Article

An ARDL Approach to Check the Linkage Between Economic Growth, Electricity Access, Energy Use and Population Growth in Pakistan: Long-run and Short-run Analysis

Abdul Rehman[1],*, Zhang Deyuan[2]

[1]   Research Center of Agricultural-Rural-Peasants, Anhui University Hefei, China; abdlrehman@ahu.edu.cn
[2]   Research Center of Agricultural-Rural-Peasants, Anhui University Hefei, China; zhdeyuan@263.net
*   Correspondence: abdlrehman@ ahu.edu.cn; Tel.: +8615256556123

Abstract: The major aim of this study was to investigate and explores the linkage between economic growth, electricity access, energy use and population growth in Pakistan. To check the variables stationarity, Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root test was applied and an Autoregressive Distributed Lag (ARDL) bounds testing approach to co-integration was applied to investigate the dynamic causality link among the study variables. These tests shed light on the long-run connection among the variables; further, the results revealed that electricity access to population, electricity access to urban population, energy usage, population growth, and urban population growth had a significant impact on economic growth, while the electricity access to rural population and rural population growth has a negative impact on the economic growth in Pakistan. According to these findings, study commends that government of Pakistan pay further attention to increase its electricity production from different sources including, hydroelectric, solar, oil and gas and nuclear in order to fulfill the country's demands.

Keywords: economic growth; electricity access, energy production, population growth; ARDL

1. Introduction

Energy has dominant role in the economic development and also a fundamental part of any national economy. It relates to energy security, economic development and social stability. Electricity has vital value and is considered the useful source of energy that boosts to support every part of the economy. Over past few decades, policies failure in the energy sector of Pakistan plunged the country into a severe power crisis, leading to poor economic performance in the country and demand of electricity is determined by the population growth and other factors, including electricity prices, people movement to the cities and weather. However, Pakistan's unique problems and the transformation of electricity shortage and crisis are due to theft, abuse and excessive usage of electricity in the industrial sectors and home, unreasonably causing huge line losses, corruption, mismanagement, institutional weakness, and political controversy [1]. In 2011, the population growth ration in Pakistan was 176.17 million as it was 79.98 million in 1980, and due to growing population demand is increasing which creates directly effect on the electricity escalation [2].

The South Asian Region (SAR) faces several deficiencies that cause the national system of electricity for a particular time. The electricity supply has not kept stride with growth and demand, resulting in long-term downtime and frequent unplanned outages. These conditions have created difficulties for families and industries and have hampered new investment in the business of any economy [3]. Pakistan has a population of about 184 million people and the rural population is high which is connected with agriculture. The agricultural sector has contributed about 25% to the GDP and provides employment more than 40% to the labor force [4]. The installed power generation in 2011 was 21036 megawatts. The demand of electricity is increasing about 9% a year, while the supply

is only about 7%, and the summer gap is even larger [5,6]. Electricity generation sources in the Pakistan include thermal energy (natural gas and oil), nuclear power and hydropower. Renewable energy and coal are currently playing a secondary role, but having hoped to boost significantly in the coming decades [7]. The identified energy renewable resources are primarily solar energy, wind energy and biomass. Hydropower, thermal and nuclear power plants are the hybrid industry in Pakistan. About 31% of electricity is produced by hydropower systems, 66.8% from thermal systems, and the remaining 2.2% from the nuclear power, and the country imports 29.4% of natural gas, 37.8% of oil, 29.4% of hydropower, and 0.26% of natural gas to meet its energy needs. Coal and nuclear power have limited contributions to their energy supply, at 0.1% and 3.02% respectively [8].

Currently, in Pakistan, energy demand is an average of 17000 megawatts while shortage is around 4000–5000 megawatts. In the next coming years energy demand will increase further and about approximately near 500 megawatts in the next ten years [9]. The electricity shortage reached 5500 megawatts in 2015, and the supply was 15500 megawatts with 23000 megawatts of installed capacity. The demand will rise in different sectors including construction, agriculture, education, manufacturing, and most importantly in the sustainable development to boost economic sector [10]. During the period of 2014-15, the total electricity generation was 109059 GWh, which nearly two-thirds came from the thermal sources [11]. The electricity demand in the Pakistan is driven by several issues such as rapidly growing population, electricity prices, economic expansion, urban resident flows and weather. However, the major specific problems in the country are the crisis that caused electricity shortages were caused by theft and excessive use of electricity in domestic and industrial sectors, resulting in huge loss of power lines, mismanagement and political controversy in mega-power projects [12]. Pakistan has energy shortage due to production and supply. This study major objective was to explore and investigate the relationships among economic growth, electricity access to rural population, electricity access to urban population, electricity access to total population, rural and urban population growth, total population growth and energy usage in Pakistan. Time span data was used in this study and was collected from the World Development Indicators (WDI). We employed the ADF and P-P unit root tests to check the variables stationarity. Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration with analysis of long-run and short-run was used to check the dynamics causality among the study variables. Besides the introduction section the remaining paper is organized as: Section 2 provides the existing literature regarding electricity production. Section 3 is materials and methods section which shows the data sources and model specification. Section 4 represents the empirical estimation strategy, and Section 5 is the results and discussion section regarding results of the unit root tests, results of the cointegration test, covariance test results, long-run and short-run results. Section 6 is conclusion and policy recommendation.

2. Existing Literature

The energy sector of any country has vital role for the economic growth and development. Energy shortage in the Pakistan has hampered the country into severe crisis form last several decades. Electricity sector got huge attention due to rapid growth in the demand. Similarly, other factors including inadequate supply of water, water pollution, air pollution, and pasture degradation are chief challenges that country is facing [13]. Electricity form of energy is playing important role to boosting the economic growth of a country including all sectors. Life quality and social life well-being can improve with severe production of sustainable electricity [14]. The total installed electricity capacity was 24823 megawatts in 2015, with a maximum demand of 26437 megawatts [15]. In response to this severe power shortage, the long-term debates regarding energy production and participation in energy summits to discover panacea to compensate for the shortage of electricity. Numerous conceivable regenerative and renewable electricity production sources are presently being deliberated, with suggesting a short-term, medium-term and long-term solution to this trouble [16].

Supply of electricity in the rural communities contributes to economic growth, leading to improvements in agriculture, education, health, gender equality and sustainable development [17,18]. Outdated equipment, Unsatisfactory installed capacity, inability to transmission systems and

deprived monetary administration are the main reasons for the letdown of electricity sector in Pakistan [19,20]. The shortage is due to the lack of political instability and large investment which has hindered the projects of hydropower or coal, thereby increasing need on imported expensive fuels and plummeting the local natural gas [21]. The country's growing population, industrialization and average household income have contributed to the growth in electricity demand [22]. Social and economic progress depends on energy flow. Currently, country is producing insufficient energy and facing crisis. Despite renewable energy sources, still traditional energy generation methods are using in the Pakistan. In the present period, energy efficiency has amplified, but energy generation systems have not been updated to meet energy needs [23,24]. The electricity deficit in 2013 was 6000 megawatts (MW), which is less than 4000 to 5000 megawatts per year, and gross domestic product decline to 3–4% due to crisis of energy. The crisis has seriously affected the economy of Pakistan due to industry closures [25,26].

Electricity is an important infrastructure for a country's socio-economic development, and it has a robust correlation among consumption of electricity and economic growth [27], but growth in the electricity is hugely sensitive to local differences and domestic income levels [28]. The traditional electricity generation systems typically rely on a large number of power generation equipment. Regarding the huge size, it would be placed in the suitable geographic location. The generated electricity will be delivered to the grid station with heavy duty transmission lines and then from grid station to the users. These sources belong to renewable sources including solar, hydro, and wind [29].

In the agricultural and industrial products Pakistan having good rank in the world due to production, but energy problems are still existing in the country due to lack of government sufficient measures. However, major cause is related to government management measures, and Pakistan is facing a severe energy crisis due to geopolitical uproar and also lack of interest [30-32]. In order to gain adequate, inexpensive and environmentally friendly energy, necessary steps should be adopted to produce alternatives mixture and existing renewables sources of energy. Many authors suggest that developing countries and developed countries use renewable energy as an alternative and sustainable energy and conventional energy [33-42]. Pakistan belongs to South Asia and most of the population living in rural areas is not linked to the power grid. The key part of rural grid electrification does not exist. The reason is that some rural areas have complex geography, moderately low electricity demand, and huge cost of long delivery systems. Furthermore, there is a daily shortage of electricity in rural areas connected to the grid, mainly through the summertime. The electricity access to population, electricity access to rural population, electricity access to urban population, energy usage, population growth, rural and urban population growth from 1980–2016 is illustrated in Figures 1-8.
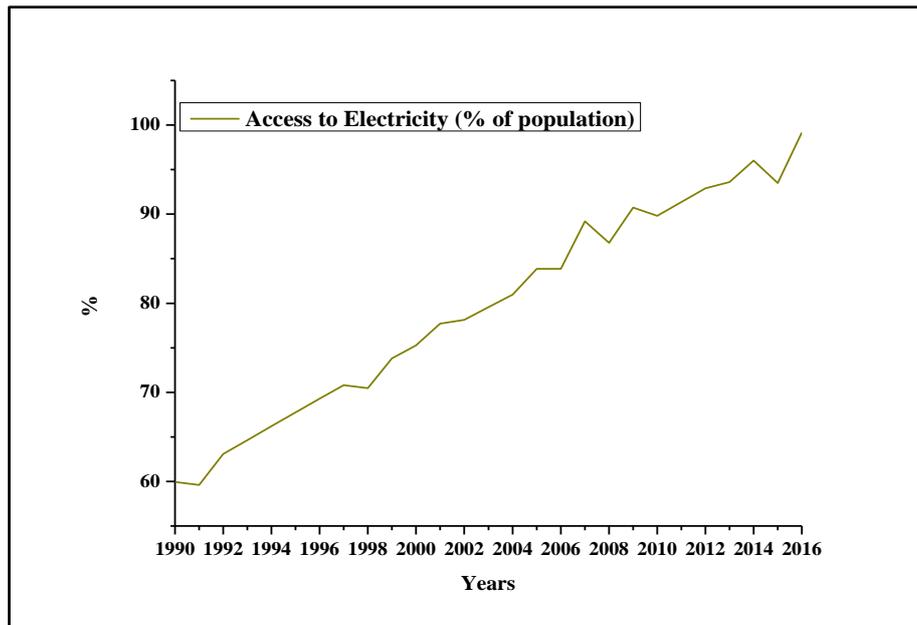
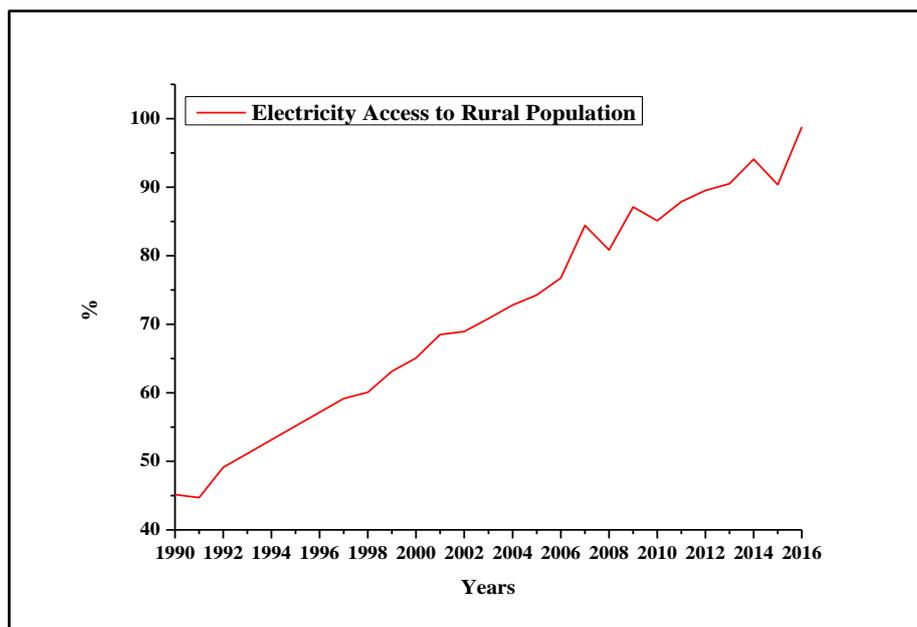Figure 1. Access to Electricity % of Population.

Figure 2. Electricity Access to Rural Population.
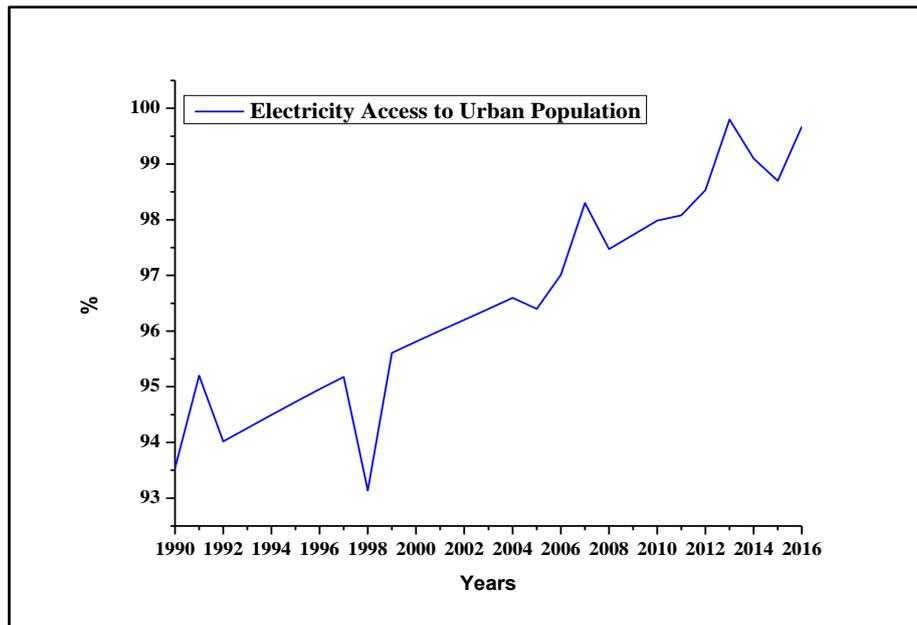
Figure 3. Electricity Access to Urban Population.
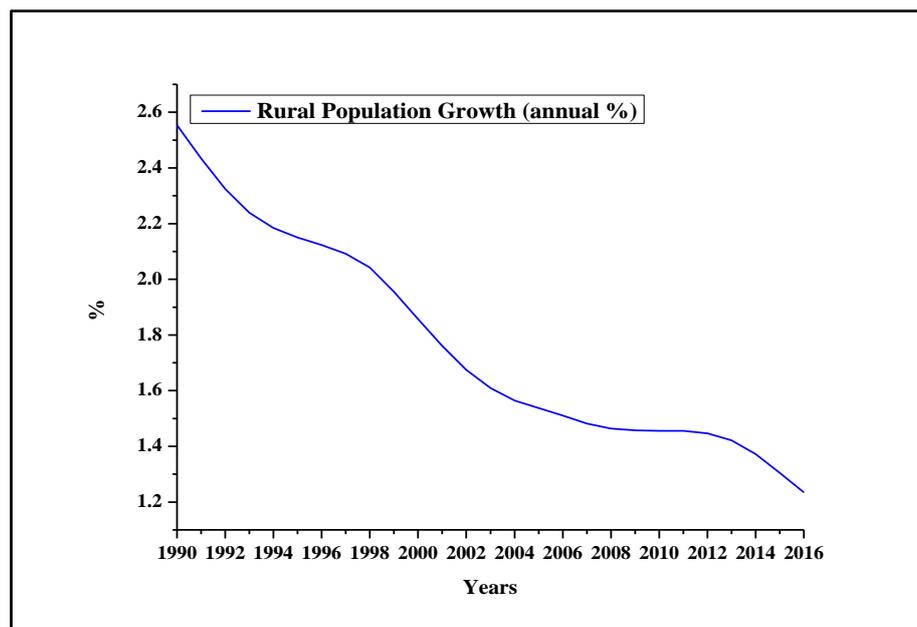
Figure 4. Rural Population Growth in Pakistan.
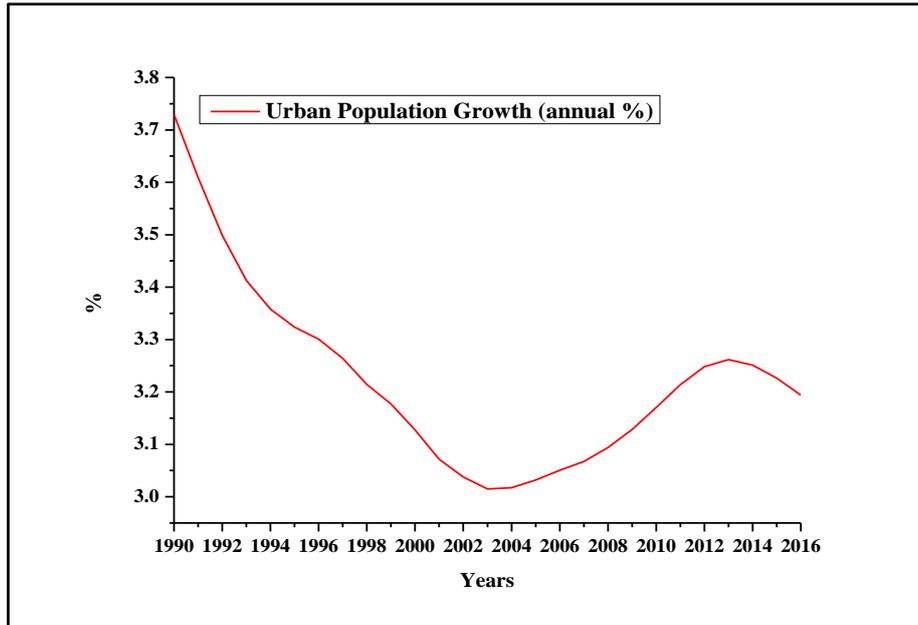
Figure 5. Urban Population Growth in Pakistan.
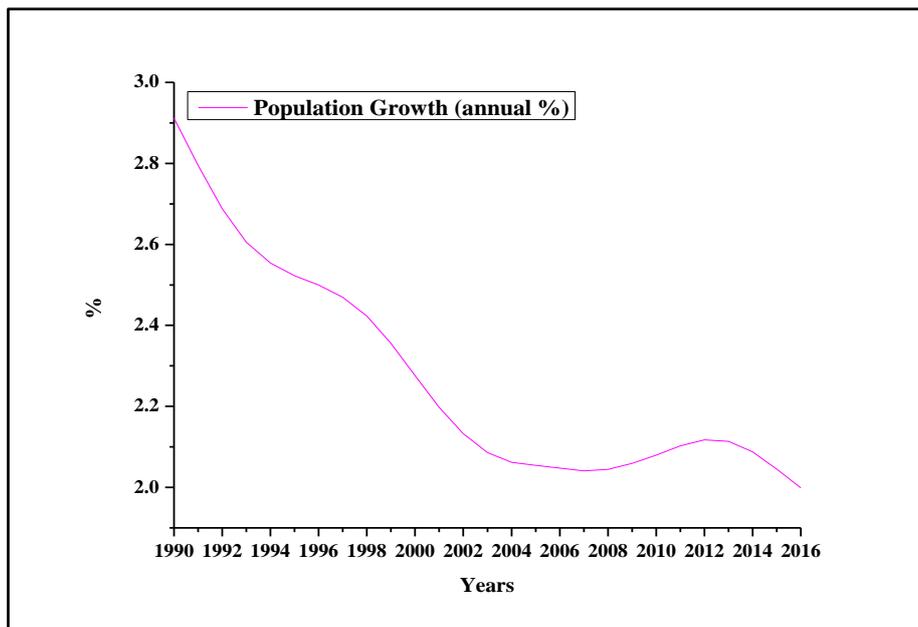
Figure 6. Population Growth in Pakistan.
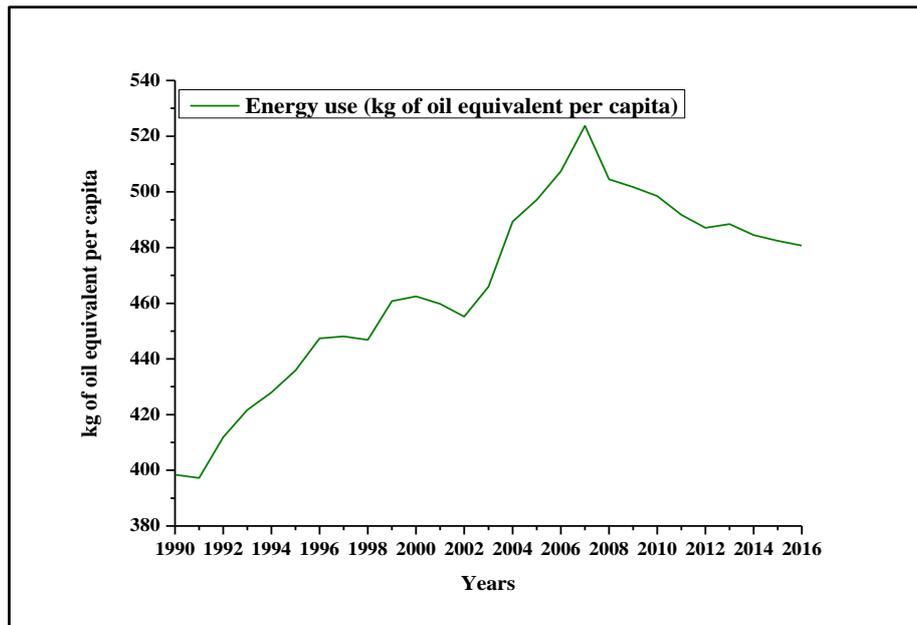
Figure 7. Energy Use in Pakistan (Kg of oil equivalent per capita).
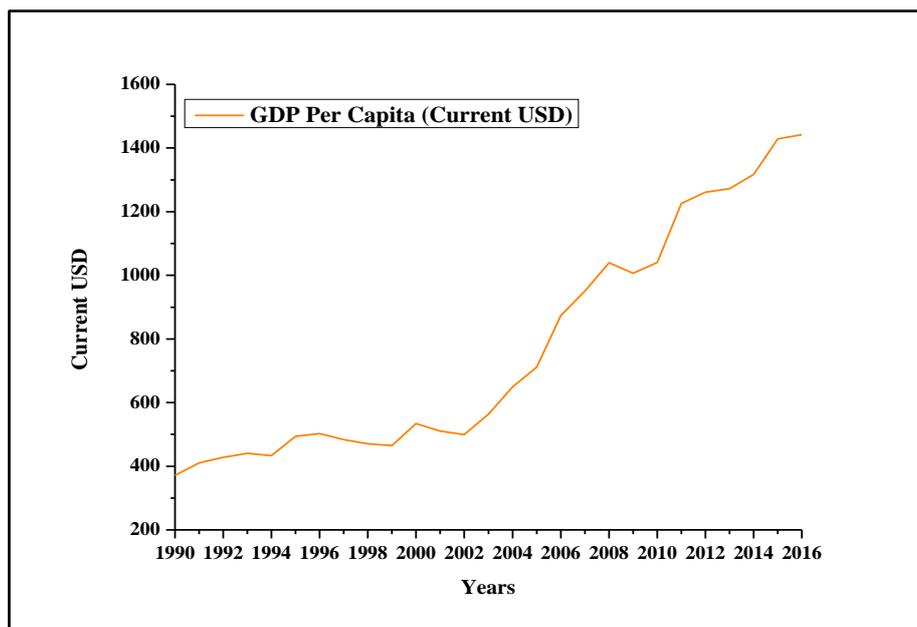
Figure 8. GDP Per Capita of Pakistan.

Figures 1-8 represents the electricity access to population, electricity access to rural population, electricity access to urban population, energy usage, population growth, rural and urban population growth.

3. Materials and Methods

3.1. Data source

Time span data from 1980-2016 was used in this study which is collected from the WDI (World Development Indicators). Below table represents the variables used in this study:

Table 1. Variables Description and Data Sources

Variables	Explanation	Data Sources
GDPPC	Gross Domestic Product Per Capita	WDI
AEP	Electricity Access to Population	WDI
AERP	Electricity Access to Rural Population	WDI
AEUP	Electricity Access to Urban Population	WDI
EN	Energy Use	WDI
PG	Population Growth	WDI
RPG	Rural Population Growth	WDI
UPG	Urban Population Growth	WDI

Note: the units of the variables are in USD and %

3.2. Model Specification

To check the association among dependent and independent variables, the model follows the Fatai (2014) [43] specification to adopt the regression procedure. The multivariate regression model specification is as follows in its implicit forms as;

$$GDPPC_t = f(AEP_t, AERP_t, AEUP_t, EN_t, PG_t, RPG_t, UPG_t) \tag{1}$$

In the equation 1, $GDPPC_t$ indicates the gross domestic product per capita, AEP_t represents the electricity access to the population, $AERP_t$ indicates the access of electricity to rural population, $AEUP_t$ represents the access of electricity to urban population, EN_t indicates the energy use, PG_t show the population growth in Pakistan, RPG_t represent the rural population growth and UPG_t indicates the urban population growth.

$$GDPPC_t = \Psi_0 + \Psi_1 AEP_t + \Psi_2 AERP_t + \Psi_3 AEUP_t + \Psi_4 EN_t + \Psi_5 PG_t + \Psi_6 RPG_t + \Psi_7 UPG_t + \mu t \tag{2}$$

By using natural logarithm to equation 2, a log-linear model is as follows:

$$lnGDPPC_t = \Psi_0 + \Psi_1 lnAEP_t + \Psi_2 lnAERP_t + \Psi_3 lnAEUP_t + \Psi_4 lnEN_t + \Psi_5 lnPG_t + \Psi_6 lnRPG_t + \Psi_7 lnUPG_t + \mu t \tag{3}$$

Equation 3 is the log-linear form of the variables. $lnGDPPC_t$ show the natural logarithm of gross domestic product per capita, $lnAEP_t$ show the natural logarithm of access of electricity to population, $lnAERP_t$ show the natural logarithm of access of electricity to rural population, $lnAEUP_t$ show the natural logarithm of access of electricity to urban population, $lnEN_t$ show the natural logarithm of energy use in Pakistan, $lnPG_t$ show the natural logarithm of population growth in Pakistan, $lnRPG_t$ show the natural logarithm of rural population growth, $lnUPG_t$ show the natural logarithm of urban population growth, t is the time dimension, μt is the error term, and the coefficients of the model Ψ_1 to Ψ_7 represent the elasticity of the long-run.

4. Empirical Estimation Strategy

4.1. Unit root test for stationarity

Despite the fact that the Autoregressive Distributed Lag (ARDL) model requires no pre-testing for inspection of variables stationarity through the unit root test. The ADF (Augmented Dickey-Fuller) (1979) [44] unit root tests and Phillips-Perron (1988) [45] unit root test with trend and intercept was used to determine that none of the variables considered were integrated to order 2. Because ARDL bounds testing approach is invalidated in cases where *I(2)* variables are used. Therefore the unit root test was performed using equation 3.

$$\Delta Z_t = \alpha_\circ + \beta_\circ T + \beta_1 Z_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Z_{t-1} + \mu_t \tag{4}$$

Where, Z indicates the variables being tested for the unit root, T represents a linear trend, Δ indicates the first difference, t shows the time, μt is the error term and m represents to achieve white noise residuals.

4.2. Co-integration with ARDL Model

Pesaran and Shin (1998) [46] developed the ARDL bounds testing approach to check the analysis of long-run and short-run relationships, and further protracted by Pesaran et al., (2001) [47], and Narayan et al., (2004) [48]. The co-integration testing approach (Johansen & Juselius, 1990) [49] is applicable regardless of the integration order with concerned variables, *I(0)* and or *I(1)*, except for the occurrence of *I(2)*. The long-run and short-run relations examined the ARDL representation of the unrestricted error correction model (UECM) of equation (2) as depicted in equation (5):

$$\begin{aligned}
\Delta lnGDPPC_t = \gamma_0 &+ \sum_{i=1}^{p} \gamma_{1i}\Delta lnGDPPC_{t-i} + \sum_{i=1}^{q^1} \gamma_{2i}\Delta lnAEP_{t-i} + \sum_{i=1}^{q^2} \gamma_{3i}\Delta lnAERP_{t-i} + \sum_{i=1}^{q^3} \gamma_{4i}\Delta lnAEUP_{t-i} \\
&+ \sum_{i=1}^{q^4} \gamma_{5i}\Delta lnEN_{t-i} + \sum_{i=1}^{q^5} \gamma_{6i}\Delta lnPG_{t-i} + \sum_{i=1}^{q^6} \gamma_{7i}\Delta lnRPG_{t-i} + \sum_{i=1}^{q^7} \gamma_{8i}\Delta lnUPG_{t-i} \\
&+ \Psi_1 lnGDPPC_{t-1} + \Psi_2 lnAEP_{t-1} + \Psi_3 lnAERP_{t-1} + \Psi_4 lnAEUP_{t-1} + \Psi_5 lnEN_{t-1} \\
&+ \Psi_6 lnPG_{t-1} + \Psi_7 lnRPG_{t-1} + \Psi_8 lnUPG_{t-1} + \varepsilon_t \tag{5}
\end{aligned}$$

Where, Δ indicates the difference operator, Ψ indicates the coefficients of long-run, while γ imprisonments the coefficients of short-run. The long-run co-movement among the variables of interest is ascertained on the basis of the estimated F-Statistic. Pesaran et al., (2001) constitutes two values available for the test of co-integration: (1) critical values of lower bound; where the variables are integrated of order zero *I(0)*, and (2) critical values of upper bound; where the variables are integrated of order one *I(1)*. The hypothesis of no presence of long-run association is excluded if F-Statistic estimation exceeds the critical values on upper bound. Eventually, this empirical study investigates the long-run elasticity and short-run adjustment parameters in equation 5.

5. Results and Discussions

5.1. Descriptive Statistics and Unit root tests results

Descriptive statistics results are interpreted in the Table 2, and Table 3 reports the results of Augmented Dickey-Fuller (ADF) unit root test and Phillips-Perron unit root test with intercept and then both intercept and trend.

Table 2. Descriptive Statistics Results

	LNAEP	LNAERP	LNAEUP	LNEN	LNGDPPC	LNPG	LNRPG	LNUPG
Mean	4.365296	4.239864	4.569133	6.141095	6.545188	0.814812	0.547510	1.169750
Median	4.376478	4.260662	4.568481	6.144151	6.334335	0.750127	0.475891	1.167486
Maximum	4.596608	4.593175	4.603168	6.261040	7.273985	1.068754	0.937553	1.316260
Minimum	4.087656	3.799974	4.534104	5.984615	5.917744	0.692428	0.210858	1.103620
Std. Dev.	0.153397	0.237229	0.019615	0.075199	0.457467	0.112720	0.210950	0.053922
Skewness	-0.282027	-0.320701	0.047087	-0.577720	0.327005	0.785219	0.306283	0.998951
Kurtosis	1.862932	1.929109	1.983000	2.437031	1.515710	2.265997	1.762606	3.669353
Jarque-Bera	1.812466	1.752979	1.173551	1.858474	2.959701	3.380662	2.144680	4.994605
Probability	0.404043	0.416242	0.556118	0.394855	0.227672	0.184458	0.342207	0.082307
Sum	117.8630	114.4763	123.3666	165.8096	176.7201	21.99992	14.78277	31.58326
Sum Sq. Dev.	0.611795	1.463224	0.010004	0.147029	5.441181	0.330349	1.156992	0.075597
Observations	27	27	27	27	27	27	27	27

Table 3. ADF and P-P unit root test Results

ADF Unit root Test				
Variables	**At level**		**First difference**	
	t-Statistic	**Critical values**	**t-Statistic**	**Critical values**
LnAEP	-1.272365 (0.8715)	1% -4.374307 5% -3.603202 10%-3.238054	-13.17405 (0.0000)	1% -4.374307 5% -3.603202 10% -3.238054
LnAERP	-1.664904 (0.7366)	1% -4.374307 5% -3.603202 10%-3.238054	-11.97595 (0.0000)	1% -4.374307 5% -3.603202 10% -3.238054
LnAEUP	-4.350711 (0.0105)	1% -4.374307 5% -3.603202 10%-3.238054	-5.926737 (0.0003)	1% -4.394309 5% -3.612199 10% -3.243079
LnEN	-0.673060 (0.9647)	1% -4.356068 5% -3.595026 10%-3.233456	-4.635827 (0.0056)	1% -4.374307 5% -3.603202 10% -3.238054
LnGDPPC	-1.575934 (0.7747)	1% -4.356068 5% -3.595026 10%-3.233456	-4.340708 (0.0108)	1% -4.374307 5% -3.603202 10% -3.238054
LnPG	-1.607271 (0.7583)	1% -4.416345 5% -3.622033 10%-3.248592	-3.544057 (0.0630)	1% -4.532598 5% -3.673616 10% -3.277364
LnRPG	-1.232135 (0.8803)	1% -4.394309 5% -3.612199 10%-3.243079	-4.406125 (0.0097)	1% -4.394309 5% -3.612199 10% -3.243079
LnUPG	-2.216098 (0.4609)	1% -4.374307 5% -3.603202 10%-3.238054	-4.502952 (0.0147)	1% -2.664853 5% -1.955681 10% -1.608793
Phillips-Perron Unit root Test				
Variables	**At level**		**First difference**	
	t-Statistic	**Critical values**	**t-Statistic**	**Critical values**
LnAEP	-2.945287 (0.1656)	1% -4.356068 5% -3.595026 10%-3.233456	-16.37533 (0.0000)	1% -4.374307 5% -3.603202 10% -3.238054
LnAERP	-2.602248 (0.2822)	1% -4.356068 5% -3.595026 10%-3.233456	-13.37829 (0.0000)	1% -4.374307 5% -3.603202 10% -3.238054
LnAEUP	-4.972231 (0.0025)	1% -4.356068 5% -3.595026 10%-3.233456	-21.59359 (0.0000)	1% -4.374307 5% -3.603202 10% -3.238054
LnEN	-0.744445 (0.9583)	1% -4.356068 5% -3.595026 10%-3.233456	-4.634863 (0.0056)	1% -4.374307 5% -3.603202 10% -3.238054

LnGDPPC	-1.575934 (0.7747)	1% -4.356068 5% -3.595026 10%-3.233456	-4.318162 (0.0113)	1% -4.374307 5% -3.603202 10% -3.238054
LnPG	-1.703555 (0.7206)	1% -4.356068 5% -3.595026 10%-3.233456	-3.745637 (0.0567)	1% -4.356068 5% -3.595026 10% -3.233456
LnRPG	-1.851566 (0.6501)	1% -4.356068 5% -3.595026 10%-3.233456	-3.908624 (0.0232)	1% -4.356068 5% -3.595026 10% -3.233456
LnUPG	-2.422004 (0.3606)	1% -4.356068 5% -3.595026 10%-3.233456	-4.281174 (0.0245)	1% -4.356068 5% -3.595026 10% -3.233456

ADF unit root test results and P-P unit root test results indicated that none of the variables was integrated with the order of I(2) and then ARDL model employed.

5.2. Co-integration Test

Co-integration test was used when F or W statistic applies upper bound of the selected significant level. It is worth noting that the F test assumes that there is no cointegration null hypothesis between variables. Cointegration results are illustrated in the Table 4.

Table 4. ARDL Bounds Test for Co-integration Results

ARDL Bounds Test for Co-integration Results				
F-Statistic	**Significance level**	**Lower Bound**	**Upper Bound**	**Decision**
5.355108	10%	2.03	3.13	Co-integrated
	5%	2.32	3.5	
	1%	2.96	4.26	

The bounds tests shown in the table summarize the existence of a cointegration connection among dependent and independent variables at 1%, 5% and 10% significance level. Furthermore the results of the Johansen co-integration test results are interpreted in the Table 5 with trace statistics and maximum eigenvalue.

Table 5. Results of the Johansen Co-integration test using Trace Statistic and Maximum Eigenvalue

Trace Statistic				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.993717	396.7264	143.6691	0.0000
At most 1 *	0.976870	269.9806	111.7805	0.0000
At most 2 *	0.944234	175.8151	83.93712	0.0000
At most 3 *	0.816141	103.6505	60.06141	0.0000
At most 4 *	0.738330	61.31087	40.17493	0.0001
At most 5 *	0.562836	27.79407	24.27596	0.0173
At most 6	0.247014	7.107881	12.32090	0.3145
At most 7	0.000607	0.015170	4.129906	0.9198
Maximum Eigenvalue Statistic				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.993717	126.7458	48.87720	0.0000
At most 1 *	0.976870	94.16546	42.77219	0.0000
At most 2 *	0.944234	72.16461	36.63019	0.0000
At most 3 *	0.816141	42.33964	30.43961	0.0011
At most 4 *	0.738330	33.51680	24.15921	0.0020
At most 5 *	0.562836	20.68619	17.79730	0.0179
At most 6	0.247014	7.092710	11.22480	0.2415
At most 7	0.000607	0.015170	4.129906	0.9198

*denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values*

5.3. Covariance Analysis

Covariance analysis results are stated in the Table 6, with having correlation among the dependent and independent variables.

Table 6. Covariance Analysis

Covariance Analysis								
Correlation t-Statistic Probability	LNAEP	LNAERP	LNAEUP	LNEN	LNGDPPC	LNPG	LNRPG	LNUPG
LNAEP	1.000000 ----- -----							
LNAERP	0.999281 131.7393 0.0000	1.000000 ----- -----						
LNAEUP	0.936264 13.32578 0.0000	0.929619 12.61276 0.0000	1.000000 ----- -----					
LNEN	0.904002 10.57240 0.0000	0.905637 10.67830 0.0000	0.785678 6.350089 0.0000	1.000000 ----- -----				
LNGDPPC	0.941761 14.00252 0.0000	0.937864 13.51378 0.0000	0.940450 13.83296 0.0000	0.795398 6.561742 0.0000	1.000000 ----- -----			
LNPG	-0.937006 -13.41213 0.0000	-0.937992 -13.52913 0.0000	-0.827342 -7.364636 0.0000	-0.943436 -14.22752 0.0000	-0.799793 -6.661881 0.0000	1.000000 ----- -----		
LNRPG	-0.986975 -30.67562 0.0000	-0.985057 -28.59753 0.0000	-0.924430 -12.12042 0.0000	-0.901346 -10.40576 0.0000	-0.922226 -11.92582 0.0000	0.962849 17.82778 0.0000	1.000000 ----- -----	
LNUPG	-0.636745 -4.128946 0.0004	-0.644678 -4.216589 0.0003	-0.450613 -2.523822 0.0183	-0.802680 -6.729276 0.0000	-0.382482 -2.069792 0.0490	0.849337 8.045222 0.0000	0.679004 4.624523 0.0001	1.000000 ----- -----

5.4. Long-run Analysis Results

Long-run analysis results are interpreted in Table 7.

Table 7. Long-Run Analysis

ARDL Cointegrating And long-run Form				
Cointegrating Form				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LNAEP)	-1.828790	1.992169	-0.917989	0.3783
D(LNAERP)	1.179909	1.159803	1.017336	0.3308
D(LNAEUP)	0.184181	1.907163	0.096573	0.9248
D(LNEN)	1.549670	0.727377	2.130490	0.0565
D(LNPG)	6.825561	3.067669	2.224999	0.0479
D(LNRPG)	-6.964634	3.127366	-2.226997	0.0478
D(LNUPG)	10.114401	6.157831	1.642527	0.1287
CointEq(-1)	-1.031504	0.233261	-4.422112	0.0010
Long-Run Coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LNAEP	1.310100	3.291778	0.397992	0.6983
LNAERP	-0.891821	1.868824	-0.477210	0.6426
LNAEUP	3.079896	2.910661	1.058143	0.3127
LNEN	2.288282	0.548249	4.173804	0.0016
LNPG	6.617094	2.840778	2.329324	0.0399
LNRPG	-3.988076	1.257097	-3.172450	0.0089
LNUPG	0.308340	2.151163	0.143336	0.8886
C	-27.082991	11.476944	-2.359774	0.0378

Focusing on the elasticity of the variables in the long-run analysis, results revealed that access of electricity to the population of Pakistan has positive and significant impact with economic growth having coefficient of 1.310100 with p-value 0.6983. Similarly the coefficients of the electricity access to urban population, energy usage, population growth, and urban population growth had a positive and significant impact with economic growth. The coefficients of the electricity access to urban population, energy usage, population growth, and urban population growth are 3.079896, 2.288282, 6.617094 and 0.308340 with their p-values 0.3127, 0.0016, 0.0399 and 0.8886 respectively. While the results of the electricity access to rural population and rural population growth has a negative impact on the economic growth having coefficients -0.891821 and -3.988076 with p-values 0.6426 and 0.0089. The negative impact regarding electricity access to rural population caused the reason due to insufficient electricity production in the country and its supply to the rural population of the country. The supply and demand of the energy having huge gap regarding flared with the passage of time, country has limited sources to produce electricity from liable sources including solar, natural gas, wind energy, hydropower and nuclear. The urban areas in the country are facing abundant load shedding while in the rural areas facing more load shedding as compare to urban areas [50,51].

5.5. Short-run Analysis Results

Table 8 depicted the short-run analysis results. Among the connection of variables, cointegration presence requires an error correction model (ECM) to imprisonment the dynamics of the short-run relation with its coefficient, which measures the adjustment speed.

Table 8. Short-Run Analysis

Short-Run Analysis				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
LNGDPPC(-1)	-0.031504	0.233261	-0.135061	0.8950
LNAEP	-1.828790	1.992169	-0.917989	0.3783
LNAEP(-1)	3.180164	2.076449	1.531540	0.1539
LNAERP	1.179909	1.159803	1.017336	0.3308
LNAERP(-1)	-2.099826	1.266322	-1.658209	0.1255
LNAEUP	0.184181	1.907163	0.096573	0.9248
LNAEUP(-1)	2.992745	1.832034	1.633564	0.1306
LNEN	1.549670	0.727377	2.130490	0.0565
LNEN(-1)	0.810703	0.732127	1.107325	0.2918
LNPG	6.825561	3.067669	2.224999	0.0479
LNRPG	-6.964634	3.127366	-2.226997	0.0478
LNRPG(-1)	2.850917	2.873768	0.992048	0.3425
LNUPG	10.11440	6.157831	1.642527	0.1287
LNUPG(-1)	-9.796348	6.585777	-1.487501	0.1650
C	-27.93622	11.64342	-2.399314	0.0353
R-squared	0.996705	Mean dependent var.		6.569321
Adjusted R-squared	0.992510	S.D. dependent var.		0.448658
S.E. of regression	0.038828	Akaike info criterion		-3.365683
Sum squared resid.	0.016584	Schwarz criterion		-2.639858
Log likelihood	58.75388	Hannan-Quinn criter.		-3.156672
F-statistic	237.6347	Durbin-Watson stat		2.575936
Prob(F-statistic)	0.000000			

The estimated value of the R-squared is 0.996705 in the dynamics of short-run relation, which show about 99% variation in the economic growth was described in the model by the independent variables. The joint significance regarding the independent variables confirmed the F-statistic at level of significance 1%. The value of DW statistic was 2.575, which was not equaled to the standard DW value for resistant of nonappearance of any autocorrelation. While this is great enough to expose the model of any autocorrelation exists.

Diagnostic and stability tests results are presented in table 9.

Table 9. Diagnostic and Stability tests

Diagnostic and Stability tests for China		
Test Statistics (LM version)	**F-statistic**	**Prob.**
Breusch-Godfrey Serial Correlation	2.857881	0.1346
Heteroscedasticity	0.696466	0.5095
CUSUM		Stable
CUSUMSQ		Stable

Table show the Breusch-Godfrey Serial Correlation LM Test, J-B Normality test and Heteroskedasticity Test with their p-values 0.2211, 0.658535 and 0.5349 respectively.

5.5. Structural Stability Test

The stability tests using CUSUM and CUSUM Square point to stable the long-run and short-run constraints. The graph of both CUSUM test and CUSUM Square test are mentioned in the Figures 9-10 which specify that all values lie within critical boundaries at significance level of 5%. It confirms the long-run and short-run parameters stability.
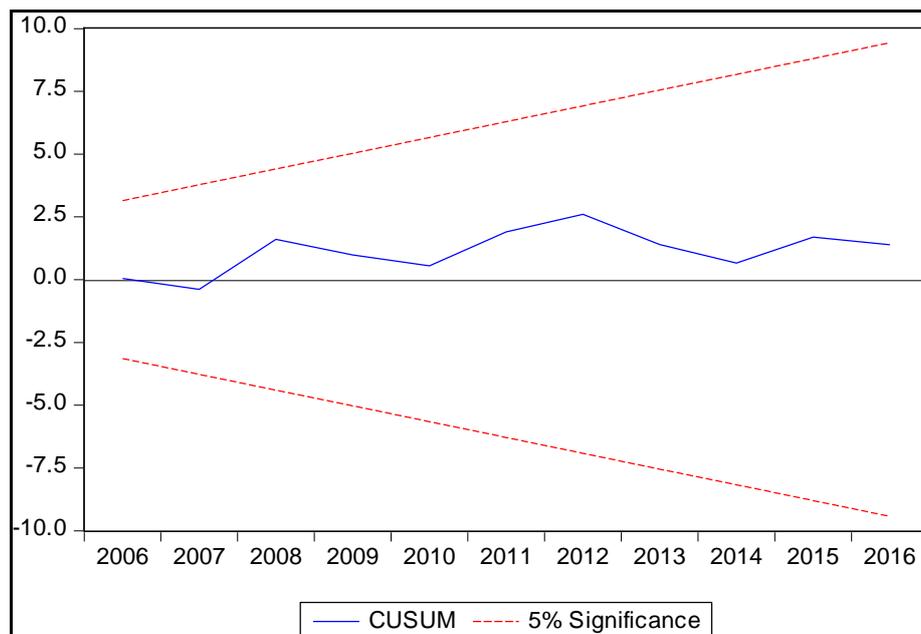
Figure 9. Plot of CUSUM.
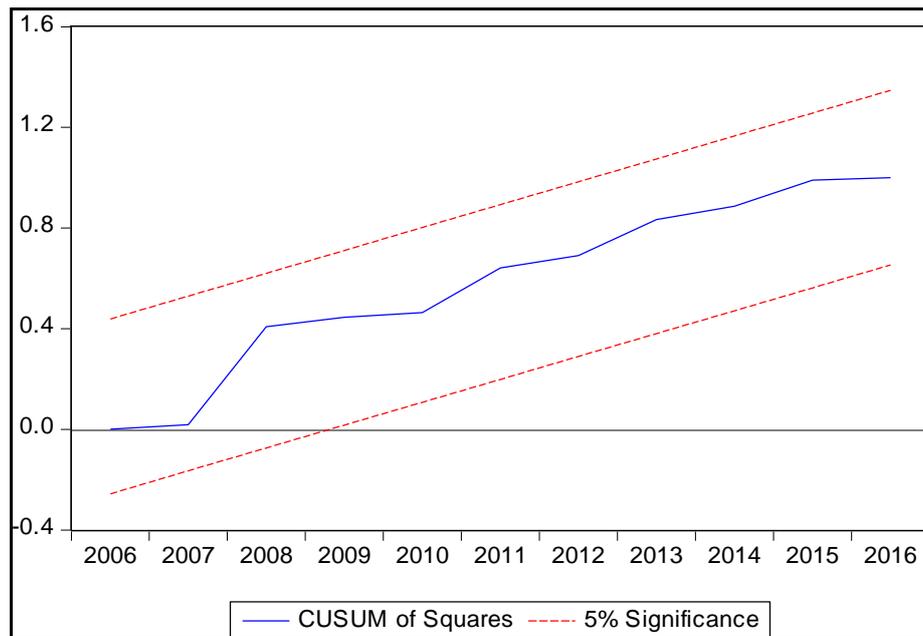
Figure 10. Plot of CUSUM of Square.

6. Conclusion and Recommendation

Pakistan has energy crisis from last few decades due to insufficient production and supply which cause the electricity shortage in the country. The key motive of this study was to explore and investigate the linkage between electricity access, energy usage and population growth and economic growth in the Pakistan. ADF unit root test was used to check the variables stationarity, and ARDL bounds testing approach to co-integration was applied to check the causality relationship among the study variables. The results revealed that access of electricity to the population of Pakistan electricity access to urban population, energy usage, population growth, and urban population growth had a significant impact with economic growth, while the electricity access to rural population and rural population growth has a negative impact on the economic growth. As the population of Pakistan is increasing with the passage of time, more electricity is required to fulfil the country needs. New policies should be implemented regarding to boost the energy sector in the country. Government should also pay attention to alternatives of the energy to produce from natural gas, oil, coal, nuclear power, solar and wind. Natural gas and oil are the dominant source of the energy in the country. Possible initiatives are necessary to produce energy from solar system to supply cheap electricity to the population of the countries. Regarding production from hydropower, necessary steps should be taken to build the new dams in the country to store water, which also important for the agricultural growth. Because in coming few years, Pakistan will also face the water crisis, which will be the big threat to the country. There should be short-term, medium-term and long-term energy production plans from the government to produce cheap energy to fulfill country demands.

References

1. Government of Pakistan, (2014). Pakistan Economic Survey 2013–2014. Ministry of Finance, Finance Division, Economic Adviser's Wing, Islamabad.

2. SESRIC, (2014). The Statistical, Economic and Social Research and Training Centre for Islamic Countries.

3. World Bank, (2014). Doing Business 2014: Understanding Regulations for Small and Medium-Size Enterprises. World Bank, Washington, DC. http://www.doingbusiness.org/reports/global-reports/doing-business-2014.

4. Rehman, A., Jingdong, L., Shahzad, B., Chandio, A. A., Hussain, I., Nabi, G., & Iqbal, M. S. (2015). Economic perspectives of major field crops of Pakistan: An empirical study. Pacific Science Review B: Humanities and Social Sciences, 1(3), 145-158. https://doi.org/10.1016/j.psrb.2016.09.002

5. Government of Pakistan, (2011). Pakistan Economic Survey 2010–2011. Ministry of Finance, Finance Division, Economic Adviser's Wing, Islamabad.

6. Pakistan Energy Yearbook, (2012). Hydrocarbon Development Institute of Pakistan, Ministry of Petroleum and Natural Resources, Government of Pakistan.

7. Sahir, M. H., & Qureshi, A. H. (2008). Assessment of new and renewable energy resources potential and identification of barriers to their significant utilization in Pakistan. Renewable and Sustainable Energy Reviews, 12(1), 290-298.

8. Government of Pakistan, (2013). National Power Policy Pakistan.

9. KazmiZ, (2014). Pakistan's energy security. Available from:⟨http://tribune.com. pk/tory/655573/pakistans-energy-security⟩

10. Santoyo-Castelazo, E., & Azapagic, A. (2014). Sustainability assessment of energy systems: integrating environmental, economic and social aspects. Journal of Cleaner Production, 80, 119-138.

11. NEPRA (National Electric Power Regulatory Authority) (2015). State of industry report 2015. http://nepra.org.pk/industryreports.htm

12. Government of Pakistan, (2015). National Power Policy Pakistan.

13. Government of Pakistan, (2013). National Power Policy Pakistan

14. Maxim, A. (2014). Sustainability assessment of electricity generation technologies using weighted multi-criteria decision analysis. Energy Policy, 65, 284-297. https://doi.org/10.1016/j.enpol.2013.09.059

15. NEPRA (National Electric Power Regulatory Authority) (2015). State of industry report 2015. http://nepra.org.pk/industryreports.htm

16. Valasai, G. D., Uqaili, M. A., Memon, H. R., Samoo, S. R., Mirjat, N. H., & Harijan, K. (2017). Overcoming electricity crisis in Pakistan: A review of sustainable electricity options. Renewable and Sustainable Energy Reviews, 72, 734-745. https://doi.org/10.1016/j.rser.2017.01.097

17. Danish, M., Naqvi, M., Farooq, U., & Naqvi, S. (2015). Characterization of South Asian agricultural residues for potential utilization in future 'energy mix'. Energy Procedia, 75, 2974-2980. doi: 10.1016/j.egypro.2015.07.604

18. Palit, D., & Bandyopadhyay, K. R. (2016). Rural electricity access in South Asia: Is grid extension the remedy? A critical review. Renewable and Sustainable Energy Reviews, 60, 1505-1515. https://doi.org/10.1016/j.rser.2016.03.034

19. Rauf, O., Wang, S., Yuan, P., & Tan, J. (2015). An overview of energy status and development in Pakistan. Renewable and Sustainable Energy Reviews, 48, 892-931. https://doi.org/10.1016/j.rser.2015.04.012

20. Naseem, I., & Khan, J. (2015). Impact of energy crisis on economic growth of Pakistan. International Journal of African and Asian Studies, 7, 33-43.

21. Aziz, R., & Ahmad, M. B. (2015). Pakistan's power crisis. Special report. United States Institute of Peace. http://www. usip. org/sites/default/files/SR375-Pakistans-Power-Crisis-The-Way-Forward. pdf.

22. Kessides, I. N. (2013). Chaos in power: Pakistan's electricity crisis. Energy policy, 55, 271-285. https://doi.org/10.1016/j.enpol.2012.12.005

23. Raza, W., Hammad, S., Shams, U., Maryam, A., Mahmood, S., & Nadeem, R. (2015). Renewable energy resources current status and barriers in their adaptation for Pakistan. J Bioprocess Chem Eng, 3(3), 1-9.

24. Nisar, J., Razaq, R., Farooq, M., Iqbal, M., Khan, R.A., Sayed, M., Shah, A. & ur Rahman, I. (2017). Enhanced biodiesel production from Jatropha oil using calcined waste animal bones as catalyst. Renewable Energy, 101, 111-119. https://doi.org/10.1016/j.renene.2016.08.048

25. Government of Pakistan, (2016). Ministry of Finance. ⟨http://www.finance.gov.pk/survey/ chapters_13/14-Energy.pdf⟩

26. Uddin, W., Khan, B., Shaukat, N., Majid, M., Mujtaba, G., Mehmood, A., Ali, S.M., Younas, U., Anwar, M. and Almeshal, A.M., (2016). Biogas potential for electric power generation in Pakistan: A survey. Renewable and Sustainable Energy Reviews, 54, 25-33. https://doi.org/10.1016/j.rser.2015.09.083

27. Kantar, E., & Keskin, M. (2013). The relationships between electricity consumption and GDP in Asian countries, using hierarchical structure methods. Physica A: Statistical Mechanics and its Applications, 392(22), 5678-5684. https://doi.org/10.1016/j.physa.2013.07.029

28. Karanfil, F., & Li, Y. (2015). Electricity consumption and economic growth: exploring panel-specific differences. Energy Policy, 82, 264-277. https://doi.org/10.1016/j.enpol.2014.12.001

29. Guerrero, J.M., Blaabjerg, F., Zhelev, T., Hemmes, K., Monmasson, E., Jemei, S., Comech, M.P., Granadino, R. and Frau, J.I. (2010). Distributed generation: Toward a new energy paradigm. IEEE Industrial Electronics Magazine, 4(1), 52-64.

30. Ali, G., Bashir, M. K., Ali, H., & Bashir, M. H. (2016). Utilization of rice husk and poultry wastes for renewable energy potential in Pakistan: An economic perspective. Renewable and Sustainable Energy Reviews, 61, 25-29. https://doi.org/10.1016/j.rser.2016.03.014

31. Khan, S. A. R., Zaman, K., & Zhang, Y. (2016). The relationship between energy-resource depletion, climate change, health resources and the environmental Kuznets curve: Evidence from the panel of selected developed countries. Renewable and Sustainable Energy Reviews, 62, 468-477. https://doi.org/10.1016/j.rser.2016.04.061

32. Arshad, M., Bano, I., Khan, N., Shahzad, M. I., Younus, M., Abbas, M., & Iqbal, M. (2018). Electricity generation from biogas of poultry waste: An assessment of potential and feasibility in Pakistan. Renewable and Sustainable Energy Reviews, 81, 1241-1246. https://doi.org/10.1016/j.rser.2017.09.007

33. Kumar, A., Holuszko, M., & Espinosa, D. C. R. (2017). E-waste: an overview on generation, collection, legislation and recycling practices. Resources, Conservation and Recycling, 122, 32-42. https://doi.org/10.1016/j.resconrec.2017.01.018

34. Amri, F. (2017). The relationship amongst energy consumption (renewable and non-renewable), and GDP in Algeria. Renewable and Sustainable Energy Reviews, 76, 62-71. https://doi.org/10.1016/j.rser.2017.03.029

35. Chang, Y. C., & Wang, N. (2017). Legal system for the development of marine renewable energy in China. Renewable and Sustainable Energy Reviews, 75, 192-196. https://doi.org/10.1016/j.rser.2016.10.063

36. Kenfack, J., Bossou, O. V., & Tchaptchet, E. (2017). How can we promote renewable energy and energy efficiency in Central Africa? A Cameroon case study. Renewable and Sustainable Energy Reviews, 75, 1217-1224. https://doi.org/10.1016/j.rser.2016.11.108

37. Marques, A. C., Fuinhas, J. A., & Neves, S. A. (2018). Ordinary and Special Regimes of electricity generation in Spain: How they interact with economic activity. Renewable and Sustainable Energy Reviews, 81, 1226-1240. https://doi.org/10.1016/j.rser.2017.09.006

38. Kamran, M. (2018). Current status and future success of renewable energy in Pakistan. Renewable and Sustainable Energy Reviews, 82, 609-617. https://doi.org/10.1016/j.rser.2017.09.049

39. Zameer, H., & Wang, Y. (2018). Energy production system optimization: Evidence from Pakistan. Renewable and Sustainable Energy Reviews, 82, 886-893. https://doi.org/10.1016/j.rser.2017.09.089

40. Qazi, U., & Jahanzaib, M. (2018). An integrated sectoral framework for the development of sustainable power sector in Pakistan. Energy Reports, 4, 376-392. https://doi.org/10.1016/j.egyr.2018.06.001

41. Rehman, A., & Deyuan, Z. (2018). Pakistan's energy scenario: a forecast of commercial energy consumption and supply from different sources through 2030. Energy, Sustainability and Society, 8(1), 26. https://doi.org/10.1186/s13705-018-0167-y

42. Gondal, I. A., Masood, S. A., & Khan, R. (2018). Green hydrogen production potential for developing a hydrogen economy in Pakistan. International Journal of Hydrogen Energy, 43(12), 6011-6039. https://doi.org/10.1016/j.ijhydene.2018.01.113

43. Fatai, B. O. (2014). Energy consumption and economic growth nexus: Panel co-integration and causality tests for Sub-Saharan Africa. Journal of Energy in Southern Africa, 25(4), 93-100.

44. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American statistical association, 74(366a), 427-431. https://doi.org/10.1080/01621459.1979.10482531

45. Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. Biometrika, 75(2), 335-346.

46. Pesaran, M. H., & Shin, Y. (1998). An autoregressive distributed-lag modelling approach to cointegration analysis. Econometric Society Monographs, 31, 371-413.

47. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, 16(3), 289-326. DOI: 10.1002/jae.616

48. Narayan, P.K. (2004). Reformulating critical values for the bounds F-statistics approach to Cointegration: an application to the tourism demand model for Fiji. Monash University, Australia, pp 1–40.

49. Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxford Bulletin of Economics and statistics, 52(2), 169-210.

50. WAPDA, (2016). Water and power development authority. http://www.wapda.gov.pk

51. Rafique, M. M., & Rehman, S. (2017). National energy scenario of Pakistan–Current status, future alternatives, and institutional infrastructure: An overview. Renewable and Sustainable Energy Reviews, 69, 156-167.