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Sustainable Development Goals and Energy Poverty Reduction: Empirical Evidence from N11 Countries

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ABSTRACT

This research aims to integrate the severity of energy poverty with a multidimensional indicator established using the GRA-SRA methodology. In this case study, N11 nations utilize data from 2001 to 2017 to create a multidimensional indicator of energy poverty by integrating 13 indicators for N11 nations (energy availability, energy cleanliness, and energy accessibility). This study combines the severity of energy poverty with a multidimensional indicator developed with the GRA-SRA approach. In this case study, N11 nations use data from 2001 to 2017 to build a multidimensional indicator of energy poverty by integrating 13 indicators for N11 nations (energy availability, energy cleanliness, and energy accessibility). South Korea discovered disparities in energy poverty among the N11 countries. It has steadily reduced its energy poverty, whereas Iran has experienced a reduction. Patterns of variation: This report also addresses global energy requirements for low-income people. According to the study, the type of energy utilized for heating is crucial in an environment of poverty and inequality. This study emphasizes the significance and use of cross-national comparisons. All locations share climate and other environmental characteristics. Energy poverty decreases as energy availability increases. Reduced energy poverty, on the other hand, leads to fewer economic disparities.

Keywords: Ecological Growth, N11 Nations, Energy Poverty, Economic Disparities, Renewable Energy
JEL Classifications: P28, O13, P48, Q00

1. INTRODUCTION

Energy poverty is a major concern for developing countries. Energy is a critical resource for meeting the contemporary world's various demands. When people cannot access domestic services, they are more likely to suffer from physical, mental, and social problems. There are several types of energy poverty in the globe, including a scarcity of clean energy (electricity and natural gas) (Chien et al., 2022). It is especially common in underdeveloped countries. Because of the global economic crisis, thirty-eight million people are going hungry. This figure climbed to eighty-five million in 2017. South Asia is home to over five hundred million of the world's 1.72 billion poor, according to the World Bank (Dong et al., 2022). According to the pricing methodology, 84% of Sri Lankan households are severely impoverished in many aspects (Hossain et al., 2023).

In 2019, 4 billion people cooked using traditional fuels, while 870 million remained powerless. Indoor air pollution from open fires kills 2.7 million people yearly (Sustainability and 2010, 2010).

Inadequate access to energy services reduces social interaction and personal well-being in general. The phrase "energy poverty" has been used to describe the lack of access to local energy services. Even though both low-and high-income countries have researched energy poverty, the discrepancy between access and cost is evident in the relevant studies (Du et al., 2022).

Given the disparity between worries about accessibility in low-income nations and concerns about cost in high-income countries, the difficulty of defining energy poverty remains global (Khokhar et al., 2022). Indeed, the boundary between cost and accessibility has become fuzzier on all three fronts, both in the literature and real life. To measure and report progress toward the Sustainable Development Goals, academics and experts on energy poverty in developing countries developed indicators(Chien et al., 2022).

According to the Communist Party of China's 19th National Congress report, China still faces several major issues, including uneven resource distribution, wide income disparities, and a discordant environment, all of which have the potential to stymie China's economy and society's green and sustainable development (Mustafa et al., 2023). Green growth, as advocated at the 2012 Rio+20 Summit, provides new ideas and techniques for China's long-term development (Khokhar et al., 2022). These principles assist China in achieving coordinated and harmonious economic, social, and environmental progress and aid in achieving carbon peak and carbon neutrality (Sy and Mokaddem, 2022). The gradual advancement of green growth within the framework of the new economic normal may effectively support the transformation of the economy and industrial structure (Irshad et al., 2019), resulting in the realization of a clean and green economic growth model as well as the attainment of the carbon peak and carbon neutrality goals(Krajnc and Glavič 2005).

The vast amount of energy consumed has significantly stifled China's green growth in the process of accelerating economic growth (Chien et al., 2021), improving people's welfare, and improving the environment, as evidenced largely by the country's reliance on traditional biomass energy (Khokhar et al., 2020), a lack of clean energy, and the inability of energy expenditures to be cheap. Even though numerous studies use a set of variables to analyze green development, green growth evaluation has yet to meet agreed-upon criteria. Furthermore, little study has been conducted into the dynamic connection between energy poverty and green growth, and the multiple consequences are often ignored. Regional energy poverty should be addressed in tandem with the country's general dependency on energy, as indicated by the country's reliance on traditional biomass energy, a lack of clean energy, and difficulty in keeping energy expenditures low. Despite multiple studies using various methodologies to evaluate green development, green growth evaluation has yet to meet agreed-upon standards. Furthermore, little study has been conducted into the dynamic interaction between energy poverty and green growth, and the multiple repercussions are generally disregarded.

2. LITERATURE REVIEW

Economic growth is a high-level concern, in addition to several macro and micro-ones. (Hailiang et al., 2023) Demonstrate that the globe is experiencing acute energy constraints. For cooking, one-third of the world's population relies on wood and other inefficient fuels like agricultural wastes, cracks, and dung. A 1/3 of the world's population lives in Poverty; most live in Sub-Saharan Africa, South Asia, and the African Sahel area (Seman et al., 2019).

Energy poverty has many implications, making these economies even more susceptible. This study examines how multidimensional energy scarcity and climate disruptions affect multivariate health deterioration in Pakistan (Khokhar et al., 2022). Despite its fundamental value, empirical findings reveal that scarcity considerably influences health poverty in Pakistan. Nawaz assesses the impact of multidimensional energy scarcity and environmental shocks on health in Pakistan. Energy-spending approaches have been employed mostly in high-income nations, where the affordability factor of energy poverty has been stressed (Maryam et al., 2021). The 10% scale established by Boardman is the typical scale used. If a household spends more than 10% of its income on energy, it is deemed energy deficient. One of the most common critiques against the 10% index is that it does not account for houses with higher incomes and demands for energy services that exceed community requirements, such as those with swimming pools (Hou et al., 2023).

Infrastructure coverage is better in industrialized countries, and fair access to modern energy sources exists. However, in developing nations, energy poverty refers to a lack of access to modern energy required to deliver contemporary energy services. This can be attributed to a lack of infrastructure, well-functioning energy service marketplaces, and adequate income to acquire contemporary energy sources (Younas et al., 2023). Energy poverty impacts whole geographic units in underdeveloped nations (Xia et al., 2022). Rural and rural communities remain particularly vulnerable, with little or no access to modern energy sources. As a result, the current study becomes more important to researchers, academics, and policymakers, as it reveals implications for theory development, management practices, and future research suggestions (Hou et al., 2022). While academic studies on energy poverty are becoming more popular, the results have remained scattered, varied, and multidisciplinary. The literature on energy poverty draws contradictory results on several social and economic elements (Hassan et al., 2022).

To correct this mistake, the Low-Income High-Cost Index (LIHC) was developed as the official definition in England and Wales (Khaskhelly et al., 2022). A household is classified as energy poor on the LIHC scale if its required fuel expenses exceed the national average and its residual income after these costs are less than the national poverty level (Li et al., 2022). The main difference between the energy expenditure-based approach and the actual expenditure-based strategy is that the former employs "desired" energy expenditure rather than "actual" energy expenditure (Ahmad et al., 2023; Khan et al., 2022). The predicted energy consumption required to support the household determines the required energy expenditure. EP also hinders daily labor and has Vast Consequences, such as lessened social involvement and banishment (Zhao et al., 2022).

Four factors provide the basis for undertaking an examination of energy poverty. For starters, there is no consensus on evaluating energy poverty in the same manner that income poverty is assessed. As a result, new criteria are necessary to reconcile the given rationalities when analyzing energy poverty statistics (Wasim et al., 2022).

The extent of the purported problem is the second impediment. Meanwhile, the third argument emphasizes the need to take the first step toward a solution by defining energy poverty (Sy and Mokaddem, 2022). The fourth point emphasizes the importance of energy availability as a driver and a byproduct of growth. Not only is energy essential for society expansion, but it is also required for health care, education, sanitation, and industrial output (Ruiz-Rivas et al., 2022). Despite its significance, the international community has mostly neglected energy poverty. Energy economists, according to them, are mostly responsible for energy poverty. The incompetence of the professionals and bureaucrats compounded the problem. In its 2002 World Energy Outlook Report, the International Energy Agency (IEA) quantified energy poverty for the 1st time. However, this decision has been modified (Hassan et al., 2022). The United Nations General Assembly declared 2014-2024 the Decade of Sustainable Energy for All. The green behaviors can be helpful for the management of a company in accomplishing its sustainable goals (Perez et al., 2023). Energy poverty appears to be a research gap that can be filled by employing comprehensive indicators to measure it. This makes effective policy solutions to the problem simpler to adopt. Researchers have previously conducted many studies with modest results (Belaïd 2022).

Data from unit-level surveys and a full collection of 15 major energy indicators reflecting various energy elements, with weights assigned using principal component analysis (PCA) (Hou et al., 2021). The energy and environmental efficiency of buildings were analyzed using a fuzzy analytic network approach and scenario modeling to handle the interconnectedness of the factors. This is consistent with those who proposed a global economic policy uncertainty index weights method that employed principal component analysis to account for indicator interaction.

Many academics have explored the influence of energy poverty on economic growth (Sorrell 2010), but few studies have concentrated on the impact of energy poverty on green growth; that is, few researchers have investigated green growth from the standpoint of alleviating energy poverty. Businesses and institutions are significant to a country since they play an important role in a country's economic development; they also come with significant societal and environmental concerns (Sahabuddin et al., 2023). However, few academics have investigated the role of technical innovation in mediating the relationship between energy poverty and green development, and many researchers opt to disregard the varied repercussions of various forms of energy poverty on green growth (Rao et al., 2022).

The interdependence and interaction of indicators is frequently the cornerstone of the weighing approach, which considers the correlations between indicators and is practical. Deng's (1982) Grey Relational Analysis (GRA) model and the Sequential Relational Analysis (SRA) technique were used to create indicator weights in this work (Awad and Warsame 2022). GRA is a prominent technique for determining the linkages or interconnections between measurements (Khokhar et al., 2020). The main advantage of this model is its ability to deliver reliable results regardless of the probability distribution, even when the sample size is tiny. The GRA model is commonly used in applications to find grey correlation coefficients or crucial components. To assess alternatives, compare performance, and study the degrees of interdependence between various factors. It is used to construct the grey relational degree matrix, which shows how the indicators are related. Meanwhile, the SRA model calculates indicator weight (a higher correlated indicator receives more weight) (Zhao et al., 2022). The integrated method explores the relationship between indicators while considering objective weighting. This approach is simpler to use than other weighing methods. For example, consider the N11 countries (Liu et al., 2022).

3. METHODOLOGY

More than 10.1 million people in Nigeria, Bangladesh, and Pakistan do not have access to basic electrical services, according to the statistics in the table 1. Simultaneously, a growing number of residences around the region are beginning to invest in them-new renewable energy sources, such as stand-alone solar PV. Our study on the N11 nations supports this. Poor countries are still suffering from acute energy shortages. Many people in these nations are also affected. Every day, people utilize traditional energy sources such as coconut husks, wood, and fossil fuels to cook and survive due to budgetary constraints.

This remains the case despite some N11 members' pledges to expand access to clean, affordable energy and recent investments in new renewable energy sources. As the table 2 shows, most N11 nations have high energy profiles. Because it relies heavily on imported oil, the populace is very susceptible to price fluctuations. The N11 energy profile is representative of the region's variety. For example, although about 100% of individuals in Turkey, South Korea, and Iran have access to power, just 75% of Mexicans have. The Philippines has 55% of Pakistan's total population, and Nigeria, which has 52.5% of Pakistan's total population, are the only two countries without electricity. As a result, this study aims to evaluate the extent of energy poverty and suggest future solutions to alleviate it.

Energy poverty is a multifaceted issue influenced by various causes, necessitating a multifaceted solution. There are a few facts. When selecting a neighborhood using income-based poverty indices, the greatest danger is an inability to satisfy necessities. It is reported that it does not work well, a major issue. The Material Difficulty Index may be a suitable substitute when energy is scarce. Although income is a significant issue in energy poverty, it is not the only one to consider. It is also linked to human health, acting as a link between energy poverty and good health. The table summarizes the four main reasons favoring this set of policies. The European Union Poverty Observatory has selected indicators from which European policymakers and a partner might choose. These are the most effective energy sources for alleviating poverty. The collection contains further information. Support redundant connections and home energy poverty measures in the region. The subjective and important variables have the largest frequency, accounting for 40% of all variables. With further information, the deprivation characteristics were chosen to encompass all aspects of energy poverty. Third, no more signs should be investigated. This is because, as shown in the figure, the indicators were chosen to provide a diversified framework for analyzing energy poverty. The indication structure employed in this study is not unique, but it does have some distinguishing characteristics.

3.1. GRA-SRA Method

At the time, there was no universal standard for measuring energy. This objective is frequently achieved using poverty and other forms of indicators. This emphasizes the need to quantify energy poverty. To assess energy poverty properly, it is required first to analyze current standards and indicators based on actual situations and then develop and create a whole evaluation indicator capable of assessing energy poverty. Simultaneously, an accurate assessment of the energy poverty index involves creating a comprehensive index system capable of measuring energy poverty and collecting the current condition of existing evaluation criteria and indicators. Due to the diversity and complexity of the difficulties, the present indicator evaluation technique cannot capture all aspects of energy poverty. Furthermore, a lack of data makes choosing and using some metrics to detect energy poverty difficult.

As a result, an effective mechanism for quantifying energy poverty is essential. It should be noted that the N11 nations' principal expressions of energy poverty are comparable to those observed in other countries. As a result, according to the International Energy Agency, all evidence indicates the (IEA). The Energy Poverty Index is available to the N11 governorates. It has the potential to create a comprehensive composite measure of energy poverty. Energy use in the home that is both efficient and ecologically beneficial-an acceptable set of indicators for China. As a result, the GRA and SRA techniques (Figure 1) are employed to generate the total energy poverty index in this study.

The following is the GRG computation procedure for X_0 and X_1 data sequences: compute the mean image (or raw picture) of $X_0^{'}$ and $X_i^{'}$, where $i = 1,2,\ldots,s$

$$X_i^{'} = \frac{X_i}{X_{i(1)}} = \left(X_i^{'}(1), X_i^{'}(2), X_i^{'}(3), \ldots, X_i^{'}(n)\right); i = 0,1,2,\ldots,s \tag{1}$$

Differ the sequence of $X_0^{'}$ and $X_i^{'}$, i=1,2,…,s, as

$$\Delta_j = | X_0^{'}(k) - X_i^{'}(k) | \tag{2}$$

$$\Delta = \left(\Delta_i(1), \Delta_i(2), \Delta_i(3), \ldots, \Delta_i(n)\right), n; 1,2,\ldots,s \tag{3}$$

Calculation of GR coefficients by

$$Y_{0i}(k) = \frac{s + \varepsilon M}{\Delta i(k) + \varepsilon M}; \varepsilon \epsilon (0,1); k = 1,2,3,\ldots,s \tag{4}$$

where ξ is the differentiating factor. It is estimated to be 0.5 in the works.

Computing GR grade by

$$Y_{0i} = \frac{1}{n}\sum_{k=1}^{n}(Y_{0i}(k)); i = 1,2,\ldots,s \tag{5}$$

Where 1/n can be swapped by W_k, as shown in the following example, if the impact of each feature is unique, where $\sum W_k = 1$,

$$Y_{0i}(k) = \frac{s + \varepsilon M}{\Delta i(k) + \varepsilon M}; \varepsilon \epsilon (0,1); k = 1,2,3,\ldots,s \tag{6}$$

Thus, 1/n denotes that the conditions are similarly weighted. The Energy Poverty Index is available to the N11 governorates. It has the potential to produce a comprehensive composite measure of energy poverty. Energy use in the home that is both efficient and ecologically beneficial. A useful set of indicators for China. As a result, the GRA and SRA techniques are employed to generate the total energy poverty index in this paper.

Assume that two data sequences X_i and X_j describe an undefined system. The bidirectional absolute GRG is calculated using the procedure below.

- Change the data sequence and their corresponding sequence.
- Normalize the data series using the minimization operator, so that the value of each data spans from 0 to 1 Order.
- Calculation of the data series' starting zero image
- According to $|Q_i|$, $|Q_j|$ as well as $|Q_i - Q_j|$
- GRG absolute account (ε)

$$\varepsilon_{ij} = \frac{1 + |Q_i| + |Q_j|}{1 + |Q_i| + |Q_j| + |Q_i - Q_j|} \tag{7}$$

- Compute the bidirectional absolute GRG ($\varepsilon \pm$) as:

$$\varepsilon^{\pm} = \{+\text{Max}\left(\varepsilon_{ij}, \varepsilon_{ij}\right); \Delta = \varepsilon_{ij} - \varepsilon_{ij} > 0 \tag{8}$$

$$\varepsilon^{\pm} = \begin{cases} +\text{Max}\left(\varepsilon_{ij}, \varepsilon_{ij}\right); \Delta = \varepsilon_{ij} - \varepsilon_{ij} > 0 \\ -\text{Max}\left(\varepsilon_{ij}, \varepsilon_{ij}\right); \Delta = \varepsilon_{ij} - \varepsilon_{ij} < 0 \end{cases} \tag{9}$$

The grey feature is an extra measure of these signs. "–" represents an inverse relation, while "+" is a direct relation.

Refers to a tight friendship. To understand the data, the JGI and JCL scales are necessary. It is possible to have bidirectional descriptions of detailed and absolute GRG. See the Bibliography for further information. Let *aij* indicate a Country's performance for the assessment period J. The indicator yields indicator weights for the multidimensional energy poverty index.

The grey feature is an extra measure of these signs. "–" represents an inverse relation, while "+" is a direct relation.

Describes a close friendship. Data interpretation necessitates the use of the JGI and JCL scales. In both directions, it is possible to describe detailed and absolute GRG. Check out the Bibliography. Let *aij* indicate a nation's real performance on indicator I during the evaluation period j. The indicator is used to calculate indicator weights in the multidimensional energy poverty index.

The average GRG φ_k represent the significance of markers. The steps of SRA method is as follows:

Step 1: Normalization of Indicators: as a standard unit of measurement Indicators are inconsistent and need to be standardized. Before computing the composite index, make any necessary changes. The following is the normalization procedure for positive measurements:

$$e_{ij}^{'} = \frac{e_{ij} - \min\left(e_{ij},\ldots,e_{nj}\right)}{\max\left(e_{ij},\ldots,e_{nj}\right) - \min\left(e_{ij},\ldots,e_{nj}\right)} \quad (10)$$

Standardization method for negative measurement,

$$e_{ij}^{'} = \frac{\min\left(e_{ij},\ldots,e_{nj}\right) - e_{ij}}{\max\left(e_{ij},\ldots,e_{nj}\right) - \min\left(e_{ij},\ldots,e_{nj}\right)} \quad (11)$$

Step 2: The grey correlation coefficient of Δ_{jk},

$$\varphi_k = min_k min_j \vee e_{ij}^{'} - e_{kj}^{'} + \lambda max_k max_j \vee e_{ij}^{'} - e_{kj}^{'}$$

$$\vee \frac{1}{e_{ij}^{'} - e_{kj}^{'} \vee + \lambda max_k max_j \vee e_{ij}^{'} - e_{kj}^{'} \vee} \quad (12)$$

Step 3: The GCD $_{\text{(grey correlation degree)}}$ value was measured by arithmetic average method:

$$\varphi_{ik} = \frac{1}{n}\sum_{k=1,k\neq i}^{s} \varphi_{ik}, where\, \varphi_i^{-} \in (0,1) \quad (13)$$

Estimated average grey relational degree as follows:

$$\varphi_i^{-} = \frac{1}{s-1}\sum_{k=1,k\neq i}^{s} \varphi_{ik} \text{ , Where } \varphi_{\bar{ik}} \in (0,1) \quad (14)$$

The SRA method is applied to calculate the weight of each indicator.

SRA-Step 1: The values were sorted in decreasing order of correlation degree from high to low,

SRA-Step 2: The values were sorted from high to low in decreasing order of correlation degree,

$$n_i = \varphi_i^{-} - 1\sqrt{\varphi_i^{-}} \quad (15)$$

SRA-Step 3: Weights were obtained:

$$\omega_s = (1 + \sum_{i=2}^{s} \prod_{j=1}^{s} n_i)^{-1} \quad (16)$$

$$\omega_i = \omega_i n_i, i = s, s-1, \ldots, 2 \quad (17)$$

The controlled amount of the e_{ij} was measured as follows: case of cost type indicator,

$$b_{ij} = \frac{\min\left(ei1, e_{i2},\ldots,e_n\right) - e_{ij}}{\min\left(ei1, e_{i2},\ldots,e_n\right) - \min\left(ei1, e_{i2},\ldots,e_n\right)} \quad (18)$$

$$b_{ij} = \frac{\min\left(e \mid i1, e_{i2},\ldots,e_n\right) - e_{ij}}{\min\left(e \mid i1, e_{i2},\ldots,e_n\right) - \min\left(e \mid i1, e_{i2},\ldots,e_n\right)} \quad (19)$$

Energy Poverty Index:

$$EPI_i = \sum_{i=1}^{m} \omega_i b_{ij}, j = 1,2,\ldots,n \quad (20)$$

The study looks at the N11 countries' multidimensional energy poverty index. The study utilized 14 indicators from 2001 to 2017. Data and information on residential energy use will be gathered from the following sources: Data gathered from individuals' residences.

The International Energy Agency produces data on carbon dioxide emissions and energy use. Data about the country's population, GDP, population share, electricity supply, mobile phones per 100 people, and homes.

Final consumption expenditures, cooking technology, the proportion of the population having access to clean fuels, and the share of thermal energy generation in total power generation are all calculated using the World Bank database.

4. RESULTS AND OBSERVATION

4.1. Overall EPI

The score for the energy poverty index is shown in the table 3. Nigeria (0.72), Bangladesh (0.65), and Pakistan (0.47) are the N11 countries with the highest levels of energy poverty. Meanwhile, the Philippines (0.36), Indonesia (0.33), and Vietnam (0.28) are less likely to become energy-poor than other countries in the

Table 1: N11 countries energy profiles 2017

	Lacking access to electricity, the population	%(Total)	Energy use (kg of oil Equivalent Per Capita, 2017)
Indonesia	14,125,879.70	5.08	907.02
Egypt, Arab Rep.	7,194,750.75	7.7	807.47
Pakistan	89,007,257.04	77.74	757.74
Korea, Rep.	0	0	5714.45
Bangladesh	58,817,872.29	47.77	247.77
Iran, Islamic Rep.	77,095.44	0.07	4241.77
Nigeria	87,070,287.80	77.5	777.12
Mexico	2,719,952.55	2.15	1547.27
Vietnam	278,041.24	0.4	777.47
Philippines	17,175,240.97	17.81	795.57

designated region. The data also suggest that Turkey and Korea are not impoverished in terms of energy.

The energy poverty score has varied in recent years, but it has never exceeded 0.93, with the lowest energy poverty score being 0.37. Energy poverty is difficult to assess since it is difficult to get reliable data from those who are affected. However, this is a worldwide issue, and it is estimated that energy poverty affects more than 50 million people in Europe. These data were created by comparing known parameters and including published studies. Energy poverty is concerned not only with the volatility of oil prices, but also with how to develop cleaner technologies such as wind, solar, biofuels, geothermal, and hydropower to meet the Paris Agreement in a sustainable manner. Even though the N11 countries have not been immune to recognized energy problems since the 1970s, the only way for them to assure their future energy is to embrace cleaner energy generation that is economically appealing to integrate into their systems.

Table 2: Energy poverty indicator

EP dimension	Indicator
	Urban electricity accessibility
	Rural electricity accessibility
	TYPES
Affordability of Energy	GDP per capita
	(HDI)
	Cellphone ownership per 100 people
	Poverty Headcount ratio
The cleanability of Energy	Energy usage
	Fuel and tech accessibility (Clean)
	EI (primary level)
	(MJ/$2001 PPP GDP)
	CO2 Emission per capita
	Fuel Energy Consumption (Fossil)
	Power generation (renewable)

4.2. Key Indicator Analysis

The findings suggest a link between all criteria and the energy poverty sub-indicator, which covers the use of clean fuel and cooking technology. In Nigeria, for example, access to power has greatly improved. Despite this, overall energy consumption remains low, with no obvious changes over time. Nigeria aims to have 48% of its people living off-grid by 2020, rising to 70% by 2030. The government intends to generate 5300 MW of power from on-grid renewable energy by 2020, with a target of 13,800 MW by 2030.

Table 3: Multi-dimensional EPI score

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bangladesh	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.34	0.35	0.36	0.38	0.37	0.4	0.38	0.4	0.46
Nigeria	0.38	0.39	0.42	0.43	0.41	0.41	0.44	0.44	0.43	0.4	0.39	0.41	0.41	0.41	0.4	0.4	0.41
Philippines	0.48	0.47	0.47	0.54	0.48	0.48	0.49	0.49	0.48	0.49	0.49	0.5	0.5	0.51	0.51	0.54	0.54
Pakistan	0.53	0.54	0.47	0.49	0.49	0.49	0.56	0.56	0.57	0.56	0.57	0.56	0.56	0.58	0.58	0.59	0.61
Indonesia	0.54	0.56	0.6	0.65	0.62	0.62	0.66	0.66	0.63	0.63	0.63	0.64	0.65	0.65	0.65	0.66	0.67
Vietnam	0.58	0.59	0.58	0.59	0.64	0.64	0.63	0.63	0.61	0.62	0.64	0.67	0.68	0.69	0.69	0.7	0.71
Korea	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.9	0.9	0.92	0.92	0.93	0.93
Iran	0.75	0.76	0.76	0.78	0.78	0.78	0.8	0.8	0.8	0.79	0.8	0.8	0.83	0.83	0.86	0.83	0.81
Egypt	0.73	0.74	0.76	0.76	0.78	0.78	0.77	0.77	0.76	0.79	0.77	0.78	0.78	0.79	0.8	0.8	0.79
Mexico	0.81	0.82	0.81	0.82	0.8	0.8	0.78	0.78	0.74	0.75	0.73	0.75	0.75	0.75	0.75	0.74	0.79
Turkey	0.91	0.93	0.92	0.92	0.92	0.93	0.94	0.94	0.94	0.95	0.93	0.96	0.95	0.97	0.97	0.99	0.98

Figure 1: GRA-SRA method

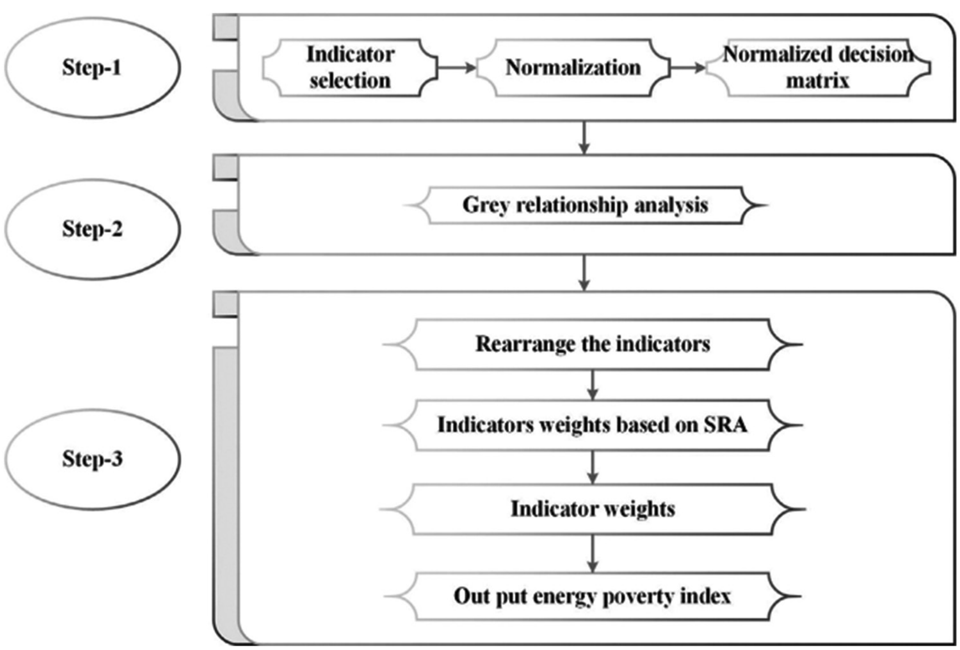

Table 4: Energy poor country (analysis)

Countries	Bangladesh	Nigeria	Philippines	Pakistan	Indonesia	Vietnam	Egypt	Iran	Mexico	Korea	Turkey
Accessibility of energy											
Fuel and Tech Accessibility (clean)	0.535	0.533	0.446	0.698	0.648	0.576	0.811	0.853	0.756	0.923	0.913
Electricity access	0.533	0.566	0.573	0.523	0.702	0.731	0.925	0.937	0.92	0.908	0.893
Electricity access urban	0.534	0.333	0.52	0.487	0.654	0.717	0.907	0.873	0.814	0.919	0.935
Electricity access rural	0.533	0.41	0.53	0.656	0.722	0.922	0.943	0.982	0.941	0.89	0.96
Affordability of energy											
GDPPC	0.333	0.334	0.334	0.333	0.463	0.449	0.333	0.96	0.334	0.448	0.448
HDI	0.333	0.404	0.65	0.64	0.781	0.58	0.607	0.467	0.487	0.34	0.504
Cell ownership (per 100 people)	0.404	0.349	0.485	0.333	0.945	0.558	0.451	0.456	0.395	0.544	0.544
Poverty headcount ratio	553	0.637	0.45	0.731	0.344	0.352	0.484	0.339	0.9	0.333	0.333
Cleanability of energy											
Usage of energy	0.333	0.3559	0.344	0.3444	0.365	0.345	0.362	0.532	0.404	0.91	0.9
(MJ/$2011 PPP GDP)	0.334	0.525	0.333	0.49	0.354	0.558	0.353	0.87	0.365	0.652	0.652
Power Generation (renewable)	0.452	0.965	0.42	0.516	0.463	0.454	0.346	0.333	0.356	0.338	0.338
Fuel Energy Consumption (Fossil)	0.613	0.333	0.623	0.517	0.549	0.529	0.973	0.897	0.821	0.707	0.707
Power consumption (kWh)	0.335	0.333	0.35	0.344	0.346	0.343	0.371	0.401	0.411	0.931	0.9
Electricity production (oil source)	0.333	0.512	0.456	0.745	0.438	0.4	0.4	0.46	0.935	0.367	0.367

All indicators in table 4 have a high degree of correlation with their dimensions, and each country's grey correlation score is more than 0.5. All metrics are only weakly associated to energy reimbursement capability, with a grey correlation value of <0.55 for each nation.

As a result, increasing the use of clean fuels, cooking methods, and access to power can help to relieve energy poverty. Energy poverty is strongly connected to per capita power use. The findings reveal a link between all energy poverty indicators and sub-indicators, including clean fuel consumption and cooking practices. For example, Nigeria's electrical supply has greatly improved. However, overall energy consumption remains low, with no obvious trends over time.

Despite having access to alternate cooking energy for one-third of the population, Pakistan, and Bangladesh rank badly in terms of access to electricity and other contemporary energy sources. Between 3% and 3.5% of the population lives in extreme poverty.

4.3. Energy Profile Contributing to EP

These nations have made significant strides toward increasing energy access, with the share of powerless families decreasing. From 50% in 2001 to 2% in 2017. It's all the same. From 2001 to 2017, the State of the Energy Transition Renewable energy looks to be taking the place of coal and wood. The proportion of N11 customers who use charcoal and biomass fell by 36%, while the proportions of those who use electricity, oil, and electricity rose by 47%, 8%, and 7%, respectively. Coal and biomass expenditures were cut by over $3 per person. Prices for electricity, oil, and energy increased by $17, $65, and $41, respectively.

According to the International Energy Agency, around 1.5 billion Chinese individuals, or nearly 20% of the entire population, lacked access to electricity in 2008. In addition, 96.2 million people in the country do not have access to power. Only 10-15% of rural communities are within a reasonable distance of a city. Only enough electricity is available to fulfil the population's basic needs. Lighting, ceiling fans, cooling, and watering are all available. This reinforces our suspicions that these nations are more concerned with satisfying their fundamental energy requirements than with lowering greenhouse gas emissions or mitigating climate change.

Nigeria's installed power generation capacity is predicted to increase from 7500 MW in 2015 to 115,000 MW in 2030, with energy efficiency rising by at least 20% by 2020 and 50% by 2030. Meanwhile, Bangladesh is one of the poorest and most densely populated countries on the planet, with just 59.6% of the population having access to electricity in 2012, rising to nearly 76% by 2016. addition, 79% of grid-connected people experienced load shedding, while 60% had access to low-voltage energy. According to 2008 IEA estimates, around 1.5 billion people in the country lack access to electricity, accounting for roughly 20% of the total population.

4.4. Socio-economic Association of EP

Politics, economics, infrastructure, and geography have all thwarted efforts to improve households' socioeconomic position and access to key energy services such as electricity, educational and entertainment assets, and home appliances. Many rural homes continue to cook using animal dung, wood, crops, and straw, which pollutes the interior air and threatens the health of children and women.

Over 40% of people in Bangladesh, Pakistan, Nigeria, and the Philippines cook on firewood. Most of these people reside in rural regions and rely mostly on agriculture, particularly wood, seasonal crops, and straw because it is inexpensive and readily accessible. Women are often in charge of gathering wood or straw, and they occasionally prepare faucal bread by collecting and drying animal faces. Indoor air pollution happens when women and children cook with their faces, which can damage their health. According to a study, electricity is the region's safest, most popular, and least ecologically damaging cooking fuel. With 2.7% of Indonesians using electricity for cooking, the country has the highest rate of power use. Despite this, household LPG and kerosene use remained high, at 23.8% and 36.7%, respectively.

4.5. Household EP

According to the International Energy Agency, around 1.5 billion Chinese citizens, or nearly 20% of the population, were without power in 2008. In addition, 96.2 million people in the country do not have access to power. Only 10-15% of rural villages are within reasonable driving distance of a metropolis. Only enough electricity is available to cover the residents' basic requirements. Lighting, ceiling fans, cooling, and watering are all available. This validates our hypothesis that these countries are more concerned with addressing their fundamental energy requirements than lowering greenhouse gas emissions or mitigating climate change.

4.6. Average Household Electricity Consumption

Choosing energy-efficient equipment is thus an excellent way to reduce home power use. Electric fans are another common domestic cooling appliance. The weather in Badong City is hot, with an average daily temperature of 32° Celsius. When paired with a lack of natural ventilation, it typically leads to increased home temperature and an increased need for electric fans. The typical household has two to three fans, according to the poll. The survey discovered that culinary activities consume the most energy, such as rice cookers, freezers, and ovens. Choosing energy-efficient equipment is thus an excellent way to save household expenditures. The amount of energy expended. Other typical types of electric fans include Refrigerators, common household equipment. The weather is nice. Badung gets hot weather with an annual average temperature of 32° Celsius. That specific day. When this is paired with a lack of natural ventilation, higher home temperatures and a greater reliance on electric fans occur. According to the poll findings, each residence has an average of 2-3 admirers.

4.7. Robustness Analysis

Another potential new energy element is energy availability. Along with two other well-known issues, energy poverty and low-cost energy. So, disregard the energy. When the mechanisms of economic disparity are studied, the likelihood of poverty arising rises. As a result, variable bias is eliminated, making the results less robust. In addition, any recommended solution to the energy dilemma must address energy poverty. In addition to the previously identified qualities of energy cleanability and affordability, energy availability is a new potential factor of energy poverty. As a result, disregarding energy poverty while investigating income disparity dynamics may result in omitted variable bias and less robust results. Furthermore, any proposed energy-crisis-reduction policy must target energy poverty. This is most likely the first attempt to analyze energy poverty for a global sample while accounting for economic disparities.

Because economic differences are expanding, government policies boosting electricity use may increase income disparity, which impacts and promotes energy poverty. Poverty revolves around money and energy. The outcomes are highlighted in addition to considerable positive connections between energy cost, poverty, availability, and cleanliness. The rise in per capita energy consumption excludes low-income people, widening economic disparities.

5. CONCLUSION AND POLICY IMPLICATION

Utilizing the N11 nations as a case study, this research computes the energy poverty index using the GRA-SRA technique and a comprehensive set of underlying metrics. The research examined data from 2000 to 2017. The study created a multidimensional energy poverty index to rank the 11 countries. The result reveals that we may examine energy poverty concerns at the dimension and sub-indicator levels since combining various sub-indicators from three dimensions produces the energy poverty score. The energy poverty score provides a baseline with comparable characteristics such as energy cost, availability, and cleanability. The grey link degrees between energy poverty and availability, energy affordability, and energy cleanability were computed using the GRA approach to be 0.658, 0.609, and 0.537, respectively.

Energy availability and energy cleanability were determined to have the strongest relationship between energy poverty and energy affordability. The GRA-SRA approach is used in this study to construct an energy poverty index based on a collection of core factors. As an example, consider the nation N11. The study examined data from 2000 to the present. The study created a comprehensive measure of energy poverty to rank 11 nations. We may investigate the factors of energy poverty along one dimension, the f sub-index level. The degree of energy poverty is formed by integrating multiple sub-indicators related to the three dimensions. We used the energy poverty scale as a starting point and compared energy affordability, availability, and energy hygiene.

The approaches used in the GRA computation of energy affordability and cleanliness have values of 0.658, 0.609, and 0.537, respectively. Energy cost is the strongest indicator of energy poverty, followed by energy availability and cleanliness. Over 40% of individuals in the N11 countries, including Bangladesh, Pakistan, Nigeria, and the Philippines, cook with wood. As a result, geopolitical, economic, and geographical concerns must be addressed as soon as possible to enhance family socioeconomic levels and offer access to contemporary energy devices such as electricity, educational assets, and domestic appliances.

The most utilized cooking materials are wood, seasonal crops, and hay. Fuel-related indoor air pollution may harm one's health, especially for women. While 22% of Filipinos are from Bangladesh, 25% are from Nigeria, 36% are from Pakistan, and 36% use LPG in their cooking. Only 2.7% of Indonesians use electricity for cooking. In 23.8% of the cases, LPG was used. A typical residence consumes around 10,649 kWh of power monthly, or an average of 877 kWh. As a result, wind turbine output ranges between 5 and 15 kW. This criterion must be met. Prove your financial viability. A modest wind power station can save up to 100% on electricity costs by avoiding the expensive cost of connecting utility power lines to remote areas.

REFERENCES

Ahmad, F., Hossain, M.B., Mustafa, K., Ejaz, F., Khawaja, K.F., Dunay, A. (2023), Green HRM practices and knowledge sharing improve environmental performance by raising employee commitment to the environment. Sustainability, 15(6), 5040.

Awad, A., Warsame, M.H. (2022), The poverty-environment nexus in developing countries: Evidence from heterogeneous panel causality methods, robust to cross-sectional dependence. Journal of Cleaner Production, 331, 129839.

Belaïd, F. (2022), Implications of poorly designed climate policy on energy poverty: Global reflections on the current surge in energy prices. Energy Research and Social Science, 92, 102790.

Chien, F., Hsu, C.C., Zhang, Y., Tran, T.D., Li, L. (2022), Assessing the impact of green fiscal policies and energy poverty on energy efficiency. Environmental Science and Pollution Research, 29(3), 4363-4374.

Chien, F., Hsu, CC., Zhang, Y., Vu, H.M., Nawaz, M.A. (2022), Unlocking the role of energy poverty and its impacts on financial growth of household: Is there any economic concern. Environmental Science and Pollution Research, 29, 13431-13444.

Dong, K., Taghizadeh-Hesary, F., Zhao, J. (2022), How inclusive financial development eradicates energy poverty in China? The role of technological innovation. Energy Economics, 109, 106007.

Du, J., Song, M., Xie, B. (2022), Eliminating energy poverty in Chinese households: A cognitive capability framework. Renewable Energy, 192, 373-384.

Hailiang, Z., Khokhar, M., Islam, T., Sharma, A. (2023), A model for green-resilient supplier selection: Fuzzy best-worst multi-criteria decision-making method and its applications. Environmental Science and Pollution Research, 30(18), 54035-54058.

Hassan, S.T., Batool, B., Zhu, B., Khan, I. (2022), Environmental complexity of globalization, education, and income inequalities: New insights of energy poverty. Journal of Cleaner Production, 340, 130735.

Hossain, M.E., Islam, M.S., Bandyopadhyay, A., Awan, A., Hossain, M.R., Rej, S. (2022), Mexico at the crossroads of natural resource dependence and COP26 pledge: Does technological innovation help? Resources Policy, 77, 102710.

Hou, Y., Khokhar, M., Khan, M., Islam, T., Haider, I. (2021), Put safety first: Exploring the role of health and safety practices in improving the performance of SMEs. SAGE Open, 11(3), 21582440211032173.

Hou, Y., Khokhar, M., Sharma, A., Sarkar, J.B., Hossain, M.A. (2023), Converging concepts of sustainability and supply chain networks: A systematic literature review approach. Environmental Science and Pollution Research, 30(16), 46120-46130.

Hou, Y., Khokhar, M., Zia, S., Sharma, A. (2022), Assessing the best supplier selection criteria in supply chain management during the COVID-19 pandemic. Frontiers in Psychology, 12, 804954.

Irshad, M., Liu, W., Arshad, J., Sohail, M.N., Murthy, A., Khokhar, M., Uba, M.M. (2019), A novel localization technique using luminous flux. Applied Sciences, 9(23), 5027.

Khan, S.A., Zia, S., Wajahat, A., Khokhar, M., Siddiqui, A.A., Ali, S.Q. (2022), Why new businesses fail due to ineffective services in marketing strategy. Webology, 19(3), 2315-2324.

Khaskhelly, F.Z., Khokhar, M., Zehra, N., Azhar, H., Mirza, M.H., Raza, A. (2022), Closed loop supply chain: Evaluating ecological footprint. Reviews of Management Sciences, 4(2), 69-94.

Khokhar, M., Devi, A., Siddiqui, M.B., Bhatti, A.A. (2022), Performance of the cosmetics industry from the perspective of corporate social responsibility and circular economy: A cross? Cultural current challenges faced in the cosmetics industry. Pakistan Journal of Humanities and Social Sciences, 10(4), 1571-1579.

Khokhar, M., Hou, Y., Rafique, M.A., Iqbal, W. (2020), Evaluating the social sustainability criteria of supply chain management in manufacturing industries: A role of BWM in MCDM. Problemy Ekorozwoju, 15(2), 185-194.

Khokhar, M., Iqbal, W., Hou, Y., Abbas, M., Fatima, A. (2020), Assessing supply chain performance from the perspective of Pakistan's manufacturing industry through social sustainability. Processes, 8(9), 1064.

Khokhar, M., Zia, S., Islam, T., Sharma, A., Iqbal, W., Irshad, M. (2022), Going green supply chain management during Covid-19, assessing the best supplier selection criteria: A triple bottom line (TBL) approach. Problemy Ekorozwoju, 17(1), 36-51.

Krajnc, D., Glavič, P. (2005), A model for integrated assessment of sustainable development. Resources, Conservation and Recycling, 43(2), 189-208.

Li, R., Guo, J., Wang, Q. (2022), Impact of foreign aid on the ecological sustainability of sub-Saharan African countries. Environmental Impact Assessment Review, 95, 106779.

Li, W., Khan, A.R., Bashir, S., Iqbal, W., Khokhar, M. (2021), Fueling the future with green economy: An integration of its determinants from renewable sources PREPRINT (Version 1); 2021. Available from: https://researchsquare

Liu, F., Feng, J., Zhai, G., Razzaq, A. (2022), Influence of fiscal decentralization and renewable energy investment on ecological sustainability in EU: What is the moderating role of institutional governance? Renewable Energy, 200, 1265-1274.

Maryam, A., Badshah, M., Sabeeh, M., Khan, S.J. (2021), Enhancing methane production from dewatered waste activated sludge through alkaline and photocatalytic pretreatment. Bioresource Technology, 325, 124677.

Mustafa, K., Hossain, M.B., Ahmad, F., Ejaz, F., Khan, H.G.A., Dunay, A. (2023), Green human resource management practices to accomplish green competitive advantage: A moderated mediation model. Heliyon, 9(11), e21830.

Perez, J.A.E., Ejaz, F., Ejaz, S. (2023), Green transformational leadership, GHRM, and proenvironmental behavior: An effectual drive to environmental performances of small-and medium-sized enterprises. Sustainability, 15(5), 4537.

Rao, F., Tang, Y.M., Chau, K.Y., Iqbal, W., Abbas, M. (2022), Assessment of energy poverty and key influencing factors in N11 countries. Sustainable Production and Consumption, 30, 1-15.

Ruiz-Rivas, U., Tahri, Y., Arjona, M.M., Chinchilla, M., Castaño□Rosa, R., Martínez-Crespo, J. (2022), Energy Poverty in Developing Regions: Strategies, Indicators, Needs, and Technological Solutions. Energy

Poverty Alleviation: New Approaches and Contexts. Berlin: Springer. p17-39.

Sahabuddin, M., Hossain, M.B., Khokhar, M., Sharaf, M., Ejaz, S., Ejaz, F., Illés, C.B. (2023), The effect of eco-preneurship and green technology management on greenhouse gas discharge: An analysis on East Asian Economies. Sustainability, 15(8), 6747.

Seman, N.A.A., Govindan, K., Mardani, A., Zakuan, N., Saman, M.Z.M., Hooker, R.E., Ozkul, S. (2019), The mediating effect of green innovation on the relationship between green supply chain management and environmental performance. Journal of Cleaner Production, 229, 115-127.

Siddiqui, M.B., Khokhar, M., Makhdoom, T.R., Devi, A., Bhatti, A.A., Hussain, N. (2023), Exploring the rural development of China Pakistan economic corridor project impact on social responsibilities and South Region of Pakistan. International Journal of Special Education, 38(1), 2023.

Sorrell, S. (2010), Energy, economic growth and environmental sustainability: Five propositions. Sustainability, 2(6), 1784-1809.

Sy, S.A., Mokaddem, L. (2022), Energy poverty in developing countries: A review of the concept and its measurements. Energy Research and Social Science, 89, 102562.

Wasim, M.S., Amjad, M., Habib, S., Abbasi, M.A., Bhatti, A.R., Muyeen, S.M. (2022), A critical review and performance comparisons of swarm-based optimization algorithms in maximum power point tracking of photovoltaic systems under partial shading conditions. Energy Reports, 8, 4871-4898.

Xia, W., Murshed, M., Khan, Z., Chen, Z., Ferraz, D. (2022), Exploring the nexus between fiscal decentralization and energy poverty for China: Does country risk matter for energy poverty reduction? Energy, 255, 124541.

Younas, N., Hossain, M.B., Syed, A., Ejaz, S., Ejaz, F., Jagirani, T.S., Dunay, A. (2023), Green shared vision: A bridge between responsible leadership and green behavior under individual green values. Heliyon, 9(11), e21511.

Zhao, J., Dong, K., Dong, X., Shahbaz, M. (2022), How renewable energy alleviate energy poverty? A global analysis. Renewable Energy, 186, 299-311.

Zhao, J., Shahbaz, M., Dong, K. (2022), How does energy poverty eradication promote green growth in China? The role of technological innovation. Technological Forecasting and Social Change, 175, 121384.