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Abstract. The ASEAN region has been experiencing a robust economic growth in the past decades and the economy is expected to expand further for the next few decades. To satisfy the thirst brought about by the economic growth, primary energy demand in the region is expected tripled its value, mainly due to progress of industrialization and motorization. An increase of energy requirement in the region will necessitate some of the energy demand to be met through imported energy sources. This highly dependency of energy import resources is a signal to policy makers to address the burgeoning concerns of the energy issues in the region. Therefore revising existing and formulating new policies are crucial to improve the energy supply security of the region. This paper looks into the challenges of the energy security in Southeast Asia by identifying the energy gaps challenges on the availability of energy resources and the energy supply and demand projection up to 2050. Finally this paper will discuss on the issues on energy governance in the region for the purpose of enhancing its energy security level.

1. Introduction

The Association of Southeast Asian Nations (ASEAN) consist of 10 countries namely Cambodia, Laos, Myanmar, Thailand, Vietnam, Brunei Darussalam, Malaysia, Indonesia, Philippines, and Singapore. The level of economic development in each country is very different from each other and most of the countries have a vastly different pattern of energy supply and demand. This ASEAN region as a whole is relatively well endowed with various energy resources however the energy resources are not evenly distributed. As the population and energy demand continues to increase and existing fuel supplies begin to run out, most ASEAN countries will have to find ways to tackle their country energy security.

Energy security is defined as "the ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of an economy" [APERC, 2007]. It is divided into four main elements namely availability, accessibility, affordability and acceptability. Availability element relates to geological existence of energy resources, accessibility elements relates to geopolitical factors, affordability elements relates to the economical aspects of the energy resources, while acceptability elements relates to the environmental impacts of energy resources life cycle [Winzer, 2012].

In this paper, the challenges of the energy security concerns in the ASEAN region resulting from the decrease of domestic production of energy resources and increase of energy demand to fuel its economic activities are discussed and suggestions on how to enhance energy security level in ASEAN region is presented.

2. Energy Supply and Demand and Economic Indicators

The main drivers that cause increase in energy demand are economy (i.e., GDP) and population [C.S. Tan et al., 2013]. For the past decades, ASEAN region has experienced a buoyant economic growth, and it is expected that the economy will expand further in the next two decades. The GDP is expected to quadrupled from 2015 to reach USD 10,390 billion at 2010 price in 2050, at 4.2% average annual growth rate. The population growth in the region is statistically estimated to growth at 0.6% annually from 2015 to 2050 as shown in Table 1.

Table 1. Energy and economic indicators

Energy and Economic Indicators	Year							AAGR (%)
	1980	1990	2000	2015	2030	2040	2050	2015-2050
GDP ($2010 billion)	440	741	1180	2490	4955	7383	10390	4.2
Population (million)	347	430	505	608	696	736	761	0.6
CO2 emissions (Mt)	205	362	711	1288	2111	2812	3602	3.0
GDP per capita ($2010 thousand)	1.3	1.7	2.3	4.1	7.1	10	14	3.5
Primary energy Supply per capita (toe)	0.4	0.5	0.8	1.0	1.4	1.7	2.0	2.0
Primary energy Supply per GDP[a]	323	314	322	249	198	171	149	-1.5
CO2 emissions per GDP[b]	466	489	602	517	426	381	347	-1.1
CO2 per primary energy consumption[c]	1.4	1.6	1.9	2.1	2.1	2.2	2.3	0.3

[a] toe/$2010 million.[b] t/$2010 million.[c] t/toe
Source: IEEJ (2017).

Table 2 shows the total primary energy supply is projected to increase from 621 Mtoe in 2015 to 1,544 Mtoe in 2050, growing at an average rate of 2.6% annually and it also shows ASEAN remain heavily dependence on fossil fuel in the years to come. Fossil fuel sources are expected to contribute almost 80% of the total primary energy supply in 2050. The high dependency on fossil-fuels coupled with the dwindling domestic fossil-fuel reserves will definitely compel the member countries to import more fossil-fuels at a high market price where the fuel price is volatile if thorough balanced fuel mix diversification is not carefully consider [Endang et al., 2013]. Due to rapid motorization in the region, oil is still expected to remains as the main source of fuel albeit at a decreasing share from 38% in 2015 to 32% in 2050 at the rate of2.5% per year from 2015 to 2050. Meanwhile it is projected the share of natural gas will increase from 13% in 2015 to 22% in 2050 growing at rate of 2.6% per year from 2015 to 2050. Among the fossil fuel sources, coal is expected to grow at a higher rate of 3.6% per year from 2015 to 2050 due to its high demand of coal consumption in power sector. Encouragingly, renewable energy is expected to grow at the fastest rate in the same period reflecting the active deployment of renewable energy sources in the region.

Table 2: Primary Energy Supply in ASEAN countries

Primary energy consumption	Mtoe							Shares (%)			AAGR (%)
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015-2050
Total	142	233	379	621	982	1259	1544	100	100	100	2.6
Coal	3.6	13	32	114	217	300	398	5.4	18	26	3.6
Oil	58	89	153	210	305	394	493	38	34	32	2.5
Natural Gas	8.6	30	74	140	216	280	344	13	23	22	2.6
Nuclear	-	-	-	-	2.2	14	23	-	-	1.5	n.a.
Hydro	0.8	2.3	4.1	9.2	18	20	22	1.0	1.5	1.4	2.6
Geothermal	1.8	6.6	18	27	79	99	109	2.8	4.3	7.0	4.1
Solar, wind, etc	-	-	-	0.3	2.3	4.9	9.4	-	0.1	0.6	9.9
Biomass and waste	70	93	98	119	141	145	143	40	19	9.2	0.5

Source: IEEJ (2017)).

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Table 3: Final Energy Demand in ASEAN countries

Final energy demand	Mtoe							Shares (%)			AAGR (%)
	1980	1990	2000	2015	2020	2030	2050	1990	2015	2050	2015-2050
Total	112	173	270	436	645	817	1006	100	100	100	2.4
By sector											
Industry	22	43	75	125	198	257	318	25	29	32	2.7
Transport	17	32	61	117	170	215	270	19	27	27	2.4
Buildings, etc.	71	87	113	147	211	262	317	50	34	32	2.2
Non-Energy Use	2.4	11	21	47	66	83	101	6.3	11	10	2.2
By energy											
Coal	2.1	6.0	13	34	50	61	70	3.5	7.8	7.0	2.1
Oil	41	67	123	193	285	370	468	38	44	47	2.6
Natural Gas	2.5	7.5	17	37	62	83	104	4.4	8.6	10	3.0
Electricity	4.7	11	28	68	129	183	249	6.4	16	25	3.8
Renewables	61	82	89	104	118	119	115	47	24	11	0.3

Source: IEEJ (2017)

Meanwhile, Table 3 shows that the total final energy demand by 2050 is projected to increase from 436 Mtoe in 2015 to 1,006 Mtoe in 2050, growing at an average rate of 2.4% annually. The final energy demand by sector shows that the industry and buildings sectors contribute the highest energy demand at the share of 32% each respectively, in the region by 2050 (i.e., rapid industrialization) follows by transport sectors at 27%. By fuel type the oil is projected to be the major contributor of final energy demand with 47% of the total share by 2050; mostly used in transport sector followed by electricity at 25%, renewable energy at 11%, natural gas and coal at 10% and 7% respectively.

3. Energy Security in Southeast Asia

3.1 Energy reserves by country

The ASEAN region is relatively well endowed with conventional energy resources, namely oil, gas and coal; however the resources are unevenly distributed among the countries and sometimes located far away from the demand centres. Based on [ACE, 2017], in 2015, ASEAN region produced a total of 2.4 million barrels of oil per day and the oil production is expected to decrease at a rate of 1.4% per year from 2015 to 2040, which results in 1.6 million barrels of oil production per day by 2040. This decreasing trend is mainly due to the mature oil fields that were in their decline phase. As for natural gas production, ASEAN region has produced a total of 205 billion cubic meter of natural gas in 2015 and that volume is expected to decrease at a rate of 0.6% per year reaching at 177 billion cubic meter by 2040. It is worth to take note that the trends of natural gas production varies among the member countries, for example annual natural gas production in Brunei Darusssalam is expected to stable while the production in Indonesia is expected to face a slightly decreasing trend and natural gas production is Viet Nam is expected to increase. Finally, the coal production in ASEAN region is expected to increase in 2040, at 487 million tonnes from 434 million tonnes of coal in 2015. Majority coal production are from Indonesia.

Apart from the abundant of conventional fossil-fuel, the region is also relatively well endowed with renewable energy sources particularly in hydro and solar as well other type of renewable energy, albeit the level and type of renewable may differs from one country to the others. This region has set out a target to contribute 23% of its primary energy supply from renewables by 2025 [IRENA & ACE, 2016]. Therefore it is challenging to see how and what member countries can contribute in meeting the target set.

3.2 ASEAN energy demand and supply through to 2050
Table 4 shows the total final energy demand, total primary energy supply and total electricity production by the ASEAN member countries between 2015 and 2050.

Table 4: Total Final Energy Demand, Total Primary Energy Supply and Total Electricity Production

	Total final energy demand (Mtoe)				Total primary energy Supply (Mtoe)				Total Electricity production(TWh)			
	2015	2030	2040	2050	2015	2030	2040	2050	2015	2030	2040	2050
Indonesia	163	245	314	382	225	394	511	619	234	520	762	1035
Thailand	98	122	144	168	135	174	210	245	178	260	341	422
Vietnam	58	96	128	167	74	128	178	240	153	320	487	716
Philippines	30	58	82	114	52	97	132	175	82	186	287	434
Malaysia	52	71	82	92	86	120	142	158	150	250	321	388
Myanmar	18	31	43	59	20	35	50	69	16	66	103	149
Other ASEAN	17	22	24	24	29	34	36	38	55	68	73	76

Sources: IEEJ (2017).

The projection shows that in 2050, Indonesia, Thailand and Vietnam have the highest total final energy demand with 382Mtoe, 168Mtoe and 167Mtoe respectively followed by Philippines, Malaysia and Myanmar with 114Mtoe, 92Mtoe and 59Mtoe respectively. Overall, ASEAN member countries shows an increase of final energy demand between 2015 and 2050. In term of electricity generation, in 2015 Indonesia is the biggest electricity producer in the region with a total electricity produced was 234TWh and it is projected to increase more than fourfold in 2050 to 1,035TWh. The second largest electricity producer in the region is Thailand, followed by Viet Nam, Malaysia, Philippines, Myanmar and other ASEAN.

3.3 ASEAN energy import/export by 2030
With the rapid industrialization in the region, energy trades is seen to help in filling up the lack of energy sources availability among ASEAN countries to meet its demand. Table 5 shows the net energy import by each ASEAN member countries between 2010 and 2030. It should be noted that a country with a negative net import reflecting that the country is actually a net exporting country. This indicator helps to determine the possibility of securing the energy supply within the region through existing and future energy infrastructure interconnection.

Table 5: Net Coal, Oil, Natural Gas and Electricity Imports

	Net Coal import (Mtoe)			Net Oil import (Mtoe)			Net Natural Gas import (Mtoe)			Net Electricity import (Mtoe)		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Brunei Darussalam	0	0	0	-7.54	-6.66	-5.09	-7.99	-7.1	-5.6	0	0	0
Indonesia	-142	-196	-279	19.28	53.63	98.74	-27.06	-6.5	36.2	0	0	0
Thailand	10.02	14.95	17.56	34.5	49.32	69.74	4.16	11.2	19.3	0.49	2.63	3.85
Malaysia	9.37	14.05	11.99	-7.7	11.45	25.16	-21.81	-36	-32	-0	-0	-0.02
Philippines	2.87	7.74	18.59	13.72	17.1	25.14	0	0	0	0	0	0
Singapore	0.12	0.63	0.49	56.8	72.15	85.13	7.82	8.91	9.5	0	0	0
Vietnam	-7.7	-4.03	7.45	-2.96	6.48	23.09	0.22	-1.7	9.34	0.48	0.69	0.69

Note: Statistics for Cambodia, the Lao PDR and Myanmar are not readily available. Projection up to 2050 is not available.
Source: APERC (2013).

As tabulated in Table 5, Indonesia remains a major coal exporter in the region between 2010 and 2030. On the other hand, Thailand, Malaysia, Philippines and Singapore are net importers of coal until 2030. Brunei Darussalam is projected to remain as net oil exporter between 2010 and 2030 and the rest ASEAN member countries remain as net oil importer by 2030. Interestingly to note, Malaysia and Vietnam will changes its position from net oil exporter in 2010 to net oil importer by 2020.

In terms of natural gas, Brunei Darussalam and Malaysia are expected to remain as net exporters between 2010 and 2030. However, Indonesia and Vietnam are expected to change their position from net exporters of natural gas in 2020 to become net importers of natural gas by 2030. Thailand and Singapore is expected to remain as the natural gas importers. On the net electricity import, Thailand

and Vietnam are projected to remain as net importers of electricity through to 2030. On the other hand, Malaysia will remain as net exporter of electricity which is insignificant.

4. Energy Gap Challenges in Southeast Asia

The above analysis shows that there are several energy security concerns in the region that need to be addressed. The concerns of energy demand and supply gap are mainly contributed from the following three factors:

4.1 Rapidly increasing of energy demand

The total primary energy supply is expected to increase 2.5 times in the projection period, increasing from 621 Mtoe in 2015 to 1,544 Mtoe in 2050, growing at an average rate of 2.6% annually.

4.2 Over-dependency on fossil-fuel resources to meet energy demand

The share of fossil fuels in the total primary energy supply is expected to remain high throughout the projection period, with the share estimated to be around 80% by 2050. The high dependency on fossil-fuels coupled with the dwindling domestic fossil-fuel reserves will definitely compel the member countries to import more fossil-fuels at a high market price where the fuel price is volatile if thorough balanced fuel mix diversification is not carefully consider.

4.3 Increasing dependence on energy imports due to depleting domestic resources

Increasing demand for fossil fuels, coupled with the depleting domestic fossil fuel reserves, is expected to result in net import by ASEAN member countries'. This trend is particularly worrying for oil: net oil import for Indonesia is projected to quadruple from 19.28 Mtoe net oil import in 2010 to 98.74 Mtoe net oil import in 2030; net oil import for Malaysia is expected to triple from a negative 7.70 Mtoe (net exporter) in 2010 to 25.16 Mtoe net oil import in 2030; net oil import for Thailand is expected to double from 34.50 Mtoe net oil import in 2010 to 69.74 Mtoe net oil import in 2030; Similar to Malaysia, Vietnam will change from being a net oil exporter in 2010 to become a net oil importer in 2030. ASEAN countries are showing vulnerability signs on its energy security with the increasing dependency on fossil fuels import and compounded by the nature of oil market and contracts that normally allow for greater price volatility.

5. Governing Energy Resources in Southeast Asia

With a strategic options governing energy resources in the ASEAN region, it could also act as potential mitigation measures to address the energy security concerns in the region. These measures can be segregated into the following five main segments namely:

5.1 Diversifying sources of energy supply

Intensifying indigenous gas and hydro resources development, securing more gas from foreign sources, strengthening and expanding supply infrastructures to facilitate regional interconnection and exploring and building capacity for the nuclear options. Promote the use of renewable energy such as solar and wind where the energy resources is abundant.

5.2 Reducing carbon content of energy

Introduction of nuclear power plant; expansion use of decentralized and centralized renewable energy-based power generation; and utilization of bio-energy in transport sector and industry sector. Even though currently the prices for green technology remain high as compared to conventional technology, nevertheless with further R&D in the area of renewable energy technology, it will bring down its cost and be more competitive.

5.3 Efficient utilization of energy

Improvements in energy efficiency and conservation both in the supply and demand sectors; moving towards a low-energy intensive industry; transition to service-based economy; improvements in the transportation sector, i.e. efficiency and modal shifts; and introduction of smart and green cities. Promotion the use of public transport will help to reduce GHG emissions through human behavioural change. Similarly, shifting from private vehicles to public transport system utilization such as railways and buses will greatly reduce GHG emissions with better connectivity to and from and transfer systems between cities, shops, shopping and culture centre for passengers should be improved and provided. Emphasis on the smart cities concept and use of information and communication technologies (ICT) to deliver it services in a more intelligent way with its resources availability will helps in cost and energy savings, improved service delivery and quality of life as well as reduced environmental footprint [Endang et al., 2012].

5.4 Facilitating low-carbon industries and service development to promote economic growth
Introduction of Feed-in Tariff Mechanism; manufacturing high energy efficiency products for example LED or PV-LED, smart grid system and smart metering products; and promoting energy efficiency improving services. The skilled and highly skilled human capital in a wide variety of different specialized disciplines is required and needed for the success of low carbon economy environment. This is because developing and adopting low carbon economy will require proper formulating of legislation and policy, law and political science, appropriate technological training and education specializing in low carbon economy to ensure work forces such as scientists, engineers, climatologists and energy and climate experts to meet the industry's needs.

5.5 Regional interconnection of energy supply infrastructure and resources
Facilitate regional interconnection is one of the key measures for diversifying the energy supply. ASEAN member countries could cooperate and working together with each other's through interconnecting arrangements for electricity, natural gas and water such as Trans- ASEAN Gas pipelines and ASEAN Power Grids. Promote cooperation in energy efficiency and conservation as well as development of new and renewable energy resources".

6. Conclusions
This paper has highlighted the key challenges of energy security concerns in most ASEAN countries and several mitigation measures to address the energy security issues face by ASEAN countries are proposed. Even though the level of economic development and energy demand in each ASEAN countries are different, nevertheless the issue concerning the energy security facing by all the ASEAN countries still remain the same.

The main issue facing by all the ASEAN countries for decades are mostly on how to reduce the energy demand and supply gap contributed mainly from the rapid increase of energy demand; over-dependency on fossil-fuel resources to meet energy demand; and increasing dependence on energy imports due to depletion of domestic resources. Government policy towards energy security through fossil fuel diversifying sources of energy supply, promoting green economy and collaboration in the regional interconnection of energy supply infrastructure and resource will greatly help to reduce energy security in the country.

Therefore, it is very important for ASEAN countries to closely work together to solve the common energy security issues in the region to ensure sustainable of energy in the near future.

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