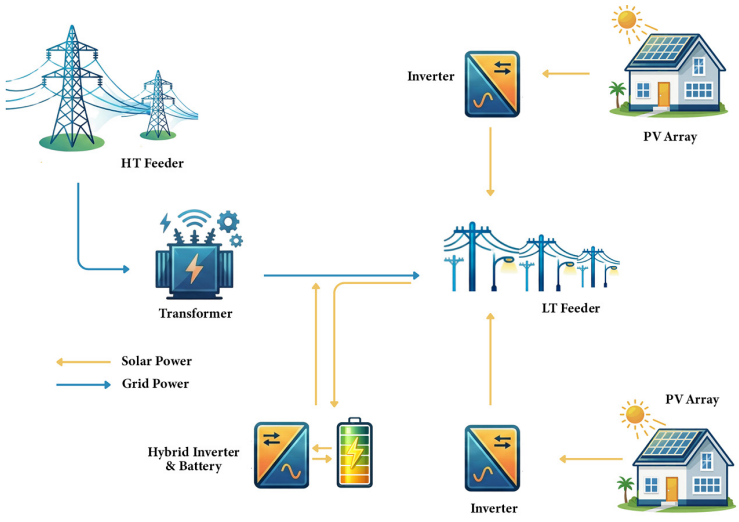

Figure 5. Schematic of C-BESS

03 Global Experience with Community-owned Battery Energy Storage Systems

International experience with community-scale energy storage offers valuable guidance as Kerala considers C-BESS[17]. Across the world, shared or neighbourhood batteries, microgrids with storage, and resilience hubs are expanding rapidly to address the mismatch between variable renewable energy generation and demand, strengthen resilience to outages and climate extremes, and democratise access to clean energy. These initiatives underline that success depends not only on technical performance, but equally on governance, tariff design, financing, data systems, and the social processes of ownership and participation[18].

Communities in different continents are deploying shared storage through neighbourhood batteries, resilience hubs, energy cooperatives, and peer-to-peer solar networks. In these models, storage is treated as part of a broader socio-technical transition rather than as an isolated device. Innovation in institutional arrangements, revenue models, safety standards, and digital infrastructure have been given equal importance alongside battery chemistry or inverter technology. This evolving practice provides a rich menu of approaches that can be adapted to Kerala's decentralised governance structures and community-centric ethos[19].

In advanced economies, distributed batteries have grown rapidly as countries integrate variable renewables generation and reduce reliance on fossil-fuelled peaking plants. Shared systems bridge the gap between midday solar output and evening demand while

retaining more value within local communities. Australia is a leading example, where high rooftop PV penetration is supported by national and state programmes funding hundreds of community batteries to absorb surplus solar and support local networks. State schemes such as Victoria's Neighbourhood Batteries programme define standard capacity ranges and promote partnerships between local councils and distribution utilities. Pilot projects, including those on Phillip Island, have reduced peak imports and network congestion, while also surfacing debates on tariff fairness, inclusion of renters, and the challenge of moving from pilots to large-scale programmes—issues directly relevant to Kerala[20].

Germany and other European countries demonstrate how democratic ownership can underpin storage deployment. German energy cooperatives have invested heavily in renewables and increasingly own and operate batteries alongside solar and wind projects. Recent EU rules give citizens and "energy communities" explicit rights to generate, store, and share electricity up to defined limits. Similarly, the 2023 Batteries Regulation, part of the European Green Deal, sets standards for safety, labelling, and recycling. Similar frameworks in the Netherlands and Denmark show that decentralisation works best when paired with transparent data, clear rights to connect and share energy, and fair revenue-sharing arrangements—features that resonate with Kerala's cooperative traditions[21].

In the United States, batteries are embedded in "Resilience Hubs" located in schools, community centres, and other public buildings equipped with rooftop solar and on-site storage. Battery systems are financed through a mix of public funds and philanthropy supported by technical standards from national laboratories. During outages, these hubs maintain refrigeration, lighting, communications, and basic services, functioning as shelters and coordination points[22]. Japan's post-2011 experience reinforces similar principles: microgrids in places like Sendai and "smart eco-towns" combining PV, storage, and backup generation keep critical loads running during disasters through clear islanding protocols, trained local operators, and strong municipal leadership[23].

Records from emerging economies highlight the links between storage, energy access, and livelihoods. In Bangladesh, "solar-swarm" networks interconnect household solar systems with peer-to-peer microgrids where surplus power is traded via mobile payments, improving utilisation and income[24]. Across Sub-Saharan Africa, batteries stabilise solar mini-grids serving households, schools, clinics, and enterprises, with

projects in countries such as Tanzania and Mozambique demonstrating the value of modular design, pay-as-you-go models, and intensive local technician training[25]. In North Africa, countries like Egypt and Morocco are adding large battery units to utility-scale solar plants, while Tunisia and Algeria are developing rules for distributed storage. Latin American initiatives, including Brazilian cooperatives piloting PV-plus-storage in rural areas and Chilean regulations that mandate storage in some new solar projects, illustrate how clear policy signals and bankable revenue streams can accelerate adoption[26].

Across these diverse contexts, several common design principles emerge. Local ownership by cooperatives, municipalities, or panchayat-like bodies builds legitimacy and stability, increasing community willingness to host infrastructure and resolve conflicts. Tariff clarity through transparent two-way, time-of-use, or demand-response structures is central to economic viability and to aligning incentives for households, utilities, and storage operators. Digital transparency using smart meters, open data platforms, and accessible dashboards, underpins credible energy-sharing arrangements and accountability. Equity and inclusion is deliberately built into programme design, or renters and low-income households risk exclusion from the benefits of shared storage. Robust approaches to safety, operations and maintenance, and lifecycle management from fire protection and thermal control to certified recycling are essential to prevent accidents and environmental harm. Blended finance that combines grants, concessional loans, cooperative equity, and aggregated project portfolios helps keep projects affordable while spreading risk. Initiatives that link storage to multiple co-benefits—grid stability, disaster preparedness, and productive uses—tend to secure more durable political and community support.

Despite these successes, persistent challenges are visible. Many jurisdictions lack clear rules on ownership of grid-connected storage, compensation for services, and interconnection of shared batteries. High transaction costs and limited concessional finance constrain replication, especially for small community projects. Maintenance capacity is often weak, which is particularly problematic in humid coastal environments similar to parts of Kerala. Cybersecurity risks in remotely monitored systems, dependence on imported components, and underdeveloped recycling supply chains further complicate long-term sustainability. Addressing these issues requires coherent policy, capable institutions, regulatory sandboxes for experimentation, open performance reporting, and systematic evaluation of pilots[27].

Such international examples suggest several practical directions for C-BESS design and roll-out in Kerala. Community-anchored ownership structures of panchayats, cooperatives, or Section-8 companies with meaningful participation by women and youth can adapt successful models to the state's decentralised governance culture. Tariff pilots under the state regulator can test two-way tariffs and demand-response structures that reward flexibility and participation in shared storage. Equity safeguards for renters, low-income households, and marginalised groups can align C-BESS with Kerala's long-standing social-justice orientation. Financing strategies that blend state support, cooperative equity, corporate social responsibility and climate funds, along with pooled Operations and Maintenance contracts, insurance, and performance guarantees, can improve bankability and reduce risk. Partnerships with Industrial Training Institutes, polytechnics, and local colleges can build a skilled workforce, turning storage deployment into a source of quality employment. Public dashboards that display shared kWh, peak-load reduction, and avoided emissions can reinforce transparency, while battery-passport and extended-producer-responsibility mechanisms can prepare the ground for a circular battery economy[28].

By linking storage with productive uses and local livelihoods, Kerala can connect resilience with everyday economic benefits. Documenting pilot experience, standardising technical and contractual templates, and building a statewide knowledge hub within existing training or research institutions can help convert field learning into policy guidance and support coordinated scale-up. Global evidence shows that when storage is socialised—owned, operated, and trusted locally—it delivers far more than electricity[29]. For Kerala, community batteries can evolve into social infrastructure that underpins resilience, equity, and democratic energy governance, shaping the next generation of community-centred clean-energy transitions.

04 Proposed Finance Models for Community-owned Battery Energy Storage System

As part of an MoU with KSEBL, Asar Social Impact Advisors Pvt Ltd conducted a techno-economic feasibility study at Perinjanam and identified multiple financial models. These financial models constitute a defined and assessable set of options for the implementation of C-BESS across different institutional and market settings. These models may be applied individually or in combination, subject to due diligence, regulatory compliance, and financial appraisal requirements. As implementation experience accumulates, additional financing structures consistent with principles of fiscal prudence, social equity, and risk management may be identified and evaluated. Such an approach will allow for measured adaptation while maintaining financial discipline, transparency, and accountability.

I. PUBLIC – COMMUNITY PARTNERSHIP MODEL (Viability Gap Funding + Soft Loan + Equity)

In this model, investment responsibility is shared between the utility and the community to keep tariffs affordable while ensuring project bankability (Figure 6). A significant portion of the upfront capital cost is met through viability gap funding (VGF) provided by the distribution company, which recognises C-BESS as a cost-effective alternative to peak power purchases and network upgrades. The remaining capital is financed through a concessional (soft) loan from a state government agency, reducing interest burden and shortening the payback period. Community-level institutions such

as cooperative societies or prosumer collectives contribute equity, signalling local ownership and commitment to prudent operation and maintenance. Revenue flows come primarily from a storage service charge paid by the Distribution Company (DISCOM) for using the C-BESS to manage peak loads, load shifting, and other grid services, and, where applicable, from peak-time energy charges levied on prosumers who draw power from the battery during high-tariff periods. This combination moderates tariff shock, strengthens lender confidence, and maintains strategic control within local institutions and users.

II. COMMUNITY-LED CONCESSIONAL MODEL (Equity + Soft Loan)

This model is designed for contexts with strong community initiative but limited access to grants. Here, community actors—cooperative societies, prosumer associations, or panchayat-anchored entities—take the lead on ownership by raising equity from members, either through direct contributions or member shares. A soft loan from a state government agency (or similar public financial institution) covers the remaining capital cost on concessional terms, such as reduced interest, longer tenors, or repayment holidays. Revenue is mainly generated through peak-time energy charges paid by participating prosumers who access stored electricity during evening peaks or outages, providing a predictable cash flow linked to local consumption patterns. Where regulations permit, additional income can be earned through feed-in tariff (FIT) or other payments from the DISCOM for surplus energy or specific grid-support services. This model suits areas where communities are willing to invest, the government is able to provide low-cost credit, but large grants or VGF pools are constrained, and strong local ownership is embedded with manageable debt obligations.

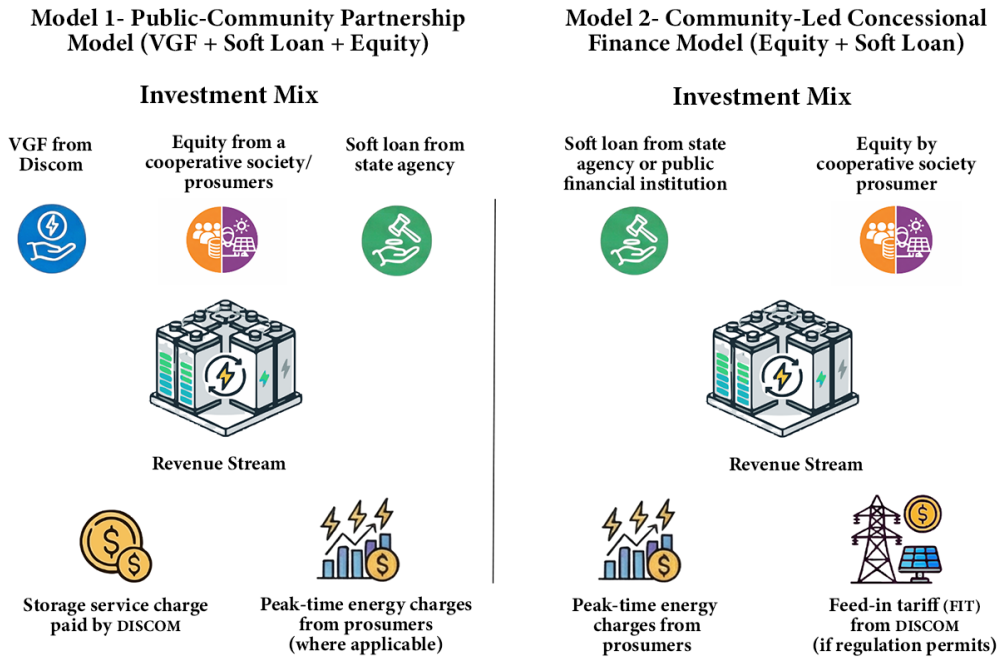

Figure 6: Finance Models 1 and 2 for C-BESS

III. DIVERSIFIED REVENUE COMMERCIAL MODEL (Equity + Bank Loan)

In this model, C-BESS projects are structured to be attractive to commercial lenders by stacking multiple revenue streams. Capital is raised through a combination of term loans from commercial or cooperative banks and equity from cooperative societies or groups of prosumers (Figure 7). Banks provide loans on standard or modestly preferential terms, backed by business plans that demonstrate diversified income sources and clear risk-mitigation measures. Equity from local stakeholders serves both as collateral comfort and as a mechanism to share financial returns. Revenues are deliberately diversified: peak-time energy charges from prosumers who use stored power, FIT or equivalent payments from the DISCOM for grid-support or export, and battery-swapping or rental charges for portable services to electric vehicles, commercial shops, events, and small vendors. This broader service portfolio improves capacity utilisation of the battery, reduces dependence on any single customer group, and supports timely debt servicing. The model is suitable for mature markets or urban/peri-urban areas where demand for multiple storage services is high and commercial banking relationships are strong.

IV. COMMUNITY SHAREHOLDING AND DIVIDEND MODEL (Equity + Shares)

This model maximises community ownership and local capital mobilisation by treating C-BESS as a member-owned infrastructure asset. A cooperative society, panchayat-linked entity, or Section-8 company provides the base equity and then issues shares to prosumers and other local consumers, allowing a wide range of households, shops, and small enterprises to become co-owners. Thus, capital is raised majorly from within the community, reducing the need for external debt and lowering financial risk exposure to interest-rate fluctuations. Income streams include peak-time energy charges from consumers drawing from the C-BESS, FIT or similar payments from the DISCOM for surplus or grid-support services, and charges for battery-swapping or rental services to EV users, shops, event organisers, and vendors. After covering operating costs, debt (if any), and lifecycle reserves for battery replacement, net surpluses can be distributed as dividends or patronage bonuses according to shareholding and agreed by-laws, with options to earmark a portion for community development funds. This model aligns financial benefits directly with participation, incentivises careful governance, and builds long-term local stewardship of the asset.

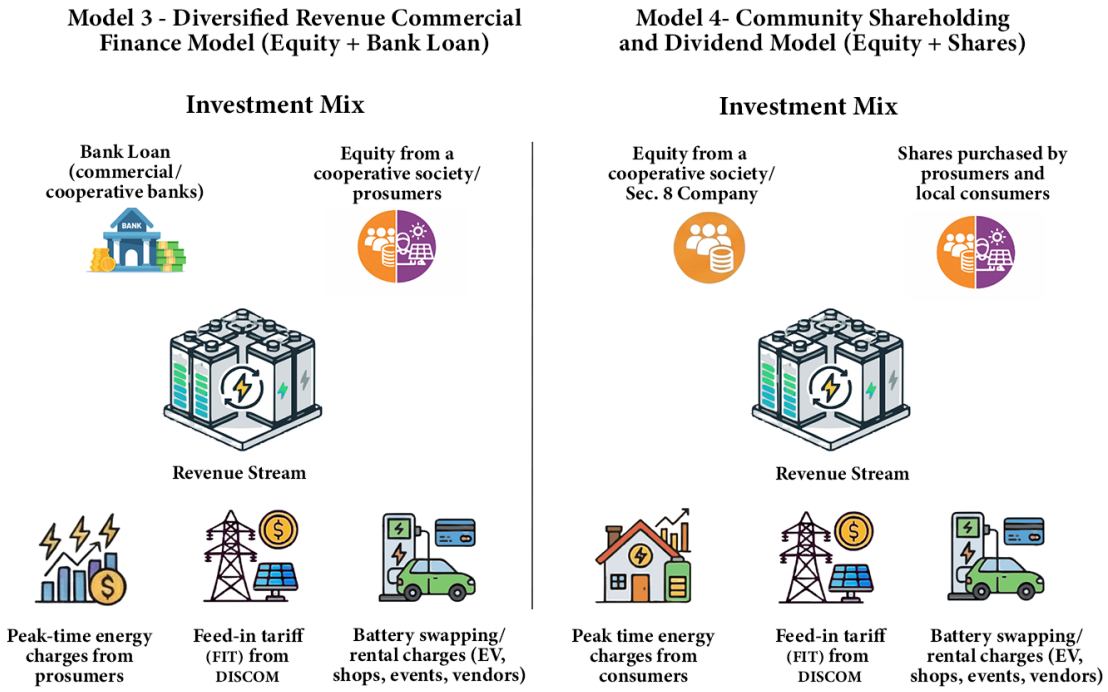

Figure 7: Finance Models 3 and 4 for C-BESS

05 Perinjanam: A Microcosm

Perinjanam, a compact coastal panchayat in Thrissur district, provides a concentrated setting in which Kerala's community-level battery storage potential can be meaningfully demonstrated and assessed. This locality combines several features that make it unusually well suited for decentralised storage: high density of rooftop solar installations, distinct residential consumption patterns, and mature institutional environment comprising panchayat governance, cooperatives, and active community networks. Together, these characteristics position Perinjanam as an ideal site to pilot a technically feasible, behaviourally informed, and institutionally grounded C-BESS model.

Approximately 21,012 residents live in Perinjanam, a region spread across a little more than 9.30 square kilometres[30]. The settlement is partly linear along the coastal corridor, with clustered neighbourhoods where households are in close proximity—conditions that have supported rapid diffusion of rooftop solar over the past decade.

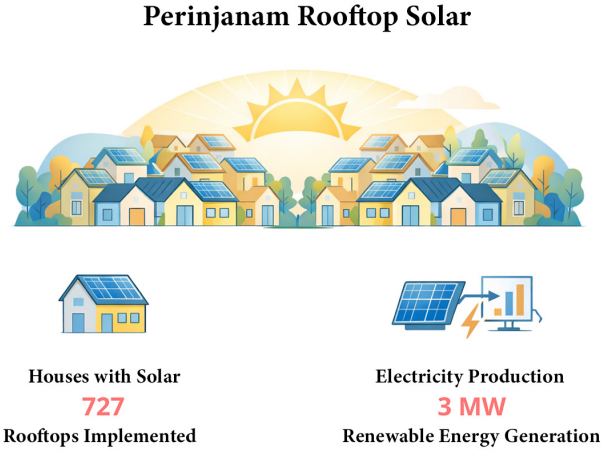

Figure 8: Perinjanam Rooftop Solar

The panchayat now has more than 727 rooftop solar systems, generating close to 3 MW of distributed capacity (Figure 8), an uncommon level of self-generation for a gram panchayat of this size. Demographically, many households are led by elderly decision-makers and have family members employed outside Kerala or overseas, contributing to relatively stable incomes and a preference for technologies that enhance long-term financial certainty. Daily energy use follows the broader state pattern of low mid-day consumption and pronounced evening peaks; when mapped against the solar generation curve, this reveals mid-day surpluses and evening deficits.

Although Perinjanam's high rooftop-solar penetration makes the value of storage particularly visible, the broader applicability of a C-BESS model is not restricted to solar-dense panchayats. Community batteries can provide balancing, resilience, peak management, and grid-support services even in areas with modest or emerging rooftop solar, because their value streams extend beyond solar absorption. Perinjanam has been selected for this study because its distinctive energy profile allows the observation and analysis of the interaction between rooftop solar, demand patterns, and storage under real-world conditions.

Perinjanam's institutional maturity is equally important in this context. While Kerala is known for strong Panchayati Raj and decentralised planning, not all local governments engage equally with sectoral innovations. Perinjanam has shown a proactive attitude to renewable-energy issues, experience in working with state agencies, and collaboration with cooperative institutions on energy-related initiatives. These governance capacities and community networks create favourable conditions for experimenting with a decentralised storage model that depends on local coordination, trust, and collective problem solving. Thus, Perinjanam represents a small but analytically rich microcosm of Kerala's wider energy-transition challenges: distributed generation outpacing local balancing capacity, social structures supportive of collective interventions, and a tangible supply-demand mismatch that can be addressed through community-level storage.

06 Methodological Approach

Perinjanam Panchayat in Thrissur district was selected as the primary case study for assessing the feasibility of C-BESS. The panchayat has a high concentration of residential rooftop solar prosumers and an active local governance ecosystem, making it a suitable setting to examine the technical, social, and institutional aspects of community-level storage.

A mixed-methods research design was used to evaluate the socio-economic feasibility of C-BESS within Kerala's decentralised energy context. A combined structured household survey of prosumer and non-prosumer households with year-long stakeholder consultations and an extensive literature review allowed triangulation and contextualisation of findings.

The primary quantitative component focused on prosumer households with rooftop solar PV in Perinjanam. The survey explored awareness, motivations, perceived barriers, willingness to invest, and support mechanisms required for battery storage. Using a purposive sampling approach 727 prosumer households were targeted. Data were obtained from 379 households (52%), following a pilot with 20 households for questionnaire refinement (Figure 9). Sixty trained enumerators conducted face-to-face interviews using Kobo Forms from 24 to 30 August 2024.

A complementary survey of 108 non-prosumer households, selected through convenience sampling due to time constraints, examined awareness of BESS, willingness to adopt, perceived

risks and benefits, community acceptance, local social structures, and support needs. Together, the two surveys offer comparative insights into expectations and concerns across different household types. Stakeholder engagement covered key power-sector and governance institutions, including KSEBL, Kerala State Electricity Regulatory Commission, Agency for New and Renewable Energy Research and Technology (ANERT), Energy Management Centre (EMC), and Local Self Government Department (LSGD), and was implemented in collaboration with Christ College of Engineering, the Perinjanorjam Consumer Society, and ward members. Ethical standards of informed consent, data privacy, and voluntary participation were rigorously upheld. Non-response was the main limitation in data collection which was addressed through repeated outreach. Overall, the surveys, consultations, and literature review provide a holistic, evidence-based assessment of how C-BESS can strengthen Kerala's energy resilience and local ownership.

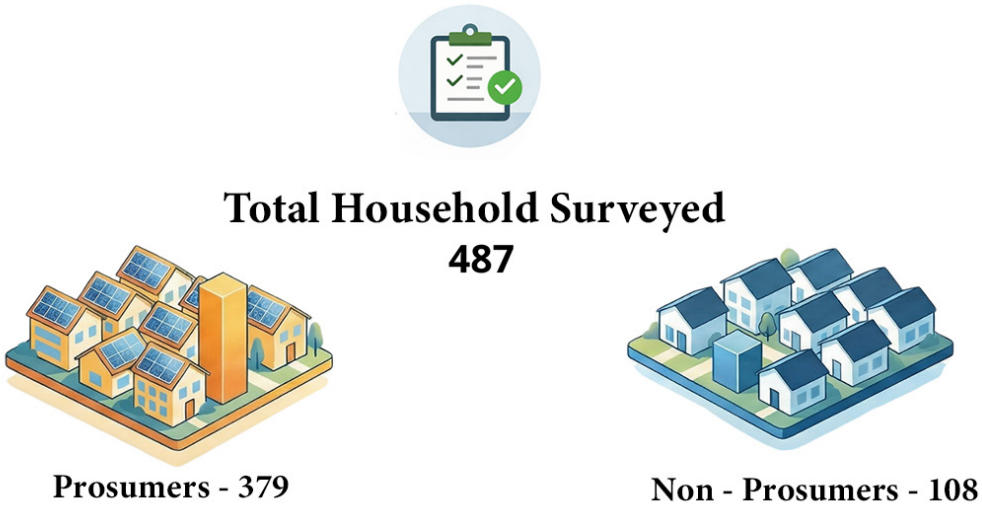

Figure 9: Sample size of the survey respondents in Perinjanam Panchayat

07 Perinjanam Survey

To understand how households perceive energy technologies and how they might respond to a community-level storage system, a detailed perception survey was conducted across the panchayat. The primary aim was to capture awareness, preferences, perceived benefits and risks, financial considerations, and behavioural barriers related to rooftop solar and battery storage. The survey used a structured quantitative questionnaire, complemented by qualitative insights from field enumerators and interactions with panchayat representatives. Households were contacted through door-to-door visits, with respondents including primary decision-makers or those closely involved in financial and energy decisions. Enumerators were trained to ensure consistent administration, clear explanation of technical concepts, and sensitivity to elderly respondents.

The questionnaire covered seven themes: household characteristics; energy-use patterns and electricity bill awareness; rooftop-solar adoption motivations and experiences; awareness and perceptions of battery storage; financial considerations including willingness to pay and preferred financing modes; perceived barriers around cost, safety, trust, maintenance, and complexity; and governance preferences regarding who should own and manage a community-level system and how it should be monitored. This design allowed the study to situate technology adoption within Perinjanam's behavioural, social, and institutional landscape rather than treating it as a purely economic decision.

PERINJANAM SURVEY FINDINGS

Survey findings highlighted both opportunities and constraints for introducing C-BESS. Despite very high rooftop-solar density, awareness of battery storage was limited; only a modest share of respondents had heard of BESS, and many were unsure of its purpose or benefits. Households commonly expressed a desire to reduce electricity bills and improve reliability, yet hesitated when faced with technologies perceived as complex or unfamiliar. Motivations for solar adoption centred on financial savings, tariff stability, and peer influence, while storage was associated with uncertainty. A clear gap emerged between motivation and adoption: many non-solar households, though not hostile to the technology, cited complexity, paperwork, and uncertainty over long-term gains as reasons for inaction, reflecting behavioural barriers such as status-quo bias and aversion to complex decisions.

Average pre-solar electricity expenditure among surveyed households clustered in the low-to-moderate range, underscoring the salience of bill reduction as a key adoption driver. Around one-third of respondents reported monthly bills between ₹1,000 and ₹3,000 prior to installation (21% in the ₹1,000–2,000 band and 12% in ₹2,000–3,000), while 13% reported very low bills below ₹1,000. A smaller subset fell into higher consumption brackets, with approximately 11% reporting bills above ₹3,000 and only a few households exceeding ₹7,000 per month. At the same time, 39% did not report their pre-solar bill, which may reflect recall limitations or reluctance to disclose exact amounts, and suggests that the observed distribution does not capture the full diversity of consumption patterns.

Post-installation, the distribution of reported bills shifts markedly towards lower expenditure, indicating a substantial reduction in grid electricity import for most adopters. Nearly half of respondents (44%) now report average monthly bills below ₹500, and an additional 10% fall within the ₹500–1,000 range, implying that a clear majority of those who provided data incur relatively modest electricity charges after going solar. Only a small minority continue to face bills above ₹2,000, and very few exceed ₹3,000, in sharp contrast to the pre-solar spread. Although 35% did not state their post-solar bill, the available responses consistently point to rooftop PV delivering meaningful and sustained savings in household electricity expenditure.

Environmental considerations appeared to play a limited role in prosumers' decision-making on solar rooftop installation. Only 9% of surveyed households identified climate or environmental benefits as a primary driver for adopting rooftop solar, indicating that decarbonisation and ecological concerns were largely secondary motivations. In contrast, adoption was predominantly anchored in financial considerations: 72% of respondents cited financial security or savings as their main motivation, while a smaller share (6%) attributed their decision to broader social or market trends.

Awareness pathways were similarly varied. About 38% of respondents reported first hearing about rooftop solar through the Perinjanorjam programme, underscoring its central role as an information and outreach channel in the panchayat. By comparison, only 7% became aware through KSEBL, suggesting scope for strengthening utility-led communication. Informal networks remained important, with friends and family accounting for 28% of initial awareness, while newspapers and solar company advertisements together contributed to 9%. Notably, 18% of respondents did not specify any source of information, pointing either to recall limitations or to more diffuse, ambient modes of awareness.

Trust in local institutions, particularly the panchayat and cooperatives, emerged as a critical enabler; households were markedly more comfortable with collective systems managed by trusted public or community bodies than with arrangements led solely by private vendors. Elderly decision-makers preferred simple, familiar procedures and clear explanations, while younger respondents were more open to

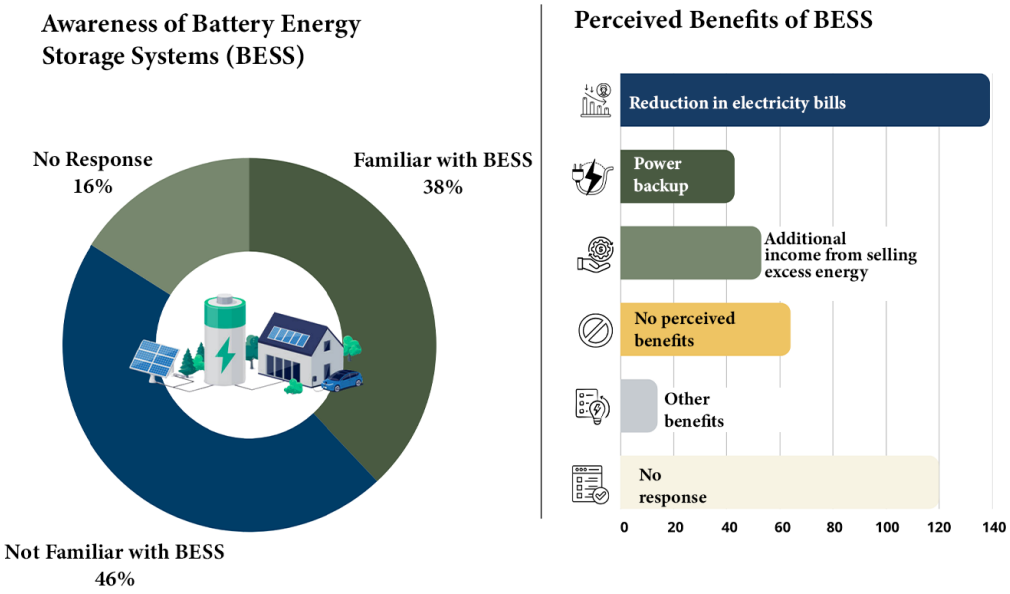

Figure 10: Awareness and perceived benefits of BESS among respondents

innovation but less influential in household decisions. Overall, education levels did not strongly predict willingness to adopt storage, underscoring the importance of confidence and perceived complexity over formal schooling.

The survey findings reveal a significant latent opportunity for BESS adoption, provided that information and financing barriers are systematically addressed. While 34% of respondents currently indicate no interest in investing, an even larger share (37%) report that they would need more information before making a decision, pointing to a sizable segment that could be persuaded through targeted communication, demonstrations, and clearer articulation of benefits and risks (Figure 11). In parallel, 21% are already willing to invest up to ₹ 50,000, and a further 7% are open to higher investment brackets, indicating the presence of an emerging early-adopter group that could anchor initial community-scale pilots and serve as demonstration communities.

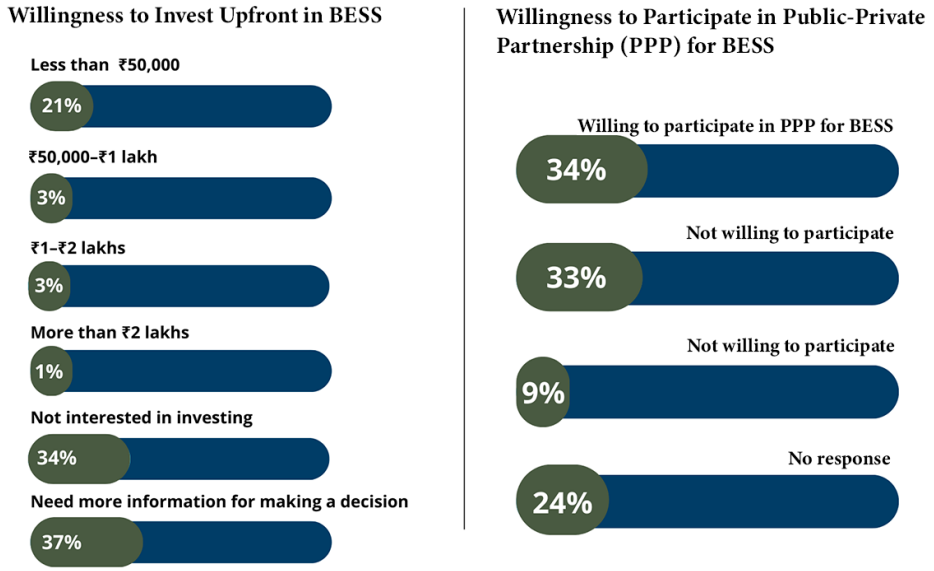

Figure 11: Willingness to invest and install BESS among respondents

Preferences regarding enabling conditions further clarify the contours of a feasible financing strategy. Respondents clearly favoured mechanisms that directly reduce upfront capital burden: 30% prioritised subsidies or grants, and 21% preferred low-interest loans, whereas only small minorities expressed interest in tax credits (5%) or leasing and rental models (1%). Taken together, these patterns suggest that well-designed awareness efforts, coupled with simple, user-friendly business models and access to direct financial support and affordable credit, could convert informationally undecided households and early adopters into a critical mass of participants in community BESS schemes.

Assessing Perinjanam's BESS potential requires aligning technical suitability, social readiness, and institutional feasibility. Technically, its substantial rooftop-solar base, mid-day surpluses, and compact settlement pattern favour a C-BESS that can serve many users with low distribution losses. Socially, the survey finds a foundation of institutional trust and interest in financial stability, but also reveals low awareness and cognitive barriers that must be addressed through simple participation pathways, clear communication of benefits, and visible demonstrations. Institutionally, the panchayat's experience in decentralised planning and communication combined with cooperative structures capable of financial oversight and member engagement offer a platform for building community-storage initiatives.

A successful C-BESS initiative in Perinjanam would generate seminal insights for other panchayats, such as accompaniment of rooftop solar with distributed storage, trusted local institutions and user-friendly processes, and responsible management of shared energy assets through community-based governance. Thus, Perinjanam is a technically suitable site and a strategic opportunity for Kerala to prototype an energy-transition model that is people-centred, institutionally grounded, and resilient to climate disruptions—displaying potential for community-level storage to anchor a broader, decentralised, storage-enabled pathway for the state's energy future.


GPS Map Came
Perinjanam, Kerala, India
845R+V25, VK Gopalan Rd, Perinjanam, Kerala 680686, India
Lat 10.309296°
Long 76.13972°
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08 Community Storage: Key to Kerala's Energy Future

C-BESS offers Kerala a strategic pathway to address interlinked challenges of energy security, grid reliability, economic sustainability, social equity, and climate action. It aligns technical storage functions with the state's strengths in decentralised governance, cooperative institutions, and community participation. Kerala exhibits high electricity demand, limited land availability, increasing climate vulnerability, and growing rooftop-solar capacity. In such a context, C-BESS represents a technical intervention and governance and development model well suited to Kerala's institutional ecosystem, including capable Local Self-Governments and community-based organisations such as Kudumbashree, cooperatives, and resident welfare associations. Additionally, C-BESS can mitigate the challenge of structural dependence on electricity imports from the national grid by storing locally generated renewable energy for use during peak-demand periods, thereby reducing high-cost short-term purchases and the need for land-intensive new generation capacity.

By generating, storing, and consuming energy within the same local network, C-BESS strengthens Kerala's control over its supply mix, lowers transmission and distribution losses, improves overall system efficiency, defers or reduces costly network upgrades. Moreover, it contributes directly to grid resilience by flattening local demand curves, easing stress on distribution assets, and enhancing voltage stability in areas with high rooftop-solar penetration. Kerala's growing climate risks—frequent floods, cyclones, heatwaves, and landslides—further underscore the value of decentralised, locally managed storage that can continue operating when upstream grid elements fail. C-BESS, paired with rooftop solar and critical

facilities such as health centres, drinking-water systems, schools, and relief shelters, can maintain essential services during emergencies and function as a core resilience asset within the state's disaster-preparedness and climate-adaptation strategies.

Economically, C-BESS creates important opportunities grounded in collective ownership and local value creation. Treating storage as shared infrastructure, rather than as an individual household asset, enables "storage as a service" models in which communities collectively manage batteries to provide peak support, backup power, and energy-balancing services to the distribution utility and local consumers. This improves asset utilisation, lowers per-unit costs, and broadens access to the benefits of storage. C- BESS also opens avenues for new local energy enterprises: panchayat-led service units, cooperative-managed storage systems, and women-led enterprises anchored in Kudumbashree networks. Such arrangements embed technical capacity within communities and help ensure that economic gains remain local rather than being extracted by external actors. Revenue streams associated with C-BESS are best framed in terms of financial sustainability and surplus reinvestment, rather than profit maximisation. Potential sources include savings from reduced peak-time power procurement, regulated payments for grid-support services, and service fees for reliable backup or energy-management offerings. Any surplus can be reinvested in system maintenance, capacity expansion, skill development, or broader community priorities, supporting long-term viability and public legitimacy. In addition, C-BESS deployment contributes to local employment in installation, operation, monitoring, and maintenance. Over time, battery-related activities such as repair, refurbishment, second-life uses, and recycling can help build a local circular economy aligned with Kerala's emphasis on sustainable livelihoods, skills, and responsible waste management.

Social equity is a defining strength of the C-BESS model. Shared-ownership structures—whether through cooperatives, Local Self-Government Institutions, or hybrid community institutions—enable broad participation in energy-infrastructure development and ensure that the benefits of storage are distributed across communities rather than concentrated among a small group of private asset owners. Kerala's strong tradition of women's collectives and grassroots organisations provides a unique opportunity to design inclusive community-energy systems. C-BESS initiatives can be explicitly structured to involve women, low-income households, renters, and marginalised groups in ownership and governance. Women-led enterprises, in particular, can play central roles in managing and maintaining systems, linking

energy-transition goals with gender equity and economic empowerment. More fundamentally, C-BESS advances the concept of energy democracy by positioning communities as active participants in the energy system instead of passive consumers. Through collective decision-making, transparent governance, and shared responsibility, community storage can strengthen local institutions and deepen trust in decentralised infrastructure. In Kerala, where participatory governance has deep roots, C-BESS represents a natural extension of long-standing social-engineering and inclusionary-development practices into the energy domain.

The state's suitability for C-BESS rests on a convergence of institutional strength, distinctive energy-system characteristics, and a high degree of social readiness. Strong Local Self-Governments with experience in planning and service delivery provide an enabling governance framework for community-owned infrastructure, while Kudumbashree networks, cooperatives, and residents' associations offer proven models of collective ownership, financial intermediation, and day-to-day management. High literacy levels, robust community participation, and widespread acceptance of cooperative models create favourable conditions for collective energy solutions, making C-BESS a natural extension of Kerala's development trajectory that integrates technological innovation with democratic governance and social equity. From an energy-system perspective, Kerala's high rooftop-solar potential, when coupled with land constraints that limit utility-scale expansion, makes distributed generation and storage a pragmatic and context-appropriate option. The state's expanding base of rooftop-solar prosumers provides a growing pool whose surplus generation can be aggregated through community-level storage.

Policy and regulatory trends further strengthen the case. KSEBL's evolving engagement with energy storage, alongside emerging initiatives in smart grids, electric mobility, and DRE, signal a policy environment that is increasingly receptive to innovative storage models. As regulators and utilities experiment with new tariff structures, flexibility services, and mechanisms for integrating distributed resources, community-owned storage can be positioned as a complementary asset that delivers both system-level benefits and local co-benefits. Taken together, Kerala's institutional depth, social capital, land-use constraints, renewable-energy profile, and evolving policy environment make it uniquely suited for C-BESS. Community batteries can leverage strong local governance and cooperative traditions to deliver energy security, resilience, and climate benefits in a way that is participatory, locally owned, and aligned with the state's broader development vision.

09 Community-owned Battery Energy Storage Systems' Potential for Kerala

According to KSEBL, approximately 36% of rooftop solar generation is consumed during the daytime by prosumers, with the remaining 64% exported to the grid[31] [32]. This surplus from the currently installed 1,600 MW of rooftop capacity represents an assured minimum technical potential for community-scale storage and is estimated at roughly 4 GWh of electricity per day that could be captured and time-shifted through C-BESS.

If a typical C-BESS unit is connected at the level of a 250 kVA distribution transformer, an indicative configuration would involve around 200 kW of power capacity and usable storage of about 1,000 kWh. Approximately 4,000 such community batteries would be required to absorb and redeploy the presently available rooftop-solar surplus. As rooftop, ground-mounted, and floating solar installations continue to expand, the aggregate storage requirement will increase correspondingly, making this estimate a conservative floor rather than a ceiling on Kerala's community-storage potential.

The effective potential is possibly higher because C-BESS is envisaged not only as a service for prosumers but also as a storage resource for KSEBL. By charging community batteries with inexpensive solar or off-peak power during the day and discharging during evening peaks, utilities can avoid costly peak-time imports and arbitrage time-of-day tariffs. Clearly defined service contracts for paid access to community storage make C-BESS attractive for managing demand, reducing power-purchase costs, and improving grid stability, while enabling communities to capture a greater share of value from local

renewable energy generation.

Using the same sizing logic, one 200 kW/1,000 kWh C-BESS for every distribution transformer of 250 kVA capacity, Kerala's C-BESS potential can also be expressed in terms of the total distribution transformer base. There are 92,203 distribution transformers across 941 grama panchayats, 87 municipalities, and 6 municipal corporations. A simple one-battery-per-transformer calculation yields 92,203 community batteries, or about 92.2 GWh of distributed storage and 18.4 GW of power capacity; however, this represents only a maximum technical envelope and not a realistic deployment target.

Given that many rural distribution transformers are of lower capacity, a more pessimistic estimate can be derived by assuming an average transformer capacity of 125 kVA, effectively halving the feasible community-battery capacity per transformer. Therefore, Kerala's upper-bound C-BESS potential would be around 46 GWh of distributed storage and roughly 9 GW of power capacity, indicating substantial room for community-scale storage even under conservative assumptions.

A more realistic medium-term scenario is to focus on a subset of transformers, particularly those serving areas with high rooftop-solar penetration, recurring peak-load stress, or critical public loads. With the C-BESS deployed at 5% of Kerala's distribution transformers, around 4,610 units would be installed, based on an estimated total of 92,203 transformers statewide. At a standard configuration of 200 kW power capacity and 1,000 kWh usable storage per unit, this deployment would yield approximately 4.61 GWh of distributed storage and about 922 MW of discharge capacity across Kerala. This scale of community-level storage would provide a meaningful buffer to absorb surplus solar generation, support local peak demand, and offer flexible services to the grid.

These distributed assets would complement KSEBL's broader generation and storage expansion plans for 2030. KSEBL is targeting a total installed capacity of 10,000 MW by 2030, comprising 500 MW of solar, 530 MW of wind, 1,500 MW of hydro, and ongoing rooftop solar additions of about 35 MW per month. In parallel, the utility plans to develop 3,000 MWh of BESS and 2,000 MW of pumped storage with six-hour discharge capability . In this context, a 5% C-BESS rollout at distribution-transformer level would function as a distributed extension of the state's

planned storage backbone—situated closer to consumers, enabling community participation, and strengthening the resilience and flexibility of Kerala's evolving low-carbon power system.

Using a differentiated siting approach, Kerala's C-BESS potential can be framed by allocating more systems to areas with higher demand and investment capacity. Assuming 1 C-BESS in each of the 941 grama panchayats, 2 in each of the 87 municipalities (174 units), and 10 in each of the 6 municipal corporations (60 units), the state could host a total of 1,175 community batteries. Together, these installations could provide approximately 1.175 GWh of distributed storage (1,175 × 1,000 kWh) and about 235 MW of flexible discharge capacity (1,175 × 200 kW).

Compared with a flat "one-per-local-body" baseline, this configuration recognises that municipalities and corporations typically have higher energy demand, denser prosumer clusters, and greater investment potential. Concentrating additional units in these urban local bodies allows community storage to address more severe peak loads and network constraints, while still ensuring that every panchayat has at least one pilot. This differentiated deployment pattern thus offers a more demand-sensitive and financially robust pathway, while retaining statewide coverage and space for locally tailored governance, tariff, and business-model experimentation.

10 Recommendations

The report introduces an innovative C-BESS design that will foster a sustainable and socially inclusive growth powered by decentralised systems. The recommendations outlined in this section set out a coordinated roadmap for designing, financing, governing, and scaling C-BESS in Kerala. They position C-BESS as community-owned infrastructure embedded within local development plans, regulatory frameworks, and financial architectures, while aligning with the state's wider energy-transition and climate-resilience objectives. They also emphasise inclusion, accountability, and long-term sustainability, ensuring that community batteries contribute to grid stability, to social equity and local empowerment, and advance renewable-energy integration.

TECHNICAL AND REGULATORY ENABLERS

I. Strengthen the technical and regulatory backbone

Power-sector institutions—KSEBL, EMC, ANERT, and the Electrical Inspectorate— can jointly provide a stable technical and regulatory spine for C-BESS. KSEBL can act as a guaranteed off-taker and integrate community batteries into distribution planning, peak-load management, and grid services, while the Electrical Inspectorate can ensure safety and grid-interaction compliance. EMC and ANERT should develop technical standards, model Detailed Project Reports, and capacity-building programmes aligned with the state's energy-transition pathway.

II. Dedicated regulatory and tariff framework for C-BESS

Establishing a dedicated regulatory and tariff framework for C-BESS would enable clarity on ownership models, permitted services, interaction with net-metering/Time-of-Day tariffs, and standardised "storage service charge" and prosumer peak-use tariffs.

III. Align C-BESS with broader power sector planning and resilience strategies

C-BESS should be aligned with broader power-sector planning and resilience strategies by co-designing community batteries alongside distribution-network upgrades, rooftop-solar expansion, and EV-charging infrastructure, rather than as stand-alone projects. C-BESS should also be explicitly integrated into disaster-management and critical-infrastructure plans, with priority given to applications that back up essential services such as health facilities, water supply systems, and emergency shelters.

FINANCE AND INCENTIVES

I. Deploy VGF for initial pilot projects

State government, local self-governments and utilities (KSEBL and the Thrissur Corporation Electricity Department) can provide targeted VGF to mitigate early-stage project risk, reflecting the nascent state of the storage market. Parallel advocacy is needed to extend national-level support—currently focused on grid-side utility BESS—to demand-side and community-scale storage, recognising rapid paybacks through avoided peak-power costs and deferred network upgrades.

II. Expand access to soft loans and concessional finance

Cooperative banks, state financial agencies (e.g., Kerala State Financial Enterprises Ltd.), and nationalised banks can design soft-loan products tailored to C-BESS, with longer tenors and repayment linked to tariff savings or dividends. The fast gestation of C-BESS and predictable revenue

from storage services should be leveraged to mobilise concessional credit and green-finance windows, using community-level guarantees instead of individual collateral where feasible.

III. Position prosumers as core operational participants

Rooftop solar prosumers—households, shops, and institutions—should be enabled to contract with community institutions to inject surplus daytime solar into C-BESS and draw stored energy during peaks or outages. Tariff structures and contracts should reward flexible, cooperative behaviour, shifting prosumers from passive net-metering participants to active actors in local energy markets, thus deepening energy democracy.

COMMUNITY OWNERSHIP AND LOCAL PLANNING

I. Anchor C-BESS ownership in community institutions

Community-level institutions—registered societies, cooperatives, and panchayats—can serve as primary owners and governors of the C-BESS assets. These institutions can aggregate households and small enterprises, manage day-to-day operations and maintenance under transparent by-laws, and allocate revenues towards member dividends, community reserves, social funds, and lifecycle replacement, embedding C-BESS in local accountability structures.

II. Integrate C-BESS into local development and climate plans

Local self-government institutions (grama panchayats, municipalities, and corporations under LSGD) can integrate C-BESS into local development, carbon-neutrality, and climate-resilience plans. This includes identifying suitable sites and critical loads (health centres, water supply, and public services), facilitating land and permissions, and convening multi-stakeholder forums where societies, utilities, and financiers can resolve implementation issues.

III. Political and institutional anchoring

Elected representatives at panchayat, municipal, and corporation levels play a critical role in providing legitimacy and institutional anchoring for the C-BESS initiatives. Their engagement can help position community energy storage within the broader development, welfare, and climate agendas, such as carbon-neutral local bodies, resilient infrastructure, and livelihood enhancement. Active involvement of elected representatives can also facilitate public consent, inter-agency coordination, and the timely resolution of administrative and financing-related clearances.

IV. Enable C-BESS within panchayat planning and budgeting frameworks

Existing local planning and budgeting guidelines can be supplemented through Planning Board or LSGD-issued guidance notes with clear provisions to accommodate shared energy-storage infrastructure such as C-BESS. Model Gram Panchayat Development Plan entries, budget heads, and planning templates can support panchayats and municipalities in recognising community batteries as eligible development and climate-resilience assets, reducing procedural uncertainty and enabling smoother appraisal, approval, and implementation.

V. Aligning with the 14th Five-Year Plan

The 14th Five-Year Plan (2022–27) provides an enabling planning framework within which C-BESS can be incorporated into local renewable energy and innovation initiatives. Incorporation of C-BESS within relevant components of local action plans, in alignment with Kerala State Planning Board guidelines and available financing mechanisms, supports wider adoption. When implemented at scale during the latter part of the Plan period, C-BESS can evolve from isolated pilots into visible elements of shared social and climate-resilient infrastructure within local energy and development systems.

GOVERNANCE, CONVERGENCE, AND LEARNING

I. Monitoring, learning, and emissions accounting

A common monitoring and learning framework should be established for C-BESS pilots to track technical performance, financial viability, social inclusion outcomes, and avoided carbon emissions. Simple, standardised metrics—aligned with local climate-action and carbon-neutrality goals—can enable evidence-based refinement of tariffs, governance arrangements, and financing models. Such a framework would support adaptive scaling while ensuring transparency, accountability, and alignment with Kerala's climate and energy-transition objectives.

II. Operationalising convergence as a governance principle

Convergence among community institutions, power-sector agencies, local self-governments, financial institutions, prosumers, and elected representatives is best treated as a core design principle for C-BESS. Clearly defined and interdependent roles within a shared governance framework are essential, with community institutions anchoring ownership, technical agencies providing standards and system integration, financiers enabling affordable capital, and prosumers supporting day-to-day operations. Such an approach allows C-BESS to evolve into a durable pillar of Kerala's energy security, social equity, and climate resilience.

EQUITY SAFEGUARDS AND SUSTAINABLE BATTERY MANAGEMENT

I. Social safeguards

Incorporate social safeguards to ensure inclusion of renters, low-income households, and marginalised groups through low-ticket shares, targeted subsidies, community quotas, and differentiated tariffs. Include provisions for representation of women and youth in C-BESS governance bodies.

II. Battery lifecycle provisions

Detailed battery-lifecycle provisions should be incorporated within state policy and project guidelines for C-BESS, requiring that each system is accompanied by a battery "passport" capturing origin, chemistry, performance history, and ownership over time to support traceability and safety oversight. Extended-producer-responsibility arrangements should be required to ensure manufacturer accountability for refurbishment, second-life applications (such as repurposing for lower-demand uses), and environmentally sound end-of-life recycling, thereby minimising waste and mitigating environmental and health risks.

These recommendations call on state agencies, local self-governments, utilities, financial institutions, and communities to treat C-BESS as a strategic public–community investment rather than a one-off technical experiment. If implemented in a phased, learning-oriented manner starting with well-supported pilots, underpinned by clear regulations, targeted VGF, concessional finance, capacity-building, and social safeguards, C-BESS can evolve into a durable pillar of Kerala's energy security, social equity, and climate resilience. In doing so, Kerala can position community batteries as visible symbols of a people-centred clean-energy transition, linking everyday reliability and affordability with long-term climate and development goals.

Abbreviations

ANERT	Agency for New and Renewable Energy Research and Technology
BESS	Battery Energy Storage Systems
C-BESS	Community-owned Battery Energy Storage Systems
DISCOM	Distribution Company
DRE	Distributed Renewable Energy
EMC	Energy Management Centre
FIT	Feed-in Tariff
KSEBL	Kerala State Electricity Board Limited
LSGD	Local Self Government Department
MU	Million Units
PHES	Pumped-Hydro Energy Storage
PV	Photovoltaics
VGF	Viability Gap Funding

References

1. The Facts, Newsletter of Kerala State Electricity Board. Vol 2, Issue 1, 4th January 2024. https://kseb.in/uploads/Downloadtemsuppy/KSEBL%20NEWS%20LETTER%2004-17054777147138641.pdf

2. Ashish Fernandes and Harshit Sharma. Greening Kerala's Grid. Climate Risk Horizons, April 2023. https://climateriskhorizons.com/app/uploads/2025/10/greening-kerala-grid.pdf

3. All India Installed Capacity (In MW) Of Power Stations (as on 31.12.2025), Central Electricity Authority, Ministry of Power, Government of India. https://cea.nic.in/wp-content/uploads/installed/2025/12/website.pdf

4. Report on Resource Adequacy Plan for the State Of Kerala. Central Electricity Authority, Ministry of Power, Government of India. https://cea.nic.in/wp-content/uploads/irp/2024/07/Kerala Report Final.pdf

5. State Load Dispatch Centre-Kalamassery. Kerala State Electricity Board Limited. https://sldckerala.com/index.php?id=9

6. Kerala State Electricity Board Limited, Expression of Interest (EoI), File No. CP/AEE-1/BESS-Planning/2024-25, April 2025. https://kseb.in/uploads/TenderItem/BESS-EoI%20-17447147021350338697.pdf

7. Analyzing Viability of Energy Storage Systems (ESS) at the Sub-national level. KPMG Analysis. 2025. https://keralaenergy.gov.in/wp-content/uploads/2023/12/Draft-for-Discussion Analyzing-Viability-of-Energy-Storage-Systems-ESS-at-the-Sub-national-level 18-March-2025.pdf

8. System Statistics, Kerala State Load Dispatch Centre. https://sldckerala.com/index.php?id=1

9. KSEB Power System Statistics 2024-25: Performance and Data Insights. Kerala State Electricity Board Limited. https://kseb.in/uploads/Downloadtemsuppy/PSS%2024-25-17631986988327571 45.pdf

10. State-wise (Location based) Installed Capacity of Renewable Power as on 31.12.2025. Ministry of New & Renewable Energy. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2026/01/202601091741212092.pdf

11. Biju E Paul. Solar shines bright, installations poised to surpass hydel capacity in Kerala. The New Indian Express. 16 Dec 2024. https://www.newindianexpress.com/states/kerala/2024/Dec/16/solar-shines-bright-installations-poised-to-surpass-hydel-capacity-in-kerala#::text=Solar%20shines%20bright%2C%20installations%20poised,power%20from%20rooftop%20solar%20installations.

12. State-wise (Location based) Installed Capacity of Renewable Power as on 31.12.2025. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2026/01/202601091741212092.pdf

13. System Operation Report, Southern Region 2024-25. Southern Regional Load Despatch Centre. April 2025. https://www.srldc.in/var/ftp/reports/Monthly/System%20Operation%20Report/2025-26/SR%20Monthly%20Grid%20Report Apr2025.pdf

14. System Operation Report, Southern Region 2024-25. Southern Regional Load Despatch Centre. May 2025. https://www.srldc.in/var/ftp/reports/Monthly/System%20Operation%20Report/2025-26/SR%20Monthly%20Grid%20Report May2025.pdf

15. Monthly Renewable Energy Generation Report. Government of India. March 2025. https://cea.nic.in/wp-content/uploads/resd/2025/03/Monthly RE Generation Report March 2025.docx.pdf

16. CSTEP. (2024). Kerala Energy Transition Roadmap 2040. https://cstep.in/wp-content/uploads/2025/06/Kerala-Energy-Transition-Roadmap-2040 3-1.pdf

17. Renewables: 2023: Analysis and Forecast to 2028. https://iea.blob.core.windows.net/assets/96d66a8b-d502-476b-ba94-54ffda84cf72/Renewables 2023.pdf; https://www.iea.org/reports/renewables-2023/executive-summary

18. RISE 2022: Regulatory Indicators For Sustainable Energy. https://documents1.worldbank.org/curated/en/099435112082279276/pdf/P17448108ac2c507a0b6c708ea6cf22f58f.pdf

19. NREL: Overview of Evolving Distributed Energy Resource Grid Interconnection Standards. https://docs.nrel.gov/docs/fy20osti/72714.pdf

20. Phillip Island Community Energy Storage System (PICESS). https://www.ausnetservices.com.au/projects-and-innovation/battery-storage/phillip-island-community-energy-storage-system

21. Barriers and benefits of energy communities in the European Union. https://www.europeum.org/wp-content/uploads/barriers-and-benefits-of-energy-communities-in-the-european-union.pdf

22. Resilience Hubs Support Communities Across the U.S. https://www.dhs.gov/archive/news/2024/06/20/resilience-hubs-support-communities-across-us

23. The Sendai Microgrid Operational Experience in the Aftermath of the Tohoku Earthquake: A Case Study. https://www.nedo.go.jp/content/100516763.pdf

24. ME SOLshare: Peer-to-Peer Smart Village Grids | Bangladesh. https://unfccc.int/climate-action/momentum-for-change/ict-solutions/solshare

25. Accelerating Minigrid Deployment In Sub-Saharan Africa: Lessons from Tanzania. https://documents1.worldbank.org/curated/en/532751512396163620/pdf/WP-acceleratingminigriddeploymentsubsaharanafrica-PUBLIC.pdf

26. World Energy Investment 2024. https://iea.blob.core.windows.net/assets/60fcd1dd-d112-469b-87de-20d39227df3d/WorldEnergyInvestment2024.pdf

27. World Energy Transitions Outlook 2023: 1.5°C Pathway. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Jun/IRENA World energy transitions outlook 2023.pdf

28. Energy Efficiency 2022. https://iea.blob.core.windows.net/assets/7741739e-8e7f-4afa-a77f-49dadd51cb52/EnergyEfficiency2022.pdf

29. Scaling Up Access to Electricity: Emerging Best Practices for Mini-Grid Regulation. https://documents1.worldbank.org/curated/en/382421468178458482/pdf/100988-REVISED-LW51-fin-logo-OKR.pdf

30. Basic details of Grama Panchayats in Thrissur District, Local Self Government Kerala. https://dop.lsgkerala.gov.in/ml/article/1032

31. KSEBL Press Release of 5 Aug 2025 (No. PR/MC2/Press Release/31/2025-26).

32. Binit Das. Kerala's solar surge puts pressure on power bills, KSEB seeks urgent policy fix. Down to Earth, 07 Aug 2025. https://www.downtoearth.org.in/renewable-energy/keralas-solar-surge-puts-pressure-on-power-bills-kseb-seeks-urgent-policy-fix

33. Power System Statistics 2024-25, Performance and Data Insights. Kerala State Electricity Board Limited. https://kseb.in/uploads/Downloadtemsuppy/PSS%2024-25-1763198698832757145.pdf

34. KSEBL: Focus on Grid Modernisation and Renewable Energy Initiatives. PowerLine. 10 Jan 2025. https://powerline.net.in/2025/01/10/ksebl-focus-on-grid-modernisation-and-renewable-energy-initiatives/#::text=KSEBL%20has%20outlined%20several%20focus,nuclear%20power%20in%20the%20state.

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