

SCALING RENEWABLE ENERGY POWERED LIFT IRRIGATION IN BHUTAN

Opportunities, Challenges, and Policy Priorities

INTRODUCTION

Agriculture is central to rural livelihoods in Bhutan. However, irrigation water shortage remains a major constraint. This is largely due to the mountainous terrain, limited irrigation infrastructure, and increasing climate variability. Moreover, most irrigation systems in Bhutan are gravity-fed, run-of-the-river schemes without storage, leaving them dependent on monsoon rainfall and vulnerable to seasonal variability, floods, and landslides. These challenges underscore the need for sustainable irrigation solutions that address water scarcity and climate change. Renewable energy (RE)-powered lift irrigation, particularly solar-powered systems, offers a promising option. Bhutan has considerable solar energy potential, receiving solar radiation of approximately 1,600–2,700 kilowatt-hours per square metre per year (kWh/m²/year)¹ and an estimated exploitable solar capacity of around 12,000 megawatts (MW).² However, the use of solar energy for agricultural irrigation remains limited. Scaling up solar-powered lift irrigation could improve reliable access to irrigation water and strengthen the resilience of farming communities to climate variability.

This policy brief is based on evidence from pilot demonstrations in Tempakha and Humpathang Villages (Chubu Gewog, Punakha Dzongkhag) and Gangri Village (Shaba Gewog, Paro Dzongkhag). It also draws on technical analyses conducted using the Sectoral landscape assessment of renewable energy-powered lift irrigation in Bhutan³, the Productive Use of Renewable Energy (PURE⁴) Platform, the Multi-Criteria Assessment (MCA⁵) Framework, and the Detailed Feasibility Study (DFS⁶) Framework for renewable energy-powered irrigation in Bhutan.

WHY DOES SOLAR-POWERED LIFT IRRIGATION MATTER IN BHUTAN?



Potential Area
62,403 acres
suitable for lift
irrigation



Energy Requirement
118 MW of RE
capacity



Promotes Gender Equity
Reduce women's
labour burden in
water management



Economic Impact
Potential
to generate
approximately
15,000 green jobs
for youth and
women



Climate Change Mitigation
Reduces CO₂
emissions by
approximately
67,779 tonnes
annually



KEY CHALLENGES AND BARRIERS TO SCALE

1. Financial Viability & Investment Gap

i. High Upfront Cost and Sub-Optimal Public Funding



The Local Viability Gap

At Gangri (Paro), an 80-acre scheme costs Nu 11 million (USD 115,000): Nu 7 million (64%) for upgrading irrigation infrastructure and Nu 4 million for a 21 kWp solar pumping system (about USD 1,990/kWp). Recovering the full cost-plus operation and maintenance (O&M) over four years would require an additional Nu 41,250 (USD 430) per acre per year, which is beyond smallholders' means.



Persistent National Shortfall

While the National Irrigation Master Plan (NIMP) targets an annual amortised investment of USD 9.3 million, actual allocations over the past five years have fallen drastically short, dropping below USD 3.0 million in the 2023–2024 fiscal cycle.



Increased Financial Burden

Households face increased financial obligations for routine operation and maintenance (O&M) and major repairs, which can strain subsistence budgets.

2. Gender Equity and Social Inclusion (GESI)

Traditional views that machinery operation is “men’s work” limit women’s technical participation and influence in decision-making.

3. Institutional & Governance Bottlenecks

i. Fragmented Regulatory Frameworks and Local Capacity Deficits



Siloed Execution

Coordination is fragmented across key entities, specifically the Department of Energy and Department of Water under the Ministry of Energy and Natural Resources; the Department of Agriculture, Ministry of Agriculture and Livestock; and the Department of Infrastructure Development, Ministry of Infrastructure and Transport.



Policy Gap

The National Energy Policy 2025 recognises water pumping as a productive end-use of renewable energy, but provides no irrigation-specific guidelines, financing or tariff provisions. Its financing measures target investor-led projects rather than community-owned systems. The DoE's mandate to develop implementing instruments offers a clear entry point to close this gap.



Technical Capacity Gaps

Even at the national level, engineers have limited capacity to design pumped systems, especially electro-mechanical components; at Dzongkhag and Gewog levels, it is non-existent.





POLICY RECOMMENDATIONS

1. Financial

i. Create Blended Financing Mechanism

Allocate at least 20%

Dedicate a portion of the National Irrigation Master Plan budget to renewable-energy-based irrigation systems.

Provide 70–80% public financing

Use capital subsidies and concessional loans to reduce the upfront investment burden.

ii. Promote Public-Private Partnership (PPP) and enterprise-led “Irrigation-as-a-Service” models

Enable private enterprises to invest in, operate, and maintain irrigation systems, offering affordable irrigation services to farmers on a commercially viable basis. Although Bhutan has an enabling framework for PPPs, including a national PPP policy, it has not yet been applied to RE-powered lift irrigation. Piloting one or two PPP-based lift irrigation schemes would help test tariff models, risk-sharing arrangements, and operation and maintenance responsibilities.

2. Ensuring Sustainable Operations

i. Promote hybrid solar–grid schemes

Solar-powered irrigation schemes should, where feasible, be connected to the grid, providing electricity when solar generation is insufficient and enabling surplus generation to be exported.

ii. Enable revenue generation from surplus electricity

Establish a mechanism for schemes to receive revenue from surplus electricity supplied to the grid.

iii. Reinvest surplus electricity revenue in O&M and replacement

In community-managed schemes, dedicate surplus revenue and user fees (with an adequate margin) to O&M and pump replacement, reducing the burden on households.

3. Institutional & Governance

i. Designate a Nodal Agency and Strengthen Institutional Coordination

Designate a nodal agency

A single lead agency should be designated as the nodal authority, mandated to coordinate across ministries, streamline approvals, and ensure accountability in implementation.

Support larger schemes

As unit costs fall with scale, guidelines should prioritise village-level over individual or small-group schemes.

ii. Invest in Capacity Building with Gender Inclusion

Integrate RE irrigation into curricula

Embed renewable energy-powered irrigation modules into engineering and agriculture programmes.

Build skills across the delivery chain

Train engineers at national and Dzongkhag levels (including in electro-mechanical design), agriculture extension officers, and farmers to plan, install, operate, and maintain RE-powered lift irrigation systems.



WHAT IS ENTERPRISE-LED IRRIGATION-AS-A-SERVICE?

Provide enterprises with subsidies and concessional loans to establish grid-connected hybrid solar irrigation systems. Enterprises manage O&M, provide farmers with affordable irrigation services, and sell surplus solar power to the grid, generating revenue to ensure business profitability and long-term sustainability.

ROAD MAP FOR NATIONAL SCALE-UP OF SOLAR-POWERED LIFT IRRIGATION (1-5+ YEARS)



PHASE I: Institutional Adoption (1–2 Years)

- Designate nodal agency
- Launch dedicated fund
- Build local operation and maintenance capacity with gender inclusion



PHASE II: Target Scaling in Priority Dzongkhags (3–4 Years)

- Focus on high-priority areas
- Promote hybrid-solar grid schemes



PHASE III: Market-Driven Expansion (5+ Years)

- Transition to enterprise-led irrigation-as-a-service model
- Expand to spring and groundwater
- Monitor national outcomes

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CONTACT

Dr. Tulsi Gurung
Associate Professor
College of Natural Resources
Royal University of Bhutan
Tgurung.cnr@rub.edu.bt