Chapter 1

Main Report

September 2016

This chapter should be cited as

Han, P., S. Kimura, and C. Malik (2016), ‘Main Report’, in Kimura, S. and P. Han. (eds.) in *Energy Outlook and Energy Saving Potential in East Asia 2016.* ERIA Research Project Report 2015-5, Jakarta: ERIA, pp.1–54.

Chapter 1

Main Report on Energy Outlook and Saving Potential in the East Asia Region

HAN PHOUMIN, ENERGY ECONOMIST, ECONOMIC RESEARCH INSTITUTE FOR ASEAN AND EAST ASIA (ERIA)
SHIGERU KIMURA, SPECIAL ADVISOR ON ENERGY AFFAIRS TO THE ERIA PRESIDENT
CECILYA LAKSMIWATI MALIK, REGIONAL CONSULTANT ON ENERGY POLICY PLANNING

1. Introduction

Sustained population and economic growth in the East Asia Summit (EAS) region have nearly doubled energy demand for both primary and final energy consumption. The increasing energy demand poses a threat to the region's energy security. Hence, potential energy saving is key to reducing energy demand and carbon dioxide (CO_2) emissions.

In 2007, leaders from the Association of Southeast Asian Nations (ASEAN) member countries, as well as Australia, the People's Republic of China (henceforth, China), India, Japan, the Republic of Korea, and New Zealand, adopted the Cebu Declaration, which focuses on energy security. The leaders agreed to promote energy efficiency, new renewable energy, and the clean use of coal. Subsequently, the EAS Energy Cooperation Task Force (ECTF) was established in response to the Cebu Declaration, and Japan proposed to undertake a study on energy savings and CO_2 emission reduction potential, one of the agreed areas of cooperation where the Economic Research Institute for ASEAN and East Asia (ERIA) also officially requested through the EAS Energy Ministers Meeting (EAS–EMM) to support studies in the agreed areas of energy work streams.

This study shows energy saving potential using both the Business-as-Usual scenario (BAU) and Alternative Policy Scenarios (APS). The BAU was developed for each EAS economy, outlining future sectoral and economy-wide energy consumption assuming no significant changes to government policies. APS were set out to examine the potential impacts if additional energy efficiency goals, action plans, or policies that are currently, or likely to be, under considered were developed. The difference between the BAU and the APS in both final and primary energy supply represents potential energy savings. The difference in CO_2 emissions between the two scenarios represents the potential for reducing greenhouse gas (GhG) emissions.

The findings of this study continue to shed light on the policy implications for decision-making to ensure that the region can enjoy both economic growth and investment opportunities without compromising on averting the threat to energy security and of environmental problems as a result of rising CO_2 emissions.

1.1. The East Asia Summit

The EAS is a collection of diverse countries, with wide variations among them in terms of per capita income, standards of living, population density, energy resource endowments, climate, and energy consumption per capita. It is composed of the 10 ASEAN member countries – Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam, and six other countries – Australia, China, India, Japan, Republic of Korea (henceforth, Korea), and New Zealand (The Ministry of Foreign Affairs of Japan, 2005).

Whereas some EAS countries are what might be called mature economies, the majority are regarded as developing economies. Several countries have a per capita gross domestic product (GDP) of less than US$1,000 (in 2005 prices[1]). Countries with mature economies have higher energy consumption per capita, whereas developing countries generally have lower energy consumption per capita. A large percentage of the people in the latter countries still meet their energy needs mainly with traditional biomass fuels.

[1] All US$ (US dollars) in this document are 2005 constant prices unless specified.

These differences partly explain why energy efficiency and conservation (EEC) goals, action plans, and policies are assigned different priorities across countries. Countries with developed economies may be very keen to reduce energy consumption, whereas developing countries tend to put more emphasis on economic growth and improving standards of living. However, as the economies of these countries grow, energy consumption per capita is expected to grow as well.

Despite the differences among the 16 countries, the EAS leaders agreed that the EAS ‘could play a significant role in community building,’ which could be an important cornerstone for the development of regional cooperation in the years to come (Ministry of Foreign Affairs of Japan, 2005).

Table 1-1 shows the geographic, demographic, and economic profiles of the 16 EAS countries. Table 1-2 shows their economic structure and energy consumption profiles.

Table 1-1. Geographic, Demographic, and Economic Profiles, 2013

	Land Area (thousand sq. km.)*	Population (million)	Population Density (persons/ sq. km.)	GDP (billion 2005 US$)	GDP per Capita (2005 US$/ person)
Australia	7,682	23.13	3.01	867.09	37,489
Brunei Darussalam	5.3	0.41	77.08	10.10	24,874
Cambodia	181	15.08	83.31	10.72	711
China	9,327	1,360.72	145.88	4,912.96	3,611
India	2,973	1,252.14	421.14	1,489.78	1,190
Indonesia	1,812	246.86	136.27	449.14	1,819
Japan	365	127.34	349.35	4,685.52	36,796
Korea, Rep. of	97	50.22	517.20	1,199.01	23,875
Lao PDR	231	6.58	28.51	5.09	774
Malaysia	329	29.47	89.68	207.95	7,057
Myanmar	653	52.98	81.10	24.93	471
New Zealand	263	4.44	16.87	120.14	27,046
Philippines	298	98.20	329.34	155.61	1,585
Singapore	0.7	5.40	7,713.14	202.42	37,491
Thailand	511	67.45	132.03	230.37	3,415
Viet Nam	310	89.71	289.32	92.28	1,029

sq. km. = square kilometres; GDP = gross domestic product.
Note: * Information on the land area data of Cambodia was provided by the Government of Cambodia.
Source: World Development Indicators, World Bank Database, November 2013.

Table 1-2. Economic Structure and Energy Consumption, 2013

	GDP (billion 2005 US$)	Share of Industry in GDP, percent*	Share of Services in GDP, percent*	Share of Agriculture in GDP, percent*	Primary Energy Supply (Mtoe)	Energy Consumption per Capita (toe/person)
Australia	867.1	28.2	69.2	2.6	129.1	5.6
Brunei Darussalam	10.1	60.9	38.3	0.8	2.9	7.1
Cambodia	10.7	29.9	43.0	27.1	6.8	0.5
China	4,913.0	48.8	43.5	7.7	3,021.9	2.2
India	1,489.8	33.5	52.0	14.5	775.4	0.6
Indonesia	449.1	39.7	49.7	10.6	223.9	0.9
Japan	4,685.5	28.1	70.7	1.3	454.7	3.6
Korea, Rep. of	1,199.0	39.6	57.8	2.6	263.8	5.3
Lao PDR	5.1	31.5	42.7	25.8	2.5	0.4
Malaysia	208.0	39.4	53.4	7.2	74.5	2.5
Myanmar	24.9	25.9	41.8	32.3	16.5	0.3
New Zealand	120.1	23.7	71.9	4.4	19.5	4.4
Philippines	155.6	33.8	56.4	9.9	44.5	0.5
Singapore	202.4	32.7	67.2	0.0	28.7	5.3
Thailand	230.4	37.4	54.4	8.2	132.3	2.0
Viet Nam	92.3	42.0	40.9	17.1	60.1	0.7

Note: * Sectoral shares to GDP of Myanmar and New Zealand are 2004 and 2009 values, respectively.
Source: World Development Indicators, World Bank Database, November 2013; International Energy Agency (IEA) (2014), Energy Balances of Organisation for Economic Co-operation and Development (OECD) countries 2013.

1.2. Objective and Rationale

This study aims to analyse the potential impact of proposed additional energy saving goals, action plans, and policies in the EAS region on energy consumption by fuel and sector and GhG emissions. The study also provides a platform for energy collaboration and capacity building on energy modelling and policy development among EAS countries.

The study supports the Cebu Declaration, which highlights a number of goals including the following:

- improving the efficiency and environmental performance of fossil fuel use;
- reducing the dependence on conventional fuels through intensified EEC programmes, increasing the share of hydropower, expanding renewable energy systems and biofuel production/utilisation, and, for interested parties, civilian nuclear power; and
- mitigating GhG emissions through effective policies and measures, thus contributing to global climate change abatement.

The Government of Japan asked ERIA to conduct a study on energy saving and potential on CO_2 emission reduction in the East Asia region. As a result, the Working Group for this study on the Analysis of Energy Saving Potential was convened. Members from all 16 EAS countries are represented in the Working Group to support this study.

2. Data and Methodology

2.1. The Scenarios

The study continues to examine two scenarios, as in the studies conducted annually from 2007 to the present – a BAU reflecting each country's current goals, action plans, and policies; and an APS.

The APS includes additional goals, action plans, and policies reported every year to the East Asia Energy Ministers Meeting (EAS–EMM). The latest updated policies were reported at the 9th EAS–EMM held on 8 October 2015 in Kuala Lumpur, Malaysia.

One might be tempted to call the APS a 'maximum effort' case, but that would not be accurate. One reason is that goals, action plans, and policies for reducing energy consumption are still relatively new in most countries. There are still many potential EEC policies and technological options that have not been examined or incorporated in the APS.

In 2014, the APS assumptions were grouped into four – (i) more efficient final energy consumption (APS1), (ii) more efficient thermal power generation (APS2), (iii) higher consumption of new and renewable energy (NRE) and biofuels (APS3), and (iv) introduction or higher utilisation of nuclear energy (APS4). The energy models are able to estimate the individual impacts of these assumptions on both primary energy supply and CO_2 emissions. The combination of these assumptions constitutes the assumptions of the APS. The main report highlights only the BAU and APS. However, each country report will analyse all the APS scenarios from APS1 to APS4.

Detailed assumptions for each APS are follows:

- The assumptions in APS1 are the reduction targets in sectoral final energy consumption, assuming that more efficient technologies are utilised and energy saving practices implemented in the industrial, transport, residential, commercial, and even the agricultural sectors for some countries. This scenario resulted in less primary energy and CO_2 emission in proportion to the reduction in final energy consumption.
- In APS2, the utilisation of more efficient thermal power plant technologies in the power sector is assumed. This assumption resulted in lower primary energy supply and CO_2 emission in proportion to the efficiency improvement in thermal power generation. The most efficient coal and natural gas combined–cycle technologies are assumed to be utilised for the construction of new power

plants in this scenario.

- In APS3, higher contributions of NRE for electricity generation and utilisation of liquid biofuels in the transport sector are assumed. This resulted in lower CO_2 emission as NRE is considered carbon-neutral or would not emit additional CO_2 in the atmosphere. However, primary energy supply may not decrease as NRE, like biomass and geothermal energy, are assumed to have lower efficiencies compared with fossil fuel–fired generation when converting electricity generated from these NRE sources into its primary energy equivalent.

- APS4 assumes introduction of nuclear energy or a higher contribution of nuclear energy in countries that are already using this energy source. This scenario is expected to emit less CO_2 because of nuclear energy's minimal CO_2 emission. However, as the assumption of thermal efficiency when converting nuclear energy output into primary energy is only 33 percent, primary energy supply is not expected to be lower than for the BAU in this scenario.

All EAS countries are actively developing and implementing EEC goals, action plans, and policies, but progress so far has varied widely. Some countries are quite advanced in their efforts, whereas others are just getting started. A few countries already have significant energy savings goals, action plans, and policies built into the BAU, whereas others have only just started to quantify their goals. However, significant potential does exist in these countries at the sectoral and economy-wide levels.

In every country, a great deal can be learned from experience on what works and what does not. It is worthwhile updating this study periodically, as the quality and scope of the national goals, action plans, and policies are likely to improve considerably over time, allowing for valuable collaboration across countries.

2.2. Data

For consistency, the historical energy data used in this analysis came from the International Energy Agency's (IEA) energy balances for Organisation of Economic Co-operation and Development (OECD) and non-OECD countries, except for Australia and Lao PDR. Australian national energy data was converted from gross calorific value (GCV) into net calorific value (NCV) to be consistent with IEA energy balances. Estimations of national energy data from Lao PDR were made using the same methodology as used by the IEA.

The socio-economic data for 15 countries were obtained from the World Bank's online World Databank – World Development Indicators (WDI) and Global Development Finance (GDF) – and the data of Myanmar were obtained from the United Nations Statistics Division (UNSD) Statistical Databases. Other data, such as those relating to transportation, buildings, and industrial production indices, were provided by the Working Group members from each EAS country where such data are available. Where official data were not available, estimates were obtained from other sources or developed by the Institute of Energy Economics, Japan (IEEJ).

2.3. Methodology

In 2007, the primary model used was the IEEJ World Energy Outlook Model, which is used by IEEJ in preparing their Asia/World Energy Outlook (Ito et al., 2014). In 2014, all 10 ASEAN member countries utilised their own energy models. Australia used its own national model as well. The remaining countries provided key assumptions to IEEJ on population and GDP growth; electric generation fuel mixes; and EEC goals, action plans, and policies. The IEEJ models were then used to develop energy projections for these countries. In the next section, brief descriptions of the energy models in this study are provided.

Australia: Australian projections were developed using the country's E_4cast model,[2] a dynamic partial equilibrium framework that provides a detailed treatment of the Australian energy sector focusing on domestic energy use and supply. The Australian energy system is divided into 24 conversion and end use sectors, and fuels comprise 19 primary and secondary fuels with all states and territories represented. Energy demand for each fuel is modelled based on econometrically estimated price and income elasticities.

[2] E_4cast is a partial equilibrium model of the Australian energy sector used to project Australia's long-term energy consumption, production, and trade.

ASEAN countries: The energy models of ASEAN countries were developed using the Long-range Energy Alternative Planning System (LEAP) software, an accounting system used to develop projections of energy balance tables based on final energy consumption and energy input/output in the transformation sector. Final energy consumption is forecast using energy demand equations by energy and sector and future macroeconomic assumptions. For this study, all 10 member countries used the LEAP model.

Other countries: Other countries used the IEEJ model, which has a macro-economic module that calculates coefficients for various explanatory variables based on exogenously specified GDP growth rates. The macro-economic module also projects prices for natural gas and coal based on exogenously specified oil price assumptions. Demand equations are econometrically calculated in another module using historical data, and future parameters are projected using the explanatory variables from the macro-economic module. An econometric approach means that future demand and supply will be heavily influenced by historical trends. However, the supply of energy and new technologies are treated exogenously. For electricity generation, the Working Group members were asked to specify assumptions about the future electricity generation mix in their respective countries by energy source. These assumptions were used to determine the future electricity generation mix.

3. Assumptions of the Study

Growth in energy consumption and GhG emissions is driven by a variety of socio-economic factors. In the EAS region, these factors, including increasing population, sustained economic growth, increasing vehicle ownership, and increasing access to electricity, will tend to increase energy demand. Together they create what might be called a huge growth ‘headwind’ that works against efforts to limit energy consumption. Understanding the nature and size of this ‘headwind’ is critical for any analysis of energy demand in the EAS region. However, an increase in consumption of energy services is fundamental for achieving a range of socio-economic development goals.

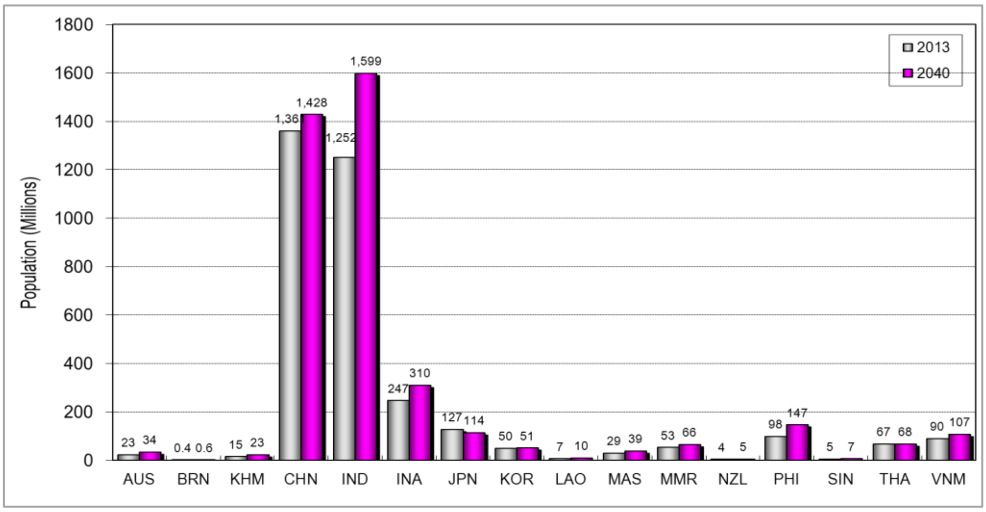
In this section, assumptions regarding key socio-economic indicators and energy policies until 2040 for EAS countries are discussed.

3.1. Population

In the models used for this study, changes in population to 2040 are set exogenously. It is assumed there is no difference in population between the BAU and the APS. Assumed changes in population were submitted by EAS countries, except China, for which the population projections from the United Nations were used.

In 2013, the total population of the EAS region was about 3.43 billion. Based on forecasts, it is projected to increase at an average annual rate of about 0.6 percent, reaching about 4 billion in 2040. **Error! Reference source not found.** 1-1 shows the 2013 and projected 2040 population by country.

Figure 1-1. Assumed Population in the EAS Region, 2013 and 2040

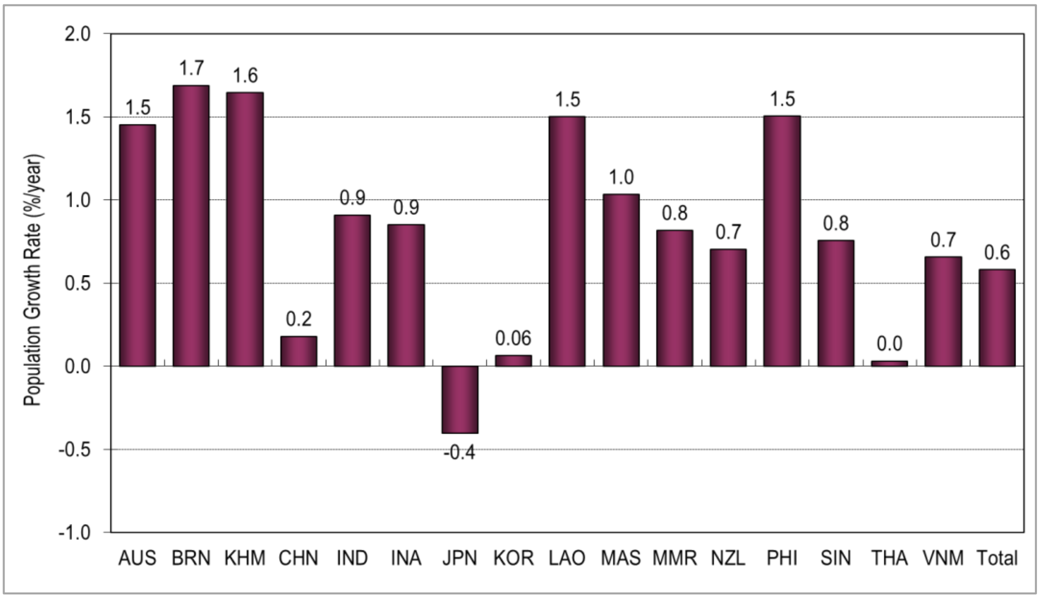


EAS = East Asia Summit (AUS = Australia; BRN = Brunei Darussalam; KHM = Cambodia; CHN = China; IND = India; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL = New Zealand; PHI = Philippines; SIN = Singapore; THA = Thailand; VNM = Viet Nam).
Source: United Nations Statistics Division (2014), United Nations Statistics Division (UNSD) Statistical Databases. https://unstats.un.org/unsd/databases.htm (accessed June 2016).

As shown in Figure 1-2, population growth is generally assumed to be fastest in developing countries. China and Thailand are notable and significant exceptions, as they are expected to have relatively modest population growth. Nevertheless, by 2040, India and China are assumed to account for over 80 percent of the total population in the EAS region with populations of around 1.42 billion for China and 1.59 billion for India.

Countries with more mature economies tend to have slower population growth. New Zealand and Singapore are assumed to have low, but still significant, population growth. Korea's population is assumed to be roughly stable. Japan's population is assumed to decline slowly throughout the projection period as the population continues to age.

Figure 1-2. Assumed Average Annual Growth in Population, 2013–2040



AUS = Australia; BRN = Brunei Darussalam; KHM = Cambodia; CHN = China; IND = India; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL = New Zealand; PHI = Philippines; SIN = Singapore; THA = Thailand; VNM = Viet Nam.

Source: United Nations Statistics Division (2014), United Nations Statistics Division (UNSD) Statistical Databases. https://unstats.un.org/unsd/databases.htm (accessed June 2016).

3.2. Economic Activity

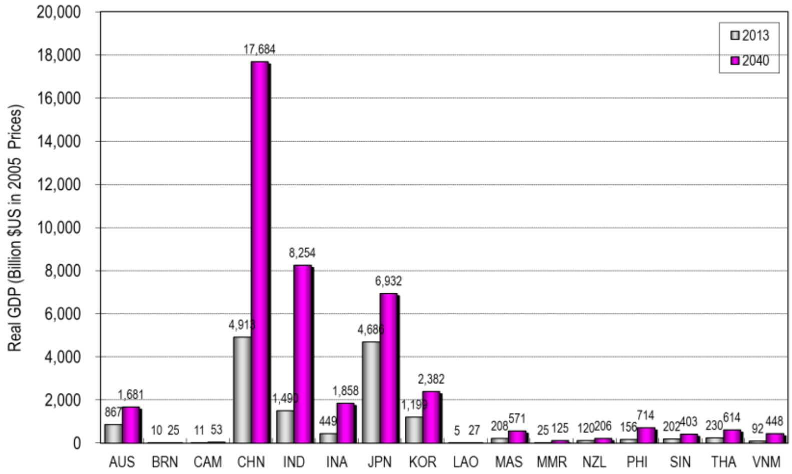
In the models used for this study, assumed changes in economic output to 2040 are set exogenously. GDP data (in 2005 US$) were obtained from the World Bank (2014). Assumed GDP growth rates to 2040 were submitted by all EAS countries. In general, these assumptions took into account actual GDP growth rates from 2005 to 2013, which already reflect the economic recession and recovery in the United States and other countries in the world. No difference in growth rates was assumed between the BAU and APS.

In 2013, total GDP in the EAS region was about 14.7 trillion in 2005 US$ and it accounted for about 26 percent of global GDP. The GDP of the EAS region is assumed to grow at an average annual rate of about 4 percent from 2013 to 2040. This implies that by 2040, total GDP of the EAS region will reach about 42 trillion in 2005 US$.

China is projected to be the largest economy in terms of real GDP of about 17.6 trillion by 2040. India and Japan are projected to be the next largest economies with projected GDPs of about 8.2 trillion 2005 US$ and 6.9 trillion 2005 US$, respectively in 2040 (Figure 1-3).

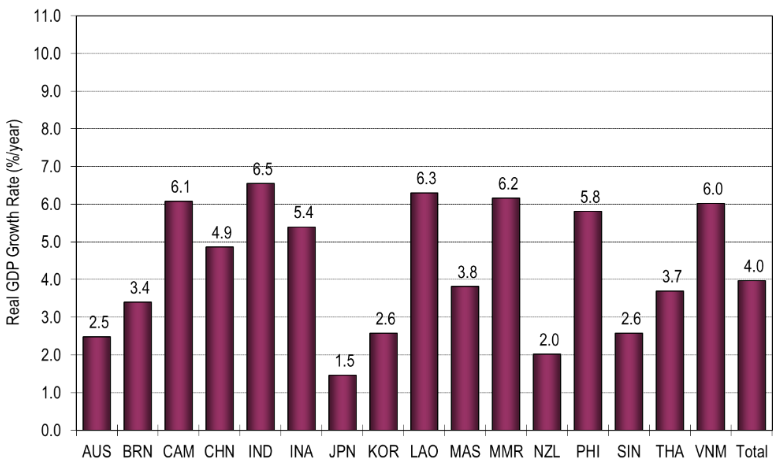
As shown in Figure 1-4, long-term economic growth rates are assumed to be quite high in the developing countries, with the highest growth rates in India, Lao PDR, Myanmar, Cambodia, Viet Nam, and the Philippines. Economic growth in other developing countries is also assumed to be relatively rapid. Due to the large size of their economies, the rapid growth in China, India, and Indonesia is likely to be especially significant for energy demand. Countries with more mature economies – Australia, Singapore, Brunei, Japan, Korea, and New Zealand – are assumed to experience slower, but still significant, economic growth.

Figure 1-3. Assumed Economic Activity in the EAS Region, 2013 and 2040



EAS = East Asia Summit (AUS = Australia; BRN = Brunei Darussalam; KHM = Cambodia; CHN = China; IND = India; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL = New Zealand; PHI = Philippines; SIN = Singapore; THA = Thailand; VNM = Viet Nam); GDP = gross domestic product.
Source: United Nations Statistics Division (2014), United Nations Statistics Division (UNSD) Statistical Databases.
https://unstats.un.org/unsd/databases.htm (accessed June 2016).

Figure 1-4. Assumed Average Annual Growth in GDP, 2013–2040



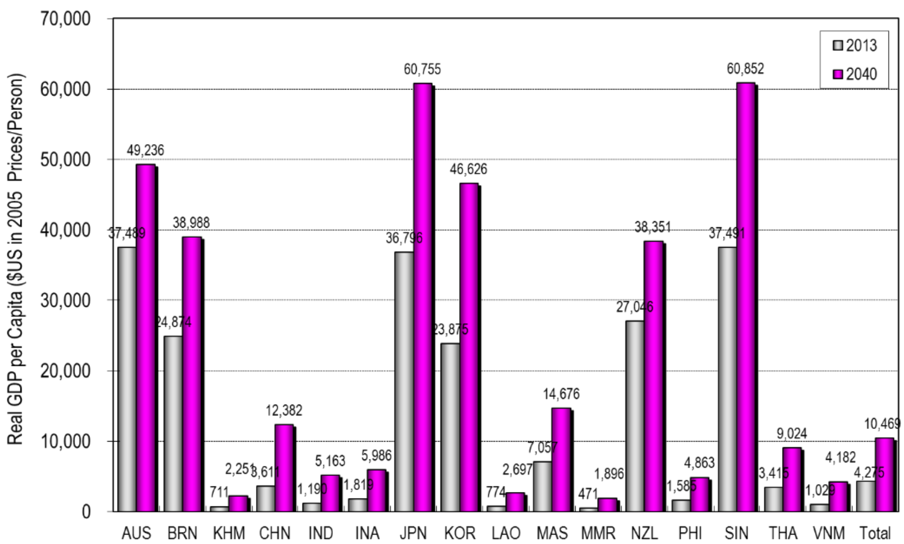
AUS = Australia; BRN = Brunei; KHM = Cambodia; CHN = China; GDP = gross domestic product; IND = India; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL= New Zealand; PHI= Philippine; SIN = Singapore; THA = Thailand; VNM = Viet Nam).
Source: United Nations Statistics Division (2014), United Nations Statistics Division (UNSD) Statistical Databases.
https://unstats.un.org/unsd/databases.htm (accessed June 2016).

Average real GDP per capita in the EAS region is assumed to increase from about US$4,270 in 2013 to about US$10,500 in 2040. However, as shown in Figure 1-5, there are, and will continue to be, significant differences in GDP per capita. In 2013, per capita GDP ranged from about US$471 in Myanmar to over US$36,000 in Australia, Japan, and Singapore. In 2040, per capita GDP is assumed to range from about US$1,896 in Myanmar to over US$60,000 in Japan and Singapore.

3.3. Vehicle Ownership

Growth in the transport sector is one of the primary drivers of growth in energy consumption, and the major driver of oil consumption. In the model used in this study, energy demand by all forms of transport is modelled. However, road vehicle ownership is a key exogenous input. Assumed changes in road vehicle ownership were made for 14 countries, except for Lao PDR and Viet Nam. There is assumed to be no difference in road vehicle ownership between the BAU and APS.

Figure 1-5. Real GDP per Capita, 2013 and 2040



AUS = Australia; BRN = Brunei Darussalam; KHM= Cambodia; CHN = China; IND = India; GDP = gross domestic product; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL = New Zealand; PHI = Philippines; SIN = Singapore; THA = Thailand; VNM = Viet Nam.
Source: United Nations Statistics Division (2014), United Nations Statistics Division (UNSD) Statistical Databases. https://unstats.un.org/unsd/databases.htm (accessed November 2014).

Strong population and economic growth is projected to drive significant increases in demand for transport services in the EAS region. By 2040, the number of road vehicles in EAS is projected to increase to about 808.9 million, increasing almost threefold from 2013. However, rail is expected to meet an increasing share of total transport demand due to repaid acceleration of rail transportation connectivity in the ASEAN region.

Average per capita vehicle ownership in the EAS region is projected to increase from 0.081 to 0.202 from 2013 to 2040. However, vehicle ownership on a per capita basis is projected to vary significantly among countries.

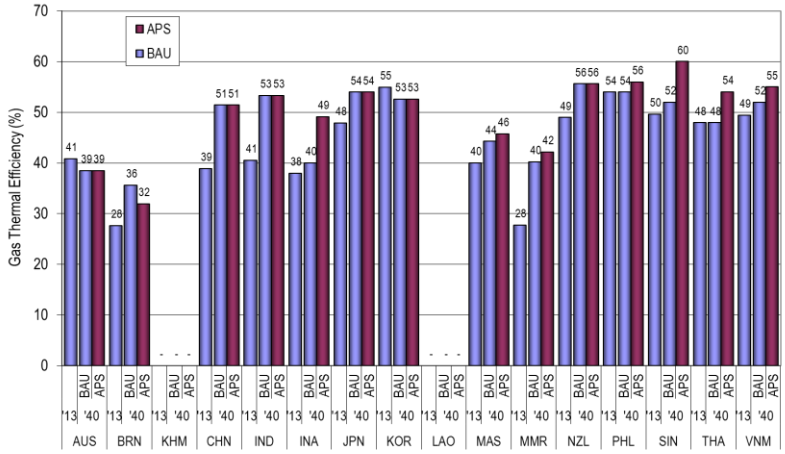
3.4. Electricity Generation

3.4.1. Electricity generation thermal efficiency

The thermal efficiency of electricity generation reflects the amount of fuel required to generate a unit of electricity. Thermal efficiency was another exogenous assumption used in this study. Base year 2013 thermal efficiencies by fuel type (coal, gas, and oil) were derived from International Energy Agency data (IEA, 2011). Thermal efficiencies by fuel (coal, gas, and oil) were projected by the following countries: Australia, Brunei Darussalam, Indonesia, Japan, Malaysia, Philippines, Singapore, Thailand, and Viet Nam, and growth rates in thermal efficiency were derived from these projections. For the remaining countries, assumptions about the potential changes in thermal efficiency were based on the IEEJ's *Asia/World Energy Outlook 2014.*

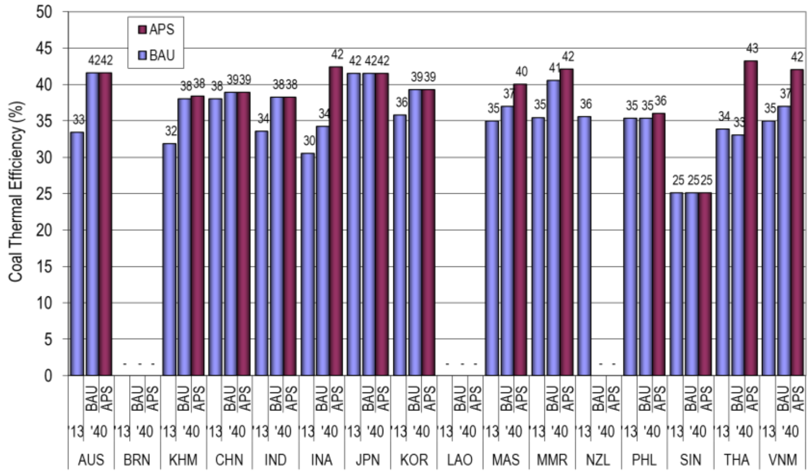
Thermal efficiencies may differ significantly between countries due to differences in technological availability, age, cost of technology, temperatures, and the cost and availability of fuel inputs. Thermal efficiency in the EAS countries is expected to improve considerably over time in the BAU as more advanced generation technologies such as natural gas combined cycle and supercritical coal-fired power plants become available. In many countries, there are also assumed to be additional improvements in the APS (see Figures 1-6 and 1-7).

Figure 1-6. Thermal Efficiencies of Gas Electricity Generation



APS = Alternative Policy Scenario; AUS = Australia; BAU = Business-as-Usual scenario; BRN = Brunei Darussalam; KHM= Cambodia; CHN = China; IND = India; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL = New Zealand; PHI = Philippines; SIN = Singapore; THA = Thailand; VNM = Viet Nam.
Source: Long-range Energy Alternatives Planning System (LEAP)'s database.

Figure 1-7. Thermal Efficiencies of Coal Electricity Generation

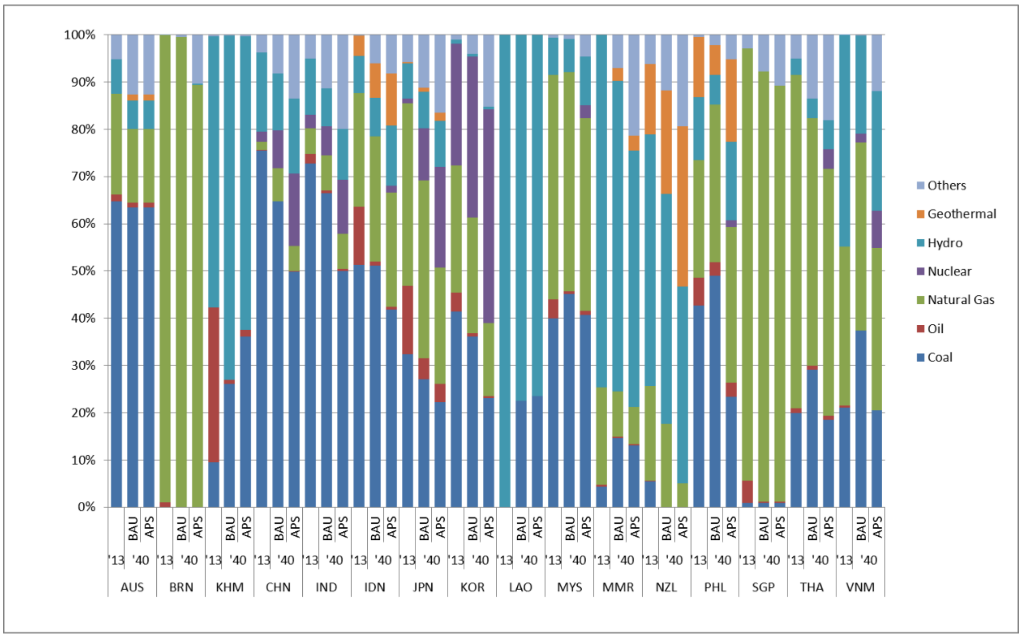


APS = Alternative Policy Scenario; AUS = Australia; BAU = Business-as-Usual scenario; BRN = Brunei Darussalam; KHM= Cambodia; CHN = China; IND = India; INA = Indonesia; JPN = Japan; KOR = South Korea; LAO = Lao PDR; MAS = Malaysia; MMR = Myanmar; NZL = New Zealand; PHI = Philippines; SIN = Singapore; THA = Thailand; VNM = Viet Nam.
Source: Long-range Energy Alternatives Planning System (LEAP)'s database.

3.4.2. Electricity generation fuel mix

The combination of fuels used in electricity generation differs among countries, reflecting both historical and current conditions, including access to and cost of resources and technology. It was, therefore, an exogenous input to the model. It is an important input, not only because it is a key driver of demand for primary fuels, but also because the fuel mix used can have important implications for GhG emissions. The projected electricity generation mix is shown in Figure 1-8.

Figure 1-8. Share of Fuel Type in the Electricity Generation Mix in the EAS Region



EAS = East Asia Summit; BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario(s).
(AUS=Australia; BRN=Brunei; KHM= Cambodia; CHN= China; IND= India; INA= Indonesia; JPN= Japan; KOR= South Korea; LAO= Lao PDR; MAS= Malaysia; MMR= Myanmar; NZL= New Zealand; PHI= Philippine; SIN= Singapore; THA= Thailand; VNM= Viet Nam).
Source: Country Energy Saving Potential Report – sub-report of this main report, 2016.

Coal is projected to remain the dominant source of electricity generation in the EAS region as a whole in both the BAU and APS. However, the share of coal in electricity generation in the EAS region is projected to decline from about 58.4 percent in the BAU to about 44.6 percent in the APS by 2040, as countries are assumed to implement policies designed to reduce the emissions intensity of electricity generation. In the APS, the share of lower emission fuels such as hydro, nuclear, and non-hydro renewable energy are expected to be higher than in the

BAU on average in the EAS region. The use of oil in electricity generation is assumed to decline to almost negligible levels across the EAS region as a whole.

3.4.3. Access to electricity

Currently, many households in developing countries lack access to electricity, and resolving this problem is a major development goal. At the Working Group meetings, a number of the developing countries reported on initiatives to significantly expand access to electricity in their countries by 2040. Although this increasing access to electricity is another one of the drivers of increasing energy demand in the EAS region, it was not explicitly represented in the model used for this study. Nevertheless, the impact of increasing access to electricity on electricity demand should be largely reflected through the increased demand for electricity as a result of the relatively rapid GDP growth that is assumed to be experienced in these same countries.

Table 1-3 shows electricity access in ASEAN and the East Asia region. It also informed the progress of access to electricity in urban versus rural area from 1990 to 2012. Whereas tremendous progress of almost 100 percent of energy access has been observed in Malaysia, Singapore, Thailand, Viet Nam, China, Korea, Japan, Australia, and New Zealand, some countries in the Southeast Asia have struggled to improve energy access for their population.

3.5. Use of Biofuels

The Working Group members from each country were asked to include information regarding the potential use of biofuels in the BAU and APS. Some, but not all, countries in the EAS region have plans to increase the contribution of biofuels in the transport fuel mix to enhance energy security or meet other policy objectives. For China and Japan, the assumptions on the use of biofuels were based on the IEEJ *Asia/World Energy Outlook 2014.* Table 1-4 summarises the assumptions regarding use of biofuels.

Table 1-3. Access to Electricity

	1990			2000			2012		
	Rural	***Urban***	***National***	***Rural***	***Urban***	***National***	***Rural***	***Urban***	***National***
Cambodia	5.0	36.6	19.2	9.0	49.9	16.6	18.8	91.3	31.1
Myanmar	.	.	.	.	.	.	.	.	32*
Lao PDR	39.7	100.0	51.5	40.0	68.7	46.3	54.8	97.9	70.0
Brunei Darussalam	56.4	70.5	65.7	61.2	72.7	69.4	67.1	79.0	76.2
India	38.7	86.5	50.9	48.4	98.6	62.3	69.7	98.2	78.7
Indonesia	.	.	66.9	.	.	.	.	.	74**
Viet Nam	84.5	100.0	87.9	86.6	96.9	89.1	97.7	100.0	99.0
Philippines	46.4	85.5	65.4	51.9	92.3	71.3	81.5	93.7	87.5
Malaysia	89.2	97.3	93.2	93.0	98.5	96.4	100.0	100.0	100.0
Singapore	99.0	100.0	100.0	99.0	100.0	100.0	99.0	100.0	100.0
Thailand	82.0	75.2	80.0	87.0	72.6	82.5	99.8	100.0	100.0
Australia	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
China	92.0	100.0	94.2	95.3	100.0	98.0	100.0	100.0	100.0
Korea, Rep. of	92.0	95.0	94.2	95.3	98.7	98.0	100.0	100.0	100.0
Japan	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
New Zealand	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* The number was taken from the presentation of Khin Seint Wint (2014), Renewable Energy Association of Myanmar.
** The number was taken from ASEAN Guideline on Off-grid Rural Electrification Approaches, ASEAN Center for Energy (ACE, 2013).
Source: World Development Indicators, 2014.

Table 1-4. Assumptions on Biofuels – Summary by Country

Country	Period	Assumptions
Australia		No targets on biofuels
Brunei Darussalam		No targets on biofuels
Cambodia		No targets on biofuels
China	2030	BAU: 20 billion litres ; APS: 60 billion litres
India	2017	20 percent blending of biofuels, both for bio-diesel and bio-ethanol
Indonesia	2025	Bioethanol: 15 percent blend from 3–7 percent in 2010 Bio-diesel: 20 percent blend from 1–5 percent in 2010
Japan	2005–2030	No biofuel targets submitted
Republic of Korea	2012 2020 2030	Replace 1.4 percent of diesel with biodiesel Replace 6.7 percent of diesel with biodiesel Replace 11.4 percent of diesel with biodiesel
Lao PDR	2030	Utilise biofuels equivalent to 10 percent of road transport fuels
Malaysia	2030	Replace 5 percent of diesel in road transport with biodiesel
Myanmar	2020	Replace 8 percent of transport diesel with biodiesel
New Zealand	2012–2030	Mandatory biofuels sales obligation of 3.4 percent by 2012
Philippines	2025–2035	BAU: The Biofuels Law requires 10 percent bio-ethanol/gasoline blend and 2 percent biodiesel/diesel blend 2 years from enactment of the law (roughly 2009) APS: Displace 20 percent of diesel and gasoline with biofuels by 2025
Thailand		Biofuels to displace 12.2 percent of transport energy demand
Viet Nam	2020	10 percent ethanol blend in gasoline for road transport

BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario.
Source: Country Energy Saving Potential Report – sub-report of this main report, 2016.

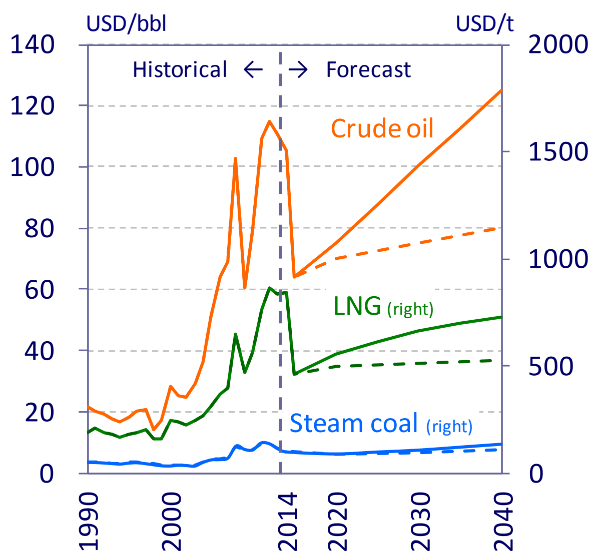
The largest increases in consumption of biofuels in the APS are expected in India and China. In all countries, biofuels are expected to meet only a small portion of the transport fuel demand by 2040.

3.6. Crude Oil Price

Figure 1-9 depicts the oil price assumptions used in the modelling. In the Reference Scenario, the crude oil price is US$100/billion barrels (bbl) in 2013, then drops to US$75/bbl in early 2014, then rises gradually to US$100/bbl by 2030, and to US$125/bbl in 2040. The rises of the oil price in 2030 and 2040 are due to combined factors such as robust demand growth in non-OECD countries, new emerging geopolitical risks and financial factors, oil supply constraints reflecting rising depletion rates for oil fields, etc. Prices of liquefied natural gas (LNG) will rise accordingly, with the existing price disparity shrinking due to expanding interregional trade.

In the Lower Price Scenario, energy prices remain lower due to dull growth in demand in accordance with the diffusion of energy saving technologies, as well as further promotion of unconventional resources development.

Figure 1-9. Real Oil, LNG, and Coal Price Assumptions
(Real prices are in 2014 US$)



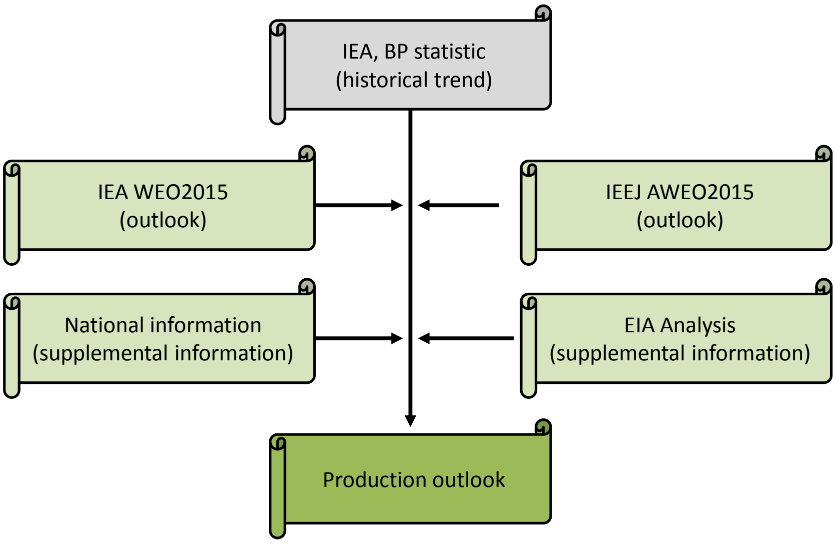
LNG = liquefied natural gas; bbl = billion barrels; t = ton.
Note: Solid line = Reference; Dashed line = Lower Price.
Source: IEEJ's oil price assumptions, 2016.

3.7. Assumption of Fossil Fuel Production Outlook

3.7.1. Analytical method

The fossil fuel production outlook is generated through the Delphi process' 'expert's judgment.' First, a historical data set of production volume is collected from British Petroleum and IEA statistics. The data is utilised to understand the transition of production volume in each country. Second, a reference was made to the IEA *World Energy Outlook 2015* and the IEEJ *Asia-World Energy Outlook 2015* in order to understand the future direction of changes in production volume. The estimated fossil fuel outlook also utilises supplementary information such as the national plans and targets provided by each Working Group member and the country analyses issued by the EIA (see Figure 1-10 and Table 1-5).

Figure 1-10. Approach of Estimation



IEA = International Energy Agency; BP = British Petroleum; IEEJ = Institute of Energy Economics, Japan; AWEO = ASIA Energy Outlook; EIA = [US] Energy Information Administration; WEO = World Economic Outlook.
Source: Working Group of this study, 2016.

Table 1-5. Reference Materials and their Estimation

	IEA WEO 2015	IEEJ AWEO 2015
Oil	• Employ the New Policies Scenario, among the Current Policies Scenario, New Policies Scenario, 450 Scenario, Low Oil Price Scenario. • Production increase until 2020 and decline after that time.	• Employ the Advanced Technologies Case, among the Reference Case, Advanced Technologies Case, Low Oil Price Case. • Production is estimated to decrease in many Asian countries.
Natural gas	• Employ the New Policies Scenario. • Production steadily increases towards 2040.	• Employ the Advanced Technologies Case. • Production is estimated to increase in line with IEA WEO 2015.
Coal	• Employ the New Policies Scenario. • Production increase in major producing countries, except China where demand for power generation and industry sectors are estimated to decrease.	• Employ the Advanced Technologies Case. • Production is estimated to decrease as demand declines.

IEA = International Energy Agency; WEO = World Energy Outlook; IEEJ = Institute of Energy Economics, Japan.
Source: Working Group of the study, 2016.

3.7.2. Results of the fossil fuel production outlook

Tables 1-6 and 1-7 present the assumptions of the fossil fuel production outlook. The results indicate that:

- For crude oil, many countries will not be able to maintain recent production levels except in some cases such as Australia and Philippines where the oil production amount surpasses that of 2014. In most countries, oil reserves are estimated to be depleted in the future, an estimate based on the size of a country's oil reservoir (ERIA, 2015). Although some countries have untapped oil resources, their size seems too small to maintain current production amounts. In addition, insufficient investment in exploring new fields will hamper increasing production amounts. Furthermore, some fields may be too costly to exploit due to their geographical condition, such as deep sea and mountainous areas.

- For natural gas, production is estimated to increase in almost all gas-producing countries. On the whole, the region is relatively rich in natural gas resources compared with oil, and therefore many countries are promoting indigenous natural gas production. In particular, Australia and China, both richly endowed with conventional and unconventional gas resources, are expected to increase production, with Australia aiming to export and China for domestic supply. Some countries, such as Viet Nam, put natural gas at the centre of their energy mix, so they are boosting production activities.

- Coal (thermal + coking) production is estimated to decrease in China, the major coal-producing country, whereas India, the second largest coal consumer, will increase production. Their energy policies are different. China has changed its policy to pursue cleaner energy use, so it intends to curb coal consumption, whereas India's priority is to ensure energy supply at an affordable price, so it plans to increase domestically available cheap energy sources such as coal. Australia, a major coal exporter, is estimated to decrease production as global coal demand declines due to its gradual shift to a low-carbon society. Another major exporter, Indonesia, will increase production to meet its own consumption.

Table 1-6. Production Outlook of Oil and Gas

	Oil Production (1000b/d)						Gas Production (Bcm)					
	2014	2020	2025	2030	2035	2040	2014	2020	2025	2030	2035	2040
Australia	448	600	650	650	600	600	58.8	133.0	144.5	165.5	175.5	174.0
Brunei	138	140	130	130	120	120	11.9	12.5	12.5	12.5	12.5	12.5
China	4,341	4,300	4,250	4,200	4,100	4,000	134.5	172.0	212.0	255.0	299.0	342.0
India	895	740	680	680	700	720	31.7	38.0	45.0	55.0	69.0	89.0
Indonesia	852	830	820	800	780	770	73.4	80.0	82.0	83.0	84.0	85.0
Japan	17	15	15	15	15	15	3.9	3.5	3.0	3.0	3.0	2.5
Korea	20	15	15	15	15	15	0.5	0.5	0.5	0.5	0.5	0.5
Malaysia	666	650	620	600	600	600	66.4	68.0	70.0	67.0	65.0	65.0
Myanmar	20	20	20	20	20	20	16.8	17.5	18.5	18.5	18.5	18.5
Philippines	24	39	35	30	30	30	3.4	3.0	4.0	7.0	7.0	8.0
New Zealand	47	27	10	3	1	1	5.4	4.0	3.0	2.0	1.0	1.0
Thailand	453	480	470	460	450	440	42.1	42.0	41.0	40.0	40.0	40.0
Vietnam	365	360	350	330	320	320	11.1	11.0	15.0	18.0	22.0	25.0
Other Asia Pacific	144	150	140	130	130	130	73.7	77.0	76.0	75.0	74.0	74.0
Total Asia Pacific	8,430	8,366	8,205	8,063	7,881	7,781	533.6	662.0	727.0	802.0	871.0	937.0

b/d = barrel/day; Bcm = billion cubic metre.
Source: Working Group of the study, 2016.

Table 1-7. Production Outlook of Coal

	Coal Production (Mton)					
	2012	2020	2025	2030	2035	2040
Australia	431	437	421	412	411	405
China	3,532	3,548	3,383	3,286	3,132	2,944
India	604	627	650	624	652	683
Indonesia	444	471	476	478	478	480
Korea	2.09	1.76	1.20	0.63	0.07	0
Lao PDR	0.5	0.7	0.7	0.7	0.7	0.7
Malaysia	3.0	3.2	3.6	4.0	4.0	4.0
Myanmar	0.8	0.6	0.8	0.9	1.0	1.0
Philippines	7.3	7.1	7.9	9	9	9
New Zealand	4.9	4.1	4.0	3.9	3.8	3.7
Thailand	18	19	18	14	10	7
Viet Nam	42	42	41	42	49	53
Total	**5,090**	**5,161**	**5,007**	**4,875**	**4,752**	**4,591**

Mton = million tons.
Source: Working Group of the study, 2016.

3.8. Energy Saving Goals

Information about the potential energy savings achievable under specific policy initiatives to increase energy efficiency and reduce energy consumption was collected from each of the Working Group members from the 16 EAS countries. Each Working Group member specified which policy initiatives were existing policy, and should be applied to the BAU, and which were proposed policies, and should apply only to the APS. Quantitative energy savings were estimated based on the countries' own assumptions and modelling results. Table 1-8 shows the summary of energy saving goals, action plans, and policies collected from each EAS Working Group member in 2014.

Table 1-8. Summary of Energy Saving Goals, Action Plans, and Policies Collected from Each EAS Working Group Member

	Indicator	Goals
Australia	Carbon pollution	5 percent reduction below 2000 level by 2020
Brunei Darussalam	Energy intensity	45 percent improvement by 2035 from 2005 level
Cambodia	Final energy consumption	10 percent reduction of BAU by 2030
China	Energy intensity	16 percent improvement during the 12th 5-year plan (2011–2015)
India	Not submitted	
Indonesia	Energy intensity	Reduce by 1 percent/year until 2025
Japan	Energy intensity	30 percent improvement in energy intensity in 2030 from 2003 level
Korea, Rep. of	Energy intensity	46.7 percent reduction by 2030 from 2006 level
Lao PDR	Final energy consumption	10 percent reduction from BAU by 2030 5 percent energy intensity reduction by 2030, from 2015.
Malaysia	Final energy consumption	8.6 percent reduction from BAU by 2020
Myanmar	TPES	• 5 percent reduction from BAU by 2020 • 10 percent reduction from BAU by 2030 (Final energy consumption: 5 percent by 2020 and 8 percent by 2030).
New Zealand	Energy intensity	1.3 percent per year improvement from 2011 to 2016
Philippines	Final energy consumption	10 percent savings from BAU by 2030
Singapore	Energy intensity	• 20 percent reduction by 2020 from 2005 level • 35 percent reduction by 2030 from 2005 level
Thailand	Energy intensity	• 15 percent reduction by 2020 from 2005 level • 25 percent reduction by 2030 from 2005 level
Viet Nam	Final energy consumption	• 3–5 percent saving from BAU until 2015 • 5–8 percent saving from BAU after 2015

EAS = East Asia Summit; TPES = Total Primary Energy Supply; BAU = Business-as-Usual scenario.
Source: Tomoyuki (2014).

3.8. Economic Growth and Climate Change Mitigation

Economic growth in the EAS countries is needed to provide for the region's growing population and improving living standards. Economic growth is assumed to exceed population growth from 2013 to 2040. This relatively strong economic growth and rising per capita incomes in the EAS countries could mean significant reductions in poverty and significant increases in living standards for hundreds of millions of people.

With economic growth will come increasing access to, and demand for, electricity and rising levels of vehicle ownership. The continued reliance on fossil fuels to meet the increases in energy demand may be associated with increased GhG emissions and climate change challenges unless low emission technologies are used. Even if fossil fuel resources are sufficient, much of the fuel is likely to be imported from other regions, and no assurance can be given that they will be secure or affordable.

Fossil fuel consumption using today's technologies will lead to considerable increases in GhG emissions, potentially creating new longer-term threats to the region's living standards and economic vitality. Growing adverse health impacts throughout the region are also likely as a result of particulate emissions.

Given this, considerable improvements in energy efficiency and greater uptake of cleaner energy technologies and renewable energy are required to address a range of energy, environmental, and economic challenges. Yet, efforts to limit energy consumption and GhG will be very challenging given such strong growth. However, as will be discussed in Section 4.3, sharp reductions in GhG are being called for by scientists. This huge 'headwind' working against EEC and emission reductions poses a challenge to the EAS region that needs to be addressed.

4. Energy and Environmental Outlook for the EAS Region

4.1. Business-as-Usual Scenario

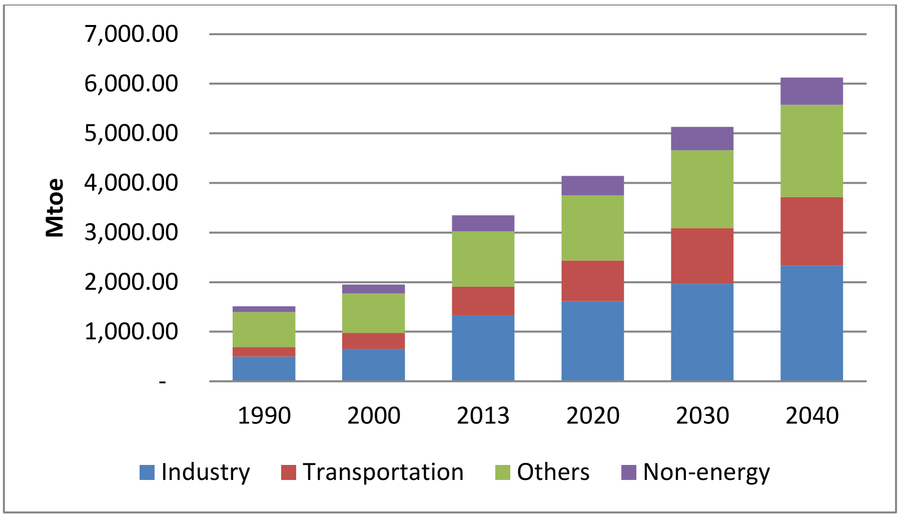
4.1.1. Final energy consumption

Between 2013 and 2040, total final energy consumption[3] in the 16 EAS countries is projected to grow at an average annual rate of 2.3 percent, reflecting the assumed 4.0 percent annual GDP growth and 0.6 percent population growth. Final energy consumption is projected to increase from 3,347 million tons of oil equivalent (Mtoe) in 2013 to 6,129 Mtoe in 2040. By sector, transport energy demand is projected to grow most rapidly, increasing by 3.3 percent per year, as a result of motorisation driven by increasing disposable income as EAS economies grow. Demand in the commercial and residential ('Others') sectors will grow 1.9 percent per year, slower than that of the industry sector. Energy demand in the industry sector is projected to grow at an average annual rate of 2.1 percent. Figure 1-11 shows final energy consumption by sector under BAU in EAS, from 1990 to 2040.

The shares of final energy consumption by sector in 2013–2040 indicate that the transport sector is projected to have an increasing share, growing from 17.2 percent to 22.6 percent in 2013–2040. The industrial and other (largely residential and commercial) sectors are projected to have decreasing shares – 39.8 percent to 38.0 percent for industry, and 33.4 percent to 30.3 percent for 'Others' – from 2013 to 2040. The share of non-energy demand is also projected to have a decreasing share, from 19.6 percent to 9.1 percent, during 2013–2040. Details of sectoral shares in final energy consumption are shown in Figure 1-12.

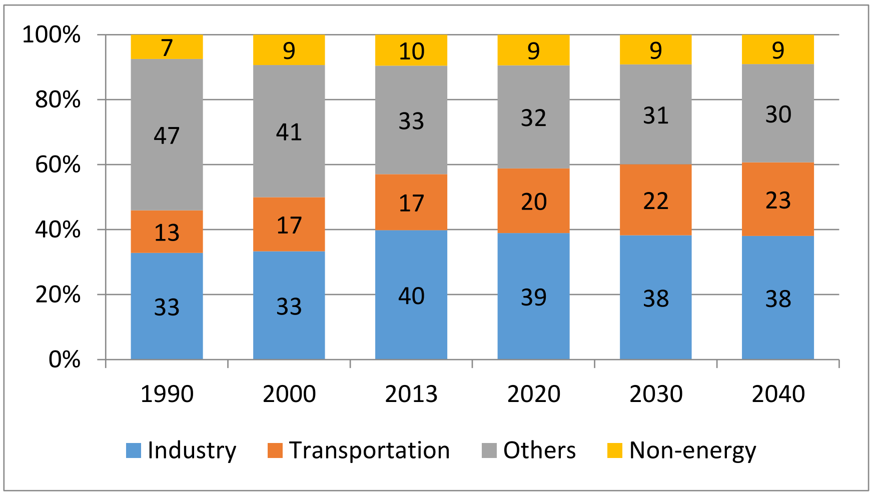
[3] Refers to energy in the form in which it is actually consumed, i.e. including electricity, but not including the fuels and/or energy sources used to generate electricity.

Figure 1-11. Final Energy Consumption by Sector (1990–2040), BAU



BAU = Business-as-Usual scenario; Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

Figure 1-12. Final Energy Consumption Share by Sector (1990–2040)

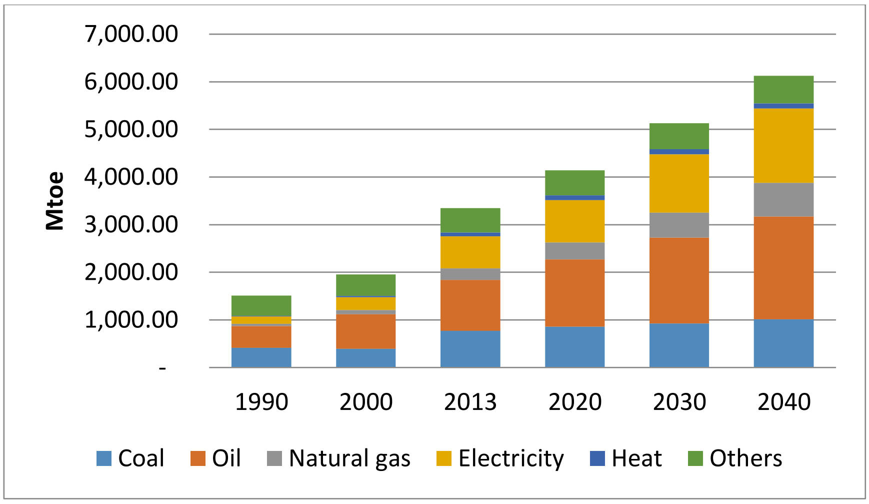


Source: Authors' calculation.

Figures 1-13 and 1-14 show final energy consumption and shares by fuel type in the EAS under the BAU from 1990 to 2040. By energy source, natural gas demand in the BAU is projected to show the fastest growth, increasing by 4 percent per year, from 243 Mtoe in 2013 to 704 Mtoe in 2040.

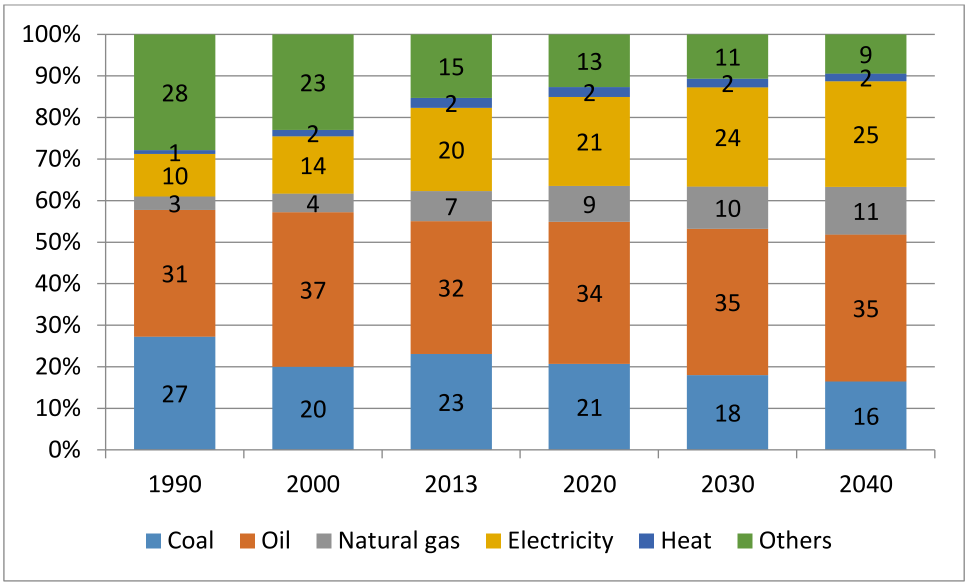
Although oil will retain the largest share of total final energy consumption, it is projected to grow at a lower rate of 2.6 percent per year in 2013–2040, reaching 2,164 Mtoe in 2040, compared with the average annual growth of 3.8 percent over the last 2 decades. However, its share will still increase from 32 percent in 2013 to 35.3 percent in 2040. Demand for electricity will grow at a relatively fast rate of 3.2 percent per year. Its share will increase from 20 percent in 2012 to 25.4 percent in 2040, surpassing the share of coal. Coal demand will grow at a slower rate of 1 percent per year on average, reaching 1,010 Mtoe in 2040. Other fuels, which are mostly solid and liquid biofuels, will have a slow annual growth rate of 0.5 percent on average, but consumption of liquid biofuels will grow rapidly, reaching 579 Mtoe in 2040. Consequently, the share of other fuels will decline from 15.3 percent in 2013 to 9.4 percent in 2035. This slow growth is due to the gradual shift from non-commercial biomass to conventional fuels such as liquefied petroleum gas (LPG) and electricity in the residential sector.

Figure 1-13. Final Energy Consumption by Fuel (1990–2040)



Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

Figure 1-14. Final Energy Consumption Share by Fuel (1990–2040)



Source: Authors' calculation.

4.1.2. Primary energy supply

Figure 1-15 shows primary energy supply from 1990 to 2040. Primary energy supply[4] in the EAS region is projected to grow at a slightly slower pace, of 2.2 percent per year, as final energy consumption grows at 2.3 percent per year.

EAS primary energy supply is projected to increase from 5,257 Mtoe in 2013 to 9,517 Mtoe in 2040. Coal will remain as the largest share of primary energy supply, but its growth is expected to be slower, increasing at 1.7 percent per year. Consequently, the share of coal in total primary energy supply (TPES) is forecast to decline from 52 percent in 2013 to 44.8 percent in 2040.

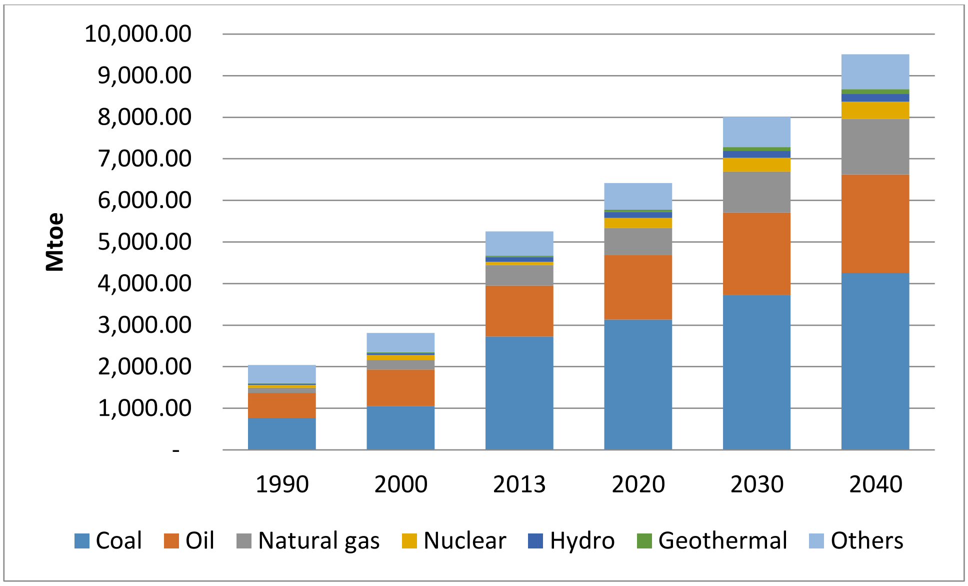
Among fossil sources of energy, natural gas is projected to see the fastest growth from 2013–2040, increasing at an annual average rate of 3.7 percent. Its share in the total will consequently increase from 9.1 percent (equivalent to 499 Mtoe) in 2013 to 12.7 percent (equivalent to 1339 Mtoe) in 2040.

Nuclear energy is also projected to increase at a rapid rate of 6.4 percent per year on average and its share will grow from 1.5 percent in 2013 to 4.3 percent in

[4] Refers to energy in its raw form, before any transformations, most significantly the generation of electricity.

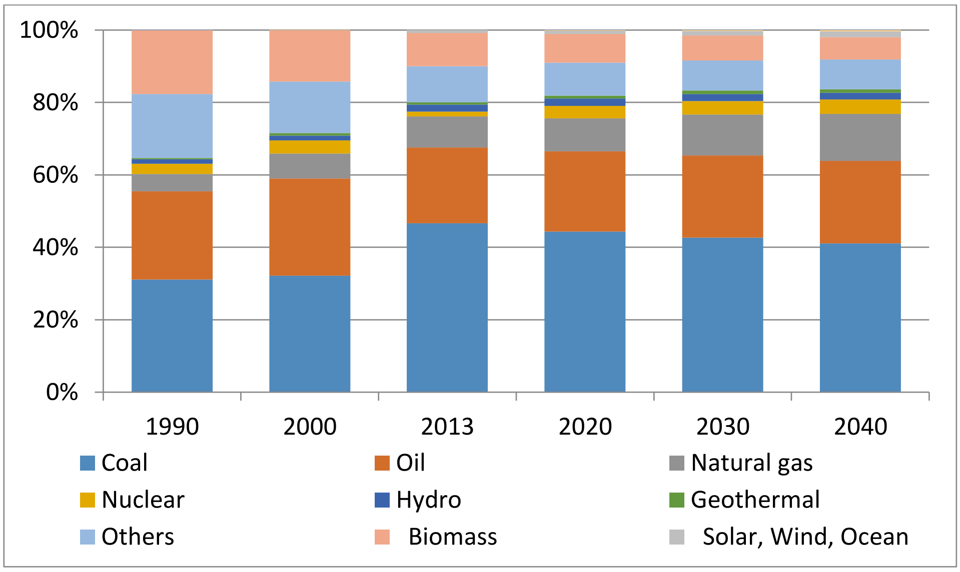
2040. This is due to the assumed resumption of nuclear power generation in Japan, the expansion of nuclear power generation capacity in China and India, and the introduction of this energy source in Viet Nam.

Figure 1-15. Primary Energy Supply in EAS (1990–2040)



Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

Figure 1-16. Share of Primary Energy Mix by Sources in EAS (1990–2040)



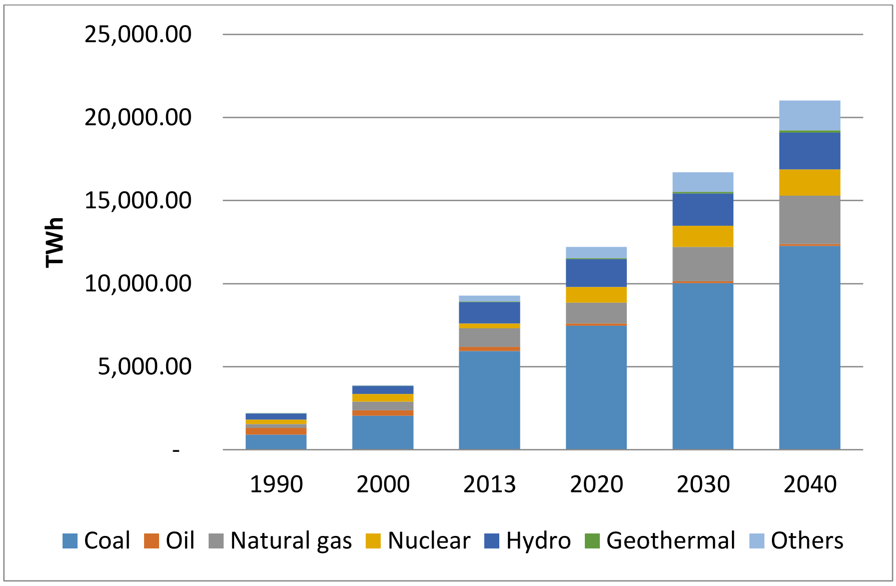
EAS = East Asia Summit.
Source: Authors' calculation.

Among the energy sources, 'Others' – which is made up of solar, wind, and solid and liquid biofuels – will see the slowest growth rate of 1.4 percent. Consequently, the share of these other sources of energy will decrease from 11.1 percent in 2013 to 8.9 percent in 2040. Geothermal energy will increase at a rapid pace of 4.1 percent per year, but its share will remain low and will reach only 1.1 percent in 2040, a slight increase from 0.7 percent in 2013. The growth of hydro will be 2.0 percent per year and its share will remain low, at around 2.0 percent from 2013 to 2040. Figure 1-16 shows the shares of each energy source in the total primary energy mix from 1990 to 2040.

4.1.3. Power generation in EAS

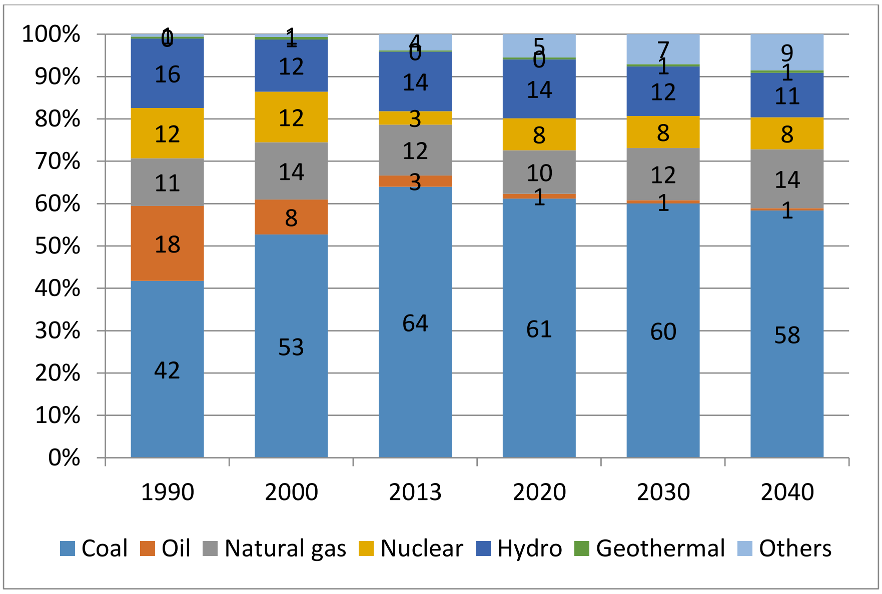
Figure 1-17 shows the power generation output in the EAS region. Total EAS power generation is projected to grow at 3.1 percent per year on average, from 2013 (equivalent to 9,282 TWh) to 2040 (equivalent to 21,015 TWh). However, the growth rate from 1990 to 2013 was 6.5 percent, more than twice as high as the projected growth rate from 2013 to 2040.

Figure 1-17. Power Generation in EAS (1990–2040)



EAS = East Asia Summit; TWh = terawatt-hour.
Source: Authors' calculation.

Figure 1-18. Share of Power Generation Mix in EAS (1990–2040)



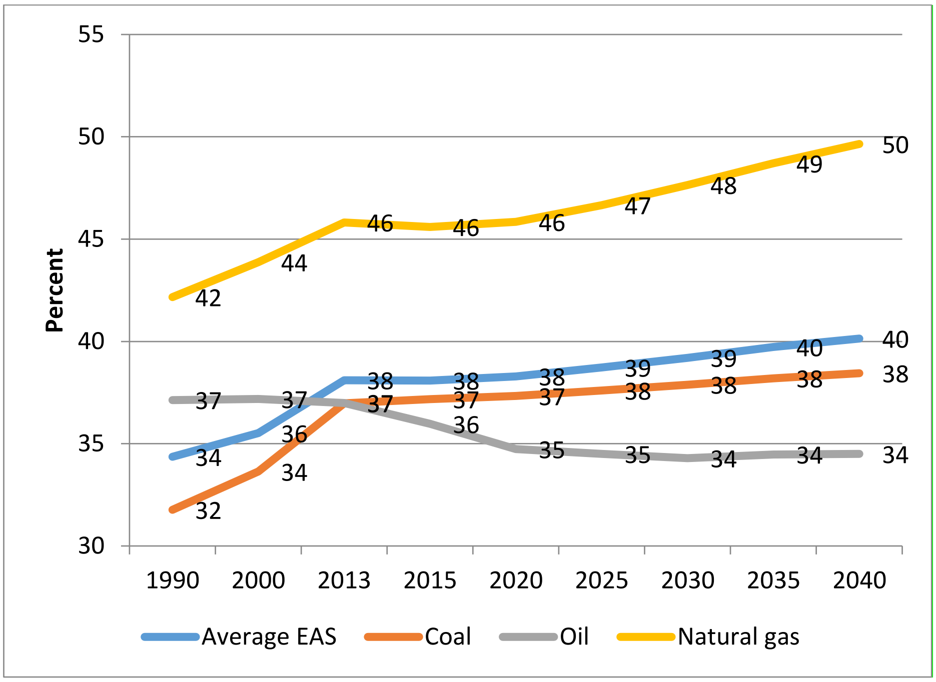
Source: Authors' calculation.

Figure 1-18 shows the shares of each energy source in electricity generation in 1990–2040. The share of coal-fired generation is projected to continue to be the largest and will be about 58.4 percent in 2040, a little drop from the 64 percent share in 2013. The share of natural gas is projected to increase from 12 percent in 2013 to 14 percent in 2040. The nuclear share (3.2 percent in 2013) is forecast to increase to 7.6 percent in 2040. Geothermal (0.3 percent in 2013) and other (wind, solar, biomass, etc., at 3.9 percent) shares will also increase to 0.6 percent and 8.5 percent in 2040, respectively. The shares of oil and hydro are projected to decrease, from 2.7 percent to 0.5 percent, and from 14.0 percent to 10.6 percent, respectively, over the same period.

Figure 1-19 shows the thermal efficiency of coal-, oil-, and natural gas-fired power plants from 1990 to 2040. Thermal efficiency is projected to grow in EAS from 2013–2040 due to improvement in electricity generation technologies such as combined-cycle gas turbines and advanced coal power plant technologies. The efficiency of coal thermal power plants, which is a mix of old and new power plants, will increase slightly, from 37 percent in 2013 to 38.4 percent in 2040. The efficiency of natural gas power plants will also increase, from 45.8 percent in 2013 to 49.6 percent in 2040. Oil power plants, which will not be used very much in future, will see a deterioration in efficiency, dropping from 37.0 percent in 2013 to

34.5 percent in 2040. The drop in thermal efficiency of oil power plants is understandable as facilities are ageing.

Figure 1-19. Thermal Efficiency by Fuel, BAU (1990–2040)



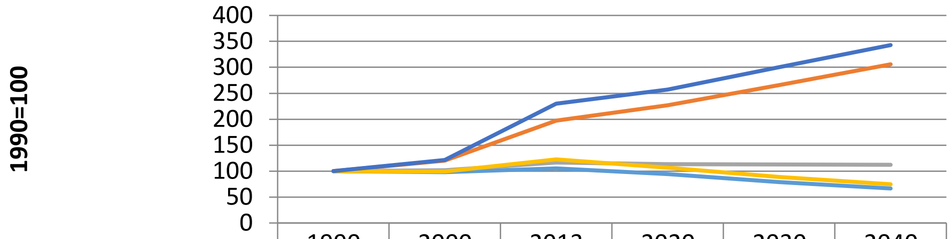
BAU = Business-as-Usual scenario; EAS = East Asia Summit.
Source: Authors' calculation.

4.1.4. Primary energy intensity and per capita energy demand

Figure 1-20 shows the energy intensity and energy per capita from 1990 to 2040. For BAU, energy intensity in EAS is projected to decline by 23 percent, from 359 toe/million US$ (constant 2005) in 2013 to 227 toe/million US$ in 2040. The improvement in energy intensity is also reflected in the improvement in CO_2 intensity at a similar pace.

In contrast to energy intensity, energy demand per capita is projected to increase by 206 percent, from 1.5 toe per person in 2013 to 2.4 toe per person in 2040. This could be attributed to the projected continuing economic growth in the region, which will bring about a more energy-intensive lifestyle as people are able to purchase vehicles, household appliances, and other energy-consuming devices due to rise in disposable income. As energy demand per capita increases, CO_2 per capita is projected to increase at a similar rate.

Figure 1-20. Energy Indicators in EAS



	1990	2000	2013	2020	2030	2040
Energy Intensity	100	98	105	94	79	67
Energy per Capita	100	120	197	227	266	306
CO2 per Energy	100	101	116	113	113	112
CO2 Intensity	100	99	123	107	89	75
CO2 per Capita	100	122	230	257	300	343

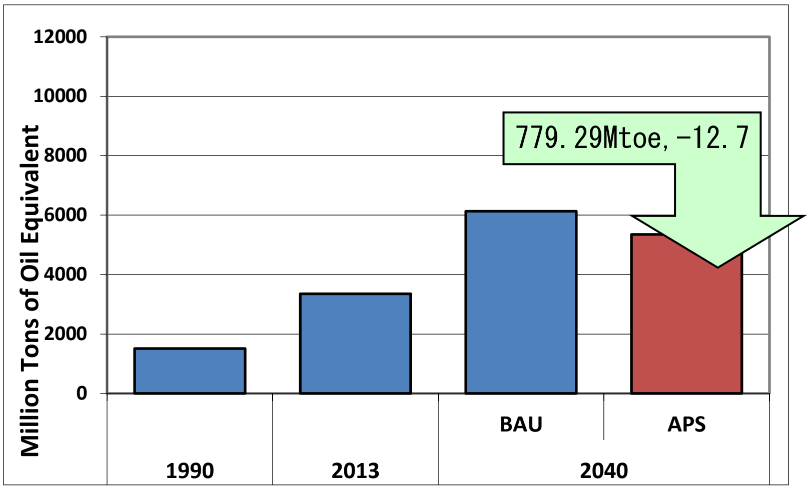
EAS = East Asia Summit; CO_2 = carbon dioxide.
Source: Authors' calculation.

4.2. Comparison of BAU and APS

4.2.1. Total final energy consumption – BAU vs APS

In the APS case, final energy consumption is projected to rise to 5,349 Mtoe, 779 Mtoe or 12.7 percent lower than in the BAU case in 2040. This is due to the various energy efficiency plans and programmes, presented in Section 3 above, on both the supply and demand sides that are to be implemented by EAS countries. Figure 1-21 shows the evolution of final energy consumption in 1990–2040 in both BAU and APS.

Figure 1-21. Total Final Energy Consumption, BAU and APS

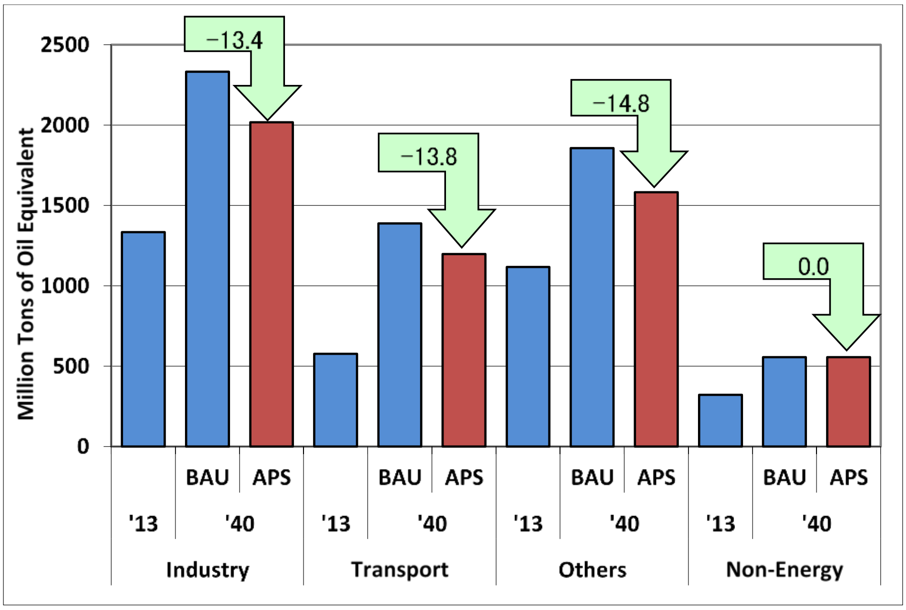


BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

4.2.2. Final energy consumption by sector – BAU vs APS

Figure 1-22 shows the composition of final energy consumption by sector in both the BAU and APS. Final energy consumption in most sectors is significantly reduced in the APS case compared with the BAU case. In percentage terms, the reduction is largest in the industry sector (13.4 percent), followed by the 'others' sector (14.8 percent), the transport sector (13.8 percent); non-energy demand will not be significantly different from the BAU.

Figure 1-22. Final Energy Consumption by Sector, BAU vs APS

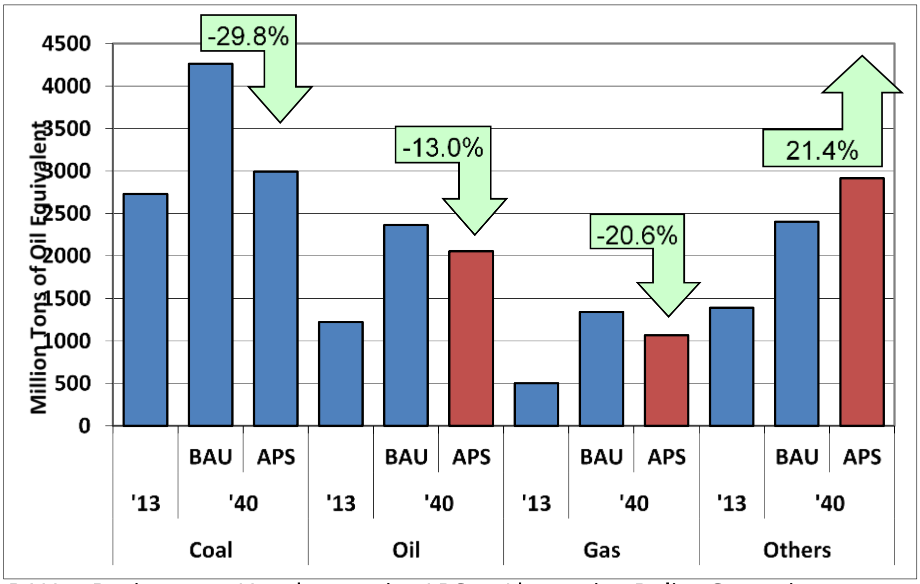


BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario.
Source: Authors' calculation.

4.2.3. Primary energy supply by sources – BAU vs APS

Figure 1-23 shows primary energy supply by fuel sources. In the APS case, growth in final energy consumption for all fuels is lower compared with the BAU case. The growth rate in final energy consumption of APS is projected to be 1.6 percent per year on average from 2013 to 2040. This rate is lower than the BAU case in which the growth rate is projected to be 2.2 percent. In absolute terms, the largest reduction will be in coal demand, by 1,268 Mtoe or 29.8 percent, from the BAU's 4,261 Mtoe to 2,993 Mtoe in the APS. The saving potentials for other fuels are projected to be 306 Mtoe for oil (equivalent to a 13 percent reduction from BAU), and 275 Mtoe for gas (equivalent to a 20.6 percent reduction from the BAU).

Figure 1-23. Primary Energy Supply by Sources, BAU and APS



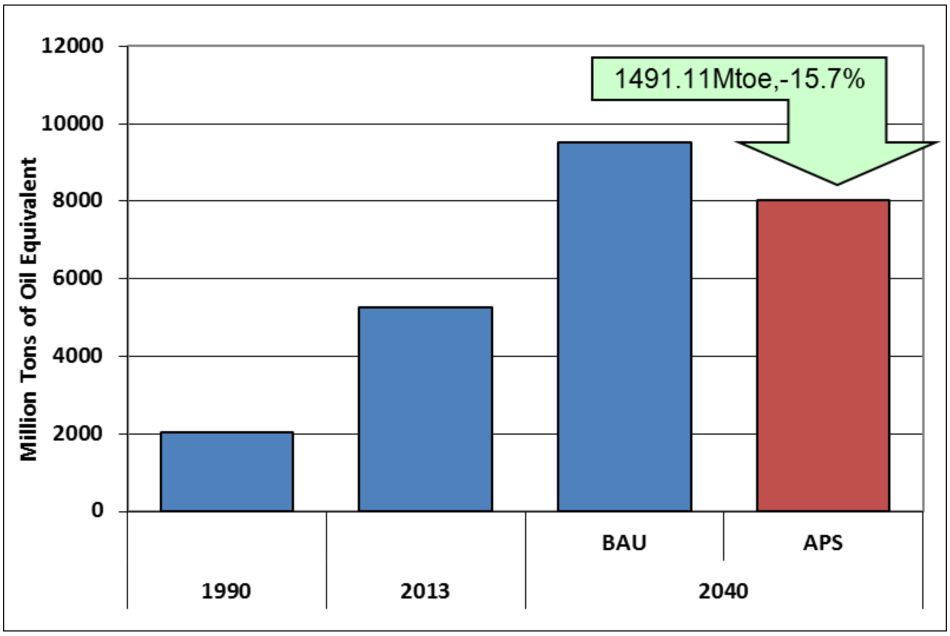
BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario.
Source: Authors' calculation.

4.2.4. Total primary energy supply – BAU vs APS

Figure 1-24 shows TPES in both BAU and APS. The total saving potential in the TPES is expected to be 1,491 Mtoe, a consumption reduction from 9,518 Mtoe in BAU to 8,026 Mtoe in APS. This saving potential represents a 15.7 percent reduction from BAU to APS.

The energy saving potential is brought about by improvements in both the transformation sector, particularly power generation, and the final energy consumption sector where efficiencies of household appliances and more efficient building designs are expected. For the 'others' sector, there is an expected increase of renewable energy in the energy supply, which is projected to be a 21.4 percent increase from the BAU to APS.

Figure 1-24. Total Primary Energy Supply – BAU and APS



BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

4.3. CO_2 Emissions from Energy Consumption

4.3.1. CO_2 emissions

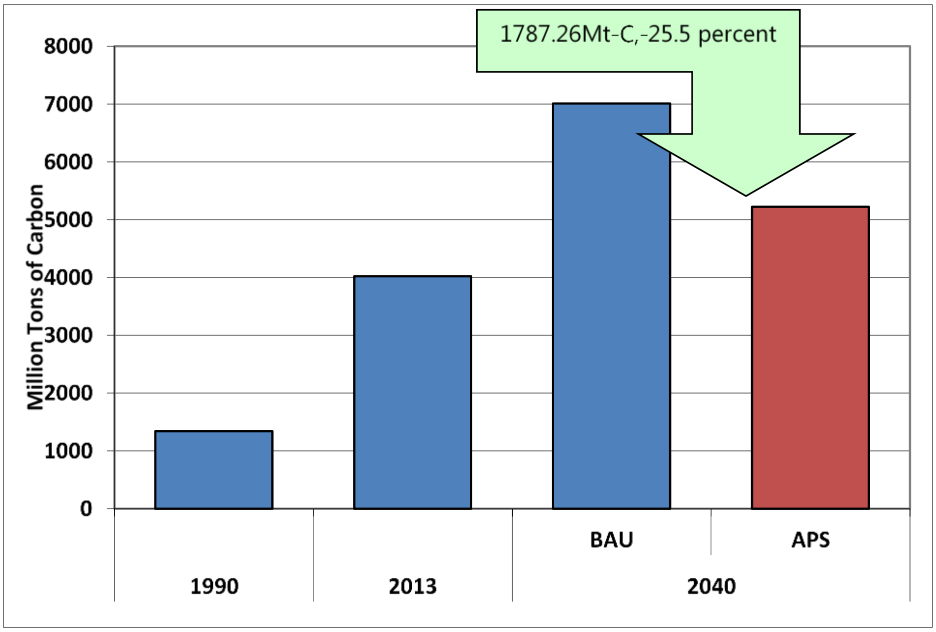
As shown in Figure 1-25, CO_2 emissions from energy consumption in the BAU case are projected to increase from 4,023 million tons of Carbon (Mt–C) in 2013 to 7,010 Mt–C in 2040, implying an average annual growth rate of 2.1 percent. This is slightly lower than growth in TPES of 2.2 percent per year. In the APS case, CO_2 emissions are projected to be 5,223 Mt–C in 2040, 25.5 percent lower than under the BAU.

At the Paris climate conference (COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2 degrees Celsius (°C). The Paris Agreement is a bridge between today's policies and climate neutrality before the end of the century.

Although the emission reductions under the APS are significant, CO_2 emissions from energy demand in the APS case in 2040 will still be above 2013 levels and more than three times higher than 1990 levels. Scientific evidence suggests that these reductions will not be adequate to prevent severe climate change impacts. Analysis by the Intergovernmental Panel on Climate Change (IPCC) suggests that to keep the increase in global mean temperature to not much more than 2°C compared with pre-industrial levels, global CO_2 emissions would need to peak between 2000 and 2015.

In the adopted version of the Paris Agreement, the parties will also 'pursue efforts' to limit the temperature increase to 1.5°C, which will require zero emissions sometime between 2030 and 2050, according to the scientists. However, this study shows that even in the APS, the emission will be about 4,870 Mt-C. It is supposed to be at zero emission for the efforts to limit the temperature increase to 1.5°C to be successful.

Figure 1-25. Total CO_2 Emissions – BAU and APS



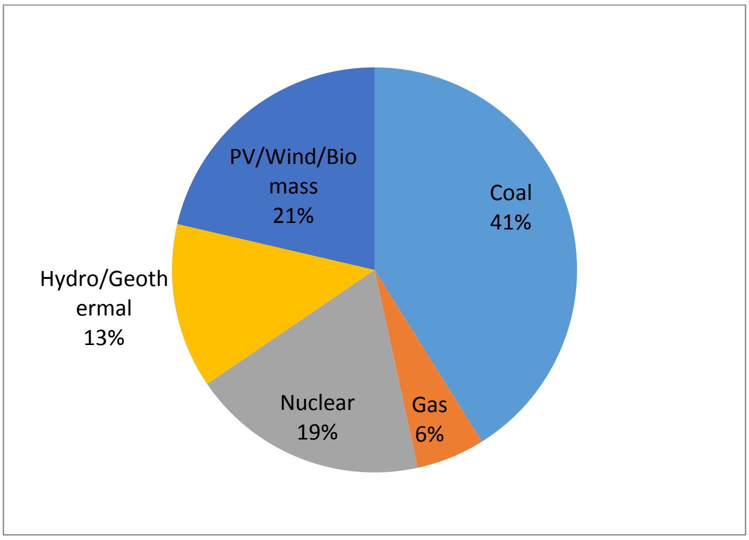
CO_2 = carbon dioxide; BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mtoe = million tons of oil equivalent.
Source: Authors' calculation.

Although much depends on the mitigation achieved in other regions, it would appear unlikely that global emissions could meet either of these profiles given the contribution of the EAS region to global total emissions under the APS results. Therefore, it is very important that the COP21 through the Intended Nationally Determined Contributions (INDCs) will need to seriously implement the GhG abatement and traces the way to achieving the targets set in INDCs.

4.4. Necessary Investment Cost for Power Sector

Based on the energy outlook results, BAU and APS, the Working Group estimated the necessary investment in the power sector, especially power generation facilities, which comprise of coal, gas, nuclear, hydro, geothermal, solar photovoltaic (PV), wind, and biomass power generation plants. It drew on several sources of information to obtain the current capital cost of each power plant, but it did not forecast future capital cost due to its uncertainty. For all EAS countries taken together, approximately US$4 trillion would be needed due to the rapid increase in electricity demand in the region. Figures 1-26 and 1-27 show the investment shares by power generation type for the BAU and the APS. It is clear that investment in power generation under the APS could shift to low-carbon power generation sources such as nuclear and PV/wind/biomass.

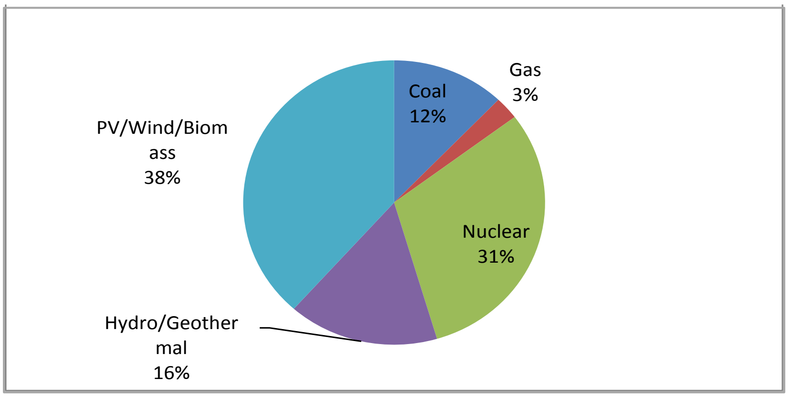
Figure 1-26. Investment Share by Power Sources (EAS–BAU)



EAS = East Asia Summit; BAU = Business-as-Usual scenario; PV = photovoltaic.
Source: Authors' calculation.

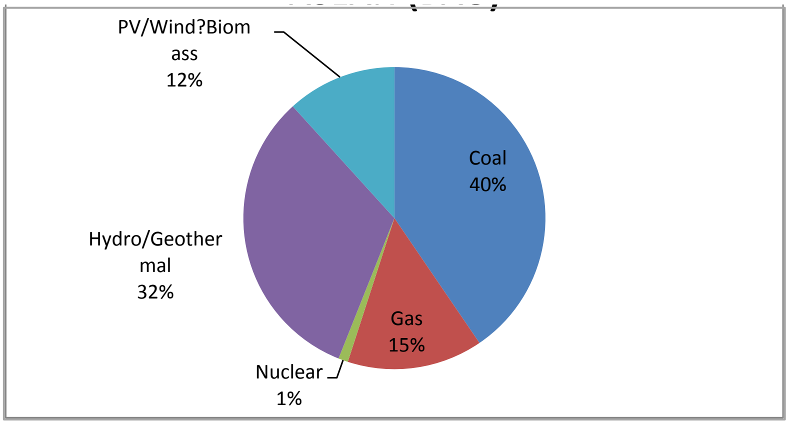
Figures 1-28 and 1-29 show the investment need for the 10 ASEAN Member States and the '+6' countries – Australia, China, India, Japan, Korea, and New Zealand. ASEAN would account around US$600 billion and the +6 countries for around US$3.4 trillion due to the huge investment in power generation needed by China and India. The investment shares by power sources are quite different. In case of the BAU, investment in coal and hydro/geothermal power are the dominant shares in the ASEAN–BAU case, whereas for the +6 countries the greatest investment needs are in coal, nuclear, and PV/wind/biomass power plants.

Figure 1-27. Investment Share by Power Sources (EAS–APS)



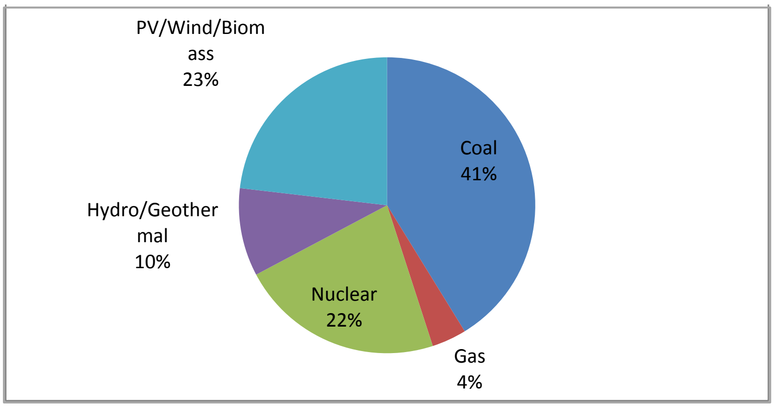
EAS = East Asia Summit; EAS = Alternative Policy Scenario; PV = photovoltaic.
Source: Authors' calculation.

Figure 1-28. Investment Share by Power Sources (ASEAN–BAU)



ASEAN = Association of Southeast Asian Nations; BAU = Business-as-Usual scenario; PV = photovoltaic.
Source: Authors' calculation.

Figure 1-29. Investment Share by Power Sources (+6 – BAU)

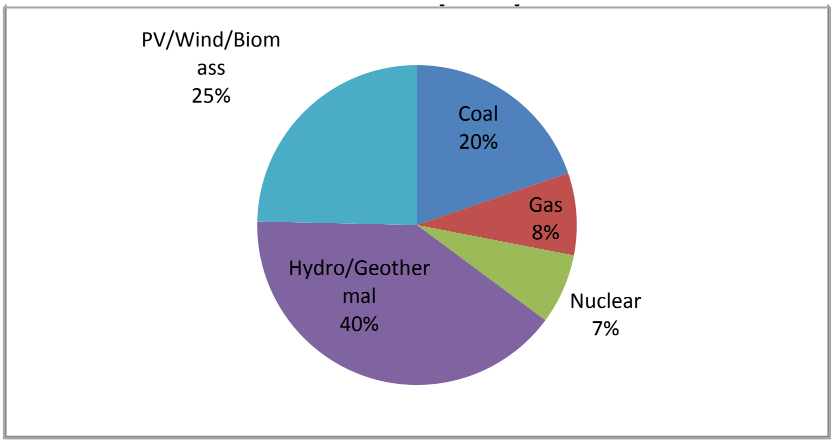


BAU = Business-as-Usual scenario: PV = photovoltaic.
Source: Authors' calculation.

In the APS case, ASEAN will shift from coal to hydro/geothermal and PV/wind/biomass, whereas the +6 countries will shift from coal to nuclear and PV/wind/biomass.

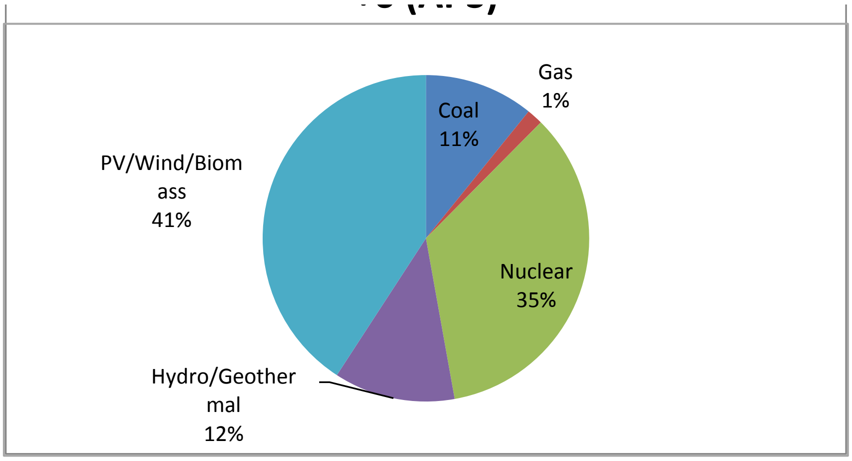
Figures 1-30 and 1-31 show the investment share by power sources under the APS for ASEAN and the +6 countries. The increase of the renewable share in power generation could be expected as the operation rate of renewable energy such as solar PV and wind power plants is quite low. If the policy to promote solar PV and wind is implemented, a large capacity of solar PV and wind will be needed; this means initial capital (investment) costs could be higher.

Figure 1-30. Investment Share by Power Sources (ASEAN–APS)



ASEAN = Association of Southeast Asian Nations; APS = Alternative Policy Scenario.
Source: Authors' calculation.

Figure 1-31. Investment Share by Power Sources (+6–APS)



APS = Alternative Policy Scenario.
Source: Authors' calculation.

5. Conclusions and Recommendations

At the third Working Group meeting, the members discussed the key findings and implications of the analysis based on the two energy outlook scenarios – BAU and APS.

5.1. Key Findings

Based on projected changes in socio-economic factors, energy consumption, and $C0_2$ emissions in the BAU and the APS, the Working Group members identified several key findings:

- Sustained population and economic growth in the EAS region will lead to significant increases in energy demand. Total final energy consumption in 2040 will increase 1.8 times from 2013, with natural gas increasing 2.9 times during this period. Oil will increase 2.0 times, but will retain its highest fuel share in final consumption at 2,164 Mtoe. Transportation sector demand – which is dominated by road transport – will increase 2.4 times to 1,388 Mtoe in 2040.
- Electricity generation from 2013 to 2040 will increase 2.3 times, to 21015.3 GWh from 2013, and coal is projected to increase 2.1 times. Although

nuclear will increase 5.4 times and NRE 2.5 times during this period, coal will still have the largest share, at 58.4 percent, in 2040. Electricity generation will be the source of 64.4 percent of the 4,261 Mtoe of primary consumption of coal in the EAS region in 2040.

- TPES will increase 1.8 times in 2013–2040. But even in the BAU, the EAS region's energy elasticity, which is defined as the growth rate of primary energy supply divided by the growth rate of GDP from 2013 to 2040, is projected to improve to 0.56 (2.2/4.0), compared with 1.06 (4.2/4.0) from 1990 to 2013.
- The continuing reliance on fossil fuels to meet increasing energy demand will also be associated with significant increases in CO_2 emissions. However, even in the BAU, CO_2 elasticity, defined as the growth rate of CO_2 emissions divided by the growth rate of GDP in 2013–2040, will be 26 percent lower than energy elasticity. There are two reasons for this. The first is diversification among fossil energy from coal to gas. Coal's share of the total primary energy mix is forecast to decline from around 52 percent in 2013 to 45 percent in 2040. On the other hand, the share of gas is projected to increase to 14.0 percent from 9.5 percent over the same period. The second reason is the increased use of carbon-neutral energy, such as nuclear power, hydro power, geothermal power, and NRE. The share of carbon-neutral energy in 2013 was 15.4 percent, but is forecast to increase to 16.3 percent in 2040.
- Overall, the EAS energy mix in the BAU will change in 2013–2040. The share of coal and oil will fall from 75 percent to 70 percent. The diversification of the regional energy mix, which increases the share of low-carbon and carbon-neutral energy, will contribute to improvements in carbon intensity.
- Industry remains a major consumer of energy, but the transport sector's consumption continues to increase rapidly. These two sectors are challenging sectors in terms of improving energy efficiency and reducing CO_2 emissions. Hence, appropriate EEC programmes and low-emission technologies are needed in these sectors.
- Throughout the region, there is strong potential to increase energy efficiency to reduce growth in energy consumption and CO_2 emissions. The results of this analysis indicate that by 2035 the implementation of currently proposed energy efficiency goals, action plans, and policies across the EAS

region could lead to the following reductions:

- 13.2 percent in primary energy supply;
- 13.2 percent in energy intensity; and
- 23.8 percent in energy derived CO_2 emissions.

Based on the key findings, this study also quantifies the power generation investment needed for the EAS region for both BAU and APS. It shows that the investment requirement for power generation for the total EAS countries will be around US$3.8 trillion under the BAU to increase the generation capacity to meet the demand over the 2013–2040 period. Most of the investment (41 percent) under the BAU will be for additional coal power plants, assumed to be mainly supercritical plants. Investment for additional nuclear power plants will be around 19 percent and 34 percent for NRE plants.

In the APS, although electricity demand is lower due to the implementation of efficiency measures, the estimated investment will be larger (US$4 trillion), mainly because of the increased share of renewable imposed under the APS in addition to the EEC measures. The largest share of total investment will be for additional capacity of NRE plants such as hydro, geothermal, solar PV, wind, and biomass, projected to account for about 54 percent. The investment share for additional capacity of nuclear power plants will also be high, at 31 percent. Investment for additional coal power plants will account for only 12 percent and the remaining 3 percent will be that of gas combined cycle plants.

5.2. Policy Implications

Based on the above key findings, the Working Group members identified a number of policy implications, which were aggregated into five major categories. The identified policy implications are based on a shared desire to enhance action plans in specific sectors, prepare appropriate energy efficiency policies, shift from fossil energy to non-fossil energy, rationalise energy pricing mechanisms, and a need for accurate energy consumption statistics. The implications identified by the Working Group are listed below. It should be noted that appropriate policies will differ between countries based on differences in country circumstances, policy objectives, and market structures and that not all members necessarily agreed to all recommendations.

1) ***Energy efficiency action plans in final consumption sectors:*** The industry sector would be a major source of energy savings because it will still be the largest energy-consuming sector by 2040. There are several EEC action plans to be implemented, which include building design and replacement of existing facilities and equipment with more efficient ones. Those policies are listed by areas/sectors:
   - The building sector would need both passive and active design policies such as:
     - Building codes and rewards for green building will need to be set up and enforced by law.
     - Governments need to provide financial support to implement building energy efficiency measures for both new buildings and existing buildings (retrofit).
     - Governments need to establish funds such as the Energy Service Company. There are ways to raise funds such as levies on petroleum.
     - A good and practical green building business model will need to be explored and established meet to the context and situation.
     - Energy building codes will need to be implemented, and designated large consumers for energy audit and applied green building need to be chosen. For example, some public buildings in Indonesia have targets of 10 percent electricity saving, and the government established energy building awards to promote the energy efficiency activity in public and commercial building sector.

- Change the industrial structure from heavy to light industries – a shift of energy-intensive industry to less energy–intensive industries would reduce energy consumption per unit of GDP output.

- The road transport sector will need to consider measures to reduce energy consumption per unit of transport activities such as:
  - Improve fuel economy;
  - Shift from personal to mass transportation mode;

    - Shift to more efficient technologies such as hybrid vehicles and clean alternative fuels;
- Other sectors will need to consider measures to improve energy efficiency such as:
    - Use demand management systems such as household energy management systems (HEMS) and building energy management systems (BEMS);
    - Improve thermal efficiency in the power generation sector by constructing or replacing existing facilities with new and more efficient generation technologies.

2) ***Renewable energy policies:*** There is a need to shift from fossil to non-fossil fuels. This could be attained by increasing the share of NRE as well as nuclear energy in the energy mix of each country. Several policies and actions will need to be considered:

- Renewable technologies are not as competitive as thermal power generation technologies using fossil fuel. Supportive renewable energy policies are needed, therefore, and they can be categorised as energy policies and financial policies. The former mainly include policies such as Feed-in-Tariff (FiT), Renewable Portfolio Standard (RPS), net metering, carbon tax, or carbon cap and trade. Financial policies include public financing, carbon financing, and banking regulations with sustainability requirements. The key to incentivise private investment in renewable energy is to lower the risks related to renewable energy projects and improve the profitability prospects.
- The intermittent nature of renewable energy sources poses significant challenges in integrating renewable energy generation with existing electricity grids. Thus, government investment in electricity storage technologies, especially for solar and wind power, will be very important.

3) ***Technology development policies:*** To curb the increasing CO_2 emissions, environmental technologies will need to be considered:

- The development of carbon capture and storage (CCS) technology will be very important in controlling the release of greenhouse gases into the atmosphere. Continued research and development (R&D) will be important to ensure the future economic viability of deploying CCS technology.

- Hydrogen fuel could be extracted during the process of fossil fuel combustion, and thus make thermal efficiency very high (for the power plant, it is IGFC – Integrated Gasification Fuel-cell). Hydrogen fuel development is very promising and could be commercialised in the future. Continued R&D in fuel cells will be important for future clean fuel utilisation.
- There needs to be a carbon market to speed up environmental technology development. Hence, development of clean coal technology (CCT) will need to be accelerated in the ASEAN region with the help of attractive financial frameworks, lowering the borrowing costs of long-term loans.
- Technological cooperation and technology diffusion will be need to be accelerated in the ASEAN region.

4) ***Energy supply security policies:*** The region is largely depending on imported oil and gas. Thus, measures to secure the supply of energy will be very important for the region. Several measures are identified:

- Promote regional energy cooperation such as the trans-ASEAN gas pipeline and the ASEAN Power Grid;
- Diversify sources of import;
- Strengthen energy infrastructure including the construction of receiving LNG terminals and re-gasification plants;
- To have an optimal energy mix (the share of energy supply from various sources), especially increasing the share of renewable energy;
- For the oil and gas producing countries, the management of and policies for up-stream activity such as oil and gas exploration and down-stream activity such as oil and gas end-use regulation will be essential;
- ASEAN may need to look into the strategic reserve or stock piling requirement in the near future under the ASEAN Petroleum Security Agreement to support the ASEAN countries in case of events such as oil supply shocks or disruptions.

5.3. Recommendations

According to this energy outlook study, energy consumption in the EAS region will increase rapidly due to stable economic and population growth, and will continue to depend largely on fossil fuel energy, such as coal, oil, and gas up until 2040 (BAU). But if EAS countries dedicate themselves to implementing their EEC policies and increase low-carbon energy technologies such as nuclear power generation and solar PV/wind (APS), the EAS region could achieve remarkable energy savings in the APS, especially through fossil fuel savings compared with BAU, and significantly reduce carbon dioxide emissions. It is essential, therefore, that EAS countries implement their EEC and renewable energy policies (energy saving targets and action plans) in accordance with their respective timetables.

This energy outlook study also shows that a lot of energy savings, especially on oil and electricity consumption by final users, will come from energy efficiency activities. So the EEC policies (specified by energy saving targets and action plans) of EAS countries, which will be applied across sectors – industry, transport, residential, and commercial – should be appropriate and feasible. Government support for the activities of energy efficiency and conservation service companies is also essential.

Increasing the share of renewable energy such as hydro, geothermal, solar PV, wind, and biomass will contribute to a reduction in fossil fuel consumption and mitigate carbon dioxide emissions. It will require appropriate government policies such as renewable targets, legal approaches such as FIT/RPS, and revised FIT to include bidding and tendering processes.

Energy supply security in the EAS region is a top priority energy issue. EEC and renewable energy contribute to maintain regional energy security through reducing fossil fuel consumption and increasing the use of domestic energy. Moreover, energy supply sources can be diversified through regional energy networks such as the Trans-ASEAN Gas Pipeline and the ASEAN Power Grid, LNG receiving terminals, and oil stockpiling through the ASEAN Petroleum Security

Agreement. And nuclear power generation is another option to maintain energy supply security in the region.

According to the Energy Outlook's results, as coal power generation will be still dominant in the EAS region in 2040, greater use of clean coal technology (CCT) and development of carbon capture storage (CCS) technology is critical because as it will make coal power plants in the region carbon free. Hydrogen technology also has a key role as an alternative to use of fossil fuels, as it can be applied across sectors such as the power generation, industrial, and residential sectors.

This Energy Outlook study has started to estimate the necessary investment cost for the power generation sector. The indication is that the EAS region will need around US$4 trillion for the construction of power plants. ASEAN will need US$600 billion, the '+6' countries US$3.4 trillion for power generation facilities. But the share of investment cost by type of power plant is quite different between the BAU and the APS. In the BAU, a lot of money will be allocated to coal power plants (CCT), whereas under the APS more money will be allocated to renewable energy electricity, such as hydro and solar PV/wind in ASEAN and renewable energy electricity and nuclear power plants in the +6 countries. If EAS countries could achieve their existing renewable energy policies (APS), they would be able to allocate significant funds for developing nuclear, hydro, and solar PV/wind power plants.

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