

Original Paper

The Impact of Greenfield Investment in Renewables on Energy Poverty

Xiong Chen^a & Gan Lin^{a*}

^a Business School, University of Shanghai for Science and Technology, Shanghai, P.R. China

* Corresponding author

Received: September 26, 2026 Accepted: October 11, 2026 Online Published: October 22, 2026

doi:10.22158/ibes.v8n4p74

URL: <http://dx.doi.org/10.22158/ibes.v8n4p74>

Abstract

Renewable Energy Greenfield Investments may influence energy poverty by expanding access to modern energy, affecting the cost of energy use, and improving the availability of clean energy services. This relationship is examined against the background of the global energy transition and the Sustainable Development Goals. Using a panel of 153 countries over 2003–2023, the study estimates a two-way fixed effects model and conducts endogeneity and robustness tests. The estimates indicate a significant negative association between Renewable Energy Greenfield Investments and energy poverty. The size of this association differs across countries and regions and is greater among non-high-income economies. An additional analysis incorporating the interaction between investment and electricity consumption finds a stronger poverty-alleviating effect in countries where electricity consumption is relatively low. These findings suggest that the contribution of renewable energy greenfield investment to energy poverty alleviation depends partly on the prevailing level of electricity use. The paper also discusses the policy implications of the empirical evidence.

Keywords

greenfield investment, renewable energy, energy poverty alleviation

1. Introduction

Energy is a fundamental material basis for economic growth, improvement in living standards, and enhancement of social welfare. For a long time, energy poverty has not only reflected the lack of stable, affordable, and clean modern energy services, but has also further widened development gaps across countries and social groups by restricting access to education, health care, productive activities, and information. Sustainable Development Goal 7 (SDG 7) calls for access to ‘affordable, reliable, sustainable and modern energy for all.’ Progress toward this target, however, has not been sufficient to

ensure its achievement by 2030. As noted in the United Nations Sustainable Development Goals Report 2024, substantial populations are expected to remain without electricity and clean cooking energy in the absence of further policy changes (United Nations, 2024).

Against this background, the analysis draws on observations for 153 countries between 2003 and 2023 to assess the relationship between Renewable Energy Greenfield Investments and energy poverty. The baseline specification includes country and year fixed effects. It therefore accounts for persistent national characteristics, including institutional settings, resource endowments, and geography, alongside shocks shared across countries in a given year. Endogeneity tests and several robustness checks are used to assess the stability of the estimates. The empirical analysis also considers whether the relationship differs by the severity of energy poverty, geographical region, and national income category. Finally, electricity consumption is incorporated into a moderating-effect analysis to investigate whether the relationship between greenfield investment and energy poverty varies with households' ability to use electricity and the availability of electricity services.

A lack of an electricity connection is only one aspect of energy poverty. Limited energy services, high costs relative to household resources, inadequate access to clean cooking, and poor quality of energy use also contribute to deprivation. González-Eguino (2015) links energy poverty to consequences for health, education, and social equity, arguing for its consideration within development policy. Nussbaumer et al. (2012) similarly caution against relying exclusively on a single indicator of access. Their multidimensional approach takes account of electricity, cooking, the quality of energy services, and household welfare. Evidence from African countries further associates energy poverty with shortcomings in governance, ageing infrastructure, access constraints, and elevated energy prices (Leal Filho et al., 2024). These distinctions matter because a household may have an electricity connection while still being unable to afford adequate consumption, obtain clean cooking energy, or rely on continuous service. Taken together, these contributions imply that increasing energy supply is insufficient where services remain unreliable, unaffordable, or unevenly distributed. Identifying the factors associated with energy poverty is therefore relevant both to SDG 7 and to the inclusiveness of the energy transition.

Research on the determinants of energy poverty has considered both socioeconomic conditions and the wider economic environment. Education, human capital, and household capabilities are prominent in one group of studies: more education may help residents obtain, understand, and use modern energy services. Using a panel of 30 developing economies, Apergis et al. (2022) report a negative relationship between education and energy poverty that persists across alternative energy-poverty measures. The emphasis on educational attainment is therefore not confined to a single definition of deprivation; it concerns how households can translate available infrastructure into effective energy use. Other work examines financial development, digitalization, institutional quality, and external disturbances. In their discussion of geopolitical risks and natural disasters, Ali et al. (2026) identify disruptions to energy supply chains, price movements, infrastructure damage, and the capacity of financial markets to absorb

shocks as relevant influences. They also identify digitalization, economic growth, and political freedom as factors associated with lower energy poverty. These analyses move beyond household resources to consider the external economic and institutional conditions under which modern energy services are provided. Renewable energy has become another focus of this literature. Zhao et al. (2022), using international data, find that renewable energy development contributes to energy poverty alleviation, partly through improvements in energy efficiency, although the estimates vary by region. From the perspective of the finance–renewables relationship, Mukhtarov and Mikayilov (2023) argue that investment in renewable energy projects, supported by financial institutions, can improve access to modern energy and reduce reliance on fossil fuels. These findings inform the present examination of investment rather than energy consumption alone.

The existing evidence nevertheless leaves several questions open. Much of the literature addresses renewable energy consumption, energy efficiency, or financial development, whereas Renewable Energy Greenfield Investments has received less direct attention as a source of new energy capacity. Unlike consumption measures, such investment is closely connected to the construction of clean-energy facilities, additions to generating capacity, and changes in the energy-supply system. Those investments may be necessary before renewable resources can be delivered as usable energy services. A further issue concerns empirical coverage: studies centered on individual countries, particular regions, or developing-economy samples provide a less extensive basis for comparison at the global level. The relationship may also differ substantially across settings. Investment in solar photovoltaics, wind, hydropower, and distributed energy systems can expand supply, but this does not ensure that households will receive affordable services. Electricity grids, access to finance, and energy-pricing arrangements affect whether new capacity becomes available to users. The cross-country analysis therefore considers both the overall association between Renewable Energy Greenfield Investments and energy poverty and its variation across different groups of economies.

This paper extends the discussion in four related respects. It examines Renewable Energy Greenfield Investments, rather than focusing solely on renewable energy consumption, to capture the relevance of capital expenditure and new clean-energy infrastructure to energy poverty. It also uses a long panel covering 153 countries, providing scope for comparisons across income groups and geographical regions. Beyond the average relationship, the analysis estimates differences associated with the level of energy poverty, geographical location, and income classification. The final component considers electricity consumption as a condition shaping the investment–poverty relationship. This makes it possible to assess whether the connection between capital committed to renewable energy facilities and the energy services used by residents varies with existing electricity consumption.

The estimates indicate that greater Renewable Energy Greenfield Investments is associated with a significant reduction in energy poverty in the full sample, consistent with possible welfare and development benefits alongside environmental gains. The magnitude of the estimated relationship is not uniform across economies. It is particularly pronounced among non-high-income countries and

countries facing higher levels of energy poverty. The analysis of electricity consumption provides further evidence on the conditions under which greenfield investment is associated with lower energy poverty. In particular, the estimates suggest a stronger effect where electricity consumption is lower, consistent with the importance of electricity supply, the extent of actual electricity use, and access to modern energy services. These results place the distribution of investment benefits, rather than investment volumes alone, at the center of the analysis.

The paper is organized into six sections. Section 2 reviews research on renewable energy and energy poverty, followed by the theoretical framework and hypotheses in Section 3. Section 4 describes the empirical specification, variables, and data. Section 5 examines the estimation results, including their robustness and heterogeneity, and Section 6 sets out the conclusions and policy recommendations.

2. Literature Review

The contemporary world faces three major challenges in the energy sector, namely energy poverty, energy supply security and climate change (IEA et al., 2025). Among these issues, energy poverty has received less attention than the other two topics. With socioeconomic development, energy poverty is no longer simply a matter of having no energy, but rather a systematic deficiency in the availability, affordability, cleanliness and reliability of modern energy services. The global context further highlights the importance of this issue. SDG7 aims to ensure access to affordable, reliable, sustainable and modern energy for all. The 2025 Tracking SDG7: The Energy Progress Report indicates that the global basic electricity access rate has approached 92%, yet more than 666 million people still lack electricity, and progress in clean cooking remains evidently lagging (IEA et al., 2025). This implies that even as the global energy transition continues to accelerate, energy poverty may persist through price shocks, inadequate infrastructure, cost pass-through of clean energy and exposure to climate risks.

Regarding the causes of energy poverty, most scholars regard insufficient income, high energy prices, and low housing or equipment energy efficiency as the three major roots of energy poverty. Research on the V4 countries explicitly argues that energy poverty can be attributed to low income, high energy prices and weak energy efficiency. The empirical results show that the Gini index is significantly and positively associated with energy poverty indicators, whereas GDP per capita growth helps mitigate energy poverty (Simionescu & Cifuentes-Faura, 2024). Nguyen and Nasir, using data from 51 economies from 2002 to 2014 and applying panel Granger causality, 2SLS, 3SLS and system GMM approaches, find that income inequality increases energy poverty across multiple dimensions. Conversely, a reduction in energy poverty also contributes to lowering income inequality (Nguyen & Nasir, 2021). Energy efficiency plays a dual role in both the formation and governance of energy poverty. Low-efficiency housing and appliances increase the real cost of obtaining the same level of energy services, making low-income households more likely to fall into bill arrears or be forced to reduce energy consumption. Meanwhile, improving energy efficiency is also an important mediating mechanism through which renewable energy alleviates energy poverty (Zhao et al., 2022).

Moving ahead, we briefly review the literature on the measurement of energy poverty. The early strand of energy poverty research relates closely to the concept of fuel poverty. Boardman argues that households may fall into fuel poverty when they must spend an excessively high proportion of their income to maintain adequate warmth (Boardman, 1991). This definition is particularly suitable for explaining the combined effects of high energy prices, poor building energy efficiency and low income in developed economies. As the literature extends to developing countries, the core meaning of energy poverty has shifted toward the lack of modern energy services. Pachauri and Spreng classify the measurement of energy poverty into three approaches, namely the technical threshold, physical threshold and economic threshold, corresponding respectively to access to modern energy services, basic energy consumption needs and the burden of energy expenditure (Pachauri & Spreng, 2011). Sovacool further points out from a political economy perspective that energy poverty closely links to the energy ladder, energy justice, public health, gender division of labor and environmental degradation (Sovacool, 2012). Hence, energy poverty is a highly complex and multidimensional concept. Although early studies mainly focused on single-indicator assessment, an increasing number of scholars tend to evaluate energy poverty from a comprehensive perspective. Specifically, the European Union (EU) fuel poverty assessment uses three proxy indicators: arrears on utility bills, the affordability of keeping the home adequately warm, and the presence of a leaking roof, damp walls or rotten windows. This index is used to examine the extent to which consumers lack access to modern energy services (Thomson & Snell, 2013). Nussbaumer et al. propose the Multidimensional Energy Poverty Index (MEPI), which simultaneously reflects the incidence and intensity of energy poverty (Nussbaumer et al., 2012). Che et al. further employ rough set theory, large-scale questionnaires and an improved TOPSIS method to construct a global energy poverty assessment framework, incorporating energy availability, affordability and cleanliness into a unified indicator system, and show that global energy poverty has generally improved (Che et al., 2021).

After scholars effectively measure energy poverty, they tend to assess its potential socioeconomic consequences. Existing studies show that energy poverty closely correlates with health and education outcomes in developing countries (Banerjee et al., 2021). The health impacts of energy poverty include not only direct channels such as indoor air pollution and exposure to cold or heat, but also indirect channels such as inadequate medical services, vaccine cold chains, lighting, drinking water and sanitation. Pan, Biru and Lettu use data from 175 countries from 2000 to 2018 and apply Oster's bounding analysis and system GMM to identify causal effects. Their results show that energy poverty has a significant negative impact on public health. Living standards constitute an important channel through which energy poverty affects health, and higher living standards weaken this adverse effect (Pan et al., 2021). Rao et al. show that achieving decent living conditions requires a minimum level of energy embodied in housing, mobility, nutrition, health, education, and other basic services (Rao et al., 2019). Micro-level studies from Europe and Australia also indicate that households experiencing fuel poverty or energy poverty generally have worse physical and mental health outcomes than

non-energy-poor households (Thomson et al., 2017). This suggests that policymakers should not treat the governance of energy poverty only as an energy-sector issue, but should also incorporate it into public health, housing policy, social security and child development policies. Lipscomb et al. (2013) provide evidence from Brazil that electrification can generate broad development gains by improving access to productive energy services. Similarly, Lenz et al. (2017) examine Rwanda's electricity access roll-out programme and show that large-scale infrastructure investment can substantially increase electricity connections, alleviated local energy poverty. Overall, it is necessary to accelerate the mitigation of energy poverty. A key pathway is to speed up the transformation of the energy structure, namely shifting from traditional fossil fuels toward clean and renewable energy. Based on data from 96 solar-electrified households and 113 non-electrified households in Ghana (Obeng et al., 2008), relevant research empirically examines the alleviating effect of solar photovoltaic (PV) rural electrification on energy poverty in rural areas. Zhao et al., using balanced panel data from 64 countries from 2000 to 2014 and a system GMM approach, find that renewable energy consumption growth helps reduce global energy poverty and can also generate an indirect mitigation effect by improving energy efficiency (Zhao et al., 2022). From a policy perspective, distributed photovoltaics, microgrids, clean cooking and renewable energy infrastructure can expand the coverage of modern energy services, especially in remote areas and regions where grid extension costs are relatively high. Using the Multidimensional Energy Poverty Index, Sadath and Acharya (2017) examine the incidence and intensity of energy deprivation among Indian households and document its relationship with wider socioeconomic conditions. Their analysis is relevant here because investment in renewable energy facilities may affect energy poverty through more than one dimension: access to electricity, the use of cleaner energy, and the quality of the services households can obtain.

Clearly, energy poverty has a substantial impact on the sustainable development of the international community and has attracted increasing academic attention. Existing studies mainly focus on energy poverty in a single country or a specific region, while quantitative assessments of global energy poverty remain insufficient. More importantly, the relationship between renewable energy and energy poverty has not yet received adequate attention in the literature. In addition, the differentiated effects of renewable energy in mitigating energy poverty across regions and the underlying mechanisms deserve further investigation.

3. Theoretical framework and hypotheses

3.1 The Impact of Renewable Energy Greenfield Investments on Energy Poverty

First, Renewable Energy Greenfield Investments usually accompanies infrastructure construction and technological upgrading, which helps break the limitations of traditional energy supply and improve the regional energy structure (Sovacool, 2012). Through the large-scale development of renewable energy sources such as wind and solar power, countries can effectively increase the total supply of modern clean energy, thereby ensuring energy supply and serving the basic needs of broad populations.

Meanwhile, as renewable energy technologies continue to mature and economies of scale gradually emerge, the levelized cost of electricity (LCOE) has declined. Such technological progress can reduce end-user energy costs in the long run, accelerate the diffusion of green energy in daily life, and thus reduce the multidimensional energy poverty index from multiple perspectives, such as access and affordability (Thomson & Snell, 2013).

Second, governments or social capital can alleviate income inequality and energy deprivation through economic spillover effects by increasing support for green innovation and Renewable Energy Greenfield Investments (Dong et al., 2022). The energy transition creates a large number of new employment opportunities. The construction, operation and maintenance of renewable energy projects provide local residents, especially low-income groups, with pathways to enter the modern labor market, thereby significantly promoting local employment and increasing absolute income levels (Dinkelman, 2011). This increase in income directly weakens household financial constraints, enabling households to afford modern clean energy and reducing their dependence on traditional and inefficient biomass energy. Based on this, present study proposes the following hypothesis:

Hypothesis 1: Renewable Energy Greenfield Investments can effectively alleviate energy poverty.

3.2 Heterogeneous Impact of Renewable Energy Greenfield Investments on Energy Poverty

The process of energy transition has profoundly reshaped social lifestyles. However, technological progress and investment dividends often reach groups with different resource endowments and poverty depths unevenly, showing differentiated landscapes of vulnerability (Thomson et al., 2017). The implementation effect of Renewable Energy Greenfield Investments closely relates to local infrastructure conditions, household credit constraints and the capacity to absorb new technologies.

According to the energy ladder hypothesis, the upgrading of household energy consumption depends not only on an increase in macro-level supply, but also heavily on the ability of micro-level agents to overcome switching costs (van der Kroon et al., 2013). For regions with mild energy poverty, relatively complete supporting infrastructure, such as microgrids, is often available, allowing Renewable Energy Greenfield Investments to transform more efficiently into energy welfare for local residents. However, as the degree of energy poverty deepens, regions suffering from severe energy poverty usually face strong equipment lock-in effects and institutional barriers. Constrained by extremely low income, these households are unable to pay the high initial fixed costs required to switch from traditional coal or firewood to clean electricity, such as purchasing modern electric cooking appliances or electric heating equipment. In addition, severely energy-poor areas often lie in remote regions and lack infrastructure such as energy storage and distribution networks, making it difficult to absorb large-scale new energy investment. This mismatch among resources, infrastructure and human capital creates high thresholds for severely energy-poor groups in the energy transition, so that the cost-reduction and income-increasing dividends of Renewable Energy Greenfield Investments cannot precisely reach the poorest groups. Therefore, the mitigation effect of investment may exhibit a nonlinear pattern of diminishing marginal returns.

Different geographical regions differ significantly in resource endowments, energy structures, infrastructure levels and policy support (Zhao et al., 2022), which may lead to regional differences in the energy-poverty-alleviating effect of Renewable Energy Greenfield Investments. Some countries in the Asia-Pacific region, the Americas and Africa still face strong constraints in energy access and serious infrastructure shortcomings; therefore, Renewable Energy Greenfield Investments may have greater marginal improvement potential in these regions. National income level also affects the capacity for energy infrastructure construction, household energy affordability and the absorption capacity of clean energy technologies. The World Bank commonly classifies economies into low-income, lower-middle-income, upper-middle-income and high-income groups based on GNI per capita, providing a basis for comparing energy poverty across countries at different stages of development. Non-high-income countries often face more severe energy access constraints and larger energy infrastructure gaps, suggesting that Renewable Energy Greenfield Investments may have greater room to improve energy poverty in these economies. Based on this, present study proposes the following hypothesis:

Hypothesis 2: The alleviating effect of Renewable Energy Greenfield Investments on energy poverty exhibits significant heterogeneity and relates to the degree of energy poverty, geographical location and income level.

3.3 Moderating Effect of Electricity Consumption in the Renewable Energy Greenfield Investments-energy Poverty Nexus

A country's initial level of electricity consumption may influence the alleviating effect of Renewable Energy Greenfield Investments on energy poverty. Bhattacharyya points out that improvements in energy access depend not only on energy supply itself, but also on the sustainability of electrification projects, infrastructure conditions and the choice of service models (Bhattacharyya, 2012). Khandker et al., based on evidence from Bangladesh, find that rural electrification significantly improves household income, expenditure and educational outcomes (Khandker et al., 2012). Dinkelman's research on rural electrification in South Africa also shows that electricity access can promote employment growth by saving household labor time and improving production conditions (Dinkelman, 2011). Therefore, for countries with lower electricity consumption levels, insufficient energy supply, weak infrastructure and a lack of modern energy services are usually important sources of energy poverty. In this context, additional Renewable Energy Greenfield Investments is more likely to transform into improved electricity accessibility and better energy services, implying a stronger marginal effect. By contrast, in countries with higher electricity consumption levels, Renewable Energy Greenfield Investments is more likely to support energy structure optimization and low-carbon substitution, leaving relatively limited room for direct improvement in energy poverty. Based on this, present study proposes the following hypothesis:

Hypothesis 3: Electricity consumption plays a moderating role in the impact of Renewable Energy Greenfield Investments on energy poverty. Compared with countries with higher electricity

consumption levels, Renewable Energy Greenfield Investments has a stronger energy-poverty-alleviating effect in countries with lower electricity consumption levels.

4. Empirical Strategy and Data

4.1 Model Specification

We examine whether Renewable Energy Greenfield Investments is related to energy poverty across countries. Consistent with the panel-data approach used in related studies, the baseline equation takes the form of a two-way fixed effects model:

$$EPI_{it} = \alpha + \beta_1 INV_{it} + \sum_{k=1}^n \gamma_k Control_{kit} + \mu_i + \delta_t + \varepsilon_{it}$$

Here, i identifies the country (or economy), while t denotes the year. The dependent variable, EPI_{it} , measures energy poverty in country i and year t using a composite index of energy accessibility, affordability, and cleanliness; larger values represent more severe energy poverty. The main explanatory variable, INV_{it} , captures total Renewable Energy Greenfield Investments, expressed in logarithmic form. The log transformation is intended to limit heteroskedasticity and permits an interpretation of the coefficient in elasticity terms. $Control_{kit}$ represents the vector of controls. Country fixed effects, μ_i , capture unobserved country characteristics that do not change over time; year fixed effects, δ_t , capture shocks common to countries in the same year. Standard errors are clustered by country to accommodate within-country serial correlation and heteroskedasticity, thereby supporting inference from the panel estimates.

4.2 Variable Selection and Data Sources

The empirical sample is an annual unbalanced panel of 153 countries for 2003–2023. Sample construction reflects three considerations. Country-year comparability is required for the principal measures, so economies without the relevant energy-poverty indicators or investment-project information are excluded. Missing observations are not interpolated, and the panel consequently remains unbalanced. The starting year also follows the coverage of fDi Markets, which has recorded global greenfield foreign direct investment projects systematically since 2003; its annual records can be combined with macroeconomic series from sources including the World Development Indicators (WDI). Finally, the retained countries cover several income categories and geographic regions, allowing the investment–energy-poverty relationship to be examined in a diverse international sample. Descriptive statistics for the principal variables appear in Table 1.

Table 1. Descriptive Statistics

Variables	Obs	Mean	SD	Min	Max
EPI	3159	0.491	0.201	0	1
INV	3486	1.950	2.948	0	10.686

Variables	Obs	Mean	SD	Min	Max
URB	3486	57.052	22.937	8.908	100
GDP	3471	8.594	1.431	5.493	11.630
EI	3246	5.069	3.077	0.970	23.680
TRD	3091	86.731	51.100	2.474	437.327

As reported in Table 1, the energy poverty index (EPI) averages 0.491 and spans the full interval from 0 to 1, indicating considerable variation among the observed countries. Renewable Energy Greenfield Investments (INV), the principal explanatory variable, has a relatively high standard deviation, reflecting differences across countries and years in the scale of renewable-energy greenfield investment received. The control variables also vary markedly: the distributions of urbanization (URB), GDP per capita (GDP), energy intensity (EI), and trade openness (TRD) are broad. Such variation makes it important to account for economic development, the spatial distribution of populations, the efficiency of energy use, and international economic openness when estimating cross-country relationships.

Energy poverty is represented by the energy poverty index (EPI). In keeping with multidimensional approaches to measurement, the index goes beyond the presence or absence of energy access to encompass the affordability and cleanliness of the energy services available to households. These elements are treated jointly rather than as interchangeable measures of a single shortfall. Its indicator system therefore covers three dimensions: energy accessibility, energy affordability, and clean energy use.

The accessibility dimension draws on overall electricity access, electricity access among urban residents, and rural access to clean cooking fuels and technologies. Affordability is represented by fuel imports as a proportion of merchandise imports and by GDP per capita, while the clean-energy dimension uses renewable energy's share of total final energy consumption. The underlying indicators are obtained primarily from World Bank WDI and UNdata. Before aggregation, the sub-indicators are adjusted to a common direction and standardized. Principal component analysis (PCA) is then used to summarize their information, with component weights determined by the respective variance contributions. The resulting composite index is calculated at the country-year level. The complete set of indicators is listed in Table 2.

Following Feng et al. (2025), GDP per capita is included among the indicators used to represent households' capacity to afford energy. The regression additionally contains the logarithm of GDP per capita as a macroeconomic control, since the national income environment is related to energy infrastructure and the extent of market development. Although both measures originate from GDP per capita, their functions in the empirical design are distinguished in the paper: purchasing capacity within the EPI and country-level economic conditions in the regression. PCA-based weighting of the index components is intended to moderate direct mechanical linear correlations arising from index

construction. The analysis also follows the robustness approach in Feng et al. (2025) by applying system generalized method of moments (SYS-GMM) to examine potential endogeneity. This additional estimator is intended to limit bias that may arise from omitted time-varying influences, address the endogeneity concerns considered in the analysis, and improve the consistency of the reported estimates for the principal explanatory variable.

Table 2. Indicator System of Energy Poverty

Category	Indicator	Measurement	Unit	Data source
Energy accessibility	Total electricity access	Share of population with access to electricity	% of population	WB_WDI
Energy accessibility	Urban electricity access	Share of urban population with access to electricity	% of urban population	WB_WDI
Energy accessibility	Rural energy access	Share of rural population with access to clean fuels and technologies for cooking	% of rural population	WB_WDI
Energy affordability	Energy burden	Fuel imports as a share of total merchandise imports	%	WB_WDI
Energy affordability	Income	GDP per capita	Constant 2015 US\$	WB_WDI
Clean energy use	Clean energy consumption	Renewable energy consumption as a share of total final energy consumption	%	UNdata

In recent years, the transition from fossil fuels to renewable energy has become a major strategy for countries to achieve carbon reduction targets. As the core explanatory variable of this study, Renewable Energy Greenfield Investments (INV) is obtained from the fDi Markets database. This database is maintained by the Financial Times and officially published by fDi Intelligence. fDi Markets is one of the most comprehensive project-level databases on cross-border greenfield investment, covering all countries and sectors worldwide since 2003.

To identify foreign direct investment (FDI) projects in the global renewable energy sector, this study extracts all global project records from 2003 to 2023 and manually checks the relevant information. The projects are classified into renewable energy FDI, non-renewable energy FDI, and uncertain types, and are then aggregated by country and year. This study subsequently matches the renewable energy FDI data with the energy poverty data from the World Bank WDI.

The core explanatory variable is Renewable Energy Greenfield Investments (INV), which captures the

scale of cross-border greenfield investment flowing into the renewable energy sector of the host country. Compared with aggregate macro-level FDI data, project-level data provide detailed information on the investment sector, destination country, source country, investment year, capital expenditure, project type, and job creation. Therefore, they are more suitable for identifying investment inflows into the renewable energy sector.

Specifically, this study first obtains global greenfield investment project records from 2003 to 2023. It then combines information on project industry, project description, and firm characteristics to manually classify each project as renewable energy FDI, non-renewable energy FDI, or uncertain type. The capital investment of renewable energy projects is then aggregated by destination country and year and matched with the EPI and control variable datasets. Considering the right-skewed distribution of investment values, the regression analysis uses the logarithmic form of Renewable Energy Greenfield Investments.

Regarding the selection of control variables, this study further includes urbanization, economic development, energy intensity, and trade openness. We measure urbanization (URB) using the share of urban population in total population, and use it to control for the effects of population concentration and infrastructure conditions on access to energy services. We measure economic development (GDP) using GDP per capita in constant 2015 US dollars, and transform it into logarithmic form to control for differences in household affordability and government public investment capacity. Energy intensity (EI) reflects the amount of energy input required per unit of economic output, and we use it to capture energy-use efficiency. We measure trade openness (TRD) using the ratio of total imports and exports to GDP, which we use to control for the degree of external openness and its influence on the flows of energy technology, capital, and goods. This study obtains all control variables from the World Bank WDI.

5. Empirical Analysis

5.1 Baseline Regression

To assess the association between Renewable Energy Greenfield Investments and global energy poverty, the baseline regressions use panel fixed effects models with standard errors clustered at the country level. Country clustering accommodates heteroskedasticity and serial dependence within countries. Table 3 presents estimates with progressively more extensive specifications, enabling comparisons between the unconditional relationship, the relationship after accounting for fixed effects, and the specification that also incorporates observable macroeconomic controls. With neither control variables nor fixed effects, column (1) yields an INV coefficient of -0.018, statistically significant at the 1% level. Introducing country and year fixed effects in column (2) reduces the coefficient to -0.001, but it remains negative and significant at 1%. The negative association thus persists after accounting for unobserved country characteristics and shocks common to countries over time. Column (3) adds the full set of controls and again reports an INV coefficient of -0.001, significant at 1%. In this

specification, differences in economic development, urbanization, energy intensity, and trade openness are held constant. The estimate therefore continues to associate larger Renewable Energy Greenfield Investments with a lower energy poverty index.

The coefficient on renewable energy greenfield investment in Table 3, column (3), is small in absolute terms (-0.001). One possible reason is that greenfield projects involve substantial capital commitments and long construction periods, so the immediate marginal change associated with an additional unit of investment is limited in a macroeconomic regression. The descriptive statistics nevertheless provide a basis for considering the economic size of the estimated association.

A one-standard-deviation increase in Renewable Energy Greenfield Investments (2.948 units) corresponds to an estimated decline of approximately 0.003 points in the energy poverty index. Relative to the index's standard deviation of 0.201, this amounts to roughly 1.47%.

Differences in grid coverage and the geographical isolation of some populations make global energy poverty a persistent structural problem. Against that background, the estimated change associated with renewable energy investment is equivalent to approximately 1.5% of the standard deviation in energy poverty, or about 0.6% of the sample mean of 0.491, after controls including GDP and urbanization are taken into account. Although modest in absolute size, this estimate points to a measurable association between Renewable Energy Greenfield Investments and lower energy poverty.

These baseline estimates are in line with studies that associate modern energy access with wider development outcomes. Countries receiving larger Renewable Energy Greenfield Investments tend to have lower energy poverty once differences in economic conditions, population structure, energy intensity, trade openness, and country and year effects are considered. The result is consistent with the argument that investment in modern energy systems can ease energy-related constraints and extend the availability of essential energy services.

Table 3. Baseline Regression Results: Renewable Energy Greenfield Investments and Energy Poverty

	(1)	(2)	(3)
VARIABLES	EPI	EPI	EPI
INV	-0.018***	-0.001***	-0.001***

	(0.003)	(0.000)	(0.000)
URB			-0.002
			(0.001)
GDP			-0.109***
			(0.018)
EI			-0.001
			(0.002)
TRD			0.000
			(0.000)
Constant	0.530***	0.516***	1.527***
	(0.018)	(0.004)	(0.172)
Observations	3159	3,159	2,669
Number of countries	166	166	153
R-squared	0.075	0.342	0.466
Country fixed effects	NO	YES	YES
Year fixed effects	NO	YES	YES

Notes. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5.2 Endogeneity Test

Country and year fixed effects cannot remove every source of endogeneity. Energy poverty may be persistent, with current outcomes partly determined by deprivation in earlier years. Reverse causality is also possible because energy poverty and Renewable Energy Greenfield Investments need not be determined independently. For instance, countries with substantial energy deprivation may have a particularly strong demand for new renewable-energy facilities while simultaneously facing constraints that discourage investment inflows.

To examine these concerns, the model is extended to include the first lag of the dependent variable (L.EPI) and is estimated using two-step system GMM. The estimator combines equations in first differences and in levels, in contrast to difference GMM, with the aim of improving efficiency and reducing problems arising from weak instruments. The dynamic-panel specification is written as follows:

$$EPI_{it} = \alpha_0 + \alpha_1 EPI_{i,t-1} + \beta_1 INV_{it} + \sum \gamma Control_{it} + \mu_i + \delta_t + \varepsilon_{it}$$

$$\Delta EPI_{it} = \alpha_1 \Delta EPI_{i,t-1} + \beta_1 \Delta INV_{it} + \sum \gamma \Delta Control_{it} + \Delta \delta_t + \Delta \varepsilon_{it}$$

where is the first lag of the energy poverty index and represents persistence in energy poverty over time.

The system GMM model is used to improve estimation efficiency and to examine concerns about reverse causality and unobserved factors that may vary over time. The corresponding estimates are reported in Table 4.

Table 4. Endogeneity Test: Dynamic Panel System GMM Estimates

VARIABLES	(1) EPI
L.EPI	0.144*** (0.015)
INV	-0.001*** (0.000)
URB	-0.000 (0.001)
GDP	-0.006 (0.010)
EI	0.001 (0.001)
TRD	-0.000 (0.000)
Observations	2487
Number of countries	153
AR(1)	-4.037
AR(2)	1.370
Hansen_p	0.573

Notes. Two-step robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4 reports the dynamic-panel estimates and the accompanying specification tests. The AR(1) statistic indicates first-order serial correlation, whereas the AR(2) statistic does not suggest second-order serial correlation. The Hansen test gives a p-value of 0.573, above 0.1; on this test, the overidentifying restrictions are not rejected. L.EPI enters positively and is significant at the 1% level, consistent with substantial persistence in energy poverty over time. The coefficient on Renewable Energy Greenfield Investments (INV) remains negative and statistically significant at 1% after the dynamic specification is introduced. Accordingly, the main investment–poverty relationship is also observed in the system GMM estimates, which address the specified dynamic-panel and potential reverse-causality concerns.

5.3 Robustness Tests

Robustness is examined first by changing the estimation method. The energy poverty index is bounded between zero and one, so Table 5 estimates the relationship using a Tobit model and a fractional response model (FRM) rather than relying only on the linear baseline specification. Column (1) contains Tobit estimates with country and year fixed effects. Column (2) reports a fractional probit model with the same fixed effects. Both specifications present average marginal effects, and standard errors are clustered by country. This provides a comparison with the fixed effects estimates while holding constant the general set of observed covariates and the country and year effects used elsewhere in the analysis. In each case, Renewable Energy Greenfield Investments retains a negative coefficient that is statistically significant. The evidence is consequently not confined to the linear form of the baseline regression: the sign and reported significance of the investment coefficient are retained in the two nonlinear approaches. The result therefore persists when the bounded range of the EPI is taken into account through these alternative model specifications.

Table 5. Robustness Checks: Tobit and Fractional Response Model Estimates

	(1)	(2)
VARIABLES	EPI	EPI
INV	-0.001*** (0.000)	-0.002*** (0.000)
Controls	YES	YES
Observations	2669	2669
Country fixed effects	YES	YES
Year fixed effects	YES	YES

Notes. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The COVID-19 pandemic disrupted economic activity and energy markets, potentially affecting both investment and energy poverty. To examine the sensitivity of the estimates to this period, observations from 2020 onward are removed and the model is estimated using data from 2003–2019. A separate check accounts for the heteroskedasticity, serial correlation, and cross-sectional dependence that can arise in international panels by using Driscoll–Kraay standard errors. Table 6 presents the two exercises. After excluding 2020 and later years, the INV coefficient in column (1) remains significant at the 5% level. With Driscoll–Kraay standard errors in column (2), the coefficient is significant at 1%. These estimates are consistent with the baseline finding under both the restricted sample period and the alternative standard-error procedure.

Table 6. Robustness Checks: Excluding the COVID-19 Period and Driscoll-Kraay Standard Errors

VARIABLES	(1) EPI	(2) EPI
INV	-0.001** (0.000)	-0.001*** (0.000)
URB	-0.002 (0.001)	-0.002*** (0.000)
GDP	-0.104*** (0.017)	-0.109*** (0.011)
EI	-0.002 (0.002)	-0.001 (0.001)
TRD	0.000 (0.000)	0.000*** (0.000)
Constant	1.487*** (0.173)	1.527*** (0.105)
Observations	2,323	2669
Number of countries	152	153
R-squared	0.442	0.466
Country fixed effects	YES	YES
Year fixed effects	YES	YES

Notes. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

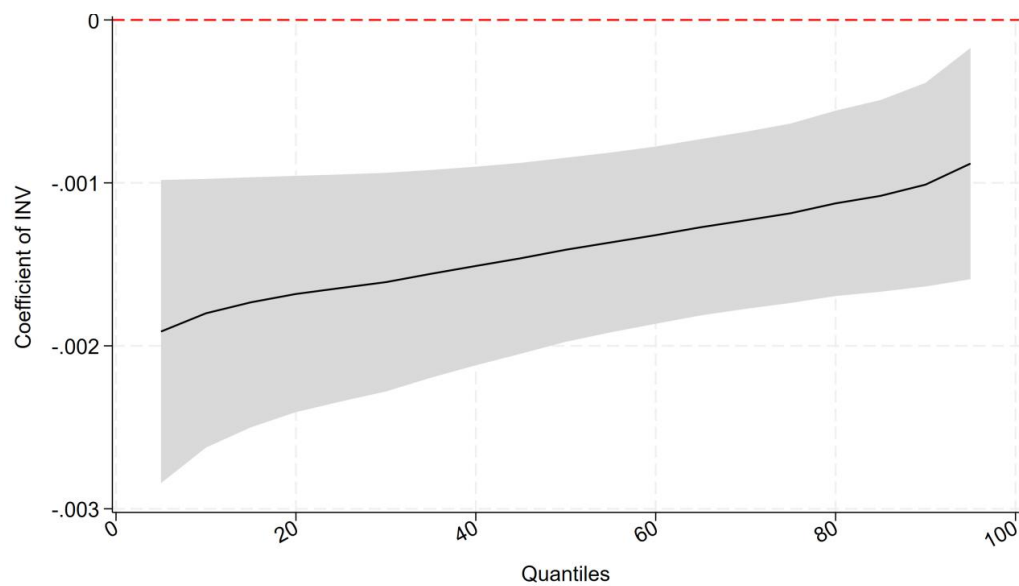
5.4 Heterogeneity Analysis

Quantile regressions are used to consider whether the relationship between Renewable Energy Greenfield Investments and energy poverty changes over the EPI distribution. In line with Feng et al. (2025), estimates are reported at the 25th, 50th, and 75th quantiles. Table 7 shows a negative and statistically significant INV coefficient at each of these points, consistent with an energy-poverty benefit associated with renewable energy investment across the distribution. The coefficients differ in magnitude, however. The estimated reduction is larger at the lower quantile and becomes smaller at higher levels of the EPI. Thus, in the quantile results, the association is strongest among observations with relatively limited energy poverty and weaker where deprivation is more severe.

Table 7. Heterogeneity Analysis: Quantile Regression Estimates

	(1)	(2)	(3)
VARIABLES	25%	50%	75%
INV	-0.002*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
URB	-0.002*** (0.001)	-0.002*** (0.000)	-0.002*** (0.000)
GDP	-0.103*** (0.008)	-0.109*** (0.007)	-0.115*** (0.008)
EI	0.000 (0.001)	-0.001 (0.001)	-0.002 (0.001)
TRD	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Constant	1.447*** (0.078)	1.528*** (0.068)	1.604*** (0.073)
Country fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Observations	2669	2669	2669

Notes. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

**Figure 1. Dynamic Effects of Renewable Energy Investment Across Quantiles**

Regional differences are considered using the grouping adopted by Zhao et al. (2022): Asia-Pacific, Europe, and the Americas and Africa. Separate fixed effects regressions are estimated for each group. Asia-Pacific comprises countries in Asia and Oceania; Europe includes European economies; and the final group contains countries in the Americas and Africa. The division allows for differences in development, renewable-energy resources, infrastructure, and the deployment of clean energy. Because the resources required to turn generation capacity into household energy services are not distributed uniformly, the same level of new investment need not have comparable implications in every regional setting. Table 8 indicates that the estimated investment–poverty relationship varies across these regions. For Asia-Pacific, the INV coefficient is -0.002 and significant at the 1% level. The Americas and Africa group also has a coefficient of -0.002, significant at 5%. Both estimates indicate a negative relationship between Renewable Energy Greenfield Investments and energy poverty. The coefficients are equal to the reported precision, although the significance levels differ across the two geographical subsamples. Europe's coefficient is negative (-0.001) but not statistically significant, so the data do not establish the same relationship there. The significant estimates are thus concentrated in Asia-Pacific and the Americas and Africa. These regions include many developing economies in which energy infrastructure and service coverage remain incomplete. Additional investment may have greater scope to expand supply systems, improve access, and strengthen electricity services under those conditions. This interpretation concerns the scope for additional improvements rather than suggesting that investments in these regions operate through an entirely different type of energy technology. In Europe, more developed infrastructure, relatively extensive energy-service coverage, and higher average income levels may leave less room for comparable marginal improvements.

Table 8. Regional Heterogeneity Analysis

	(1)	(2)	(3)
	Asia-Pacific	Europe	Americas and Africa
INV	-0.002*** (0.001)	-0.001 (0.000)	-0.002** (0.001)
URB	0.001 (0.002)	-0.001 (0.001)	-0.001 (0.002)
GDP	-0.147*** (0.027)	-0.105*** (0.031)	-0.056* (0.028)
EI	-0.002 (0.004)	0.005 (0.004)	0.001 (0.003)
TRD	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Constant	1.697*** (0.264)	1.373*** (0.334)	1.152*** (0.256)
Observations	768	736	1165
Number of countries	48	37	68
R-squared	0.540	0.591	0.471
Country fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES

Notes. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Income-related heterogeneity is examined by separating high-income economies from non-high-income economies using the World Bank classification. Fixed effects models are then estimated for the two groups. In both, the coefficient on Renewable Energy Greenfield Investments is negative and significant at the 1% level. The point estimate is -0.001 in the high-income sample and -0.002 among non-high-income countries. These figures are taken from the separate income-group regressions rather than a pooled estimate, and the comparison concerns the magnitude of the reported investment coefficients. The larger absolute coefficient for the latter group suggests a stronger relationship where gaps in electricity access, weaknesses in energy infrastructure, and limited clean-energy supply leave greater scope for improvement. The interpretation is therefore linked to the different starting conditions of the two income groups, rather than to an assumption that all countries experience the same improvement from additional capital. GDP per capita is also negatively and significantly associated with energy poverty in each income group, consistent with a role for broader economic development. The results therefore indicate that the negative investment–poverty relationship

extends across income categories but is more pronounced for non-high-income economies, a distinction relevant to assessments of energy poverty in developing countries.

Table 9. Income-Group Heterogeneity Analysis

	(1)	(2)
	High-income countries	Non-high-income countries
INV	-0.001*** (0.000)	-0.002*** (0.001)
URB	0.000 (0.001)	-0.001 (0.001)
GDP	-0.133*** (0.025)	-0.067*** (0.020)
EI	0.002 (0.004)	-0.000 (0.003)
TRD	0.000 (0.000)	-0.000 (0.000)
Constant	1.576*** (0.287)	1.191*** (0.175)
Observations	1035	1612
Number of countries	54	97
R-squared	0.454	0.528
Country fixed effects	YES	YES
Year fixed effects	YES	YES

Notes. Cluster-robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5.5 Moderating Mechanism Analysis

Electricity consumption is examined as a moderating condition in the relationship between Renewable Energy Greenfield Investments and energy poverty. The EPI reflects shortcomings in both energy supply and the actual consumption of energy services. Electric power consumption per capita is consequently used as a proxy for electricity availability and the extent to which energy services are used. The moderating-effect specification is given below:

$$EPI_{it} = \alpha + \beta_1 INV_{it} + \beta_2 EPC_{it} + \beta_3 INV_{it} \times EPC_{it} + Controls_{it} + \mu_i + \delta_t + \epsilon_{it}$$

Table 10 presents the results of the moderation analysis. The interaction between Renewable Energy Greenfield Investments and electricity consumption is positive and significant at the 1% level. Together with the negative coefficient on INV, this positive interaction implies that the estimated

poverty-reducing association becomes smaller as electricity consumption increases. Countries starting from lower levels of electricity use therefore exhibit the stronger estimated effect. One interpretation is that restrictions on electricity availability are more binding in such settings, making additional investment in renewable generating capacity and related infrastructure particularly relevant to access. New facilities may expand clean power supply, improve electricity networks, and extend modern energy services. The interaction results are consistent with the proposed role of electricity availability in shaping the investment–energy–poverty relationship.

Table 10. Moderating Mechanism: Electricity Consumption Channel

	(1)	(2)
	EPI	EPI
INV	-0.001*** (0.000)	-0.002*** (0.000)
EPC		-0.059*** (0.022)
INV × EPC		0.001*** (0.001)
Controls	YES	YES
Country fixed effects	YES	YES
Year fixed effects	YES	YES
Observations	2669	2302
R-squared	0.466	0.508

Notes. Cluster-robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6. Conclusions and Policy Recommendations

This study examines the impact of Renewable Energy Greenfield Investments on energy poverty using a global multi-country panel dataset. The baseline results from a two-way fixed effects model show that Renewable Energy Greenfield Investments significantly reduces energy poverty after controlling for macroeconomic conditions, demographic structure, energy intensity, trade openness, and unobserved country and year effects. This finding suggests that Renewable Energy Greenfield Investments generates not only environmental benefits, but also important development and welfare gains by promoting energy access and energy equity.

Several robustness checks support this conclusion. The results remain consistent when this study uses system GMM to address potential endogeneity, employs Tobit and fractional response models to account for the bounded nature of the energy poverty index, excludes the post-2020 sample, and applies Driscoll-Kraay standard errors. The Driscoll-Kraay standard error provides more robust estimates for

both cross-sectional and time-related correlations (Blundell & Bond, 1998; Papke & Wooldridge, 1996). Hence, the main finding does not depend on a specific model specification, sample period, or inference method.

The heterogeneity analysis provides three further observations. First, the mitigating effect of Renewable Energy Greenfield Investments weakens as energy poverty becomes more severe, indicating that investment alone may be insufficient in countries with deep energy deprivation. Second, the effect has greater magnitude in the Asia-Pacific region, the Americas, and Africa, where modern energy services and infrastructure still have greater room for improvement. Third, Renewable Energy Greenfield Investments has a stronger effect in non-high-income countries, highlighting its role in promoting inclusive development.

The mechanism analysis shows that electricity consumption is an important condition shaping the effect of Renewable Energy Greenfield Investments. In countries with lower electricity consumption, Renewable Energy Greenfield Investments plays a stronger role in reducing energy poverty. This indicates that its key contribution lies not only in replacing traditional energy sources, but also in improving electricity supply capacity and modern energy accessibility through distributed solar power, wind power, small hydropower, energy storage, and microgrids.

Based on these findings, this study draws several policy implications:

First, Renewable Energy Greenfield Investments should be treated as a key policy instrument for both alleviating energy poverty and promoting energy transition. Previous studies emphasize that energy poverty policies require more than infrastructure expansion; they also depend on affordability, institutional recognition, targeted assistance, and effective policy design (Bouzarovski et al., 2012; Bednar & Reames, 2020). Therefore, governments should use fiscal subsidies, green credit, tax incentives, public investment and risk-sharing mechanisms to guide more capital into renewable energy infrastructure, especially in regions with weak grids, insufficient energy services and high dependence on traditional fuels. At the same time, governments should improve approval procedures, grid connection rules, renewable energy absorption mechanisms and electricity pricing systems to reduce institutional transaction costs and increase the efficiency with which Renewable Energy Greenfield Investments converts into actual energy services. For countries facing severe energy poverty, renewable energy policy should not serve only emission-reduction goals, but governments should also integrate it with energy accessibility, household affordability and social equity objectives.

Second, policymakers should implement differentiated policies according to the development stage of each country or region. The Asia-Pacific region, the Americas and Africa should strengthen renewable energy infrastructure construction, particularly by developing distributed energy, microgrids and energy storage systems in remote areas and regions with low electricity consumption, so as to improve the stability and accessibility of energy supply. For non-high-income countries, international organizations and high-income economies should reduce Renewable Energy Greenfield Investments costs through climate finance, technology transfer, capacity building and concessional loans, helping them overcome

infrastructure constraints. For high-income countries, policymakers should pay greater attention to the coordination between Renewable Energy Greenfield Investments, energy efficiency improvement, smart grid development and energy price stability, so as to avoid the emergence of new energy affordability problems during the energy transition.

Third, policy efforts should focus on the infrastructure constraints faced by countries with low electricity consumption. The mechanism analysis shows that Renewable Energy Greenfield Investments has a stronger energy poverty-reducing effect in countries with lower electricity consumption. Therefore, policymakers should prioritize policy resources toward countries and regions with insufficient energy access, weak grid coverage and more severe energy poverty. In terms of policy design, governments should establish a coordinated mechanism linking Renewable Energy Greenfield Investments, grid construction and end-use energy service improvement. This can help avoid an excessive focus on installed capacity while neglecting actual improvements in household energy use. At the same time, residential subsidies, electricity price protection for low-income households, clean cooking energy promotion and support for small-scale distributed energy equipment should be strengthened to improve the real affordability of modern energy services for low-income groups.

Finally, policymakers should establish an energy poverty evaluation mechanism for Renewable Energy Greenfield Investments. When formulating renewable energy development policies, countries should incorporate energy poverty indicators into project evaluation systems. In addition to installed capacity, power generation and carbon emission reduction, policy evaluation should also assess the effects of projects on electricity accessibility, household energy expenditure burden, the share of clean energy use and the quality of energy services. Only by linking energy transition policies with energy equity objectives can low-income groups avoid marginalization during the energy transition, and policymakers can achieve the dual goals of clean energy development and energy poverty alleviation.

References

- A. C. Sadath, & R. H. Acharya. (2017). *Assessing the extent and intensity of energy poverty using Multidimensional Energy Poverty Index: Empirical evidence from households in India*, *Energy Policy*, 102(2017), 540-550. <https://doi.org/10.1016/j.enpol.2016.12.056>
- Ali, W., Dhankar, N., Dagar, V., & Rao, A. (2026). Energy poverty dynamics and geostrategic shocks: Moderation of financial markets. *Energy Policy*, 215, 115278. <https://doi.org/10.1016/j.enpol.2026.115278>
- Apergis, N., Polemis, M., & Soursou, S.-E. (2022). Energy poverty and education: Fresh evidence from a panel of developing countries. *Energy Economics*, 106, 105430. <https://doi.org/10.1016/j.eneco.2021.105430>
- Boardman, B. (1991). *Fuel Poverty: From Cold Homes to Affordable Warmth*. London: Belhaven Press.
- Che, X., Zhu, B., & Wang, P. (2021). Assessing global energy poverty: An integrated approach. *Energy*

- Policy*, 149, 112099. <https://doi.org/10.1016/j.enpol.2020.112099>
- Bednar, D. J., & Reames, T. G. (2020). Recognition of and response to energy poverty in the United States, *Nat. Energy*, 5(2020), 432-439. <https://doi.org/10.1038/s41560-020-0582-0>
- Dinkelman, T. (2011). The effects of rural electrification on employment: New evidence from South Africa. *The American Economic Review*, 101(7), 3078-3108. <https://doi.org/10.1257/aer.101.7.3078>
- Dong, K., Dou, Y., & Jiang, Q. (2022). Income inequality, energy poverty, and energy efficiency: Who cause who and how? *Technological Forecasting and Social Change*, 179, 121622. <https://doi.org/10.1016/j.techfore.2022.121622>
- Feng, Y., Han, Y., Hu, S., & Pan, Y. (2025). Alleviating energy poverty globally: Does digital government matter? *Energy Economics*, 143, 108272. <https://doi.org/10.1016/j.eneco.2025.108272>
- G.Y. Obeng, H. D. Evers, F. O., Akuffo, I., & Braimah, A. B. (2008). Hammond, Solar photo voltaic electrification and rural energy-poverty in Ghana, *Energy Sustain. Dev*, 12(2008), 43-54, [https://doi.org/10.1016/S0973-0826\(08\)60418-4](https://doi.org/10.1016/S0973-0826(08)60418-4)
- Thomson, H., & Snell, C. (2013). *Quantifying the prevalence of fuel poverty across the European Union*, *Energy Pol*, 52(2013), 563e572. <https://doi.org/10.1016/j.enpol.2012.10.009>
- IEA, IRENA, UNSD, World Bank, & WHO. (2025). Tracking SDG7: The Energy Progress Report 2025. *International Energy Agency*. <https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2025>
- L. Lenz, A. Munyehirwe, J. Peters, M. Sievert, Does large-scale infrastructure investment alleviate poverty? Impacts of Rwanda's electricity access roll-out program, *World Dev*. 89 (2017) 88-110, <https://doi.org/10.1016/j.worlddev.2016.08.003>
- M. Gonzalez-Eguino, Energy poverty: an overview, *Renew. Sustain. Energy Rev*. 47 (2015) 377-385. <https://doi.org/10.1016/j.rser.2015.03.013>.
- M. Lipscomb, A.M. Mobarak, T. Barham, Development effects of electrification: Evidence from the topographic placement of hydropower plants in Brazil, *Am. Econ. J. Appl. Econ*. 5(2) (2013) 200-231, <https://doi.org/10.1257/app.5.2.200>
- Mukhtarov, S., & Mikayilov, J. I. (2023). Could financial development eliminate energy poverty through renewable energy in Poland? *Energy Policy*, 182, 113747. <https://doi.org/10.1016/j.enpol.2023.113747>
- N.D. Rao, J. Min, A. Mastrucci, Energy requirements for decent living in India, Brazil and South Africa, *Nat. Energy* 4 (2019) 1025-1032, <https://doi.org/10.1038/s41560-019-0497-9>
- Nguyen, C. P., & Nasir, M. A. (2021). An inquiry into the nexus between energy poverty and income inequality in the light of global evidence. *Energy Economics*, 99, 105289. <https://doi.org/10.1016/j.eneco.2021.105289>
- Nussbaumer, P., Bazilian, M., & Modi, V. (2012). Measuring energy poverty: Focusing on what matters. *Renewable and Sustainable Energy Reviews*, 16(1), 231-243.

- <https://doi.org/10.1016/j.rser.2011.07.150>
- Pachauri, S., & Spreng, D. (2011). Measuring and monitoring energy poverty. *Energy Policy*, 39(12), 7497-7504. <https://doi.org/10.1016/j.enpol.2011.07.008>
- Pan, L., Biru, A., & Lettu, S. (2021). Energy poverty and public health: Global evidence. *Energy Economics*, 101, 105423. <https://doi.org/10.1016/j.eneco.2021.105423>
- Papke, L. E., & Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics*, 11(6), 619-632. [https://doi.org/10.1002/\(SICI\)1099-1255\(199611\)11:6%3C619::AID-JAE418%3E3.0.CO;2-1](https://doi.org/10.1002/(SICI)1099-1255(199611)11:6%3C619::AID-JAE418%3E3.0.CO;2-1)
- R. Banerjee, V. Mishra, A.A. Maruta, Energy poverty, health and education outcomes: Evidence from the developing world, *Energy Econ.* 101 (2021) 105447, <https://doi.org/10.1016/j.eneco.2021.105447>
- R. Blundell, S. Bond, Initial conditions and moment restrictions in dynamic panel data models, *J. Econom.* 87 (1998) 115-143, [https://doi.org/10.1016/S0304-4076\(98\)00009-8](https://doi.org/10.1016/S0304-4076(98)00009-8)
- S. Bouzarovski, S. Petrova, R. Sarlamanov, Energy poverty policies in the EU: A critical perspective, *Energy Policy* 49 (2012) 76-82, <https://doi.org/10.1016/j.enpol.2012.01.033>
- S.C. Bhattacharyya, Energy access programmes and sustainable development: A critical review and analysis, *Energy Sustain. Dev.* 16 (2012) 260-271, <https://doi.org/10.1016/j.esd.2012.05.002>
- S.R. Khandker, D.F. Barnes, H.A. Samad, The welfare impacts of rural electrification in Bangladesh, *Energy J.* 33 (2012) 187-206, <https://doi.org/10.5547/ISSN0195-6574-EJ-Vol33-No1-7>.
- Simionescu, M., & Cifuentes-Faura, J. (2024). Evaluating the relationship between income inequality, renewable energy and energy poverty in the V4 countries. *Energy Research & Social Science*, 115, 103640. <https://doi.org/10.1016/j.erss.2024.103640>
- Sovacool, B. K. (2012). The political economy of energy poverty: A review of key challenges. *Energy for Sustainable Development*, 16(3), 272-282. <https://doi.org/10.1016/j.esd.2012.05.006>
- Thomson, H., Bouzarovski, S., & Snell, C. (2017). Energy poverty in the European Union: landscapes of vulnerability. *Wiley Interdisciplinary Reviews: Energy and Environment*, 6(5), e258. <https://doi.org/10.1002/wene.258>
- Thomson, H., Snell, C., & Bouzarovski, S. (2017). Health, well-being and energy poverty in Europe: A comparative study of 32 European countries. *International Journal of Environmental Research and Public Health*, 14(6), 584. <https://doi.org/10.3390/ijerph14060584>
- United Nations, The Sustainable Development Goals Report 2024, United Nations, New York, 2024. <https://unstats.un.org/sdgs/report/2024/>
- van der Kroon, B., Brouwer, R., & van Beukering, P. J. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews*, 20, 504-513. <https://doi.org/10.1016/j.rser.2012.11.045>
- W. Leal Filho, A. Gatto, A. Sharifi, A.L. Salvia, Z. Guevara, S. Awoniyi, C. Mang-Benza, C.N. Nwedu,

D. Surroop, K.O. Teddy, U. Muhammad, V.R. Nalule, I. da Silva, Energy poverty in African countries: An assessment of trends and policies, *Energy Res. Soc. Sci.* 117 (2024) 103664, <https://doi.org/10.1016/j.erss.2024.103664>

Zhao, J., Dong, K., Dong, X., & Shahbaz, M. (2022). How renewable energy alleviate energy poverty? A global analysis. *Renewable Energy*, 186, 299-311. <https://doi.org/10.1016/j.renene.2022.01.005>