The Determinants of Mini-Grid Technology Diffusion in Rural Areas

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by

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Certificate

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This is to certify that the thesis entitled **The Determinants of Mini-Grid Technology Diffusion in Rural Areas**, submitted by **Sidhartha Vermani** to the *Indian Institute of Technology, Delhi*, for the award of the degree of Doctor of Philosophy in **Public Policy**, is a record of the original, bona fide research work carried out by him under my supervision and guidance. The thesis has reached the standards fulfilling the requirements of the regulations related to the award of the degree.

The results contained in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma to the best of our knowledge.

Professor Ambuj D. Sagar

……

Vipula and Mahesh Chaturvedi Professor of Policy Studies & Deputy Director (Strategy & Planning)

Indian Institute of Technology, Delhi

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Abstract

Mini-grid technology can provide electricity access to rural areas in India, but it faces many challenges in its diffusion. Historically, mini-grid deployments in rural India saw limited success despite substantial subsidies.

In the contemporary context, despite India affirming complete village electrification through the national grid, a new breed of private developers has pursued mini-grid deployments in rural Uttar Pradesh and Bihar with no or low public incentives.

By keeping the current milieu in the background, this study investigates the factors that affect mini-grid technology diffusion in rural areas. Firstly, it examines user-level factors, probing their socioeconomic characteristics, service and supply satisfaction levels, and the impact of pricing and competitive dynamics on their choices. Second, it investigates the private sector's capacity and viability to foster a sustainable mini-grid market in light of user-level adoption factors—finally, the role of policy incentives in promoting a rural mini-grid market in light of these findings.

This study uses three distinct datasets to explore these market developments in UP and Bihar. The two data sets are qualitative user formative research and quantitative survey data of mini-grid users—the second is operational data from private mini-grid installations.

The study applies statistical techniques to analyze the user data, such as principal component analysis, logarithmic demand estimation, and binary logistic regression. Further, it uses capital budgeting techniques, viz., discounted cash flow method, sensitivity analysis, and scenario analysis, to examine the suppliers' operational data and evaluate the role of policy incentives.

Finally, the study suggests recommendations for policymakers and private operators to advance the prospects of mini-grid advancement in the present-day realities.

सार

मिनी-ग्रिड तकनीक ग्रामीण भारत में बिजली पहुंचाने की क्षमता रखती है, लेकिन इसके प्रसार में कई चुनौतियाँ हैं। ऐतिहासिक रूप से, ग्रामीण भारत में मिनी-ग्रिड की तैनाती को पर्याप्त सब्सिडी के बावजूद सीमित सफलता मिली है। वर्तमान संदर्भ में, भारत द्वारा राष्ट्रीय ग्रिड के माध्यम से पूर्ण गाँव विद्युतीकरण की पुष्टि के बावजूद, उत्तर प्रदेश और बिहार के ग्रामीण क्षेत्रों में निजी डेवलपर्स ने बिना या कम सार्वजनिक प्रोत्साहनों के मिनी-ग्रिड तैनात करना शुरू किया है।

इस अध्ययन में इन पहलुओं की पृष्ठभूमि में मिनी-ग्रिड तकनीक के प्रसार को प्रभावित करने वाले कारकों की जांच की जाती है। सबसे पहले, यह उपयोगकर्ता स्तर के कारकों की जांच करता है, जिसमें उनके सामाजिक-आर्थिक लक्षण, सेवा और आपूर्ति संतुष्टि स्तर, और उनकी पसंद पर मूल्य निर्धारण और प्रतिस्पर्धी गतिशीलता का प्रभाव शामिल है। दूसरा, यह उपयोगकर्ता-स्तर के अंगीकरण कारकों के आलोक में एक स्थायी मिनी-ग्रिड बाजार को बढ़ावा देने के लिए निजी क्षेत्र की क्षमता और व्यवहार्यता की जांच करता है। अंत में, इन निष्कर्षों के आलोक में ग्रामीण मिनी-ग्रिड बाजार को बढ़ावा देने में नीति प्रोत्साहनों की भूमिका की जांच करता है।

यह अध्ययन यूपी और बिहार में इन बाजार विकासों का पता लगाने के लिए तीन अलग-अलग डेटासेट्स का उपयोग करता है। दो डेटा सेट गुणात्मक उपयोगकर्ता प्रारंभिक शोध और मिनी-ग्रिड उपयोगकर्ताओं के मात्रात्मक सर्वेक्षण डेटा हैं—दूसरा निजी मिनी-ग्रिड प्रतिष्ठानों से परिचालन डेटा है।

अंत में, अध्ययन नीति निर्माताओं और निजी ऑपरेटरों के लिए सिफारिशें देता है ताकि वर्तमान वास्तविकताओं में मिनी-ग्रिड प्रगति की संभावनाओं को आगे बढ़ाया जा सके।

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List of Abbreviations

Abbreviation	Definition	Abbreviation	Definition
AME	Average Marginal Effect	MNP	Minimum Needs Programme
AUC	Area Under ROC Curve	MNRE	Ministry of New and Renewable Energy
BPL	Below Poverty Line	MW	Megawatt
BTS	Base Transceiver Station	NAED	Net Annual Energy Delivered
CERC	Central Electricity Regulatory Commission	NPV	Net Present Value
CI	Confidence Interval	PBP	Payback Period
C-Model	Community Lighting-Appliance-Plus	PCA	Principal Components Analysis
CUF	Capacity Utilization Factor	PMGY	Pradhan Mantri Gramodaya Yojana
DDG	Decentralized Distributed Generation	PPA	Power Purchase Agreement
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana	PV	Solar Photovoltaics
DISCOM	'Distribution company' or the Indian government's electric utilities	RAP	Rapid Assessment Process
DRE	Distributed Renewable Energy	RE	Renewable Energy
EBIT	Earnings Before Interest and Taxes	REC	Rural Electrification Corporation
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization	RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
EBT	Earnings Before Tax	ROC	Receiver Operating Characteristic
FCFE	Free Cash Flow to Equity	ROE	Return on Equity
FCFF	Free Cash Flow to Firm	RVEP	Remote Village Electrification Programme
GNP	Gross National Product	SAUBHAGYA	Sahaj Bijli Har Ghar Yojana
IDI	In-depth Interviews	SEB	State Electricity Board
IREDA	Indian Renewable Energy Development Agency	SERC	State Electricity Regulatory Commission
IRR	Internal Rate of Return	SES	Socioeconomic Status
JNNSM	Jawaharlal Nehru National Solar Mission	SHS	Solar Home Systems
KJY	Kutir Jyoti Yojana	SLA	Service-Level Agreement
kWp	Kilowatt peak	T-Model	Telecom Anchor
LCOE	Levelized Cost of Electricity	VESP	Village Energy Security Programme
LED	Light Emitting Diode	WACC	Weighted Average Cost of Capital
LPG	Liquefied Petroleum Gas	WTP	Willingness to Pay
LR	Likelihood-Ratio		