

Journal of Human-Social Nexus

Contents lists available at: journals.absresearchacademy.com

eISSN: 3136-4519

ABS Research Academy

Research Article

OPEN ACCESS

Impact of Clean Energy Access on No Poverty (SDG1) in South Asian Countries

Sanjida Anjum Nigar[1*]

[1] *Department of Economics and Banking, International Islamic University Chittagong, Kumira, Chittagong, 4318, Bangladesh*

[*] *Corresponding author.*

Article info

Received: 2026-03-02

Revised: 2026-09-09

Published: 2026-09-20

Keywords

Clean energy access; SDG 1 (No Poverty); Poverty reduction; South Asia; Panel ARDL; Urban–rural heterogeneity; Sustainable development

DOI

https://doi.org/10.64939/jhsn.1.2.0011

Check for updates

A B S T R A C T

Access to clean and affordable energy is widely recognized as a fundamental driver of sustainable development and poverty reduction, particularly in developing regions. In South Asia, where a significant proportion of the global poor reside, expanding clean energy access has become a policy priority to achieve sustainable development goals. However, despite growing attention to renewable energy and poverty alleviation, limited empirical evidence exists on the dynamic relationship between clean energy access and the achievement of the No Poverty goal (SDG 1) in South Asian countries. This study examines the impact of access to clean energy on the achievement of the No Poverty goal (SDG 1) in South Asian countries. Using the panel ARDL method and data from 2000 to 2024, the findings indicate that access to clean energy contributes significantly to poverty reduction in the long run; however, its effect is insignificant in the short run. The analysis further reveals that the impact of clean energy access is stronger in urban areas than in rural areas. These findings suggest that policymakers should prioritize long-term investments in clean energy infrastructure to achieve sustainable poverty reduction. Moreover, targeted policies are needed to expand clean energy access in rural areas to ensure more inclusive and equitable development outcomes.

© 2026 Journal of Human-Social Nexus. Published by ABS Research Academy. All rights reserved.

HOW TO CITE

Nigar, S. A. (2026). Impact of Clean Energy Access on No Poverty (SDG1) in South Asian Countries. Journal of Human-Social Nexus, 1(2). https://doi.org/10.64939/jhsn.1.2.0011

Introduction

The eradication of poverty remains the foremost objective of the 2030 Agenda for Sustainable Development **(United Nations, 2015)**. Sustainable Development Goal 1 (SDG 1) aims to end poverty in all its forms everywhere, recognizing poverty as a multidimensional phenomenon linked to income, productive capacity, access to services, and structural inequalities. Achieving SDG 1 is intrinsically connected to Sustainable Development Goal 7 (SDG 7), which calls for universal access to affordable, reliable, and modern energy. Clean energy access is not merely a technical infrastructure issue; it constitutes a foundational input into economic transformation, labor productivity, human capital formation, and inclusive development.

Energy access influences poverty reduction through multiple economic channels. First, electricity enhances labor productivity by enabling mechanization, supporting micro and small enterprises, and extending working hours. **(Dinkelman, 2011)** shows that rural electrification significantly increased female employment and working hours in South Africa by reducing time spent in home production. Second, electrification generates broad-based productivity gains across sectors rather than simple labor reallocation effects, as documented by (Lipscomb et al., 2013) in Brazil. Third, long-term household electrification leads to sustained consumption and labor earnings growth, as evidenced in rural India (van de Walle et al., 2017). Collectively, these studies indicate that electricity access strengthens income generation, employment opportunities, and structural transformation, which are core mechanisms underlying poverty reduction.

In South Asia, the energy–poverty nexus is particularly critical. The region hosts a substantial share of the global poor and continues to experience uneven access to modern energy services. Rural electrification in Bangladesh increased household income by up to 21 percent and significantly reduced poverty incidence (Khandker et al., 2012b) More broadly, panel evidence from developing economies suggests that affordable electricity access contributes to long-run poverty reduction, although short-run effects may be ambiguous due to adjustment costs and structural rigidities (Asghar et al., 2022).

While much of the empirical literature has traditionally focused on electrification, access to clean and modern energy services increasingly constitutes a central pillar of sustainable development strategies under SDG 7. In many developing economies, expansions in electricity access are progressively linked with the deployment of renewable and low-carbon energy infrastructure, thereby aligning poverty reduction objectives with environmental sustainability. Consequently, the mechanisms identified in the electrification literature namely productivity enhancement, income generation, and structural transformation provide an important analytical foundation for understanding how clean energy access may influence the achievement of SDG 1.

However, access to clean energy does not operate uniformly across contexts. Governance quality and income distribution shape electricity expansion and its welfare effects. (Sarkodie & Adams, 2020) show that governance improvements enhance electricity access and human development, while income inequality constrains equitable energy distribution. From a justice-based perspective, energy planning that neglects equity considerations risks reinforcing spatial and socio-economic disparities (Sovacool & Dworkin, 2015). These issues are particularly salient in South Asia, where urban–rural disparities in infrastructure provision and institutional capacity may generate heterogeneous poverty outcomes from clean energy expansion.

Despite the expanding literature, several critical gaps remain. First, most existing studies rely on single-country case analyses, limiting the generalizability of findings to the broader South Asian region. Second, prior research typically examines employment, consumption, or welfare effects independently, rather than explicitly linking clean energy access to the achievement of SDG 1. Third, the dynamic nature of the energy–poverty relationship remains underexplored. Infrastructure investments may produce insignificant or even transitional effects in the short run while generating substantial poverty reduction in the long run. Fourth, limited empirical evidence distinguishes between urban and rural impacts within a unified dynamic framework, despite structural differences in energy access and labor market integration across regions.

Against this background, this study examines the impact of clean energy access on the achievement of SDG 1 in South Asian countries over the period 2000–2024. Using the panel Autoregressive Distributed Lag (ARDL) methodology, the study captures both short-run adjustment dynamics and long-run equilibrium relation-

ships. The ARDL framework is particularly appropriate for distinguishing temporary from persistent effects and accommodating mixed orders of integration in panel data**.** Given the structural heterogeneity and varying stages of economic development across South Asian economies, the panel ARDL approach further allows for capturing cross-country dynamics while preserving long-run equilibrium relationships. Furthermore, the analysis explicitly investigates urban–rural heterogeneity to assess whether clean energy expansion generates inclusive poverty reduction outcomes.

This study contributes to the literature in four key ways. First, it provides region-wide dynamic evidence on the clean energy–poverty nexus in South Asia, moving beyond single-country case studies. Second, it distinguishes between short-run and long-run effects, offering a clearer understanding of the temporal dynamics of energy-driven poverty reduction. Third, it examines urban–rural heterogeneity, addressing distributional dimensions often neglected in the literature. Fourth, by explicitly linking clean energy access to SDG 1, the study advances the growing research agenda on Sustainable Development Goal interlinkages and policy coherence.

Literature review

Theoretical Framework

The relationship between clean energy access and poverty reduction can be understood through two main perspectives. The first is the Energy–Poverty Nexus, which explains how limited access to modern energy can deepen poverty, while improved access can support household welfare and economic activity. The second is the Energy Justice perspective, which focuses on whether the benefits of energy access are distributed fairly across income groups and geographical areas. These perspectives are relevant to the present study because clean energy access may affect poverty through several channels. It may reduce the time households spend collecting traditional fuels, improve health conditions, support employment, and create better opportunities for productive activities. At the same time, the benefits may not be equal for all households. Urban and rural populations often face different levels of infrastructure, affordability, market access, and institutional support.

The Energy–Poverty Nexus explains the close connection between energy deprivation and poverty. Poor households often have limited access to affordable, reliable, and modern energy services because of low income, weak infrastructure, and limited institutional support. At the same time, inadequate energy access can make it harder for those households to improve their income and living conditions. In this way, poverty can lead to energy deprivation, while energy deprivation can also reinforce poverty. Clean fuels and modern cooking technologies can reduce the time and health costs associated with traditional fuels. Over time, these changes may improve labour participation, productivity, and household income. **Figure 1** shows the conceptual framework used in the study.

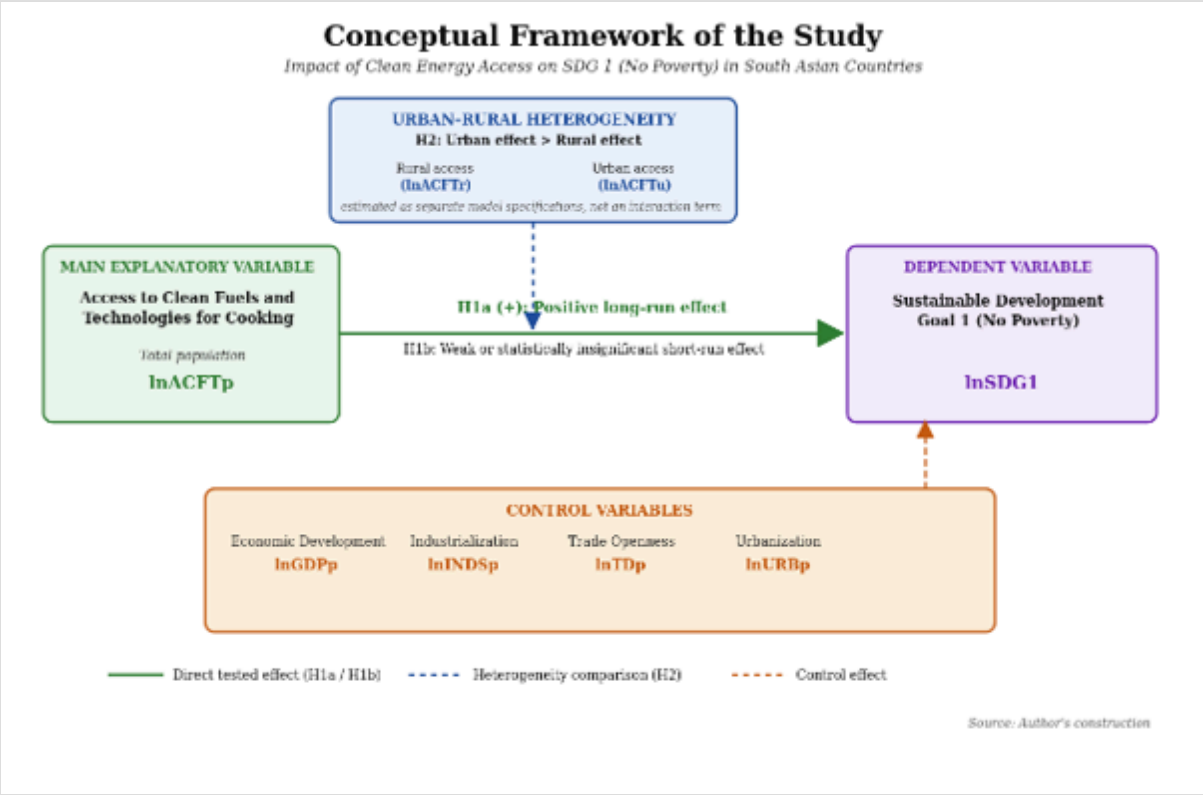


Figure 1. *Conceptual Framework of the Study.*

The Energy Justice perspective focuses on fairness within energy systems. It asks whether energy services are affordable, reliable, and available to all groups and whether the benefits and costs are distributed equally. (Sovacool & Dworkin, 2015) explained that energy justice includes fair distribution, recognition of disadvantaged groups, and participation in energy-related decisions. Urban households tend to have better access to finance, employment, transportation, and markets, while rural communities often face higher delivery costs, weaker infrastructure, and lower income. Therefore, the Energy Justice perspective helps explain why clean energy access may not produce equal poverty-reduction outcomes across locations.

Clean Energy Access and Sustainable Development Goal 1

Prior studies have examined the relationship between clean energy access and poverty reduction, particularly within the Sustainable Development Goals (SDGs) framework. Access to reliable electricity and clean cooking fuels plays a central role in improving economic and social conditions, particularly in developing countries. (Adenle, 2020) examined the linkage between access to clean and affordable energy and SDG performance and found that improved energy access significantly reduces poverty while enhancing health and education outcomes, particularly in developing economies. The study indicated that clean energy access plays a stronger role in countries with lower development levels. Similarly, (Nepal & Paija, 2019) investigated how modern energy access influences poverty reduction and environmental sustainability. The authors showed that improved access to modern energy services increases economic activity, improves quality of life, and simultaneously supports SDG 1 and SDG 7 objectives.

Energy Poverty and Its Socio-Economic Determinants

A growing body of research has explored what drives energy poverty and how these factors shape broader development outcomes. (Amin et al., 2025) analyzed socio-economic determinants of energy poverty in six

SAARC countries using panel ARDL techniques. The study found that political stability and female employment significantly reduce energy poverty, whereas corruption, income inequality, trade deficits, and urbanization increase it(Batool et al., 2022) examined energy poverty in South Asia and reported that income levels, infrastructure, and institutional quality significantly influence energy access conditions. (Bellepea & Türüç, 2024) studied the long-run relationship between gender inequality and energy poverty and found that higher gender inequality increases energy deprivation, while improved clean energy access reduces it. (Bonatz et al., 2019) investigated energy poverty in Pakistan and showed that lack of reliable modern energy services is closely associated with poor health conditions, limited income opportunities, and restricted educational access. (Bouzarovski & Petrova, 2015) further emphasized that energy poverty is multidimensional, shaped by income, affordability, infrastructure gaps, and access constraints. In addition, (Khanna et al., 2019) developed a comprehensive energy poverty index for South and Southeast Asia and revealed substantial deprivation driven by limited availability, accessibility, and affordability of modern energy services.

Renewable Energy, Rural Development, and Urban–Rural Differences

Furthermore, other studies have examined whether renewable energy expansion and improved access to clean fuels contribute directly to poverty alleviation. (Zhao et al., 2022) employed dynamic panel data techniques and found that renewable energy consumption significantly reduces energy poverty globally, both directly and indirectly through improvements in energy efficiency. (He et al., 2022) further showed that renewable energy adoption reduces energy poverty across income levels, with stronger effects under favorable economic and institutional conditions. (Simionescu et al., 2023) analyzed renewable energy policies in European Union countries and indicated that renewable energy consumption and technological innovation reduce energy bill arrears in the long run. Similarly, (Simionescu & Cifuentes-Faura, 2024) confirmed that renewable energy expansion and strong institutional quality significantly improve sustainable development outcomes. (Day et al., 2016) and (Sy & Mokaddem, 2022) highlighted the importance of properly conceptualizing and measuring energy poverty to design effective policy responses. (Song et al., 2023) found that reducing energy poverty improves income, educational attainment, and health outcomes across countries. Likewise, (Li et al., 2025) demonstrated that increased adoption of clean cooking fuels significantly raises household income and reduces inequality, particularly benefiting lower-income groups. (Byaro et al., 2024) also indicated that improved access to electricity and clean cooking fuels enhances welfare outcomes, reinforcing the critical role of modern energy services in socio-economic development.

At the micro and rural level, numerous empirical studies provide direct evidence linking energy access expansion to poverty reduction. (Pereira et al., 2010) evaluated rural electrification programs and found that electrification significantly reduces energy poverty and improves household welfare. (Thiam, 2011) examined renewable energy technologies in rural areas and showed that photovoltaic systems lower electricity costs while contributing to improvements in education, gender equality, and living standards. (Yadoo & Cruickshank, 2012) analyzed renewable mini-grid projects and indicated that low-carbon electrification technologies support poverty reduction and climate mitigation strategies. (Pandey & Asif, 2022) studied solar home system adoption in rural Pakistan and found that clean energy access enhances income opportunities, educational outcomes, and overall household welfare. (Yadava & Sinha, 2024) further reported that improved energy access strengthens livelihood resilience and adaptive capacity among rural populations. Earlier evidence from (Biswas et al., 2001) and (Karekezi & Kithyoma, 2002) also showed that renewable energy systems

empower rural communities and improve socio-economic conditions when supported by appropriate institutional and policy frameworks.

Despite these positive findings, several researchers point out that structural and policy barriers often limit the effectiveness of energy access expansion. (Tarekegne, 2020) argued that traditional electrification planning often neglects equity considerations and may fail to address access inequalities. (Monyei et al., 2022) highlighted the importance of coordinated policy and institutional interventions to address the multidimensional nature of energy poverty. (Rasul, 2016) stressed the interconnected food–water–energy nexus in South Asia and suggested that integrated policies are essential for sustainable development. (Murshed & Ozturk, 2023) found that renewable energy transitions and improvements in energy efficiency reduce energy poverty, although external shocks such as oil price volatility may offset these gains. (Tamasiga et al., 2024) indicated that high energy prices can weaken the poverty-reducing effects of energy access. (P & R, 2025) further showed that renewable energy expansion may not automatically improve access to electricity and clean cooking fuels unless infrastructure modernization and targeted policies are strengthened.

Knowledge Gap

Finally, while existing studies provide substantial evidence linking clean energy access and renewable energy adoption to energy poverty reduction and broader development outcomes, limited research has directly examined the dynamic impact of clean energy access on SDG 1 (No Poverty) in South Asian countries. Most studies focus primarily on energy poverty indicators rather than macro-level poverty outcomes aligned with SDG 1. Moreover, the distinction between short-run and long-run effects of clean energy access remains underexplored. The urban–rural heterogeneity of clean energy access impacts has also received limited attention within the South Asian context.

Hence, this study's novelty exists in three aspects. First, it investigates the impact of access to clean fuels and technologies for cooking on SDG 1 (No Poverty) in South Asian countries. Second, it distinguishes between short-run and long-run effects using a panel ARDL framework covering 2000–2024. Third, it examines differential impacts between urban and rural areas to provide inclusive and equitable policy implications. By addressing these gaps, this study contributes region-specific empirical evidence supporting sustainable poverty reduction strategies in South Asia.

Hypotheses

Clean Energy Access and the Achievement of SDG 1

Access to clean fuels and modern energy technologies plays a critical role in improving welfare and reducing poverty. At the household level, clean energy reduces time burdens associated with traditional biomass collection and lowers exposure to indoor air pollution, thereby enhancing labor availability and income-generating capacity (Khandker et al., 2012a). At the macro level, electrification improves employment outcomes and labor market participation by reallocating time from home production toward productive activities **(Dinkelman, 2011)** Long-term evidence further shows that sustained electrification contributes to higher consumption levels and labor earnings growth (van de Walle et al., 2017)

Through productivity enhancement, income expansion, and structural transformation, clean energy access directly contributes to improvements in SDG 1 (No Poverty), including reductions in income poverty and broader dimensions of deprivation. However, clean energy infrastructure expansion is capital-intensive and

may involve institutional and affordability constraints. Empirical evidence suggests that while long-run poverty-reducing effects are significant, short-run impacts may remain limited due to adjustment costs and structural rigidities (Asghar et al., 2022).

These findings are closely related to the present study. Access to clean fuels and technologies for cooking may improve SDG 1 performance by reducing health risks, saving time, supporting employment, and increasing productive capacity. However, the full benefit may take time to appear. This provides a theoretical explanation for expecting a stronger long-run effect and a weaker short-run effect. Accordingly, the study proposes:

H1a. Clean energy access positively affects the achievement of SDG 1 (No Poverty) in the long run.

H1b. Clean energy access has a weak or insignificant effect on the achievement of SDG 1 in the short run.

Urban–Rural Heterogeneity in the Impact of Clean Energy Access on SDG 1

The impact of clean energy access on SDG 1 is unlikely to be spatially uniform. Urban areas typically exhibit stronger labor market integration, higher enterprise density, and better complementary infrastructure, allowing energy expansion to translate more rapidly into income growth and poverty reduction. In contrast, rural regions often face infrastructure deficits, limited market access, and weaker institutional capacity, which may constrain the immediate translation of energy access into improvements in SDG 1 outcomes (Sarkodie & Adams, 2020).

Moreover, unequal distribution of modern energy services may reinforce spatial disparities if equity considerations are not embedded in policy design (Sovacool & Dworkin, 2015). Given the pronounced urban–rural disparities across South Asia, the magnitude of the clean energy effect on SDG 1 (No Poverty) is therefore expected to differ between regions.

This perspective is important for the urban–rural analysis in the present study. If urban households have stronger infrastructure and more productive opportunities, clean energy access may produce a larger effect on SDG 1 in urban areas. In rural areas, the same level of access may have a smaller effect unless it is supported by finance, market connectivity, transport, enterprise development, and other services. Therefore, the Energy Justice perspective helps explain why clean energy access may not produce equal poverty-reduction outcomes across locations. Thus, the study proposes:

H2. The positive impact of clean energy access on the achievement of SDG 1 (No Poverty) is stronger in urban areas than in rural areas.

Data, model and methodology

Data and sources

This study uses annual panel data from eight South Asian countries: Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka covering the period from 2000 to 2024. The countries were selected based on the availability of consistent data for the variables included in the empirical model. The final dataset contains 200 country-year observations. The study relies entirely on secondary data collected from internationally recognized sources. Data for the main independent variable and all control variables were obtained from the World Development Indicators database of the World Bank. The data for Sustainable Development Goal 1 were collected from the Sustainable Development Report. The longer study period also

makes it possible to observe how the relationship has developed over time rather than relying on evidence from a single year or a short period. The measurements and definitions of the variables are reported in **Table 1**.

Table 1. Variable description

Variables type	Symbol	Variables Name	Measurement	Sources
Dependent variable	lnSDG1	No Poverty	No Poverty, sustainable development goal 1	SDR
Independent variable	lnACFTp	Clean energy access	Access to clean fuels and technologies for cooking (% of population)	WDI
Control variables	lnGDPp	Economic development	GDP per capita (constant 2015 US$)	WDI
	lnINDSp	Industrialization	Industry (including construction), value added (% of GDP)	WDI
	lnTDp	Trade	Trade (% of GDP)	WDI
	lnURBp	Urbanization	Urban population (% of total population)	WDI

Note: WDI refers to the World Development Indicators, while SDR refers to the Sustainable Development Report.

Model specification

This study examines the effect of clean energy access on the achievement of Sustainable Development Goal 1 in eight South Asian countries. Based on the conceptual framework, SDG 1 is treated as the dependent variable, while access to clean fuels and technologies for cooking is the main explanatory variable. Economic development, industrialization, trade, and urbanization are included as control variables.

The functional relationship of the study is expressed as follows:

$$SDG1_{it} = f\left(ACFTp_{it}, GDPp_{it}, INDSp_{it}, TDp_{it}, URBp_{it}\right) \qquad (1) \tag{1}$$

The variables are transformed into their natural logarithmic form. The baseline econometric model is therefore written as:

$$\begin{aligned} ln\left(SDG1\right)_{it} = \beta_0 & \\ & + \beta_1 lnACFTp_{it} \\ & + \beta_2 lnGDPp_{it} \\ & + \beta_3 lnINDSp_{it} \\ & + \beta_4 lnTDp_{it} \\ & + \beta_5 lnURBp_{it} \\ & + \epsilon_{it} \left(2\right) \end{aligned} \tag{2}$$

In Equation 2, $lnSDG1_{it}$represents the No Poverty index for country $i$in year t. It is the dependent variable used to measure the achievement of Sustainable Development Goal 1. The main independent variable is $lnACFTp_{it}$, which represents access to clean fuels and technologies for cooking as a percentage of the total population. The coefficient $\beta_1$shows the relationship between clean energy access and SDG 1 performance. A positive coefficient would indicate that greater access to clean fuels and technologies is associated with better progress toward the No Poverty goal. The model also contains four control variables. The variable $lnGDPp_{it}$

represents economic development, measured by GDP per capita in constant 2015 US dollars. The variable $lnINDSp_{it}$represents industrialization, measured by industry, including construction, value added as a percentage of GDP. The variable $lnTDp_{it}$represents trade as a percentage of GDP, while $lnURBp_{it}$represents urbanization, measured by the urban population as a percentage of the total population. These variables are included because changes in poverty outcomes may also be related to the wider economic and structural conditions of the countries. In the model, $\beta_0$is the constant term, while $\beta_1$to $\beta_5$represent the coefficients of the explanatory variables. The error term is represented by ϵ_{it}. The subscript $i$refers to the individual country, and t refers to the year. The prefix lnindicates that the variables are expressed in natural logarithmic form. Therefore, the estimated coefficients show how a percentage change in an explanatory variable is related to the percentage change in SDG 1 performance, while the remaining variables are held constant.

The baseline model uses clean energy access for the total population. To examine urban–rural differences, the empirical analysis also considers access to clean fuels and technologies among rural and urban populations separately. In these estimations, total clean energy access is replaced by rural clean energy access, represented by $lnACFTr$, and urban clean energy access, represented by $lnACFTu$. The remaining control variables are kept unchanged. These specifications allow the study to examine the overall relationship between clean energy access and SDG 1 and to identify whether the effect differs between rural and urban areas. The short-run and long-run relationships are later estimated through the panel ARDL method reported in the study.

The main independent variable used in this study is access to clean fuels and technologies for cooking, represented by lnACFTp. It is measured as the percentage of the total population with access to clean fuels and technologies for cooking. The data for this variable were collected from the World Development Indicators of the World Bank.

Accordingly, in the empirical analysis, the term clean energy access refers specifically to access to clean fuels and technologies for cooking rather than to all dimensions of modern energy access. Governance quality and income inequality are discussed in the literature as important contextual factors, but they are not included in the empirical specification; the estimated model therefore focuses on economic development, industrialization, trade, and urbanization as control variables. The panel ARDL framework is used to distinguish short-run and long-run relationships, but it does not by itself establish the direction of causality or eliminate the possibility of reverse causality.

Result and Discussion

Descriptive statistics

Table 2 reports the descriptive statistics of the variables used in the study. The mean value of lnSDG1 is 4.091, with values ranging between 2.753 and 4.596, indicating differences in poverty performance across South Asian countries. Clean energy access (lnACFTp) shows a mean of 3.469 and comparatively higher dispersion (0.697), suggesting uneven access to clean fuel and technology within the region. Economic growth (lnGDPp) has a mean of 7.381, reflecting notable cross-country income disparities. Industrial structure (lnINDSp) and urbanization (lnURBp) exhibit relatively lower variability, whereas trade openness (lnTDp) demonstrates moderate dispersion. Overall, the statistics reveal sufficient cross-sectional variation, supporting the use of panel estimation techniques.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lnSDG1	200	4.091	.428	2.753	4.596
lnACFTp	200	3.469	.697	1.668	4.602
lnGDPp	200	7.381	.912	5.624	9.389
lnINDSp	200	3.065	.41	2.087	3.729
lnTDp	200	3.992	.723	1.48	6.169
lnURBp	200	3.326	.304	2.595	3.807

Source: World Development Indicators (WDI) and Sustainable Development Report (SDR).

Pairwise Correlation

Table 3 presents the pairwise correlation matrix among the variables. The results indicate that clean energy access (lnACFTp) is positively and significantly correlated with poverty reduction (lnSDG1) ($r = 0.697$, $p < 0.01$), suggesting that higher access to clean fuel and technology is associated with improved poverty outcomes. Similarly, economic growth (lnGDPp) shows a strong positive correlation with lnSDG1 ($r = 0.754$, $p < 0.01$), indicating that higher income levels are linked with better SDG 1 performance. Trade openness (lnTDp) and urbanization (lnURBp) are also positively correlated with lnSDG1, though the magnitudes are comparatively smaller. In contrast, industrial structure (lnINDSp) exhibits a weak and statistically insignificant relationship with poverty reduction. Overall, most explanatory variables display moderate to strong correlations with lnSDG1; however, none of the correlation coefficients exceed 0.80, suggesting the absence of severe multicollinearity concerns. However, the correlation results only demonstrate preliminary associations and do not establish the direction of causality. The panel ARDL results provide a more detailed assessment of the short-run and long-run relationships.

Table 3. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) lnSDG1	1.000					
(2) lnACFTp	0.697	1.000				
	(0.000)					
(3) lnGDPp	0.754	0.710	1.000			
	(0.000)	(0.000)				
(4) lnINDSp	-0.071	-0.214	-0.168	1.000		
	(0.319)	(0.002)	(0.017)			
(5) lnTDp	0.297	0.488	0.722	-0.301	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)		
(6) lnURBp	0.331	0.651	0.401	0.028	0.194	1.000
	(0.000)	(0.000)	(0.000)	(0.699)	(0.007)	

Source: World Development Indicators (WDI) and Sustainable Development Report (SDR)

Cross-sectional Dependence Test

Table 4 presents the results of the Pesaran CD test used to examine the presence of cross-sectional dependence among the variables. The results show that lnSDG1, lnACFTp, lnGDPp, and lnURBp have positive and

statistically significant Pesaran CD test statistics at the 1% level, with values of 21.971, 24.380, 22.052, and 23.864, respectively. Trade openness (lnTDp) also shows a statistically significant test statistic of 1.990 at the 5% level. In contrast, industrialization (lnINDSp) records a test statistic of 1.021 and is statistically insignificant. Overall, the results provide evidence of considerable cross-sectional dependence among most of the variables in the panel. Therefore, PCSE is later employed as a robustness estimator to account for correlation across the cross-sectional units.

Table 4. Presents the results of the Pesaran CD test.

Cross-sectional dependence test	**Pesaran CD**
Variables	Statistic
lnSDG1	21.971***
lnACFTp	24.38***
lnGDPp	22.052***
lnINDSp	1.021
lnTDp	1.99**
lnURBp	23.864***

The notations *, **, and *** indicate significance at the 10%, 5%, and 1% levels.
Source: World Development Indicators (WDI) and Sustainable Development Report (SDR).

Slope Homogeneity Test

Table 5 reports the results of the slope homogeneity test used to determine whether the slope coefficients are homogeneous across the countries included in the panel. The Delta statistic is 9.251 and is statistically significant at the 1% level, with a p-value of 0.000. Similarly, the adjusted Delta statistic is 11.028 and is also statistically significant at the 1% level, with a p-value of 0.000. Therefore, the null hypothesis of homogeneous slope coefficients is rejected. The findings indicate the presence of slope heterogeneity across the cross-sectional units, suggesting that the effects of the explanatory variables on SDG 1 performance may differ across the countries rather than remaining identical throughout the panel. This result highlights the importance of considering cross-country heterogeneity in the subsequent panel analysis.

Table 5. Results of the Slope Homogeneity test

	Delta	p-value
	9.251***	0.000
adj.	11.028***	0.000

The notations *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Panel Unit Root Test

Table 6presents the results of the CADF and CIPS panel unit root tests used to examine the stationarity properties of the variables. The findings show mixed stationarity at the level. Clean energy access (lnACFTp) is stationary at level under both the CADF and CIPS tests, with statistics of −3.550 and −3.068, respectively, both significant at the 1% level. Trade openness (lnTDp) is also stationary at level under both tests, with a statistic of −2.781 that is significant at the 1% level. In contrast, lnSDG1, lnGDPp, lnINDSp, and lnURBp are non-stationary at level according to both tests.After taking the first difference, all variables become statistically significant under both the CADF and CIPS tests. lnSDG1 records first-difference statistics of −3.060 and −3.710, while lnGDPp

records −3.715 and −3.704 under CADF and CIPS, respectively. Industrialization (lnINDSp) also becomes stationary at first difference, with statistics of −2.846 and −4.178. Similarly, urbanization (lnURBp), which is non-stationary at level, becomes stationary at first difference, with CADF and CIPS statistics of −2.624 and −4.079, respectively, both significant at the 1% level.Overall, the unit root results indicate a combination of I(0) and I(1) variables. While lnACFTp and lnTDp are stationary at level, the remaining variables become stationary after first differencing. Since all variables are stationary either at level or at first difference and none requires second differencing, the findings support the application of the panel ARDL approach for examining the short-run and long-run relationships among the variables.

Table 6. Results of panel unit root tests

Variables	**CADF**		**CIPS**	
	Level	First difference	Level	First difference
lnSDG1	-1.464	-3.060***	-1.774	-3.710***
lnACFTp	-3.550***	-3.010***	-3.068***	-3.459***
lnGDPp	-1.733	-3.715***	-1.653	-3.704***
lnINDSp	-1.861	-2.846***	-1.792	-4.178***
lnTDp	-2.781***	-2.665***	-2.781***	-2.665***
lnURBp	0.279	-2.624***	-0.050	-4.079***

The notations *, **, and *** indicate significance at the 10%, 5%, and 1% levels.
Source: World Development Indicators (WDI) and Sustainable Development Report (SDR).

Results of the Panel ARDL Model

Table 7 reports the long-run and short-run estimates of the panel ARDL model. The main result in Column (1) shows that access to clean fuels and technologies for cooking for the total population has a positive and statistically significant long-run relationship with SDG 1 performance. The coefficient of lnACFTp is 0.804 and is statistically significant at the 1% level. As all variables are expressed in natural logarithmic form, the coefficient can be interpreted as an elasticity. Therefore, a 1% increase in access to clean fuels and technologies for cooking is associated with an approximately 0.804% improvement in SDG 1 performance in the long run, holding the other variables constant.

Table 7. Baseline Outcomes

	(1)	(2)	(3)
	lnSDG1	lnSDG1	lnSDG1
Long-run			
lnACFTp	0.804***		
	(0.067)		
lnACFTr		0.254***	
		(0.034)	
lnACFTu			1.570***
			(0.189)
lnGDPp	-0.122	-0.014	0.263***
	(0.111)	(0.148)	(0.088)
lnINDSp	0.220***	0.391***	0.261***

	(0.081)	(0.099)	(0.096)
lnTDp	0.337***	0.296***	0.116**
	(0.049)	(0.063)	(0.056)
lnURBp	1.001***	1.700***	1.521***
	(0.270)	(0.346)	(0.262)
Short-run			
ECM	-0.414*	-0.372**	-0.433**
	(0.215)	(0.180)	(0.190)
D.lnACFTp	-1.862		
	(1.602)		
D.lnACFTr		-0.924	
		(0.727)	
D.lnACFTu			-4.766
			(3.405)
D.lnGDPp	0.501***	0.378**	0.380**
	(0.180)	(0.173)	(0.189)
D.lnINDSp	-0.244	-0.216	-0.178
	(0.166)	(0.175)	(0.131)
D.lnTDp	-0.001	-0.007	-0.007
	(0.103)	(0.109)	(0.100)
D.lnURBp	-19.370	-26.575	-14.714
	(19.615)	(25.557)	(15.076)
_cons	-1.358	-1.625	-4.803**
	(1.018)	(1.150)	(2.365)
N	181	181	181

Notes: Standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01; The PMG estimator implemented through xtpmg does not report a conventional R^2 statistic; therefore, no R^2 value is reported for Table 7.

In Column (2), rural access to clean fuels and technologies for cooking (lnACFTr) has a positive coefficient of 0.254 and is statistically significant at the 1% level. In Column (3), urban access to clean fuels and technologies for cooking (lnACFTu) has a positive coefficient of 1.570 and is statistically significant at the 1% level. Although both rural and urban clean cooking access have positive and statistically significant long-run relationships, the urban coefficient is substantially larger than the rural coefficient. The results therefore indicate a stronger estimated poverty-related relationship in the urban specification.

Among the control variables, industrialization, trade openness, and urbanization have positive and statistically significant long-run coefficients across the reported specifications. Economic development remains statistically insignificant in the total-population and rural models, but becomes positive and statistically significant in the urban model, with a coefficient of 0.263.

In the short run, neither total, rural, nor urban clean energy access has a statistically significant effect. The error-correction term is negative and statistically significant in all specifications. In Column (1), the ECM coefficient is −0.414 and is significant at the 10% level; in the rural specification it is −0.372 and significant at the 5% level; and in the urban specification it is −0.433 and significant at the 5% level. The negative and statisti-

cally significant error-correction coefficients indicate that the system returns toward its long-run equilibrium following short-run disturbances.

Overall, the findings indicate that access to clean fuels and technologies for cooking is positively associated with improved SDG 1 performance primarily in the long run. The results also reveal that the estimated relationship is stronger in the urban specification than in the rural specification.

The positive long-run relationship can be explained through the economic and social benefits of modern energy access. At the household level, clean energy reduces the time required to collect traditional biomass and lowers exposure to indoor air pollution. These improvements can increase labour availability and strengthen households' ability to engage in income-generating activities (Khandker et al., 2012b). **(Dinkelman, 2011)** also found that electrification increased employment and labour-market participation by allowing individuals to shift time away from household production. Similarly, (van de Walle et al., 2017) showed that continued access to electricity contributes to higher household consumption and labour earnings in the long run. The statistically insignificant short-run result is consistent with (Asghar et al., 2022), who found that the poverty-reducing effects of energy access are more evident in the long run, while short-run outcomes may remain limited because of adjustment costs and structural rigidities.

The larger urban coefficient is consistent with the argument that urban areas generally have stronger labour-market integration, greater enterprise density, and better supporting infrastructure. These conditions may allow households and businesses to use clean energy more effectively for income generation and poverty reduction. Rural areas, in contrast, often face infrastructure shortages, limited market access, and weaker institutional capacity, which may reduce the extent to which energy access improves SDG 1 outcomes (Sarkodie & Adams, 2020). The result also reflects the importance of fairness in the distribution of modern energy services. (Sovacool & Dworkin, 2015) explained that energy policies that do not consider equity may reinforce existing spatial and socio-economic differences.

Because rural and urban clean cooking access are estimated in separate specifications rather than through an interaction term, the difference between the 1.570 urban coefficient and the 0.254 rural coefficient is interpreted as descriptive heterogeneity across specifications rather than as a formal causal interaction effect.

Robustness Test

Table 8 presents the robustness results obtained from the Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) estimations. These alternative estimators are used to examine whether the main findings remain stable under different estimation techniques. Since the preliminary analysis indicates the presence of cross-sectional dependence among most of the variables, the PCSE estimator is employed to account for correlation across the cross-sectional units and to provide corrected standard errors. In addition, FGLS is applied with panel-specific heteroskedasticity to account for differences in error variances across countries.

Table 8. Robustness results obtained from the PCSE and FGLS estimations.

	(1)	(2)
	lnSDG1	lnSDG1
lnACFTp	0.279***	0.223***
	(0.027)	(0.040)

lnGDPp	0.367***	0.326***
	(0.033)	(0.029)
lnINDSp	0.047***	0.134***
	(0.016)	(0.037)
lnTDp	-0.250***	-0.185***
	(0.027)	(0.026)
lnURBp	-0.288***	-0.190***
	(0.020)	(0.062)
_cons	2.232***	1.881***
	(0.201)	(0.282)
N	189	189
R^2	0.676	—

Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

The results show that access to clean fuels and technologies for cooking (lnACFTp) remains positive and statistically significant at the 1% level under both estimators. The coefficient is 0.279 under PCSE and 0.223 under FGLS. Economic development (lnGDPp) is also positive and statistically significant in both models, with coefficients of 0.367 and 0.326. Industrialization (lnINDSp) shows positive and statistically significant coefficients of 0.047 and 0.134. In contrast, trade openness (lnTDp) has negative and statistically significant coefficients of −0.250 and −0.185, while urbanization (lnURBp) has negative and statistically significant coefficients of −0.288 and −0.190.

Although the magnitude of the coefficients differs between the two estimators, the positive direction and statistical significance of the clean cooking access variable remain unchanged. Overall, the PCSE and FGLS results strengthen the reliability of the main finding that greater access to clean fuels and technologies for cooking is positively associated with improved SDG 1 performance. The robustness findings confirm the stability of this central relationship, although some control-variable results vary across specifications.

The sign changes for trade openness and urbanization relative to the panel ARDL long-run estimates indicate that these control-variable relationships are sensitive to estimator specification. These control-variable sign changes should therefore be interpreted cautiously. They do not alter the central robustness result because access to clean fuels and technologies for cooking remains positive and statistically significant under both PCSE and FGLS.

These alternative estimators are used to examine whether the main findings remain stable under different estimation techniques. Since the preliminary analysis indicates the presence of cross-sectional dependence among most of the variables, the PCSE estimator is employed to account for correlation across the cross-sectional units and to provide corrected standard errors. In addition, FGLS is applied with panel-specific heteroskedasticity to account for differences in error variances across countries. Therefore, the use of PCSE and FGLS provides an additional robustness assessment of the main panel ARDL findings. The results show that clean energy access (lnACFTp) remains positive and statistically significant at the 1% level under both estimators. The coefficient is 0.279 under PCSE and 0.223 under FGLS, indicating a consistent positive relationship

between access to clean fuels and technologies for cooking and SDG 1 performance. Although the magnitude of the coefficients differs between the two estimators, their positive direction and statistical significance remain unchanged. This provides further evidence that the positive relationship between clean energy access and SDG 1 is robust to alternative estimation methods. Economic development (lnGDPp) also has a positive and statistically significant relationship with SDG 1 performance in both models. The estimated coefficient is 0.367 under PCSE and 0.326 under FGLS, with both results significant at the 1% level. Industrialization (lnINDSp) similarly shows a positive and statistically significant effect, with coefficients of 0.047 under PCSE and 0.134 under FGLS. In contrast, trade openness (lnTDp) has a negative and statistically significant relationship with SDG 1 performance in both estimations. The coefficient is −0.250 under PCSE and −0.185 under FGLS, both significant at the 1% level. Urbanization (lnURBp) also shows a negative and statistically significant relationship, with coefficients of −0.288 under PCSE and −0.190 under FGLS. Despite some differences in coefficient magnitude, the signs and statistical significance of the variables remain broadly consistent across the two estimators. Overall, the PCSE and FGLS results strengthen the reliability of the main finding that greater clean energy access is positively associated with improved SDG 1 performance.

Conclusion and Policy implications:

Conclusion

This study examined the relationship between access to clean fuels and technologies for cooking and the achievement of Sustainable Development Goal 1 in South Asian countries over the period 2000–2024. The panel ARDL method was used to distinguish the short-run and long-run relationships between clean cooking access and SDG 1 performance. The findings show that access to clean fuels and technologies for cooking is positively and statistically significantly associated with SDG 1 performance in the long run, while the short-run relationship is statistically insignificant. The negative and statistically significant error-correction terms confirm the presence of a stable long-run relationship. The urban–rural analysis shows positive long-run relationships in both specifications, with a substantially larger coefficient in the urban specification than in the rural specification. The robustness results also support the central finding, as the clean cooking access variable remains positive and statistically significant under the alternative specifications. Overall, the findings indicate that access to clean fuels and technologies for cooking is associated with improved SDG 1 performance in South Asia mainly over the long run, although the strength of the estimated relationship differs between urban and rural areas.

The findings are also consistent with the theoretical perspectives used in the study. The Energy–Poverty Nexus explains how energy deprivation and poverty can reinforce one another and why the benefits of improved access may become more visible over time. The Energy Justice perspective emphasizes that the benefits of energy access may not be distributed equally across geographical areas. The stronger long-run relationship in the urban specification is therefore consistent with the study's theoretical expectation that differences in infrastructure, affordability, market access, and institutional support can produce unequal poverty-related outcomes.

The study contributes to the understanding of the connection between SDG 7 and SDG 1 through one specific SDG 7-related dimension: access to clean fuels and technologies for cooking. This clean-cooking dimension is connected with household welfare, health, time use, employment, productivity, and income opportuni-

ties. The findings therefore provide evidence on how progress in clean cooking access is associated with poverty-related development outcomes while not representing all dimensions of energy access.

The panel ARDL approach allows the study to distinguish short-run adjustment from the long-run relationship. The study also compares rural and urban clean cooking access in separate specifications, providing evidence on spatial heterogeneity while not constituting an interaction-based causal test. The robustness analysis strengthens the reliability of the central association because the clean cooking access variable remains positive and statistically significant under the alternative specifications.

The study also provides practical policy value because the estimated long-run relationship is stronger in the urban specification than in the rural specification. This finding suggests that rural households may need more than clean cooking access alone. Additional support through finance, market development, transport, enterprise opportunities, and rural infrastructure may be necessary for clean cooking access to be associated with stronger poverty-related outcomes.

Policy Implications

The findings of this study provide several important policy directions for South Asian countries seeking to accelerate progress toward SDG 1 through cleaner cooking access. First, governments should prioritize sustained long-term investment in access to clean fuels and technologies for cooking and the infrastructure that supports it. Because the estimated relationship with SDG 1 is strongest in the long run, stable and continuous policy commitments are important, while short-term interventions alone may not produce immediate measurable changes in SDG 1 performance.

Second, the substantial urban–rural difference identified in the analysis calls for targeted rural strategies. The estimated long-run relationship is stronger in the urban specification than in the rural specification. Policymakers should therefore complement rural clean cooking access with supportive measures such as rural enterprise development, microfinance access, infrastructure connectivity, and market integration so that households are better able to translate access into broader welfare gains.

Third, the control-variable results should be interpreted cautiously because trade openness and urbanization change signs across the baseline and robustness estimations. The policy conclusions should therefore focus primarily on the central clean cooking access result and on complementary economic and institutional conditions rather than treating the control-variable coefficients as uniformly stable across estimators.

Fourth, inclusive urban planning remains important, but the urbanization coefficient is sensitive to estimator specification. Policymakers should therefore focus on equitable access to clean cooking services within growing cities, including informal settlements and low-income urban households, rather than assuming that urban growth alone improves poverty-related outcomes.

Finally, regional cooperation within South Asia can strengthen clean energy deployment and poverty reduction efforts. Cross-border infrastructure initiatives, knowledge-sharing platforms, and coordinated financing mechanisms can reduce costs and enhance technological diffusion. Ensuring affordable access to clean cooking technologies, particularly for women and low-income households, should remain central to inclusive development strategies.

Overall, improving SDG 1 outcomes through clean cooking access requires more than infrastructure investment alone. It requires long-term and context-sensitive policies that connect access to clean fuels and tech-

nologies for cooking with complementary economic opportunities and social inclusion.

Study Limitations

The study has several limitations that should be considered when interpreting the findings. First, the main independent variable is access to clean fuels and technologies for cooking, measured as the percentage of the population with access to clean cooking fuels and technologies. Therefore, the empirical analysis does not represent all dimensions of energy access, such as electricity access. Second, the baseline model includes economic development, industrialization, trade, and urbanization as control variables, while governance and income inequality are discussed in the literature but are not included in the empirical specification. Third, the correlation results demonstrate associations and do not establish the direction of causality. The panel ARDL framework distinguishes short-run and long-run relationships, but the study does not use an instrumental-variable strategy to explicitly address reverse causality. Fourth, the urban–rural analysis is based on separate rural and urban clean-energy specifications rather than an interaction-based test. The larger urban coefficient should therefore be interpreted as a stronger estimated relationship in the urban specification. Finally, the robustness findings confirm the stability of the positive relationship for the central clean-energy-access variable, although some control-variable results vary across specifications.

Future Research Directions

Future research can extend the analysis by using broader measures of energy access that include electricity alongside clean cooking access, incorporating institutional variables such as governance and income inequality, applying instrumental-variable or other endogeneity-robust approaches to examine reverse causality, and using interaction-based tests to assess urban–rural heterogeneity more formally. These extensions would allow future studies to examine whether the relationships identified here remain stable under broader measurement and stronger causal identification strategie

Funding

This research received no external funding.

Author contributions

Sanjida Anjum Nigar: Conceptualization, Investigation, Software, Writing – original draft, Writing – review & editing, Formal analysis.

Declaration of competing interest

The authors declare no conflicts of interest.

Ethics statement

Not applicable.

Data availability

Data available on request from the corresponding author.

References

Adenle, A. A. (2020). Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals. *Energy Policy*, *137*, 111180. https://doi.org/10.1016/j.enpol.2019.111180

Amin, A., et al. (2025). Achieving Sustainable Development Goal-7: Exploring the Determinants of Energy Poverty in SAARC Countries. *Sustainable Development*, *33*(S1), 630-649. https://doi.org/10.1002/sd.3556

Asghar, N., et al. (2022). Achieving sustainable development resilience: Poverty reduction through affordable access to electricity in developing economies. *Journal of Cleaner Production*, *376*, 134040. https://doi.org/10.1016/j.jclepro.2022.134040

Batool, K., et al. (2022). Nexus Between Energy Poverty and Technological Innovations: A Pathway for Addressing Energy Sustainability. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.888080

Bellepea, N. Y. & Türüç, F. (2024). The effect of energy poverty on gender inequality in Southern Asian countries. *International Journal of Energy Sector Management*, *19*(3), 691-709. https://doi.org/10.1108/IJESM-07-2024-0043

Biswas, W. K., et al. (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. *Environmental Science & Policy*, *4*(6), 333-344. https://doi.org/10.1016/S1462-9011(01)00031-4

Bonatz, N., et al. (2019). A comparative study of the interlinkages between energy poverty and low carbon development in China and Germany by developing an energy poverty index. *Energy and Buildings*, *183*, 817-831. https://doi.org/10.1016/j.enbuild.2018.09.042

Bouzarovski, S. & Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. *Energy Research & Social Science*, *10*, 31-40. https://doi.org/10.1016/j.erss.2015.06.007

Byaro, M., et al. (2024). Tackling energy poverty: Do clean fuels for cooking and access to electricity improve or worsen health outcomes in sub-Saharan Africa?. *World Development Sustainability*, *4*, 100125. https://doi.org/10.1016/j.wds.2024.100125

Day, R., et al. (2016). Conceptualising energy use and energy poverty using a capabilities framework. *Energy Policy*, *93*, 255-264. https://doi.org/10.1016/j.enpol.2016.03.019

Dinkelman, T. (2011). The Effects of Rural Electrification on Employment: New Evidence from South Africa. *American Economic Review*, *101*(7), 3078-3108. https://doi.org/10.1257/aer.101.7.3078

He, Y., et al. (2022). Social benefit evaluation of China's photovoltaic poverty alleviation project. *Renewable Energy*, *187*, 1065-1081. https://doi.org/10.1016/j.renene.2022.02.013

Karekezi, S. & Kithyoma, W. (2002). Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?. *Energy Policy*, *30*(11), 1071-1086. https://doi.org/10.1016/S0301-4215(02)00059-9

Khandker, S. R., et al. (2012). The Welfare Impacts of Rural Electrification in Bangladesh. *The Energy Journal*, *33*(1), 187-206. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol33-No1-7

Khandker, S. R., et al. (2012). The Welfare Impacts of Rural Electrification in Bangladesh. *The Energy Journal*, *Volume 33*(Number 1).

Khandker, S. R. B. D. F., et al. (2012). The Welfare Impacts of Rural Electrification in Bangladesh. *The Energy Journal, Volume 33(Number 1)*.

Khanna, R. A., et al. (2019). Comprehensive energy poverty index: Measuring energy poverty and identifying micro-level solutions in South and Southeast Asia. *Energy Policy*, *132*, 379-391. https://doi.org/10.1016/j.enpol.2019.05.034

Li, C., et al. (2025). Energy–poverty–inequality SDGs: A large-scale household analysis and forecasting in China. *Proceedings of the National Academy of Sciences*, *122*(1), e2408167121. https://doi.org/10.1073/pnas.2408167121

Lipscomb, M., et al. (2013). Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil. *American Economic Journal: Applied Economics*, *5*(2), 200-231. https://doi.org/10.1257/app.5.2.200

Monyei, C. G., et al. (2022). Regional cooperation for mitigating energy poverty in Sub-Saharan Africa: A context-based approach through the tripartite lenses of access, sufficiency, and mobility. *Renewable and Sustainable Energy Reviews*, *159*, 112209. https://doi.org/10.1016/j.rser.2022.112209

Murshed, M. & Ozturk, I. (2023). Rethinking energy poverty reduction through improving electricity accessibility: A regional analysis on selected African nations. *Energy*, *267*, 126547. https://doi.org/10.1016/j.energy.2022.126547

Nations, U. (2015). Transforming our world: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs. .

Nepal, R. & Paija, N. (2019). Energy security, electricity, population and economic growth: The case of a developing South Asian resource-rich economy. *Energy Policy*, *132*, 771-781. https://doi.org/10.1016/j.enpol.2019.05.054

P, J. & R, R. (2025). Towards sustainable energy access: Investigating the relationship between renewable energy consumption and energy poverty. *Energy Policy*, *200*, 114553. https://doi.org/10.1016/j.enpol.2025.114553

Pandey, A. & Asif, M. (2022). Assessment of energy and environmental sustainability in South Asia in the perspective of the Sustainable Development Goals. *Renewable and Sustainable Energy Reviews*, *165*, 112492. https://doi.org/10.1016/j.rser.2022.112492

Pereira, M. G., et al. (2010). Rural electrification and energy poverty: Empirical evidences from Brazil. *Renewable and Sustainable Energy Reviews*, *14*(4), 1229-1240. https://doi.org/10.1016/j.rser.2009.12.013

Rasul, G. (2016). Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia. *Environmental Development*, *18*, 14-25. https://doi.org/10.1016/j.envdev.2015.12.001

Sarkodie, S. A. & Adams, S. (2020). Electricity access, human development index, governance and income inequality in Sub-Saharan Africa. *Energy Reports*, *6*, 455-466. https://doi.org/10.1016/j.egyr.2020.02.009

Simionescu, M., et al. (2023). The role of renewable energy policies in TACKLING energy poverty in the European UNION. *Energy Policy*, *183*, 113826. https://doi.org/10.1016/j.enpol.2023.113826

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

Song, Y., et al. (2023). Study on the impact of energy poverty on income inequality at different stages of economic development: Evidence from 77 countries around the world. *Energy*, *282*, 128816. https://doi.org/10.1016/j.energy.2023.128816

Sovacool, B. K. & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy*, *142*, 435-444. https://doi.org/10.1016/j.apenergy.2015.01.002

Sy, S. A. & Mokaddem, L. (2022). Energy poverty in developing countries: A review of the concept and its measurements. *Energy Research & Social Science*, *89*, 102562. https://doi.org/10.1016/j.erss.2022.102562

Tamasiga, P., et al. (2024). Pricing the future: unveiling the effects of carbon pricing on socio-economic outcomes and energy poverty. *International Journal of Sustainable Energy*, *43*(1), 2362334. https://doi.org/10.1080/14786451.2024.2362334

Tarekegne, B. (2020). Just electrification: Imagining the justice dimensions of energy access and addressing energy poverty. *Energy Research & Social Science*, *70*, 101639. https://doi.org/10.1016/j.erss.2020.101639

Thiam, D. R. (2011). Renewable energy, poverty alleviation and developing nations: Evidence from Senegal. *Journal of Energy in Southern Africa*, *22*(3), 23-34. https://doi.org/10.17159/2413-3051/2011/v22i3a3219

United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs. .

Walle, D., et al. (2017). Long-term Gains from Electrification in Rural India. *The World Bank Economic Review*, *31*(2), 385-411. https://doi.org/10.1093/wber/lhv057

Yadava, R. N. & Sinha, B. (2024). Energy–poverty–climate vulnerability nexus: an approach to sustainable development for the poorest of poor. *Environment, Development and Sustainability*, *26*(1), 2245-2270. https://doi.org/10.1007/s10668-022-02812-7

Yadoo, A. & Cruickshank, H. (2012). The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini-grids with case studies in Nepal, Peru and Kenya. *Energy Policy*, *42*, 591-602. https://doi.org/10.1016/j.enpol.2011.12.029

Zhao, J., et al. (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

OPEN ACCESS

This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. (CC BY 4.0).

Disclaimer/Publisher's Note: All views and opinions expressed in this publication are those of the author(s) and do not necessarily reflect those of the editors or ABS Research Academy. The publisher and editors accept no responsibility for any consequences arising from the use of the information contained herein.