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Modeling the Drivers for Renewable Energy in Developing Economies: A Case Study of India

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Abstract

Renewable energy sources offer sustainable alternatives to meet the energy demands of developing economies. India, as a developing economy, has undertaken key initiatives to promote the use of renewable energy, which can be attributed to various factors. Increasing awareness about clean energy sources, rising concerns about environmental degradation, and the prominence of Sustainable Development Goals (SDGs) are other factors that have led countries to view renewable energy as a sustainable alternative to fossil fuels. The primary objective of this paper is to understand the factors that facilitate the development and adoption of renewable energy as a sustainable and clean source of energy. The paper also aims to understand the hierarchical relation between the identified enablers and further investigate the nature of linkages between them. The Total Interpretive Structural Modeling (TISM) and Fuzzy MICMAC approach were adopted to achieve the research objectives. The study's findings identify six enablers: environmental enablers, institutional enablers, regulatory enablers, economic enablers, technological enablers, and social enablers. The TISM model displays three levels of hierarchy between the identified enablers, and the Fuzzy MICMAC analysis helped categorize them into driver and dependent clusters. The findings have been discussed in an Indian context. The study has profound implications for theory, management, and society.

INTRODUCTION

Fossil fuels are the main source of energy in many countries, and with constant growth and economic development, countries heavily rely on fossil fuels for their uninterrupted energy supply. The use of fossil fuels comes with its own set of challenges, the biggest being the alarming rate at which carbon dioxide emissions have increased. A commonly known byproduct of fossil fuels is carbon dioxide (Gyimah et al., 2022; Wang et al., 2023). There has been growing concern about the rising levels of carbon dioxide, which are contributing to climate change, in many global forums. In developing economies, dependency on fossil fuels remains high (Gyimah et al., 2022), resulting in large-scale chemical emissions that have devastating consequences for the environment (Li et al., 2020; Yang et al., 2022). Climate activists have repeatedly raised concerns about the adverse effects of not striking a balance between economic and ecological development. Developing economies, along with developed economies, have initiated processes to re-examine their energy production and consumption patterns in order to strive for a balance between development and the environment (Chenyang et al., 2023). The oil crises of the 1970s, global warming, and warnings about climate change prompted countries to seek sustainable alternatives to fossil fuels (Lal and Kumar, 2022). Increasing awareness about clean energy sources, rising concerns about environmental degradation, and the prominence of Sustainable Development Goals (SDGs) are other factors that have led countries to view renewable energy as a sustainable alternative to fossil fuels. Over the past few decades, countries have explored renewable energy sources as a more sustainable alternative and have taken initiatives in this regard. Sustainable Development Goals (SDG's) have gained prominence, and countries have started aligning their initiatives with SDG's which has further given a boost to adopt sustainable alternatives such as renewable energy sources to meet the energy requirements of the country. Renewable energy has social, economic, and environmental impacts for the country (Virah-Sawmy and Sturmberg, 2025) and enables the shift towards clean energy for everyone. Efforts to increase renewable energy help improve access and affordability in remote areas, which in turn contribute to poverty alleviation and overall well-being (Charfeddine and Kahia , 2021). Investing in renewable energy technology would help to foster innovation and the development of sustainable infrastructure.

Countries have begun exploring various forms of renewable energy. One popular form is solar energy. If prioritized and strategized well, solar energy may be a good alternative to complement energy requirements (Wang et al., 2024). Solar energy, though available in abundance, has challenges in storing and transferring this form of energy (Ukoba et al., 2024). There is a need to invest a high amount of capital in the initial setup and maintenance of equipment for solar heating, storage, and transfer. However, despite the challenges, the benefits of solar energy are substantial, including its abundance, long-term affordability, and its status as a clean source of energy, which should be harnessed for long-term economic benefits (Kishore et al., 2025; Maka and Alabid, 2022). Another popular form of renewable energy is wind energy, which is viewed in research as a long-term sustainable solution, as it generates electricity through turbines. The benefits of harnessing wind energy include its scalability for both large and small applications, its clean and environmentally friendly nature, and its suitability for coastal and high-wind regions (Boadu and Otoo, 2024; Liu et al., 2025). Countries have also invested in geothermal energy, which is obtained from natural heat below the earth's surface. The resources are located at various depths, ranging from shallow ground to many kilometers below the Earth's surface. This form of energy is applied in various fields, including agriculture, heating, and cooling. (Pambudi and Ulfa, 2024; Rohit et al., 2023). Another popular form of energy is Hydrogen energy. Hydrogen gas can be produced from various sources, including oil, natural gas, biomass, and coal (Odoi-Yorke et al., 2025). Based on location, availability, and feasibility, countries have made concentrated efforts to harness the available sources of energy to meet their energy requirements and demonstrate environmentally conscious behavior.

Renewable energy in developing economies

A large part of the world's population resides in developing countries. These countries play a significant role in the global economy due to their expanding economies and increasing populations. Developing countries differ from developed economies in terms of economic growth and energy stability, which are prime focal areas for the former. Action areas are dominated by economic growth (Raza et al., 2025). The global carbon project identifies China, the United States of America, India, Russia, and Japan as the top countries by carbon dioxide emissions. The energy decisions of developing countries have a significant impact on their own progress, and economic expansion has been primarily fueled by fossil fuels (Briera and Lefèvre, 2024; Chaikumbung, 2025). There have, however, been increasing efforts to invest in renewable energy sources, as the long-term benefits for countries include energy security, lower import costs, economic opportunities, and improved accessibility in rural areas. India began investing in renewable energy in the 1980s and has undertaken numerous initiatives to promote solar and wind energy (Lal et al., 2025). India is among the world's largest producers of renewable energy. India has pledged to generate 50% of its total energy requirement from non-fossil fuel sources by 2030 (Khare et al., 2023). India declared turning carbon neutral by 2070 at the twenty-sixth Parties in Glasgow which shows India's commitment to the environment (Alam et al., 2023). In 2020, 38% of India's total installed capacity was from renewable energy. As a developing country, Bangladesh is experiencing rapid growth in energy demand. The country has looked at renewable energy as a crucial solution to replace fossil fuels. Government institutions in Bangladesh have started promoting large-scale renewable energy projects (Joardee et al., 2024). Bangladesh plans to replace its fossil-fuel fleet with solar-powered vessels. Bangladesh has an effective off-grid renewable energy system. Approximately 6% of

Bangladesh's energy needs are met by renewable energy sources. The government has initiated measures to promote electric vehicles by constructing solar charging units for these vehicles (Mahbub and Islam, 2023). A study by Islam et al. (2022) showed that Bangladesh's demographic factors, urbanization that has resulted in an environmentally conscious community, and technological advancements are key factors that have encouraged renewable energy consumption. The country's institutional and regulatory framework has prioritized the establishment of renewable energy plants, given the country's geographical advantage. Bangladesh is a semitropical country that receives sunlight year-round. To encourage the establishment of renewable energy plants, the government offers multiple incentives to public and private developers (Hossain et al., 2024). Sri Lanka has set targets to achieve energy independence. Thermal power, hydroelectric power, and other non-conventional renewable energy sources are the primary sources of electricity in this country (Koswatte et al., 2024). Investment and strategic thinking for renewable energy in developing economies can lead to enhanced energy security, reduced import dependence, economic growth, job creation, Improved access to electricity and basic services, and Sustainable long-term development potential. From a societal standpoint, a cleaner environment for future generations and employment generation through funded renewable energy projects were key enablers that helped foster a positive outlook towards renewable energy in Sri Lanka (Herath et al., 2022).

Rationale and Objectives of the Study

It is crucial to strike a balance between economic development and environmental protection. Energy production, transfer, and consumption are vital to a nation's growth, especially in developing economies like India. Given rising population, industrialization, and urbanization, India's energy demand is expected to increase significantly in the coming years. India has set an ambitious target to reduce its dependence on fossil fuels and its carbon footprint. Existing studies on renewable energy have examined generic drivers of renewable energy implementation; the current study will focus on India-specific enablers that highlight India's efforts to meet its future energy requirements while reducing its dependency on fossil fuels. Furthermore, existing studies have discussed the enablers in isolation; the current study proposes integrating these enablers to develop a comprehensive framework and further explore the nature of the linkages among the identified enablers. With this background, the objectives of the study are:

O1: To analyze the key drivers that aid the implementation of renewable energy sources with special reference to India.

O2: To interpret the critical linkages between the identified enablers through a comprehensive framework using the Total Interpretive Structural Model (TISM).

O3: To infer the nature of linkages between the identified enablers using Fuzzy MIC MAC analysis.

2. LITERATURE REVIEW

This section discusses the constructs that facilitate the implementation of renewable energy in India, derived from a literature review. Environmental and geographical factors significantly impact the adoption of renewable energy (Nieboer et al., 2025; Obuseh et al., 2025). Regions with minimal cloud cover, ample sunlight, and low population density are ideal for generating solar power. Abundant sunshine makes it ideal for storing solar energy (Erol et al., 2024). India, as a country, is rich in geography and has a diverse range of climate zones (Beck et al., 2018). Given its tropical location, the country boasts immense solar and wind potential. To harness wind energy, environmental enablers such as consistent wind patterns, mountain ranges, or coastal areas are crucial, with an average wind speed of at least 13mph (Vaidya, 2025). Hydroelectric power generation relies on high rainfall and mountainous topography. Biomass energy is dependent on agricultural output and byproducts(Dashtpeyma and Ghodsi, 2021). As a country, India boasts a diverse geography and climate, ranging from mountain ranges and rivers to abundant sunshine and monsoon rains, making it ideal for various sources of renewable energy. Institutional enablers include policies, reforms, the Government, and private players that support the implementation of renewable energy (Apolonia and Simas, 2021). In India, the Government and private players have come together to support renewable energy generation. India has committed to mitigating greenhouse gas emissions and scaling up renewable energy on a significant global platform. National policies provide financial incentives that encourage corporations to invest in renewable energy (Mohammadi and Mohammadi, 2024; Rincón et al., 2021). Decentralized policies generate support for participatory energy planning. Appropriate regulatory frameworks are necessary to monitor the implementation of renewable energy policies. In India, the Ministry of New and Renewable Energy (MNRE) is the primary ministry for renewable energy policies. It has played a key role in advancing wind energy through policy support and a conducive regulatory environment. MNRE introduced generation-based incentives, renewable purchase obligations, competitive bidding, and other reforms to encourage wind energy generation (Kumar et al., 2022).

It is vital to overcome institutional constraints for effective stakeholder engagement in sustainable decision-making for renewable energy. For the same reason, institutional capacity-building is vital to improving awareness (Wretling et al., 2021). The Solar Energy Corporation of India (SECI) is a Central Public Sector Undertaking under MNRE dedicated to capacity building for implementing large-scale solar, wind, and hybrid projects.

Regulatory enablers include policies that guarantee long-term contracts, providing renewable energy investors with a secure return (Oduro et al., 2025). Regulations that permit green credits and tradable certificates that provide benefits to corporations that adopt renewable energy. The National Renewable Energy Act (NREA) in India provides a legal foundation and path for renewable energy growth. The renewable purchase obligation mandates a certain percentage procurement of energy from renewable sources.Technology is crucial to renewable energy, and regulatory frameworks should encourage grid modernization that enables efficient grid installation, maintenance, and flexibility, enabling effective management of renewable energy sources. Technological innovations can help reduce energy consumption and minimize dependency on fossil fuels. Technology helps in energy storage, access to clean energy, enabling grid stability which supports a sustainable energy system (Behera et al., 2024) Renewable energy technologies (RETs) play a crucial role in addressing environmental sustainability (Tabrizian, 2019). Technological innovations have a significant impact on renewable energy (Tigabu, 2018). It is important to have the right technologies that enable energy storage, smart grids, and power electronics. Financial incentives and subsidies are economic enablers that encourage the transition to renewable energy sources (Guy, 2022; Hao and Khan, 2025). There are many central and state government subsidies and incentives such as the flagship rooftop solar scheme called the “PM Surya Ghar: Muft Bijli Yojana” which offers subsidies for residential rooftop solar systems. There are schemes that offer subsidies upto 30% to farmers that use solar pumps. Policies such as feed-in tariffs (Kurbatova et al., 2023; Azhgaliyeva and Mishra, 2022), which encourage investment in clean energy, and renewable portfolio standards (Joshi, 2021; Feldman and Levinson, 2023) , which require sourcing a minimum percentage of power from clean energy sources, help promote environmental sustainability (Malik et al., 2019).

Strong public awareness and support are crucial factors for the successful adoption of renewable energy sources. Positive community engagement, which raises awareness of environmental sustainability through renewable energy sources, helps foster its acceptance (Opstal and Smeets, 2022; De Simone et al., 2025). Local organisations can play a crucial role in sensitizing communities, thereby helping mobilize community-led projects (Granit, 2023). Green governance helps build trust, which in turn fosters community confidence and acceptance. Another crucial aspect is the impact on job creation for local communities, which helps in local economic development. Solar cooperatives in parts of the country, Village-level biomass and biogas plants are examples of engaging the local communities towards renewable energy initiatives in India.

Table 1 presents the identified enablers, along with their descriptions and contributing authors.

Table 1: Details of identified enablers

Enabler Nomenclature	Enabler Name	Description	Key Authors
Enb1	Environmental Enablers	The enabler discusses the country's geographical and climatic conditions that support renewable energy initiatives.	Nieboer et al., 2025; Obuseh et al., 2025; Erol et al., 2024; Vaidya, 2025; Dashtpeyma and Ghodsi, 2021.
Enb2	Institutional Enablers	The enabler highlights forums, platforms, governance initiatives, and agencies that improve the ease of renewable energy implementation.	Apolonia et al., 2021; Rincón et al., 2021; Dlamini, 2023; Wretling et al., 2021.
Enb3	Regulatory Enablers	The enabler looks at policies, regulators, and certificates that authenticate renewable energy practices and help build trust.	Oduro et al., 2024; Agupugo et al., 2022; Tian et al., 2024.
Enb4	Technological Enablers	This enabler discusses digitalization, grid modernization, energy storage technologies and renewable energy technologies that are essential.	Hwang and Venter,2025; Eleksiani et al., 2025; Tabrizian, 2019; Agupugo et al., 2022; Tigabu, 2018
Enb5	Economic Enablers	The enabler looks at incentives, subsidies, feed-in tariffs, renewable portfolio standards that help to attract investors and corporations for renewable energy investment and adoption.	Guy, 2022; Hao and Khan, 2025; Kurbatova et al., 2023; Azhgaliyeva and Mishra, 2022; Joshi, 2021;Feldman and Levinson,2023.
Enb6	Social Enablers	The enabler elaborates on the role of local communities, local	Opstal and Smeets, 2022; De Simone et al., 2025; Granit, 2023; Tian et al., 2024.

	organisations, and community engagement, which are crucial.	

3. MATERIALS AND METHODS

The study adopts a mixed research approach that combines qualitative and quantitative analyses. Qualitative aspects of the paper were obtained through literature review, the Delphi method, and case study discussions of India. Quantitative techniques include Total Interpretive Structural Modeling (TISM) and Fuzzy MICMAC analysis. In the first stage of the study, the authors analysed existing literature from Scopus, Web of Science, Ebscohost, and Google Scholar. Both national and international studies were referred to to ensure that all relevant literature is reviewed. The repetitive themes were identified as important enablers for successful renewable energy implementation. The authors collaborated to identify the final enablers, which were subsequently validated through expert opinion. A structured Delphi method helped to identify and validate the identified enablers. The experts in the Delphi method were identified based on predefined criteria, including a minimum of 5 years of experience in renewable energy policy, sustainability, and related research. The experts included academicians and professionals from private and government sectors. For academicians, their expertise was demonstrated through their peer-reviewed publications in related areas. Twenty-five experts with relevant experience were identified for the study, of whom 18 agreed to participate. The experts were selected from academics, government and policy experts, and industry professionals with relevant experience in renewable energy and sustainable development. The experts were assured of anonymity and confidentiality. Informed consent was taken prior to the interview. The experts were provided with a semi-structured questionnaire and participated in three iterative rounds of interaction. In the first round, the experts were asked to validate the identfied enablers. The six identified enablers were validated through a monitored questionnaire and follow-up interviews. A scale of 1 to 5 was used to rate the enablers; a mean score of 3 or higher was used for validation, as shown in Table 3. In the second round, the experts helped assess the contextual relationships and direction of influence between the enablers shown in the structural self-interaction matrix (Table 4). In the third round, the experts discussed the associability of variables (table 11).

Table 2: Summary of Experts

Expert	Years of relevant experience	Type of sector	Designation
Expert 1	5-10 years	Industry-Government	Energy Economist

Expert 2	11-15 years	Industry-Government	Project Manager
Expert 3	5-10 years	Industry-Private	ESG officer
Expert 4	15-20 years	Academia-Government	Professor and Researcher
Expert 5	15-20 years	Academia-Private	Professor and Researcher
Expert 6	Above 20 years	Industry-Government	Senior Operations Manager
Expert 7	5-10 years	Academia-Government	Assistant Professor-Sustainability
Expert 8	15-20 years	Industry-Private	Fund Manager
Expert 9	5-10 years	Academia-Private	Junior Research Fellow
Expert 10	15-20 years	Industry-Government	Senior Project Manager
Expert 11	5-10 years	Academia-Private	Assistant Professor-Sustainability
Expert 12	15-20 years	Industry-Government	Senior Consultant
Expert 13	15-20 years	Industry-Government	Consultant
Expert 14	11-15 years	Academia-Government	Associate Professor
Expert 15	Above 20 years	Academia-Private	Professor
Expert 16	11-15 years	Academia-Private	Associate Professor
Expert 17	11-15 years	Industry-Private	Consultant
Expert 18	Above 20 years	Industry-Private	Senior Policy Advisor

The identified six enablers were validated through a monitored questionnaire with further interview discussions. A scale of 1 to 5 was used to rate the enablers; a mean score of greater than 3 was used for validation, as shown in Table 3.

Table 3: Mean Scores of Enablers

Enabler Nomenclature	Enabler Name	Mean Score	Comments
Enb1	Environmental Enabler	3.21	Acceptable
Enb2	Institutional Enabler	3.43	Acceptable
Enb3	Regulatory Enabler	3.63	Acceptable
Enb4	Technological Enabler	3.05	Acceptable
Enb5	Economic Enablers	3.75	Acceptable
Enb6	Social Enabler	3.45	Acceptable

Data Analysis and Interpretation

In the next stage, the steps outlined by TISM were followed to develop the interpretive model, which revealed the hierarchical levels between the identified enablers. TISM is an extension of the well-established Interpretive

Structural Modelling (ISM) technique, which is used to establish the hierarchical relationships between interacting variables. The method is a well-accepted approach that is particularly useful when existing literature is scarce. The method is preferred over other modeling techniques as it is interpretive, i.e., based on the knowledge and experience of the experts in the field of study. The expert opinion is then structured to depict the hierarchy between the variables, which helps to arrive at a conceptual framework or model.

Structural Self-Interaction Matrix(SSIM)

The SSIM table is based on the knowledge, experience, and opinion of the experts. The experts were provided with a questionnaire designed to understand the relationship dynamics between the identified enablers. According to TISM, the row is labeled as "i" and the column as "j"; the relation between i and j is denoted as "V,A,X,O", where V and A denote a unidirectional relation, X denotes a bidirectional relation, and O denotes no relation.

If i has an impact on j but j has no impact on i, the relation is denoted as 'V', similarly if i has no impact on j but j has an impact on i, the relation is denoted as 'A'. If both i and j mutually impact each other, the relation is denoted by 'X', and if there is no relation between i and j, then the notation is 'O. Table 4 demonstrates the results of the SSIM.

Table 4: Structural Self-Interaction Matrix (Source: Authors own contribution)

	Enb6	Enb5	Enb4	Enb3	Enb2	Enb1
Enb1	V	V	A	V	V	
Enb2	X	X	X	V		
Enb3	V	X	V			
Enb4	V	X				
Enb5	A					
Enb6						

Interpretations of the SSIM

Table 5: Interpretive logic –Knowledge base

Code	Pairwise Comparison	Interpretation
Enb1-Enb6	Environmental Enablers have an impact on Social Enablers	Environmental degradation and climate risks raise public awareness and concern, resulting in greater social acceptance, pro-renewable attitudes, and community participation.

Enb1-Enb5	Environmental Enablers have an impact on Economic Enablers	Environmental goals justify green investments, subsidies, and carbon pricing, thereby creating markets for green jobs, renewable manufacturing, and clean energy finance.
Enb1-Enb4	Technological Enablers have an impact on Environmental Enablers	Technology and innovation in renewable energy make it affordable and scalable, thereby strengthening environmental outcomes.
Enb1-Enb3	Environmental Enablers have an impact on Regulatory Enablers	Environmental pressures drive regulations that encourage renewable energy sources through initiatives such as renewable purchase obligations (RPOs), emissions norms, and environmental clearances.
Enb1-Enb2	Environmental Enablers have an impact on Institutional Enablers	Environmental objectives, commitment to sustainable development, and commitment to reducing carbon footprints result in institutional frameworks that encourage and incentivise renewable energy initiatives.
Enb2-Enb6	Institutional Enablers and Social Enablers influence each other.	Institutions help to shape awareness programs and trust in renewable energy initiatives. This, in turn, helps to generate social awareness and acceptance. The rising awareness and environmental consciousness among the community have also pushed institutions to take up initiatives that promote clean energy.
Enb2-Enb5	Institutional Enablers and Economic Enablers influence each other.	Institutions are responsible for developing incentive schemes and subsidies to attract investors in renewable energy. Economic enablers influence institutional enablers because improved financial viability and investment flows enhance institutional capacity and long-term sustainability.
Enb2-Enb4	Institutional Enablers and Technological Enablers influence each other.	Institutional enablers support research and development, investment in renewable energy technology(RET). Emerging technologies necessitate capacity building and institutional adaptation.
Enb2-Enb3	Institutional Enablers have an impact on Regulatory Enablers	Institutional enablers influence regulatory enablers as institutional capacity and governance structures are essential for designing, implementing, and enforcing renewable energy regulations.
Enb3-Enb6	Regulatory Enablers have an impact on Social Enablers	Regulatory enablers influence social enablers, as clear, supportive regulations build public confidence, increase awareness, and foster societal acceptance of renewable energy systems.
Enb3-Enb5	Regulatory Enablers and Economic Enablers influence each other.	Regulatory enablers influence economic enablers, as stable, transparent regulations reduce investment risk and facilitate market growth in renewable energy. Economic enablers influence regulatory enablers because evolving market conditions and investment dynamics necessitate regulatory adaptation and reform.

Enb3-Enb4	Regulatory Enablers have an impact on Technological Enablers	Regulatory enablers influence technological enablers, as regulatory standards, mandates, and compliance requirements shape the development, deployment, and innovation in renewable energy.
Enb4-Enb6	Technological Enablers have an impact on Social Enablers	Technology has enabled the community to connect with each other. Social media helps generate curiosity and interest among the community about renewable energy, which results in smoother adoption.
Enb4-Enb5	Technological Enablers and Economic Enablers influence each other.	Technology can help scale renewable energy projects with economic consequences. Funding RET can increase research and innovation.
Enb5-Enb6	Social Enablers have an impact on Economic Enablers.	Social enablers influence economic enablers by increasing demand, reducing implementation risks, and improving the economic viability of renewable energy projects.

Reachability Matrix

The SSIM is converted into binary digits using the rules of TISM. The unidirectional relation of V is represented as (1,0), and A is represented as (0,1). Bidirectional relation X is represented as (1,1), and no relation O is represented as (0,0). Table 6 presents the initial reachability matrix based on these guidelines. The principle of transitivity is checked to arrive at the final reachability matrix, as shown in Table 7

Table 6: Initial Reachability Matrix (Source: Author's own contribution)

	Enb1	Enb2	Enb3	Enb4	Enb5	Enb6
Enb1	1	1	1	0	1	1
Enb2	0	1	1	1	1	1
Enb3	0	0	1	1	1	1
Enb4	1	1	0	1	1	1
Enb5	0	1	1	1	1	0
Enb6	0	1	0	0	1	1

Table 7: Final Reachability Matrix (Source: Authors own contribution)

	Enb1	Enb2	Enb3	Enb4	Enb5	Enb6
Enb1	1	1	1	0	1	1
Enb2	0	1	1	1	1	1
Enb3	1*	0	1	1	1	1
Enb4	1	1	0	1	1	1
Enb5	0	1	1	1	1	0

Enb6	0	1	0	1*	1	1

Hierarchical Level Partitioning

Level partitioning helps to develop the hierarchical relation between the different factors. It considers the intersection between the "antecedent" (AS) and the "reachability set" (RS) derived from the FRM. Iterations are repeated for all the factors to arrive at the different levels of the model as shown in Table 8, 9 and 10.

Table 8: Level Partitioning Iteration Matrix 1 (Source: Author's own contribution)

	Antecedent Set (AS)	Reachability Set (RS)	AS RS	Level
Enb1	(1,2,3,5,6)	(1,3,4)	(1,3)	
Enb2	(2,3,4,5,6)	(1,2,4,5,6)	(2,4,5,6)	Level 1
Enb3	(1,3,4,5,6)	(1,2,3,5)	(1,3,5)	
Enb4	(1,2,4,5,6)	(2,3,4,5,6)	(2,4,5,6)	Level 1
Enb5	(2,3,4,5)	(1,2,3,4,5,6)	(2,3,4,5)	
Enb6	(2,4,5,6)	(1,2,3,4,6)	(2,4,6)	

Table 9: Level Partitioning Iteration Matrix 2 (Source: Author's own contribution)

	Antecedent Set (AS)	Reachability Set (RS)	AS RS	Level
Enb1	(1,3,5,6)	(1,3)	(1,3)	
Enb3	(1,3,5,6)	(1,3,5)	(1,3,5)	Level 2
Enb5	(3,5)	(1,3,5,6)	(3,5)	
Enb6	(5,6)	(1,3,6)	(6)	

Table 10: Level Partitioning Iteration Matrix 3 (Source: Author's own contribution)

	Antecedent Set (AS)	Reachability Set (RS)	AS RS	Level
Enb1	(1,3,5,6)	(1,3)	(1)	Level 3
Enb5	(3,5)	(1,3,5,6)	(5)	Level 3
Enb6	(5,6)	(1,3,6)	(6)	Level 3

TISM MODEL

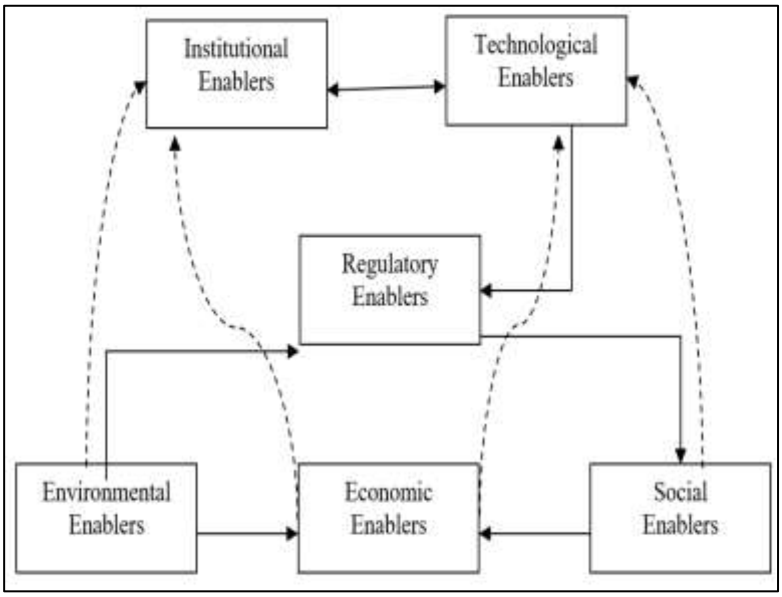

Figure 1 : TISM model of Enablers of Renewable Energy(Source: Author's Contribution)

Figure 1 represents the TISM model derived from the level partitioning. Level one of the model includes Institutional Enablers (Enb2) and Technological Enablers (Enb4), followed by Regulatory Enablers (Enb3) at level 2 of the model. Environmental enablers (Enb1), economic enablers (Enb5), and Social enablers (Enb6) form part of level 3 of the model. The TISM model is discussed in detail in the Results and Discussion section.

Fuzzy MICMAC Analysis

The third objective of the study aims to understand the nature of linkages between the identified enablers, which is achieved through fuzzy MICMAC analysis. Fuzzy MICMAC analysis considers the driving and dependent powers of the enablers from Table 7, which helps to classify the factors into four clusters.

Table 7: Final Reachability Matrix (Source: Authors own contribution)

	Enb1	Enb2	Enb3	Enb4	Enb5	Enb6
Enb1	1	1	1	0	1	1
Enb2	0	1	1	1	1	1
Enb3	1*	0	1	1	1	1
Enb4	1	1	0	1	1	1
Enb5	0	1	1	1	1	0
Enb6	0	1	0	1*	1	1

Tables 11 and 12 discuss the associability of values and the fuzzy reachability matrix. Expert judgment about the influence among enablers was derived using the associability of variables as presented in Table 11. This ensured that the risk of bias from rigid binary judgments was reduced. The experts were provided with the table of associability to judge the extent of association between the identified enablers. The values of associability ranged from 0 to 1 with 0 indicating no associability and 1 indicating complete associability.

Table 11: Associability of values for expert opinion

0	0.1	0.3	0.5	0.7	0.9	1
No relation	Very Low	Low	Average	High	Very High	Complete

Table 12: Fuzzy Reachability Matrix

	Enb1	Enb2	Enb3	Enb4	Enb5	Enb6	Driving Power
Enb1	1	0.7	0.5	0.3	0.9	0.7	4.1
Enb2	0	1	0.9	0.7	0.5	0.7	3.8
Enb3	0.7	0.3	1	0.5	0.9	0.9	4.3
Enb4	0.7	0.5	0.1	1	0.7	0.9	3.9
Enb5	0.3	0.7	0.7	0.9	1	0.3	3.9
Enb6	0.1	0.9	0.3	0.7	0.7	1	3.7
Dependence Power	3.5	4.1	3.5	4.1	4.7	4.5	

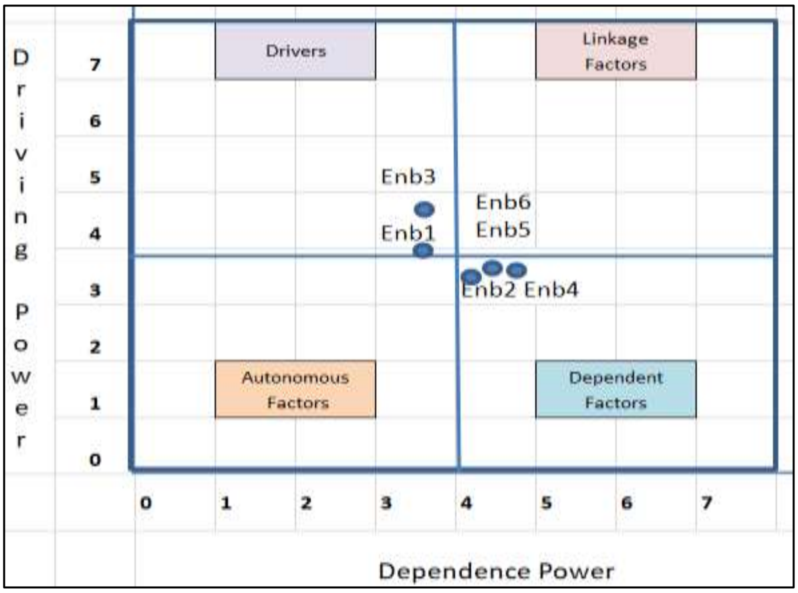

Figure 2 : Fuzzy MICMAC Analysis(Source: Author’s Contribution)

As shown in Figure 2, the Fuzzy MICMAC analysis helps to classify the enablers into four clusters. Cluster 1 is called the autonomous cluster, which is characterized by low "driving power" and low "dependence power". The second cluster is called the driving cluster, which represents enablers with high "driving" but lower "dependence power." The third cluster is called the linkage cluster that comprises of enablers with high "driving power" and high "dependence power." The final cluster is called the dependent cluster that has enablers categorized with weak "driving power" and higher "dependence power." The results of the Fuzzy MICMAC analysis are discussed in the next section.

4. RESULTS AND DISCUSSIONS

TISM Model

The TISM Model shows institutional enablers and technological enablers at level 1 of the model. The institutional enablers in India include a comprehensive network of government-enabled bodies such as the Ministry of New and Renewable Energy (MNRE), Solar Energy Corporation of India (SECI), NITI Aayog, and State Renewable Energy Development Agencies (SREDAs). These are institutions that are responsible for formulating policies, providing subsidies, and implementing large-scale projects. NITI Aayog offers long-term strategies for integrating renewable energy. The MNRE has numerous credible initiatives in India, including the National Solar Mission, which focuses on grid-connected, rooftop, and off-grid solar capacity. The institute is responsible for subsidies through DISCOM and various bioenergy initiatives. SREDAs are nodal agencies at the state level that look at energy efficiency and conservation programs. The institutional frameworks promote investment in technologies needed for renewable energy. Globally, India is the fourth-largest producer of wind energy and has access to sound, state-of-the-art technology to aid in production. Solar energy technologies in India under the National Solar Mission include rooftop, off-grid, and utility-scale technologies. The second level of the model focuses on regulatory frameworks. The bidirectional linkage between institutional and technological enablers in Figure 1 above shows how each enabler reinforces the other: Institutions enable the deployment of technology through funding, coordination, and capacity building. Technological development, on the other hand, requires adaptation and learning by institutions. Regulations translate institutional intent into enforceable rules, standards, and incentives, thereby enabling social acceptance and economic participation. The regulatory framework in India encompasses provisions such as the Renewable Purchase Obligation (RPO), renewable energy certificates, and grid standards for renewable energy. Regulatory frameworks are crucial for facilitating the development of infrastructure. These frameworks provide policy certainty and protect investors.

The third level of the model comprises environmental enablers, social enablers, and economic enablers. Environmental Enablers are the lowest level in the TISM framework, thus having strong driving forces and less reliance on other enablers.The direct effect on economic enablers and the indirect effect on institutional and regulatory enablers make them the major trigger of the renewable energy system. Social acceptance and economic viability emerge as system outcomes, not initiating forces—challenging the common assumption that awareness or finance alone can drive renewable energy transitions. India, as a country, has been blessed with abundant sunlight, mountain ranges, and coastal areas that facilitate the harnessing of wind energy. The agricultural sector in India contributes to biomass production, which can be utilized for fuel generation. There has been a growing awareness and environmental consciousness among Indians about climate change, energy security, and pollution caused by fossil fuels. People have shown interest in solar energy and have taken steps to install solar panels in their own houses. Universities and educational institutions in India have raised awareness through sustainability modules integrated into their curricula. Social enablers are crucial for driving awareness about renewable energy sources. The Government of India has undertaken initiatives, such as PM-KUSUM, that provide subsidies to farmers for solar pumps and the setting up of small solar power plants. Small power plants enable farmers to sell excess energy back to the grid. The Unnat Jyoti by Affordable Lighting for All(UJALA) scheme was launched by the Government in 2015 to promote energy efficiency by distributing affordable LED bulbs. India also offers numerous subsidies and incentives to promote the mainstream adoption of renewable energy sources. The PM Surya Ghar Muft Bijli Yojana offers subsidies for residential solar rooftop installations. Solar modules are taxed at a rate of 5%.

Fuzzy MICMAC Analysis

The results of the Fuzzy MICMAC analysis show that the model has Drivers and Dependent Variables. Environmental enablers and regulatory enablers are the drivers of the model. They are crucial enablers for the successful implementation of renewable energy sources. These are the enablers that do not depend on other enablers, but if missing, can have an impact on the model. To harness renewable energy effectively, it is essential to have access to a diverse range of energy sources. The positioning confirms that environmental concerns (e.g., climate change mitigation, emission reduction) are not outcomes of the system but initiators that shape policy priorities, institutional responses, and market behaviour. The regulatory enablers ensure that systems and processes are in place to encourage and monitor the adoption of renewable energy for energy efficiency and sustainable development. Institutional enablers, technological enablers, economic enablers, and social enablers are the dependent variables in the model. Institutional enablers are dependent on regulatory frameworks, public demand for clean energy, international sustainability agenda and goals. This feedback loop places institutional and technological enablers at an intermediate but influential level, acting as system stabilizers rather than independent drivers. Institutional, regulatory, and technological enablers typically fall here, which explains Continuous policy revisions, Regulatory learning, Technology–policy feedback cycles. This validates their central but sensitive role observed in the TISM structure. Technology is dependent on policies, available funds for innovation, market demand for renewable energy technologies. Economic enablers are an outcome of the budget, they are dependent on fiscal policies, funding support and regulatory frameworks for renewable energy. Social enablers are dependent on campaigns, consumer attitude, accessibility and affordability.

5. CONCLUSIONS

The authors in the study attempted to analyze three objectives. The primary objective was to understand the key drivers that facilitate the successful implementation of renewable energy sources, with a special focus on India. This objective was achieved through an extensive literature review and consultation with experts. The outcome helped identify six enablers: environmental enablers, institutional enablers, regulatory enablers, technological enablers, economic enablers, and social enablers, which facilitated the adoption and implementation of renewable energy as a clean energy source in India. The second objective of the study focused on identifying the linkages between the identified enablers. The TISM model illustrates the three levels that help understand the hierarchical relationships between the six enablers. Various institutions and initiatives by the Government of India have helped to streamline and regulate the renewable energy landscape in India. The third objective of the study focused on inferring the nature of linkages between the identified enablers using Fuzzy MICMAC Analysis. The results helped categorize the enablers into driving and dependent variables that are crucial to the model's success.

5.1 Implications of the study

The study has profound implications for theory, management, and society. The identified enablers contribute to the existing body of literature in this domain. The study also helps to understand the nature of the relation between the identified enablers. The TISM method provides a framework for understanding the hierarchical relationships among the three identified enabler levels, thereby elucidating the nature of the linkages between them. The framework helps identify and prioritize the enablers. Experts' opinions help provide qualitative feedback on the study, which can be further explored, thus providing a foundation for future research. The study highlighted practices adopted by India that can be further studied and translated into policies for other developing countries. The results indicate that policymakers should target high-driving enablers more than the dependent outcomes. Enhancing environmental commitments, such as emission standards and sustainability policies, can create a ripple effect across institutions, regulations, and markets. Building institutional capacity and regulatory consistency is essential because high-driving enablers convert environmental intentions into feasible action and technology adoption. Policies targeting only social acceptance or financial support might not be very effective unless they are accompanied by strong institutional and regulatory foundations. In this manner, the present study offers policymakers a guide to targeting policy interventions based on systemic reach rather than isolated outcomes. For project developers, investors, and implementing agencies, the study's findings have the following implications: Economic viability and social acceptability result from system readiness, not premises. Engagement strategies need to be coordinated with regulatory clarity to minimize project-related risks. Institutional learning and regulatory adaptation are necessary alongside technological innovation to scale up. The position of each enabler in the system helps practitioners to forecast potential bottlenecks and develop more robust renewable energy projects.

Author Contributions: Conceptualization-The study's idea was conceptualized by Dr. Adya Sharma and Dr Nehajoan Panackal. Dr Adya contributed to the Literature review and the Delphi method. Dr Nehajoan Panackal contributed to the methodology. Both authors were involved in the preparation, review, and editing of the original draft. All authors have read and agreed to the published version of the manuscript."

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