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Multi-Level Determinants and Livelihood Implications of Household Renewable Energy Adoption: An Integrated Conceptual Framework with Reference to Punjab, Pakistan

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Abstract

Renewable energy shifts in developing economies are influenced by complex inter-relationship between macro-institutional structures, household level behavioural dynamics and livelihood systems. While existing literature has focused on national policy reforms, technological diffusion and consumer behaviour in isolation, little attention has been given to bringing together structural determinants and micro-level decision-making and developmental outcomes within a common analytical framework. This research is a multi-level conceptual development of linkages between macro-structural conditions, institutional frictions, household behavioural determinants and livelihood resilience. Drawing on the Theory of Planned Behaviour, the Diffusion of Innovations theory and the Sustainable Livelihoods Framework, the adoption of renewable energy is conceptualised as a structurally conditioned investment process within institutional opportunity constraints. The framework proposes mediation and moderation mechanisms as a means of explaining the extent to which policy ambition is translated into actual household adoption and then into livelihoods effects. By linking the macro level transition discourse with the micro level behavioural and development perspectives, the study moves towards an integrated analytical architecture for future empirical research and policy design in the developing countries with reference to the province of Punjab, Pakistan.

Keywords: Renewable Energy Adoption; Household Energy Behaviour; Energy Transition; Institutional Constraints; Sustainable Livelihoods; Punjab, Pakistan

Introduction

The worldwide shift towards renewable energy has accelerated in the last two decades in response to climate change commitments, energy security issues and technological innovation (Smil, 2017; UNFCCC, 2015). Although there has been a significant expansion of renewable capacity at the national and international level, there is still a lack of uniformity of diffusion at the level of developing economies where there are structural constraints and institutional fragility which limit decentralized adoption (e.g. Markard et al., 2012; Geels, 2014). Energy transitions are coming to be seen as socio-technical transformations that are embedded in political, economic and governance regimes, rather than as technological substitutions in the narrow sense of the word (Jacobsson and Lauber, 2006; Meadowcroft, 2009). Consequently, there is often a co-existence of high levels of aggregate policy ambition coupled with limited levels of household level uptake, especially in cases of income heterogeneity, regulatory uncertainty and dependence on fossil fuel based systems of energy supply (Painuly, 2001; Karakaya and Sriwannawit, 2015).

Existing scholarship has addressed renewable transitions from three relatively different perspectives. Transition studies have focused on macro-level regime shifts, path dependency and structural resistance within the incumbent energy systems (Geels, 2014; Markard et al., 2012). Behavioural research is concerned with the behaviour of individual decision-making, emphasizing the importance of attitudes, subjective norms and perceived behavioural control in the adoption intention (Ajzen, 1991; Wolske et al., 2017). Diffusion research has also shown that peer effects, social learning and perceived relative advantage play a significant role in household renewable uptake (Rogers, 2003; Bollinger and Gillingham, 2012; Wustenhagen et al., 2007). In parallel, development-oriented scholarship stresses the importance of energy access in supporting livelihood assets, productivity (Scoones, 1998), and vulnerability to economic shocks (Chambers and Conway, 1992; Sovacool, 2012; Bhattacharyya, 2012).

Despite these huge contributions, however, the three strands are not sufficiently integrated. Transition studies too often privilege macro-institutional analysis without fully taking account of the household-level behavioural realization, but behavioural models usually abstract from structural governance constraints. Similarly, livelihood frameworks consider the developmental results of energy access and do not often place decisions of adoption in broader political economy and institutional regimes. As a result, the structural conditioning of household decision-making and the livelihood implications of the renewable adoption are often explored independently.

This study attempts to overcome this analytical fragmentation by developing a multi-level conceptual framework which integrates macro-structural determinants, institutional mechanisms of mediation, household-level behavioural drivers, and livelihood outcomes in a conceptual framework. The main contribution of this work is to show the role of structural opportunity conditions in micro-level adoption processes through institutional frictions and how renewable uptake processes back into household resilience. By introducing both the mechanism of mediation and moderation, the framework broadens both existing transition and behavioural models and creates a structured analytical architecture that can be a subject of empirical investigation in the future.

With reference to Punjab, Pakistan - a region that is characterized by policy ambition and institutional and socio-economic heterogeneity - the study depicts the operation of the renewable adoption in a macro-micro structural paradox. In developing contexts characterized by dynamic relationships among governance capacity, financial access, and fossil fuel dependency, grasping renewable adoption need integrative frameworks that are able to bridge structural feasibility on one hand, and household-level decision-making and livelihood resilience on the other (Painuly, 2001; Karakaya and Sriwannawit, 2015). The potential model offers a theoretically based basis for future research and policy design in developing economies.

Theoretical Framing

Understanding household renewable energy adoption calls for bringing together behavioural, diffusion and livelihood perspectives in a wider structural and institutional context. Energy transitions are increasingly being viewed as socio-technical transformations, conditioned by the interplay of technology, governance, markets and user practices (Geels, 2014; Markard et al., 2012). However, micro-level adoption decisions are simultaneously affected by cognitive, social and economic determinants, which requires to employ a multi-theoretical synthesis.

The Theory of Planned Behaviour (TPB) is a basis micro level explanation of adoption behaviour. According to TPB, behavioural intention is influenced by attitudes towards behaviour, subjective norms and perceived behavioural control (Ajzen, 1991). Within the context of renewable energy, positive environmental beliefs, cost savings expectations and social approval enhance adoption intentions (Wolske et al., 2017; Sundt and Rehdanz, 2015). Perceived behavioural control, especially when it concerns financial affordability and technical feasibility, is a crucial element in the formation of realized behaviour (Ajzen, 1991). However, empirical research shows that positive intention is not always translated into adoption as long as institutional, regulatory or infrastructural barriers remain binding (Wustenhagen et al., 2007; Karakaya and Sriwannawit, 2015). Thus, while TPB has a strong micro-foundational understanding of decision-making processes, it does not explain, in and of itself, the structural feasibility conditions that are rooted in the governance regimes.

Diffusion of Innovations theory is an extension of the analysis that focuses on the role of social systems and communication networks in shaping the technology uptake (Rogers, 2003). Adoption decisions are based on perceived relative advantage, compatibility with existing practices, complexity, observability and trialability (Rogers, 2003). Renewable technologies can be introduced through peer demonstration effects, neighbourhood clustering and social learning effects (Bollinger and Gillingham, 2012; Rai and Robinson, 2013). Empirical studies demonstrate that living near those who have already installed solar panels makes one much more likely to install the panels, suggesting powerful network externalities (Bollinger and Gillingham, 2012). Diffusion processes are thus working along a meso-level, at the interface between the individual cognition and the gauge of a larger society (Wustenhagen et al., 2007). Nevertheless, diffusion theory is mainly concerned with social transmission mechanisms and does not fully take into account institutional or macro-structural constraints.

The Sustainable Livelihoods Framework (SLF) represents a new way of thinking in development by viewing household welfare as being dependent on a portfolio of interconnected assets: financial, human, social, physical and natural capital (Chambers and Conway, 1992; Scoones, 1998). Energy access and reliability have an impact on several dimensions of livelihood such as income, productivity, education outcome and vulnerability reduction (Bhattacharyya, 2012; Sovacool, 2012). Renewable energy use can lead to better financial capital due to lower energy spending, better human capital thanks to improved health and educational conditions and lower exposure to fuel price fluctuations and supply shortfalls (Bhattacharyya, 2012; Sovacool, 2012). However, livelihood frameworks tend to explore the results of energy access without explicitly modelling the behavioural and institutional determinants of adoption decisions.

While TPB explains the formation of individual intentions, the diffusion theory emphasizes the dynamics of social transmission and SLF reflects the consequences of development, none of them simultaneously take into account the structural conditioning of behavioural realization in the context of macro-institutional regimes. Sustainability transition literature highlights the existence of path dependency, regime resistance and structural inertia in incumbent energy systems that affect the environment for adoption (Geels, 2014; Meadowcroft, 2009). Fossil fuel lock-in, regulatory instability and governance weaknesses might therefore moderate the process of intention turned to real adoption (Jacobsson and Lauber, 2006; Painuly, 2001).

The integration of these perspectives enables renewable uptake to be conceptualized as a structurally embedded investment decision that is inspired by macro-level governance regimes, institutional frictions, social diffusion processes and household asset constraints. By placing behavioural intention into structural opportunity conditions and linking the adoption outcomes to livelihood resilience, the present study contributes to a multilayered analytical synthesis that bridges the gap between transition theory, behavioural economics, and development studies.

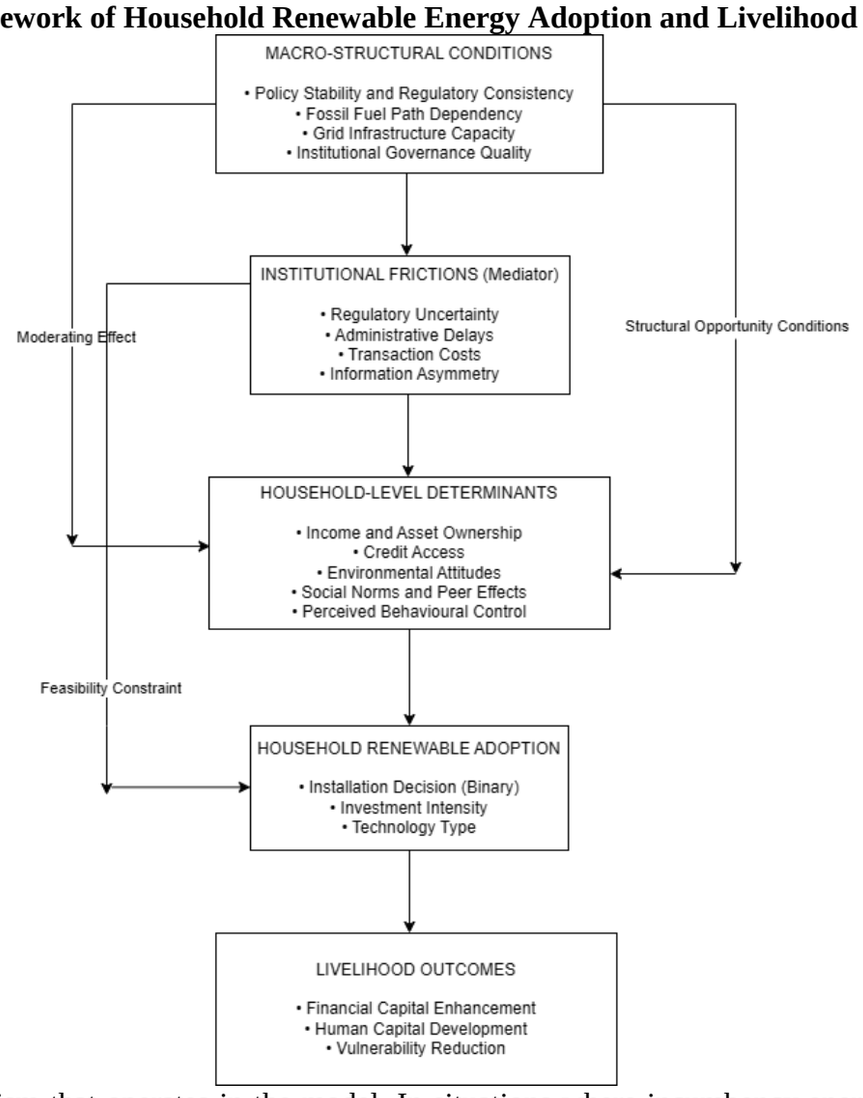
Conceptual Model

The proposed conceptual model organizes renewable adoption dynamics into three inter-related domains: macro-structural conditions, household-level determinants, and livelihood outcomes, which are connected with mediation and moderation mechanisms. The model is based on transition theory in sustainability (Geels, 2014; Markard et al., 2012), behavioural decision models (Ajzen, 1991), diffusion theory (Rogers, 2003), and livelihood analysis (Chambers and Conway, 1992; Scoones, 1998) and combines them in an overall analytical framework.

At the macro-level, policy stability, regulatory consistency, the quality of governance, fossil fuel path dependency and infrastructure capacity characterize the structural opportunity environment for renewable diffusion (Jacobsson and Lauber, 2006; Meadowcroft, 2009). Transition scholarship emphasises the fact that energy systems are characterised by regime resistance and institutional inertia, which shape the feasibility of the adoption of low-carbon (Geels, 2014; Markard et al., 2012). Fossil fuel path dependency, which is reinforced through subsidies and infrastructural lock-in, puts structural barriers on the renewable competiveness (Painuly, 2001; Jacobsson and Lauber, 2006). These macro-structural conditions affect the household adoption indirectly through institutional frictions such as regulatory uncertainty, administrative delays, transaction costs and informational asymmetries (Painuly, 2001; Karakaya and Sriwannawit, 2015). Institutional frictions therefore mediate the relationship between macro-level ambition and household-level feasibility in order to translate policy frameworks into perceived investment conditions.

At the household level, the adoption decisions are made on the basis of economic capacity and behavioural readiness. Income and possession of assets affect liquidity and potential for investment, whereas access to credit helps to overcome capital issues that often prevent renewable investment in developing contexts (Karakoa and Sriwannawit, 2015). Behavioural intention is formed by environmental attitudes, subjective norms and perceived behavioural control (theory of planned behaviour by Ajzen, 1991) and Wolske et al. (2017). Social norms and peer demonstration effects also strength diffusion from network externalities and observational learning (Rogers, 2003; Bollinger and Gillingham, 2012; Wustenhagen et al., 2007). However, behavioural intention alone cannot be considered as a guarantee of realized adoption if there are still institutional constraints that cannot be loosened (Wolske et al. 2017; Karakaya and Sriwannawit 2015). Adoption thus requires the micro and macro level to be in alignment in terms of behavioural motivation versus structural feasibility.

Figure 1. Integrated Multi-Level Conceptual Framework of Household Renewable Energy Adoption and Livelihood Outcomes



Fossil fuel path dependency is a moderating mechanism that operates in the model. In situations where incumbency energy regimes continue to be structurally embedded, the process of translating behavioural intention to realised adoption is weakened because of reduced relative advantage and continuance of regime resistance (Geels, 2014; Meadowcroft, 2009). Structural lock-in therefore structures behavioural effectiveness by limiting the opportunity set that one has as a household (Jacobsson and Lauber, 2006; Painuly, 2001).

Renewable adoption creates livelihood results such as increasing financial savings, improving productivity and lowering vulnerability to energy price fluctuations and supply interruptions (Bhattacharyya, 2012; Sovacool, 2012). Within the Sustainable Livelihoods Framework, better access to energy is part of the process of accumulating financial capital, developing human capital, and lowering the risk of exposure to external shocks (Chambers and Conway, 1992; Scoones, 1998). Renewable adoption can therefore work as more than just a technological transition but as an instrument of livelihood resilience and developmental reinforcement (Sovacool, 2012).
The integrated framework takes into account top-down structural conditioning and bottom-up behavioural transformation simultaneously within a cohesive analytical framework. By explicitly adding mechanisms of mediation and moderation, the model goes beyond descriptive transition narratives and provides a structured theoretical foundation to analyse the impact of institutional regimes on household-level adoption of renewables and subsequent livelihood outcomes.

Figure 1 shows the interconnected multi-level scheme of relationships between macro-structural conditions, institutional mechanisms, determinants at the household level of analysis, renewable adoption and livelihood outcomes in a comprehensive analytical structure. Macro-level governance conditions influence the structural opportunity environment within which renewable diffusion occurs, but it is through institutional frictions that selectional feasibility and perceived investment risk are conditioned by these broad-level conditions. At the micro level, economic capacity and behavioural intention determine adoption likelihood, however, the process of translating intention to realised adoption is moderated by fossil fuel path dependency, which reflects regime resistance and structural lock-in of incumbent energy systems. Renewable adoption then creates livelihood outcomes in terms of improved financial capital, increased productivity and a decreased vulnerability to energy shocks. The framework thus represents the twin agendas of top-down structural conditioning and bottom-up behavioural realization, and the incorporation of renewable adoption in a more holistic development-oriented perspective.

Formal Propositions
The conceptual model that is developed in this study is an integrated model and this model positions renewable energy adoption as a multi-level process wherein conditioning from the 'macro-structural' process, mediating 'institutional' process, behavioural realization process and livelihood feedback effects are present. The following propositions are a logical consequence of the theoretical synthesis and define the structural relations which are embedded in the framework:

Macro-Structural Conditioning and Institution Mediation
Sustainability transition scholarship has highlighted that energy systems operate in socio-technical regimes that are deeply embedded in processes of path dependency, institutional inertia and governance structures that determine technological feasibility (Geels, 2014; Markard et al., 2012). Policy stability and regulatory consistency lead to less uncertainty and lower transaction costs and boosts credibility of long term investments (Jacobsson and Lauber, 2006; Meadowcroft, 2009). On the contrary, inconsistent tariff regimes, bureaucratic delays and administrative opacity create institutional frictions which impede in the uptake of renewables (Painuly, 2001; Karakaya and Sriwannawit, 2015).
Institutional frictions are the medium of transmission from macro-level ambition to household-level feasibility. The risk perceived by households and the confidence they have to invest is lower if the regulatory procedures are transparent and stable. In contrast, weak governance structures increase the perceived uncertainty and hold back adoption, despite the case of supportive policy rhetoric (Jacobsson and Lauber, 2006).
Proposition 1: Policy frictions are minimized where there is stability and consistency in policy and regulation which increases the structural feasibility of household renewable adoption.
Institutional frictions thus act as a mediating mechanism between, on the one hand, macro-structural conditions and, on the other, micro-level adoption outcomes. This mediation logic is in agreement with political economy analyses of energy transitions, which show that governance arrangements influence technology diffusion indirectly via the institutional effectiveness (Geels, 2014; Meadowcroft, 2009).
Proposition 2: Institutional frictions mediate the link between macro-structural conditions and household renewable adoption.

Structural Lock-In and Moderation Effect
Fossil fuel-based energy systems are characterised by infrastructural lock-in, subsidy entrenchment and vested interests against transition (Geels, 2014; Jacobsson and Lauber, 2006). Such path dependency has the effect of mitigating the relative advantage of renewables and locking in regimes against renewables (Markard et al., 2012). Furthermore, even in the case of favourable attitudes towards renewable technologies among households, there is a possibility that lock-in is structural and weakens the translation from behavioural intention to realized adoption.
The Theory of Planned Behaviour acknowledges that intention is a necessary but not sufficient predictor of behaviour, when there are still some external constraints binding behaviour (Ajzen, 1991). In the case of a high fossil fuel dependency, perceived behavioural control may be compromised by systemic barriers and subsequently weaken the intention-behaviour link (Wolske et al., 2017).
Proposition 3: Fossil fuel path dependency has a negative moderating effect on a relationship between behavioural intention and actual adoption of renewables.
This mechanism of moderation captures the conditioning of behavioural effectiveness structurally in incumbent regimes of energy.

Household Economic and Behavioural Determinants
At the micro level, the adoption of renewables is a mix of both an economic and behavioural choice. Feasibility of adoption The financial capacity is a key factor in adoption feasibility. Studies have consistently identified income, asset ownership and access to credit as important factors in determining renewable uptake, especially in developing sectors that are marked by capital constraints (Karakawa and Sriwannawit, 2015; Painuly, 2001). Liquidity lowers the upfront investment barriers and makes it more feasible.
Proposition 4: Household economic capacity as measured by income, asset ownership, and access to credit have a positive impact on renewable adoption likelihood.
Behavioural drivers influence the adoption intention further. According to the Theory of Planned Behaviour, attitudes towards renewable technologies, supportive subjective norms and perceived behavioural control have a significant positive impact on the formation of intentions (Ajzen, 1991; Wolske et al., 2017). Diffusion research has further shown that these homes will have accelerated residential renewable uptake due to peer effects and social learning mechanisms (Rogers, 2003; Bollinger and Gillingham, 2012; Wustenhagen et al, 2007). Social acceptance is therefore a reinforcing mechanism in the diffusion processes within the community.
Proposition 5: Positive environmental attitudes, social norms and perceived behavioural control positively affect behavioural intention to renewables.

Renewable Adoption and Living Outcomes

Apart from the environmental benefits, there are developmental implications to renewable energy adoption. The Sustainable Livelihoods Framework sees household welfare as an interaction between financial, human and social capital assets (Chambers and Conway, 1992; Scoones, 1998). Reliable and low-cost energy improves productivity, keeps expenditures stable and bolsters income security (Bhattacharyya, 2012; Sovacool, 2012). Renewable adoption can make the system less vulnerable to tariff shocks and supply disruptions for greater resilience.

Consistent results in energy access studies have shown that energy reliability is positively associated with better economic activity and welfare outcomes (Bhattacharyya, 2012; Sovacool, 2012). Within this integrated model, the adoption of renewables is a technological transition as well as a livelihood-enhancing investment.

Proposition 6: Household renewable adoption enhances livelihood resilience by improving financial capital, productivity and reducing vulnerability.

Policy Implications

The integrated framework posits that strategies for achieving renewable transition in developing economies will need to go beyond aggregate capacity targets, to deal with the issues of institutional and behavioural alignment. Sustainability transition literature emphasizes the importance of stable and credible policy environments in order to reduce uncertainty and promote investment in low-carbon technologies (Jacobsson and Lauber, 2006; Meadowcroft, 2009). Regulatory stability and administrative clarity has the effect of reducing institutional frictions, lower transaction costs and perceived feasibility of renewable investments (Painuly, 2001; Karakaya and Sriwannawit, 2015).

Gradual restructuring of fossil fuel incentives is needed to reduce structural lock-in and bolster the relative advantage of renewables in the incumbent energy regimes (Geels, 2014; Markard et al., 2012). Fossil fuel subsidies and infrastructural entrenchment are distorting price signals and dampening the competitiveness of renewables, thus reducing incentives for adopting renewables at the household level (Jacobsson and Lauber, 2006).

Mechanisms for financial accessibility such as concessional credit, green financing tools and risk-sharing mechanisms can address the issue of liquidity, which often restricts the adoption of renewables in developing countries (Painuly, 2001; Karakaya and Sriwannawit, 2015). Behavioural research also finds community-based demonstration projects and information campaigns reinforce the social diffusion processes and reinforce behavioural realisation through peer effects and observational learning (Rogers, 2003; Bollinger and Gillingham, 2012; Wustenhagen et al., 2007).

For regions like Punjabs, coordinated governance reforms that simultaneously strengthen regulatory credibility, financial inclusion and institutional efficiency are a must to bridge the macro-micro adoption gap. Energy access research has shown that the adoption of renewables can serve as both an environmental strategy and a development tool as it increases financial resilience and decreases vulnerability (Bhattacharyya, 2012; Sovacool, 2012). Frame renewable adoption in a livelihood enhancement context helps to enhance the developmental legitimacy of energy transition policies.

Limitations

This study proposes a forward step in the direction of a theoretically integrated framework that needs to be validated empirically in diverse institutional contexts. Sustainability transition research shows that various governance levels, markets and political economy structures differ significantly between different regions, which in turn plays a role in the dynamics of the transition process (Geels, 2014; Markard et al., 2012). Consequently, institutional capacity and socio-cultural norms may vary across context and influence the strength and direction of the proposed relationships.

The framework does not explicitly include macroeconomic volatility, political instability or cycles of technological innovation which have been shown to affect energy transition trajectories (Meadowcroft, 2009; Jacobsson and Lauber, 2006). In addition, although behavioural intention is modelled based on established theoretical constructs (Ajzen, 1991), empirical research shows that there may be differences in intention-behaviour gaps between contexts based on structural constraints (Wolske et al., 2017). Empirical investigation of the proposed mediation and moderation mechanisms and testing of cross-regional applicability within and outside the developing economies should be a focus of future research.

Conclusion

Renewable energy adoption in developing economies cannot be explained adequately by means of isolated macro transition measures or mere behavioural analyses. Transition scholarship has focused on the fact that socio-technical change occurs within structurally conditioned regimes of institutional inertia and path dependency (Geels, 2014; Markard et al., 2012). Simultaneously, behavioural studies have shown that the formation of individual intention is alone not sufficient to guarantee the adoption of a new technology if the structural constraints that bound their technology use remain binding (Ajzen, 1991; Wolske et al., 2017).

This study contributes to a multi-level conceptual framework of structural opportunity conditions, institutional mediation mechanisms, household behavioural determinants and livelihood outcomes in a unified analytical structure. By drawing on behavioural theory (Ajzen, 1991), diffusion processes (Rogers, 2003) and livelihood perspectives (Chambers and Conway, 1992; Scoones, 1998), the framework emphasises the structural paradox of how policy ambition can co-exist with institutional constraints and socio-economic heterogeneity.

Renewable adoption is not just a technological substitution, but a developmentally significant investment process that itself is embedded in governance regimes (Bhattacharyya, 2012; Sovacool, 2012). So bridging the disconnect between macro and micro is an integrated policy approach, to reduce the frictions of institutions, improve financial accessibility and weaken the fossil fuel lock-in (Jacobsson and Lauber, 2006; Painuly, 2001). The proposed model creates a structured theoretical basis for future empirical research and presents a coherent analytical architecture for the advancement of sustainable energy transitions and livelihood resilience in developing contexts.

References

Ahmed, M. (2024). Renewable energy policy evolution in Pakistan: Institutional challenges and transition pathways. *Energy Policy, 181*, 113711.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Bhattacharyya, S. C. (2012). Energy access programmes and sustainable development: A critical review and analysis. *Energy Policy, 47*, 260–271. https://doi.org/10.1016/j.enpol.2012.04.049

Bollinger, B., & Gillingham, K. (2012). Peer effects in the diffusion of solar photovoltaic panels. *Marketing Science, 31*(6), 900–912. https://doi.org/10.1287/mksc.1120.0727

Chambers, R., & Conway, G. (1992). *Sustainable rural livelihoods: Practical concepts for the 21st century* (IDS Discussion Paper 296). Institute of Development Studies.

Geels, F. W. (2014). Regime resistance against low-carbon transitions: Introducing politics and power into the multi-level perspective. *Energy Research & Social Science, 1*, 21–40. https://doi.org/10.1016/j.erss.2014.01.002

IRENA. (2023). *Renewable capacity statistics 2023*. International Renewable Energy Agency.

Jacobsson, S., & Lauber, V. (2006). The politics and policy of energy system transformation—Explaining the German diffusion of renewable energy technology. *Energy Policy, 34*(3), 256–276. https://doi.org/10.1016/j.enpol.2004.08.029

Karakaya, E., & Sriwannawit, P. (2015). Barriers to the adoption of renewable energy technologies: A literature review. *Renewable and Sustainable Energy Reviews, 49*, 108–121. https://doi.org/10.1016/j.rser.2015.04.155

Khan, S. A. (2024). Household renewable energy adoption patterns in Punjab: Income heterogeneity and diffusion dynamics. *Renewable Energy, 215*, 1198–1210.

Malik, A. (2024). Renewable energy transition and policy reforms in Pakistan. *Energy Policy, 179*, 113569.

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy, 41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long-term energy transitions. *Policy Sciences, 42*(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z

Painuly, J. P. (2001). Barriers to renewable energy penetration: A framework for analysis. *Renewable Energy*, *24*(1), 73–89. https://doi.org/10.1016/S0960-1481(00)00186-5

Rai, V., & Robinson, S. A. (2013). Effective information channels for reducing costs of environmentally-friendly technologies: Evidence from residential PV markets. *Energy Policy*, *60*, 289–297. https://doi.org/10.1016/j.enpol.2013.04.076

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Scoones, I. (1998). *Sustainable rural livelihoods: A framework for analysis* (IDS Working Paper 72). Institute of Development Studies.

Siddiqui, M. (2024). Net-metering reforms and decentralized solar expansion in Pakistan. *Energy for Sustainable Development, 77*, 102–114.

Smil, V. (2017). *Energy transitions: Global and national perspectives* (2nd ed.). Praeger.

Sovacool, B. K. (2012). Deploying off-grid technology to eradicate energy poverty. *Energy Policy, 45*, 229–238. https://doi.org/10.1016/j.enpol.2012.02.044

Sundt, S., & Rehdanz, K. (2015). Consumers' willingness to pay for green electricity: A meta-analysis of the literature. *Energy Economics, 51*, 1–8. https://doi.org/10.1016/j.eneco.2015.06.005

UNFCCC. (2015). *Paris Agreement*. United Nations Framework Convention on Climate Change.

Wolske, K. S., Stern, P. C., & Dietz, T. (2017). Explaining interest in adopting residential solar photovoltaic systems in the United States. *Energy Research & Social Science, 25*, 134–151. https://doi.org/10.1016/j.erss.2016.12.006

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation. *Energy Policy, 35*(5), 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001