https://doi.org/10.52131/jee.2024.0501.0042

*i*RASD Journal of Energy & Environment

Volume 5, Number 1, 2024, Pages 12 - 23

Journal Homepage:
https://journals.internationalrasd.org/index.php/jee

Economic Growth, Access to Clean Fuels & Technologies for Cooking, and Renewable Energy Consumption: Case of South Asian Economies

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ARTICLE INFO

Article History:

Received: March 08, 2024
Revised: June 10, 2024
Accepted: June 11, 2024
Available Online: June 13, 2024

Keywords:

Clean cooking fuels
Economic growth
Renewable energy consumption
South Asia

JEL Classification Codes:

O47, Q41, Q42

Funding:

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

Economic growth—through growth affordability, growth investments, and growth-awareness associations—may lead to increased access to clean fuel and technologies for cooking (ACF&T). The current paper presents the trend and comparative analyses regarding GDP per capita, access to clean fuels and technologies for cooking, and renewable energy consumption (REC) in the South Asian economies. The data from Bangladesh, India, and Pakistan between 2000 and 2020 shows a strong positive correlation between GDP per capita and access to clean cooking technologies. India has made the most significant improvements, followed by Pakistan and Bangladesh. All three economies negatively correlate GDP per capita and renewable energy consumption. Bangladesh shows the steepest decline, followed by India and Pakistan, indicating a more pronounced shift towards nonrenewable energy sources as economic prosperity increases. The study concludes that economic development often involves transitioning from traditional renewable energy sources (such as biomass) to more modern, nonrenewable energy sources (such as fossil fuels), often more efficient and reliable for industrial and large-scale energy needs. Hence, developing infrastructure and industrial sectors might lead to higher consumption of nonrenewable energy sources. This points to a potential challenge for sustainable development, as increased economic prosperity might be accompanied by more significant environmental impact unless there are concerted efforts to promote renewable energy sources.

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Citation: Khan, Z., Ali. A., Rizwan, M., & Ismail, M. (2024). Economic Growth, Access to Clean Fuels & Technologies for Cooking, and Renewable Energy Consumption: Case of South Asian Economies. *IRASD Journal of Energy & Environment*, *5*(1), 12–23. https://doi.org/10.52131/jee.2024.0501.0042

1. Introduction

The impact of economic growth on renewable energy use is complex and can have both positive and negative effects. According to various studies, economic growth can lead to more significant investment in renewable energy technologies. As countries and businesses become wealthier, they may be more willing to allocate resources towards research and development of solar panels, wind turbines, and other renewable sources (Bhuiyan et al., 2022; Xie et al., 2023). Likewise, economic prosperity can also enable

governments to implement policies that incentivize renewable energy use. This can include tax breaks, subsidies, and feed-in tariffs that make renewables more cost-competitive with traditional fossil fuels. Shifting to renewables can reduce dependence on volatile fossil fuel prices and foreign oil imports, a significant concern for growing economies (Xie et al., 2023).

According to a study conducted for a panel of ten African countries, rising renewable energy consumption was intensely driven by rising domestic incomes (Nyiwul, 2018). In a study conducted in China, Saliminezhad and Bahramian (2020) examined the causal relationship between economic growth and clean energy consumption from 1965 to 2017. Applying the asymmetric causality analysis, they found that a 1% decrease in economic growth resulted in a 0.13% reduction in clean energy consumption.

The impact of economic growth on renewable energy use can also have negative effects. Economic growth often leads to a rise in overall energy demand. While renewables can help meet this demand, they may also temporarily increase nonrenewable energy use in the short term. As economies grow, there is a tendency for urbanization. This can put a strain on energy grids and lead to a rise in energy consumption, potentially outweighing the benefits of renewable energy adoption in those areas (Bhuiyan et al., 2022).

Studies suggest that the relationship between economic growth and renewable energy use is not always linear. There might be a "threshold effect" where developing countries see a more robust increase in renewable energy use with initial economic growth, while developed economies might see a saturation point (Jia et al., 2023). Several studies have evidenced the existence of a two-way relationship between economic growth and renewable energy consumption, like Akkemik and Göksal (2012); Apergis and Payne (2011); Belke et al. (2011); Ohler and Fetters (2014); Shahbaz et al. (2015); Taşkın et al. (2020); Tugcu et al. (2012) and Zafar et al. (2019).

1.1 Contextualization and Research Hypotheses Formulation

Based on the shared picture, we can compare the energy consumption profiles of Bangladesh, India, and Pakistan, mainly focusing on the share of renewable energy sources (biofuels and waste) and the overall energy mix in each country.

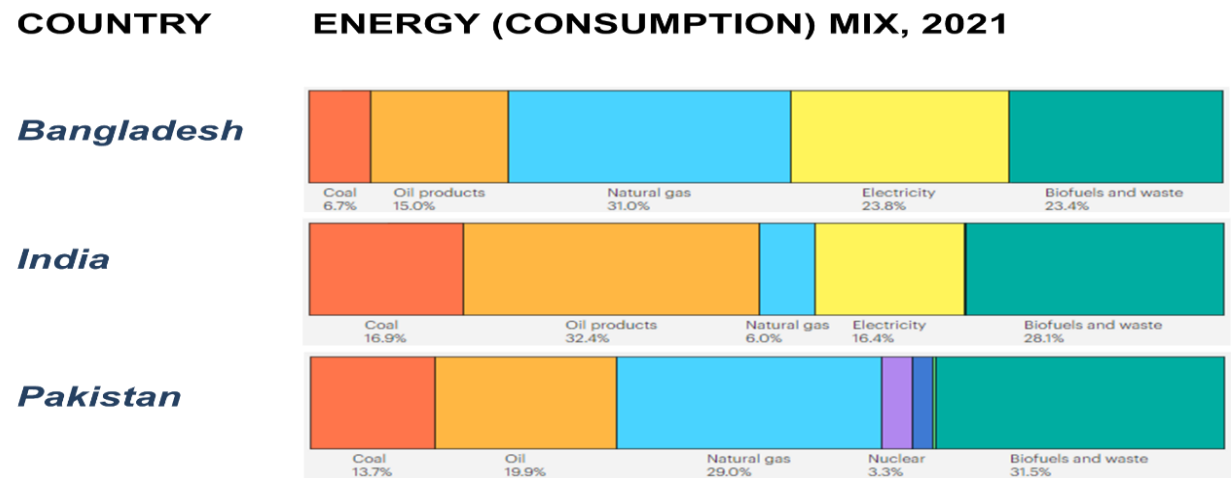

Figure 1: Energy (Consumption) Mix in Bangladesh, India, and Pakistan
Source: IEA (authors' compilation)

Pakistan is the only country among the three with a nuclear share of 3.3%. At the same time, Pakistan has the highest share of renewable energy consumption through biofuels and waste, indicating a solid reliance on renewable energy sources compared to Bangladesh and India. India shows a higher dependency on nonrenewable coal and oil products, which have significant environmental impacts. Bangladesh relies heavily on natural gas and has a balanced energy mix with a relatively higher share of electricity

consumption. These differences highlight the varying energy strategies and resource availability among these South Asian countries. Pakistan's reliance on biofuels and waste suggests a greater use of traditional biomass energy, while India's higher coal and oil product usage reflects its industrial energy needs. Bangladesh's reliance on natural gas indicates significant domestic gas reserves.

Regarding macroeconomic indicators, despite its smaller economy than India, Bangladesh has shown significant economic progress with the highest GDP per capita among the three countries (see Table 1). The high GDP growth indicates solid economic momentum. Bangladesh has the lowest unemployment rate among the three, suggesting better job creation relative to its population size. The inflation rate, while moderate, is still a concern. Bangladesh has the highest HDI among the three, reflecting better overall development outcomes in health, education, and living standards; from this context, we may hypothesize that:

H_1: Bangladesh's high GDP per capita may likely increase the ACF&T and REC.

Table 1
Comparison Regarding Economic Development Levels of South Asian Economies

Macroeconomic Indicators	Bangladesh	India	Pakistan
GDP (nominal, trillion USD) (2022)	0.46	3.42	0.37
GDP per capita (current US$) (2022)	2688.31	2410.89	1588.88
GDP growth (annual %) 2022	7.100	7.240	4.706
Unemployment, ILO Estimates (2023)	4.19	4.67	5.72
Inflation, consumer prices (annual %) 2022	7.70	6.70	19.87
Human Development Index (HDI) (2021)	0.668 (M)	0.645 (M)	0.562 (L)

Note: M=medium, L=low

India has the largest economy but a slightly lower GDP per capita than Bangladesh, indicating a more extensive population base diluting the per capita value. Its high growth rate is indicative of rapid economic expansion. India faces a slightly higher unemployment rate than Bangladesh but lower inflation, which could indicate better economic stability. India follows closely, but despite its economic size, its HDI is slightly lower than Bangladesh's, suggesting disparities in the distribution of development benefits. In the Indian context, we may have a research hypothesis that:

H_2: India's high GDP per capita may be associated with a higher probability of ACF&T and REC.

Pakistan lags in GDP per capita and overall GDP, coupled with a lower growth rate, indicating slower economic development. Pakistan struggles with the highest unemployment and inflation rates, pointing to economic instability and difficulties in managing economic pressures. Pakistan has the lowest HDI, indicating significant challenges in achieving comprehensive human development. In the scenario of Pakistan’s lower GDP per capita and slower economic development pace, it could be hypothesized that:

H_3: Pakistan's Low GDP per capita may likely be associated with comparatively less ACF&T and REC.

Pakistan is experiencing a stagflation-like situation compared to India and Bangladesh. Pakistan has a significantly higher inflation rate (19.87%) compared to India (6.70%) and Bangladesh (7.70%). This indicates a significant price increase for goods and services. Pakistan has the slowest GDP growth rate (4.7%) among the three. This suggests a sluggish economy that is not expanding as rapidly as its neighbors. Pakistan has the highest official unemployment rate (5.72%). However, unemployment data, especially in South Asia, can be unreliable due to the large informal sector. There is no universally agreed-upon definition for the exact thresholds of inflation, unemployment, and growth needed to constitute Stagflation. In this way, we can say that Pakistan is facing a

stagflation-like situation with high inflation and slow economic growth compared to India and Bangladesh. Hence paving the way for formulating the fourth research hypothesis as:

H_4: Stagflationary economic pressures may be associated with comparatively less ACF&T and REC.

The study is unique in that it investigates the effect of economic growth on using renewable energy. The previously done research has explored chiefly the effect of REC on economic growth. The current study is also unique in terms of its context, presenting fresh empirical evidence based on the latest dataset. In this paper, after the introduction section, the upcoming sections are ordered as data and methodology, results and discussion, and conclusion and policy suggestions.

2. Data and Methodology

The study intends to investigate the effect of GDP per capita on the percentage of the population having ACF&T and REC in three South Asian economies. The description of the variables is given in the Table 2. So, keeping in view these research objectives, the functional and simple econometric forms of the models are:

$$ACF\&T = f(GDP\ per\ capita, Stagflation) \quad (1)$$

$$REC = f(GDP\ per\ capita, Stagflation) \quad (2)$$

Equation (1) can be written as:

$$ACF\&T = \psi 0 + \psi 1\, GDP + \psi 2\, STAG\_FL + \varepsilon \quad (3)$$

In the same way, equation (2) can be written as:

$$REC = \psi 0 + \psi 1\, GDP + \psi 2\, STAG\_FL + \varepsilon \ldots \quad (4)$$

Table 2
Description of the Variables

Metric	Unit of Measurement	Definition
GDP per capita (GDP)	In hundreds of Current US$	GDP per capita is calculated without deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.
Access to Clean Fuels and Technologies for Cooking (ACF&T)	% of population	The proportion of the total population primarily uses clean cooking fuels and technologies. (Under WHO guidelines, kerosene is excluded from clean cooking fuels)
Renewable Energy Consumption (REC)	% of total final energy consumption	the share of renewable energy in total final energy consumption.
The stagflation-like situation of an economy (STAG_FL)	A country having relatively lower economic growth with high inflation and unemployment	Pakistan (codified as 1) is unfortunately facing this situation, as compared to Bangladesh and India (codified as 0)

The year-wise data (from the year 2000 to the year 2020) on GDP per capita (GDP), ACF&T (ACF&T), and REC (REC) was obtained from the World Bank's World Development Indicators (WDIs). Amongst the South Asian economies, Bangladesh, India, and Pakistan were chosen for the comparative and trend analyses.

3. Results and Discussion

3.1 Relationship between GDP per capita and ACF&T in Bangladesh: Trend Analysis

There is a consistent increase in GDP per capita from $413.10 in 2000 to $2,233.31 in 2020 in Bangladesh. Likewise, there has been a steady increase in the percentage of the population with ACF&T (ACF&T) from 7.8% in 2000 to 25% in 2020. In this way, the two seem to have a positive correlation. As GDP per capita increases, the percentage of the population with ACF&T also increases. In 2000, when GDP per capita was $413.10, only 7.8% of the population had access to clean cooking fuels and technologies. Whereas, by 2020, with a GDP per capita of $2,233.31, 25% of the population had access to these clean fuels and technologies.

The possible explanations for the positive relationship between GDP per capita and ACF&T could be the growth-affordability, growth-investments, and growth-awareness associations. Higher GDP per capita indicates economic growth, often leading to improved living standards and increased affordability of cleaner cooking technologies. Similarly, increased economic resources may enable the government to invest more in infrastructure and subsidies for clean cooking technologies. Likewise, economic growth may also lead to better education and awareness about the health benefits of using clean cooking fuels and technologies.

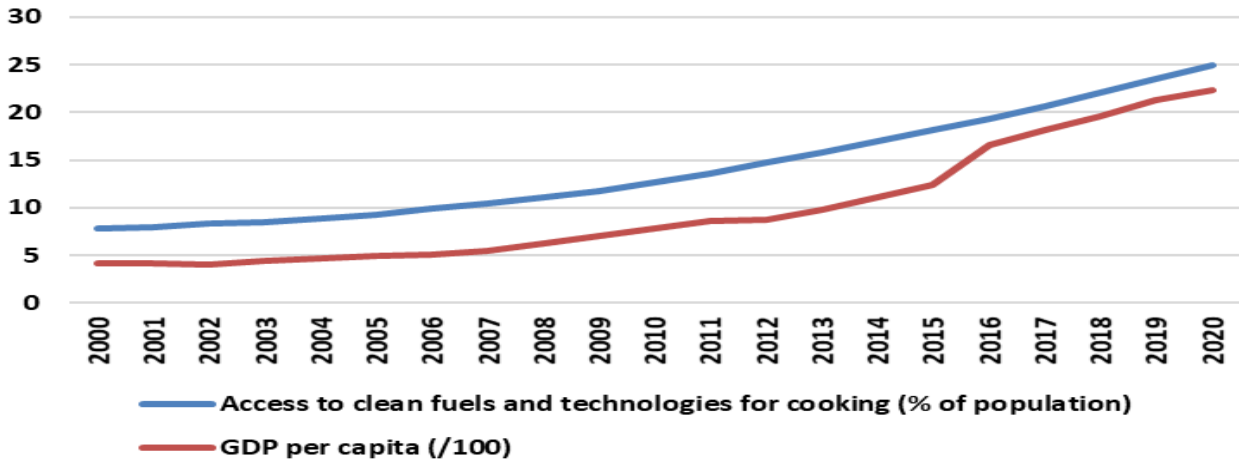

Figure 2: Per Capita GDP and Population having Access to Clean Fuel and Technology in Bangladesh

3.2 Relationship between GDP per Capita and REC in Bangladesh: Trend Analysis

As noted, Bangladesh continuously increased its GDP per capita from 2000 to 2020. The REC (REC) percentage as a part of total final energy consumption decreased from 60.2% in 2000 to 27.96% in 2020. In this way, there seems to be a negative correlation between GDP per capita and REC. That is, as GDP per capita increases, the percentage of REC decreases. In 2000, with a GDP per capita of $413.10, renewable energy accounted for 60.2% of total final energy consumption.

Meanwhile, by 2020, with a GDP per capita of $2,233.31, the renewable energy share had dropped to 27.96%. The possible explanations for the negative relationship between GDP per capita and REC could be the growth-energy transition, growth-industrial development, and growth-energy availability or cost associations. Economic development often involves transitioning from traditional renewable energy sources (such as biomass) to more modern, nonrenewable energy sources (such as fossil fuels), often more efficient and reliable for industrial and large-scale energy needs. Developing infrastructure and industrial sectors might lead to higher consumption of nonrenewable energy sources. The decreasing

share of renewable energy could also reflect market dynamics and policy choices that favor nonrenewable energy sources due to cost or availability.

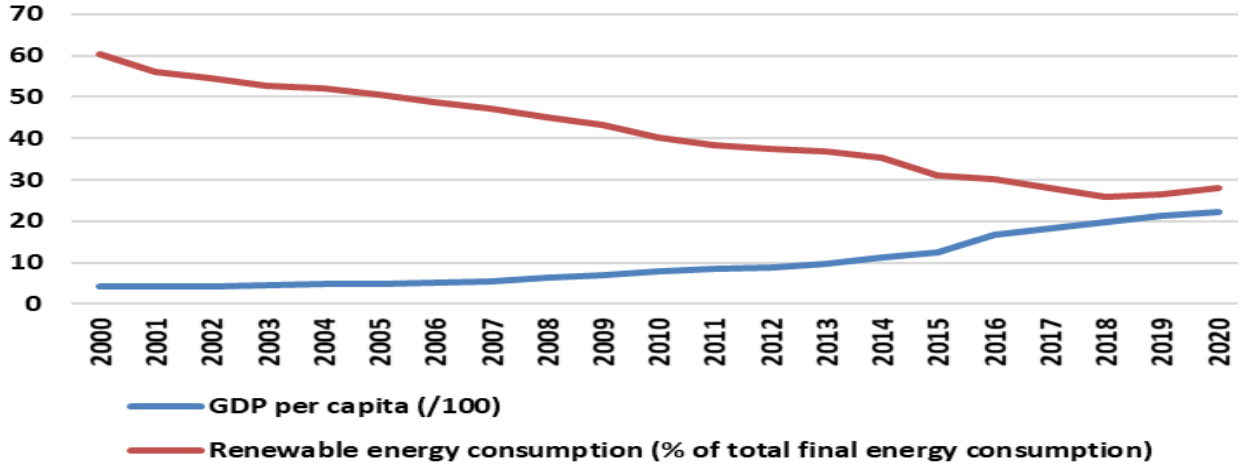

Figure 3: Per Capita GDP and REC in Bangladesh

3.3 Relationship between GDP per Capita and ACF&T in India: Trend Analysis

There is a consistent increase in GDP per capita in India from $442.03 in 2000 to $1,913.22 in 2020, with some fluctuations. Also, there is a steady increase in the percentage of the population with ACF&T, from 22.1% in 2000 to 67.3% in 2020 in India. As GDP per capita increases, the percentage of the population with ACF&T also increases. In 2000, when GDP per capita was $442.03, 22.1% of the population had access to clean cooking fuels and technologies. In the same way, by 2020, with a GDP per capita of $1,913.22, 67.3% of the population had access to these clean fuels and technologies in India. Once again, the possible reason for the existence of this positive association between GDP per capita and ACF&T could be attributed to improvement in living standards, an increase in government investments in infrastructure and subsidies for clean cooking technologies, and better education and awareness about the health benefits of using clean cooking fuels and technologies due to economic growth.

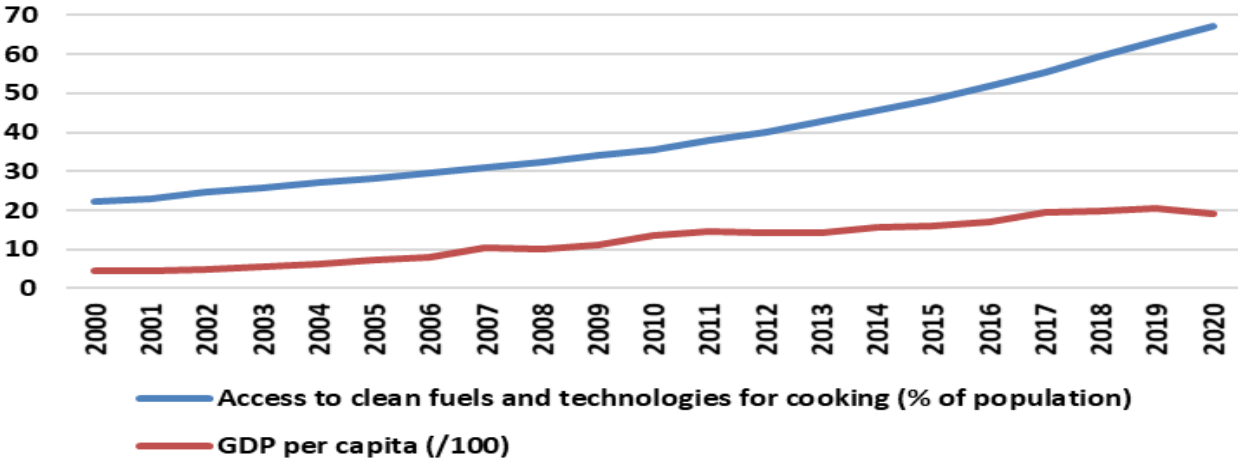

Figure 4: Per Capita GDP and Population having Access to Clean Fuel & Technology in India

3.4 Relationship between GDP per Capita and REC in India: Trend Analysis

As in the case of Bangladesh, there has also been a continuous increase in GDP per capita from 2000 to 2020 (though with some year-to-year fluctuations) in India. A similar trend prevails (as in the case of Bangladesh) in India, where the percentage of REC as a

part of total final energy consumption decreased from 46.88% in 2000 to 35.82% in 2020. An increase in GDP per capita is associated with a decrease in the percentage of REC. In 2000, with a GDP per capita of $442.03, renewable energy accounted for 46.88% of total final energy consumption. By 2020, with a GDP per capita of $1,913.22, the renewable energy share had decreased to 35.82%. The likely reasons for the negative relationship between GDP per capita and REC in India could be, yet again, the growth-energy transition, growth-industrial development, and growth-energy availability or cost associations.

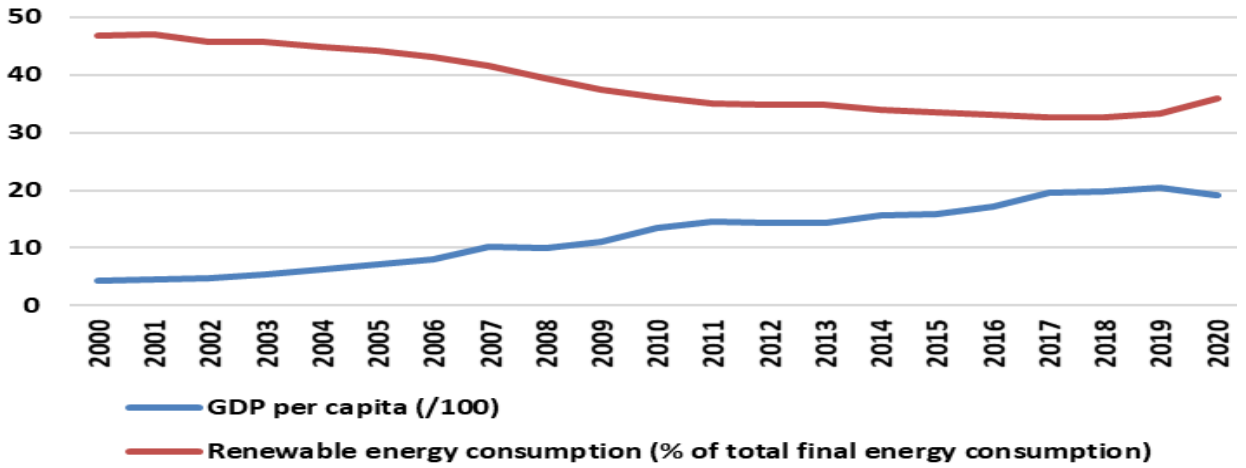

Figure 5: Per Capita GDP and REC in India

3.5 Relationship between GDP per Capita and ACF&T in Pakistan: Trend Analysis

There is a general increase in GDP per capita from $644.46 in 2000 to $1,322.32 in 2020 (with fluctuations around 2008 and 2019-2020) in Pakistan. There is a steady increase in the percentage of the population with ACF&T, from 23.8% in 2000 to 49% in 2020. As GDP per capita increases, the percentage of the population with ACF&T also increases in Pakistan. In 2000, when the GDP per capita in Pakistan was $644.46, 23.8% of the population had access to clean cooking fuels and technologies. By 2020, with a GDP per capita of $1,322.32, 49% of the population had access to these clean fuels and technologies.

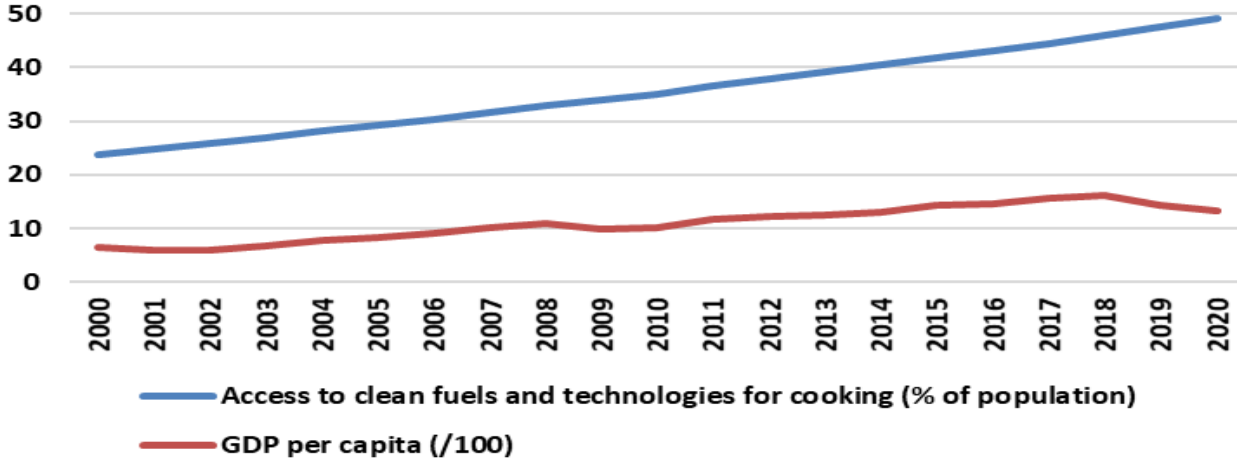

Figure 6: Per Capita GDP and Population having Access to Clean Fuel & Technology in Pakistan

3.6 Relationship between GDP per Capita and REC in Pakistan: Trend Analysis

There is a general upward trend in GDP per capita with some fluctuations. The percentage of REC as a part of total final energy consumption shows a decline from 51.05%

in 2000 to 46.6% in 2020, with some variability. That is, as GDP per capita increases, the percentage of REC generally decreases. In 2000, with a GDP per capita of $644.46, renewable energy accounted for 51.05% of total final energy consumption. By 2020, with a GDP per capita of $1,322.32, the renewable energy share had decreased to 46.6%.

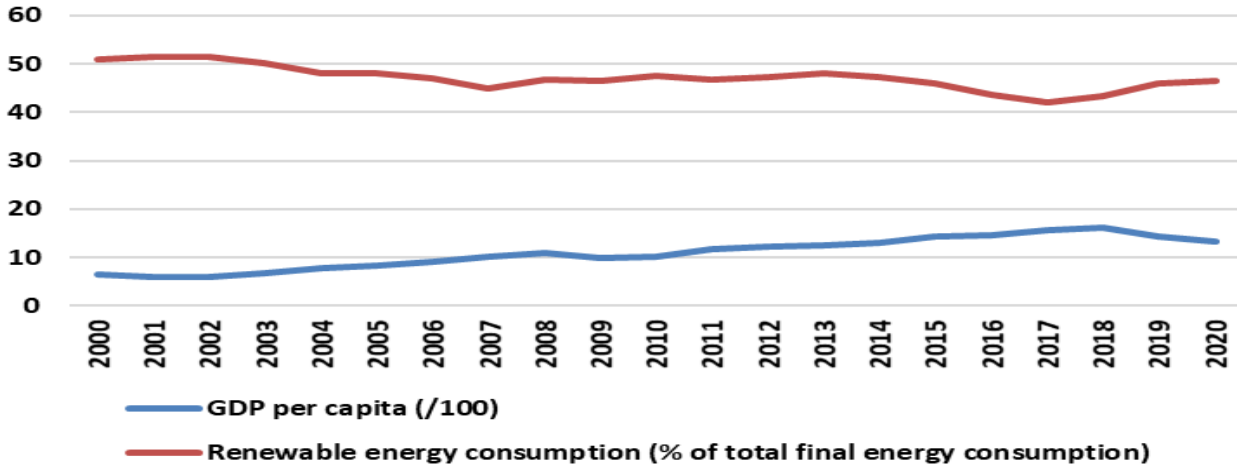

Figure 7: Per Capita GDP and REC in Pakistan

Based on the previously presented data, we have compared Bangladesh, India, and Pakistan regarding the relationship between GDP per capita and ACF&T. Also, we have compared the relationship between GDP per capita and REC among Bangladesh, India, and Pakistan.

3.7 Relationship between GDP per Capita, ACF&T, and REC: Comparison among South Asian Economies

In all the selected South Asian economies, economic growth has led to improved access to clean cooking technologies. In Bangladesh, as GDP per capita increased from $413.10 in 2000 to $2,233.31 in 2020, ACF&T also increased from 7.8% to 25%. Same for India, as GDP per capita increased from $442.03 in 2000 to $1,913.22 in 2020, ACF&T increased from 22.1% to 67.3%. Pakistan also exhibited the same trend. As GDP per capita increased from $644.46 in 2000 to $1,322.32 in 2020, ACF&T increased from 23.8% to 49%. All three countries show a strong positive correlation between GDP per capita and ACF&T. India shows the highest improvement in access, from 22.1% to 67.3%, followed by Pakistan, from 23.8% to 49%, and then Bangladesh, from 7.8% to 25%.

Table 3
Comparison among South Asian Economies

Parameters	Bangladesh	India	Pakistan
GDP per Capita Trend*	increased from $413.10 to $2,233.31	increased from $442.03 to $1,913.22	increased from $644.46 to $1,322.32
ACF&T Trend*	increased from 7.8% to 25%	increased from 22.1% to 67.3%	increased from 23.8% to 49%
REC Trend*	decreased from 60.2% to 27.96%	decreased from 46.88% to 35.82%	decreased from 51.05% to 46.6%
Strength of Positive Correlation between GDP per Capita and ACF&T	strong	the strongest	stronger
Strength of Negative Correlation between GDP per Capita and REC	the steepest decline	steeper decline	steep decline

Unlike increasing access to clean fuel for cooking, economic growth has led to a shift towards nonrenewable energy sources in Bangladesh, India, and Pakistan. An increase in

GDP per capita from 2000 to 2020 decreased REC from 60.2% to 27.96% in Bangladesh, 46.88% to 35.82% in India, and 51.05% to 46.6% in Pakistan. Regarding the strength of association, Bangladesh shows the strongest negative correlation, followed by India and Pakistan.

3.8 Descriptive Analysis

The average percentage of the population with ACF&T is approximately 29.7%, indicating moderate access across South Asian countries. The average GDP per capita is around $1,097.90, suggesting varying levels of economic development. REC stands at an average of 42.36%, reflecting a significant but not dominant reliance on renewable energy sources. See the findings given in the table 4 below.

Table 4
Descriptive Statistics

Variables	Mean	Std. Dev.	N
ACF&T	29.695	14.724	63
GDP per capita (in 100s $)	10.979	5.123	63
REC	42.358	7.826	63

There is a strong positive correlation (0.688) (2-tailed) between GDP per capita and ACF&T (significant at the 0.01 level), indicating that higher economic growth is associated with better access to clean cooking technologies. A strong negative correlation (-0.799) exists between GDP per capita and REC, indicating that higher economic growth is associated with lower REC (see Table 5 of a correlation matrix, given below).

Table 5
Correlation Matrix

	ACF&T	GDP	REC
ACF&T	1		
GDP	0.688**	1	
REC	-0.352**	-0.799**	1

3.9 Regression Analysis

GDP per capita has a significant positive effect (B = 1.983, p < 0.001) on ACF&T, indicating that higher GDP per capita is associated with increased access. The stagflation-like situation in Pakistan also has a significant positive effect (B = 9.132, p = 0.001), suggesting that Pakistan, compared to Bangladesh and India, has relatively better access to clean fuels despite economic challenges (see Table 6). The model explains 56% (R Square = 0.560) of the variance in access to clean fuels, indicating a good fit.

Table 6
Economic Growth and Access to Clean Fuel for Cooking in South Asia

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Err.	Beta		
(Constant)	4.881	3.113		1.568	0.122
GDP per capita	1.983	0.246	0.690	8.053	0.000
Stagflation-like Situation (Pakistan=1, Other=0)	9.132	2.654	0.295	3.440	0.001
Model Summary			**Value**		
R			0.748		
R Square			0.560		
Adjusted R Square			0.545		
Std. Error of the Estimate			9.931		

GDP per capita has a significant negative effect (B = -1.216, p < 0.001), indicating that higher GDP per capita is associated with lower REC. The stagflation-like situation prevailing in Pakistan has a significant positive effect (B = 7.015, p < 0.001), suggesting that Pakistan has higher REC compared to Bangladesh and India (see Table 7). The model explains 82% (R Square = 0.820) of the variance in REC, indicating a perfect fit.

Despite its stagflation-like situation, higher GDP per capita significantly increases ACF&T. Pakistan shows better access to clean fuels compared to Bangladesh and India. Higher GDP per capita is associated with lower REC, indicating that economies might rely more on nonrenewable energy sources as they grow. Pakistan has a higher share of REC than Bangladesh and India, possibly due to its energy policies or resource availability.

Table 7
Economic Growth and REC in South Asia

Dependent Variable: REC (% of total final energy consumption)					
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Err.**	**Beta**		
(Constant)	53.370	1.057		50.470	0.000
GDP per capita (/100)	-1.216	0.084	-0.796	-14.541	0.000
Stagflation-like Situation (Pakistan=1, Other=0)	7.015	0.902	0.426	7.781	0.000
Model Summary			**Value**		
R			0.906		
R Square			0.820		
Adjusted R Square			0.814		
Std. Error of the Estimate			3.373		

4. Conclusion and Policy Suggestions

The data from Bangladesh, India, and Pakistan between 2000 and 2020 shows a clear positive relationship between GDP per capita and ACF&T, indicating that economic growth facilitates better access to clean energy for cooking. Conversely, there is a negative relationship between GDP per capita and the share of REC, suggesting that as the economy grows, the reliance on nonrenewable energy sources increases.

The three South Asian economies show a strong positive correlation between GDP per capita and access to clean cooking technologies. India has made the most significant improvements, followed by Pakistan and Bangladesh. The selected economies also negatively correlate GDP per capita and REC. Bangladesh shows the steepest decline, followed by India and Pakistan, indicating a more pronounced shift towards nonrenewable energy sources as economic prosperity increases.

Despite having the highest GDP per capita, access to clean fuels is still relatively low, but it is improving in Bangladesh, highlighting ongoing efforts to catch up in infrastructure and public services. Bangladesh exhibits a sharp decline in REC as GDP per capita rises, indicating a transition to nonrenewable energy sources, typical of rapid industrialization. India shows a significant improvement in access to clean fuels correlating with its GDP per capita growth, reflecting effective policy implementation.

India also shows a decrease in REC but less steeply than Bangladesh, possibly due to a more balanced approach to energy policy. Improvement in access to clean fuels is moderate, aligning with Pakistan's lower GDP per capita and slower economic development pace. Pakistan displays a fluctuating but generally declining trend in REC, reflecting inconsistent energy policy and slower economic transition.

The study suggests that economic growth should be accompanied by targeted policies to ensure that the benefits of growth translate into improved access to clean energy technologies. The study also suggests that the countries must balance economic growth with sustainable energy policies to ensure that growth does not come at the cost of renewable energy adoption. Investments in renewable energy infrastructure and incentives for renewable energy use could help mitigate the negative relationship between GDP growth and REC.

Authors Contribution

Zahid Khan: study design & concept, incorporation of intellectual content, drafting
Abid Ali: critical revision, data interpretation, write-up
Muhammad Rizwan: data collection, literature review
Muhammad Ismail: data analysis, write-up

Conflict of Interests/Disclosures

The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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