SUSTAINABILITY CHALLENGES FOR ELECTRICITY INDUSTRIES IN ASEAN NEWLY INDUSTRIALIZING COUNTRIES

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ABSTRACT
The region of the Association of Southeast Asian Nations (ASEAN) is one of the fastest developing regions in the world. Strong economic and social development have contributed to rapid growth in electricity consumption within this region, which whilst representing significant societal progress has potentially growing adverse environmental impacts. This study evaluates some key challenges in the electricity industries of five ASEAN newly industrializing countries: Indonesia, Thailand, Malaysia, the Philippines and Vietnam. The framework for this study is the 3A's energy sustainability objectives: Accessibility, Availability and Acceptability introduced by the World Energy Council. The key sustainability challenges in these countries are generally attributable to satisfying rapid demand growth; enhancing security of electricity supply; and mitigating the increase in CO_2 emissions as a result of electricity consumption. We assess the status of the electricity industries in these countries against a range of performance indicators for these challenges. Our study highlights some of the key issues facing governments, the electricity industry and investors, and the need for new decision support tools to guide electricity sector development.

KEY WORDS
Energy sustainability, electricity industries in ASEAN, electricity industry investment.

1. Introduction

Sustainable development, as defined by the Brundtland Commission, is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs [1]. There are continuing debates about whether sustainability is better seen as a desired end point or, rather, process of improvement. It has also proved a difficult concept to implement in practice. What is clear is that energy sustainability has vital social, economic and environmental dimensions. In terms of social sustainability, energy is a basic need which can greatly improve our quality of life. In sustainability's economic dimension, energy availability is a key driver in economic welfare. Of particular relevance to this paper, access to modern energy services such as electricity at an affordable price is essential to poverty eradication and economic development within developing countries [2]. Environmentally, the world's present energy systems are key drivers of some of our greatest environmental challenges including, of course, climate change. The global electricity sector is the largest single contributor to anthropogenic greenhouse gas emissions due to its heavy reliance on fossil fuels [3].

Countries within the Association of Southeast Asian Nations (ASEAN) have been identified as playing an increasing important role in future world energy demand in the next few decades due to their rapid economic expansion, large population size, and consequent growing energy consumption. It is predicted that the total investment in the power sector in the ASEAN region in the next twenty years would amount to $0.6 trillion despite the financial crisis [4]. Five ASEAN member countries: Indonesia, Thailand, Malaysia, the Philippines and Vietnam, referred as the ASEAN-5, are currently the five largest energy consumers in ASEAN, which account for more than 80% of ASEAN total primary demand, and are projected to account for more than 75% of incremental energy demand through to 2030 [4]. Countries in the ASEAN-5 possess some important similarities in both their economic and social development status. These countries have strong economic growth prospects and large populations. Rapid economic growth and social development have implications for energy and environmental situations since economic activities are the main driver in energy consumption [5]. Increases in energy consumption given current energy infrastructure almost always lead to higher greenhouse gas emissions. Therefore it is important that energy development in these countries progresses in a sustainable manner - that is to ensure adequate and affordable access to energy for present and future generations in an economic viable, socially acceptable and environmentally sound manner.

This paper aims to evaluate and identify key sustainability challenges for the electricity industries in the ASEAN-5. This study adopts the energy sustainability framework introduced by the World Energy Council (WEC) to identify key sustainability challenges based on energy sustainability objectives of accessibility, availability and acceptability in the ASEAN-5.

In the next section, we briefly describe the social and economic context of the ASEAN-5. The detail of the energy sustainability framework used in the paper is presented in section 3. Section 4 presents the

sustainability analysis in the electricity industries of the ASEAN-5. Key challenges in electricity industries of these countries are summarized in section 5 and followed by the conclusion in section 6.

2. Social and economic context of ASEAN-5

Thailand, Indonesia, Malaysia, the Philippines and Vietnam have a total population of nearly 500 million people [6]. These five countries have a rapid rate of urban growth of around 1.7-3.4% per year [7]. Generally urbanization is high in the fast developing countries since levels of urbanization is closely linked to economic growth where better economic opportunities and access to services in the cities attract migrants from rural areas [7]. In terms of human development, according to the United Nations based in the Human Development index, all of the countries in the ASEAN-5 are classified in the medium human development category, except Malaysia which is in the high human development category [8].

The ASEAN-5 has achieved a strong economic growth over the past few decades. Figure 1 shows the GDP growth rate of the ASEAN-5 compared with the OECD.

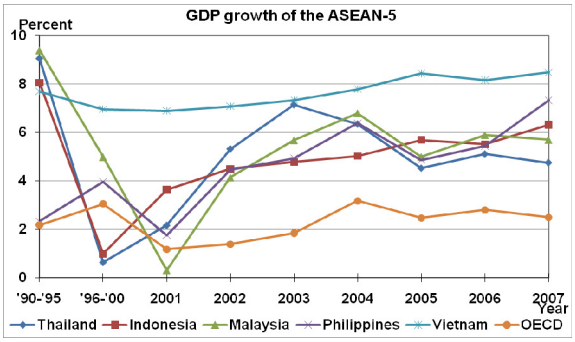

Figure 1. GDP growth rate in the ASEAN-5
Data Source: World Bank [9]

After the Asian economic crisis in the late 1990's, these five countries have been able to maintain economic growth at the rate between 4-8 percent with Vietnam being the country with the highest growth of around 8% over the past twenty years.

The proportion of sectoral value added to GDP of the ASEAN-5 and the OECD are shown in figure 2.

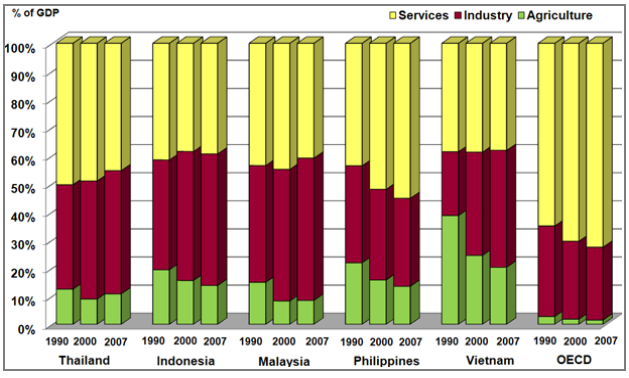

Figure 2. Share of sectors in GDP during 1990-2007
Data Source: World Bank [9]

Other than the Philippines, the trend of industry value added in these countries is gradually increasing since 1990 at the expense of the agriculture and service sectors. The share of GDP from the industry sector in 2007 for every country, except the Philippines, is accounted for almost half of the total GDP whereas in the OECD, industry value added accounted for only about 25% of total GDP. Higher contributions of industry sector value added to GDP indicates, of course, that the country is moving towards industrialization [10].

In conclusion, the ASEAN-5 economies can be characterized by rapid economic growth, a high contribution of industry value added to GDP, high level of foreign direct investment, and recent substantial increases in per capita income. There is strong evidence that these five countries are moving towards industrialization. In developing countries, increasing population, urbanization, economic growth and rapid industrialization constitute the major factors of growth in electricity demand [11].

3. Energy Sustainability Framework

3.1 Energy Sustainability Objectives

The framework for assessing sustainability in the electricity sector in this study is based on the 3A's energy sustainability objectives proposed by the World Energy Council (WEC) which are;

- **Accessibility** – is the provision of modern energy services at a socially affordable price for all. It has been argued in this regard that prices should reflect the true marginal costs of production, transmissions and distribution to enable utilities to maintain and develop energy services [12]. Furthermore prices should reflect the external costs due to emissions and waste management [13].
- **Availability** - is related to long-term continuity of supply and short term quality of service. It is argued that a well diversified portfolio of domestic or imported traded fuels and energy services is required in this regard. The key to achieve this is to keep all energy options open [12].
- **Acceptability** – relates to public attitudes and the environmental impacts at the global and local levels. Climate change is the most serious longer-term environmental threat and arises from the use of fossil fuels. This sustainability dimension also includes social concerns regarding nuclear security. Various electricity generation technologies can also have other significant adverse environmental impacts including regional air pollution associated with fuel combustion, and land-use change from options such as large-scale hydro [12].

3.2 Energy sustainability indicators and criteria

A set of indicators can be used to assess the current state of achieving sustainability and/or monitor the progress towards energy sustainability objectives. The International Atomic Energy Agency (IAEA) has established a comprehensive set of energy indicators for sustainable energy development which addresses important issues in three major dimensions of sustainable development: economic, social and environmental [14]. Relevant Indicators within the proposed set of indicators

can be selected to fit specific objectives and context of the electricity industry in each country or region.

In this study, a set of indicators and criteria, both quantitative and qualitative, are selected for each aspect of the 3A's energy sustainability objectives in order to analyze the current state as well as key sustainability challenges in the electricity industries in the ASEAN-5. These indicators are considered to be appropriate for the context of the electricity industry in these countries. However, these indicators only provide some guidance since there are no standard benchmarks for the value of these indicators.

3.2.1 Accessibility indicators

Accessibility is referred to as the access to electricity at affordable prices in a sustainable manner, which reflects the true marginal costs of electricity generation, transmission and distribution. The indicators chosen include electrification rate, electricity tariff, expenditure on electricity, per capita electricity consumption growth and electricity intensity. The level of electricity intensity could have several implications such as a change in energy efficiency, the structural change of the economy, and the penetration of electricity equipment and appliances as well as the utilization of existing appliances [10]. Another qualitative criterion considered for this aspect is the electricity tariff subsidy. Although subsidies can accelerate electricity access among lower income groups, the subsidy burden can lead to deficit in the national budget which costs many countries as much as 1 percent of GDP [15]. Non-cost reflective tariffs could also create price distortions since it may lead to inappropriate end-user and supply decision making.

3.2.2 Availability indicators

Availability reflects the energy security aspect since it relates to long-term continuity of supply and short term quality of supply. Unreliable electricity supply arises from insufficient generation capacity, lack of electricity access and inefficient systems hinder economic growth and productivity of the country. The cost of power outages in some countries can be as high as 1-2% of GDP [15]. The indicators selected to measure the quality of supply are reserve margin, the System Average Interruption Frequency Index (SAIFI), and the System Average Interruption Duration Index (SAIDI). The reliability operating standard for maintaining operating reserve margin is another qualitative criterion.

With regard to long term security of supply, the indicators and criteria selected are the share of fuel mix in electricity generation, reliance on import fuel for electricity generation, cross-border interconnections. Heavy reliance on particular types of fuels would have serious potentially consequences for energy security. Security of supply can also be measured based on diversity which might refer to fuel type, fuel sources by geographic regions or supplier, or technology types [16]. Diversifying energy resources can reduce the risks arise from fuel price fluctuation as well as physical supply interruption. The Shannon-Wiener Index (SWI) can be used as a quantifiable indicator to measure diversity of fuel types for electricity generation. SWI has been argued to represent the most useful index, and has the following mathematical expressions [16-17]:

$$H = -\sum_i p_i . \ln p_i \quad (1)$$

where p_i is the proportion of electricity generation from fuel source i.

Higher values of SWI imply greater diversity. It has been suggested that a value of below 1.0 indicates a highly concentrated system and a value above 2.0 implies a system with numerous sources [16].

3.2.3 Acceptability indicators

Acceptability addresses public attitudes and environmental concerns which cover various issues such as air pollution, climate change and greenhouse gas emissions, and nuclear security. The indicators selected for the acceptability aspect focus particularly on CO_2 emissions from the electricity sector. The increase in electricity consumption leads to the increase in emissions, particular in countries that rely heavily on fossil fuels. The CO_2 emissions from the electricity sector have increased at faster rates than global emissions. In 2007, the electricity sector produced around 40% of the global CO_2 emissions compared to 27% in 1971 [2]. The quantitative indicators chosen include CO_2 emissions from the electricity sector per capita and CO_2 intensity both in terms of economic output (CO_2/GDP) and electricity generation (CO_2/kWh). The CO_2 intensity of electricity generation depends largely on the type of fuels that are used to generate electricity and on the share of low and non-emitting sources such as gas, hydro, nuclear, and renewable energy [18]. It is also important to consider the strategy for nuclear power and renewable energy policy of each country since they have environmental and social implications.

Table 1 provides a summary of indicators for each aspect the 3A's energy sustainability objectives.

Table 1
Summary of selected sustainability indicators

3A's Energy objectives	Criteria	Indicators
Accessibility	Affordable price	1. Electricity prices
		2. Expenditure on electricity
		3. Electricity tariff subsidy
	Energy Services	1. Electrification rate
		2. Electricity Intensity
		3. Electricity consumption per capita
Availability	Quality of supply	1. Reserve Margin
		2. Supply reliability indices
		3. Reliability operating standard
		4. cross-border interconnection
	Continuity of Supply	1. Fuel mix in electricity generation
		2. Reliance on import
		3. The SWI to measure diversity
Acceptability	Safety	1. Strategy for nuclear power
	GHG Emissions	1. Renewable energy policy
		2. Share of renewable energy sources
		3. CO_2 emission/capita
		4. CO_2 intensity

4. Energy sustainability in ASEAN-5

The indicators and criteria chosen for each aspect of the 3A's energy sustainability objectives are applied to the ASEAN-5 in order to assess the current state of energy sustainability in terms of accessibility, availability and acceptability. However due to the limited availability of data and information, not every indicator and criteria selected will be applied.

4.1 Accessibility

Electricity access in the ASEAN-5 has been improving over the past decades with Thailand and Malaysia being able to provide nearly 100% electricity access. These countries also continue to progress towards providing electricity access to rural population. Table 2 shows electrification rate of each country in ASEAN-5 in 2008.

Table 2
Electricity access in 2008

Country	Electrification rate (%)		
	Total	Urban	Rural
Thailand	99.3	100	99.0
Indonesia	64.5	94.0	32.0
Malaysia	99.4	100	98.0
Philippines	86.0	97.0	65.0
Vietnam	89.0	99.6	85.0

Source: IEA [19]

Urban electrification rates in all five countries are fairly high with Indonesia being the lowest at 94%. Increased urbanization has also contributed to the improvement in the electricity access in urban area [19]. Rural electrification rate in Indonesia and the Philippines are the lowest, which are 32% and 65% respectively. This is due in large part to geographical barriers since Indonesia and the Philippines contain numerous small islands which makes it difficult to implement cost effective large scale grid systems. Rural electrification is a key priority for Indonesia and the Philippines in order to alleviate poverty and support economic growth.

Every country, with the exception of the Philippines, provide subsidies for electricity prices, particularly Indonesia [4] as reflected by its relatively low electricity tariffs compared with other ASEAN member countries (table 3).

Table 3
Electricity tariff year 2005

Country	Electricity tariffs ($US/kWh)		
	Residential	Commercial	Industry
Thailand	0.051	0.053	0.051
Indonesia	0.028	0.038	0.027
Malaysia	0.071	0.064	0.064
Philippines	0.073	0.071	0.074
Vietnam	0.052	0.085	0.079
OECD	0.124	0.078	

Sources: ASEAN energy; IEA [20]

Subsidized electricity prices do not reflect the true marginal costs, and it may not be sustainable in the long run if subsidy policies lead to deficit in the national budget. Subsidies will often have significant adverse effects due to revenue shortfall which prevents the electric utility to undertake necessary investment to increase the generation capacity [12]. Indonesia is a good example since its non-cost reflective tariff is a major factor which hinders generation investment resulting in supply shortages [21]. Although the purpose of the subsidized electricity tariff has historically been to increase electricity affordability, especially for the poor, it needs to be arranged in a sustainable manner that would not prevent electric utilities to maintain their services.

Figure 3 and 4 shows the electricity consumption per capita and the electricity consumption growth rate of these five countries since 1990 respectively.

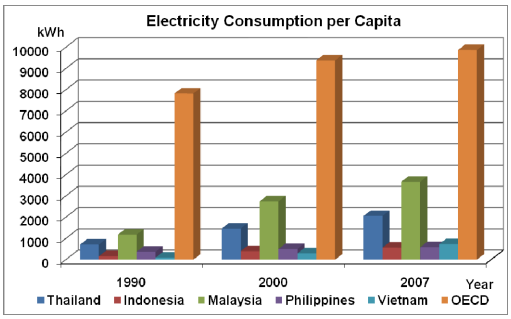

Figure 3: Per capita electricity consumption
Data Source: World Bank [9]

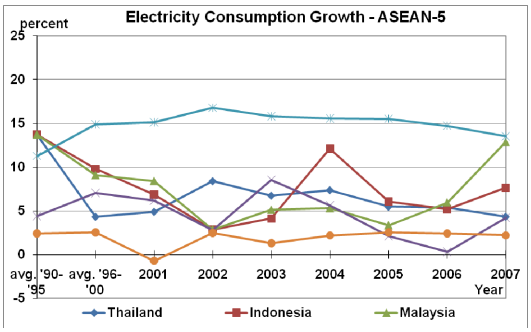

Figure 4: Electricity consumption growth rate
Data Source: World Bank [9]

The average electricity consumption growth in these countries is between 6 – 15%, which is higher than that of OECD average, which is around 3%. However, the average electricity consumption of the OECD is still considerably higher than those of the ASEAN-5. Vietnam has the highest growth in electricity consumption which is around 15% due mainly to its strong economic growth. In 1990, per capita electricity consumption in Vietnam was the lowest among these five countries but its per capita consumption in 2007 has exceeded those of Indonesia and the Philippines. This suggests that Vietnam is fast progressing in terms of affordability and accessibility since higher electricity consumption implies greater affordability and accessibility [10].

Figure 5 shows the electricity intensity per unit of GDP adjusted 2005 purchasing price parity (PPP) US dollars. The electricity intensity reflects the ratio of electricity consumption to economic output. Generally, the electricity intensity of the ASEAN-5 is on the rise, which implies that electricity consumption growth has outpaced the economic growth. This is opposite to the OECD in which the electricity intensity has been declining.

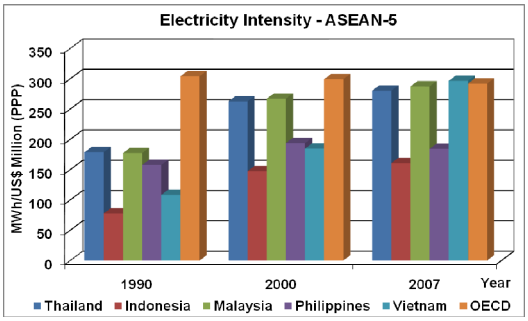

Figure 5: Electricity intensity per unit of GDP
Data Source: World Bank [9]

The increase in electricity intensity does not necessarily mean a decrease in energy efficiency. The exact nature of the change in electricity intensity can be determined by decomposing into sectoral electricity intensity to isolate the effect of changes in the economy structure [10]. Pure electricity intensity can then be used to indicate the change in energy efficiency. However such analysis is beyond the scope of this study. In this case, the increase in electricity intensity is likely due to the shift in economic structure from agriculture and services to industry as indicated by the increase in the share of industry value added in total GDP shown in previous section. Furthermore, it is likely due to higher electricity access as well as greater penetration of electricity equipment and appliances. Electricity intensity in these countries increased between 30-90% during 1990-2000 but during 2000-2007 the rate of increase has slowed down to about 10%, with the exception of Vietnam.

The above indicators suggest that the ASEAN-5 is progressing in terms of affordability and accessibility. However, for Indonesia, the Philippines and, to some extent, Vietnam, further improvement is still required to increase electricity access.

4.2 Availability

Strong electricity consumption growth in the ASEAN-5 poses a challenge in terms of maintaining adequate and reliable electricity supply on a continuous basis to meet the electricity demand.

Table 4 shows indicators related to the short term quality of electricity supply. Among the ASEAN-5, Thailand and Malaysia appear to have the most reliable electricity supply. Reserve margin in both countries are relatively high, especially in Malaysia with a reserve margin of around 40%. This is reflected by the relatively low value of SAIFI and SAIDI which measures the yearly average interruption frequency and duration respectively. SAIFI and SAIDI are not only influenced by generation reserve margin but also network reserve such as the available capacity of transmission network elements. Excessive reserve margin such that in Malaysia, however, incurs unnecessary costs resulting in an increase in the overall generation cost. Indonesia has negligible reserve margin which resulted in a considerable amount of unserved demand as reflected by its relatively high SAIFI and SAIDI indexes. Cross-border interconnections such that of Thailand, Malaysia and Vietnam can also help to enhance the reliability and security of the electricity supply in the country.

Table 4
Indicators related to quality of supply in ASEAN-5

Country	Reserve Margin	Cross border supply and connection	SAIFI	SAIDI
Thailand	25%	Malaysia & Laos	0.26	6.62
Indonesia	Deficit	-	6.8	332
Malaysia	40%	Thailand & Singapore	0.287	68.6
Philippines	30%	-	0.8-1.3	70-90
Vietnam	25%	China, Laos Cambodia	N/A	N/A

Sources: Indonesia [21-22], Thailand [23], Malaysia [24], Philippines [25], Vietnam [26]

Security of supply in the long run can also be gauged from the trend of fuel mix. Figure 6 shows the fossil-fuel mix in electricity generation for these five countries during 1990-2007. Generally, the use of natural gas for electricity generation has considerably increased over the past two decades and it has become the preferred fuel source in all countries with the exception of Indonesia. Thailand and Malaysia depend heavily on natural gas for electricity generation, accounting for more than 60% of the total electricity generation in 2007. The concern over energy security due to heavy reliance of natural gas has resulted in a recent increase in coal-fired electricity generation particularly in Thailand and Malaysia. Indonesia has the largest share of coal in electricity generation and the share of coal has been increasing from 30% in 1990 to 45% in 2007 due to the abundant low-cost coal reserves within the country [19]. Whilst coal is a lower priced fuel with lower price volatility, this development does of course work against progress on managing greenhouse emissions and hence environmental acceptability, which will be discussed in the next section.

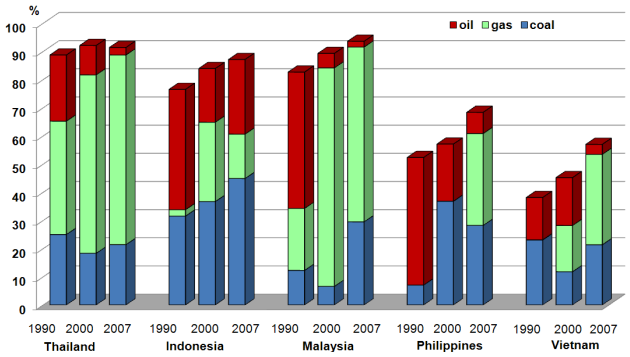

Figure 6. Fossil-fuel mix in generation in 1990-2007
Data Source: IEA [20]

Figure 7 illustrates the detailed fuel mix in 2007 for the ASEAN-5 compared with five OECD countries: Australia, the USA, the UK, Japan and France. It appears that Indonesia, the Philippines and Vietnam have a relatively well diversified fuel mix. Vietnam may face the problem of supply shortages during the dry season since the majority of electricity supply is from hydro. The Philippines and Indonesia have significant potential in geothermal power, ranking second and third in the world in terms of geothermal generation capacity [19]. In 2007, the share of geothermal power in Indonesia and the Philippines was 5% and 17% respectively.

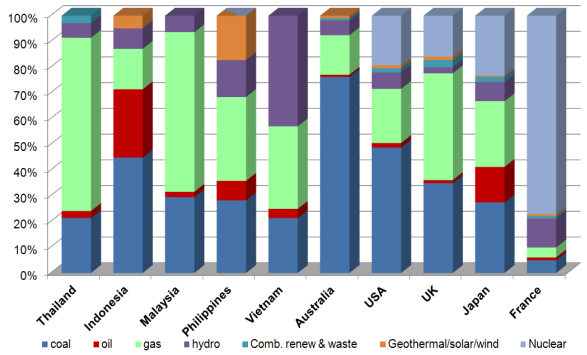

Figure 7. Fuel mix in electricity generation in 2007
Data Source: IEA [20]

Thailand and Malaysia rely heavily on natural gas and their fuel mixes are rather concentrated. This could have significant energy security implications in the long run due to the exposure to risk from fuel supply availability and price fluctuation. This is particularly the case for Thailand due to the increasing amount of gas imports since 1999 [27]. Furthermore, although the majority of natural gas supply are sourced domestically, natural gas prices in both Thailand and Malaysia are highly dependent on international prices through indexation with fuel oil in the Singapore market [27-28]. The dependence on international prices raises greater concern over energy security.

Fuel diversity can be measured using the Shannon-Wiener Index (SWI) which is shown in figure 9 for the ASEAN-5 and five selected OECD countries. As illustrated in figure 8, Thailand and Malaysia have the lowest SWI which are below 1.0 A value of SWI below 1.0 indicates that the fuel source is highly concentrated and could clearly threaten security of electricity supply [16]. On the other hand, Indonesia, the Philippines and Vietnam have a more diversified fuel mix as indicated by their SWI of around 1.2.

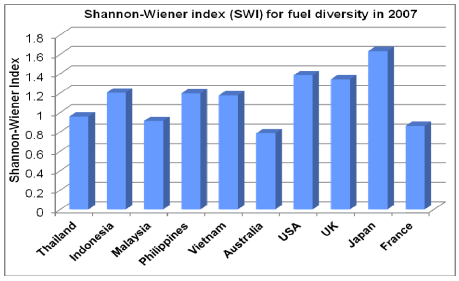

Figure 8. Shannon-Wiener index in 2007
Source: This study

In terms of availability, Thailand and Malaysia appear to have a fairly reliable electricity supply given their relative low supply interruption indexes as well as acceptable level of reserve margin. However, there are concerns over their long-term energy security due to heavy reliance on natural gas. Indonesia has the poorest supply reliability as indicated by its deficit reserve margin as well as high interruption indexes. This is a result of insufficient generation capacity due to the lack of investment in generation capacity which could potentially disrupt its economic and social development.

4.3 Acceptability

Acceptability relates to social and environmental implications in the electricity sector. CO_2 emissions is a major concern since the electricity sector is the world largest source of CO_2 emissions [2]. Figure 9 shows CO_2 emission per capita from electricity sector in 1990-2007. Although the CO_2 emissions in these countries are still well below that of OECD average, the trend of CO_2 emissions is on the rise, and the rate of increase is rather alarming. CO_2 emissions in these countries have increased between 100-300% over the past twenty year with Malaysia having per capital CO_2 emissions relatively closed to that of OECD average in 2007.

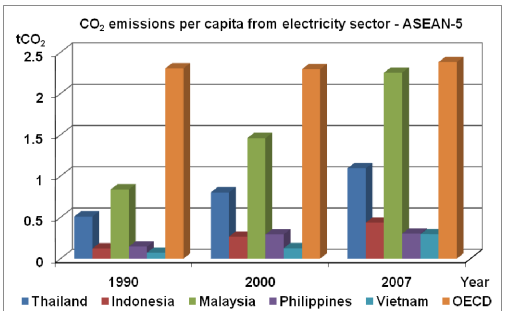

Figure 9. CO_2 emissions per capita in 1990-2007
Data Source: IEA [2]

As shown in figure 10, CO_2 intensity in terms of economic output (CO_2/GDP) in these countries, except the Philippines, is also increasing, which means that CO_2 emissions from the electricity sector increase at a faster rate than the economic growth. The ratio of CO_2 emissions per unit of GDP responds to changes in electricity intensity [2], which has been previously shown that the increase is largely due to greater electricity access and the structural shift from agriculture and services sector to industry sector.

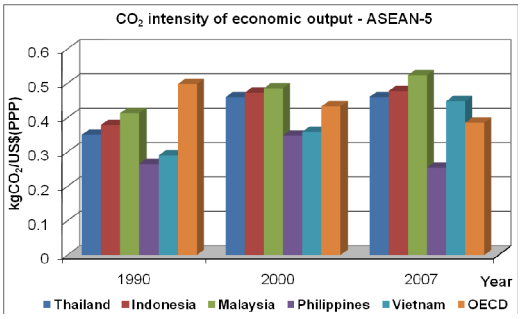

Figure10. CO_2 intensity of economic output in 1990-2007
Data Sources: IEA [2]; World Bank [9]

CO_2 intensity of electricity generation (CO_2/kWh) is related to the structure of fuels used for electricity generation. From figure 11, CO_2 intensity of electricity generation of these five countries has been decreasing since 1990, which indicates the decrease in CO_2 emissions per unit of electricity generated. The decline is due to the shift of fuel mix from high emitting sources of oil and coal to natural gas which has the lowest CO_2 emissions of all fossil fuel-based generation technologies. Furthermore the improvement in power plant efficiency due to the

increasing popularity of combined-cycle gas turbines has also contributed to the reduction in CO_2 intensity in electricity generation [18].

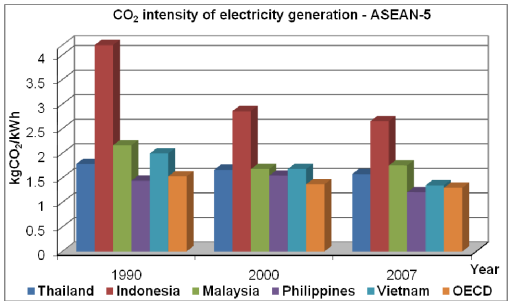

Figure 11. CO_2 intensity of generation in 1990-2007
Data Sources: IEA [2]; World Bank [9]

Other than meeting domestic energy demand, the increasing pressure on GHG emissions, depleting fossil fuel reserves, fossil fuel price volatility and the need to diversity fuel mix have led countries in the ASEAN-5 to consider nuclear power as one of the options to solve such problems [19]. However, there are social and environmental acceptability implications related to nuclear safety, waste management and nuclear proliferation which need to be addressed. Renewable energy policy and target is also another factor that can influence CO_2 emissions. Every country in the ASEAN-5 places particular importance on renewable energy as a measure to mitigate increasing CO_2 emissions as reflected by the policies and strategies to promote renewable electricity generation [19, 21, 24, 29].

While the sustainable level of CO_2 emissions is difficult to determine, it is imperative that the rate of CO_2 emissions per capita growth and CO_2 intensity of economic output in these five countries needs to be addressed to ensure environmental sustainability.

5. Key challenges in the electricity industry

Based on the 3A's energy sustainability framework and selected indicators described in previous sections, some key sustainability challenges in the electricity industry in these five ASEAN member countries can be identified. In general, the electricity industry in these five countries faces increasing challenges attributable to satisfying rapid demand growth, security of electricity supply due to the reliance of fossil fuel in electricity generation, and environmental concern due to increase CO_2 emissions as a result of growing electricity consumption. Furthermore many specific challenges will need to be overcome in order to ensure adequate and affordable access to electricity in an economic viable, socially acceptable and environmentally sound manner. These challenges include:

- Ensure sufficient generation capacity and reliability of electricity supply to meet growing demand and improve electricity access in rural areas, particularly in Indonesia and the Philippines to ensure economic and social development of these countries.
- Subsidy challenges in Thailand, Indonesia, Malaysia and Vietnam. It is vital that electric utilities are able to receive revenues sufficient to maintain and expand their service through new investment. Subsidy policies should also take into account the issue of equitability between different income groups – for example the cross subsidization.
- Diversifying fuel mix to enhance long term security of electricity supply and minimizing the exposure to risk arising from fossil fuel availability and price uncertainty, particularly in Thailand and Malaysia. Often the expansion of the local fuel supplies to reduce the amount of fuel import can enhance security of supply but this may not be the case of Thailand and Malaysia since fuel prices in both countries are highly dependent on international prices.
- Increase the share of renewable energy to mitigate the rise in CO_2 emissions as well as reducing dependence on fossil fuels.
- Reduce environmental emissions by establish climate change policies to address environmental externalities to ensure the environmental sustainability while achieving acceptable growth rate.
- Address social and environmental acceptability implications relating to nuclear power.

5.1 Generation Investment Challenges in ASEAN-5

The above challenges have implications for investment and generation planning as these factors need to be taken into consideration during investment decision making processes. Investment in the electricity sector is expected to be a major challenge among these five countries. With rapid increase in electricity demand, a significant amount of investment will be needed to expand the electricity supply infrastructure especially in Indonesia [19]. Given the nature of generation and network investment, the industry must build ahead of time to meet uncertain and potentially highly variable future demand.

Investment decision making in the electricity industry has becoming increasingly challenging due the increased volatility and future uncertainty about fuel prices and availability as well as growing concerns about climate change worldwide. Increased electricity consumption leads to environmental problems especially the emission of CO_2. Efforts by many countries to address climate change are based around establishing mechanisms and policies that put a price on CO_2 emissions. Measures to mitigate CO_2 emissions potentially have a major impact on the level and pattern on electricity industry investment since they encourage the installation of low carbon technologies resulting in the change in fuel mix [11]. Furthermore, with the concern of energy security, there is a need to diversify fuel mix in order to mitigate the exposure to fuel price fluctuation and availability. Flexibility strengthens sustainability, particularly in situations where future uncertainty has a great influence such as that surrounds the electricity industry [30]. Therefore a well diversified electricity generation portfolio which has an appropriate allowance for uncertainty would seem to offer significant benefits. Decision making processes in electricity generation

investment need to consider these factors. However, many key drivers are uncertain and correlated – such as future fuel price, demand growth and climate change policy.

Such challenges have added a new dimension to decision making processes in electricity industry investment. In addition to minimise the overall electricity industry cost, investment decision making needs to consider these risks and uncertainties as well as environmental concerns. Therefore, there is a considerable value for having decision support tools in electricity industry investment that formally incorporating risk assessment as well as taking into consideration the environmental aspects such as carbon pricing [31].

6. Conclusion

Five ASEAN member countries: Thailand, Indonesia, Malaysia, the Philippines and Vietnam have been identified to possess similarities in terms of social and economic status as well as the progress towards industrialization. Strong economic and social developments in these countries have induced substantial growth in electricity consumption in these countries. The increase in electricity consumption in these countries has led to the increase in CO_2 emissions due to the heavy reliance of fossil-fuels for electricity generation.

The 3A's energy sustainability objectives framework: Accessibility, Availability and Acceptability have been adopted to evaluate and identify key challenges in the electricity industries in these countries. A set of indicators and criteria have been proposed for assessing each aspect of the energy sustainability objectives. Although electricity access in these countries have remarkably improved over the past decades, there are many challenges that will need to be overcome in order to facilitate the growing demand in a sustainable manner. These challenges have implications for generation investment hence there is considerable value for having generation investment decision support tools that formally incorporate these issues.

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