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Are Shocks to Energy Consumption in USA Permanent or Temporary? Sectoral Analysis

ABD'nin Enerji Tüketiminde Şoklar Geçici mi Kalici mı Etkiye Sahip? Sektörel Analiz

Abstract

Energy is one of the most important strategic factors for sustainable economic growth. The energy consumption levels of the four main sectors, long-term consumption amounts and the sustainability of this consumption as well as whether these shocks are temporary or permanent play a role in the development of energy policies for countries. In this respect, the purpose of this study is to analyze at the sectoral level whether the shocks in the USA's energy consumption are temporary or permanent. The annual data over the period 1949 – 2014 are analyzed using the RALS LM unit root test method in this study. According to the analyses made, the shocks in energy consumption in the transport sector of the US have got a permanent impact.

Key Words: U.S. Energy Consumption, U.S. Energy Shocks, Sectoral Energy Consumption, RALS LM Unit Root Test

Jel Code: O13, Q47

Özet

Enerji, sürdürülebilir ekonomik büyüme açısından en önemli stratejik faktörlerin başında gelmektedir. Dört ana sektörün enerji tüketimleri, uzun dönem tüketim miktarları ve bu tüketimin sürdürülebilirliği ve şokların geçici mi kalıcı mı olduğu ülke ekonomilerinin enerji politikalarının yapılanmasında rol oynamaktadırlar. Bu çerçevede çalışmanın amacı ABD'nin enerji tüketiminde şokların geçici mi kalıcı mı olduğunu sektörel bazda analiz etmektir. Bu çalışmada 1949 – 2014 dönemine ait yıllık veriler RALS LM birim kök testi ile analiz edilmiştir. Yapılan analiz sonucunda ABD'nin ulaştırma sektörünün enerji tüketimine şokların kalıcı etkiye sahip olduğu görülmüştür.

Anahtar Kelimeler: ABD Enerji Tüketimi, ABD Enerji Şokları, Sektörel Enerji Tüketimi, RALS LM Birim Kök Testi

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Introduction

Energy is one of the most important strategic factors in terms of sustainable economic growth. Developments in the energy sector in the world forces countries to implement comprehensive policies to increase energy production and efficiency.

The US is the largest economy in the world. According to EIA (2014), the US is the second largest energy producer in the world after China. In 2013, the total amount of energy produced in the US accounted for around 13% of the world total. Domestic production in the US was around approximately 85% of total primary energy supply. The US imports 27% of its total energy need. The transport sector in the US is the sector where the energy consumption level is the highest with around 42% followed by the industrial sector with 25%, residential with 18% and commercial sector with 16%.

The analyses made indicate that the energy consumption increases steadily in connection with the economic growth of the US. Investigation of this increase at the sectoral level is important to develop sustainable energy policies.

In this respect, the purpose of this study is to analyze at the sectoral level whether the shocks in energy consumption in the US are temporary or permanent. The energy consumption data by sector obtained from the US Energy Information Administration over the period 1949 – 2012 were used for the US.

There is growing tendency in the energy economics literature to analyze the unit root properties of energy consumption series in order to improve effective energy policies. Unit root tests are used in empirical studies that investigate whether the shocks have got temporary or permanent impact. The unit root tests used frequently in applied studies are based on the basic assumption that data distribution is normal. Considering economic data, it is quite a frequent situation that this assumption is not met. This dilemma causes unit root test results to have a tendency. To overcome this problem, the transformed LM unit root tests with level and trend-shifts proposed by Lee et al. (2012) and the transformed residual augmented least squares (TR RALS) LM test by Meng et al. (2016) were used.

The study introduced two basic contributions to literature. The first one is that it is the first study examining the US at the sectoral level. The second contribution is the methodology used. The RALS LM unit root test offers two basic advantages. Firstly, the RALS LM test does not depend on the nuisance parameter and secondly, the RALS LM test utilizes information on non-normal errors (Mishra and Smyth 2016).

The results of the analysis indicate that the shocks in energy consumption in the transport sector in the US have got a permanent impact.

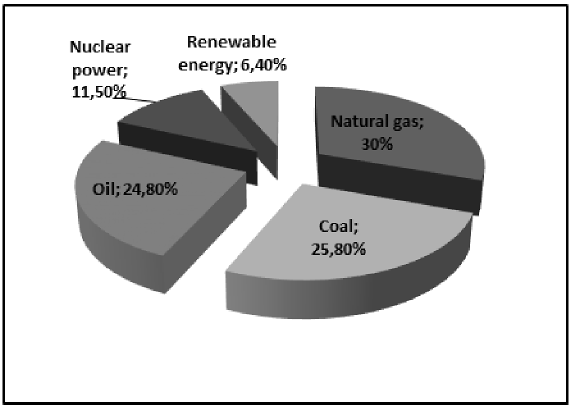
1. USA Energy Outlook

According to BP's Energy Outlook, energy consumption is expected to increase by 34% between 2014 and 2035 due to the growth in world economy and the rise in world population (BP Outlook to 2035).

The US is the world's largest economy. According to the EIA (2014), the US is the second largest energy producer in the world after China. In 2013, the total amount of energy produced in the US was 1,859.3 million tons of oil-equivalent (Mtoe) which represents approximately 13% of the world total. According to BP (2016), the US share of global energy consumption was 17,3% whereas its share in global energy production was 15,6 %.

30% of energy production in the US comes from natural gas, 25,8% from coal, 24,8% from oil, 11,5% from nuclear power and 6,4% from renewable energy. Domestic production accounts for approximately 85% of total primary energy supply (Figure 1). The US is reliant on imports for 27%. The US is a net importer of oil and natural gas and a net exporter in coal. Energy exports constitute around 12% of energy production (EIA, 2014, p. 20-21).

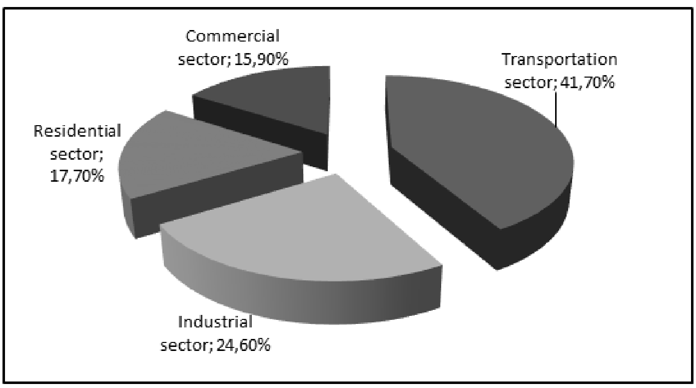
Figure 1: The Distribution of Energy Production in the US According to Resources, 2013



Source: IEA, 2014 Review, p. 21, 113.

The transport sector in the US is the sector with the highest energy consumption of 41,7% followed by the industrial sector with 24,60%, residential sector with 17,70% and commercial sector with 15,90% (Figure 2).

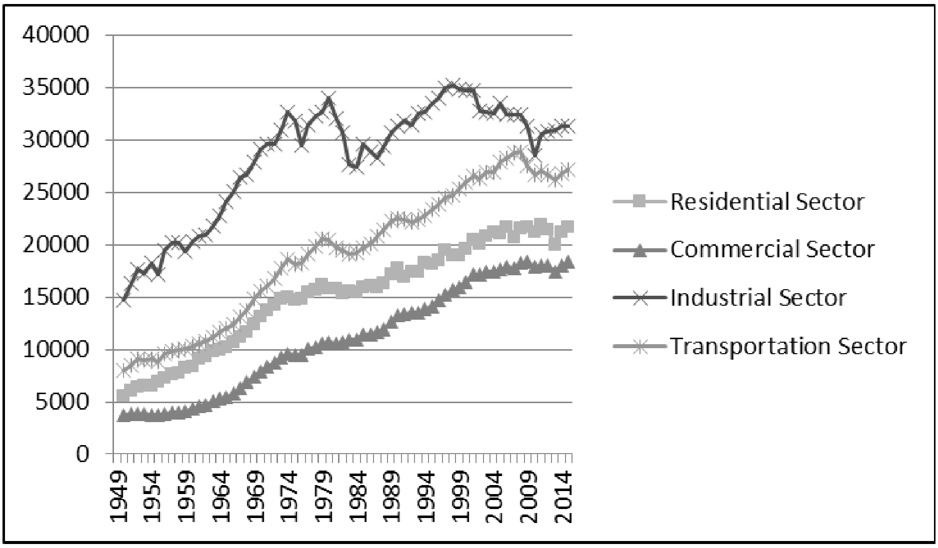
Figure 2: Distribution of the US Energy Demand According to Sectors, 2013



Source: IEA, 2014 Review, p. 22.

The growth path of sectoral energy consumption in the US over the period 1949-2014 can be seen in the figure. The momentum of increase in the industrial sector with the economic crises survived has seen interruptions from time to time. There was a significant decrease in energy consumption in the industrial sector especially after the 2008 crisis. The transport sector, on the other hand, displayed a steadier and faster increase in the examined period (Figure 3).

Figure 3: US Energy Consumption by Sector, 1949-2014, (Trillion Btu)



Source: U.S. Energy Information Administration, 2015.

2. Literature Review

Demand for energy has been increasing due to high level of urbanization and industrialization leading researchers to carry out a new research on new unit root properties of energy consumption in the field of energy economy.

Özcan and Özturk (2016) state that because of the close relationship between energy use and economic growth, the structural breaks in energy markets may cause fluctuations in macroeconomy. For this reason, such tests provide the opportunity to find out whether the shocks seen in energy markets create a permanent or temporary impact. On the other hand, it is important to understand that the time series features of energy consumption has implications for the design of energy policies that aim to achieve specified levels of energy consumption in time. According to Narayan and Smyth (2007), as structural changes in the oil market have got an impact on macroeconomic variables, the stationarity properties of energy consumption have important implications for economy policies. If energy consumption is not stationary, the unit root will be applied to other macroeconomic variables. From an economics point of view, if these macroeconomic series are not stationary, then business cycle theories that describe output fluctuations as temporary deviations from long-term economic growth trends can no longer provide any support from an empirical point of view.

Shahbaz, et. al. (2014) state that several factors motivate to a large extent these empirical analyses on energy consumption stationarity. To start with, if energy consumption is stationary at level, then shocks to energy consumption will have temporary impact in time and the economic policies designed accordingly will have a temporary impact. If energy consumption is stationary, the shocks to energy consumption will be temporary in line with prominent structural changes in energy consumption and the energy consumption demand will go back to its original pace shortly. Moreover, if energy consumption includes a unit root then the shocks to energy consumption will have permanent or long-term impact. If this is the case, then the shocks to energy consumption will have a permanent impact on energy demand. Therefore, fluctuations in energy consumption will have a permanent impact on economic activities carried out and the designed policies will, hence, be more effective.

Introduced by Narayan and Smith (2007), a significant number of studies analyze integration properties of energy consumption and production. Narayan and Smyth (2007) applies univariate and panel data unit root tests to annual panel data for 182 countries over the period 1979-2000 by using ADF and *t*-bar unit root tests. As a result of the ADF univariate test, they found that a unit root in per capita energy consumption was only for 31% of the 182 countries. By applying the panel version of the ADF test, they found that there was no unit root in per capita energy consumption for various panels.

Chen and Lee (2007), one of the first studies in the field, applies a new panel unit root testing procedure developed by Carrion-Silvestre et. al. (2005) to investigate whether shocks to time paths of per capita energy consumption are permanent and/or temporary for seven regional-based panels over the 1971-2002 period. When structural breaks and cross-sectional correlations are added in the model, all regional-based panels of energy consumption per capita are stationary.

Narayan et. al. (2008) examine the unit root properties of crude oil production for 60 countries by using Langrange Multiplier (LM) panel unit root test with structural break over the period 1971-2003. According to the results of the study, crude oil and NGL production are jointly stationary.

Aslan and Kum (2011) aims to investigate the stationarity of energy consumption for Turkish disaggregated data by employing LM univariate tests and Kruse (2010) non-linear unit root tests over the period 1970-2006. According to the results of the study, the hypothesis of linearity for 4 cases in 7 Turkish sectors was rejected.

Kum (2012) examines whether the fluctuations in energy consumption are temporary or permanent for 15 East Asia and Pacific countries by applying the Lagrange Multiplier (LM) panel unit root test with one structural break over the period 1971-2007. According to the results of the analysis carried out by adding structural break to the LM test, there is no unit root in per capita energy consumption for these 15 countries.

In their study covering 115 countries over the period 1980-2008, Lean and Smyth (2013) analyze whether the policies to encourage renewable electricity could have an impact by applying panel unit root and stationary tests to time series data on renewable electricity generation. The conclusion is that considering all of the countries analyzed, for almost three quarters of the individual countries, renewable electricity generation is characterized by a unit root.

Öztürk and Aslan (2014) investigate the stationary properties of per capita electricity consumption by applying a nonlinear unit root test for 23 high-income OECD countries over the period 1960–2005. Using the Lagrange Multiplier and Kruse's (2011) unit root test, they conclude that electricity consumption is a non-stationary process for 12 countries and any shock to electricity consumption is likely to be permanent and energy policies will have a permanent impact.

By applying the Harvey et al. linearity test to determine the type of the unit root tests (the Kruse (2010) nonlinear unit root or LM (Lagrange Multiplier) linear unit root tests) over the period 1971-2010, Shahbaz, et. al. (2014) analyze the panel unit root properties of natural gas energy consumption of 48 countries. The conclusion is that the stationarity of natural gas consumption cannot be rejected for more than 60% of countries.

Tiwari and Albulescu (2016) investigate the stationarity properties of the renewable-to-total electricity consumption ratio for 90 countries by using flexible Fourier stationarity and unit root tests over the period 1980-2011. According to the Fourier ADF test results, the null hypothesis of unit root is rejected for all countries except for the UK.

Gozgor (2016) examines stochastic properties of renewable energy consumption in three large developing economies, namely Brazil, China, and India over the period 1971-2014 by using some of the unit root tests. The results of the study show that renewable energy consumption is a unit root process in Brazil, however stationary in China and India.

Özcan and Öztürk (2016), examine the time series properties of per capita energy consumption for 32 OECD countries over the period 1971-2013 by using the CBL univariate and panel stationary tests extended with a Fourier function. According to the results of the study, 16 OECD countries have nonstationary per capita energy consumption and there is a hysteresis or path dependence in their energy demand. 16 OECD countries, including the US, on the other hand, have stationary per capita energy consumption so the shocks to energy demand will have only temporary impact.

Doğan (2016) investigates the unit root properties of electricity consumption for 12 regions of Turkey across four sectors in addition to total electricity consumption by regions over the period 1995-2013 by implementing Dickey-Fuller and DFGLS unit root test. They find that 48 cases are non-stationary, and 12 cases are stationary.

Fallahi et. al. (2016) examine persistence in energy consumption across 107 countries for the period 1971-2011 by using subsampling confidence interval methods. According to the results of the study, 107 countries are classified under three persistence classes: those whose energy consumption is explosive, those with nonstationary energy consumption and those whose energy consumption is stationary.

Eren (2016) analyzes the stationarity of energy demand for 30 countries over the period 1960-2013 by using Fourier Augmented Dickey Fuller unit root test. The results show that the energy demand is not stationary in 28 countries including the U.S. For this reason, the energy demand management policies of these countries have lasting and long-term impact.

Studies on sectoral energy consumption of countries have been increasing fast in literature. Zhang et. al. (2011) analyzes energy and energy efficiencies in Chinese transport sector over the period 1980- 2009. Hessari (2005) investigates detailed sectoral energy consumption in Iran. Song et. al. (2016) measure the level of sustainable development and energy consumption of highway transport system in regions of China by data envelopment analysis model. Achour and Belloumi (2016) aim to identify the driving factors and measures of energy consumption in Tunisian transport sector by using the LMDI model over the period 1985-2014. Rahman et. al. (2016) investigate the long-run relationship between industrial sectors and energy consumption by using the Toda Yamamoto model over the period 1971-2011. Mishra and Smyth (2016) examine the convergence of energy consumption per capita at the sectoral level in Australia by using the LM and RALS-LM unit root tests over the period 1973-74 to 2013-2014.

3. Data and Econometric Methods

3.1. Data

The data over the period 1949 – 2014 were used in this study investigating whether the shocks in total energy consumption with respect to sectors were temporary or permanent in the US economy. The total energy consumption measured in trillions of Btu was obtained from the Energy Information Administration. All the data available were transformed to natural logarithms before the analysis.

3.2. Econometric Methods

Unit root tests are used in empirical studies that investigate whether shocks have got temporary or permanent impacts. The stationarity obtained as a result of these tests indicate that the shocks are temporary whereas the unit root indicates that the shocks are permanent.

Conventional unit root tests were introduced in the study by Dickey and Fuller (1979). Different unit root tests have been proposed in many studies after this study. The main difference in unit root tests was introduced by Perron (1989). Perron (1989) shows that when existing structural break ignored the conventional unit root tests will be biased towards not rejecting a false null of a unit root.

When the unit root test process is examined, the LM type unit root tests are generally more powerful than the usual DF type tests (Meng et. al. 2013). The LM type unit root tests are based on the following regression;

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + e_t \qquad (1)$$

where $\tilde{S}_t$ denotes $\tilde{S}_t = y_t - \tilde{\psi} - Z_t\tilde{\delta}$, Z_t denotes deterministic terms while Z_t is described as $Z_t = [1, t, D_t]'$ for a level shift and $Z_t = [1, t, D_t, DT_t]'$ for a trend break. Where $D_t = 1$ for $t \geq T_B + 1$ and zero otherwise, $DT_t = t - T_B$ for $t \geq T_B + 1$ and zero otherwise and T_B is break date. This model could be generalized by adding a dummy variable for multiple break. In this case, $Z_t = [1, t, D_{1t}, \dots\dots\dots D_{Rt}, DT_{1t}, \dots\dots\dots DT_{Rt}]'$ where $D_{it} = 1$ for

$t \geq T_{Bi} + 1$ and zero otherwise and $DT_{it} = 1$ for $t \geq T_{Bi} + 1$ and zero otherwise. Test statistics for testing unit root is t statistics for $\phi = 0$. Lee et al. (2012) propose a transformation procedure to remove the dependency on the nuisance parameter.

$$\tilde{S}_t^* = \begin{cases} \frac{T}{T_{B_1}} \tilde{S}_t & for\ t \leq T_{B_1} \\ \frac{T}{T_{B_2} - T_{B_1}} \tilde{S}_t & for\ T_{B_1} \leq t \leq T_{B_2} \\ \vdots & \\ \frac{T}{T - T_{B_R}} \tilde{S}_t & for\ T_{B_R} \leq t \leq T \end{cases} \quad (2)$$

When $\tilde{S}_{t-1}$ is replaced by $\tilde{S}_t^*$, the testing equation will be as follows:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1}^* + \sum_{j=1}^{k} d_j \tilde{S}_{t-j} + e_t \quad (3)$$

Using this equation, the test statistics is calculated as t statistics for $\tilde{\tau}_{LM}^*$, $\phi = 0$. This test statistics will be different depending on the number of breaks.

Meng et al. (2013) propose transformed RALS LM test to improve the power of the test in the information on non-normal errors. According to this proposed procedure, the $\widehat{w}_t = [\hat{e}_t^2 - \widehat{m}_2, \hat{e}_t^3 - \widehat{m}_3 - 3\widehat{m}_2 \hat{e}_t]'$ term will be added in the test equation. Where $\hat{e}_t$ is the residual from the testing equation, $\widehat{w}_t$ are associated with moment condition of $\hat{e}_t$, $m_{j+1} = j\sigma^2 m_{j-1}$, where $\widehat{m}_j = T^{-1} \sum_{t=1}^{T} \hat{e}_t^j$. Based on this, the RALS-LM test statistics will be obtained using the following regression equation.

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1}^* + \sum_{j=1}^{k} d_j \tilde{S}_{t-j} + \widehat{w}_t^t \gamma + u_t \quad (4)$$

The test statistics is calculated as t statistics for $\tilde{\tau}_{RALS-LM}^*$, $\phi = 0$ using this equation. Meng et al. (2016) show that the asymptotic distribution of $\tilde{\tau}_{RALS-LM}^*$ is $\tilde{\tau}_{RALS-LM}^* \rightarrow p \tilde{\tau}_{LM}^* + \sqrt{1 - p^2 Z}$ where p reflects the relative ratio of the variance of two error terms. Meng et al. (2016) also demonstrate that the critical values of this test statistic do not depend on the break location parameter and the critical values of this test statistics are tabulated.

3.3. Empirical Findings

The analyses were carried out using the TR LM test developed by Lee et al. (2012) and Meng et al. (2016) TR RALS LM unit root test with two breaks in this study that investigates the temporary or permanent impact of shocks in energy consumption and the results are tabulated in Table 1.

Table 1: Unit Root Tests Results with Two Breaks

	TR LM		TR RALS LM					Critical Values		
Sectors	[illegible]		[illegible]	k	ρ^2	[illegible]		%1	%5	%10
Commercial	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Industrial	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Residential	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Transportation	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

τ^*_{LM} and $\tau^*_{RALS\,LM}$ denote the test statistics for TR LM test and TR RALS LM test, respectively. $\hat{T}_B$ denotes the estimated break date. k denotes the optimal number of lags. The critical values of the τ^*_{LM} are -3.921, -4.183 and -4.689 at the 10%, 5%, and 1% levels, respectively. . [a] means that break point is not significant at the 10% level.

Following Payne et al (2014), the general to specific approach is used in this article. When the structural break dummy is not significant based on the standard t test, the test with one structural break was applied. One statistically insignificant structural break in the industrial and commercial sectors requires the use of single structural break tests.

Table 2: Unit Root Tests Results with One Break

	TR LM	TR RALS LM				Critical Values		
Sectors	τ^*_{LM}	$\tau^*_{RALS\,LM}$	k	ρ^2	$\hat{T}_B$	1%	5%	10%
Commercial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Industrial	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Residential	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Transportation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

τ^*_{LM} and $\tau^*_{RALS\,LM}$ denote the test statistics for TR LM test and TR RALS LM test, respectively. $\hat{T}_B$ denotes the estimated break date. k denotes the optimal number of lags. The critical values of the τ^*_{LM} are -3.403, -3.671 and -4.199 at the 10%, 5%, and 1% levels, respectively. [a] means that break point is not significant at the 10% level.

According to results presented in Table 2, stationarity is not observed in the transport sector whereas it is observed in other sectors.

Conclusion

Energy management is one of the important factors of sustainable development programs of the countries. Energy consumption in the US saw a steady increase over the period 1949-2012. According to BP (2016), the US share of global energy consumption was 17,3% whereas its share in global energy production was 15,6 %. Thus, it is very important for energy policy makers in the US to investigate energy consumption by sectors to develop efficient energy policies.

The energy consumption by sector data over the period 1949-2012 were used in this study that investigates whether the shocks in energy consumption are permanent or temporary in the US. What differentiates this study from other studies is the use of the RALS LM unit root test due to its basic advantages. According to the analysis made, it was seen that the shocks in energy consumption in the transport sector of the US have got a permanent impact.

This result is important for the development of relevant economy policies. As energy is a more essential factor input in the transport sector than in the labor-intensive commercial sector, changes in energy supply, energy prices etc. have got a strong impact on the transport sector, hence on economic growth. According to Gross (2012), the main difference between the transport sector and other sectors is the fact that the production process of the transport sector is both inseparable and highly energy intensive. Moreover, the transport sector has got an important impact both on the sustainability of earth and people's economic and social lives. In like manner, Zhang et. al. (2011) state that there are two sides of energy use in the transport sector. The first one is about the large-scale contribution made especially by highways transport resources to pollution problems while the second is related to energy supply security.

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