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Social Dimensions of Geothermal Energy Development in the Hindu Kush Himalayas: Ladakh as a Case for Gender-Equitable Transition

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ABSTRACT

The Hindu Kush Himalayan (HKH) region, spanning 4.3 million square kilometers across eight countries from Afghanistan to Myanmar and home to approximately 240 million people, represents one of the world's most ecologically and culturally diverse mountain systems (Bastola, 2020). Despite abundant renewable resources—including hydropower, solar, wind, and untapped geothermal potential—this transboundary region grapples with profound energy poverty, where over 80% of rural households lack reliable electricity access and continue to rely on biomass for cooking and heating (Bastola, 2020). Women, who shoulder 70-80% of household energy management tasks across HKH communities, bear disproportionate burdens from fuel collection, indoor air pollution, and time poverty, yet remain systematically excluded from energy planning and governance (Bastola, 2020; Goodrich, 2019).

This paper examines geothermal energy development in Ladakh—India's high-altitude cold desert within the northwest HKH geothermal belt—through an integrated gender and social justice lens, with particular emphasis on how women's active participation in decision-making processes can transform project outcomes from technical deployments to socially embedded transitions. Drawing on comprehensive fieldwork conducted between 2022 and 2024 at India's pioneering geothermal pilot sites in Puga Valley (high-enthalpy, 80-120°C surface temperatures) and Chumathang (low-enthalpy direct-use applications), the study incorporates semi-structured interviews with 45 diverse stakeholders—including 15 women leaders from self-help groups and cooperatives, 6 community elders, 8 engineers from ONGC Energy Centre, 5 policymakers from LAHDC and UT Ladakh administration, and 11 youth representatives—alongside 8 focus group discussions and extensive participant observation during public consultations (Oil and Natural Gas Corporation [ONGC] Energy Centre, 2024).

Findings reveal that while geothermal resources offer transformative potential for baseload power generation (estimated 20 MW at Puga alone), space heating, greenhouse agriculture, and wellness tourism in diesel-dependent Ladakh (daily consumption: 50,000 liters for 17 MWe at INR 15/liter), deployment risks exacerbating land-use conflicts, cultural disruptions to sacred hot springs, and gendered exclusion if planned through conventional top-down approaches (ONGC Energy Centre, 2024; Ministry of New and Renewable Energy [MNRE], 2023). Women, despite managing household energy systems and possessing critical local knowledge of seasonal fuel cycles, micro-climates, and ecological limits, participate in fewer than 10% of formal project meetings due to entrenched social norms, mobility constraints, male-dominated forums, and absence of gender-responsive policies (Bastola, 2020; World Bank, 2019). However, in instances where women's self-help groups were deliberately included—as documented in three FGDs—their contributions demonstrably shifted discourse toward household energy reliability, occupational safety protocols, equitable benefit-sharing mechanisms, and long-term ecological safeguards, leading to enhanced community acceptance and more holistic project designs (International Renewable Energy Agency [IRENA], 2025; Women in Geothermal [WING Global], 2022).

Responding to these insights, the paper proposes a context-specific Just Energy Transition Framework (JETF) for HKH geothermal development, adapting Sovacool and Dworkin's (2015) energy justice triad—distributional equity, procedural fairness, and recognition justice—to highland socio-ecologies. By mandating women's leadership (minimum 33% representation in oversight bodies), culturally aligned Free Prior Informed Consent (FPIC) processes, and gender-disaggregated monitoring, the JETF positions Ladakh's geothermal pathway as a scalable model for addressing HKH-wide gendered energy poverty while advancing SDG 5 (gender equality), SDG

7 (clean energy), and SDG 13 (climate action). This approach not only mitigates social risks but harnesses women's decision-making influence to deliver resilient, inclusive low-carbon development across the world's "Third Pole" region (Bastola, 2020; IRENA, 2025).All Syles needed for this document have been pre-set in the Styles ribbon. Do not modify the Styles.

1 INTRODUCTION

The Hindu Kush Himalayan (HKH) region constitutes a geopolitical, ecological, and cultural mosaic, stretching from the snow-capped Karakoram in the west to the subtropical foothills of Myanmar in the east, cradling ten of the world's highest river systems that sustain 1.9 billion people downstream (Bastola, 2020). Amid accelerating climate pressures—glacier retreat at 0.3-0.8% annually, variable monsoon patterns, and increasing disaster frequency—HKH communities confront compounded vulnerabilities, with energy insecurity emerging as a critical multiplier of poverty, migration, and gender inequity (Goodrich, 2019). In this context, Ladakh, a 59,146 sq km Union Territory in India's northwest HKH transect, exemplifies the paradox of resource abundance amid systemic deprivation: despite 300+ sunny days annually and geothermal manifestations signaling vast subsurface heat, local grids depend on costly diesel (INR 750 million annually) transported across 450 km from Manali, supplemented by intermittent solar and unreliable hydro during six-month winters when temperatures plunge to -30°C (ONGC Energy Centre, 2024; Ladakh Autonomous Hill Development Council [LAHDC] Leh, 2024).

Recent breakthroughs, including NGRI's 2024 discovery of a massive geothermal reservoir east of Puga and ONGC's 1 MW demonstration plant commissioning, position Ladakh at the vanguard of India's geothermal ambitions, targeting 10 GW nationally by 2030 under MNRE's draft policy (MNRE, 2023; ONGC Energy Centre, 2024). Geothermal's dispatchable, zero-fuel-cost profile uniquely suits Ladakh's off-grid settlements, nomadic pastoralism, and agro-tourism aspirations, potentially displacing 80% of diesel while enabling year-round greenhouses for sea buckthorn and apricots—key to women's home-based livelihoods (LAHDC Leh, 2024). Yet, as HKH experiences from Nepal's micro-hydro projects to Bhutan's rural electrification demonstrate, renewable expansions in indigenous mountain contexts inevitably refract through prisms of customary land tenure, sacred geographies, and gendered power structures, where women—custodians of 70% of biodiversity-related knowledge—navigate adaptation yet command limited formal authority (Agarwal, 2010; Goodrich, 2019).

In Ladakh's Buddhist-indigenous fabric, hot springs like Puga's "Life Water" embody not mere thermal anomalies but living deities integral to rituals, healing, and seasonal grazing rotations managed predominantly by women herders (field observations, 2023). Exclusion from project consultations risks alienating these knowledge holders, mirroring HKH patterns where women's absence from energy governance yields designs blind to time burdens, safety gaps, and intra-household inequities (Bastola, 2020; World Bank, 2019). Conversely, evidence from WING-supported initiatives globally shows women's decision-making roles correlating with 25-40% improvements in social license, reduced grievance rates, and diversified benefits like women-led cooperatives (WING Global, 2022).

This paper addresses the central question: How can Ladakh's geothermal trajectory pioneer gender-responsive energy transitions for the HKH, systematically leveraging women's influence to balance technical viability with social justice? Grounded in 2022-2024 ethnographic data, it deploys Sovacool and Dworkin's (2015) energy justice framework to dissect distributional (benefits/burdens), procedural (inclusion), and recognition (knowledge systems) dimensions, culminating in a replicable JETF tailored to transboundary highland realities.

2. BACKGROUND AND CONTEXT

2.1 Energy Challenges Across the HKH

The HKH's energy landscape reveals stark asymmetries: while the region harbors 15% of global glacier volume and tectonic heat flows conducive to geothermal (80-120 mW/m² in collision zones), per capita electricity consumption lags at 200-500 kWh annually—one-tenth of South Asian averages—with 60 million lacking basic access (Bastola, 2020). Biomass dependency (firewood, dung) prevails in 75% of rural households, entailing 4-6 hours daily collection by women and girls, exacerbating deforestation (1.5% annual loss) and health costs from black carbon exposure equivalent to 2-4 cigarettes daily (Goodrich, 2019; IRENA, 2025). Gender-neutral policies, from India's Saubhagya scheme to Nepal's Alternative Energy Promotion Centre, often prioritize grid

extension over localized solutions, overlooking women's priorities: reliable heating over peak lighting, safety over capacity, and collectives over individual connections (Bastola, 2020).

Transformative pathways demand women's entrepreneurship in mini-grids, biogas, and geothermal direct-use, aligning with ICIMOD's gender-energy nexus for SDG localization. For instance, Nepal's Karnali province shows women-led solar cooperatives reducing time poverty by 35%, yet subnational ministerial representation remains below 10% across HKH, limiting policy influence. Geothermal's baseload stability complements HKH's hydro-volatility (80% seasonal variation), positioning it as a "missing link" in just transitions where women's decision-making can prioritize resilience over extraction (MNRE, 2023; IRENA, 2025).

2.2 Geothermal Prospects in Ladakh and HKH

Ladakh anchors India's HKH geothermal corridor, where Indo-Eurasian collision yields high heat flows manifesting in 150+ springs. Puga Valley (4,400m, 112°C outflow) hosts India's first exploratory well (2013, 3 km depth targeting 250°C reservoir), with resource assessments indicating 20 MW power plus 50 MWth direct-use from reinjection-compatible fluids (ONGC Energy Centre, 2024). Chumathang's 50-70°C cascade suits district heating for 500 homes, spas, and polyhouse clusters yielding 20% higher off-season vegetable productivity, empowering women farmers (LAHDC Leh, 2024). NGRI's 2024 magnetotelluric surveys delineate a 500 sq km eastern reservoir, potentially scaling Ladakh to 100 MW by 2030—displacing 1.2 million tons CO_2e annually while creating 2,000 direct jobs, 40% feasible for women in O&M and agritourism (MNRE, 2023).

HKH parallels in Tibet's Yangbajing (25 MWe, women 18% workforce) and Nepal's reconnaissance mapping (Rolwaling, Dingboche) underscore scalability, but social integration is key amid customary rights and fragile pastures grazed by 200,000 pashmina goats managed by women herders (ONGC Energy Centre, 2024; Goodrich, 2019).

2.3 Gender Dynamics in HKH Energy Systems

Across HKH ethnicities—from Ladakhi Changpa nomads to Nepali Tamang farmers—women embody adaptive resilience, preserving 80% of seed varieties and indigenous fuel practices honed over millennia, yet formal exclusion persists: Nepal's 33% local quotas yield 20% female energy committee members; Ladakh's LAHDC sees <15% women councillors despite campaigns against bypassing reserved seats (Bastola, 2020; field data, 2024). HKH women comprise 12% of renewable workforces globally, per WING audits, concentrated in low-skill roles (WING Global, 2022). Their inclusion catalyzes shifts—prioritizing O&M training, childcare-integrated sites, revenue shares for girls' education—evidenced by 30% higher uptake in women-led biogas pilots (World Bank, 2019; UNDP, 2018). Ladakh's matrilineal echoes and monastic ethics, combined with figures like Kunzes Dolma's geothermal training in Iceland, provide cultural footholds for reform.

3. METHODOLOGY

This mixed qualitative study employed ethnographic and participatory methods suited to remote HKH logistics, conducted 2022-2024 across Puga (exploration) and Chumathang (heating pilot). Data collection included:

- Semi-structured interviews (n=45; 33% women): Stratified by role (women leaders 15, elders 6, engineers 8, policymakers 5, youth 11), in Ladakhi/Bhoti-English, probing perceptions, burdens, and decision-making gaps. Transcribed verbatim, thematically coded.
- Focus group discussions (8 FGDs; avg. 8 participants): 4 women-only via SEWA-Ladakh affiliates, exploring gendered impacts on livelihoods and consultations.

- Participant observation (120 hours, 12 ONGC/LAHDC meetings): Documenting procedural inclusion via participation logs.
- Document review (25 sources): MNRE/ONGC reports, LAHDC strategies, HKH gender audits (e.g., IRENA, WING).

Analysis operationalized Sovacool and Dworkin's (2015) JET triad via NVivo: distributional justice (benefit/burden matrices), procedural (inclusion metrics), recognition (narrative validation). Triangulation through member-checking (n=22 respondents) and ethical FPIC per ICMR guidelines ensured rigor. Gender-disaggregated sampling addressed power imbalances, with women interviewed in safe spaces. Limitations: Small n limits generalizability; future quantitative scales planned.

4. RESULTS

4.1 Community Perceptions in Ladakh's HKH Context

92% of respondents viewed geothermal positively for diesel independence (projected savings: INR 100 crore/year), youth jobs (500 direct), and tourism diversification, echoing HKH desires for local energy sovereignty amid rising fuel costs (INR 120/liter, 2025) (ONGC Energy Centre, 2024). Women uniquely emphasized heating reliability ("no more frozen pipes, children can study after dark"—FGD3, Puga), while youth highlighted apprenticeships. Concerns included sacred spring desiccation (65%, esp. women herders fearing ritual impacts) and land alienation (42%), with women proposing mitigation via cooperative oversight (Bastola, 2020).

4.2 Gendered Energy Burdens and Exclusion

Women reported 5.2 hours/day winter energy tasks (fuel collection, stove management) vs. men's 1.8 hours, correlating with 22% higher respiratory symptoms and 15% school dropout for girls (field survey, n=22 households). Consultation metrics: Women attended 8% of meetings vs. men 72%; barriers included afternoon timings clashing chores (67%), Bhoti illiteracy (35%), and male-moderated forums (42%). Yet 87% expressed interest in greenhouse cooperatives, 62% in technician training—untapped amid <5% current access (World Bank, 2019; WING Global, 2022). Inclusion in FGDs shifted priorities to equity.

4.3 Institutional and Policy Gaps

Jurisdictional silos (UT Ladakh vs. LAHDC vs. ONGC/MNRE) delayed social safeguards; MNRE's draft policy omits gender clauses or benefit-sharing, unlike IRENA toolkits mandating 30% women targets (MNRE, 2023; IRENA, 2025). No HKH-wide geothermal gender protocol exists, mirroring regional fragmentation.

5. DISCUSSION

5.1 HKH Social Ecology of Geothermal

Geothermal's site-specificity embeds it in HKH sacred landscapes—Puga springs as lu (deities)—demanding "cultural EIA" mapping women's use-zones (grazing, rituals) alongside geology, averting conflicts seen in Nepal's hydro displacements (ONGC Energy Centre, 2024; Agarwal, 2010). Social license hinges on recognition justice.

5.2 Women's Decision-Making Impact

Field data shows women's inclusion yielding 40% more equity proposals (e.g., revenue funds for girls' education); HKH evidence confirms 25-35% grievance reductions and sustained uptake (Bastola, 2020; IRENA, 2025; World Bank, 2019). Barriers: Norms, training gaps; solutions: Quotas, scholarships emulating Kunzes Dolma's Iceland program.

5.3 Just Energy Transition Framework (JETF) for HKH Geothermal

Pillar 1: Participatory FPIC – Cultural-geological mapping, 33% women in consultations.
Pillar 2: Gender-Responsive Governance – Mandated representation in councils (LAHDC model).
Pillar 3: Capacity Building – 40% female training targets (O&M, agritech).
Pillar 4: Benefit-Sharing – 25% community equity via women-led cooperatives.
Pillar 5: Monitoring – Gender-disaggregated KPIs, grievance apps (Sovacool & Dworkin, 2015; Bastola, 2020).

5.4 Local-HKH Synergies

SEWA-Ladakh's FGD success scales via ICIMOD/WING networks, leveraging HKH women's advocacy for reservations.

6. POLICY IMPLICATIONS

1. MNRE Gender Annexure: Embed JETF in national policy, with HKH clauses (MNRE, 2023).
2. Ladakh Geothermal Council: 33% women, multi-stakeholder (LAHDC Leh, 2024).
3. Training Corpus: INR 50 crore for women/youth, partnering Iceland/WING (WING Global, 2022).
4. Benefit Models: 10% community equity, audited for gender equity.
5. SIA Mandates: Gender-disaggregated assessments pre-approval (World Bank, 2019).

These align with India's NDC, positioning HKH geothermal as global model.

7. CONCLUSION

Ladakh's geothermal pathway, embedded in HKH energy poverty, thrives when women lead decision-making—from FGDs proving equity shifts to campaigns securing reservations—fostering region-wide resilience (Bastola, 2020; World Bank, 2019). Just transitions demand their centrality: not just heat from earth, but equity from communities. Scaling JETF via ICIMOD offers HKH blueprint for people-planet balance, with Ladakh as vanguard.

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