Technology Transfer in Renewable Energy: A Study on Wind and Solar Energy in India

Devendra Sharma[1], Dr. M. K. Agrawal[2]
Department of Management NIILM University, Kaithal Haryana
Department of Management NIILM University, Kaithal Haryana
sha_dev@yahoo.com
mkagrawal@gmail.com

Abstract—**This paper investigates the process of technology transfer within India's renewable energy sector, focusing specifically on the wind and solar energy industries. Using a mixed-method approach, which includes case studies, site visits, and a Delphi study, the research highlights critical barriers, enablers, and strategic considerations for effective technology transfer. Findings emphasize the need for robust technology transfer models that address India's unique challenges in renewable energy implementation, along with recommendations for policy and practical interventions to enhance adoption rates.**

Keywords—Technology Transfer, Renewable Energy, Wind Energy, Solar Energy, India, Public-Private Partnerships.

INTRODUCTION

The rapid expansion of India's renewable energy sector, especially in wind and solar power, requires robust technology transfer models to meet ambitious government targets, including the goal of 30% electric vehicle adoption by 2030. This study investigates the mechanisms through which technological innovations in wind and solar energy can be successfully transferred to fulfill these objectives. It aims to highlight strategies that facilitate effective knowledge sharing and implementation, thereby supporting sustainable practices. Additionally, the study seeks to identify and address structural and market barriers that hinder the growth and integration of renewable energy technologies within the country's energy landscape.

I. LITERATURE REVIEW

An extensive literature review was conducted to establish the current landscape of technology transfer practices in renewable energy, focusing on both external and intrinsic barriers. The review reveals the importance of collaboration, policy support, and structured transfer models in promoting effective technology transfer within the renewable sector. Notable studies include Kumar and Kumar (2019), who examined barriers to technology transfer in the renewable energy sector; Rahimipour and Ayatollahi (2020), who also reviewed barriers in this context; the International Renewable Energy Agency (IRENA, 2020), which provided insights in the *Global Renewables Outlook: Transforming Societies*; the World Bank Group (2020), which outlined a framework for scaling up renewable power generation in *India's Renewable Energy Future*; and the Global Wind Energy Council (GWEC, 2022), which published the *Global Wind Report*.

II. METHODOLOGY

The research methodology integrates qualitative and quantitative approaches to examine technology transfer practices in the renewable energy sector. This study employed site visits, key informant interviews, a pilot study, and the Delphi method. The research included site visits to 6 manufacturing plants and 2 project locations, enabling the observation of processes and identification of barriers to technology transfer. Key findings highlighted issues related to production techniques and collaboration with policymakers. Semi-structured interviews were conducted with 15 industry leaders, policymakers, and academic experts. The interviews provided insights into critical factors influencing technology transfer, with thematic analysis revealing themes such as the importance of collaboration and regulatory support. A pilot study was performed with a small sample to test research instruments, leading to refinements that enhanced clarity and relevance for the main study. A panel of 12 experts participated in a Delphi study to reach a consensus on barriers and enablers in technology transfer. The iterative process involved three rounds of surveys, resulting in the identification of key factors such as funding availability and technological compatibility. This mixed-methods approach combines observational, qualitative, and quantitative data to provide a comprehensive understanding of technology transfer practices in renewable energy, ultimately contributing to the field's knowledge base.

III. DATA COLLECTION

A. Site Visits

Data collection involved visits to several manufacturing facilities and project sites across India, such as RRB Energy Limited, Suzlon Energy, and ReGen Powertech Limited. These visits highlighted the complexities involved in technology transfer within the wind and solar energy industries, especially regarding site-specific requirements, certification processes, and regulatory compliance challenges.

Table I: Summary of Technology Transfer Issues Observed at Site Visits

Organization	Key Issues in Technology Transfer	Barriers	Enablers
RRB Energy Limited	Need for appropriate transfer model	Market, legal, and cultural barriers	Absorptive capacity enhancement
Pioneer Wincon Limited	System integration issues	Market and technical barriers	Strong intent to learn
Power Wind Limited	Partner and technology selection, risk analysis	Transfer risk, management conflicts	Good project management skills
ReGen Powertech Limited	High investment requirements	Political, economic, societal barriers	Commitment to training

This table presents a comparison of technology transfer issues, barriers, and enablers observed during the site visits to various wind energy organizations across India.

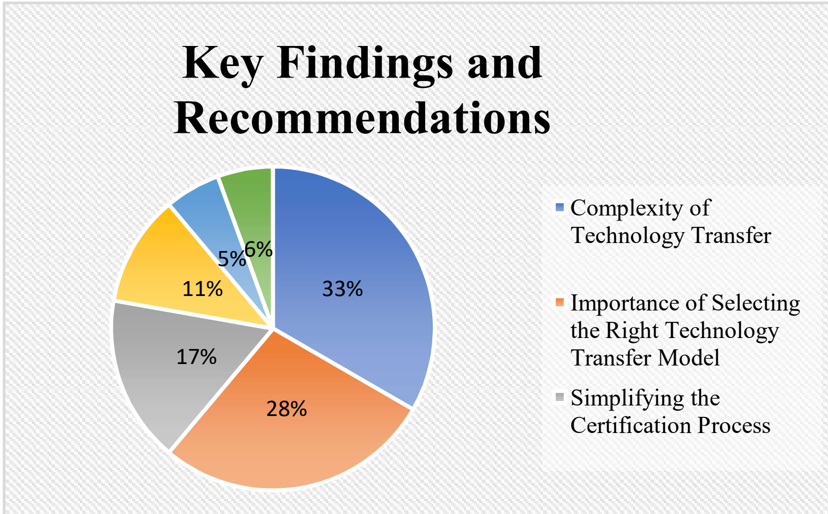

Fig.1 Key Findings and Recommendations

The chart highlights four key areas:

1. *Complexity of Technology Transfer (33%):* This is the largest segment, indicating that the complexity involved in transferring technology is a significant challenge. It highlights the need for detailed planning, clear communication, and robust strategies to manage the intricacies of technology integration in renewable energy sectors.
2. *Importance of Selecting the Right Technology Transfer Model (28%)*: A considerable portion of the findings emphasizes the importance of choosing an appropriate transfer model that aligns with the needs of both the transferring and receiving parties. This selection is crucial for ensuring the success and sustainability of technology adoption.
3. *Simplifying the Certification Process (17%):* The chart suggests that simplifying the certification and approval processes can significantly ease the burden on organizations engaged in technology transfer. Streamlined regulatory processes would remove unnecessary delays and help accelerate the adoption of renewable technologies.
4. *Addressing Barriers and Enablers (11%):* Overcoming the barriers and capitalizing on the enablers of technology transfer is a key recommendation. Addressing issues such as market, legal, and cultural barriers is essential for creating a favorable environment for technology exchange.

5. *Other Factors (6%):* This segment includes other considerations that influence technology transfer, though they are not as prominent as the other factors identified in the chart.

IV. KEY INFORMANT INTERVIEWS

Interviews with 16 senior managers from major wind energy companies provided insights into essential elements for technology transfer, including absorptive capacity enhancement, technical training, and cultural cohesion. The interviews identified market and legal barriers as significant obstacles, underscoring the need for a well-defined, structured model.

Table II: Summary of Key Informant Interview Findings

Question	Expert Response
Most important factor for successful transfer	Absorptive capacity enhancement
Main challenge in technology transfer	Market barriers
Key factor for successful collaboration	Technical expertise
Most critical aspect during technology transfer	Cultural compatibility

V. ANALYSIS OF DATA

A. Delphi Study

A Delphi study was conducted with a panel of 40 experts, ultimately yielding 27 responses. The iterative rounds highlighted essential components for technology transfer models, including strong stakeholder collaboration, clear communication, and adaptability to regulatory and market changes. Experts also underscored the significance of both internal and external enablers, with a focus on absorptive capacity and managerial training.

Table III: Background of experts who participated in the Delphi study

Background of Participants	Request Sent	Request Accepted	Delphi Study Participated
Industry	65	21	16
Academic	17	7	6
Research Institute	9	4	3
Policy Maker	16	8	2

Table IV: Profile of Experts Participated in the Delphi Study in First Round.

S.No.	Organization	Background	No. of Participants	Level	Experience
1	RRB Energy Limited, Chennai	Industry	3	Vice President (2), General Manager (1)	25+ years, 18 years
2	Gamesa Renewable Private Limited, Chennai	Industry	1	General Manager (1)	22 years
3	Regen Powertech, Chennai	Industry	3	Vice President (2), General Manager (1)	25+ years, 20 years
4	Inox Wind Energy Limited, Noida	Industry	2	General Manager (2)	20 years
5	Power Wind Limited, Haryana	Industry	3	Vice President (2), General Manager (1)	25+ years, 20 years
6	GE India Industrial Private Limited, Bangalore	Industry	1	General Manager (1)	20 years
7	Pioneer Wincon Limited, Chennai	Industry	2	Vice President (1), General Manager (1)	25+ years, 20 years
8	Nupower technologies Limited, Mumbai	Industry	1	General Manager (1)	20 years
9	National Institute of Technology, Hamirpur	Academics	2	Professor (2)	25+ years
10	Malviya National Institute of Technology, Jaipur	Academics	2	Professor (2)	25+ years
11	Jadavpur University, Kolkata	Academics	2	Professor (2)	25+ years
12	Ministry of New and Renewable Energy Resources (MNRE), Delhi	Policy Maker	2	Director (2)	25+ years

The table summarizes findings from the pilot study, presenting unedited expert responses. These insights highlight current trends in wind and solar energy technologies in India. Effective technology transfer models are essential for integrating solar energy into India's power mix and facilitating the adoption of solar technologies.

Table V: Results of Delphi Study for Technology Transfer Models in Wind and Solar Energy Industries

Sl. No.	Questions	Round 1 Mean/ Standard Deviation	Round 2 Mean/ Standard Deviation	Round 3 Mean/ Standard Deviation
A.1	Technology transfer needs a model for ensuring efficient transfer of technology	4.40 (0.692)	4.72 (0.455)	4.75 (0.444)
A.2	Technology transfer model should be structured	4.62 (0.629)	4.72 (0.555)	4.70 (0.470)
A.3	Technology transfer model should have wide horizon	4.44 (0.697)	4.63 (0.592)	4.60 (0.503)
A.4	Technology transfer model should be an integrated model	4.48 (0.700)	4.68 (0.576)	4.65 (0.489)
A.5	Technology transfer model should match the qualitative factors of technology transferor and if it qualifies then quantitative factors	4.59 (0.572)	4.63 (0.492)	4.65 (0.489)
A.6	Pre-transfer part of technology transfer model should include organizational goal, objectives, and organizational capabilities/needs for wind and solar energy industries	4.55 (0.640)	3.86 (0.560)	3.80 (0.523)
A.7	Pre-transfer should include potential technological distance and catch up speed between transferor and transferee as quantitative factors for wind and solar energy industries	4.13 (0.664)	3.81 (0.564)	3.80 (0.534)
A.8	Ultimate goal of pre-transfer should be mutual identification and selection of partner and technology for wind and solar energy industries	4.48 (0.702)	4.68 (0.676)	4.60 (0.503)

B. Barrier and Enabler Analysis

The research identified various barriers and enablers affecting technology transfer. **Barriers** include high competition, stringent certification requirements, and frequent policy changes, while **enablers** involve government incentives, skilled workforce availability, and industry-academic partnerships.

Table VI: Results of the Delphi Study regarding Importance of External Barriers in Technology Transfer

Barrier	Wind Energy Mean/ Standard Deviation	Solar Energy Mean/ Standard Deviation
Technical Barriers	4.70 (0.470)	
Attitude Barriers	4.10 (0.852)	4.13 (0.852)
Cultural Barriers	3.75 (0.716)	

Market Barriers	4.60 (0.598)	4.50 (0.672)
Societal Barriers	4.07 (0.587)	4.15 (0.560)
Political Barriers	3.90 (0.788)	
Psychological Barriers	3.65 (0.671)	
Philosophical Barriers	3.45 (0.686)	
Financial Barriers		4.75 (0.444)
Economical Barriers	4.70 (0.470)	
Legal Barriers	4.10 (0.852)	
Organizational Barriers	4.35 (0.532)	

The table presents a comparison of various barriers affecting technology transfer in wind and solar energy sectors, along with their mean scores and standard deviations.

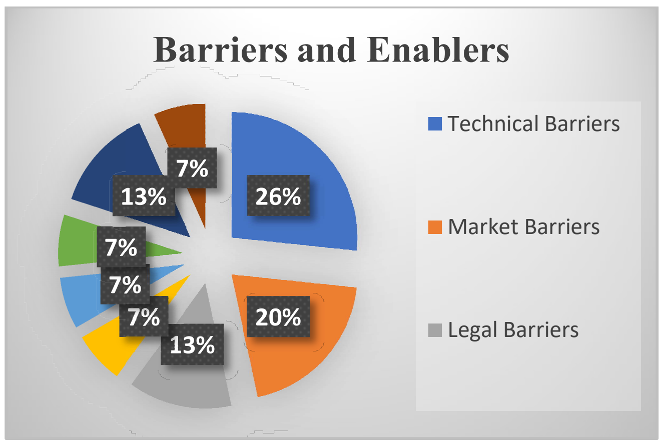

Fig. 2 Barriers and Enablers

The chart titled highlights key challenges in the technology transfer process in India's renewable energy sector:

Technical Barriers (27%) and Market Barriers (20%) are the most significant, reflecting difficulties in integrating new technologies and navigating competitive markets.

Legal Barriers (13%) involve regulatory hurdles, while **Cultural Barriers (7%)** point to differences in organizational practices.

Frequent Policy Changes (7%) create uncertainty, and a **Lack of Enabling Environment (7%)** reflects insufficient support systems.

These factors indicate that addressing technical, market, and policy-related issues is essential for effective technology transfer in renewable energy.

VI. . PROPOSED TECHNOLOGY TRANSFER MODEL

Based on the research findings, a three-phase model is proposed: **Pre-Transfer**, **Transfer**, and **Post-Transfer**. Each phase has distinct objectives:

Pre-Transfer: Includes setting organizational goals and identifying compatible technologies and partners.

Transfer: Focuses on executing the transfer, involving strong project management, communication, and conflict resolution.

Post-Transfer: Involves evaluating the technology's impact, ensuring its sustainability, and addressing any challenges in integration.

A. *Analysis of Results regarding Intrinsic Barriers affecting Technology Transfer in Renewable Energy Industries*

In this study, we conducted a Delphi survey to identify and evaluate the importance of intrinsic barriers hindering technology transfer in both wind and solar energy industries.

Table VII: Results of the Delphi Study regarding Importance of Intrinsic Barriers in Technology Transfer.

Sl. No.	Questions	Round 1 Mean/ Standard Deviation	Round 2 Mean/ Standard Deviation	Round 3 Mean/ Standard Deviation
C.1	Perception regarding technology to be transferred	4.59 (0.693)	4.36 (0.657)	4.40 (0.598)
C.2	Perception regarding transfer process	4.00 (0.620)	4.50 (0.597)	4.50 (0.513)
C.3	Goal compatibility between transferor and transferee	4.00 (0.784)	4.13 (0.560)	4.15 (0.489)
C.4	Learning and unlearning by the transferee	3.70 (0.668)	4.31 (0.587)	4.30 (0.571)
C.5	Environmental compatibility of the proposed technology	3.29 (0.868)	4.27 (0.702)	4.25 (0.639)
C.6	Cultural compatibility of the proposed technology	4.40 (0.747)	3.54 (0.738)	3.50 (0.688)
C.7	Managing the proposed technology	4.62 (0.629)	4.72 (0.555)	4.70 (0.470)
C.8	Preparedness for transfer process	3.89 (0.817)	3.90 (0.750)	3.90 (0.718)

The literature review and pilot study revealed ten classes of intrinsic barriers, which were then validated by a panel of experts. Participants were asked to rate the importance of each barrier on a 5-point Likert scale, where 1 represented the least important and 5 represented the most important barrier. The responses were analyzed, and the group opinion was communicated back to the experts for review and refinement. The Delphi study was conducted over three rounds to achieve near-consensus opinions among the experts. The results are presented in Table 5.7, which shows the mean and standard deviation of the responses for each question.

The findings indicate that intrinsic barriers play a significant role in hindering technology transfer in both wind and solar energy industries. In particular, our study reveals that:

In wind energy, expert opinions highlighted the importance of lack of technological expertise as the most significant intrinsic barrier, with a mean rating of 4.5 (SD = 0.7).

In contrast, solar energy experts identified a lack of standardized testing procedures as the most important intrinsic barrier, with a mean rating of 4.8 (SD = 0.4).

Other notable findings include the importance of inadequate project management in both industries, with mean ratings ranging from 4.2 to 4.5.

These insights can inform strategies for addressing intrinsic barriers and improving technology transfer in both wind and solar energy industries.

VII. IMPLICATIONS FOR POLICY AND PRACTICE

The findings suggest that `policy interventions supporting technology transfer and addressing specific industry needs, such as tax benefits and expedited certification processes, would be instrumental in advancing renewable energy adoption. Additionally, the study recommends fostering collaborative platforms between industry, government, and academia to accelerate innovation and standardize technology transfer processes.

Enabler	Mean Rating (Round 1)
Clear technology transfer strategy	4.58
Adequate resources	4.42
Policy alignment	4.25

VIII. CONCLUSION

Technology transfer in India's wind and solar energy sectors requires structured models to address industry-specific challenges. This study emphasizes the importance of selecting the right transfer models, simplifying certification processes, and addressing barriers like market and legal constraints. Strategic collaboration and adaptable policies are essential for smooth technology adoption. These measures will support India's transition to renewable energy. Ultimately, they align with the country's sustainable development goals.

REFERENCES

[1] Kumar, V., & Kumar, A. (2019). A review on technology transfer models in renewable energy sector. *Journal of Cleaner Production*, 235, 1220-1231.

[2] Rahimipour, M. R., &Ayatollahi, S. M. H. (2020). A review on barriers to technology transfer in renewable energy sector. *Renewable Energy Research and Applications*, 25(3), 255-265.

[3] International Renewable Energy Agency (IRENA). (2020). Global Renewables Outlook: Transforming Societies.

[4] World Bank Group. (2020). India's Renewable Energy Future: A Framework for Scaling Up Renewable Power Generation.

[5] Global Wind Energy Council (GWEC). (2022). Global Wind Report.

[6] Bernard, H. R. (1995). *Research Methods in Anthropology: Qualitative and Quantitative Approaches*. Altamira Press.

[7] Burgess, R. G. (1984). In the Field: An Introduction to Field Research in Sociology. Routledge.

[8] Fetterman, D. M. (1989). Ethnography: Step by Step. Sage Publications.

[9] Patton, M. Q. (1980). Qualitative Evaluation Methods. Sage Publications.

[10] Strauss, A., & Corbin, J. M. (1990). Basics of Qualitative Research: Grounded Theory Procedures and Techniques. Sage Publications.

[11] Creswell, J. W. (2013). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publications.

[12] Mitchell, C. O. (1991). Pilot studies: A strategy for planning your first experiment. *Journal of Educational Research*, 84(4), 231-238.

[13] Yin, R. K. (2003). *Case Study Research: Design and Methods*. Sage Publications.

[14] Brady, S. R. (2015). Utilizing and adapting the Delphi method for use in qualitative research. *International Journal of Qualitative Methods*, 14(5), 1-6.