

Energy Poverty and Economic Development in South Asia: A Panel Data Analysis

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Abstract

This study examines the impact of energy poverty on economic development in six South Asian countries: Bangladesh, Bhutan, India, Sri Lanka, Nepal, and Pakistan, using panel data from 2001 to 2025. Economic development is measured through GDP per capita growth, while energy poverty is proxied by access to electricity (AELC) and access to clean cooking fuels and technologies (ACFT). The study also incorporates ICT imports (ICTM), inflation (INF), urbanization (URB), and foreign direct investment (FDI) as control variables. To investigate the long-run and short-run relationships among the variables, the Panel Mean Group Autoregressive Distributed Lag (PMG-ARDL) model, panel cointegration analysis, is employed. The empirical findings confirm a significant long-run relationship between energy poverty and economic development. Improved access to electricity and clean cooking technologies positively and significantly enhances economic growth. Moreover, ICT imports and foreign direct investment contribute positively to economic development. The study concludes that reducing energy poverty through improved access to modern energy services is essential for promoting inclusive and sustainable economic growth in South Asia.

Keywords: Energy Poverty, Economic Development, FDI, ICT, GDP per-capita, South Asia, PMG-ARDL

1. Introduction

Energy poverty and economic development is quite debatable yet an under-considerate matter, for the past few decades. The base for this phenomenon is largely provided by the energy crisis of 1980's, which affects almost all economies of the globe. The oil price shock forecasts a direct influence on energy poverty by exacerbating availability and affordability of energy sources for millions of people around the globe. This initiated the conception of the reversal of "energy ladder hypothesis" mainly in developing regions (Guevara, Espinosa-Aldama, & López-Corona, 2025).

There exists a complex integration between energy poverty and economic development as both are fundamentally associated in a bidirectional link. Energy availability serves as a prerequisite as well as a byproduct for economic growth. Conversely, the inadequacy of modern energy facilities acts as a "barrier" for fast economic progress and creates a state of underdevelopment. In contrast, access to energy resources is imperative for uplifting the industrial productivity level. Thus, energy serves as a "booster" for industrialization (Amin et al., 2020; and Naz & Afzal, 2025).

With common access to energy resources a nation can reduce their manufacturing as well as transportation costs, which in turn enables small entrepreneurs to raise the profits and creates income surplus. Additionally, improved access to available energy resources causes human capital formation as it diverts the individual's attention from traditional fueling means (dung & wood) which causes wastage of individual time and energy (labor productivity). In this context, energy availability also facilitates individuals' health as reliance on traditional polluting fueling cause indoor air pollution (Yang & Gan, 2024; and Naz & Afzal, 2025).

With the passage of time as economic structural transformation occurs it generates necessary conditions for mitigating energy poverty. In this regard, with increased Infrastructural investment (which is caused by increased GDP) governments tend to fund energy projects at large scale like natural-gas pipelines and grid extensions. With improved economic development, per-capita income of individuals may tend to increase which eventually moves their energy preference from traditional biomass means to clean fuels. Thus, labeled as "energy ladder" (Yang & Gan, 2024).

This study integrates a panel research methodology which aims to differentiate the influences of energy poverty (such as access to electricity, and access to clean fuels & technology) on GDP per-capita growth.

2. Literature Studies

Westphal (2002) deliberated about the technological strategies role for the advancement of economic development. In this regard, contribution of inventions, digitalization, and the knowledge-based transformation in industries have been stressed for achieving sustainable development in developing economies. Scholars emphasized the empirical significance of the technological adoption which in turn enhances productivity level, brings inclusive developments, cause global competitiveness, and thus assist the attainment of sustain development. Based on estimations, researchers suggested the promotion of effective technological strategies and skills development.

Kyprianou et al. (2019) explored some imperative strategies and approaches applied by EU nations to combat the issue of energy poverty (energy affordability and energy access). This research incorporated selected twenty-eight (28) European nations for empirical investigation. The research variables were energy poverty, consumer protection, social subsidies, financial aids, and economic growth. To apply analytical methodology, a mixed methodology has been incorporated by the researchers. Additionally, this paper considered the effect of social-support aids, subsidies, and improvement in energy efficacy. In the end, researchers suggested effective multi-dimensional policies concerning energy poverty for addressing diverse EU nation's context.

Prime and Slabe-Erker (2020) highlighted the influence of prevailed socio-economic frameworks in addressing the phenomenon of energy poverty. Similarly, researchers highlighted the significance of socio-economic frameworks in formulation of energy related policies. The secondary data for selected economies has been collected for investigation. The variables of the study were energy poverty, economic growth, socio-economic frameworks, and energy usage. This research incorporated systematic literature review-based analysis for empirical methodology. The estimates concluded that there exists strong cointegration between the research indicators examined.

Ceglia et al. (2022) scrutinized Energy poverty and the household's well-being in context of vulnerability in developing economies. In this regard, a panel data from selected European Union economies has been collected. The variables of this research examined were energy poverty, energy affordability, local investments, and access to electricity, renewable energy consumption, and economic growth. Results of the research disclosed that energy poverty can be reduced by promoting the usage of renewable energy resources along with improving energy affordability for the case of targeted developing economies. Additionally, empirical significance of governance and technological advancements has also been observed here.

Tariq et al. (2022) analyzed about the contribution of green energy consumption, green technology, and green-house gasses (GHS) in forming climate changes in South Asian nations. The panel data for selected South-Asian economies has been collected for investigation. The research period ranges from 1981-2018. The variables of the study were energy poverty, economic growth, carbon emissions, trade openness, green energy usage, and the green technology. This research incorporated FMOLS and DOLS analysis along with the causality analysis for empirical methodology. The estimates concluded that there exists strong cointegration between the research indicators examined. Besides, trade, growth, and exports significantly raise GHS level while green technology, energy efficacy, and the green energy usage confirmed negative affiliation with GHS level in South Asia.

Chan and Delina (2023) investigated the influence of geographic conditions and diversity in socio-economic environment in formulation of energy poverty. In addition, they highlighted the conceptions of 'hidden energy-poverty', 'cooling poverty', and the 'urban energy-poverty' here. The panel data for selected 23 Asian economies has been collected for investigation. The research period ranges from 2004-2023. The variables of the study were energy poverty, economic growth, carbon emissions, trade openness, urbanization, energy usage, and income poverty. This research incorporated systematic literature review analysis along with the statistical inference analysis for empirical methodology. The estimates concluded that there exists strong cointegration between the research indicators examined.

Katoch et al. (2024) deliberated some literature studies which prompted advancement of solar power and the attainment of economic sustainability. For the case of empirical investigation, Indian economy has been targeted. This paper mainly incorporated time-series data in the period-

frame 2008-2022. The examined variables utilized here were economic growth, solar energy usage, renewable electricity, and the total energy supply as the examined indicators of this research. The estimation technique employed here was a mix methodology. Empirical results revealed that solar energy advancement prompted as an effective gadget for the eradication of energy poverty in India. Additionally, researchers stressed the usage of renewable energy resources to attain sustainable development.

Rao et al. (2024) highlighted the complex integration between environmental sustainability and energy poverty. The panel data for selected South-Asian economies has been collected for investigation. The research period ranges from 1996-2019. The variables of the study were energy poverty, economic growth, carbon emissions, electricity usage, and the environmental quality. This research incorporated quantile-on-quantile (QQ) regression analysis for empirical methodology. The estimates concluded that there exists strong cointegration between the research indicators examined. Additionally, energy poverty degraded environmental quality of targeted economies.

Conable and Olsson (2024) observed two distinct concepts in a diverse manner that are economic development and economic growth. This research incorporated a systematic review-based methodology for empirical investigation. This paper signified that economic growth mainly denotes increase in country's production or income level while economic development is a broad concept which entails education, health, and living standards. They demonstrated economic development as a multi-dimensional concept. The literature had debated the limitations of policies which focuses growth. Although, prompts sustainable development as it comprises institutional, economic and social forces.

Amjad et al. (2025) displayed about the complex coordination between energy poverty and the sustainable development in context of South Asian economies. The panel data for selected South-Asian economies has been collected for investigation. The research period ranges between 1990-2023. The variables of the study were energy poverty, economic growth (GDP per capita), human development index, trade, electricity access, sustainable development index, gross capital formation, and urbanization. This research incorporated cross-sections dependence, moments in quantile regression (MQR) analysis along with the causality analysis for empirical methodology. The estimates concluded that there exists strong cointegration between the research indicators

examined. Besides, a u-shaped integration has been witnessed between energy poverty and sustainable development.

3. Research Modeling and Empirical Analysis

The central focus of the currently examined study is to explain the empirical validity of affiliation between energy poverty and economic growth. In this regard, researcher is aimed to utilize a panel series data from South Asian economies. Energy Poverty contains multiple dimensions and indicators therefore this research primarily stressed two major contributors or indicators that are access to the electricity, and access to clean cooking fuels & technology. This study used one dependent (GDPP) and the six independent variables for empirical investigation. This statement can be re-written in economic modeling form as;

$$GDPP = f(AELC, ACFT, ICTM, INF, URB, FDI) \dots\dots\dots(3.1)$$

Here, above equation-line deliberates that GDPP is a function of AELC, ACFT, ICTM, INF, URB, and FDI. Therefore, GDPP is a dependent while AELC, ACFT, ICTM, INF, URB, and FDI are the independent research indicators. The econometric equation of the above model will be;

$$GDPP_{it} = \alpha_0_{it} + \alpha_1 AELC_{it} + \alpha_2 ACFT_{it} + \alpha_3 ICTM_{it} + \alpha_4 INF_{it} + \alpha_5 URB_{it} + \alpha_6 FDI_{it} + \mu_{it} \dots\dots(3.2)$$

Here:

GDPP is the dependent indicator while AELC, ACFT, ICTM, INF, URB, and the FDI are independent variables,

i= cross-section i.e. South Asian countries: Bangladesh, Bhutan, India, Sri Lanka, Nepal, & Pakistan = time covered i.e. time 2001-2025.

3.1. Panel Unit Root Analysis (LLC)

To detect the presence of unit root or the stationary of under examination variables of the research, this study employed Levin, Lin, and Chu unit root testing. The statistics analyzed show the trend (over the time) for the examined panel data set.

Table 1: Stationary Test

Variable	AT LEVEL		1 ST DIFFERENCE		
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Remarks
GDPP	-4.5194* (0.0000)	-4.1839* (0.0000)	-10.7541* (0.0000)	-9.0210* (0.0000)	(I₀ , I₁)
AELC	0.2113 (0.5837)	1.0904 (0.8622)	-2.6573* (0.0039)	-0.5238 (0.3002)	(I₁)
ACFT	0.1756 (0.5697)	-1.2627 (0.1033)	-3.2110* (0.0007)	0.1345 (0.5335)	(I₁)
FDI	0.0482 (0.5192)	0.2073 (0.5821)	-5.2334* (0.0000)	-3.0582* (0.0011)	(I₁)
INF	-3.0204* (0.0013)	-1.9147** (0.0278)	-8.0031* (0.0000)	-5.9820* (0.0000)	(I₀ , I₁)
URB	0.3377 (0.6322)	-2.6049* (0.0046)	2.1457 (0.9841)	6.7174* (0.0000)	(I₀ , I₁)
ICTM	-2.8519* (0.0022)	-2.4250* (0.0077)	-4.8386* (0.0000)	-2.3607* (0.0091)	(I₀ , I₁)

Note: *, **, *** shows panel significance at 1 percent, respectively. **Source:** Researcher Creation Using Eviews-9

The obtained statistics of panel unit root testing have shown that the examined indicators of this research are statistically stationary at 1 percent level of significance. Here, the GDP per capita (GDPP) is statistically stationary both at level (**I₀**) and first difference (**I₁**) criterion. Although, the access to electricity (AELC) is statistically stationary at the 1st difference and non-stationary at level (**I₀**). Similarly, the access to clean fuels & technology (ACFT) and foreign direct investments (FDI) are statistically stationary at the 1st difference (**I₁**) and non-stationary at level (**I₀**). On the contrary, inflation (INF) rate is statistically stationary both at level (**I₀**) and first difference (**I₁**)

criterion. Conversely, urbanization (URB) and the information & technology imports (ICTM) are statistically stationary at level (I_0) as well as at first difference (I_1) criterion.

3.2. Cointegration Analysis

To check the long run co-integration between examined indicators of the research, this study employed two different types of panels cointegration testing that are Pedroni cointegration analysis and Kao cointegration analysis. The statistics obtained show the cointegration for the examined data set, in the long run.

Table 2: Pedroni Cointegration Test

Pedroni Cointegration Test				
Null Hypothesis: No cointegration				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	-2.7713	0.9972	-3.3279	0.0096*
Panel rho-Statistic	0.4174	0.6618	-3.0894	0.0620***
Panel PP-Statistic	-7.7663	0.0000	-9.6894	0.0000*
Panel ADF-Statistic	-3.0791	0.0010	-4.0275	0.0000*
Alternative hypothesis: individual AR coefs. (between-dimension)				
Statistics	Statistic	Prob.		
Group rho-Statistic	-3.2636	0.0882***		
Group PP-Statistic	-13.2260	0.0000*		
Group ADF-Statistic	-3.5675	0.0002*		

Note: *, **, *** shows panel significance at 1, 5, & 10 percent, respectively. *Source:* Researcher Creation Using

Eviews-9

The measured statistics of Pedroni cointegration analysis demonstrate that there exists long run co-integration between the examined panel series. In this regard, different statistics has been utilized. All the statistics examined (that are panel-v; panel-rho; panel-PP; and panel-ADF) confirmed the existence of long run co-integration. As the statistics examined are statistically significant at 1% and 5%, respectively (as shown in above table).

Table 3: Kao Cointegration Test

Kao Residual Cointegration Test		
Null Hypothesis: No cointegration	t-Statistic	Prob.
ADF	-2.6049	0.0046*
Residual variance	31.9509	
HAC variance	18.4899	

*Note: *, **, *** shows panel significance at 1, 5, & 10 percent, respectively. Source: Researcher Creation Using Eviews-9*

The obtained statistics of Kao cointegration test reflect that there exists long run co-integration between the examined panel series. In this regard, different statistics has been utilized. All the statistics examined (that are ADF, residual variance, and the HAC variance) confirmed the presence of long run co-integration. As the examined statistics are statistically significant at 1%, respectively (as shown in above table).

3.3. Cross Sectional Dependence Analysis

Table 4: Cross Sectional Dependence Estimates

Null hypothesis: No cross-section dependence (correlation) in residuals			
Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	64.363	28	0.000*
Pesaran scaled LM	3.790		0.000*
Pesaran CD	3.004		0.002**

*Note: *, **, *** shows panel significance at 1, 5 percent, respectively. Source: Researcher Creation Using Eviews-9*

The following table deliberates the cross-sectional dependence estimates for the targeted panel economies. The null hypothesis rejects the presence of cross-sectional dependence meaning that collaborative efforts for the betterment of complete region is not effective. Although, alterations hypothesis postulates the effectiveness of joint efforts for the betterment of complete panel. As, in the above table, it's shown that there exists cross sectional dependence, based on three different

criteria. Therefore, we can accept the alternative hypothesis by rejecting the null hypothesis of no cross-sections dependence.

3.4. PMG/ARDL Estimation

To scrutinize the affiliation between examined dependent and independent variables of the research, this study employed panel mean-groups autoregressive distributional lag modeling (PMG/ARDL) testing. This analysis contains two different estimations, separate cointegration for short run as well as for long run. The statistics obtained show the cause and effect affiliation for the examined panel data set.

Table 5: Short Run PMG/ARDL

Short Run Equation				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
COINTEQ01	-0.8784	0.2061	-4.2609	0.0000*
D(GDPP (-1))	0.1811	0.1462	1.2391	0.2177
D(AELC)	0.0694	0.2604	0.2667	0.7901
D(ICTM)	-0.0799	0.2694	-0.2969	0.7670
D(ACFT)	0.6585	1.7352	0.3795	0.7050
D(INF)	-0.1879	0.0678	-2.7707	0.0065*
D(URB)	-0.4698	0.9478	-0.4957	0.6210
D(FDI)	0.4152	0.6998	0.5933	0.5540
C	-1.1008	2.9811	-0.3692	0.7126

Note: *, **, *** shows panel significance at 1, 5, & 10 percent, respectively. **Source:** Researcher Creation Using

Eviews-9

The statistics obtained from short run show that there exists the potential of long-term co-integration between the examined research indicators. As the value of Coint-equation is less than one (-0.87), and it is statistically significant at the significance criteria of 1%. Although, in short run not all variables confirm their statistical significance as the period examined under consideration is quite short here. Therefore, the short run estimates are not quite reliable. The inflation rate confirms its statistical significance in short run. And it shows that in short run with

increased inflation there's a 18 percent decline in GDP per-capita growth. Though, this effect is insignificant and has been reduced in the long run. On the contrary, all other research variables fail to validate their statistical significance in short run, but they prove their empirical significance in the long run.

Table 6: Long Run PMG/ARDL

Long Run Equation				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
AELC	0.0484	0.012	3.7821	0.0002*
ICTM	0.4067	0.1086	3.7425	0.0003*
ACFT	0.1136	0.0340	-3.3384	0.0011*
INF	0.0262	0.0284	0.9232	0.3577
URB	0.0405	0.0490	0.8267	0.4100
FDI	0.6736	0.2687	2.5062	0.0135*

Note: *, **, *** shows panel significance at 1, 5, & 10 percent, respectively. *Source:* Researcher Creation Using

Eviews-9

The obtained statistics of long run PMG/ARDL deliberates that in long run all examined variables significantly determine the economic development of South Asian economies. Although, inflation and urbanization assert insignificant effect in long run, on the economic development of targeted nations. Therefore, we can conclude that energy poverty significantly influences economic development in South Asian economies. As both indicators (AELC and ACFT) of energy poverty assert a significant effect on economic development.

The access to electricity causes an affirmative effect on the economic development. With increased yet affordable access to electricity can uplift the GDP per capita of targeted economies, in the long run. Access to electricity has been perceived as a precondition for advancement in the economic growth (Best & Burke, 2018; Wang, Rani, & Amjad, 2025). As access to electricity asserts significant effect on the productivity level and thus on GDP per capita level, as well. A one percent increase in access to electricity can cause a 4% increase in economic development and this effect is statistically significant at a static level of 1%. Therefore, researchers accepted the alternative

hypothesis-1 and thus rejected the null-hypothesis-1 (Best & Burke, 2018; Milin, 2022; and Naz & Afzal, 2025).

Similarly, increase number of ICT imports has also deliberate as an affirmative determinant of economic development. A one percent increase in access to ICT imports can cause a 40% increase in economic development and this effect is statistically significant at a static level of 1%. Therefore, researchers accepted the alternative hypothesis-4 and thus rejected the null-hypothesis-4. The reason behind this static influence has been rewarded to the easiness and effectiveness in productive activities caused by ICT infrastructure in the targeted nations. Multiple research projects disclosed that with increased investment in the ICT industry, economic growth uplift manifold (Plăcintă et al., 2022) and Oliinyk, 2023).

The access to clean cooking fuels & technology has also been regarded as a positive contributor of economic development. With increased yet affordable access to clean cooking fuels & technology can uplift the human capital formation of targeted economies, in the long run. Access to clean cooking fuels & technology has been perceived as a saver of human capital time and energy from traditional highly polluting energy sources (Yang & Gan, 2024). As, the access to clean cooking fuels & technology asserts significant effect on the GDP per capita level. A one percent increase in access to clean cooking fuels & technology can cause a 11% increase in economic development and this effect is statistically significant at a static level of 1%. Therefore, researchers accepted the alternative hypothesis-2 and thus rejected the null-hypothesis-2 (Garba, I., & Bellingham, 2018; Garba, I., & Bellingham, 2021; and Naz & Afzal, 2025).

On the contrary, inflation rate asserts a positive yet an insignificant effect on the targeted developing economies GDP per-capita level. A one percent increase in inflation rate can cause a 2% increase in economic development. Although, this effect is statistically insignificant at a static level of 5% as well as 10%. The Asian economies encounter multiple challenges comprising larger informal sectors, disturbance in supply chain, and the effect of external shocks (such as trade deficits and foreign investments) which in turn complicate the inflationary pressure as well as the monetary policy effect (Haidar et al., 2024).

Conversely, the urbanization level causes a positive yet insignificant effect on the targeted developing economies GDP per-capita level. A one percent increase in urbanization can cause a

4% increase in economic development. Although, this effect is statistically insignificant at a static level of 5% as well as 10%. Therefore, researchers accepted the null hypothesis-3 and thus rejected the alternative-hypothesis-3. For the case of South Asian economies, urbanization level often asserts an initially minor effect on GDP per-capita as because the growth of an economy is primarily driven more via changes in employment (from agri. sector to industrial sector) than via massive productivity-gains incurred from urbanization. Besides, The Asian economies encounter multiple challenges containing large reliance on informal sectors, disturbance in supply chain, and the effect of external shocks, which in turn manipulate the urbanization effect (Nguyen & Nguyen, 2018; and Chen & Nguea, 2025).

On the contrary, increased foreign direct investment has also deliberated as an affirmative determinant of economic development. A one percent increase in foreign investment can cause a 67% increase in economic development and this effect is statistically significant at a static level of 1%. Therefore, researchers accepted the alternative hypothesis-5 and thus rejected the null-hypothesis-5. The reason behind this static influence has been awarded to the increased productivity activities and the expansion of business due to increased number of investments in the economy. With increased productive activities, employment level increases, which in turn raises GDP per-capita level and thus incurs economic development in the South Asian economies (Edward, Naanwaab, & Romero, 2017; and Wang, Yang, & Wang, 2023).

4. Conclusion

For the case of developing nations, the energy consumption or the available energy facilities are quite limited and are bound with few groups or individuals of the economy. Therefore, there arises the phenomenon of energy poverty. This captures the researchers' attention, and the current study is initialized with the motive to evaluate the affiliation between energy poverty and the economic development of selected developing economies. In today's modernized World, the energy has become a vital component of an individuals' day to day activity. And thus, significantly contributes to the economic development of a nation.

Therefore, there's needed to integrate the long run association between energy consumption and economic development. In this regard, a panel of six South Asian economies is finalized for empirical investigation comprising Bangladesh, Bhutan, India, Sri Lanka, Nepal, and Pakistan.

The panel data has been collected for selected economies during 2001-2026. Furthermore, the researcher has shortlisted GDP per-capita growth, access to electricity (AELC), access to clean cooking fuels & technology (ACFT), ICT imports (ICTM), inflation (INF), urbanization (URB), and foreign investments (FDI) as research indicators.

Here, GDPP is the dependent while AELC, ACFT, ICTM, INF, URB, and FDI are the independent variables. For statistical estimation, panel mean-group Autoregressive distributed lagged (PMG-ARDL) modeling, causality test of Dumitrescu and Hurlin, and the panel cointegration analysis has been applied. All the statistical calculations denote that energy poverty significantly determines the economic development of targeted developing economies. And the access to electricity and clean cooking fuels & technology can significantly bring the economic development in South Asian economies. Besides, ICT Development and foreign investment also contribute the economic development.

5. Policy Suggestions

The central objective behind the conduction of every research is to provide or suggest some static policies for empirical implications to solve or eliminate the research problem examined. As the observed problem of this research is energy poverty, therefore here researchers suggested possible ways to combat or overcome the problem of energy poverty. Additionally, researcher has suggested some effective policies for obtaining economic development in the South Asian economies. These policies are detailed below as;

1. The South Asian economies should introduce subsidies and some other incentives for improving the energy production and resources utilization. To attract investors in energy sector, there's needed to attract investors through tax exemptions or other incentives providence.
2. Electricity providence needs to be improved, and the load shedding needs to be combatted for facilitating daily life activities of inhabitants. The electricity providence also significantly influences the production activities of industries as most of the machinery operates with electric energy. Therefore, access to electricity and the providence scale of electricity need to be wider for all classes of society. The reduction in the billing or cost system of electricity can also attract consumers of electricity.

3. The targeted economies need to ease the import duties on imported ICT goods to improve the ICT infrastructure of their economies.

4. The targeted economies should introduce serious & strict policies and regulations for controlling the urbanization rate. As, urbanization causes a load or burden on energy resources providence, when the number of inhabitants in a city increases. Availability of energy resources need to be circulated in rural and urban areas, equally, to resolve the disparity or deprivations from energy sources such as electricity, and clean cooking fuels & technology.

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