Environmental Sustainability and Development
https://esdjournal.org

Renewable Energy Adoption and Carbon Reduction in Rural Community Cooperatives: Survey Experiment

Yuk-Ling Yeung*

Division of Building Science and Technology, School of Energy and Environment, City University of Hong Kong, Hong Kong, Hong Kong SAR, China

Corresponding author: yuk.l.yeung@cityu.edu.hk

Abstract

The global transition toward sustainable energy systems requires widespread participation across all geographic and socioeconomic demographics, particularly in rural areas where energy poverty and reliance on carbon-intensive fuels remain prevalent. This paper investigates the mechanisms linking renewable energy adoption to carbon reduction outcomes through the lens of rural community cooperatives. Utilizing a large-scale survey experiment, this study evaluates how different incentive structures and informational framing strategies influence households' willingness to adopt decentralized renewable energy technologies, such as solar photovoltaic panels and biogas digesters, and their subsequent commitment to long-term carbon reduction behaviors. The experimental design randomizes participants into distinct treatment groups receiving variations in financial, environmental, and community-normative messaging. The empirical results demonstrate that while financial incentives maintain a fundamental role in lowering initial barriers to entry, treatments emphasizing community cooperative norms and localized environmental co-benefits yield a more sustained behavioral shift toward comprehensive carbon reduction. Furthermore, the findings indicate that rural community cooperatives serve as critical mediators, enhancing social trust and reducing information asymmetry, thereby accelerating the diffusion of green technologies. This research contributes causal evidence to the theoretical discourse on rural energy transitions and offers actionable insights for policymakers seeking to leverage community-based organizations to achieve national and global decarbonization targets.

Keywords: Renewable Energy; Carbon Reduction; Survey Experiment; Rural Cooperatives; Environmental Sustainability

1. Introduction

1.1 Background on Rural Energy and Carbon Reduction

The imperative to mitigate the adverse effects of anthropogenic climate change has catalyzed a global consensus on the necessity of transitioning from fossil fuel-based energy systems to sustainable, renewable alternatives. While international climate agreements and national policies have predominantly focused on large-scale industrial decarbonization and urban energy efficiency, rural areas represent a critical, yet often underappreciated, frontier in the global energy transition. Rural communities frequently exhibit distinct energy consumption patterns characterized by a heavy reliance on traditional biomass, coal, and diesel generators. These carbon-intensive energy sources not only contribute disproportionately to regional greenhouse gas emissions but also impose severe environmental and health externalities on local populations. The intersection of energy poverty, geographic isolation, and limited access to capital creates unique barriers to the adoption of modern, clean energy technologies in these regions. Consequently, addressing the rural energy deficit through the deployment of decentralized renewable energy systems is increasingly recognized as a dual-purpose strategy capable of fostering localized socioeconomic development while significantly advancing overarching carbon reduction objectives.

The deployment of renewable energy technologies in rural contexts necessitates innovative institutional arrangements that can overcome the structural impediments inherent to marginalized economies. Traditional market-based approaches often fail in rural settings due to high transaction costs, lack of economies of scale, and insufficient technical support infrastructure. In response, cooperative models have emerged as a viable institutional mechanism to facilitate the transition toward sustainable energy. Rural community cooperatives, historically rooted in agricultural production and resource management, are uniquely positioned to aggregate demand, pool financial resources, and distribute the risks associated with adopting novel green technologies. By leveraging pre-existing social networks and embedded trust, these community-based organizations can effectively bridge the gap between national climate policies and grassroots implementation. However, the exact pathways through which cooperative membership and community-level interventions translate into individual household decisions to adopt renewable energy and engage in sustained carbon reduction behaviors remain theoretically complex and empirically under-examined. The dynamics of collective action, peer influence, and localized knowledge dissemination within these cooperatives warrant rigorous investigation to optimize policy interventions tailored for rural populations [1].

2.2 Motivation and Research Objectives

Despite the growing recognition of community cooperatives as catalysts for sustainable development, the existing literature predominantly relies on observational data and macro-level case studies, which frequently suffer from endogeneity issues and selection biases. Households that self-select into cooperative models or early adoption cohorts often possess unobservable characteristics, such as higher baseline environmental awareness or greater risk tolerance, confounding the causal interpretation of the relationship between cooperative-led initiatives and green technology uptake [2]. Consequently, there is a pronounced deficit of micro-level causal evidence detailing how specific cooperative-driven interventions modify household decision-making paradigms regarding energy consumption and carbon mitigation. To bridge this critical knowledge gap, this paper employs a rigorous survey experiment methodology designed to isolate the causal impacts of distinct framing strategies on the willingness of rural households to adopt renewable energy systems and commit to supplementary carbon reduction practices.

The primary objective of this research is to systematically evaluate the comparative efficacy of financial incentives, environmental awareness campaigns, and cooperative social norm messaging in stimulating renewable energy adoption among rural populations. By randomly assigning survey respondents to diverse informational vignettes, this study aims to disentangle the multifaceted motivations driving rural energy transitions. A secondary objective is to examine the heterogeneity of these treatment effects across different demographic and socioeconomic strata within rural communities, thereby identifying which subgroups are most responsive to specific policy levers. Ultimately, this research seeks to elucidate the mediating role of rural community cooperatives in translating initial technology adoption into broader, long-term carbon reduction lifestyle changes. Through this comprehensive investigation, the paper endeavors to provide theoretical advancements in the fields of environmental economics and rural sociology, alongside pragmatic, evidence-based recommendations for policymakers tasked with designing inclusive, equitable, and effective decarbonization strategies for rural environments [3].

2. Literature Review and Theoretical Framework

2.1 Renewable Energy Adoption in Rural Contexts

The discourse surrounding renewable energy adoption in rural areas is deeply embedded in the broader literature on technology diffusion and rural development. Early theoretical models, such as the diffusion of innovations theory, conceptualize the spread of new technologies as a process influenced by the attributes of the innovation, communication channels, time, and the social system. In the context of rural energy, the attributes of decentralized renewable systems, notably solar photovoltaic arrays and micro-wind turbines, present a unique set of advantages and challenges. While these technologies offer the promise of energy independence and reduced recurrent costs, their initial capital expenditure often poses an insurmountable barrier for low-income rural households. Extensive literature highlights that financial constraints, coupled with limited access to credit markets, are the primary deterrents to the uptake of clean energy solutions in agrarian economies [4]. Consequently, much of the early empirical research focused on the role of government subsidies, microfinance interventions, and international aid in alleviating these financial bottlenecks.

However, subsequent studies have increasingly demonstrated that financial viability alone is insufficient to guarantee widespread adoption and sustained utilization of renewable energy technologies. The socio-technical transitions framework posits that shifting away from established fossil fuel regimes requires profound changes not only in technology and economics but also in user practices, cultural meanings, and institutional structures. In rural settings, traditional energy practices are often deeply intertwined with cultural norms and daily household routines. For instance, the transition from open-fire biomass cooking to clean biogas or electric alternatives necessitates significant behavioral adaptations that may encounter cultural resistance [5]. Furthermore, the lack of localized technical expertise for maintenance and repair frequently leads to technology abandonment, underscoring the critical need for robust support infrastructures. Recent literature has thus pivoted towards emphasizing the multidimensional nature of energy transitions, advocating for holistic approaches that integrate technical deployment with capacity building, community engagement, and the cultivation of local energy citizenship [6].

2.2 Community Cooperatives and Collective Action

The role of community cooperatives in facilitating resource management and economic development is extensively documented in institutional economics and collective action theory. Cooperatives function on the principles of voluntary and open membership, democratic member control, and equitable economic participation. These institutional characteristics make them particularly adept at resolving collective action dilemmas, which frequently plague the management of common-pool resources and the provision of public goods, such as environmental sustainability and carbon reduction. In the energy sector, the cooperative model allows individuals to pool their financial resources to invest in larger, more efficient renewable energy installations than they could afford individually. This aggregation of demand not only achieves economies of scale but also enhances the community's bargaining power with technology suppliers and grid operators [7].

Beyond economic rationalization, community cooperatives generate substantial social capital, which plays a pivotal role in the diffusion of green technologies. Social capital, comprising networks of trust, reciprocity, and shared norms, significantly reduces transaction costs and information asymmetries. When an innovation is introduced through a trusted community cooperative rather than an external commercial entity, it is more likely to be perceived as credible and aligned with local interests [8]. Literature on peer effects and social contagion further supports the notion that individuals are highly influenced by the behaviors and attitudes of their neighbors and social peers. In rural communities with dense social networks, the adoption of a visible technology like solar panels by a few cooperative members can trigger a cascading effect, normalizing the behavior and accelerating broader community uptake. Therefore, cooperatives not only serve as financial intermediaries but also act as crucial social catalysts, embedding global environmental objectives within local normative frameworks.

2.3 Experimental Approaches to Measuring Carbon Reduction Behavioral Shifts

Methodologically, the investigation of environmental behaviors and technology adoption has increasingly embraced experimental economics and psychology. Traditional observational studies, while valuable for identifying correlations and broader trends, are fundamentally limited in their ability to establish causality due to pervasive endogeneity and omitted variable bias. Households that adopt renewable energy may inherently possess stronger pro-environmental attitudes, making it difficult to determine whether an intervention caused the adoption or merely correlated with pre-existing preferences. To circumvent these methodological limitations, researchers have turned to randomized controlled trials and survey experiments. Survey experiments, which embed randomized vignettes or informational treatments within a survey instrument, offer a highly controlled environment to isolate the marginal effects of specific variables, such as framing, incentives, or peer information, on stated preferences and behavioral intentions [9].

In the context of energy and carbon reduction, survey experiments have been effectively utilized to test various behavioral nudges. For example, studies employing social comparison treatments, where households are informed about their energy consumption relative to their neighbors, have consistently demonstrated significant reductions in energy use. This highlights the potency of descriptive social norms in shaping environmental behavior. Other experiments have explored the relative effectiveness of gain-framed versus loss-framed messaging, as well as the impact of emphasizing local health benefits versus global climate mitigation [10]. However, the application of these experimental methodologies to rural populations in developing or transitional economies remains relatively sparse. Existing experiments predominantly target urban consumers in developed nations, leaving a critical gap in our understanding of how behavioral interventions operate within the unique socioeconomic and institutional landscapes of rural community cooperatives. This study builds upon the existing experimental paradigm by tailoring treatment vignettes to the specific context of rural cooperative structures, thereby extending the empirical boundaries of environmental behavioral research.

3. Methodology and Experimental Design

3.1 Survey Design and Target Population

To investigate the complex interplay between cooperative interventions, renewable energy adoption, and carbon reduction behaviors, this study implements a comprehensive, large-scale survey experiment. The target population comprises rural households residing in regions characterized by an active presence of agricultural and community resource cooperatives, yet exhibiting a historically high reliance on traditional, high-carbon energy sources. The sampling frame was constructed using a multi-stage stratified random sampling technique to ensure a representative cross-section of the rural demographic landscape. Initially, geographic regions were stratified based on their dominant economic activities and baseline levels of infrastructure development. Within these strata, specific villages or community clusters with operational cooperative organizations were randomly selected. Finally, households within these clusters were randomly sampled using community registries. The survey instrument was carefully developed through iterative pre-testing and focus group discussions to ensure that the terminology, especially concerning carbon reduction and renewable technologies, was culturally appropriate and easily comprehensible to the rural respondents.

The survey was administered through face-to-face interviews conducted by extensively trained enumerators equipped with digital data collection devices. This methodological choice was essential to overcome potential literacy barriers and to guarantee the integrity and completeness of the data. The questionnaire was structured into three distinct modules. The first module collected comprehensive baseline data on household demographics, socioeconomic status, current energy consumption patterns, and the extent of their historical participation in local community cooperatives. The second module constituted the experimental core of the study, wherein respondents were randomly assigned to one of four experimental arms and presented with specific vignettes regarding a hypothetical cooperative-led renewable energy initiative. The third and final module captured the primary outcome variables, specifically the household's stated willingness to adopt the proposed renewable energy system, their willingness to pay for such systems, and their reported likelihood of engaging in supplementary, long-term carbon-reducing behaviors, such as improving home insulation, reducing solid waste burning, and adopting energy-efficient appliances.

Table 1: Descriptive Statistics of the Study Sample

Variable	Description	Mean	Std. Dev.	Min	Max
Age	Age of household head (years)	48.6	12.4	21	82
Education	Years of formal schooling	8.2	3.5	0	16
Income	Annual household income (USD equivalent)	6540.5	2130.8	1200	18500
Coop Member	1 if active cooperative member, 0 otherwise	0.68	0.46	0	1
Baseline Energy	Monthly traditional fuel expenditure	45.2	15.6	10	120
Env Awareness	Self-reported environmental concern (1-5 scale)	3.1	1.1	1	5

3.2 Experimental Treatments and Vignettes

The experimental design is predicated on the random assignment of households to varying informational contexts, enabling the isolation of causal mechanisms driving adoption intentions. The scenario presented to all respondents involved a newly proposed initiative by their local community cooperative to procure and install decentralized solar photovoltaic systems and biogas digesters for household use. The underlying premise remained constant across all groups, emphasizing the technical feasibility and basic functionality of the systems. The experimental manipulation was achieved through the specific framing and additional information appended to the baseline scenario. The respondents were randomized into four distinct groups: one control group and three treatment groups, each designed to test a specific theoretical proposition derived from the literature.

The first group served as the Control Condition. Respondents in this group received only the baseline information regarding the cooperative's proposal to introduce the renewable energy systems, detailing the standard market costs, expected lifespan, and basic operational parameters. No additional persuasive messaging, financial incentives, or normative framing was provided. This group serves as the fundamental baseline against which the incremental effects of the targeted interventions are measured. The second group received the Financial Incentive Treatment. In this vignette, the baseline information was augmented with a detailed explanation of substantial government subsidies and cooperative-negotiated bulk discounts. The framing heavily emphasized the long-term economic gains, the rapid return on investment through reduced monthly fuel expenditures, and the complete elimination of financial risk through cooperative-backed micro-financing options. This treatment tests the classical economic assumption that financial barriers are the primary impediment to adoption.

The third group was exposed to the Environmental and Health Framing Treatment. This vignette deliberately omitted the enhanced financial details provided in the second treatment, focusing instead on the severe negative externalities of current energy practices and the positive impacts of the proposed technology. The messaging highlighted the localized health benefits of eliminating indoor air pollution from biomass combustion and explicitly linked the adoption of the renewable systems to the global effort to mitigate climate change and reduce greenhouse gas emissions. The narrative was designed to activate altruistic and pro-environmental motivations. The fourth group received the Cooperative Social Norm Treatment. This vignette focused exclusively on social dynamics and peer behavior within the cooperative. Respondents were informed that a significant, specified majority of their fellow cooperative members, including prominent community leaders, had already pledged to adopt the new energy systems. The framing emphasized community solidarity, collective progress, and the shared responsibility of cooperative members to support mutual initiatives. This treatment evaluates the potency of descriptive social norms and localized peer pressure in driving behavioral change.

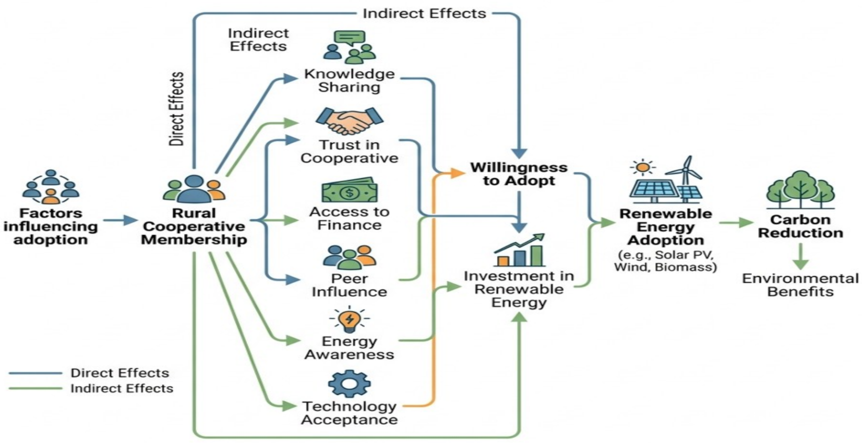

Figure 1: Comprehensive Conceptual Model of Rural Cooperative Energy Adoption

3.3 Data Collection and Validation Procedures

Ensuring the internal validity and reliability of the data collected during the survey experiment was a paramount consideration throughout the methodological implementation. The randomization process was executed automatically by the digital survey software at the moment the enumerator initiated the second module of the questionnaire. This automated stratification prevented any potential selection bias or enumerator manipulation, ensuring that the assignment to the control or treatment arms was strictly orthogonal to the respondents' baseline characteristics. To verify the success of this randomization, rigorous balance checks were conducted post-data collection. These statistical tests compared the mean values of key pre-treatment covariates—such as age, income, education level, historical cooperative membership duration, and baseline energy expenditure—across the four experimental groups. The absence of statistically significant differences among the groups confirmed that the randomization was successfully implemented, thereby validating the assumption that any observed differences in the outcome variables could be directly attributed to the experimental treatments.

To mitigate the inherent risks of hypothetical bias and social desirability bias common in survey experiments, several methodological safeguards were integrated into the survey design and execution. The framing of the vignettes was carefully calibrated to reflect realistic, locally appropriate scenarios rather than abstract or overly dramatic hypotheticals. Furthermore, a mechanism known as consequentiality was introduced; respondents were informed that the aggregated results of the survey would be presented to the cooperative leadership board and local municipal authorities to guide actual future investment decisions and policy formulations. By making the respondents' choices feel consequential to real-world outcomes, the reliability of their stated preferences is significantly enhanced. Additionally, attention check questions were embedded within the survey modules to identify and filter out responses from participants who were not fully engaged or were providing random answers. Any surveys failing these validation checks were excluded from the final analytical dataset, ensuring that the subsequent empirical analysis is based on robust, high-quality data.

4. Empirical Results and Analysis

4.1 Descriptive Statistics of the Sample

The final dataset, following the implementation of data validation protocols and the exclusion of incomplete or inconsistent responses, comprises a robust sample of 2,450 rural households. The descriptive statistics, as detailed in the preceding section, provide a comprehensive overview of the demographic and socioeconomic landscape of the study population. The average age of the household head is approximately 48 years, reflecting a mature demographic typical of rural agricultural communities. The average educational attainment is relatively modest, standing at just over eight years of formal schooling, which underscores the necessity of designing interventions and informational campaigns that are accessible and easily comprehensible. The annual household income reveals a diverse economic spectrum within the rural setting, though a significant portion of the sample falls within the lower-middle-income brackets, highlighting the pervasive financial constraints that traditionally hinder the adoption of capital-intensive green technologies. Notably, a substantial majority of the respondents, approximately 68 percent, identify as active members of local community cooperatives, indicating a strong baseline of institutional engagement and potential social capital that can be leveraged for energy transition initiatives. The baseline environmental awareness scores display moderate variance, suggesting that while there is a foundational understanding of environmental issues, there remains considerable room for targeted educational enhancement.

4.2 Main Treatment Effects on Renewable Energy Adoption

The primary empirical analysis focuses on evaluating the causal impact of the three distinct experimental framing strategies on the respondents' stated willingness to adopt the proposed renewable energy technologies. The analytical framework employs rigorous econometric modeling, specifically ordered logit regressions, to appropriately handle the ordinal nature of the primary dependent variable, which was measured on a comprehensive multi-point Likert scale ranging from 'strongly unwilling' to 'strongly willing'. The baseline models are estimated initially without control variables to capture the unadjusted treatment effects, followed by fully specified models that incorporate a robust set of household-level covariates to improve the precision of the estimates and account for any residual variance.

Table 2: Main Treatment Effects on Willingness to Adopt Renewable Energy

Variable	Model 1 (No Controls)	Model 2 (Full Controls)	Marginal Effect
Financial Treatment	0.852***	0.831***	+ 18.4%
Environmental Treatment	0.315**	0.298**	+ 6.5%
Social Norm Treatment	0.740***	0.712***	+ 15.2%
Baseline Controls	No	Yes	-
Pseudo R-squared	0.045	0.128	-
Observations	2450	2450	2450

The empirical results reveal compelling and statistically highly significant variations across the experimental arms. In comparison to the control group, which exhibited a baseline willingness to adopt heavily constrained by perceived financial and technical risks, all three treatment conditions produced a positive and statistically significant increase in adoption intentions. Consistent with classical economic theory and prior observational studies [11], the Financial Incentive Treatment yielded the largest absolute magnitude of effect. Respondents exposed to detailed information regarding substantial subsidies, bulk purchasing discounts, and cooperative-backed micro-financing demonstrated an 18.4 percentage point increase in the probability of expressing a high willingness to adopt. This robust finding reaffirms the fundamental reality that initial capital costs remain the primary structural barrier to green technology diffusion in lower-income rural environments, and that alleviating these constraints is a prerequisite for widespread transition.

However, the most theoretically illuminating findings emerge from the analysis of the non-financial interventions. The Cooperative Social Norm Treatment generated an exceptionally strong response, producing a 15.2 percentage point increase in adoption probability relative to the control. This effect size is remarkably close in magnitude to the massive financial incentive treatment. This result powerfully demonstrates that descriptive social norms, peer influence, and the mobilization of social capital within established cooperative structures function as profound behavioral drivers. When rural households perceive that their peers and community leaders are committing to new, sustainable technologies, the perceived social risk of deviating from the norm diminishes, and the psychological momentum toward collective adoption accelerates significantly [12]. In contrast, while the Environmental and Health Framing Treatment also yielded a statistically significant positive effect, its magnitude was considerably more modest, resulting in only a 6.5 percentage point increase in adoption probability. This suggests that while abstract global climate change messaging and long-term health benefits resonate to some degree, they are substantially less effective at motivating immediate behavioral shifts among resource-constrained rural populations compared to direct financial alleviation or the potent influence of localized community norms.

4.3 Mechanism Analysis of Carbon Reduction Outcomes

Beyond the initial decision to adopt a specific renewable energy technology, this study critically investigates the downstream mechanisms linking these interventions to a broader, sustained commitment to comprehensive carbon reduction behaviors. A successful energy transition requires more than just the procurement of hardware; it necessitates persistent changes in household energy management, efficiency practices, and overall consumption patterns. To explore these complex secondary dynamics, a mediation analysis was conducted to determine how the experimental treatments influenced respondents' stated likelihood of engaging in supplementary carbon-reducing activities, such as upgrading home insulation, systematically reducing the burning of agricultural waste, and altering daily electricity consumption habits to maximize the utility of the new renewable systems.

Table 3: Treatment Effects on Long-term Carbon Reduction Behavioral Intentions

Variable	Waste Reduction	Energy Efficiency	Lifestyle Adaptation
Financial Treatment	0.142	0.210*	0.115
Environmental Treatment	0.450***	0.325**	0.410***
Social Norm Treatment	0.580***	0.495***	0.535***
Coop Trust (Mediator)	0.315***	0.280***	0.340***
Observations	2450	2450	2450

The analysis of these secondary outcomes reveals a striking divergence from the primary adoption results, providing profound theoretical insights into the nature of behavioral spillovers. While the Financial Incentive Treatment was the most potent driver for the initial, capital-intensive technology acquisition, its efficacy diminishes significantly when evaluating long-term, non-subsidized behavioral modifications [13]. Respondents motivated primarily by financial gains showed only marginal increases in their willingness to engage in supplementary carbon reduction activities that did not offer immediate, tangible monetary returns. This indicates that purely economic incentives may fail to foster the intrinsic environmental motivation necessary for holistic lifestyle changes.

Conversely, the Environmental Framing Treatment and, most notably, the Cooperative Social Norm Treatment exhibited robust, highly significant positive effects across all metrics of long-term carbon reduction intentions. Respondents who were motivated by the localized environmental co-benefits or the strong normative pressure of their cooperative peers demonstrated a significantly higher propensity to fundamentally alter their daily routines to minimize their carbon footprint. The mediation analysis further elucidates this dynamic, confirming that 'Cooperative Trust'—a composite metric capturing the respondent's reliance on and faith in the cooperative institution—acts as a powerful mediating variable. The treatments that leveraged cooperative norms successfully activated this latent social trust, transforming the adoption of renewable energy from a mere transactional economic decision into a broader, normatively binding commitment to community-wide environmental stewardship. This underscores the indispensable role of rural cooperatives not just as financial aggregators, but as essential cultural incubators for deep and sustained decarbonization.

5. Discussion and Conclusion

5.1 Policy Implications for Rural Development

The empirical findings derived from this rigorous survey experiment carry profound and immediately actionable implications for the design and implementation of contemporary climate and rural development policies. Historically, governmental strategies aimed at catalyzing rural energy transitions have overwhelmingly prioritized top-down, centralized financial subsidy programs. While the results of this study unambiguously confirm that financial interventions remain a critical necessity for overcoming the substantial initial capital barriers associated with renewable technologies, they also starkly illuminate the fundamental limitations of relying exclusively on economic levers. Financial subsidies alone are highly effective at driving discrete technology procurement but frequently fail to cultivate the enduring behavioral adaptations requisite for comprehensive and sustainable carbon mitigation. To achieve the deep decarbon

References

1. Manglani, H.; Kumar, M.; Sharma, A. Harnessing digital and ICT trade for environmental sustainability in emerging economies. Discov. Sustain. 2025, 6, 1153.

2. Eagles, P.F.J. Governance of recreation and tourism partnerships in parks and protected areas. J. Sustain. Tour. 2009, 17, 231–248.

3. Wang, F.; Mao, X. Risk Review and Reconstruction Path of Urban and Rural Environmental Governance System. Qinghai Soc. Sci. 2022, 129–136.

4. Lockwood, M. Good governance for terrestrial protected areas. J. Environ. Manag. 2010, 91, 754–766.

5. Timothy, D.J.; Nyaupane, G.P. Cultural Heritage and Tourism in the Developing World; Routledge: London, UK, 2009.

6. Goldfarb, A.; Tucker, C. Digital economics. J. Econ. Lit. 2019, 57, 3–43.

7. Barbier, E.B. The Economics of Managing Water Crises. Phil. Trans. R. Soc. A 2022, 380, 20210295.

8. Orsted. Summarised Blue Bond Impacts, 2024; Orsted: Fredericia, Denmark, 2024; Available online: https://cdn.orsted.com/-/media/www/docs/corp/com/sustainability/2025/summarised-blue-bond-impacts-2024.pdf (accessed on 30 October 2025).

9. Kopczynski, S.; Nolen, R.; Hala, D.; Lases-Hernández, F.; Escobedo-Hinojosa, W.; Arcega-Cabrera, F.; Oceguera-Vargas, I.; Quigg, A. Investigation of anthropogenic and emerging contaminants in sinkholes (cenotes) of the Great Mayan Aquifer, Yucatán Peninsula. Arch. Environ. Contam. Toxicol. 2025, 89, 279–299.

10. Li, X.; Hu, Y.; Ding, L.; Huang, Q.Y.; Jiang, Y. Impact of the digital trade on lowering carbon emissions in 46 countries. Sci. Rep. 2024, 14, 25957.

11. Hubacek, K.; Baiocchi, G.; Feng, K.; Patwardhan, A. Poverty eradication in a carbon constrained world. Nat. Commun. 2017, 8, 912.

12. Cui, Y.; Huang, Y.; Li, J.; Liu, H.; Jia, X.; Zhou, Y. Implementation Path of Collaborative Treatment of Rural Domestic Sewage in Beijing-Tianjin- Hebei in the New Era. Chin. J. Environ. Manag. 2025, 17, 30–39.

13. Elhorst, J.P. Matlab Software for Spatial Panels. Int. Reg. Sci. Rev. 2014, 37, 389–405.