ASHOKA UNIVERSITY

CENTRE FOR A **People-centric Energy Transition**

# Mine Water Repurposing for Sustainable Livelihoods: Leveraging Water Bodies through Solar Lift Irrigation (SLI)

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# PREFACE

The Ashoka Centre for a People-centric Energy Transition (ACPET) launched the Trans-Mine project to address the livelihood and environmental challenges faced by communities impacted by coal mine closures in India. With over 100,000 hectares of abandoned mining land and millions affected by job losses, ACPET aims to develop people-centric solutions that promote economic resilience and land rehabilitation. In Rajhara, Jharkhand, ACPET piloted three on-ground interventions—solar-based lift irrigation, Farmer Producer Organizations, and clean cooking practices—to support sustainable livelihoods and catalyze a just transition for coal-dependent communities. This case elaborates on the Solar Lift Irrigation Pump initiative.

# 1. INTRODUCTION

Mornings in *Rajhara's* Kurkutia Pati hamlet began with a queue—not for food or wages, but for water. A single public handpump was all that stood between 30 households and dehydration, with residents often waiting more than 30 minutes to collect a single bucket. "There are no facilities for water provisioning here," a resident had told us. "Leave aside water for agriculture—there is even scarcity of drinking water. We are quite stressed because of it." Those with means installed borewells plunging up to 300 feet deep, only to encounter polluted and fast-depleting groundwater. The nearby river, once a seasonal fallback, had dried up with the rising heat. Even the Jal Jeevan Mission, intended to provide piped water to every rural household, had not reached the settlement.

This snapshot from 2024 reflects the lived reality of communities grappling with the aftermath of extractive industries. In places like *Rajhara*—long reliant on coal mining—the closure of mines is not just a bureaucratic endpoint, but a turning point with far-reaching environmental and socio-economic consequences.

Mine closure is a comprehensive and multidimensional process that significantly affects land, communities, and infrastructure formerly supported by mining activities. Properly managed, these sites can transition from potential liabilities to valuable assets that enhance environmental sustainability and community well-being.

India's Mine Closure Plan Guidelines are designed to ensure scientific closure and rehabilitation of mining sites, emphasizing the restoration of the land to a condition suitable for future use or returning it to a near-natural state. These guidelines mandate both Progressive and Final Mine Closure Plans. The Progressive Mine Closure Plan includes continuous and sequential land use activities throughout the mining operation, while the Final Mine Closure Plan commences towards the end of mine life, focusing on intensive rehabilitation efforts.

*Rajhara* Coal Mines, part of Central Coalfield Limited (CCL) in Jharkhand's *Palamu* district, span 736 hectares across *Rajhara* and *Pandwa* villages. Originally operated by the Bengal Coal Company and nationalized in 1973, the mine shifted from underground to open-cast methods before its initial closure in 2010 due to environmental issues. It briefly reopened in 2019 and again in 2024 but faced disruptions due to land acquisition conflicts. The mine's operational instability has significantly impacted the livelihoods of the local communities by reducing their household income, inducing forced migration to nearby urban centres, and causing the loss of informal jobs in the coal sector.

In *Rajhara*, a region with an extensive mining legacy, there lies a unique opportunity to repurpose water bodies created by mining activities to restore livelihoods and ensure economic sustainability. This case study will examine how these water bodies can be utilized for irrigation, pisciculture, and other livelihood activities, turning them into sustainable economic resources for local communities. By aligning with best practices for mine repurposing, this initiative aims to transform *Rajhara* into a model for integrating economic and social revitalization efforts into post-mining landscapes. *Rajhara* can thus serve as a pilot for just transformation, where mine closure and repurposing efforts converge to create a self-sustaining ecosystem that supports both the environment and the socio-economic framework of the community.

Through this case study, we aim to outline the strategic considerations, including objectives, responsible stakeholders, financial requirements, timelines, and sustainability measures, essential for the successful repurposing of water bodies in closed mining areas.

*Building concrete ring lining to prevent soil collapse*

# 2. PROBLEM STATEMENT

## 2.1. ECONOMIC VULNERABILITY POST-MINING CLOSURE: A MULTI-DIMENSIONAL CRISIS

The closure of mining operations often triggers severe socio-economic distress for local communities, especially in mining-dependent regions. Mining closures lead to unemployment, land degradation, and the deterioration of infrastructure, making economic diversification challenging (Tripathi, Singh, & Hills, 2016). The lack of alternative livelihoods exacerbates poverty, as local economies remain tethered to mining activities with little or no preparation for a transition. Furthermore, without effective reclamation plans, abandoned mines leave behind degraded landscapes and water bodies that are either underutilized or pose environmental hazards (Singh, 2008).

### 2.1.1. LAND, PEOPLE, AND INFRASTRUCTURE: THE TRIO OF ABANDONMENT

1. Land Degradation and Unplanned Abandonment

Mining activities significantly alter land use patterns, often leaving behind infertile land that remains economically unproductive. In many cases, mining companies fail to rehabilitate the land effectively, leading to long-term degradation and restricted agricultural use (Sarkar, 2013). Unplanned abandonment results in unsafe mining voids and waste dumps that further restrict land utilization. While mine reclamation plans exist, their implementation remains weak due to lack of enforcement by stakeholders(Husain, Wang, Pirasteh, & Mafi-Gholami, 2024).

2. People: Socio-Economic Vulnerability

Communities dependent on mining for employment and ancillary businesses experience immediate economic shocks upon closure. Affected workers often lack the necessary skills to transition to alternative employment, deepening their economic vulnerability (Van Heerden, 2016). Furthermore, compensation by mining companies and rehabilitation measures are often inadequate, leading to social unrest and migration to urban areas in search of low-paying jobs (Dhyani, Santhanam, & Dasgupta, 2023). Women and marginalized groups, particularly, suffer from a lack of access to reskilling programs and alternative livelihood opportunities (Singh, 2008).

3. Infrastructure and Water Bodies: An Untapped Asset

Mining activities frequently result in the creation of large water bodies due to excavation. These water bodies have significant potential for economic reuse, including irrigation, fisheries, and hydro-energy production. However, these assets are often ignored in post-mining land-use planning in India (Yadav & Goyal, 2022). Poor management of these water bodies results in water pollution, loss of biodiversity, and missed opportunities for sustainable economic activities (Sarkar, 2013). The effective repurposing of these water bodies can contribute to local food security and clean energy solutions (Dhyani et al., 2023).

## 2.2. EXISTING GOVERNMENT INITIATIVES

The Indian government has introduced various schemes aimed at promoting rural development which can largely contribute towards sustainable livelihood transitions post-mining. However, their effectiveness has been limited so far, presenting opportunities for improvement in implementation, awareness-building, and streamlining administrative processes.

- PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan): This scheme aims to promote solar energy adoption among farmers. However, its reach in mining-affected regions remains limited due to high initial investment costs and complex subsidy procedures (Husain et al., 2024). Notably, Component B (installation of standalone solar pumps) and Component C (solarization of existing grid-connected pumps) are particularly suited for areas like *Rajhara*, characterized by off-grid conditions and fragmented landholdings (Ministry of New and Renewable Energy, 2024). These components offer a 30% Central Financial Assistance (CFA) and at least a 30% state subsidy, leaving farmers to contribute up to 40% of the cost. To overcome this financial barrier, shared ownership models involving Self-Help Groups (SHGs) or water entrepreneurs can be instrumental. Additionally, leveraging Corporate Social Responsibility (CSR) funds and philanthropic capital can further reduce the upfront costs for farmers, facilitating broader adoption of solar pumps in such regions (Centre for Science and Environment, 2023)

- NRLM (National Rural Livelihoods Mission): Designed to support rural self-employment and entrepreneurship, NRLM faces implementation challenges in mining-affected areas. Many ex-mine workers lack access to credit and market linkages, making sustainable livelihood creation difficult (Van Heerden, 2016). NRLM's approach is rooted in community-led development, emphasizing the mobilization of rural poor, especially women, into Self-Help Groups (SHGs). These SHGs are federated into higher-level institutions, fostering collective decision-making and ownership of development processes (Ministry of Rural Development, 2017). Such community institutions are pivotal in tailoring interventions to local needs, ensuring that livelihood programs are context-specific and sustainable. However, in mining-affected regions, the disruption of traditional community structures and economic activities poses additional challenges to the effective implementation of NRLM's community-driven strategies (World Bank, 2020).

- DMF (District Mineral Foundation) Funds: Established to address the socio-economic impact of mining, DMF funds have been underutilized in many regions. Reports indicate that funds are often diverted to other infrastructure projects rather than livelihood development (Singh, 2008).
  Established to mitigate the adverse socio-economic impacts of mining, DMF funds have often been underutilized and mismanaged in several states. A CAG audit report reviewing nine DMFTs from 2016-17 to 2020-21 found that only 63% of the ₹1,918.84 crore received had been utilized, resulting in fund accumulation and delays in delivering benefits to mining-affected communities. Additionally, poor financial planning led to a loss of ₹24.87 crore in interest due to failure to use sweep/flexi deposit facilities. There were also expenditures of ₹14.94 crore made in violation of state directives, and

₹219.31 crore was blocked in incomplete projects due to poor monitoring. These inefficiencies were further compounded by the absence of annual plans, Master Plans/Vision Documents, and irregular meetings of the DMFT Governing Councils—highlighting serious gaps in governance and planning (Comptroller and Auditor General of India [CAG], 2023).

- Jal Shakti Abhiyan: This water conservation campaign, spearheaded by the Government of India, promotes the reuse of mine water for community use. Coal/Lignite PSUs under the Ministry of Coal have initiated the utilization of mine water—both from active and abandoned mines—for irrigation, drinking, and domestic purposes, aligning with the goals of Jal Shakti Abhiyan (Ministry of Coal, 2024).

## 2.3. COMMUNITY PERCEPTIONS AND BARRIERS

Local communities are often not fully informed about government initiatives due to limited outreach. These schemes are sometimes perceived as complex and difficult to navigate. Interviews with local stakeholders highlight the need for decentralized decision-making and community-led initiatives to ensure effective economic transition (Yadav & Goyal, 2022).

The repurposing of water bodies in abandoned mining areas presents a viable and sustainable solution to post-mining economic distress. However, the lack of planned rehabilitation, ineffective government schemes, and infrastructural challenges hinder this potential. Addressing these issues requires a multi-stakeholder approach involving local communities, policymakers, and mining companies to ensure long-term socio-economic resilience.

# 3. CONCEPT OF REPURPOSING

Mine repurposing is a holistic approach to transforming post-mining landscapes into sustainable assets through land rehabilitation, community-based livelihood generation, and infrastructure reuse (Rana, Pachu, Jeeva, & Rao, 2024). Just transition aims to mitigate the environmental and economic impacts of mining closures while fostering long-term regional development. The process involves remediating degraded land, reusing existing mining infrastructure, and repurposing mining voids and water bodies for economic activities such as irrigation, fisheries, and renewable energy generation (Dubey, Kumar, & Dutta, 2024).

## 3.1. LOCAL GOVERNANCE, COMMUNITY PARTICIPATION, AND INSTITUTIONAL READINESS

The success of mine repurposing hinges on strong local governance mechanisms and active community participation. This includes:

- Decentralized Planning: Empowering local self-governments to lead repurposing initiatives (Dubey et al., 2024).
- Capacity Building and Skill Development: Training former mine workers in sustainable agriculture, fisheries, and renewable energy sectors (Kumar, Kala, Mina, Ali, & Meena, 2024).
- Transparent Fund Utilization: Ensuring that District Mineral Foundation (DMF) funds are used for sustainable economic activities rather than diverted to unrelated projects (Singh, 2008).

Repurposing mining water bodies presents a viable pathway for sustainable development in India’s post-mining regions. By integrating global best practices with localized governance and financing models, mining-affected areas like *Rajhara* can transition toward a resilient and diversified economy. The key to successful repurposing lies in proactive policy reforms, targeted investment, and community-driven implementation.

# 4. LIVELIHOOD SUPPORT THROUGH REPURPOSING

Repurposing water bodies in abandoned mining offers a transformative opportunity for mining communities to transition towards diversified livelihoods in agriculture, fisheries, aquaculture, eco-tourism, and renewable energy solutions. Among these, solar lift irrigation (SLI) emerges as a viable and scalable approach, by leveraging abandoned mine water reservoirs to enhance agricultural productivity.

## 4.1. POTENTIAL LIVELIHOOD MODELS FOR REPURPOSED MINING WATER BODIES

### *FISHERIES AND AQUACULTURE*

Mining pits (if left as it is and not refilled) and abandoned reservoirs provide ideal conditions for developing fisheries and aquaculture, supporting local employment and ensuring food security. Studies have highlighted the potential of utilizing disused mining voids for fish production, especially abandoned waterlogged quarries can be utilized commercially for fisheries (Samanta, 2022). The introduction of high-value fish species, such as catla, rohu, and tilapia, alongside aquaponic systems, can generate year-round income for affected communities (Dubey, Kumar, & Dutta, 2024).

### *ECO-TOURISM AND RECREATION*

Several global case studies, including those from South Africa, Germany, and Australia, have demonstrated the successful conversion of mining voids into eco-tourism hubs. In India, the Chhattisgarh government has repurposed several abandoned mines into lake tourism sites that attract visitors for boating, birdwatching, and adventure tourism (Singh, 2008). *Rajhara's* abandoned mines, if developed strategically, can create a local tourism economy by offering nature trails, biodiversity conservation parks, and water-based recreational activities.

## 4.2. AGRICULTURE-BASED REPURPOSING: SOLAR LIFT IRRIGATION (SLI) FOR WATER SECURITY

Given the seasonal water scarcity and the high costs associated with conventional irrigation methods, abandoned mining reservoirs offer a low-cost, year-round irrigation solution. Solar Lift Irrigation (SLI) utilizes solar-powered pumps to lift water from the ground, which is recharged through the surrounding water reservoirs, to agricultural fields, ensuring energy-efficient and climate-resilient irrigation (Husain, Wang, Pirasteh, & Mafi-Gholami, 2024).

Key Benefits of SLI for Post-Mining Communities

- Sustainable Water Management: Ensures year-round water availability, addressing drought-prone conditions in mining-affected regions.
- Yield Improvement: Studies show that SLI can increase crop yields by 10% to 40%, depending on crop and location, due to reliable irrigation and reduced water stress (Raut & Uikey, 2023); (Tekam, 2023).
- Cost-Effective Farming: Reduces dependency on expensive diesel-powered irrigation, lowering input costs for farmers. For instance, replacing diesel pumps with solar pumps in Rajasthan resulted in annual savings of approximately ₹36,600 per farmer, along with a reduction of 446.4 liters of diesel consumption per farm per year (Jat et al., 2019).
- Climate Resilience: Enhances adaptive capacity against climate change by ensuring stable crop cycles.
- Employment Generation: Supports local farmers and laborers, fostering agro-based entrepreneurship.

## 4.3. INVESTMENT NEEDS AND FINANCING MODELS

Effective SLI deployment in mine reservoirs requires a combination of government funding, private investment, and community participation. The following financing models can support this transition:

- Microfinance and Self-Help Groups (SHGs): Community-driven financial models to enhance farmer participation.
- Corporate Social Responsibility (CSR): Mining companies can contribute under their CSR obligations towards water conservation and sustainable livelihoods (Katyal, 2024).
- Public-Private Partnerships (PPPs): Collaboration between government agencies and private firms to fund and manage repurposing projects.
- Government Grants and Subsidies: Policies such as the PM-KUSUM scheme provide financial incentives for solar energy projects on reclaimed mining land (Husain, Wang, Pirasteh, & Mafi-Gholami, 2024).
- Carbon Credits and Environmental Bonds: Monetizing ecological benefits through global carbon markets and green bonds for sustainable mining rehabilitation (Pagouni, Pavloudakis, Kapageridis, & Yiannakou, 2024).
- Renewable Energy Service Company (RESCO) Model: A public-private partnership model where private developers install, operate, and maintain renewable energy systems—such as solar panels on reclaimed mining land—while end-users pay only for the electricity consumed. This approach eliminates upfront capital costs for users and ensures long-term maintenance through fee-for-service arrangements, as demonstrated in Indian solar PV deployments (Anand & Rao, 2016).

## 4.4. COMMUNITY PERCEPTIONS AND READINESS FOR AGRICULTURAL EXPANSION

The field study in *Rajhara* reveal a strong willingness among local farmers to adopt Solar Lift Irrigation (SLI) systems, provided they receive adequate training, infrastructure, and policy support. A significant 90.5% of respondents[1] believe that adopting the SLI system will allow them to cultivate a greater variety of crops, demonstrating high aspirational potential linked to improved irrigation access. This sentiment highlights the community's readiness to expand crop production significantly if assured of a consistent water supply through solar-powered irrigation.

However, actual uptake has been limited due to ongoing infrastructure challenges and water flow inconsistencies. Many farmers reported that water had not yet reached their fields, which delayed planned transitions to multi- season farming or vegetable cultivation. In instances where water was briefly available, some initiated irrigation for crops like wheat or arhar, but these were isolated and short-lived efforts. As a result, the broader adoption of revised cropping strategies remains aspirational and heavily dependent on the restored functionality of the SLI systems.

Historically, the small fraction of farmers who had access to electric or diesel pump systems used these pumps for an average of 31.7 hours per farming cycle, which underscores the modest scale of prior irrigation arrangements and supports the case for expanding solar-based systems.

However, barriers such as high initial setup costs, lack of technical knowledge, and limited access to financing further hinder widespread adoption of SLI systems. Addressing these challenges requires localized capacity-building initiatives, including:

- Farmer Training Programs: Conducting hands-on workshops on SLI operation and maintenance to ensure farmers can independently manage and troubleshoot the systems.
- Demonstration Projects: Implementing pilot projects to showcase the economic benefits of SLI, thereby increasing farmer confidence in the technology.
- Cooperative Farming Models: Encouraging group-based investment in irrigation infrastructure to distribute costs and benefits more equitably among the community.

Together, these measures can help leverage the strong community interest in SLI systems, transforming *Rajhara's* agricultural landscape into a more productive and sustainable environment.

[1] *Data based on semi-structured interviews administered to 42 households in Rajhara*

## 4.5. ALIGNMENT WITH INDIA'S MINE CLOSURE GUIDELINES

The Ministry of Coal's Mine Closure Guidelines (2025) emphasize the integration of sustainable economic alternatives for communities transitioning away from mining. Agriculture-based repurposing aligns with key mandates of the guidelines, including:

- Land Rehabilitation and Ecological Restoration: Encouraging agricultural reuse of degraded mining land.
- Water Resource Management: Mandating efficient utilization of mine voids for irrigation.
- Community-Led Transition Strategies: Promoting inclusive participation of local stakeholders in post-mining economic planning (Government of India, 2025).

Repurposing mining water bodies presents a high-impact strategy for post-mining livelihood support, with Solar Lift Irrigation (SLI) emerging as a game-changer for sustainable agriculture. However, current mine closure guidelines mandate technical evaluations and safety assessments of water bodies prior to their repurposing, which can delay or limit immediate reuse for irrigation or livelihood purposes (Ministry of Coal, 2024).

While groundwater is currently being utilized in this project, the long-term goal remains the reuse of abandoned mine water bodies, in line with successful examples documented by Coal India Limited (CIL), South Eastern Coalfields Limited (SECL), and Western Coalfields Limited (WCL), where treated mine water has been used for irrigation, drinking, and domestic needs (Ministry of Coal, 2024).

In *Rajhara*, the proposed SLI model will not only facilitate climate-resilient agriculture but also promote self-governance through community-led ownership structures, making it a compelling component of inclusive mine closure planning. By integrating fisheries, eco-tourism, and community-managed irrigation models, mining-affected regions can foster economic self-sufficiency, water security, and long-term resilience.

Enforcement of these guidelines remains a challenge. The Coal Controller Organisation (CCO) is responsible for overseeing mine closure compliance, including the approval of Mine Closure Plans and the issuance of mine closure certificates (Coal Controller Organisation, n.d.). Despite this, implementation has been weak. As of early 2025, only 3 out of 299 coal mines identified for closure had been formally closed under the guidelines, highlighting significant enforcement gaps (Business & Human Rights Resource Centre, 2025).

Factors contributing to this include inadequate monitoring, limited financial resources, and lack of accountability mechanisms. The absence of stringent penalties for non-compliance further exacerbates the issue, allowing mine operators to delay or neglect closure obligations without significant repercussions (Business & Human Rights Resource Centre, 2025). Strengthening institutional capacities, enhancing transparency, and enforcing accountability are crucial steps toward effective implementation of mine closure policies.

# 5. SOLAR LIFT IRRIGATION: FEASIBILITY AND IMPLEMENTATION

Beyond environmental considerations, solar-based irrigation systems have profound socio-economic implications in mining-distressed areas. Case studies from Indian states such as Karnataka demonstrate that while solar irrigation pumps involve higher initial investment, they result in long-term savings through reduced fuel and electricity costs, increased system reliability, and improved agricultural productivity (Spielberg et al., 2016). The technology generates new employment opportunities related to the maintenance and technical monitoring of these systems, thereby contributing to local skill development and employment. Moreover, consistent water supply and enhanced irrigation efficacy improve food security and spur income generation from diversified cropping systems, providing farmers with economic resilience in the face of fluctuating market conditions (Renjini et al., 2021).

### *Infrastructure Requirements for Solar Lift Irrigation (SLI)*

The successful implementation of Solar Lift Irrigation (SLI) in repurposed mining water bodies requires a well-structured infrastructure. The key components include:

- Solar Photovoltaic (PV) Panels: Installed near the water body or on floating platforms for maximum sun exposure.
- Submersible Solar Pumps: Used to lift water from mining reservoirs to irrigation fields.
- Storage and Distribution System: Including water storage tanks and drip or sprinkler irrigation networks.
- Grid-Connectivity Infrastructure: To facilitate surplus electricity sales where applicable.
- Battery Backup Systems: For ensuring water availability on cloudy days.
- Farmer Training Centers: To educate smallholder farmers on SLI maintenance and operational efficiency (Dubey, Kumar, & Dutta, 2024).

### *COMPARATIVE ANALYSIS OF SLI VS. TRADITIONAL IRRIGATION*

A cost-benefit analysis (CBA) of repurposing mining voids for irrigation and renewable energy reveals long-term economic gains, including reduced water scarcity, increased agricultural productivity, and lower dependency on fossil fuels (Katyal, 2024). A general comparative analysis of traditional irrigation (diesel-based or rainfed) versus solar-powered irrigation reveals significant economic and environmental benefits:

| Parameter | Diesel-Based Irrigation | Rainfed Agriculture | Solar Lift Irrigation (SLI) |
|---|---|---|---|
| Initial Investment | Low | No Cost | Medium-High (One-time investment) |
| Operating Cost | High (Diesel and maintenance) | No cost, but seasonal water scarcity | Low (Minimal maintenance) |
| Energy Dependency | Fossil Fuel-Based | Dependent on Rainfall | Renewable Solar Energy |
| Water Reliability | Limited by diesel costs | Seasonal & uncertain | Year-round access |
| Environmental Impact | High emissions, groundwater depletion | Dependent on monsoons | Low emissions, efficient water use |

Studies indicate that shifting to solar irrigation can reduce diesel costs by up to 70% and increase annual farm income by 30-40% (Husain, Wang, Pirasteh, & Mafi-Gholami, 2024). Farmers using SLI avoid recurring fuel expenses, allowing them to invest in farm expansion, improved seeds, and modern irrigation techniques.

### Social Impact: Smallholder Farmers and Gender Inclusion

- Empowerment of Small Farmers: SLI reduces input costs, making irrigation affordable for marginal and small-scale farmers.
- Women in Agriculture: Solar-powered irrigation reduces the labor burden on women, who traditionally fetch water for household and agricultural use.
- Climate Resilience: Ensures sustained agricultural output even in drought-prone regions, reducing migration due to water scarcity (Dhyani, Santhanam, & Dasgupta, 2023).

## Grid Integration and Income Generation from Surplus Power

A crucial aspect of SLI's long-term viability is its potential for excess electricity generation. Farmers can sell surplus solar power back to the grid, ensuring an additional income source.

Key Policies Supporting Grid Integration

- PM-KUSUM Scheme: The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) promotes decentralized solar energy adoption in agriculture. It enables farmers to install solar panels and sell excess power to DISCOMs (electricity distribution companies).
- State-Specific Solar Policies: States like Rajasthan, Gujarat, and Madhya Pradesh offer higher feed-in tariffs for agricultural solar energy producers.
- Net-Metering Mechanism: Allows farmers to offset energy costs by injecting surplus power into the grid.

Despite the advantages, a few barriers limit farmers' participation in grid-connected solar programs:

- High Upfront Costs: Many small farmers lack access to credit or financing options.
- Technical Complexity: Connecting small-scale solar units to the grid requires infrastructure upgrades.
- Bureaucratic Hurdles: Lengthy approval processes for grid integration discourage farmers.
- Limited Awareness: Many farmers are unaware of PM-KUSUM benefits and net-metering policies (Katyal, 2024).

## Cooperative-Based Energy Sales Models

To overcome these barriers, Water User Groups (WUGs) and farmer cooperatives can be leveraged for collective solar energy management. Successful cooperative-based models include:

- Farmer-Owned Solar Plants: Smallholders pool resources to install community solar pumps and share operational profits.
- Cooperative-Based Microgrids: Village-level solar grids managed by local farmer groups can supply power for both irrigation and domestic use.
- Third-Party Aggregators: Private companies partner with farmer cooperatives to facilitate grid connections and power sales (Singh, 2008).

*Rajhara's* abandoned mine water bodies present ideal conditions for SLI adoption. However, feasibility depends on sufficient reservoir capacity for year-round irrigation, adequate sunlight for continuous energy generation, willingness of local farmers to adopt solar irrigation, and availability of subsidies, microfinance, and cooperative funding to offset installation costs.

# 6. SOLAR-BASED LIFT IRRIGATION (SLI) IN *RAJHARA* – INSIGHTS FROM THE FIELD[2]

### SOCIO-ECONOMIC PROFILE OF SLI BENEFICIARY FARMERS

In *Rajhara*, the SLI system aims to actively transform the agricultural landscape. Surveyed households predominantly consist of small to marginal farmers with an average landholding of 2.32 acres, ranging from 0.20 to 8 acres. The community is primarily composed of Other Backward Classes (69.0%), followed by General (19.0%) and Scheduled Castes (11.9%).

Although only 9.5% of surveyed respondents were women, field interactions confirm that women are represented in Water User Groups (WUGs). This presents a critical opportunity to further strengthen their involvement by promoting leadership roles within WUGs and integrating women-focused training on irrigation planning and water-use practices, thereby ensuring more inclusive governance and decision-making.

### AVAILABILITY, ACCESSIBILITY & ADOPTION OF SLI

Before SLI, all farmers (100%) depended solely on rainfall for irrigation, with minimal use of supplementary sources like electric pumps and open wells (each used by 7.1%). The introduction of SLI was met with enthusiasm, with 90.5% of farmers expecting to diversify crops significantly. However, initial technical challenges have highlighted the need for robust system maintenance, reinforcing the importance of reliable infrastructure to fully realize the initiative's potential and meet its aspirations.

### FARMER ADOPTION & USAGE PATTERNS

Despite strong initial acceptance, the actual use of the SLI system was constrained by initial infrastructural and operational challenges. However, with the SLI system now fully operational, the community's willingness to embrace new agricultural methods is clear, highlighting the need for reliable and continuous irrigation support to unlock this potential impact on agriculture & livelihoods

The potential for SLI to transform agricultural productivity in *Rajhara* is significant. Farmers are eager to shift to high-value crops and increase production scales. The economic impact is currently constrained, as many farmers are still awaiting the anticipated rise in incomes from expanded agricultural activities. Specifically, 84.2% of respondents plan to grow wheat, 81.6% vegetables, and 76.3% rice once the system is fully functional.

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[2] *Methodology: These findings are based on a census survey involving semi-structured interviews with all 42 households directly associated with the project in Rajhara—24 current beneficiaries and 18 neighboring households likely to benefit soon. Key informant interviews were also conducted with a Panchayat Raj Institution (PRI) member and the implementation partner from ACPET.*

## *FINANCIAL FEASIBILITY & WILLINGNESS TO PAY FOR SLI SERVICES*

Farmers demonstrate a willingness to invest in the SLI system, contingent upon its reliability. There's a preference for a per-acre payment model, reflecting the agricultural practices of the region. However, there is growing concern among farmers regarding fees paid without visible improvements, underscoring the importance of transparent and accountable financial management within the project. The average landholding among beneficiaries is 2.32 acres, with a median of 2 acres, indicating a predominance of small to marginal farmers. Landholdings range from 0.20 acres to a maximum of 8 acres. A clear majority (83.3%) expressed a preference for a per-acre pricing model, citing its simplicity and alignment with existing landholding practices. Only a tiny segment (14.3%) preferred a per-hour usage model, often associated with greater flexibility but also higher monitoring overhead. In terms of payment capacity, the median and modal amount farmers are willing to pay per acre of cultivation is ₹100, while for those preferring a per-hour basis, the willingness to pay stands at ₹10. Despite the variation in willingness to pay, a common preference emerged for low initial rates, particularly among farmers with marginal incomes.

A few respondents advocated for a phased pricing approach, where lower charges would apply in the early operational period, increasing gradually once crop yields and incomes improved. Others highlighted the need for transparent communication on how fees would be used, especially for maintenance and spare part procurement.

## *WATER QUALITY AND AGRICULTURAL SUSTAINABILITY*

The implementation of the Solar-Based Lift Irrigation (SLI) system in *Rajhara* represents a forward-thinking approach to leveraging abandoned mining infrastructure for agricultural revitalization. This case study underscores the significant potential of SLI systems to enhance agricultural productivity and livelihoods in post-mining communities. By providing a sustainable, renewable source of irrigation, SLI addresses the critical challenge of water scarcity that many former mining areas face, potentially transforming these regions into fertile agricultural lands.


*FDG with Self Help Group (SHG) members*

Despite the obstacles, the community's strong interest in and positive reception towards the SLI system are promising indicators of its potential success. With 90.5% of farmers expressing a desire for crop diversification and improved agricultural outputs, the demand and willingness to adapt are evident. To realize this potential fully, it is imperative to address the operational inefficiencies, enhance system reliability, and foster inclusive governance practices that involve all stakeholders.

## 6.1. DATA INSIGHTS AND PROJECTIONS

### *COMPARATIVE INSIGHTS FROM SIMILAR SLI INTERVENTIONS*

- In Sohagpur Block, Madhya Pradesh, 46 SLI systems over 30 villages improved crop diversification and increased household incomes significantly (Ahake, 2022). *Rajhara's* 90.5% interest in diversification mirrors this trend, suggesting a strong likelihood of parallel income uplift once system reliability improves.
- Studies in Ethiopia showed that solar irrigation systems increased crop yields by 30-50% and improved food security through better dietary diversity (Negera et al., 2025). Solar lift irrigation increased water use efficiency by up to 40% and crop
productivity by up to 43% for vegetables (Adadu & Eyoma, 2024; Assefa et al., 2020).

EXTRAPOLATIONS FOR *RAJHARA*:

| Parameter | Expected under SLI | Source |
|---|---|---|
| Average crop yield improvement | 30%-50% increase | (Negera et al., 2025) |
| Cropping intensity | 150%-200% (multi-cropping) | (Ahake, 2022) |
| Household income | 1.5x to 2x increase | (Ahake, 2022; Negera et al., 2025) |
| Water-use efficiency improvement | 34%-40% improvement | (Sihombing et al., 2025; Adadu & Eyoma, 2024) |
| Payback time for investment | 2-3 years (based on similar SLI projects) | (Guno & Agaton, 2022) |

Projected Socio-Economic Outcomes

- Agricultural Revenue: Average household agricultural revenue could double within 2-3 years of stable SLI operation.
- Food Security: Increased crop diversity and year-round farming could significantly improve food security, measured by enhanced Household Food Consumption Scores (HFCS).
- Social Inclusion: Structured interventions promoting women's participation could enhance social equity and governance outcomes.

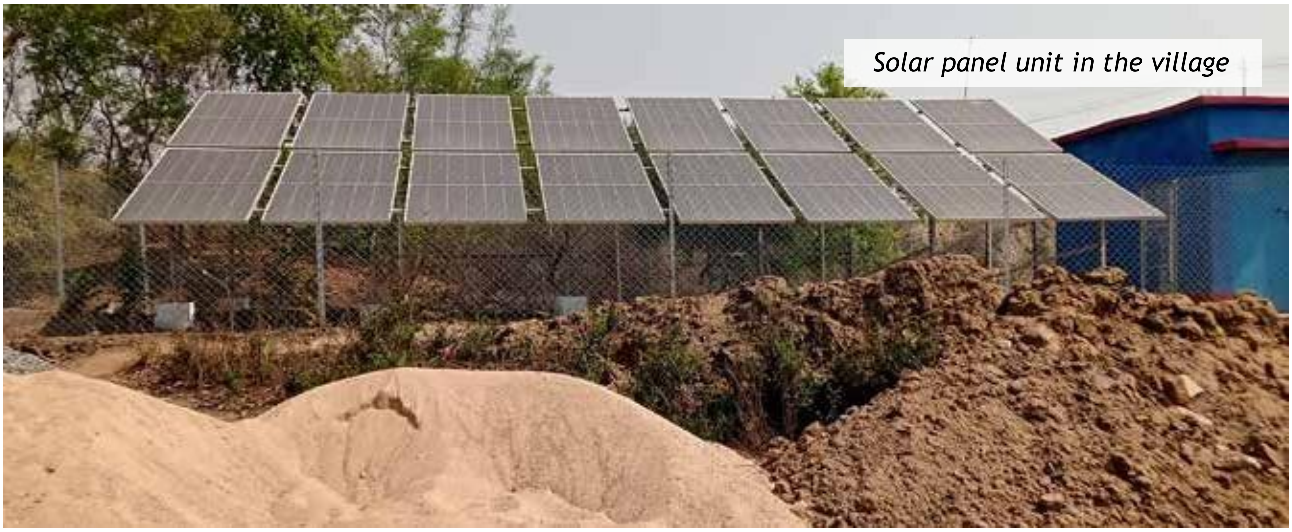
Environmental Benefits

- Transitioning to solar-powered irrigation will offset significant diesel consumption, reducing GHG emissions by up to 26.5 tons $CO_2$eq/ha/year (Guno & Agaton, 2022).

**Leveraging Post-Mining Water Assets for Irrigation – The *Rajhara* Example**

In *Rajhara*, the installation of a solar lift irrigation (SLI) pump has demonstrated how abandoned mining water bodies can be effectively repurposed to support agricultural livelihoods. This initiative taps into one of the reservoirs formed due to mining excavation, converting a legacy of environmental degradation into a functional community resource.

Critically, the water from this reservoir has been found to be of high quality, as confirmed by recent laboratory testing: the sample met all key chemical and microbiological safety benchmarks under IS 10500:2012 standards. The absence of harmful heavy metals, low total dissolved solids (TDS of 174 mg/l), and neutral pH (7.49) make it well-suited for agricultural irrigation.



*Solar panel unit in the village*

*Concrete ring lining to prevent soil collapse*

# 7. POLICY AND GOVERNANCE LANDSCAPE

## 7.1. POLICY GAPS IN MINE CLOSURE FRAMEWORKS AND LIVELIHOOD REHABILITATION

While mine closure plans in India emphasize environmental restoration, they often lack structured strategies for livelihood rehabilitation, particularly for irrigation-based farming. The Ministry of Coal's Mine Closure Guidelines (2025) outline ecological recovery measures, such as afforestation and water body reclamation, but fall short of offering clear guidance on post-mining economic transitions for affected communities (Government of India, 2025). Current mine closure frameworks primarily focus on land reclamation but lack detailed provisions for agriculture-based livelihoods. While government programs like PM-KUSUM and NRLM promote sustainable agriculture and solar irrigation, they are not explicitly linked to mine repurposing efforts. Additionally, DMF funds intended for the welfare of mining-affected communities, are often diverted to general infrastructure projects rather than targeted livelihood development (Singh, 2008).

**Evaluation of the Governance Model for SLI in Rajhara**

The Solar Lift Irrigation (SLI) project in Rajhara introduced a structured governance model centered around Water User Groups (WUGs) to promote equitable access, local ownership, and system sustainability. As part of this model:

- Each farmer group made an initial financial deposit, aimed at instilling collective ownership and enabling a revolving fund for maintenance and minor repairs.
- WUGs were intended to manage water scheduling, resolve conflicts, and oversee routine operations, with internal representatives nominated to liaise with the implementation team.
- Caretaker roles were informally suggested by farmers for pump management, and some proposed that WUG member contact information be displayed publicly to foster transparency and accountability.

However, the governance model's effectiveness could not be fully assessed due to the non-operational status of the irrigation system at the time of evaluation. Although 95.2% of farmers were enrolled in WUGs, most had limited understanding of operational rules, cost-sharing norms, or dispute resolution mechanisms. Field interviews also revealed uncertainty around decision-making responsibilities and technical support protocols, signaling that while the structure exists, its operationalisation remains incomplete.

In essence, the governance model has been initiated but not activated. To realise its full potential, there is a need to:

- Formalise orientation sessions for WUG members.
- Clarify governance protocols such as water allocation rules, caretaker responsibilities, and cost calculations.
- Establish grievance redress systems and financial transparency mechanisms.

This would enable WUGs to evolve from nominal collectives to effective rural water governance institutions, supporting the long-term sustainability of SLI infrastructure in post-mining landscapes.

## 7.2. OPPORTUNITIES FOR FORMALIZING IRRIGATION-BASED FARMING IN MINE CLOSURE POLICIES

### Integrating Agricultural Repurposing into Government Schemes

- PM-KUSUM: By aligning mine closure policies with PM-KUSUM, repurposed mine water bodies can be utilized for solar lift irrigation (SLI), ensuring sustainable livelihoods for local farmers (Katyal, 2024).
- DMF Funds: Strengthening fund allocation transparency and prioritizing irrigation-based projects can improve livelihood outcomes for mining-affected communities.
- CSR Initiatives by Coal Companies: Coal India Limited and private mining corporations invest in community development under Corporate Social Responsibility (CSR) mandates. Encouraging agriculture-based rehabilitation as part of CSR activities can bridge the policy gap in mine closure frameworks (Dhyani, Santhanam, & Dasgupta, 2023).

### Stakeholder Mapping and Governance Mechanisms

Effective implementation of mine repurposing strategies depends on multi-stakeholder collaboration involving local governance, the private sector, and community participation.

### Key Stakeholders and Their Roles

| Stakeholder | Role in Policy Implementation |
|---|---|
| State and Central Governments | Policy formulation, regulatory oversight, and integration of schemes like PM-KUSUM into mine closure plans. |
| District Mineral Foundation (DMF) | Fund allocation for irrigation projects and community-led agricultural initiatives. |
| Mining Companies (CIL, Private Firms) | Investment in agricultural rehabilitation under CSR obligations and land reclamation programs. |
| Local Self-Governments (Panchayats, Municipalities) | Implementation of irrigation projects, farmers' training, and land-use planning. |
| Farmer Cooperatives & Water User Groups (WUGs) | Operation of solar lift irrigation systems and cooperative-based energy sales. |

### Leveraging Local Governance and Community Participation

- Decentralized Planning and Implementation: Panchayati Raj Institutions (PRIs) play a crucial role in ensuring that mine repurposing projects align with local needs. Additionally, community-led land-use planning can enable affected populations to participate in decision-making processes.
- Private Sector Engagement and Investment: Public-Private Partnerships (PPPs) can help bridge financing gaps in irrigation-based mine repurposing projects. Mining companies can collaborate with agricultural cooperatives to establish sustainable post-mining economies (Dubey, Kumar, & Dutta, 2024).

A well-structured policy and governance framework is critical for the successful repurposing of mining landscapes into productive agricultural hubs. By integrating irrigation-based livelihood strategies into existing mine closure policies, leveraging government schemes, and ensuring multi-stakeholder collaboration, post-mining communities can achieve long-term economic resilience. Addressing funding inefficiencies, decentralizing decision-making, and fostering private sector participation will be crucial in making irrigation-based repurposing a scalable and sustainable model for India's mining-affected regions.

# 8. PROJECTED SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACT

## 8.1. ECONOMIC UPLIFTMENT AND LIVELIHOOD CREATION

The repurposing of abandoned mining sites into functional water bodies presents significant opportunities for income diversification and livelihood generation. By providing reliable irrigation access, smallholder farmers can enhance agricultural productivity and reduce dependency on costly, unsustainable irrigation methods such as diesel-powered pumps. Studies indicate that rainwater harvesting and mine spoil restoration in arid regions, such as Rajasthan, have led to substantial increases in crop yields and farmer incomes (Pandey, Chaubey, & Gupta, 2005).

Moreover, the introduction of sustainable irrigation techniques has enabled communities to shift away from water-intensive, high-cost farming models, thereby reducing the economic vulnerability of rural populations (Elmahdi, 2024). In India, repurposing mining sites into water reservoirs has also supported fisheries, ecotourism, and small-scale agroforestry, providing alternative income sources for marginalized communities, including Scheduled Castes (SC) and Scheduled Tribes (ST) (Sandrasekaran, Thilagam, & Khola, 2017).

## 8.2. SOCIAL INCLUSIVITY AND COMMUNITY PARTICIPATION

A crucial element of mine repurposing projects is ensuring equitable access to irrigation and resource management, particularly for women, smallholder farmers, and marginalized groups. Research on mining-induced displacement highlights the importance of incorporating community-driven decision-making processes to ensure social sustainability (Ahmer & Ostendorf, 2025). This can be achieved through:

- Participatory water governance models that involve local farmers in irrigation planning.
- Capacity-building programs to educate farmers on efficient water use and sustainable agriculture.
- Gender-sensitive policies to ensure women's inclusion in irrigation and land-use planning.

The successful integration of local knowledge with scientific interventions has been documented in various reclamation and rehabilitation strategies across India (Rana et al., 2024). Such participatory models can enhance social cohesion and empower communities to take an active role in water management.

## 8.3. ENVIRONMENTAL SUSTAINABILITY AND WATER MANAGEMENT

From an environmental perspective, abandoned mines pose significant challenges due to soil degradation, water contamination, and ecosystem disruption. However, innovative land and water reclamation strategies have proven successful in restoring ecological balance. Research on mine reclamation in Jharkhand demonstrated that properly managed mine water can recharge groundwater tables, mitigate drought effects, and improve soil fertility (Murmu & Behera, 2024).

Additionally, zero-waste adaptation technologies have been effectively used in Indian mining operations to treat and repurpose mining wastewater for irrigation purposes (Patra & Dash, 2024). By employing bioremediation techniques and sedimentation processes, contaminants in mine-affected water bodies can be neutralized, ensuring safe and sustainable water reuse.

Moreover, research has highlighted that integrated land-use planning—combining afforestation, biodiversity conservation, and water body restoration—can transform abandoned mines into functional ecosystems that support both wildlife and agricultural activities (Deb & Sarkar, 2017). This holistic approach aligns with India's National Adaptation Strategies for Climate Resilience, reinforcing long-term sustainability.

The repurposing of abandoned mining sites into sustainable water bodies offers a transformative solution to challenges in livelihood security, agricultural resilience, and environmental sustainability. By enhancing irrigation access, improving social inclusivity, and adopting eco-friendly water management techniques, such initiatives can significantly contribute to rural economic development. Future policies should focus on scaling these models across different regions, ensuring long-term sustainability and resilience in India's post-mining landscapes.

# 9. ROADMAP FOR IMPLEMENTATION

To ensure the successful implementation and long- term scalability, a phased approach involving short-term, medium-term, and long-term strategies is necessary. This roadmap identifies the key enablers, technological interventions, policy frameworks, financial mechanisms, and governance models required to institutionalize SLI within India's mine closure and agricultural sustainability framework.

## 9.1. PROJECT-LEVEL RECOMMENDATIONS: PHASED IMPLEMENTATION OF SOLAR LIFT IRRIGATION SYSTEMS

PHASE 1: SHORT-TERM (1-3 YEARS)

- Deploy GIS-based tools, soil and water quality testing to identify feasible locations for SLI systems (Bastakoti, Raut, & Thapa, 2020).
- Establish pilot SLI projects in priority mining districts to validate technical and economic feasibility (Shaffer, 2012).
- Introduce low-water-use irrigation technologies tailored for semi-arid regions to maximize water efficiency (Wahab et al., 2016).

PHASE 2: MEDIUM-TERM (3-7 YEARS)

- Mobilize funding through coal companies, microfinance agencies, and public-private partnerships to support SLI expansion (Barlow et al., 2024).
- Leverage India's KUSUM Solar Pump Program to subsidize solar pump installations for smallholders (Chakraborti, Mondal, & Palit, 2024).
- Develop community training programs on solar pump operations and sustainable farming practices, ensuring inclusivity for women and SC/ST farmers (Mahto, 2024; Wadsworth & Burgess, 2022).

PHASE 3: LONG-`TERM (7+ YEARS)

- Facilitate the formation of Water User Groups (WUGs) to manage water-sharing frameworks and avoid overuse (Wahab et al., 2016).
- Ensure Representation in Water User Committees: Mandate reserved seats for women in Water User Committees to facilitate their active participation in governance and decision-making related to water resource management (Paul & Velpuri, 2024).
- Provide Targeted Capacity-Building Programs: Develop and implement training programs focused on technical skills related to solar pump operation, maintenance, and agronomic practices, tailored specifically for women farmers (India Water Portal, 2021).
- Promote cooperative-based solar energy sales, enabling farmers to sell excess power to the grid and gain additional income (Thomas et al., 2023).

## 9.2. POLICY-LEVEL RECOMMENDATIONS

PHASE 1: INSTITUTIONALIZING AGRICULTURAL REPURPOSING IN MINE CLOSURE FRAMEWORKS

- Mandate the inclusion of agricultural and renewable energy-based end uses in mine closure plans under guidelines issued by the Ministry of Mines and Ministry of Coal (Tsybina et al., 2023).
- Offer policy incentives such as carbon credits, tax exemptions, or CSR scoring benefits to mining companies engaging in land repurposing (Nazir et al., 2024).

PHASE 2: ENHANCING POLICY ALIGNMENT AND MULTI-STAKEHOLDER GOVERNANCE

- Align SLI with ongoing government schemes like PM-KUSUM and District Mineral Foundation (DMF) funds to streamline resource allocation for infrastructure and training (Chakraborti, Mondal, & Palit, 2024).
- Integrate repurposing guidelines with broader national objectives for climate resilience and sustainable rural development through amendments in India's renewable energy and agriculture policies (Tsybina et al., 2023).

The successful implementation of Solar Lift Irrigation (SLI) as a mine repurposing model requires a structured policy framework, robust financial mechanisms, technological interventions, and inclusive community governance. The strategies outlined above will ensure scalability, financial sustainability, and long-term resilience in India's post-mining landscapes, transforming abandoned mines into productive, community-driven agricultural hubs.

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