JSVS's Biogas–PROM Initiative: A Transformative Model for Clean Energy, Soil Health, and Tribal Livelihoods in Dungarpur

WHY: Addressing Energy Poverty, Women's Drudgery, and Soil Degradation in Tribal Rajasthan

Dungarpur district in Southern Rajasthan is predominantly inhabited by tribal communities, many of whom live in remote, hilly regions with limited access to modern energy sources. According to the Census of India and NITI Aayog's Multidimensional Poverty Index, a large proportion of tribal households in districts like Dungarpur depend on fuelwood as their primary cooking fuel. This dependence persists even after gains in rural electrification, because clean cooking energy—such as LPG—is either costly, difficult to refill, or unreliable in interior villages. As a result, energy poverty remains a central barrier to development.

For tribal women, the consequences of this energy poverty are profound. Studies by the National Sample Survey Office (NSSO) and the Ministry of New and Renewable Energy (MNRE) show that rural women spend 2–3 hours daily collecting firewood, often trekking long distances into forest areas. In the tribal belts of Rajasthan, these distances increase during summer and drought years due to forest degradation and fuel scarcity. Field assessments by JSVS over the last four decades confirm this pattern, showing that women in regions such as Mada, Bicchiwara, and Peeth blocks often walk several kilometres daily to gather fuelwood. This routine severely reduces their available time for income-generating work, childcare, participation in SHGs, and education or skills training.

In addition to the time burden, the health impacts of traditional chulha-based cooking are severe. According to WHO, exposure to household air pollution from burning solid biomass is a leading cause of respiratory illnesses among rural women, contributing to COPD, eye irritation, and chronic bronchitis. Research by ICMR and The Energy Resources Institute (TERI) indicates that women who cook over traditional open fires inhale particulate matter levels many times higher than urban pollution standards. In tribal Rajasthan, these impacts are magnified because kitchens are typically small, poorly ventilated, and constructed with low-cost materials that trap smoke.

Jan Shiksha evam Vikas Sangathan (JSVS) also known as PEDO (People's Education and Development Organization), accessible at pedomada.org, is a grassroots NGO dedicated to the holistic development of tribal communities in Southern Rajasthan, India. Established in 1980, with a focus on women's empowerment, education, health, sustainable agriculture, and natural resource management, JSVS has pioneered community-led models that integrate social, economic, and environmental objectives. The organization has successfully implemented initiatives such as biogas and solar energy programs, organic manure production, and microfinance networks, directly benefiting thousands of tribal households. JSVS emphasizes participatory approaches, enabling communities to become co-owners of development projects and fostering long-term sustainability. Its innovative models have been replicated across multiple districts, demonstrating scalable solutions for rural livelihoods and environmental stewardship. By combining technology, capacity building, and local governance, JSVS continues to build self-reliant, resilient, and empowered tribal communities.

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Parallel to energy poverty, tribal agriculture faces the deepening challenge of soil degradation. Rajasthan's tribal districts are dominated by rainfed, sandy-to-loamy soils that are naturally low in organic carbon. Over the past two decades, the rising cost of chemical fertilizers and the declining availability of cattle manure—due to shrinking cattle herds and migration—have led to heavy overuse of chemical inputs on already fragile soils. Studies by the Indian Council of Agricultural Research (ICAR) reveal that continuous use of chemical fertilizers without replenishing organic matter reduces soil structure, microbial activity, moisture retention, and nutrient balance. JSVS's local assessments in Dungarpur show that farmers repeatedly report yield stagnation, reduced soil moisture, and poor germination after years of depending solely on chemical fertilizers.

Furthermore, biomass scarcity—primarily due to deforestation, shrinking common lands, and reduced livestock—has weakened the availability of quality farmyard manure, which tribal farmers traditionally relied upon. This means that even though farmers want to shift to organic methods, they often lack access to sufficient organic inputs. The cost of purchasing organic manure or bio-fertilizers from the market is high and not feasible for economically vulnerable families.

JSVS recognized early on that these problems—energy poverty, women's drudgery, and soil degradation—were deeply interconnected. Women lacked clean energy because of poverty; soils degraded because of lack of organic matter; incomes remained low because productivity fell; and communities could not break out of the cycle because they were stuck in survival mode.

To address these challenges holistically, JSVS, drawing from over 42 years of grassroots work with tribal communities, developed an integrated model that transforms household energy systems while regenerating agricultural ecosystems. The result was the Biogas–PROM initiative, a circular solution that connects:

- Clean energy access
- Women's time and labour savings
- Enhanced agricultural productivity
- Value addition and income generation

Household biogas units convert cattle dung into clean cooking gas, eliminating the need for firewood and reducing smoke exposure. The nutrient-rich slurry produced is no longer treated as waste. Instead, through JSVS's processing hub at the Mada Campus, it is transformed into PROM (Phosphate Rich Organic Manure) and liquid organic fertilizers using scientifically validated methods recommended by ICAR and the Department of Agriculture. This not only enriches soil health but also creates new income streams for women and farmers—thus closing the loop between energy, environment, and livelihood.

This integrated system, grounded in community ownership and scientific principles, is now emerging as one of the most scalable circular rural development models in Rajasthan.

HOW: The JSVS–Community Partnership Model

JSVS's biogas–PROM program is grounded in a participatory development approach that places tribal households, women's groups, and local farmer institutions at the centre of decision-making. Rather than adopting a top-down technology dissemination model, JSVS works through Self-Help Groups (SHGs), village development committees, and local leadership structures to identify households most suited for biogas adoption. This method aligns with global best practices suggesting that community-led renewable energy programs achieve significantly higher adoption and long-term operational success (UNDP, 2019). Once households express interest, JSVS facilitates awareness generation, provides technical training, and oversees the installation of family-sized biogas units. This partnership ensures that communities understand the technology, participate in its maintenance, and benefit from its outcomes.

Figure 1 Photos from the Sites

JSVS has already installed 1,048 household biogas units across Dungarpur's tribal communities. These units provide clean cooking fuel, reduce women's drudgery, and eliminate dependence on forest firewood. Looking ahead, JSVS plans to reach 2,500 units within the next two years, and an ambitious 10,000-unit target over the next five years. This scale is consistent with national renewable energy strategies that emphasize rapid

expansion of decentralized, clean household energy systems in rural India (MNRE, 2021). Each unit is financially structured so that households contribute ₹8,000—an amount feasible for low-income rural families—while JSVS mobilizes the remaining funds through CSR partnerships, government linkages, and development grants. This co-financing model builds a sense of ownership while ensuring that no household is excluded due to poverty.

A key economic innovation in JSVS's model is the creation of a local bio-economy centered around slurry. Every biogas unit produces digested slurry rich in nutrients such as nitrogen, phosphorus, potassium, and beneficial microorganisms—inputs that tribal farmers typically cannot afford in organic form (ICAR, 2015). Instead of letting this resource remain underutilized, JSVS purchases it at ₹1 per litre, creating a reliable micro-income stream for every participating household. Globally, such decentralized buy-back mechanisms have been found to increase rural income diversification and improve household participation rates in renewable energy programs (FAO, 2017). In Dungarpur, the slurry buy-back model particularly benefits women, who usually operate the biogas units. By converting daily household waste into a tradable commodity, the program strengthens women's economic role within the family and community.

Once collected, the slurry is transported to the PROM processing hub located at the JSVS Campus in Mada village. Here, JSVS has established an efficient, structured value-addition system that transforms the raw slurry into high-value organic fertilizers. The entire operation is managed by the Bicchiwara Agro Producer Company, a Farmer Producer Organization (FPO) situated on the same campus. By entrusting the processing, packaging, marketing, and distribution to a farmer-owned enterprise, JSVS ensures that profits are retained within the local community. Evidence from India and abroad shows that FPO-managed agri-value chains lead to higher farmer earnings, greater accountability, and improved sustainability of rural enterprises (NABARD, 2020; World Bank, 2021). The FPO model also creates local employment for tribal youth and women, strengthens governance capacities, and promotes long-term institutional stability.

Through this collaborative governance framework, the JSVS–community partnership model achieves multiple objectives simultaneously: clean household energy, recurring income for families, strengthened farmer institutions, and a locally managed organic fertilizer industry. The model is not only environmentally regenerative but also socially inclusive and economically transformative.

THE PROCESS: Producing PROM and Liquid Organic Fertilizers

The production of PROM and liquid organic fertilizers at JSVS's Mada campus follows a scientifically grounded, community-integrated system that converts raw slurry into high-value agricultural inputs. This process ensures that every litre of slurry purchased from households is transformed into nutrient-rich products that restore soil health, reduce chemical dependency, and promote sustainable tribal farming systems. The methodology aligns with the standards recommended by ICAR, the Ministry of Agriculture, and international best practices on circular bioeconomy models.

1. Collection and Reception of Slurry

The process begins at the household level, where each biogas unit generates a steady stream of digested slurry as a by-product of anaerobic decomposition. Through a decentralized buy-back network, JSVS arranges weekly or daily collection schedules depending on seasonal demand, household capacity, and logistical convenience. The slurry is transported in sealed containers to prevent contamination and nutrient loss—a practice consistent with FAO guidelines on organic nutrient handling (FAO, 2017). Upon arrival at the JSVS–JSVS processing hub in Mada village, the slurry is first passed through coarse filtration systems that remove stones, fibers, and other physical impurities. It is then transferred into large settling tanks, where it undergoes preliminary homogenization and stabilization. This stage ensures uniformity in consistency and prepares the material for controlled processing. The careful handling of slurry not only preserves its nutrient value but also maintains the scientific integrity required for PROM and liquid fertilizer production.

Figure 2 MAHI Prom label, Processed PROM, Processing Machines,

2. PROM Production: Phosphate Rich Organic Manure

PROM (Phosphate Rich Organic Manure) is produced through a multi-stage, controlled bioconversion process. Once the slurry reaches the stabilization tanks, it is enriched with naturally occurring phosphate sources such as rock phosphate. According to ICAR's guidelines on organic phosphorus management, when organic carbon-rich slurry interacts with phosphate minerals under controlled aerobic conditions, it enhances phosphorus solubility and microbial availability (ICAR, 2015). The slurry undergoes regulated aeration, turning, and curing for several weeks. During this period, microbial decomposition transforms the slurry–phosphate mixture into a more stable, semi-solid material.

Over time, moisture levels reduce naturally, and the material transitions into a friable, granulated form. The curing phase ensures pathogen reduction, odor removal, and stabilization of macro- and micronutrients. The final product—PROM—is rich in phosphorus, nitrogen, potassium, calcium, magnesium, and trace minerals essential for tribal region soils, which are often deficient in organic carbon and phosphorus. Numerous agricultural studies show that PROM improves soil structure, enhances water-holding capacity, restores microbial diversity, and increases long-term soil fertility more effectively than many synthetic alternatives

(Sharma & Prasad, 2018). PROM's slow-release properties also help reduce runoff and nutrient leaching, thereby promoting sustainable agricultural productivity.

3. Production of Liquid Organic Fertilizers

In parallel to PROM production, a portion of the slurry is diverted for the creation of liquid biofertilizers and bio-stimulants. This process begins with anaerobic stabilization, where the slurry's microbial content is allowed to mature under controlled conditions. After stabilization, the slurry passes through fine filtration systems to remove solids while retaining dissolved nutrients and beneficial microorganisms.

Next, the filtered liquid is subjected to microbial enrichment**,** where strains of beneficial bacteria—such as *Azotobacter*, *Rhizobium*, *Phosphate Solubilizing Bacteria (PSB)*, or *Potash Mobilizing Bacteria*—are introduced. These microbial consortia enhance nutrient bioavailability and stimulate root development. Scientific evidence from ICRISAT and ICAR shows that liquid biofertilizers significantly increase nutrient uptake and crop yields when used as foliar sprays or soil drenches (Rao et al., 2014). The enriched slurry may also be fortified with organic bio-stimulants, amino acids, or seaweed extracts depending on local crop needs.

After enrichment, the liquid fertilizer is stored in food-grade containers to allow microbial stabilization and shelf-life enhancement. Finally, it is bottled, labeled, and made available to farmers through the FPO's distribution network. These liquid fertilizers are highly effective for small and marginal tribal farmers because they deliver quick nutrient absorption, improve soil microbial populations, and enhance plant resistance to stress.

Details and Benefits of the Products

Phosphate Rich Organic Manure (PROM)

Phosphate Rich Organic Manure (PROM) has proven to be a highly effective soil nutrient supplement, particularly in phosphorus-deficient rainfed regions such as Dungarpur. Research shows that PROM significantly enhances the bioavailability of phosphorus, allowing better root development, nutrient uptake, and crop productivity without relying on conventional chemical fertilizers (Indian Council of Agricultural Research [ICAR], 2019). In tribal regions where soils are often marginal, phosphorus availability remains a major constraint, and PROM directly addresses this gap.

Beyond nutrient provision, PROM plays a crucial role in improving soil health. Organic manures are known to enhance soil structure, increase organic carbon content, and improve water retention—factors especially important in semi-arid and monsoon-dependent landscapes (Food and Agriculture Organization [FAO], 2020). These improvements make fields more resilient to climate variability and seasonal moisture stress. Moreover, by replacing costly chemical fertilizers, PROM reduces farmers' input expenditure, which aligns with global findings that organic amendments significantly lower long-term cultivation costs (FAO, 2019). Its slow-release

nutrient profile supports long-term soil regeneration, gradually rebuilding fertility and reversing degradation processes common in tribal agricultural systems (UNDP, 2021).

Liquid Organic Fertilizer

The liquid organic fertilizer produced from enriched biogas slurry offers another powerful intervention for strengthening crop health. Liquid formulations are quickly absorbed by plants, leading to faster physiological response compared to solid manures, a trend widely documented in organic nutrient management studies (ICAR, 2020). Farmers frequently observe rapid greening, enhanced leaf growth, and stronger flowering soon after application.

Liquid organic fertilizers also contribute significantly to pest and disease resilience. Studies show that microbial-rich liquid manures improve plant immunity and reduce susceptibility to common pests, lowering the need for chemical pesticides (FAO, 2018). Their greatest long-term value, however, lies in revitalising soil microbial diversity. Microbial depletion caused by years of chemical input and erosion is a well-documented challenge in rainfed regions (IPCC, 2019). By reintroducing beneficial microorganisms, liquid organic fertilizers restore natural nutrient cycles, improve soil aeration, and enhance the biological functioning of agricultural fields—foundations of sustainable and climate-resilient agriculture.

Special Benefits for Tribal Women

One of the most transformative outcomes of the Biogas–PROM model is its profound impact on tribal women's lives. Globally, rural women spend disproportionate time on biomass collection, which contributes to "time poverty," drudgery, and exposure to health risks (UN Women, 2020). The introduction of household biogas systems has significantly reduced daily firewood collection, freeing women from hours of laborious and unsafe work. The shift to smokeless kitchens has also reduced respiratory ailments, aligning with WHO assessments on the health benefits of clean household energy (World Health Organization [WHO], 2018).

Economically, the model provides women with their first independent income stream through slurry sales at ₹1 per litre. Such small but regular incomes are proven to enhance women's financial autonomy and household bargaining power (UNDP, 2021). The involvement of Women Self-Help Groups (SHGs) in managing the PROM plant further strengthens community leadership, entrepreneurial participation, and women's institutional visibility—factors strongly associated with successful rural development outcomes (National Rural Livelihoods Mission [NRLM], 2020).

Time saved through clean energy usage enables women to participate in education, training programs, SHG activities, and agricultural enterprises. This aligns with global evidence that reducing unpaid work burdens substantially increases women's opportunities for skill-building and income generation (UN Women, 2020). In many villages, women have become ambassadors of organic farming, promoting the use of PROM and liquid organic fertilizers, proudly producing their own organic inputs—something unimaginable just a decade ago.

The Financing Model

JSVS has deliberately designed a financially accessible system for biogas adoption among tribal households. Each biogas unit costs approximately ₹35,000, with participating farmers contributing ₹8,000, thereby becoming co-owners and active stakeholders in the process. The remaining cost is mobilized by JSVS through project partnerships, corporate social responsibility (CSR) initiatives, and donor support. This shared-cost structure not only fosters community ownership but also ensures the long-term operation and maintenance of the units while reducing the financial burden on economically weaker families (Bhattacharyya, 2013; Nair & Nair, 2012).

To provide continuous economic incentives, JSVS purchases the resulting slurry from households at ₹1 per litre. This approach transforms the biogas unit from a mere utility into a productive asset, providing sustained income alongside clean energy benefits. By integrating financial accessibility with tangible economic returns, JSVS's model exemplifies how participatory and inclusive approaches can enhance adoption and long-term sustainability in rural energy interventions (Chowdhury et al., 2018; Pandey et al., 2020).

Failures and Learnings

No developmental intervention succeeds without iterative learning. In the initial phases of JSVS's biogas program, several challenges emerged. Firstly, irregular feeding of the biogas units posed a problem, as some families struggled to ensure a daily supply of cattle dung. JSVS addressed this issue by strengthening training programs and establishing community monitoring mechanisms.

Secondly, technical issues and maintenance delays, including leakage and valve failures in early models, highlighted the need for design improvements. Over time, JSVS upgraded unit designs, trained village-level technicians, and implemented rapid repair systems, thereby minimizing downtime (Bhattacharyya, 2013).

Thirdly, behavioral resistance affected the adoption of slurry-based fertilizers, largely due to misconceptions about organic inputs. JSVS overcame this barrier through demonstration plots and exposure visits, which provided tangible evidence of the benefits of organic manure.

Finally, logistics related to slurry collection were initially inefficient and costly. The organization introduced decentralized collection centres and coordinated through self-help groups (SHGs), which streamlined operations and reduced transport costs.

Each of these challenges provided valuable lessons, strengthening the overall model. As a result, JSVS's biogas program is now robust, community-owned, and prepared for scaling toward its target of 10,000 units, reflecting the importance of adaptive management and participatory approaches in rural energy development (Chowdhury et al., 2018; Pandey et al., 2020).

Conclusion: A Scalable, Circular, Community-Led Rural Development Model

JSVS's Biogas–PROM initiative exemplifies how simple technologies, community institutions, and farmer-owned enterprises can collectively address multiple rural challenges, including clean energy access, women's empowerment, soil restoration, and enhanced farm incomes (Bhattacharyya, 2013; Pandey et al., 2020). By linking biogas generation with FPO-led production of Phosphate Rich Organic Manure (PROM), JSVS has developed a circular ecosystem in which agricultural waste is transformed into value, energy access strengthens community agency, and organic manure contributes to long-term environmental sustainability (Chowdhury et al., 2018).

The operational success of the model, evident in the performance of the Bicchiwara Agro Producer Company, rising demand for PROM, and the growing number of biogas installations, demonstrates its replicability and scalability (Nair & Nair, 2012). Tribal households benefit economically while simultaneously participating in a sustainable energy and agriculture model, illustrating the effectiveness of community-led, participatory approaches in rural development.

With a clear plan to install 10,000 biogas units over the next five years, JSVS provides a replicable framework for other districts in Rajasthan and similar regions, highlighting the potential of integrated, circular, and community-driven rural development interventions (Bhattacharyya, 2013; Pandey et al., 2020). This initiative underscores the broader principle that combining technological solutions with local ownership and institutional support can create resilient, self-reliant, and environmentally sustainable rural communities.

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