# Energy Use and Policy Implications for Energy Security in Asia: A Panel Data Approach

Anh Tru Nguyen*

Newcastle Business School, Faculty of Business and Law, The University of Newcastle, Australia

**Abstract**

The article aims to investigate impacts of determinants on energy use in 13 Asian countries for the past two decades (1996-2015) by employing a panel database. We found that electric power per capita, fossil fuel consumption, fuel exports, and gross domestic product (GDP) per unit of energy use have positives influences on energy use in Asia. However, fuel imports and investment in energy with participation of the private negatively affects energy use in this region. Our results also addressed that energy use in Asian countries still heavily depends upon fossil energy such as coal, oil, and natural gas. Indeed, our findings stated that economic growth is a positive motivation in terms of enhancing energy use in Asia. Lastly, policies are recommended to ensure energy security and foster economic growth in Asia.

Keywords: energy use, energy security, Asia, panel data

## 1. Introduction

Energy security has been considered not only in the national and international energy policies, but also at the heart of the national and international security policies [1]. However, future economic growth in Asia and the Pacific will be reduced due to shortage of energy resources. Vulnerable supplies and unstable prices of energy can be seen as consequences of the dependence on imported energy [2]. Energy consumption of other regions in the world tends to stabilize or even decrease, while the demand for energy in Asia increases sharply. By 2013, Asia accounted for 73 percent of coal, 44 percent of oil, and 35 percent of natural gas of the global [3]. In Asia and the Pacific, energy prices are predicted to increase by coupled because of growth in energy demand and dependence on fossil fuels and as a result, energy security must face more obstacles than before. Countries in Asia and the Pacific have owned the majority of fossil and non-fossil energy resources and these are net exporters of coal, natural gas (through the pipeline), and electricity, but net importers of oil and liquefied natural gas (LNG). Although controlling the majority of coal and natural gas reserves, demand for fossil fuel in Asia and the Pacific is increasing, especially in the long term. In order to ensure energy security along with maintain economic growth, it is necessary for Asian countries to establish energy cooperation, enhance regional connectivity, and invest in adequate infrastructure [4]. For example, regional cooperation in integrating the power grid in Central Asia would make the system operates more effectively for larger shares of renewables and

*Corresponding author: anhtru.nguyen@uon.edu.au
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also reduced the cost of importing fuel for economies by 2035 [5]. Moreover, energy efficiency can be seen as an essential component of the sustainable energy policies in Asia by reducing carbon emissions from energy use [3].

There are a number of researches on energy use and energy security in Asia in recent years. Although these studies focus on energy use and energy security in either the sub-region level [6–8] or the national level [9–11], but none of these researches energy use in order to recommend policies for energy security in the context of entire Asia. Thus, it is necessary to carry out this study to narrow down the gap in the research scale of previous studies. This research presents significant contributions to not only the empirical aspect, but also the policy implication to ensure energy security in entire Asia. Furthermore, there are some significant contributions of this research to knowledge. Firstly, the ordinary least square (OLS), fixed effect (FE), and random effect (RE) models are used to estimate impacts of determinants on energy use in Asia for the past two decades (1996-2015). Thus, findings can be more significant because we are able to compare outcomes of three models. Secondly, the FE and RE models are employed to overcome limitations of the OLS model in terms of the OLS assumptions (linear functional relationship, data distribution, resilience to outliers, and independence of observations) and the omission of variables since both observed and unobserved variables can affect the dependent variable. Finally, a panel data presents advantages compared to a cross-sectional data since it displays variations of subjects during the time.

This article aims to examine influences of determinants on energy use in Asia for the past two decades (1996-2015). Specifically, factors such as the proportion of electric access, electric power per capita, fossil fuel energy consumption, fuel exports, fuel imports, gross domestic product (GDP) per unit of energy use, investment in energy, and sub-regions, affecting energy consumption for the past two decades (1996-2015) in 13 Asian countries, are estimated by a panel dataset. Further, policies are recommended to the governments of these countries to ensure energy security and facilitate economic growth.

The rest of this paper is organized as follows. Section 2 highlights literature review by interpreting concepts and indicators of energy security as well as reviewing previous empirical studies on energy use and energy security in the world. Methodologies are presented in section 3. Section 4 presents results and discussion. Lastly, conclusion and policy implications are summarized in section 5.

## 2. Literature review

### 2.1. Concepts of energy security

The debates surrounding concepts of energy security have become more disparate and scattered because energy penetrates all aspects of our lives and therefore it is very difficult to concentrate on specific aspects [12]. The definition of energy security has been discussed in previous studies. According to the Asia Pacific Energy Research Centre (APERC, 2007), energy security comprises "four As", such as availability, accessibility, affordability, and acceptability. However, only a research by Jewell et al. (2014) [13] mentioned "5As" of access to health care, including availability, accessibility, accommodation, affordability, and acceptability proposed by [14,15]. Von Hippel et al. (2009) [16] proposed four major challenges that need to be incorporated into a new concept of energy security, including environment, technology, demand-side management, and domestic socio-cultural and political factors. According to Vivoda (2010) [17], four dimensions such as human security, international, public relations, and policy, should be added in a new concept of energy security. Human security refers to the situation of independent energy. International states regional and global implications of energy security challenges. Public relations demonstrate participation of the regular public in energy security. Policy states the actual existence of energy security policy.

## 2.2. Indicators of energy security

There are three components in the energy system, including the energy source (production), the energy services (consumption), and the transfer from the production to consumption [18]. Due to the importance of diversity of energy sources and suppliers in European Union, energy security focuses on four indicators, namely primary energy, foreign primary energy supply, primary energy carriers, and foreign primary energy suppliers [19].

The indicators of energy security, which related to threats of human intervention, equipment failure, and extreme weather, are mentioned as follows: (i) energy resources (supply and prices can be disrupted by political action; energy security is threatened by the depletion of conventional oil reserves; restricted reserves of oil and gas threatens energy security; import dependence is an indicator of reduced energy security; and a more diverse energy system contributes energy security); (ii) infrastructure (electricity networks can be damaged by bad weather; energy security metrics used in international index are classified as global fuels, fuel imports, energy expenditure, price and market volatility, energy use intensity, electric power sector, transportation sector and environment); and (iii) demand (overall energy demand; energy demand per home or unit of economic activity; energy costs as a proportion of total expenditure; and capacity for demand side response).

Energy security metrics include global fuels, fuel imports, energy expenditure, price and market volatility, energy use intensity, electric power sector, transportation sector and environment. Global fuels measure the reliability and diversity of global reserves and supplies of oil, natural gas and coal and higher reliability and diversity mean a lower risk to energy security. Fuel imports measure the exposure of the national economies to unreliable and concentrated supplies of oil, natural gas and coal. Higher supply reliability and diversity and lower import levels mean a lower risk to energy security. Energy expenditure measures the magnitude of energy costs to national economies and the exposure of consumers to price shocks. Lower costs and exposure mean a lower risk to energy security. Price and market volatility measure the susceptibility of national economies to large swings in energy prices. Lower volatility means a lower risk to energy security. Energy use intensity measures energy use in relation to population and economic output. Lower use of energy by industry to produce goods and services means a lower risk to energy security. Electric power sector measures indirectly the reliability of electricity generating capacity. Higher diversity means a lower risk to energy security. Transportation sector measures efficiency of energy use in the transport sector per unit of GDP and population. Greater efficiency means a lower risk to energy security. Environment measures the exposure of national economies to national and international greenhouse gas emission reduction mandates. Lower emissions of carbon dioxide from energy mean a lower risk to energy security [1].

## 2.3. Empirical studies in energy use and energy security

There are various previous studies on energy use and energy security all over the world. Choi (2009) [6] investigated energy security in Northeast Asia. She argued that energy can create shared interests and opportunities for cooperation rather than act as a source of confrontation. China, Japan, and South Korea should cooperate in building security institutions such as offshore energy exploration, clean energy programs, antipiracy activities, and pipeline construction in East Siberia. Likewise, Farkhod (2015) [7] examined energy security in Central Asia. He concluded that issues in uneven distribution of resources and energy supplies in Central Asia can be solved by energy trade and governments of Central Asian countries should take full advantage of assistance offered by multilateral programs. Kanchana and Unesaki (2015) [8] assessed energy security indicators in nine countries of the Association of Southeast Asian Nations (ASEAN) for the past 12 years (2001-2012). Their findings stated that energy security among ASEAN member nations is a result of uneven economic and energy infrastructure developments. At a national level, effects of the context on the connotation of energy security and the interpretation of the indicators reflect different primary obstacles of energy security. In terms of the international level, the interconnection of intra-regional energy markets may contribute to energy self-reliance of the region due to the diversity.

Further, Jiang and Khan (2017) [9] studied structural change and energy use in China by a computable general equilibrium model. Their results addressed that structural change associated with raising industrial labor productivity and employment-share in China. In addition, when the industrial exports are inelastic to price changes, currency devaluation becomes contractionary and wage increase results in a slight contraction in real GDP due to the "forced saving" effect. A study by Munim et al. (2010) [10] investigated energy consumption and use in Bangladesh. Their conclusions addressed that change in energy intensity is due to structural effect, while growth in aggregate energy consumption is due to both the activity effect and structural effect. Likewise, Nasab et al. (2012) [11] analyzed energy consumption in transportation and industrial sectors of Iran for six years (2001-2006). Their findings showed that the activity levels affect changes of energy consumption and the significant energy consumption determinants are structural and energy intensity effects.

Onanuga (2017) [20] estimated impacts of income, population, and energy use on carbon dioxide ($CO_2$) emissions in 26 African countries for the past 43 years (1971-2013). He claimed that environmental quality is not a luxury goods. Countries, where have cleaner environment, is found to be an inferior good are of higher threat to their counterparts where have cleaner environment is a normal good. Sadorsky (2014) [21] examined influences of urbanization and industrialization on energy use in emerging economies. His results demonstrated that economic growth will boost energy consumption. Because the majority of energy demand in emerging economies are currently met by the burning of fossil fuels, economic growth and industrialization policies should be at odds with sustainable development. Lastly, Shaari et al. (2014) [22] investigated the relationship among economic growth, energy use, and $CO_2$ emissions in Malaysia for the past 34 years (1975-2008) by the Granger causality model. Their findings concluded that environmental problems in Malaysia are results of energy consumption and growth of energy consumption facilitates economic growth and also escalates carbon dioxide emission.

Although most of previous studies focus on energy use and energy consumption in either the sub-region level [6–8] or the national level [9–11] in Asia, but none of these researches energy use in order to recommend policies for energy security in entire Asia. This study, therefore, expects to narrow down the gap in the research scale of previous studies. Indeed, the research presents significant contributions to not only the empirical aspect, but also the policy implication to ensure energy security in Asia.

## 3. Methodology

### 3.1. Data and sources

A panel dataset for effects of determinants on energy use in Asia is gathered from the database released by the World Bank (WB). Due to limitations in human and financial resources for the

**Table 1:** *Description of covariates in the OLS model*

| Variable definitions | Labels | Unit | Expected signs |
|---|---|---|---|
| Dependent variable: Energy use | $Y$ | Kg of oil | |
| Covariates: | | | |
| The proportion of electric access | $X_1$ | % | + |
| Electric power per capita | $X_2$ | kWh | + |
| The rate of fossil fuel energy consumption | $X_3$ | % | +/- |
| Fuel exports | $X_4$ | % | +/- |
| Fuel imports | $X_5$ | % | +/- |
| GDP per unit of energy use | $X_6$ | US$ | + |
| Investment in energy with the participation of privates | $X_7$ | US$ | +/- |
| Northeast Asia (1=Northeast Asia and 0=Otherwise) | $D_1$ | | +/- |
| Southeast Asia (1=Southeast Asia and 0=Otherwise) | $D_2$ | | +/- |

study, 13 countries are chosen to represent for five sub-regions of Asia, including Northeast Asia (China, Japan, and the Republic of Korea); Southeast Asia (Indonesia, Thailand, and Viet Nam); South Asia (India, Pakistan, and Sri Lanka); Central Asia (Kazakhstan); and Middle East (the Islamic Republic of Iran, Saudi Arabia, and Oman). A panel dataset is collected for the past two decades (1996-2015). Thus, a total of 260 observations are entered for data analysis. The panel data is used for this research because of the following advantages: (1) it benefits in terms of obtaining a large sample, giving more degree of freedom, more information, and less multicollinearity among variables; and (2) it may overcome constraints related to control individual or time heterogeneity faced by the cross-sectional data [23, 24].

## 3.2. Data analysis

### 3.2.1 The OLS model

$$Y = \alpha_0 + \sum \alpha_i X_i + \sum \gamma_i D_i + \mathcal{E}_i \tag{1}$$

Where: Y represents energy use (the dependent variable); $\alpha_0$ is the intercept; $\alpha_i$ and $\gamma_i$ denote parameters to be estimated; $X_i$ represents independent variables such as the proportion of electric access, electric power per capita, fossil fuel energy consumption, fuel exports, fuel imports, GDP per unit of energy use, and investment in energy with the participation of privates; $D_i$ is dummy variables; and $\mathcal{E}_i$ denotes the error term.

Description of variables in the OLS model is presented in Table 1.

### 3.2.2 The FE and RE models

The purpose of OLS assumptions (linear functional relationship, data distribution, resilience to outliers, and independence of observations) is to simplify reality in order to respond to manageable questions that will provide insights into cause-effect relationships. However, these assumptions may be violated due to the model either oversimplifies or misrepresents and therefore the OLS model is not appropriate [25]. Estimators of the OLS model are inconsistent if the dependent variable correlates with the error term [26]. Moreover, the main drawback of the OLS regression is

**Table 2:** *Description of covariates in the FE and RE models*

| Variable definitions | Labels | Unit | Expected signs |
|---|---|---|---|
| Dependent variable: Energy use | $Y$ | Kg of oil | |
| Covariates: | | | |
| The proportion of electric access | $A$ | % | + |
| Electric power per capita | $P$ | kWh | + |
| The rate of fossil fuel energy consumption | $F$ | % | +/- |
| Fuel exports | $X$ | % | +/- |
| Fuel imports | $M$ | % | +/- |
| GDP per unit of energy use | $G$ | US$ | + |
| Investment in energy with the participation of privates | $I$ | US$ | +/- |
| Northeast Asia (1=Northeast Asia and 0=Otherwise) | $D_1$ | | +/- |
| Southeast Asia (1=Southeast Asia and 0=Otherwise) | $D_2$ | | +/- |

the omission of variables since both observed and unobserved variables can affect the dependent variable [27].

Panel estimation techniques are used to overcome limitations of the OLS model. Specifically, both the FE and RE models are employed to estimate impacts of covariates on energy use. The FE model presents advantages when we omit variables and these variables are correlated with other explanatory variables in the model. Indeed, this model assists to control for differences in time-invariant and unobservable characteristics which can influence the energy use. The RE model is useful if we have no omitted variables and these variables are uncorrelated with the explanatory variables in the model. In this model, the individual-specific effect is a random variable which is uncorrelated with explanatory variables [28].

The equation for the FE and RE models can be defined as follows:

$$Y_{it} = \alpha_i + \beta A_{it} + \lambda P_{it} + \varphi F_{it} + \rho X_{it} + \mu M_{it} + \gamma G_{it} + z I_{it} + \varpi D_{it} + \delta_t + \mathcal{E}_{it} \quad (2)$$

$$(i = 1, \ldots, N; t = 1, \ldots, T_i)$$

Where: $Y_{it}$ represents the energy use (kg of oil); $\alpha_i$ is the fixed effect; $\beta$, $\lambda$, $\varphi$, $\rho$, $\mu$, $\gamma$, $z$ and $\varpi$ are parameters to be estimated; $A_{it}$ is the proportion of electric access; $P_{it}$ denotes the electric power per capita; $F_{it}$ is the rate of fossil fuel energy consumption; $X_{it}$ represents the rate of fuel exports; $M_{it}$ is the rate of fuel imports; $G_{it}$ represents GDP per unit of energy use; $I_{it}$ is investment in energy with the participation of privates; $D_{it}$ denotes dummy variables; $\delta_t$ presents the trend rate of change over time t; and $\mathcal{E}_{it}$ denotes the error term.

Description of covariates for the FE and RE models is presented in Table 2.

# 4. RESULTS AND DISCUSSION

## 4.1. Energy use in Asia: An overview

The proportion of electric access in the world and regions tended to rise for a decade (2006-2015). Specifically, the percentage of access to electricity of the world increased by nearly 6 percent from 81.2 percent in 2006 to 87 percent in 2015. In the same period, South Asia presented the strongest increase by 19.4 percent, followed by East Asia and the Pacific (3.2 percent), and Middle East and North Africa (2 percent). The proportion of electric access of East Asia and the Pacific and Middle East and North Africa was higher than that of the world, while the rate in South Asia was slight lower compared to the proportion of the world. High percentage of electric access in total population implies advantages of East Asian countries in the energy sector and Middle East and North Africa in exporting oil (Figure 1).

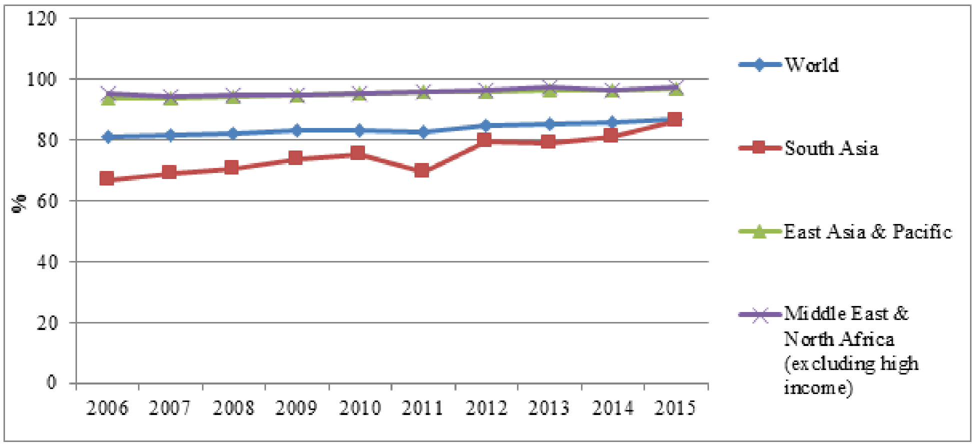


**Figure 1:** *The proportion of electric access in the world [33]*

Similar to access to electricity, electric power per capita of the world and regions tended to go up for nine years (2006-2014). In this period, electric power per capita of the world rose by nearly 396 KWh from 2,729 kWh in 2006 to 3,125 kWh in 2004. In the same period, East Asia and the Pacific had the strongest increase by 1,243 kWh, followed by Middle East and North Africa by 308 kWh, and South Asia by 238 kWh. From 2009 to 2014, electric power per capita of East Asia and the Pacific was higher than that of the world by about 550 kWh. In contrast, by 2014, electric power per capita of both Middle East and North Africa and South Asia were lower than that of the world by more than 1,400 kWh and 2,400 kWh, respectively (Figure 2).

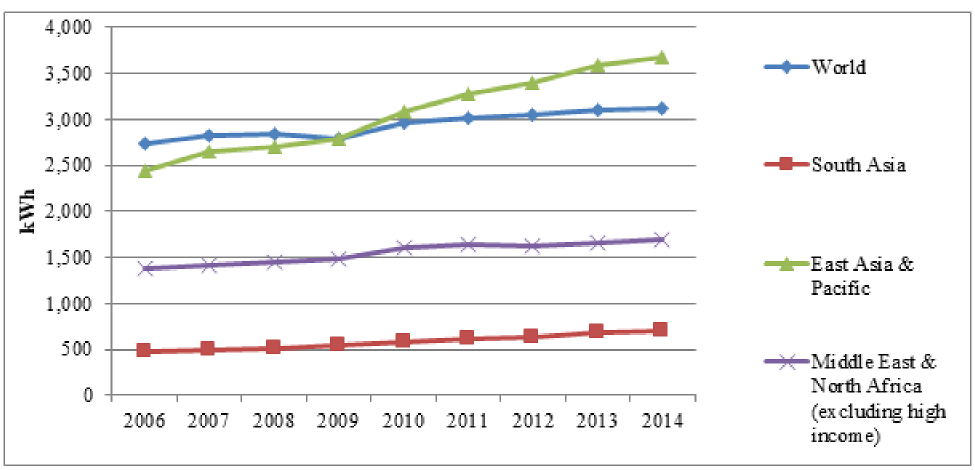


**Figure 2:** *Electric power per capita in the world [34]*

Energy use of the world and regions tended to rise for nine years (2006-2014). Specifically, energy use of the world rose by about 125 kg of oil from 1,794 kg in 2006 to 1,919 kg in 2014. East Asia and the Pacific presented the strongest increase by 507 kg, followed by Middle East and North Africa (222 kg), and South Asia (135 kg). By 2014, energy use of East Asia and the Pacific has overcome the level of the world by about 216 kg, while energy use of both Middle East and North Africa and South Asia was lower than that of the world by about 442 kg and more than 1,300 kg, respectively. The growth of energy use in the world reflects an increased demand in energy for economic development and consumption in the life of population (Figure 3).

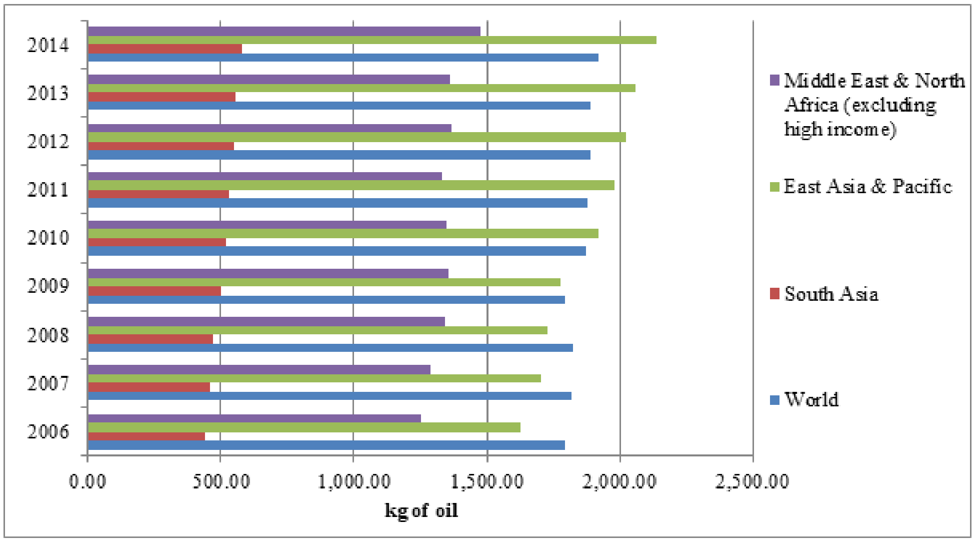


**Figure 3:** *Energy use in the world [35]*

For six years (2006-2011), data showed that Middle East and North Africa had a tremendous advantage in exporting oil and the rate of exported fuel in this region varied from 67 percent to 74 percent of total merchandise. The proportion of exported fuel in South Asia was slightly higher than that of the world by about 1 percent for two years (2013-2014). By contrast, the rate of exported fuel in East Asia and the Pacific accounted for only from 6 percent to 8 percent of total merchandise (Figure 4).

Fuel imports of the world decreased by 3 percent from 15 percent in 2006 to 12 percent in 2015. South Asia had the strongest fuel imports with the rate varied from 26 percent to nearly 40 percent in total merchandise, followed by East Asia and the Pacific with the import level fluctuated from 15 percent to 22 percent, while Middle East and North Africa had the lowest imports which varied from 11 percent to 17 percent. In 2015, fuel imports of the world and regions, except Middle East and North Africa, sharply declined compared to this of previous years and this implies an active policy of countries in terms of supplying fuel to domestic markets and the development of alternative energy sources which assist countries to reduce the dependence on oil (Figure 5).

Time to get electricity in the world is presented in Figure 6. This indicator can be calculated by the number of days to obtain a permanent electricity connection annually. The time to get electricity of the world dropped by about 20 days from 114 days in 2009 to 93 days in 2015. In the same period, the time to get electricity of South Asia and East Asia and the Pacific decreased by 22 days and 14 days, respectively. By contrast, the time to get electricity of Middle East and North Africa rose by 3 days. The number of days to obtain a permanent electricity of East Asia and the Pacific and Middle East and North Africa was shorter than that of the world by nearly 22 days and 9 days, respectively. However, the number of days to obtain a permanent electricity

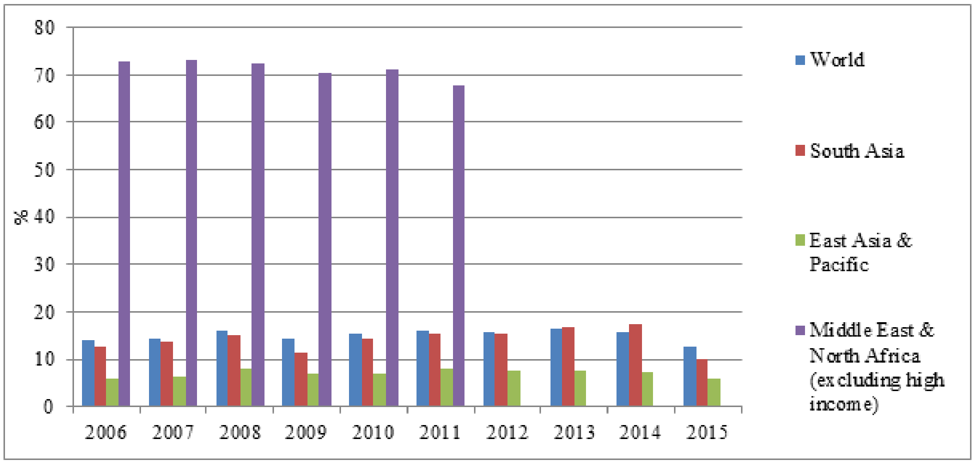


**Figure 4:** *Fuel exports in the world [36]*

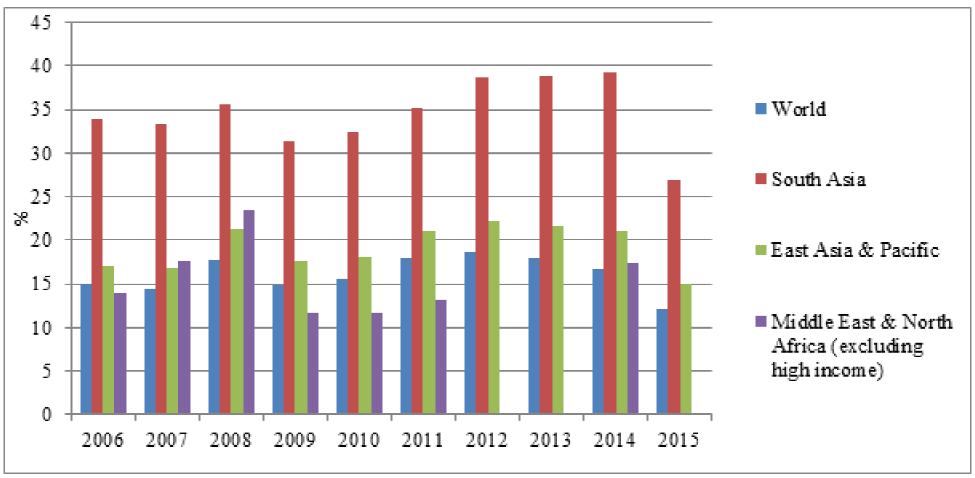


**Figure 5:** *Fuel imports in the world [37]*

of South Asia was longer than that of the world by 49 days and this implies that the number of disconnected electricity days in this region was longer (Figure 6).

## 4.2. Characteristics of the energy sector in Asia

Characteristics of the energy sector in five sub-regions of Asia, including Northeast Asia, Southeast Asia, South Asia, Central Asia, and the Middle East, are presented in Table 3. The Middle East has become the leading sub-region in using energy in Asia by nearly 4,000 kg of oil, followed by Central Asia (more than 3,300 kg of oil), Northeast Asia (more than 3,200 kg of oil), Southeast Asia (860 kg of oil), and South Asia (447 kg of oil) (Table 3). The rate of electric access in total population of Northeast Asia and Central Asia accounts for nearly 100 percent, while the Middle East stands at the end of the list with more than 67 percent. Electric power per capita in Northeast Asia reaches more than 5,600 kWh, while value of South Asia and the Middle East account for about 418 kWh. Central Asia is a sub-region where has the strongest consumption of fossil fuel energy by nearly 94 percent, followed by the Middle East by 88 percent, while South Asia only

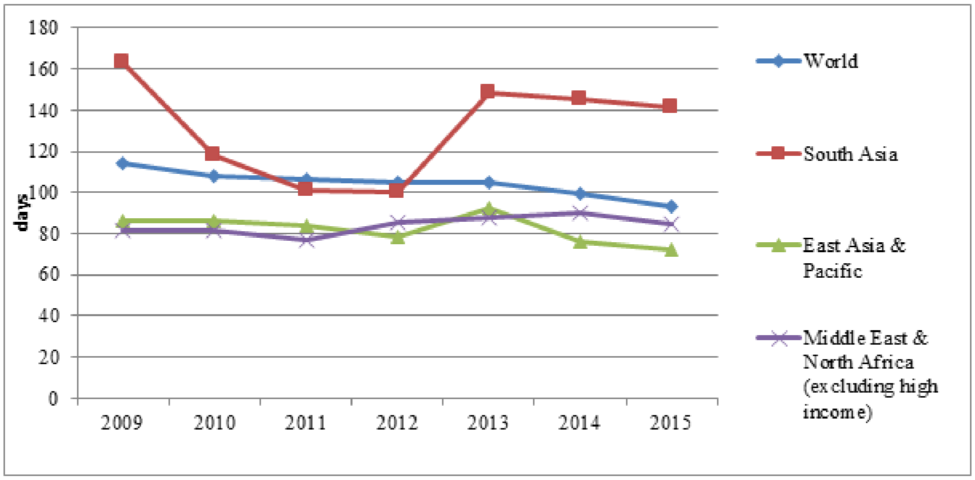


**Figure 6:** *Time to get electricity in the world [38]*

consumes about 54 percent of fossil fuel energy. The highest exporting fuel belongs to the Middle East by nearly 71 percent in total merchandise, while South Asia exports only 4.5 percent. By contrast, South Asia is a sub-region where imports the largest proportion of fuel by more than 25 percent, while the Middle East imports only about 3 percent (Table 3).

The largest GDP per unit of energy use belongs to South Asia by more than 8 US$, while the number in Central Asia accounts for only more than 3 US$. Southeast Asia has become a sub-region which has the strongest investment in energy with participation of the private by US$88.7 billion, followed by Northeast Asia (US$82.2 billion), while Central Asia is ranked at the end of the list by US$10.7 billion (Table 3).

## 4.3. Influences of determinants on energy use in Asia

The OLS model, FE model, and RE model are employed to assess impacts of determinants on energy use in 13 Asian countries for two decades (1996-2015).

F-value and P-value account for 245.24 and 0.000, respectively imply the fitness of the model. Adjusted R-squared is equal to 0.894 suggests that 89.4 percent of variation in energy use can be interpreted by independent variables in the model (Table 4).

All independent variables are statistically significant, except access to electricity. Electric power per capita, fossil fuel consumption, fuel exports, GDP per unit of energy use, and Northeast Asia have positive impacts on energy use in Asia. Specifically, if electric power per capita increases by 1 kWh, then energy use rises by 0.4 kg of oil, ceteris paribus. If fossil fuel consumption rises by 1 percent, then energy use increases by 0.4 kg of oil, ceteris paribus. If fuel exports increases by 1 percent, then energy use rises by 0.1 kg of oil, ceteris paribus. If GDP per unit of energy use increases by 1 US$, then energy use rises by 0.7 kg of oil, ceteris paribus. Northeast Asia has a higher energy use than other sub-regions by 0.29, ceteris paribus. By contrast, if fuel imports increases by 1 percent, then energy use decreases by 0.06 kg of oil, ceteris paribus. If investment in energy with participation of the private increases by 1 US$, then energy use decreases by 0.01 kg of oil, ceteris paribus. Lastly, Southeast Asia tends to use less energy than other sub-regions by 0.08, ceteris paribus (Table 4).

F-value and P-value account for 114.4 and 0.000, respectively imply the fitness of the model. Overall R-squared is equal to 0.874 suggests that 87.4 percent of variation in energy use can

**Table 3:** *Characteristics of the energy sector in Asia*

| Variables | Mean | SD | Min | Max |
|---|---|---|---|---|
| Northeast Asia | | | | |
| Energy use (kg of oil) | 3229.18 | 1443.29 | 0 | 5413.3 |
| Access to electricity (%) | 99.28 | 1.42 | 94.8 | 100 |
| Electric power per capita (kWh) | 5644.06 | 3309.02 | 0 | 10496.5 |
| Fossil fuel consumption (%) | 82.56 | 11.54 | 0 | 94.7 |
| Fuel exports (%) | 3.17 | 2.58 | 0.4 | 10.4 |
| Fuel imports (%) | 20.65 | 8.66 | 4.9 | 35.6 |
| GDP per unit of energy use (US$) | 5.84 | 2.32 | 0 | 11.9 |
| Investment in energy (US$) | 8.22e+08 | 1.44e+09 | 0 | 5.95e+09 |
| Southeast Asia | | | | |
| Energy use (kg of oil) | 860.96 | 504.02 | 0 | 1991.6 |
| Access to electricity (%) | 91.43 | 6.67 | 72.4 | 100 |
| Electric power per capita (kWh) | 968.01 | 726.38 | 0 | 2539.6 |
| Fossil fuel consumption (%) | 62.63 | 20.26 | 0 | 82.1 |
| Fuel exports (%) | 15.59 | 10.81 | 0 | 34.1 |
| Fuel imports (%) | 15.68 | 6.83 | 0 | 31.5 |
| GDP per unit of energy use (US$) | 6.71 | 2.32 | 0 | 11.9 |
| Investment in energy (US$) | 8.87e+08 | 1.00e+09 | 0 | 3.54e+09 |
| South Asia | | | | |
| Energy use (kg of oil) | 447.95 | 117.53 | 0 | 637.4 |
| Access to electricity (%) | 76.47 | 11.43 | 53.1 | 96 |
| Electric power per capita (kWh) | 418.72 | 153.48 | 0 | 805.6 |
| Fossil fuel consumption (%) | 54.11 | 15.99 | 0 | 73.5 |
| Fuel exports (%) | 4.50 | 6.05 | 0 | 20.3 |
| Fuel imports (%) | 25.17 | 10.67 | 0 | 43 |
| GDP per unit of energy use (US$) | 8.72 | 4.65 | 0 | 21.8 |
| Investment in energy (US$) | 2.74e+09 | 6.37e+09 | 0 | 3.45e+10 |
| Central Asia | | | | |
| Energy use (kg of oil) | 3337.03 | 1165.42 | 0 | 4786.6 |
| Access to electricity (%) | 99.3 | 0.69 | 97 | 100 |
| Electric power per capita (kWh) | 3905.47 | 1221.72 | 0 | 5600.2 |
| Fossil fuel consumption (%) | 93.47 | 22.01 | 0 | 99.2 |
| Fuel exports (%) | 61.33 | 13.97 | 32.9 | 76.7 |
| Fuel imports (%) | 11.64 | 3.12 | 5.6 | 19 |
| GDP per unit of energy use (US$) | 3.75 | 1.25 | 0 | 5.6 |
| Investment in energy (US$) | 1.07e+08 | 2.82e+08 | 0 | 1.08e+09 |
| The Middle East | | | | |
| Energy use (kg of oil) | 3983.35 | 1904.19 | 0 | 6937.2 |
| Access to electricity (%) | 67.83 | 46.57 | 0 | 100 |
| Electric power per capita (kWh) | 4179.90 | 2374.32 | 0 | 9444.2 |
| Fossil fuel consumption (%) | 88.10 | 32.29 | 0 | 100 |
| Fuel exports (%) | 70.86 | 30.73 | 0 | 92.2 |
| Fuel imports (%) | 3.17 | 6.15 | 0 | 40.5 |
| GDP per unit of energy use (US$) | 6.89 | 2.22 | 0 | 11 |
| Investment in energy (US$) | 1.35e+07 | 8.60e+07 | 0 | 6.50e+08 |

*Source*: Survey data (1996-2015)

**Table 4:** *Regression of the OLS model*

| Variables | Coef. | SE | t | P-value |
|---|---|---|---|---|
| Log_Access to electricity | 0.022 | 0.03 | 0.61 | 0.544 |
| Log_Electric power per capita | 0.433*** | 0.02 | 14.81 | 0.000 |
| Log_Fossil fuel consumption | 0.493*** | 0.05 | 9.75 | 0.000 |
| Log_Fuel exports | 0.167*** | 0.02 | 6.26 | 0.000 |
| Log_Fuel imports | -0.061* | 0.03 | -1.80 | 0.073 |
| Log_GDP per unit of energy use | 0.783*** | 0.09 | 8.34 | 0.000 |
| Log_Investment in energy | -0.014*** | 0.00 | -3.35 | 0.001 |
| Northeast Asia (1=Northeast Asia and 0=Otherwise) | 0.295*** | 0.05 | 5.65 | 0.000 |
| Southeast Asia (1=Southeast Asia and 0=Otherwise) | -0.086** | 0.04 | -2.03 | 0.044 |
| Constant | 0.105 | 0.10 | 0.99 | 0.325 |
| Number of observations | 260 | | | |
| F(9, 250) | 245.24 | | | |
| Prob > F | 0.000 | | | |
| R-squared | 0.898 | | | |
| Adjusted R-squared | 0.894 | | | |
| Root MSE | 0.255 | | | |

*Source*: Survey data (1996-2015)
*Note*: SE means standard errors; ***, **, and * mean statistical significance at 1%, 5%, and 10%, respectively

be interpreted by independent variables in the model. U_i presents unobserved heterogeneity. Correlation (u_i, Xb) is equal to -0.85 implies that unobserved heterogeneity has a negative relationship with explanatory variables in the model. Sigma_u is equal to 0.308 and this reflects that the estimate of standard deviation between variables is equal to 0.308. Sigma_e is equal to 0.243 and this implies that the estimate of standard deviation within variables is equal to 0.243. Rho is equal to 0.616 and this suggests that variation of variance due to the error term accounts for 61.6 percent (Table 5).

All independent variables are statistically significant, except fuel imports and investment in energy. Access to electricity, electric power per capita, fossil fuel consumption, fuel exports, GDP per unit of energy use, and Northeast Asia have positive effects on energy use in Asia. Specifically, if access to electricity increases by 1 percent, then energy use rises by 0.1 kg of oil, ceteris paribus. If electric power per capita increases by 1 kWh, then energy use rises by 0.7 kg of oil, ceteris paribus. If fossil fuel consumption rises by 1 percent, then energy use increases by 0.4 kg of oil, ceteris paribus. If fuel exports increases by 1 percent, then energy use rises by 0.1 kg of oil, ceteris paribus. If GDP per unit of energy use increases by 1 US$, then energy use rises by 1.2 kg of oil, ceteris paribus. Northeast Asia tends to use more energy than other sub-regions by 0.14, ceteris paribus. In contrast, energy use of Southeast Asia is lower than that of other sub-regions by 0.1, ceteris paribus (Table 5).

Wald chi2 and P-value account for 2207.12 and 0.000, respectively imply the fitness of the model. Overall R-squared is equal to 0.898 suggests that 89.8 percent of variation in energy use can be interpreted by independent variables in the model. U_i presents unobserved heterogeneity. Correlation (u_i, X) is assumed to equal to zero and this implies that there is no relationship between unobserved heterogeneity and explanatory variables in the model. Sigma_u is equal to

**Table 5:** *Regression of the FE model*

| Variables | Coef. | SE | t | P-value |
|---|---|---|---|---|
| Log_Access to electricity | 0.130*** | 0.04 | 3.14 | 0.002 |
| Log_Electric power per capita | 0.721*** | 0.05 | 12.35 | 0.000 |
| Log_Fossil fuel consumption | 0.474*** | 0.05 | 8.77 | 0.000 |
| Log_Fuel exports | 0.178*** | 0.02 | 6.51 | 0.000 |
| Log_Fuel imports | -0.010 | 0.03 | -0.3 | 0.763 |
| Log_GDP per unit of energy use | 1.205*** | 0.11 | 10.50 | 0.000 |
| Log_Investment in energy | 0.000 | 0.00 | 0.11 | 0.911 |
| Northeast Asia (1=Northeast Asia and 0=Otherwise) | 0.145** | 0.05 | 2.52 | 0.012 |
| Southeast Asia (1=Southeast Asia and 0=Otherwise) | -0.106*** | 0.04 | -2.59 | 0.010 |
| Constant | -1.353*** | 0.26 | -5.05 | 0.000 |
| Number of observations | 260 | | | |
| Number of groups | 20 | | | |
| F(9, 231) | 114.40 | | | |
| Prob > F | 0.000 | | | |
| R square: | | | | |
| Within | 0.816 | | | |
| Between | 0.986 | | | |
| Overall | 0.874 | | | |
| Correlation (u_i, $X_b$) | -0.850 | | | |
| Sigma_u | 0.308 | | | |
| Sigma_e | 0.243 | | | |
| Rho | 0.616 | | | |

*Source*: Survey data (1996-2015)
*Note*: Rho is the faction of variance due to u_i; ***, **, and * mean statistical significance at 1%, 5%, and 10%, respectively

**Table 6:** *Generalized least squares (GLS) regression for the RE model*

| Variables | Coef. | SE | z | P-value |
|---|---|---|---|---|
| Log_Access to electricity | 0.022 | 0.03 | 0.61 | 0.543 |
| Log_Electric power per capita | 0.433*** | 0.02 | 14.81 | 0.000 |
| Log_Fossil fuel consumption | 0.493*** | 0.05 | 9.75 | 0.000 |
| Log_Fuel exports | 0.167*** | 0.02 | 6.26 | 0.000 |
| Log_Fuel imports | -0.061* | 0.03 | -1.80 | 0.072 |
| Log_GDP per unit of energy use | 0.783*** | 0.09 | 8.34 | 0.000 |
| Log_Investment in energy | -0.014*** | 0.00 | -3.35 | 0.001 |
| Northeast Asia (1=Northeast Asia and 0=Otherwise) | 0.295*** | 0.05 | 5.65 | 0.000 |
| Southeast Asia (1=Southeast Asia and 0=Otherwise) | -0.086** | 0.04 | -2.03 | 0.043 |
| Constant | 0.105 | 0.10 | 0.99 | 0.324 |
| Number of observations | 260 | | | |
| Number of groups | 20 | | | |
| Wald chi2 (9) | 2207.12 | | | |
| Prob > chi2 | 0.000 | | | |
| R square: | | | | |
| Within | 0.795 | | | |
| Between | 0.992 | | | |
| Overall | 0.898 | | | |
| Correlation (u_i, $X_b$) | 0 (assumed) | | | |
| Sigma_u | 0 | | | |
| Sigma_e | 0.243 | | | |
| Rho | 0 | | | |

*Source*: Survey data (1996-2015)
*Note*: Rho is the faction of variance due to u_i; ***, **, and * mean statistical significance at 1%, 5%, and 10%, respectively

zero and this reflects that the estimate of standard deviation between variables is equal to zero. Sigma_e is equal to 0.243 and this implies that the estimate of standard deviation within variables is equal to 0.243. Rho is equal to zero and this suggests that there is no variation of variance due to the error term (Table 6).

All independent variables are statistically significant, except access to electricity. Electric power per capita, fossil fuel consumption, fuel exports, GDP per unit of energy use, and Northeast Asia have positive impacts on energy use in Asia. Specifically, if electric power per capita increases by 1 kWh, then energy use rises by 0.4 kg of oil, ceteris paribus. If fossil fuel consumption rises by 1 percent, then energy use increases by 0.4 kg of oil, ceteris paribus. If fuel exports increases by 1 percent, then energy use rises by 0.1 kg of oil, ceteris paribus. If GDP per unit of energy use increases by 1 US$, then energy use rises by 0.7 kg of oil, ceteris paribus. Northeast Asia tends to use more energy than other sub-regions by 0.29, ceteris paribus. By contrast, fuel imports, investment in energy with participation of privates, and Southeast Asia negative affect energy use in Asia. If fuel imports increases by 1 percent, then energy use declines by 0.06 kg of oil, ceteris paribus. If investment increases by 1 US$, then energy use decreases by 0.01 kg of oil, ceteris paribus. Energy use of Southeast Asia is lower than that of other sub-regions by 0.08, ceteris paribus (Table 6).

### 4.4. Discussion

We found that electric power per capita, fossil fuel consumption, fuel exports, GDP per unit of energy use, and Northeast Asia are statistically significant and have positive impacts on energy use in three models. These imply the importance of these variables to energy use in Asia. If fact, currently fossil energy such as coal, oil, and natural gas, still play an important role in the energy sector of Asian countries because by 2013, Asia accounted for 73 percent of coal, 44 percent of oil, and 35 percent of natural gas of the global [3]. Moreover, this also suggests that Asian economies still heavily depend upon fossil fuel sources. Clearly, fuel exporting countries and high GDP per unit of energy use countries often have higher energy use compared to their counterparts. In contrast, investment in energy is statistically significant and has a negative effect on energy use in the OLS and RE models. In Asia, the energy sector is often managed and controlled by the State with minor participations of the private. Our results showed that if investment in energy with participation of the private increases, then energy use declines. In addition, this sector has been seen as an essential pistol, which maintains and facilitates the growth of industrial, construction, agricultural, and service sectors in the economy. Hence, if participation of the private in investing in energy increases, especially in sub-regions, where have high investments from the private like Southeast Asia and Northeast Asia, then this can assist to save energy use. However, the energy sector should be managed and controlled by the government since the energy sector is a crucial sector of the national economy, which exploits and uses national natural resources such as coal, oil, and natural gas and its products are associated with various production and consumption activities. Moreover, the energy market can be collapsed if the State monopoly is transferred to the private monopoly in the energy sector.

Furthermore, our results also stated that countries in Northeast Asia use more energy than other sub-regions, while countries in Southeast Asia tend to use less energy than other sub-regions. These imply that the demand in energy to supply to production and consumption in Northeast Asian countries such as China, Japan, and the Republic of Korea is still increasing. These also reflect scarcity in natural resources in these economies. According to estimation of the Institute of Energy Economics in Japan (IEEJ), by 2030, energy consumption of Northeast Asia is predicted to reach 3,963 Mtoe, which accounts for nearly 25 percent of the world's total energy consumption. In the same time, coal consumption of China is forecasted to increase by 44 percent and coal imports of this country is expected to reach 3 percent. Oil consumption of China is estimated to rise by doubled to reach 758 million tons [6]. China currently is the largest energy consumer in the world [9]. Although China has emphasized to construct the energy security strategy which relies on domestic resources, but oil and gas outputs have failed to meet consumption growth because of resource shortages. Thus, this country has to chase a policy of using domestic and oversea resources and markets. In order to diversify energy resource supply sources, China develops friendly relations to oil producing countries such as Saudi Arabia and the United Arab Emirates in the Middle East. Moreover, China has consolidated traditional relations with Iran and participated to Iraq's postwar restoration to ensure establishing a stable crude oil supply source [29].

By contrast, countries in Southeast Asia use less energy than their counterparts. According to estimation of the International Energy Agency (IEA), in Southeast Asia, about 65 million people are still unable to access electricity and 250 million rely on solid biomass as a cooking fuel in total of 640 million people. Investment in upstream oil and gas has been harmed because of lower prices since 2014 and the region must depend more on imported oil [30].

Our findings are consistent with conclusions of Munim et al. (2010) [10], Nasab et al. (2012) [11], Sadorsky (2014) [21], and Shaari et al. (2014) [22] because these studies argued that the increase in energy use positively affects economic growth in Asian countries. However, degradation in environment has been an adverse consequence of over-exploitation in natural resources and a fast growth of the economy.

## 5. CONCLUSION AND POLICY IMPLICATIONS

The research aims to investigate impacts of determinants on energy use in 13 Asian countries for the past two decades (1996-2015) by employing a panel dataset. We found that electric power per capita, fossil fuel consumption, fuel exports, and GDP per unit of energy use have positives influences on energy use in Asia. However, fuel imports and investment in energy with participation of the private negatively affects energy use in this region.

Our results also addresses that energy use in Asian countries still heavily depends upon fossil energy such as coal, oil, and natural gas. Countries, where have higher fuel exports and GDP per unit of energy use, often present higher energy use compared to their counterparts. Our findings state that economic growth is a positive motivation in terms of enhancing energy use in Asia. We also demonstrate that Northeast Asian countries consume more energy than other sub-regions, while energy consumption of Southeast Asia is lower than that of their counterparts.

Energy demand in almost sub-regions of Asia is predicted to increase in the future. For instance, energy consumption of Northeast Asia is forecasted to reach 3,963 Mtoe, accounting for nearly 25 percent of the world's total energy consumption by 2030 [6]. The Chinese government believes that "One Belt, One Road" initiative will play an important contribution to the energy security strategy. In fact, "One Belt, One Road" initiative includes both domestic and oversea components and therefore it affects energy cooperation between China and other countries in Asia. The main purpose of the oversea component is the diversification of import sources, import routes, and energy sources. For example, China has completed to construct three natural gas pipelines from Turkmenistan via Uzbekistan and Kazakhstan from December 2009 to May 2014 and the fourth pipeline has been started building in September 2014. If four pipelines complete in 2020, these can convey 85 billion cubic meters of natural gas annually. Indeed, China has intended to construct a pipeline connecting this country to Iran via Pakistan and Afghanistan [29]. By 2040, Southeast Asia's energy demand is predicted to grow by almost two-thirds, in which coal alone accounts for nearly 40 percent of the growth, oil demand increases from 4.7 million barrels to around 6.6 million barrels per day, and natural gas is also estimated to rise by about 60 percent [30]. Currently, energy demand in the Middle East and North Africa (MENA) rises by more than 5 percent annually, especially in electricity [31]. In addition, Central Asian countries are challenging by low prices for oil and gas, economic dependence, and political pressure because of dependence on Russian pipeline network in exporting oil and natural gas [7]. Therefore, in order to ensure energy security along with enhancing economic growth, it is necessary for countries in Asia to cooperate in the energy sector. For example, South Asian countries have vast potentials to cooperate in the energy sector because India, Pakistan, and Bangladesh account for the major natural gas and coal resources, while Bhutan and Nepal have large hydropower resources [32]. Regional cooperation should be enhanced because it assists to ensure not only energy security but also energy affordability. In which, the win-win model in energy cooperation among countries can be seen as the core of successful integration. For instance, renewables or clean coal in Kazakhstan, and the energy-water exchange in Central Asia. In Southeast Asia, Cambodia, Indonesia, Lao PDR, Myanmar, Singapore, and Viet Nam may increase the diversification of their power systems through regional integration [5].

Lastly, regional energy security in the Asia-Pacific requires a multilateral approach because it is a complex issue, which faces multiple challenges, including reduction of dependence on fossil fuels and/or securing an adequate alternative supply to meet rising demand, demonstration of the environmental impact of the region's energy use, and implementation of specific policies to improve the regional energy infrastructure and transportation networks. Thus, multilateral initiatives are preferable to either unilateral or bilateral efforts [17].

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