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Article

Evaluating multidimensional energy poverty of South Asian countries: An in-depth analysis using household surveys

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Abstract: This study examines the multidimensional energy poverty index (MEPI), headcount ratio, and intensity in six South Asian countries. Using two datasets (India, 2005 and 2015), (Bangladesh, 2011 and 2017), (Afghanistan, 2010 and 2015), (Pakistan, 2012 and 2017), (Nepal, 2011 and 2016), and (the Maldives, 2009 and 2016), this study employs an adjusted MEPI to compare each country's effort in multidimensional energy poverty reduction (2005 to 2017). The empirical results indicate that India, Bangladesh, Pakistan, Nepal, and the Maldives significantly reduced MEPI, headcount ratio, and intensity compared to past years. However, in the case of Afghanistan, MEPI and the headcount ratio increased. The empirical results further indicate that although there has been a significant reduction in MEPI, the deprivation of modern cooking fuel and access to electricity remains high in India, Bangladesh, Pakistan, and Nepal. The study invites attention towards clean energy sources and proposes that if these countries provide modern energy fuel to households, a significant reduction is possible in the MEPI score. In our study, the results obtained with modern cooking fuel significantly dropped MEPI, headcount ratio, and intensity. These findings explain the necessary attention toward multidimensional energy poverty reduction strategies in South Asia and other developing countries.

Keywords: multidimensional energy poverty; multidimensional energy poverty reduction; multidimensional energy poverty index; South Asia; policy implications

1. Introduction

Energy poverty is among the most critical barriers to sustainable development, especially in the developing world [1]. The United Nations' Sustainable Development Goal 7 (SDG 7) focuses on ensuring that everyone has access to affordable, reliable and modern energy. However, thousands of households, particularly in South Asia, lack access to clean cooking facilities, electricity and other modern energy services. The absence of access in turn constrains socio-economic advancement and expands inequalities and environmental devastation. Energy poverty is considered a multidimensional phenomenon [2]; which includes a lack of access to modern energy fuel and, a lack of affordability to buy televisions, refrigerators, and mobile phones [3–5]. Multidimensional energy poverty is a social and economic problem worldwide, and it has a negative impact on health, the environment, and the economy. The World Economic Forum confirms that due to contaminated fuel burning such as coal, wood, straws, and animal dung, 1 of 5 deaths is caused by fossil fuel consumption [6]. The consequences of multidimensional energy poverty are not just having access to modern energy services; this multidimensional energy poverty impacts physical and mental illnesses, as most people depend on contaminated fuel consumption for cooking, which caused millions of premature deaths [7,8].

Multidimensional energy poverty represents a significant challenge in developing countries, where restricted access to affordable energy and insufficient infrastructure exacerbate the situation. It is imperative to address these issues, as alleviating energy poverty can enhance livelihoods and foster sustainable development. Electricity access is essential for households as all the appliances and physical assets like refrigerators and televisions are operated with electricity. Access to clean fuel allows societies not to spend time collecting firewood, dung, or straws for cooking purposes. Moreover, cleaner energy can provide a carbon-free environment, and prevent respiratory and other health issues in children and females [9,10]. Thus, multidimensional energy poverty reduction can improve living standards and ensure a safe and healthy life. As energy poverty is a multidimensional phenomenon that requires comprehensive and effective policies, therefore, to achieve sustainable development goals, households must have access to modern energy sources that are safe, reliable, and affordable, which can be possible through efficient government policies [11,12].

South Asia is a developing region, mainly dependent on solid fuels for cooking. The region is one of the world's most vulnerable to multidimensional energy poverty. Consequently, the population in South Asia suffers more; such as, lack of electrification, inability to produce modern appliances and poor policies are the common issues in the region. However, the region has accelerated efforts to reduce multidimensional energy poverty. According to the United Nations, approximately 870 million people in Asia had access to electricity in 2016 [13], which shows a significant achievement in energy poverty reduction. Similarly, in 2017, around 83% of the population in Bangladesh had access to electricity; among them, most of the people were living in urban areas [13]. India, and Nepal also improved electrification. India lifted 270 million people from multidimensional energy poverty in the last ten years. Pakistan was ranked among the 15 countries that successfully reduced energy poverty between 2000 and 2015 [14]. Bangladesh has achieved massive poverty reduction since 1990 when most people were living on less than $1.9; in this regard, the statistics show the country has reduced poverty from 44% to 14% until 2016 [15].

The literature on previous studies widely discusses multidimensional energy poverty in terms of affordability, reliability, and access to modern energy services; in contrast, to the best of our knowledge, none of the studies attempted to understand the multidimensional energy poverty trend in South Asia in comparing the past and current MEPI trend. Besides, the study critically analyzes multidimensional energy poverty from a policy perspective. With this attempt, this study aims to debate and analyze to what extent South Asian countries remain successful in multidimensional energy poverty reduction in the past and current stages. In this regard, the study compares each country (India, 2005 and 2015), (Bangladesh, 2011 and 2017), (Afghanistan, 2010 and 2015), (Pakistan, 2012 and 2017), (Nepal, 2011 and 2016), (Maldives, 2009 and 2016) past and current intensity, headcount ratio, and multidimensional poverty index score and examines their contribution to multidimensional energy poverty reduction. Second, as highlighted, South Asian countries mainly depend on solid fuels; this study proposes that if these countries provide clean energy fuels to households, a significant reduction is possible in the MEPI score. Third, based on the primary household's survey data, the empirical results provide detailed analysis, which is helpful in multidimensional energy poverty reduction. Accordingly, the study suggests

policies that can benefit socio-economic development in South Asia and other developing countries.

2. Literature review

2.1. Impacts of energy poverty on social development, environment, and health

Energy poverty should be understood as a form of capability deprivation [16]. They emphasize that access to modern energy services is crucial for achieving fundamental human capabilities, such as health, education, and social participation. For instance, the absence of clean cooking facilities undermines healthy living, while unreliable electricity access hampers educational and economic opportunities. This capability-based framework provides a robust foundation for understanding the multidimensional nature of energy poverty, particularly in developing countries where these deprivations are most pronounced. Energy poverty is a major cause of deprivation, affecting human well-being, the environment, and economic development [17–19]. Consequently, energy poverty, a multidimensional phenomenon, is a pressing issue among developing countries due to its broad implications [7]. Lack of access to electricity and clean energy fuel is a leading destructive [20,21], which hurdles a country's economic and social development [22]. In the backward areas of India, women and children collect wood, straw, or dung for cooking, which directly impacts social well-being [9]. Further, burning solid fuel consumption increases indoor air and outdoor pollution, affecting the climate [23,24]. Firewood, straws, and animal dung also result in global warming. Every year, 2.5 million premature deaths are caused by indoor pollution, which can be controlled with clean energy fuels [25]. Contaminated fuel burning produces hazardous pollutants, which are dangerous to health. Most rural areas rely on traditional energy fuels for cooking purposes, resulting in many respiratory and lung diseases [26]. Women and children suffer more as women spend more time on cooking and children stay at home. Consequently, energy poverty is associated with mental health, especially because poor economic conditions increase stress and anxiety [27,28]. Thus, unavailability to access electricity services and traditional use of energy fuels negatively impacts economic development, human well-being, environment, and climate [29].

2.2. Energy scenario and deprivations of multidimensional energy poverty in South Asia

South Asian countries, with more than one-third of the world's population, consume 6% of the world's energy resources. The statistical figure shows the region's significant potential to harness its resources for electricity generation. However, the installed capacity is quite below to meet the electricity demand in many Asian countries. Pakistan has installed around 17,000 megawatts (MW) of electricity from oil, coal, renewable, and other resources. The government has proposed policies to generate power from renewable resources and plans to install 20% to 30% by 2030 to reduce electricity shortages [30]; the country still faces a deficit of 4000 MW. The total power installed capacity in India is about 382700 MW; among them, 45% of electricity

is generated from coal; however, the installed capacity cannot meet the demand of households. Urpelainen found that many states in India are dissatisfied due to electricity load shedding [31]. The other countries in South Asia, such as Nepal, are rich in natural resources and have great potential to generate power from solar and wind turbines; however, the country primarily uses fossil fuels for electricity generation [32]. On the other hand, 70% of Nepal's population is deprived of modern cookstoves [33]. Despite having natural resources, Afghanistan faces severe electricity shortages. Due to political instability and the fight against war, many industries have shut down their businesses in Afghanistan. The inability to provide clean fuel further worsens human life in Afghanistan. Most of the population depends on contaminated fuel, which produces many respiratory diseases [34]. In contrast, Afghanistan has a great potential to generate electricity from solar and other renewable sources. For example, 300 sunny days in a year and the number of dams determine the country with proper management can fulfill energy demands for households in Afghanistan. The Maldives set up a sound energy system with the lowest solid fuel consumption among other South Asian countries.

South Asian countries are deprived in many dimensions of multidimensional energy poverty. 87% of households in Afghanistan don't have a refrigerator, and around 50% of the population lacks basic assets like television for entertainment and learning [35]. Similarly, around 80% of the population in Bangladesh is deprived of modern cooking fuel, and many households use animal dung and burn wood and grass for cooking [5]. Likewise, the rural population in Pakistan, India, and Nepal relies on traditional and contaminated energy fuels such as straws and firewood for cooking purposes. Moreover, the study conducted by Abbas et al. [36] found that most households in South Asia are deprived of household possessions such as washing machines and mobile phones.

2.3. Energy poverty reduction

Global warming, climate change, and the increasing adverse impact of solid fuels on humans' living conditions have shifted the focus of energy policies towards an accessible, affordable, reliable, and clean energy supply [37–39]. The shift from solid fuel consumption to clean energy fuels helps many countries reduce their dependency on contaminated fuel, which further reduces energy poverty [36,40]. Similarly, electricity access significantly reduces poverty by providing opportunities for households [41]. Other studies also support that electrification reduces energy poverty and boosts economic growth [42].

With a long-term vision to minimize the dependency on contaminated fuels, many countries have shifted their energy sources from contaminated energy fuels to clean energy fuels. For instance, Liquefied Petroleum Gas (LPG), one of the sources of clean energy, was promoted in Ghana, and the purpose was to reduce the dependency on solid fuel. The government distributed modern cookstoves and succeeded in energy poverty reduction [43]. Similarly, LPG is cheap and environmentally friendly compared to other traditional solid fuels; in this vein, the Indonesian government launched an LPG program to reduce energy poverty. The program achieved massive success, through which many households shifted energy

connection from traditional kerosene to LPG connection [44]. Other studies, for instance, Wirawan and Gultom [45] examined the capability of renewable energy to reduce energy poverty in rural areas of Indonesia. The results indicate that the renewable-based program successfully reduced poor people, enriching social development and increasing small industries. Clean energy like solar power, which converts sunlight into electricity, and wind turbines, which convert kinetic energy, makes it easier and more sustainable to fulfill energy demands. Access to clean energy reduces dependency on fossil fuels; this progress improves the quality of life and positively affects health and climate [46–48]. This implies that access to clean energy is an important determinant that contributes to a sustainable environment; also, households avail themselves of an eco-friendly environment. Thus, the purpose is to improve electrification and extend clean fuel supply to households like electricity, natural gas, and LPG.

2.4. Literature gap

Most of the studies in the scholarly literature have been carried out in African countries related to energy poverty [43,49]. In Asia, most studies related to energy poverty focus on India, Indonesia, Sri Lanka, Pakistan, and other Asian countries with single-country analysis [4,50–52].

Prior research predominantly emphasizes the phenomenon of energy poverty in the context of its affordability, reliability, and the resultant ramifications on both public health and the environment. A subset of investigations has been dedicated to probing the multifaceted implications of energy poverty on economic development. Nonetheless, this current study strives to bridge existing gaps within the extant literature. Specifically, this research delves into the multidimensional aspects of energy poverty from a policy-oriented standpoint and engages in a discourse concerning the contributions of South Asian nations in the provision of modern cooking fuels, access to electricity, and other relevant dimensions.

The study compares the previous and current MEPI of South Asian countries and analyzes the MEPI score based on the available datasets (2005 to 2017). Second, the previous literature suggests that South Asian countries depend on contaminated fuel for cooking; this study proposes that if these countries provide modern cooking fuel to households, a significant reduction is possible in MEPI reduction. Thus theoretically, this study invites attention to the sources of multidimensional energy poverty reduction and empirically highlights each country's contribution to multidimensional energy poverty reduction.

3. Methodology

The criteria to measure multidimensional energy poverty are not limited to income or a single indicator. A single indicator cannot capture all aspects of energy poverty, not suitable for the energy poverty measurement [53]. Under the one-dimensional concept of energy poverty, the poverty threshold is considered based on the income and expenditure level. It sheds light on per capita income but is not enough to understand how these people cope with poverty in their daily lives. The MEPI was proposed and explained by Nussbaumer [3]; Alkire and Foster [54], and the index was

applied with the support of the Oxford Poverty and Human Development Initiative (OPHI) and the United Nations Development Programme (UNDP) in different countries. In order to measure poverty in a multi-dimensional approach, it is necessary to combine multiple dimensions/indicators simultaneously to capture gaps in different basic needs and provide comprehensive information for poverty reduction; therefore, multidimensional energy poverty measures poverty with respect to different aspects. The multidimensional energy poverty index measures energy poverty by a composite index that determines the poor households and their intensity; it provides a valuable tool for understanding poverty in its multidimensionality, considering those who are poor and severely poor.

MEPI measures energy poverty in terms of its intensity and headcounts in the dimension "m" over the total population of households, 'n'. This model explains, $Y = y_{ij}$, an achievement matrix in populations $(m \times n)$ of individuals i in variables j. Where by $y_{ij} \geq 0$ is the grade of individual's achievement $(i = 1, \ldots\ldots, n)$ over the variables $(j = 1, \ldots\ldots, m)$. Formally MEPI is constructed by assigning a specific weight to each indicator, such that weights sum up to 1. Since each dimension of deprivation is considered an essential aspect of energy poverty, we treat each dimension on an equal basis with respect to importance. Assigning equal weights is common in many studies on multidimensional energy poverty [55].

We identify all the households deprived of achievement and count the sum of weighted deprivations suffered by a household, $\sum_j^d wj = 1$. The model uses dual cut-off parameters, such as the deprivation cut-off z and the poverty cut-off k, the intensity and the number of people living in energy poverty. This matrix represents the achievement of deprivations across individuals and variables, where zj represents the level of deprivation in variable j and $gij = wj$ represents the matrix of deprivations. Whenever the deprivation matrix g of an individual i in a variable j exceeds the deprivation cut-off value $(gij > zj)$, the individual i is deprived of the relevant dimension. If this achievement exceeds the deprivation cut-off for any variable, the variable's assigned weight (0.16) is then included in the row vector as a result of the deprivation cut-off being exceeded, otherwise counted zero, then we created a column vector (C_i) that shows an individual's score across the variables for each individual, $ci = \sum_{j=1}^{d} g_{ij}$ Shows the summations of weighted deprivation for the ith entry. We can then find the multidimensional energy-poor individuals by setting a cut-off and applying it across the column vector. We classify an individual as being energy-poor if their sum of the weighted deprivation count (C_i) reaches the cut-off $(k \geq 0.33)$, is considered the multidimensional energy-poor. Through this way, we set out the deprived households in two out of six dimensions; otherwise, below this threshold is considered not multidimensional energy poor. Lastly, a censor column vector $(C_i k)$ is used for truncating the observations for the households that are multidimensional energy-poor. After computing the necessary indices, finally, we can compute the headcount ratio (H) and intensity (A) by the following equations for the multidimensional energy poverty index.

$$H = q/n \tag{1}$$

$$A = \sum_{i-1}^{n} ci(k)/\mathrm{q} \tag{2}$$

where,

n = total population;

q = number of poor households;

$ci(k)$= deprivation count of the multidimensional energy poor.

The MEPI, which is the product of the headcount ratio and intensity, can now be calculated by the following equation.

$$\mathrm{MEPI} = H \times A \tag{3}$$

3.1. Multidimensional energy poverty dimensions and dataset

As energy poverty is a multidimensional phenomenon, this study employed an adjusted multidimensional energy poverty index to measure energy poverty. Based on the available data, six South Asian countries—India, Bangladesh, Afghanistan, Pakistan, Nepal, and Maldives—are part of this research. **Table 1**. provides detailed information on dimensions, indicators, and their weights and the deprivation cut-off explanation. For example, cooking fuel reflects the type of fuel used for cooking, such as electricity, gas, kerosene, animal's dung, LPG, etc. Under the cooking fuel dimension, if a household has modern cooking fuel, it is coded with 1, otherwise zero for the contaminated cooking fuel (animal dung, charcoal, straws, coal and others). Lighting reflects whether a household has an electricity connection (1) or not (0). Similarly, assets such as a refrigerator, television, and mobile phone are reflected as the owner's assets and coded with (1), if the household possesses these assets; otherwise, zero. The indoor pollution dimension provides the detail of whether a household has a separate kitchen (1) or not (0).

Table 1. Dimension, indicators, and threshold of deprived households.

Dimensions	Indicators and their weights	Deprivation cut-off explanation
Cooking fuel	Type of cooking fuel (16.66)	Deprived if households use fuel other than electricity, natural gas, Biogas, or LPG.
Lighting	Electricity access (16.66)	Deprived if a household has no electricity access.
Household appliances	Refrigerator (16.66)	Deprived if a household has no fridge.
Entertainment	Television (16.66)	Deprived if a household has no television.
Communication	Mobile/Phone (16.66)	Deprived if a household has no Mobile/Phone.
Indoor pollution	Separate kitchen (16.66)	Deprived if a household has no separate kitchen for cooking in the household.

The data was collected from the United States Agency for International Development. The USAID is an international development agency that conducts different surveys in Pakistan. Similarly, USAID works in India, Bangladesh, and other South Asian countries. The agency collects surveys on nutrition, childhood mortality, health, and household conditions. A dataset from 2005 to 2017 (DHS Phase V, VI and VII) was collected after formal approval from the DHS Program website. A dataset of 459,470 households from the past survey and 674,833 households from the recent survey was collected for six South Asian countries. The empirical results provide

essential policy suggestions to reduce multidimensional energy poverty in South Asian countries based on past and recent data.

4. Empirical results and discussion

This section presents the results of each country's MEPI score, headcount ratio, and intensity. **Tables 2** and **3**, and **Figure 1** summarize the results obtained from past and latest surveys of MEPI. In Afghanistan, the headcount ratio increased from 0.75 (in 2010) to 0.91 (in 2015), and the MEPI score increased from 0.40 (in 2010) to 0.43 (2015).

Table 2. Results of headcount ratio, intensity, and MEPI (based on past household survey data).

Year	Country	H	A	MEPI
2010	Afghanistan	0.75	0.53	0.4
2011	Bangladesh	0.89	0.6	0.53
2005	India	0.79	0.58	0.46
2011	Nepal	0.91	0.68	0.62
2012	Pakistan	0.79	0.54	0.43
2009	Maldives	0.25	0.34	0.08

Table 3. Results of headcount ratio, intensity and MEPI (based on recent household survey data).

Country	Year	H	A	MEPI
2015	Afghanistan	0.91	0.47	0.43
2017	Bangladesh	0.77	0.47	0.36
2015	India	0.64	0.51	0.33
2016	Nepal	0.75	0.4	0.3
2017	Pakistan	0.47	0.49	0.23
2016	Maldives	0.03	0.37	0.01

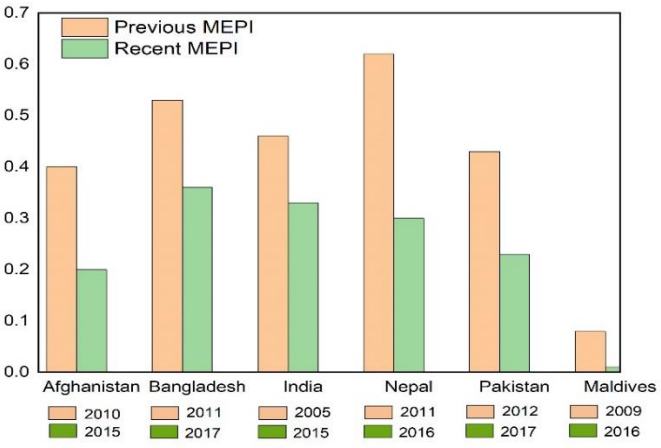

Figure 1. Comparison of past and recent MEPI.

Bangladesh significantly reduced multidimensional energy poverty. Compared to

2011, the MEPI score declined from 0.53 in 2011 to 0.36 in 2017. The headcount ratio dropped from 0.89 to 0.77, and intensity dropped from 0.60 to 0.47 between 2011 and 2017. At the same time, in Bangladesh, there has been an increase in the percentage of modern cooking fuel from 22.8% in 2007 to 33% in 2017. Besides, access to electric power supply increased from 57.1% to 63.4% (2007 to 2017), see **Figures 2** and **3**. India, the most populous country in South Asia, has succeeded in multidimensional energy poverty reduction during the period between 2005 and 2015. The results show India reduced its MEPI score from 0.46 in 2005 to 0.33 in 2015. The results further revealed a significant decline in headcount ratio from 0.79 to 0.64, and intensity declined from 0.58 to 0.51 during the years' period (2005 to 2015). Results presented in **Figure 2** further show that the deprivation of cooking fuel dropped by around 10% in India between 2005 and 2015. In contrast, access to power supply increased around 16% during these ten years in India. Nepal, compared to 2011, has reduced the MEPI score by more than 50% in 2016. The headcount ratio declined from 0.91 (in 2011) to 0.75 (in 2016), and intensity declined from 0.68 (in 2011) to 0.40 (in 2016). Moreover, access to modern energy fuel increased from 17% in 2011 to 30% in 2017; also, there has been an increase in the percentage of electricity connections from 70.6% in 2011 to 88.7% in 2017. The second most populous country in South Asia, Pakistan reduced the MEPI score from 0.43 in 2012 to 0.23 in 2017. The headcount ratio declined from 0.79 in 2012 to 0.47 in 2017. At the same time, there was an increase of 11.2% in access to modern cooking fuel (from 2011 to 2017). Lastly, we checked the results for the Maldives. The Maldives, a country with the lowest MEPI score of 0.01 in South Asia, has provided power supply and modern cooking fuel to households. More than 96% of households in the Maldives use modern cooking fuel, and 99% have electricity connections.

The results presented in **Table 3** show that Afghanistan, Bangladesh, India, and Nepal are the highest multidimensional energy-poor countries, respectively. Pakistan and Maldives are the least multidimensional energy-poor countries with MEPI scores of 0.23 and 0.01, respectively. Although these countries have declined in headcount ratio, intensity, and MEPI score, the findings of the result show that most countries in South Asia are still deprived in many dimensions. **Figures 2** and **3** compare previous and recent access to modern cooking fuel and access to electricity.

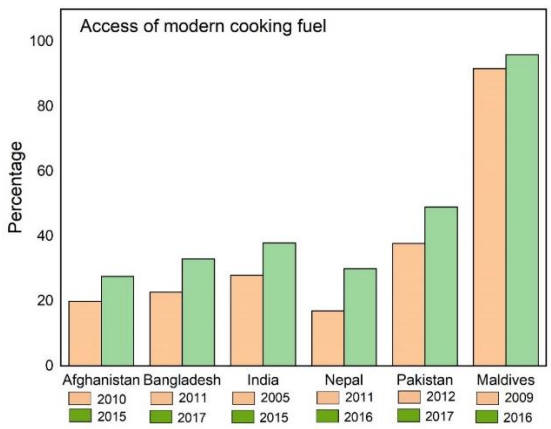

Figure 2. Access to modern cooking fuel (past and recent comparison).

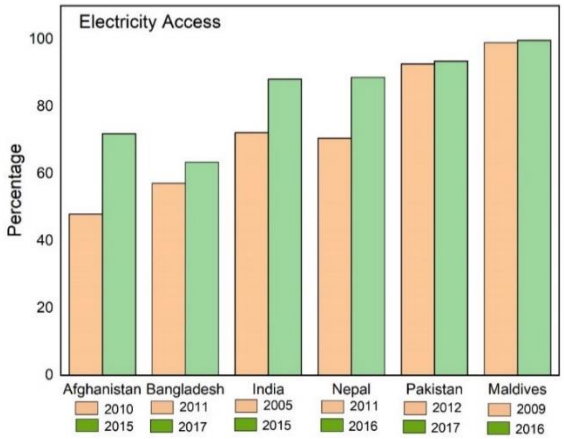

Figure 3. Electricity access (past and recent comparison).

We further separated households in rural and urban areas to assess households deprived in each dimension. The results revealed that around 96% of households in rural areas and 60% of households in urban areas of Bangladesh are deprived of modern cooking fuel; furthermore, 88% and 68.28% are deprived of refrigerators and education in rural areas, compared to 62.2% and 31.8% in urban areas of Bangladesh, respectively. Most of the rural areas in India are deprived of modern cooking fuel (76.2%), refrigerators (82.4%), entertainment (47.9%), and electricity (15.8%). Whereas, compared to households in rural areas, urban households are less deprived in India. In urban areas of India, 26.4%, 19.5%, and 14.6% are deprived of indoor pollution, modern cooking fuel, and entertainment, respectively. Around 95.2% and 88.2% of households are deprived of refrigerators and clean fuel in rural areas of Nepal. In contrast, households in the dimension of indoor pollution, electricity, and entertainment are deprived by 33.5%, 17.2%, and 16.4%, respectively. Urban households' deprivation in the dimensions of a refrigerator, modern cooking fuel, indoor pollution, and entertainment is 80.7%, 59.4%, 26.3%, and 25.5%, respectively. In rural areas of Afghanistan, the households are more deprived in the dimension of a refrigerator (95.5%), modern cooking fuel (87.4%), entertainment (62.8%), electricity (34.2%), and indoor pollution (19.5%), respectively. However, the results indicate that urban households in Afghanistan are less deprived than households in rural areas. The results show that in Afghanistan, 63.4%, 30.2%, and 22.9% of urban households are deprived of the dimensions of a refrigerator, modern cooking fuel, and entertainment. Rural households in Pakistan are also more deprived of modern cooking fuel (77.6%), refrigerators (62%), entertainment (54%), and electricity (11.7%); in contrast, 24.4%, 23.3%, and 20% of urban households are deprived in the dimension of a refrigerator, modern cooking fuel, and entertainment, respectively. The Maldives is the least multidimensional energy-poor country; less than 2% of households are deprived of modern cooking fuel and electricity in urban and rural households; however, the results indicate the Maldives is more deprived in the dimension of indoor pollution (73.1%) in urban households.

Overall, the above results explain that deprivation of modern cooking fuel, access to electricity, and refrigerators contribute more to multidimensional energy poverty in South Asian countries; the above findings also explain that rural households suffer more than households in urban areas. The results indicate that most countries depend

on contaminated fuel for cooking; however, providing them with modern fuel may significantly reduce multidimensional energy poverty. As proposed in the beginning, if these countries are provided with modern cooking fuel, we expect a significant drop in MEPI score. **Table 4**. presents the results obtained with modern cooking fuels such as electricity supply, gas, and LPG connection. Surprisingly, we found interesting results. The results show that, with modern cooking fuel, the MEPI score dropped significantly. For example, Afghanistan, Bangladesh, India, Nepal, and Pakistan can reduce MEPI scores from 0.43, 0.36, 0.33, 0.30, and 0.23 to 0.27, 0.26, 0.21, 0.13, and 0.15, respectively. Maldives has the lowest MEPI score with 0.01 and has already provided more than 97% modern cooking fuel to households. These findings confirm that cooking fuel is one of the leading causes of increased MEPI scores.

Table 4. Results of headcount ratio, intensity, and MEPI (based on past household survey data with modern cooking fuel).

Country	Year	H	A	MEPI
2015	Afghanistan	0.63	0.43	0.27
2017	Bangladesh	0.58	0.44	0.26
2015	India	0.49	0.44	0.21
2016	Nepal	0.36	0.36	0.13
2017	Pakistan	0.36	0.41	0.15
2016	Maldives	0.03	0.34	0.01

H = Headcount ratio, A = Intensity.

To eradicate energy poverty, Bangladesh initiated different programs. Bangladesh covered 10% of households by providing solar home systems, and it is one of the largest plans in the world. During the 6th plan period, Bangladesh set a skills and development policy to reduce poverty and increase employment. The country also banned fuel generated from bricks; thus, a priority was given to promoting modern cooking fuel. The Government of India offers subsidies on gas to encourage clean energy. Moreover, around 80 million LPG connections were supplied in 2019, which shows that India has spent a significant amount to reduce energy poverty [56]. Different programs and strategies have been formulated to lift the economically weaker sections out of poverty in Pakistan, such as successful businesses, successful farmers, and successful skills programs under successful youth programs to promote small businesses and decrease unemployment. The priority of the Pakistani government is to make the lower classes self-sufficient in employment; these programs provide large-scale new entrants in businesses and low-cost housing. However, the power crisis is getting worse across the country in Pakistan during the summer season. Rural areas of Pakistan are most affected by the load shedding of electricity and gas. The government of Pakistan has no proper strategy to overcome power crises and provide clean fuels to households. In Maldives, more than 98% of households have access to electricity and modern cooking fuel, and Maldives is the only country that utilizes a minimum level of solid fuels. Nepal is also one of the 22 countries that reduced multidimensional energy poverty faster than income poverty [57].

5. Conclusion and policy suggestions

The paper compares multidimensional energy poverty in South Asian countries, India (2005 and 2015), Bangladesh (2011 and 2017), Afghanistan (2010 and 2015), Pakistan (2012 and 2017), Nepal (2011 and 2016), and the Maldives (2009 and 2016). Using two datasets by employing an adjusted multidimensional energy poverty index, the study analyzes to what extent these countries remain successful in multidimensional energy poverty reduction. The results revealed that South Asian countries had declined the multidimensional energy poverty index, headcount ratio, and intensity compared to the past years. However, in the case of Afghanistan, there has been an increase in MEPI scores. Based on the current household survey data, the results revealed that Afghanistan, Bangladesh, India, and Nepal are the most multidimensional energy-poor countries, respectively. At the same time, Pakistan and Maldives are the least multidimensional energy-poor countries. Overall results show that the deprivation of modern cooking, lighting, and refrigerators is the most dominant indicator in these countries except for the Maldives. This implies that most households in these countries depend on fossil fuels for cooking and cannot afford electricity. Finally, the objective of this study was to assess the multidimensional energy poverty level if these countries provide modern cooking fuel to households. We find interesting results with modern cooking fuel. The results confirm a significant MEPI score, headcount ratio, and intensity reduction. Afghanistan, Bangladesh, India, Nepal, and Pakistan can reduce the MEPI score by 37.2%, 27.7%, 36.3%, 56.6%, and 34.7%. The Maldives is the only country that provides more than 97% of modern cooking fuel to households.

The study provides theoretical and practical implications for stakeholders, states, and policymakers. It is noteworthy that Asian countries have taken significant steps recently, focusing on issues related to multidimensional energy poverty. However, it was identified that the deprivation of modern cooking fuel and electricity supply is relatively high in these countries; especially, households in rural areas suffer more compared to households in urban areas; therefore, it is an urgent concern to overcome multidimensional energy poverty issues. For that, the following recommendations and suggestions are offered.

(1) Most households in rural areas rely on traditional sources for cooking. On the other hand, due to a lack of education, most people are unaware of the health consequences. The need is to educate people and spread awareness for the positive use of crops, straws, and animal dung instead of burning for cooking purposes; in this vein, the Government should pay attention to rural areas and increase awareness among farmers.

(2) Industries should be strengthened to turn farming into promising work, and the government should create a favorable environment for people to settle in rural areas. Besides, the government should protect the environment and involve the people at the village level to contribute and maintain the environment; furthermore, linking farmers to agri-markets will also benefit food security and rural development.

(3) As countries in South Asia are heavily dependent on importing oil and petroleum to meet the demands of commercial and households, around 6% oil consumption growth and 7% electricity demand are expected in these countries. In

contrast, solar and hydro energy potential is one of the largest sources to meet demands for electricity generation; for example, Pakistan, India, and Nepal have 40,000 MW, 84,000 MW, and 43,000 MW of hydro energy potential. A move towards renewable energy fulfills energy demands and enhances regional cooperation; this way, countries in South Asia may mutually expend energy for regional development. These countries may avail themselves of opportunities to initiate gas pipeline projects from neighboring countries. Suppose the gas pipeline established between Pakistan, India, and Iran and its route to Central Asian countries will promote clean energy, and it could be a step towards economic and financial development. Since Pakistan has abundant natural resources such as huge gas reservoirs available in Baluchistan, the country still faces severe gas load shedding in rural and mountain areas due to a lack of technical capability and inefficient government policies. Even this problem has become so serious that big cities suffer gas load shedding on summer days. If these resources are utilized properly, Pakistan can fulfill energy demands. Furthermore, the power crisis and lack of access to clean fuel in low-populated areas have been a challenge for every government because most households in these areas are far from the main electricity grid station. To provide electricity, governments should move towards renewable energy and give subsidies to households for solar panels; in this way, other countries in South Asia can adopt the same strategies to fulfill energy demands, living in remote areas. Besides, the government should ease taxes, provide incentives and subsidies to people, and initiate modern cookstoves for cooking. This way, the government can promote awareness, which can benefit their health and the overall environment.

(4) Asian countries are among the world's nations rich in agricultural resources, while a large portion of the population still resides in rural areas. In such a situation, the need for rural development is acutely felt. Modernization of agriculture, development of basic infrastructure in rural areas, provision of adequate employment to rural people, improvement in their living standards, and provision of basic necessities of life in rural areas can improve a living standard; furthermore, in rural areas, the Internet has allowed farmers to sell their products online as delivery of goods has also been facilitated, these are all factors that have sustainable results for the betterment of people living in rural areas.

The study is limited to Asian countries, particularly, India, Bangladesh, Afghanistan, Pakistan, Nepal, and the Maldives. This study employs an adjusted MEPI to compare each country's effort in multidimensional energy poverty reduction (2005 to 2017). By acknowledging these limitations, the study provides a foundation for future research to expand the geographical scope, and incorporate more diverse data sources.

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