ASEAN Energy Technology Strategy, 2015-2030

By Bundit Fungtammasan,Christoph Menke, Suneerat Fukuda, Athikom Bangviwat, Atit Tippichai, Lim Chee Ming, Aishah Mohd Isa, Maxensius tri Sambodo and Agya Utama

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Abstract

One of the key issues facing the Association of Southeast Asian Nations (ASEAN) in meeting the formidable challenge of providing affordable, lower carbon emission and modern energy services while ensuring equitable access is ASEAN's capability to adapt and apply best available energy technologies, and to innovate energy technology solutions appropriate to the local context. This review paper reveals that, in general, a significant gap exists between the technologies in stock in ASEAN and the best available technologies globally. There is also a huge knowledge and capacity divide between current, predominant practices and the best practices in energy efficiency within each ASEAN member as well as in the design and implementation of supportive policy measures for the development and deployment of cleaner technologies among the member States. Taken together, significant scope exists for efficiency upgrading of conventional power generation facilities.

There are abundant renewable energy sources, particularly bio-based resources for heat, electricity, and transport fuel production, hydropower, geothermal and solar energy. Potential exists for the applications of carbon capture and storage (CCS) technology in enhanced oil recovery (EOR) as well as for power generation and industry sectors, although CCS technology feasibility has yet to be determined. In addition, opportunities abound for energy saving and, hence CO_2 emission reduction, in all end-use and final service sectors.

However, developing countries in ASEAN generally face difficulties in following, adopting and implementing policies and strategies on the development and deployment of appropriate energy technology options to ensure energy security and access on the one hand, and on limiting greenhouse gases (GHG) emissions on the other. This is due to a number of economic and non-economic barriers, ranging from (a) the lack of technical information and capability, financial schemes and investment resources, and human capital capacity, cultural, institutional and legal barriers, to (b) the absence of forward-looking science, technology and innovation policies.

To move the energy technology agenda in ASEAN forward, it is proposed, first and foremost, that Governments set clear and achievable long-term goals/targets, with appropriate implementation strategies. Agencies responsible for establishing strategies and implementing programmes must be in place, together with programme monitoring and evaluation mechanisms. Energy technology development and innovation policies should be sector and end-use specific, and their definition and formulation should be based on clear and achievable objectives as well as in-depth consultation with relevant stakeholders. A well-defined technology development plan covering 3-5 years could then be developed in collaboration with the respective ministries.

In the case of research and development (R&D), such programmes should be well-defined with a perspective for eventual commercialisation, and should therefore cover the research, development, demonstration and deployment (RDD&D) aspects. Research and development grants should also be awarded on a transparent, competitive basis to collaborative project proposals involving academic institutions and industry partners.

In addition, Governments should provide easy access to financing for innovation and investment in innovative projects through various schemes. Currently, a number of international financing mechanisms/schemes can be accessed by ASEAN countries, particularly with regard to climate or green financing.

At the ASEAN level, a number of policy recommendations are proposed for the promotion of intra-ASEAN and ASEAN-dialogue partner co-operation in science, technology innovation. These recommendations cover human capacity development, talent mobility, ASEAN centres of excellence in energy technology, joint international energy science and scientific research programmes, industry-targeted translational programmes, energy technology facilitation services, and energy-orientated science, technology and innovation (STI) policy research.

With regard to financing, it is felt that an ASEAN-focused trust fund that would support a specific clean energy technology development and deployment agenda is desirable. Thus the setting up of an ASEAN Clean Energy Technology Trust Fund (CETTF) is proposed in order to serve as a key instrument to remove financial and related barriers to the development and deployment of clean energy technologies at the ASEAN level. The objectives of the fund are to (a) provide financial support for projects, (b) divert private investors' risks by leveraging with its own funds and (c) offer technical assistance to investors through project loans, grants, and technical knowledge provision and exchange. However, a more detailed definition of CETTF based on broader stakeholder consultation needs to be conducted, and an in-depth investigation should be carried out to test and validate its feasibility and practicality.

Introduction

ASEAN, a vibrant region with a total population close to 600 million, is experiencing very rapid economic growth while gearing up for regional economic integration through the ASEAN Economic Community (AEC) by end-2015. With the region's population predicted to expand by almost 25 per cent and gross domestic product (GDP) to nearly triple within the next two decades, its energy demand will grow by more than 80 per cent while demand for electricity will more than double. However, despite this projected phenomenal growth, the reality at present is that more than 20 per cent of the region's population still has no access to electricity and nearly half of the population relies on the use of traditional biomass. At the same time, the region's fossil fuel reserves are rapidly being depleted, turning some of the net energy exporting ASEAN member States into net importers.

The fact that ASEAN's energy consumption is likely to continue during the next several decades to be dominated by fossil fuels is also a source of concern in the face of the increasing threat of climate change, with South-East Asia being one of the world's most vulnerable regions. Thus, the provision of secure and affordable energy while ensuring equitable access and environmental sustainability will be a formidable task for each ASEAN member as well as the region as a whole.

Because of the relatively long lifetime of most energy technologies, one of the critical challenges in meeting the above demands is the choice of technology, as the technology stock in place or under planning will dictate how efficient, environmentally benign energy will be generated, transmitted or transported, and used during the next several decades. This will have significant ramifications on the security and sustainability of energy supply and use in the region. Other technology-related, critical issues include: (a) the ability to apply and adapt the best available technologies to suit the local physical, social and environmental conditions; (b) the capacity to innovate in order to lower the cost of energy technologies; and (c) the ability to improve the efficiency of existing or to be installed facilities.

Therefore this paper aims to identify barriers to and opportunities for the deployment of more energy-efficient and less carbon-intensive energy technologies in the electricity supply, transportation, industry and building sectors in ASEAN. It also attempts to analyse and suggest strategies and policy instruments, particularly financing mechanisms, which are needed at the ASEAN level to support the realisation of those opportunities.

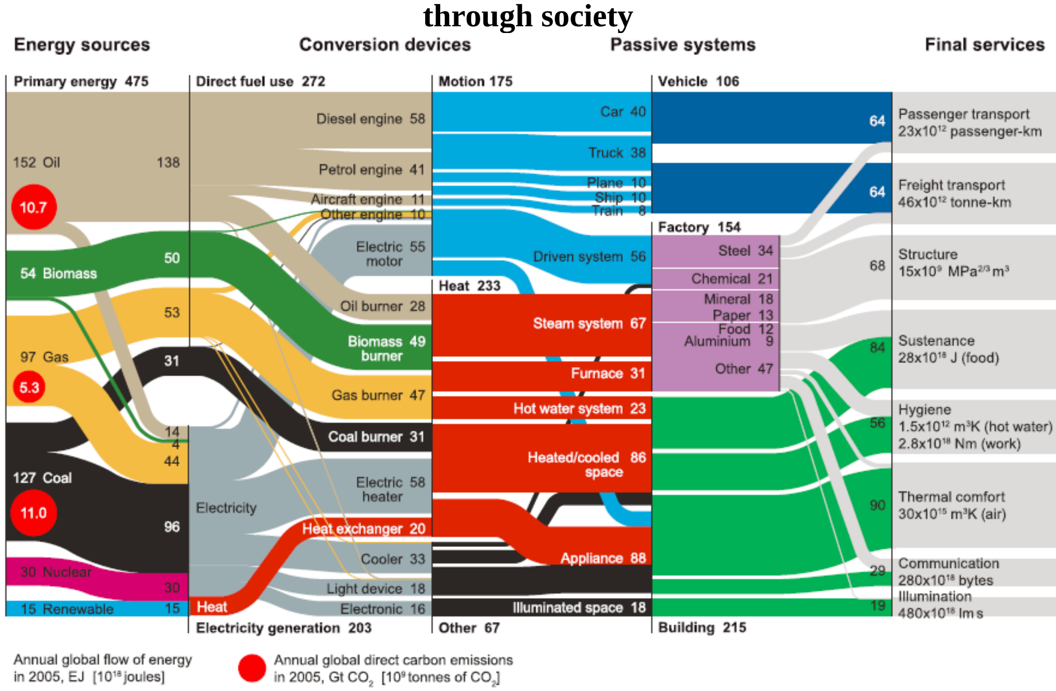
The paper begins with a macroscopic view of global energy flows, energy resources of ASEAN nations and their future demand. A perspective on new energy technologies that will likely shape the global energy landscape in meeting the dual demands of energy security and sustainability is given in section 2. Sections 3 and 4 review and take stock of the predominant types and status of energy technologies currently in use in the major economic sectors in ASEAN, followed by a review of the main types of cleaner energy technologies that should be promoted during 2015-2030. Section 5 identifies the challenges and barriers to the development and deployment of these technologies, including the technical, financial, investment, cultural, institutional, legal and human capital capacity aspects. Finally, section 6 provides recommendations on strategies and mechanisms at the ASEAN level for removing major barriers to, and providing support for the development and deployment of more energy-efficient and less carbon-intensive energy technologies.

A. Global energy flows, and energy supply and demand in ASEAN

1. Global energy flows

Figure 1 maps global energy flow through society, from primary energy sources, through different conversion devices to various end-uses or services, as of 2005 (Cullen and Allwood, 2010). Although the data may be somewhat dated, they serve to demonstrate the nature of the flows, the critical role of energy technology in various stages, and the order of magnitude of the share of each component. For example, the global primary energy mix, shown in the left-hand column, is: oil, 32 per cent; 27 per cent coal; 20 per cent gas; 12 per cent biomass; 6 per cent nuclear; and 3 per cent renewables (hydropower included). It is clear that fossil fuels still dominate, while low-carbon sources (nuclear, biomass and renewables) make up only 20 per cent of energy supply. Thus de-carbonising the energy supply remains a formidable challenge when compared with gains from energy efficiency. The majority, about 70 per cent, of electricity is generated by burning coal and natural gas.

Figure 1. From fuel to service: Tracing the global flow of energy through society



Source: Cullen and Allwood, 2010.

On the final services side, 45 per cent of total energy is used in buildings, 32 per cent in factories, and the remaining in transportation services, primarily powered by oil.

Thus efforts should be focused on improving energy efficiency throughout the conversion chain to end-uses. For example, combustion processes should be improved (as more than 90 per cent of energy sources are fuels that are combusted), while technical options for converting the chemical energy of fuels directly to electricity, heat, or motion should be explored.

The challenge for passive systems is to design technologies that make better use of energy, by preserving and recovering the heat in buildings, the materials in products, and the momentum in vehicles. Improvements can also be made by reducing the demand for final services, through behavioral and lifestyle changes. Furthermore, thermal comfort also ranks high on the list and can be targeted by reversing the practice of using high-quality fossil fuels to supply low temperature heat. Significant savings are available from the wider use of heat pump technology as well as improving the insulation of buildings (Cullen and Allwood, 2010).

2. Energy profile of ASEAN members

Despite having more than 28,000 billion barrels of oil reserves, the Association of South East Asian Nations (ASEAN) members (possibly with the exception of Brunei Darussalam) are predicted to become net importers of oil in the next 5-10 years. Apart from oil reserves, the region has other natural resources such as natural gas and coal, but these resources are rapidly being depleted due to the rapid growth of the global economy, particularly in developing world. Anticipating to downward movement of these fossil energy resources, most countries have begun developing renewable energy and even consider developing nuclear power plants to reduce their dependence on fossil energy and in some respects to help mitigate the impact of climate change.

The reserves on natural gas, for instance in Indonesia and Malaysia alone, are proven to be more than 5.5 TCM (terra cubic metres) or almost 37 per cent of the reserve available (more than 15 TCM) in the whole Asian region. According to data from the ASEAN Center for Energy, (ACE) (2005), and the International Energy Agency and the Economic Research Institute for ASEAN and East Asia (IEA and ERIA, 2013), the total reserves of more than 4,300 million metric tonnes (mmt) coal in Indonesia (bituminous and lignite), Viet Nam and Thailand (lignite) represent the biggest fossil fuel reserves in the region. However, these reserves are relatively low compared with worldwide reserves.

At of the end of 2011, Indonesia had 13.5 billion mt of hard coal reserves and 9 billion mt of brown coal reserves, ranking tenth- and sixth-largest globally, and by far the largest in South-East Asia (German Federal Institute for Geosciences and Natural Resources, 2012). Its reserves have risen significantly since the end of 2010 – hard coal by 45 per cent and brown coal by 15 per cent (IEA and ERIA, 2013). Moreover, the country's coal production reached 296 metric tons carbon equivalent (Mtce) in 2011, increasing by 15 per cent per year on average since 2000, the largest output in the region, followed by Viet Nam (IEA and ERIA, 2013). The region's total final coal consumption increased from 248.7 million tonnes of oil equivalent (Mtoe) in 1997 to 1,620 Mtoe in 2006 in order to meet electricity needs, which gradually increased from 369 terawatt-hours (TWh) in 2000 to 3,600 TWh in 2010 (ACE, 2005; IEA, 2008).

The oil price boom in 2007-2008 was the crucial moment for policy makers in ASEAN member countries to consider reducing dependence on fossil fuels by shifting to other renewable energy resources. According to the projection by ACE (2005), the share of generation mix in the region will move towards non-oil fuels. However, by 2020, almost 45 per cent of the fuel mix for power generation in ASEAN will still be coal, followed by natural gas (40 per cent) and oil (less than 2 per cent). The rest of the electricity will be generated either by renewable energy or nuclear power.

Table 1 shows the comparison for ASEAN members with the world in terms of population, GDP and energy consumption growth during the past 20 years. It shows that ASEAN's GDP growth has been far ahead of the global average. In contrast to GDP growth, energy consumption per capita growth in most ASEAN members has been lower than the global average, except for Malaysia and Thailand where the growth has been much higher than the global average.

Table 1. Demographic and economic growth in relation to energy consumption per capita in ASEAN

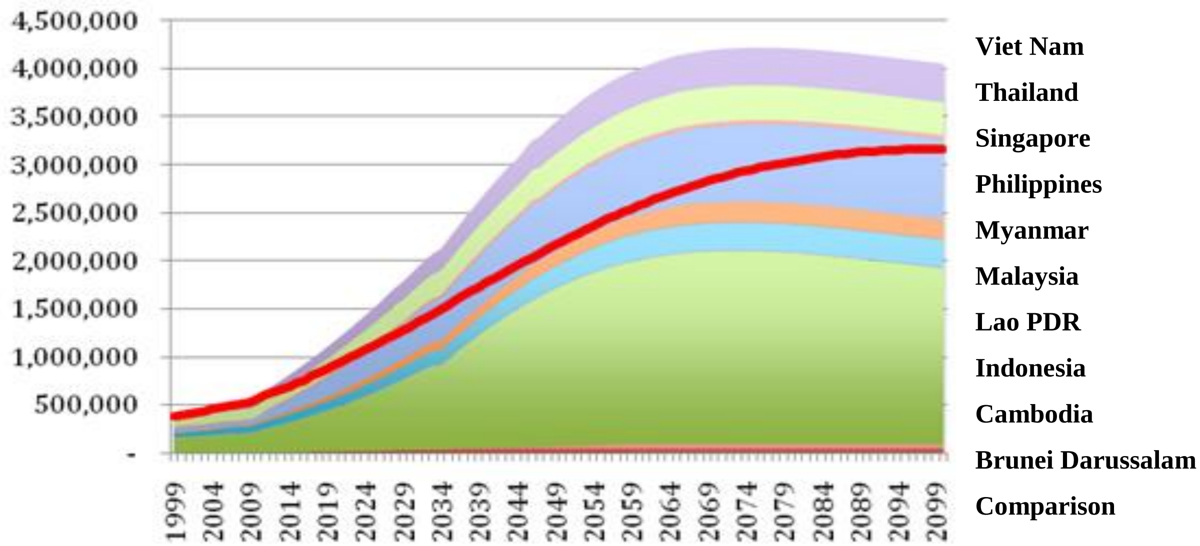
Country	GDP [billion US$]			Population [thousand]			Energy consumption (KTOe/capita)			Total area
	1990	2010	Growth (20 y) (%)	1990	2010	Growth (20y) (%)	1990	2010	Growth (20y) (%)	('000 km^2)
Brunei Darussalam	3.5	14.0	300	252	399	58	6.99	7.50	7	5,765
Cambodia	2.2	11.24	411	9,532	14,138	48	n/a	0.32	n/a	181,035
Indonesia	114.4	706.6	518	184,346	239,871	30	0.55	0.73	33	1,904,569
Lao PDR	0.865	7.29	743	4,192	6,201	48	n/a	n/a	n/a	236,800
Malaysia	44.0	237.8	440	18,209	28,401	56	1.21	2.02	67	329,847
Myanmar	2.0	19	850	39,268	47,963	22	0.27	0.28	2	676,578
Philippines	44.3	119.6	170	61,629	93,261	51	0.47	0.52	12	300,000
Singapore	36.1	208.7	478	3,017	5,086	69	3.80	4.91	29	683
Thailand	85.3	318.5	273	57,072	69,122	21	0.73	1.15	56	513,115
Viet Nam	6.5	106.4	1,537	743	1,124	51	0.36	0.47	29	331,689
World	21,900	63,120	188	5,306,425	6,895,889	30	2.27	3.12	37	n/a

Sources: Global Center of Excellence (GCOE), 2013; AEC, 2005.

3. Future energy supply and demand in ASEAN

The true challenge in the region is not coming from its limited fossil fuel supply; the vast growth in energy demand shows the staggering challenge to be faced for all nations in the region. The energy consumption projection should show fewer disparities in order to optimise regional energy policies. A study by Kyoto University Energy Science (figure 2), which integrated not only the demographic and economic aspects as its variables but also the geographical and landscape challenge into the model, showed an approximate 5-15 per cent higher energy consumption from 2020 up to 2100, when compared to the common forecast on energy consumption based on the assumed population and economic growth (figure 2).

Figure 2. Energy demand projection between business as usual (BAU: red line) and model (Unit: Mtoe)



Source: GCOE, 2013.

When considering the potential future scenarios for energy in ASEAN, it is important to consider that all these developing nations will at some stage attain a 100 per cent electrification rate and close to 100 per cent share of modern fuels in residential energy mix. The crucial elements will be at what level of final energy consumption, what efficiency rate and from what mix of primary energy sources that the energy will be provided (Keiichi and others, 2013). In order to make the transition from a fossil-based energy system to a more sustainable system, a strong policy for improving energy efficiency should be given high priority as there is significant room for improvement in the current system.

B. Global energy technology perspective

1. Power generation: Centralized and decentralized

The past five years have seen major changes in power infrastructure development trends around the world. Emerging technologies such as solar and wind power generation have experienced dramatic price decreases – up to 80 per cent decrease during a decade for wind power generation and up to 50 per cent decrease during the past five years for solar power generation.[1] This trend of decreasing prices combined with technologies that are more robust, efficient and increasingly able to generate power, even in sub-optimal conditions such as low wind speeds and low solar irradiation, has moved renewable energy technologies from niche to mainstream according to an International Renewable Energy Agency (IRENA) (2014) report. Global renewable power capacity reached 1,700 GW in 2013, constituting about 30 per cent of all installed power capacity, while renewables have accounted for more than half of net capacity additions in the global power sector since 2011.

Unlike large-scale power infrastructure such as coal and hydropower technologies, emerging renewable energy resources are generally site-specific and mostly small-scale; thus this energy resource is economically suitable for off-grid systems, micro-grid systems or for deployment at the distribution level. In rural or off-grid areas, renewables such as biomass, biogas and wind power serve as a power resource, while for urban areas decentralized power largely comes from solar power, and combined heat and power systems (CHP) for providing electricity (e.g., district cooling). In addition, solar power will increasingly contribute to decentralized power in urban areas through rooftop and building integration. As these power sources are located close to the point of consumption, electricity transmission losses are greatly reduced and energy security and flexibility is improved with a more diversified energy mix.

The increase in integration of variable renewable energy into the grid requires the transformation of the whole energy system (IEA, 2014b), which involves many aspects, e.g., smart grid, DSM and energy storage. The technology for the transformation of energy systems mainly exists, but the economic and regulatory aspects have yet to be resolved with regard to how to optimise and make use of various technologies.

On the other hand, power grids are traditionally designed to allow only a unidirectional flow of electricity from source to load, which means that adding a power source at the load point can cause disruptions to the overall system, especially if the power source is intermittent. However, this challenge has generally been mitigated with improvements in smart grid, power grid and energy storage technologies.

[1] GE Workout on Power Sector Trends and Technology Update" held on 12 September 2014 in Kuala Lumpur, Malaysia.

In recent years, several events such as the Fukushima nuclear accident in 2011, the shale gas revolution in the United States and China's PM2.5 air pollution crisis has sparked public concerns over how energy is being extracted and generated, and what the impact will be on public health and the environment. The ensuing pressure has encouraged greater development and deployment of more sustainable energy technologies that include cleaner coal technologies, high-efficiency thermal power technologies as well as research into carbon capture, utilization and storage technologies.

Coal thermal plants employing ultra-supercritical coal technology are now able to reach up to 46 per cent thermal efficiency, with advanced technologies such as integrated gasification combined cycle (IGCC) and pressurized fluidized bed combustion (PFBC) enabling even higher efficiencies, expected to be up to 50 per cent in the future (World Nuclear Association, 2014a). Gas power plants (a) are less controversial than nuclear plants, (b) produce less emissions than coal combustions, (c) have shorter start and shutdown times than both nuclear and coal powered plants, and (d) with the shale gas revolution and improving LNG technologies, are becoming more easily available. Furthermore, with their dispatchable and flexible operations, gas power plants can complement the variable nature of renewables, thereby enhancing the transition to a cleaner and more secure energy future.

For nuclear power, IEA (2014b) reports that global nuclear capacity is stagnating at this time. This is due both to safety regulations and to public opinion concerning this resource becoming stricter after the Fukushima nuclear accident, making it extremely difficult for new nuclear capacities to come online. In Japan, as of July 2014, all nuclear facilities were still offline and under inspection. On the other hand, the heightened scrutiny of nuclear power facilities have brought about more stringent safety and security protocols, which would ultimately ensure that the development of global nuclear power programmes will take place in a safe, efficient, responsible and sustainable manner (International Atomic Energy Agency, 2014).

In summary, it is clear that the power generation industry is in a state of transition, shifting from fossil fuels to renewables, moving towards higher efficiencies across the board, and becoming more decentralized with the support of improved power grid and energy storage technologies. It is vital that this transition is managed holistically and effectively to ensure a sustainable future.

2. Industry

(a) Technology penetration

According to IEA (2014a), global industrial energy use reached 143 exajoules (EJ) in 2011, up 36 per cent since 2000. The increase was largely fuelled by rising materials demand in non-Organisation for Economic Co-operation and Development (OECD) countries, in which industrial energy use accounts for 66 per cent, up from 50 per cent in 2000. Growth in industrial energy use must be cut to 1.7 per cent per year during 2011-2025 compared with 3.3 per cent per year in 2000-2011 to meet the 2DS (2-degree Celsius scenario to mitigate climate change) targets set by IEA (2014a) for 2050.

Similarly, trends in industrial CO_2 emissions must be reversed; from 2007 to 2011, emissions grew by 17 per cent. By 2025, they must be reduced by 17 per cent to meet 2DS targets (IEA, 2014a).

Improvements in energy efficiency have offset the upward trend of structural changes in the industrial sector, such that overall industrial energy intensity is decreasing; in 2011, most regions were below a level of 10 gigajoules per thousand US dollars purchasing power parity (PPP) of industrial value-added. China (2.4 per cent) and India (1.9 per cent) have had the highest annual reductions since 2000 due to high shares of new capacity. China is now among the world's most energy-efficient primary aluminium producers (IEA, 2014a).

Substantial potential to further improve energy efficiency exists. By applying current best available technologies, the technical potential to reduce energy use in the cement sector is 18 per cent, 26 per cent in pulp and paper, and 11 per cent in aluminium (IEA, 2014a).

This potential is unlikely to be fully tapped by 2025 due to slow turnover of capacity stock, high costs and fluctuation in raw material availability. Meeting 2DS targets will also require resolving challenges related to increased use of alternative fuels and clinker substitutes, and greater penetration of waste heat recovery in the cement sector, among others (IEA, 2014a).

(b) Market creation

Energy management systems can be effective tools to enable energy efficiency improvements, but in most countries they are still voluntary. In 2013, China mandated provincial-level implementation of energy management programmes by companies covered by the Top 10,000 Programme, an energy conservation policy for large-sized energy users. In the United States, pilot companies in the Superior Energy Performance programme on average improved their energy performance by 10 per cent in 18 months. The Australian Energy Efficiency Opportunities programme, which is mandatory for large energy users, was estimated to have enabled 40 per cent energy savings in participating firms (IEA, 2014). A growing number of industrial sites have certified energy management systems (ISO 50001) in place: 6,750 in 70 countries in March 2014, up by more than 300 per cent during the previous year (Peglau, 2014).

(c) Technology developments

Innovative energy-saving technology developments have been relatively slow in energy-intensive industries during the past decade and need to be accelerated; in the 2DS, for example, deployment of CCS starts before 2025. To stimulate investment in CCS, industry is investigating opportunities for CO_2 use in enhanced oil recovery and in developing processes that use CO_2 as a feedstock (e.g., in polymer production). In pulp and paper, the Confederation of European Paper Industries (CEPI) announced in 2013 promising lab-scale results of deep eutectic solvents, allowing the production of pulp at low temperatures and atmospheric pressure, Applying deep eutectic solvents-based pulp-making throughout the sector could reduce CO_2 emissions by 20 per cent from current levels by 2050 (CEPI, 2013).

3. Buildings

The global trend for energy performance of buildings is to achieve near-zero net energy buildings (NZEB). This means the import and export ratio of energy tends toward 1:1. This vision in achieving NZE for buildings is considered highly challenging, and the measure used for determining this energy balance is still being debated (Crawley and others, 2009; Deng and others, 2014). Despite the ambiguity, different economic zones (such as the European Union) have introduced the European Union Energy Performance of Buildings Directive, which sets targets for achieving near-NZEB (European Union, 2014).

Energy technology for NZEB comes in the forms of building designs, equipment and control. In building designs, the form factor, tightness, envelope materials and orientation all combine to determine the heat transfer between the outside and inside of the building (Sadineni, 2011; Pacheco and others, 2012; Sozer, 2010;). The technologies aimed at the envelope materials involve new designs and new materials, for example, composite cavity walls infused with phase change materials. The use of coatings will be dominant as this approach is effective for existing buildings. Coating technology has the function of reducing thermal conduction and solar heat gain; these parameters are measured in terms of U-value, and g-value, respectively. Building-integrated energy harvesting claddings are increasingly being used as building envelopes.

To achieve NZEB, the energy use intensity has to be improved, and renewable energy harvesting capabilities installed (Anderson and Roberts, 2008); Li and others, 2013; Oliveiri and others, 2014; Intergovernmental Panel on Climate Change, 2014). The control system, or more commonly refer to as the energy management system (EMS), plays an important role in binding the equipment and the renewable energy sources.

The matrix of benefits versus risk, prepared by Anderson and Roberts (2008), showed that the high-impact and low-risk technologies were centred on climate control. The use of combined cooling, heating and power (CCHP), and a combination of renewable energy sources will dominate either as standalone systems or as a collective community level system.

4. Transport

To respond to the global challenge of climate change, energy technologies in the transport sector are always deemed an important component of greenhouse gas emissions reduction options. These technologies are widely examined by an analytical approach, called ASIF (Facanha and others, 2012; Bongardt and others, 2013; Sims and others, 2014), as detailed below:

(a) Avoiding or shortening journeys **(A)** by, for example, densifying urban landscapes, sourcing localised products, internet banking, internet shopping, and utilising information and communication technologies such as teleconferences and, navigator systems. Smart land-use planning in a compact city could save energy in a sustainable manner for long periods;

(b) Mode shift **(S)** to lower-carbon transport systems – encouraged by increasing investment in public transport, walking and cycling infrastructure, improved railways, water transport and logistic systems – to make them more attractive to users. A mass rapid transit system (MRT) that is well-connected with feeder systems (e.g., light rail transit and bus systems) is crucial to shifting private car users to public transport in a large city. A bus rapid transit system (BRT) with dedicated lanes that form a backbone system for a small to medium-sized city, instead of an MRT, can be developed with lower investment and a shorter construction period. However, preserved space on roads for the BRT system is needed in order to avoid future objections from private car users;

(c) Lowering energy intensity **(I)** by enhancing vehicle and engine performance, using lightweight materials, increasing freight load factors and passenger occupancy rates, and deploying new technologies such as electric-drive vehicles, hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) and battery-electric vehicles (BEV). HEV has been fully commercialised in many countries. BEV is a promising technology for reducing oil-based fuels and pipe-line emissions, but a cost-effective electricity supply infrastructure and storage for vehicles are still the main challenges for establishing its widespread use. Combining batteries and internal combustion engines (i.e., PHEV) would be a solution during the transition period (IEA, 2014a). Technologies for on-road vehicles, such as an idling stop system and fuel-efficient tyres, can improve energy efficiency in the range of 3-10 per cent (Sims and others, 2013; Kojima and Ryan, 2012);

(d) Fuel choice **(F),** by shifting to efficient and low-carbon content fuels, including electricity and hydrogen.

5. Carbon dioxide capture and storage

The use of CCS technologies can reduce carbon dioxide equivalent (CO_{2eq}) life-cycle emissions of fossil power plants, and their deployment in power generation and industry is critical to addressing climate change. According to the Intergovernmental Panel on Climate Change (IPCC) (2014), at the global level, atmospheric greenhouse gas mitigation scenarios reaching 450 ppm CO_{2eq} by 2100 (to prevent exceeding the 2-degree Celsius rise in global temperature) are characterised by the tripling to nearly quadrupling of the share of zero and low carbon energy supply from renewables, nuclear energy and fossil fuel energy with CCS. Currently, only six of the 10 ASEAN members have working energy performance measurement standards. Although all of the components of integrated CCS systems exist and are in use today by various industry sectors, with significant progress being made in demonstrating elements of capture, transport and storage, CCS has not yet been applied at scale to large, commercial fossil-fired power plants. As of end-2013, eight large-scale CCS projects – all using anthropogenic CO_2

for enhanced oil recovery – were in operation. However, two of the first projects built in the electricity sector are among nine large-scale projects that are under construction (IEA, 2014a).

Applying CCS in an electricity generation facility incurs substantial efficiency penalty and additional capital investment. Up-scaled commercial operation of CCS in this sector is therefore unlikely without stringent limits on GHG emissions or regulatory mandates requiring the installation of CCS. In addition, there are other significant barriers, including concerns about the operational safety and long-term integrity of CO_2 storage as well as transport risks. There is, however, a growing body of literature on how to ensure the integrity of CO_2 wells, the potential consequences of a pressure build-up within a geologic formation caused by CO_2 storage (such as induced seismicity), and the potential human health and environmental impacts (IPCC, 2014; IEA, 2014a).

C. Current stock of energy technology in use in ASEAN

1. Power production and distribution

Since 2002, the number of people in the ASEAN region without access to electricity has decreased by approximately 60 million, despite the growth in population. While this is a positive achievement, access to modern energy services is still limited for several ASEAN members, with the exception of Brunei Darussalam, Malaysia, Thailand and Singapore. In 2011, as many as 134 million people in South-East Asia, or 22 per cent of the region's total population, still did not have access to electricity. In addition, some 280 million people (i.e., almost half of the region's population) still relied on the traditional use of biomass for cooking (table 2). These numbers actually exceed the global average for the same year, whereby the share of world population without access to electricity was 19 per cent while the share of the world population still relying on biomass for cooking was 39 per cent (IEA, 2011).

Table 2. Access to modern energy services in ASEAN

	Population without access to electricity		Population relying on traditional use of biomass for cooking*	
	Million	**Share (%)**	**Million**	**Share (%)**
Brunei Darussalam	0	0	0	0
Cambodia	9	66	13	88
Indonesia	66	27	103	42
Lao PDR	1	22	4	65
Malaysia	0	1	1	3
Myanmar	25	51	44	92
Philippines	28	30	47	50
Singapore	0	0	0	0
Thailand	1	1	18	26
Viet Nam	3	4	49	56
Total ASEAN	134	22	279	47

Source: IEA, 2013.

* Preliminary estimated based on IEA and World Health Organization (WHO) databases. Final estimates for 2011 will be published online at www.worldenergyoutlook.org

At the same time, ASEAN is a fast–growing region and IEA projects the regional GDP to almost triple between 2011 and 2035, while population will expand by almost 25 per cent (IEA, 2013). Both these factors will drive energy demand to increase by more than 80 per cent during the same time horizon. In the power sector, electricity demand will more than double from about 600 TWh in 2011 to about 1,500 TWh in 2035 (IEA, 2013). The technology stock in place and planning is underway, which will dictate how electricity will be generated and transmitted during the next 20 to 50 years; this will have significant ramifications for the energy security and energy sustainability in the region. Ideally, the current and new stock chosen will be the latest and most efficient technology available, but as will be seen in the following discussion, this may not always be the case.

(a) Conventional power production technology

Traditionally, electricity is produced and managed centrally by utilities, and the technology utilised depends on the resources availability in the country, which could either mean exploiting already existing resources or relying on imports. This is obviously reflected in ASEAN where, for example, Brunei Darussalam as a major gas producer relies almost exclusively on gas power technologies for its electricity supply, whereas Singapore with limited resources relies on its own imports fuel from neighbouring countries and abroad. The power capacity developed would then depend on the expected demand requirements of the country.

As of 2011, ASEAN electricity is largely derived from fossil fuels, i.e., coal, gas and oil. Gas currently dominates the mix, but cheaper coal will likely overtake gas in the future given the large number of units being added around the region within the next decade. One example is Indonesia, which plans to add more than 10 GW of coal power capacity under the 10,000 MW Accelerated Power Programme, Phases I and II.

According to IEA (2013), the existing stock for coal power in ASEAN has an average efficiency of about 34 per cent, which is quite low considering the fact that current ultra-supercritical coal technologies are able to reach up to 46 per cent efficiency. This is due to the proliferation of sub-critical coal power plants in the ASEAN power systems, which will remain in operation for at least another 20-30 years. The choice of how efficient the technology to be added will be depends largely on the cost and highly efficient cleaner coal technologies (CCT) – some are still in demonstration process – which can be prohibitively expensive. However, CCT incorporate technologies and industry practices that enhance coal-derived generation efficiency, such as coal gasification, carbon capture and storage, and conversion of coal to chemical fuels.

The resulting trade-off in choosing less–efficient technologies will be higher fuel costs and increased emissions, especially over the long term, as coal power plants have a technical lifetime of more than 30 years. However, given the rapidly growing electricity demand in the region, particularly among the segment of the population that is newly gaining access to electricity as well as the urbanizing population, power planners are under pressure to provide capacity as quickly, securely and as economically as possible. Therefore, this may also be a deciding factor in mature coal technologies being chosen rather than new, more efficient cleaner coal technologies.

To accelerate the deployment of CCT in ASEAN, its member States have listed four strategies under the Coal and Clean Coal Technology Programme Area of the ASEAN Plan of Economic Co-operation 2010-2015:

(a) Strengthen the institutional and policy framework and build an ASEAN coal image;
(b) Promote coal and CCT;
(c) Promote intra-ASEAN coal trade and investment;
(d) Enhance environmental planning and assessment of coal projects.

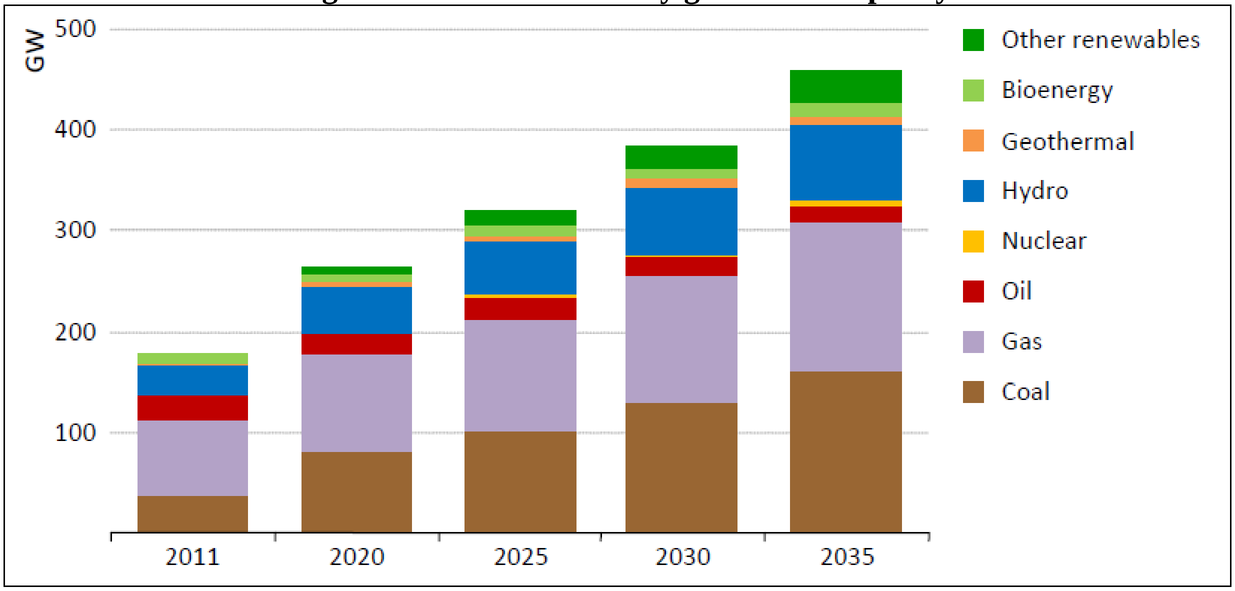
For gas power technologies, there are still a number of open-cycle turbines in operation around the region; however, with increasing realisation of the benefits of the more efficient combined-cycle gas turbines, there has been a definite shift towards this technology during the past decade, which will likely continue in the future. Other factors such as dwindling gas reserves and increasing gas prices may also play a role in this development; for example, gas producers Malaysia and Thailand began to import LNG in 2013. Thus, it makes economic sense for these countries to begin repowering or replacing open-cycle turbines with combined-cycle gas turbines, thus improving fuel utilisation. Instead of using inefficient open-cycle gas turbines for meeting peak load, the economy could consider employing demand side management or renewable energy to shave or shift demand peaks, or involving the hydropower stations available under its portfolio to meet peak demand.

In addition to fossil fuel technologies, hydropower also plays a small but significant role in the ASEAN electricity mix, accounting for up to 10 per cent of the electricity generation in 2011. ASEAN has significant potential in this area, and there are already several large-scale hydropower projects either in operation or under construction, especially in the Greater Mekong Subregion. The ASEAN Power Grid project is a big factor driving this development as it enables countries with limited energy resources to purchase electricity from countries with an abundance of hydro resources but lower demand. However, plans in some countries (particularly Thailand) to build large storage dams for hydropower have met with strong public resistance. In such cases, improving the efficiency of existing hydropower plants and building more eco-friendly alternatives such as run-of-river type power plants should be investigated. Such strategies have been widely adopted in the United States and Europe.

A third type of existing power technology is nuclear. Currently, the ASEAN members do not have any nuclear power capacity. Prior to the Fukushima nuclear accident in 2011, several ASEAN members (Indonesia, Malaysia, Thailand and Viet Nam) were in the early stages of feasibility studies on adding nuclear power capacity to their electricity mix, with concrete dates of commissioning set for the early 2020s. Since May 2011, these plans have been reconsidered; only Viet Nam is forging ahead, with its first 2GW plant in Phuoc Dinh expected to begin construction in 2017 or 2018 (World Nuclear Association, 2014b) *(b) Renewable energy technology*

Energy demand in ASEAN is rapidly growing, driven by the region's economic and demographic growth. ASEAN's primary energy requirement (Reference Scenario) is projected to triple between 2005 and 2030 by an average annual growth rate of 4 per cent. While being highly dependent on oil and gas imports, the issue of climate change mitigation will pose constraints on the use of coal, which is currently the dominant energy source of the region. Therefore, meeting the region's energy needs is a challenge, and diversification of energy resources as well as seeking for any available and possible energy resources should be pursued. In 2011, the share of renewable energy (including hydro-electric) in ASEAN power generation was 29.3 per cent. Biomass is the second-largest source of renewable energies after hydropower and accounts for 3.6 per cent of total power generated (figure 3).

Figure 3. ASEAN electricity generation capacity



Source: IEA, 2013.

(i) Biomass and bio-energy

Biomass is an important energy source since it is renewable, widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. The utilisation of biomass as an essential energy resource is increasing continuously. In ASEAN, energy from biomass such as wood and agricultural residues represented about 12.41 per cent of total renewable energy consumption in 2011. Wood and agricultural wastes are widely used as fuel in the domestic sector and small-scale industries for cooking and heating, while modern biomass systems (including CHP generation and large-scale power plants) are also being adopted in many countries such as Indonesia, Malaysia, the Philippines and Thailand. Sugar/starch-rich and oil-rich plants have also been used as raw materials for bioethanol production mainly in Thailand and biodiesel mainly in Malaysia, Indonesia and Thailand. Nevertheless, energy production from biomass still has a significant potential since a large portion of biomass is still under-utilised.

Moreover, increasing potential of energy crops and the development of plant yield improvement technology will extend the bio-energy potential even more. Therefore, biomass is considered as a major issue in both national and regional future strategic energy planning as an alternative primary energy source for meeting energy demand.

Among biomass technologies for heat and power generation, combustion is most commonly used in all the ASEAN members except Brunei Darussalam and Singapore, which have either no or limited biomass resources. Biomass combustion applications include traditional uses for cooking and heating, heat and steam generation, or CHP generation in industry and large-scale power plants. In some countries, such as Malaysia, Thailand and Viet Nam, biomass combustion for electricity, heat and CHP is considered to be fully commercial with local capability for manufacture. However, very high-efficiency boilers and related components are still imported from China, Japan and Europe. Large-scale biomass power plant projects are also implemented in the Lao People's Democratic Republic and the Philippines solely by foreign companies. The types of technology utilised are mainly grate-fired and some are fluidised beds.

Apart from combustion, biomass gasification has also been adopted for heat and power production but on a smaller scale, in many cases for rural energy purposes. Most members of ASEAN have developed gasification technology from imports as well as through self-development. The major barriers to biomass gasification for power generation are similar in all countries, including the problem of high tar content in production gas, the lack of technical skills and the need for local development to reduce the cost of technology.

Anaerobic digestion of organic wastewater to produce biogas for heat and power production has also been practiced in household and industrial sector. Among the ASEAN members, Thailand and Malaysia are considered to be the technology leaders in both development and implementation of biogas production.

(ii) Geothermal

Unlike other renewable resources, geothermal production is a mature technology that is dependable as a base-load. However, development is tied to locational potential. Of the 10 ASEAN economies, the Philippines and Indonesia have the biggest geothermal resource potential. The Philippines currently ranks second in the world after the United States for the highest geothermal capacity. Indonesia is building up several geothermal supply sources, with about 49 per cent of the 10,047 MW of new capacity to be built under the 10,000 MW Accelerated Power Programme Phase II to be geothermal-based. Malaysia will also be exploring its geothermal resource for the first time during 2015.

(iii) Solar and wind power

Several ASEAN members are offering attractive incentives such as feed-in tariffs and tax exemptions to encourage solar and wind power development, in particular for solar PV, since they are located near the equator with reliable solar irradiance throughout the year. As a result, a large number of solar PV systems are already in operation in different forms, including solar rooftop installations (solar PV are placed on the roof, making it very popular for residential buildings and factories), building-integrated systems installations (solar PV modules are integrated into the building, acting as walls or roofs) and solar farm installations (ground installed modules). Thailand and Malaysia are also exploring the potential for concentrated solar technology, although this is still in the experimental stage as the technology is more suitable for a desert climate, where direct radiation is more intense.

(c) Carbon capture, utilisation and storage

Carbon capture and storage is a technology that can capture up to 90 per cent of CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes (Carbon Capture Storage Association, 2014), and its deployment both in power and industry is critical to addressing climate change. Indeed, at the global level, atmospheric greenhouse gas mitigation scenarios reaching 450 ppm CO_2eq by 2100 (to prevent exceeding the two-degree Celsius rise in global temperature) are characterised by tripling to nearly quadrupling of the share of zero and low carbon energy supply from renewables, nuclear energy and fossil energy with CCS (IPCC, 2014). The CCS chain typically consists of three components:

(a) Capturing the carbon dioxide;
(b) Transporting the carbon dioxide;
(c) Securely storing the carbon dioxide emissions either underground in depleted oil and gas fields or in deep saline aquifer formations.

Although all the components of integrated CCS systems are in use today by various industry sectors, and despite the fact that significant progress is being made in demonstrating elements of capture, transport and storage, CCS has not yet been applied at scale to large, commercial fossil-fired power plants.

According to the Global CCS Institute (2014), there are 21 “active” large-scale CCS projects globally, 12 of which are already in operation and the other nine under construction. Seven of the projects in operation are in the United States, two in the Europe Union, one each in Canada, South America and Africa. Two of the projects are nearing completion in North America and will be the first developed for the power sector.

So far, there are no definite plans yet for installing CCS facilities in any of the ASEAN members, but the technology has generated much interest and various feasibility studies. The Asian Development Bank (2013) identified possible key sites for CCS development in four of the 10 ASEAN members – Indonesia, the Philippines, Thailand and Viet Nam.

2. Buildings

The concept of green buildings is well understood in ASEAN, and this is reflected in the various localised forms of sustainable building assessment standards found in ASEAN. The technologies used to achieve energy savings and sustainability are off-the-shelf products widely available in the global market.

(a) Commercial

In the commercial sector, the energy saving in buildings is benchmarked using local measures such as Green Mark, Lotus and TREES, or by using standards from outside the ASEAN region such as CASBEE or LEED. As space cooling takes up 60 per cent of the energy use of buildings, the technology for control and CCHP are the main focus. Currently, only six of the 10 ASEAN members have working energy performance measurement standards, the guidelines and standards for which are provided by the Thai Green Building Institute (2014), Vietnam Green Building Council (2014), Building Construction Authority of Singapore (2014a), Philippines Green Building Council (2014), Malaysia Green Building Index (2014) and Green Building Council Indonesia (2014). There is no indication of a regional ASEAN standard like the European Union's energy performance of building directive.

Buildings achieving green or sustainable status based on local or regional measures such as Green Mark, Lotus, TREES, or those based on standards outside ASEAN such as CASBEE and LEED, are all commercial or public buildings. As space cooling takes up 60 per cent of the energy use of buildings, the technology for control and CCHP are the main focus.

(b) Residential

The focus on energy saving in residential buildings is mainly for high-rise tower blocks rather than small buildings with less than 500 m^2 floor area and standalone buildings (Building Construction Authority of Singapore, 2014b). The use of building-integrated solar photovoltaic and solar thermal are popular in the residential sector (Sharpe, 2014).

3. Industry

Industry is currently the largest end-use sector in ASEAN, with energy demand accounting for 30 per cent of total final consumption in 2011. Industry has seen rapid growth in energy consumption, in line with a move towards more energy-intensive manufacturing activities, at the expense of agriculture. In the New Policies Scenario[2] of the IEA (2013), final energy consumption in this sector was projected to grow at an average annual rate of 2.7 per cent through to 2035, driven by a continued structural shift from labour-intensive activities to more energy- intensive ones.

In ASEAN'S major economies (primarily Indonesia, Malaysia, the Philippines, Thailand and Viet Nam), a growing manufacturing sector is increasing the demand for cement, steel, brick/ceramic, glass, pulp and paper, plastics, chemicals, food processing and textiles. Manufacturing these products involves energy-intensive processes and, taken together, they make up a very high proportion of total energy demand in the industry sector. In Thailand, for example, the non-metallic materials (cement, ceramics and glass), food and beverage, chemicals,

[2] The New Policies Scenario is the central scenario of the IEA report, which incorporates policies and measures that had been adopted as of mid-2013 that affect energy markets, as well as other relevant commitments that have been announced.

paper and pulp and basic metals sectors combined make up about 85 per cent total industry energy demand (Energy Policy and Planning Office, 2013. Compared to world best practices (WBP), the average specific energy consumptions (SEC) or energy demand per ton of products of these industries are generally quite high, even in the case of modern cement and chemical plants. Table 3 compares the average Thai SEC of some industries with WBP and Thai best practices (TBP). While some production processes are already quite efficient with an SEC/WBP of around 1, other processes still consume up to 2-3 times the amount of energy needed for WBP. It should be noted that in the chemical/petrochemical industries the product range and specifications vary widely, and it is therefore difficult to compare SEC with WBP. The best that can be done is to compare the average SEC with the local best – in this case, the TBP, which shows a wide gap. Therefore, there is much room for energy efficiency improvement in the industry sector in Thailand and in ASEAN as a whole, both in existing processes and in the installation of new plants (Roland Berger Strategy Consultants, 2011).

Table 3. Average specific energy use in major Thai energy-consuming industries

Production process or product type	Comparison to WBP (times)	Production process or product type	Comparison to TBP
Cement (raw materials preparation)	3.1	Chemicals	
Cement (kiln)	1.3	(primary products)	1.0-2.2
		(downstream products)	>4
Ceramics (floor tiles)	1.1	Petrochemicals	
Ceramics (sanitary products)	2.3	(midstream products)	1.1
		(downstream products)	3-15
Flat glass	2.3		
Scrap metal arc furnace (different products)	1.2-1.4		
Billet heating (different forms of metal)	1.2-2.2		
Food (sugar)	1.3		
Food (canned vegetables/fruits)	1.9-2.1		
Food (frozen seafood)	1.1		
Feed meals	1.1-1.3		

Source: Joint Graduate School of Energy and Environment, 2011.
Note: WBP = World Best Practices, TBP = Thai Best Practices

4. Transport

(a) Alternative fuels

Alternative fuels that are currently used for transportation in ASEAN are biodiesel and ethanol. Major biofuel-producing countries include Indonesia, Malaysia, the Philippines and Thailand. Indonesia and Malaysia are the two largest palm oil producers – jointly producing 85 per cent of world's output, while Thailand is leading in ethanol production in the region. Main drivers in the development of biofuel in the region are energy security and socio-economic concerns; a minor driver is the reduction of oil import dependence at the same time to boost up income generation for farmers while, climate change.

Current blending ratios of biodiesel are 5 per cent for Malaysia, Indonesia and Thailand, and 2 per cent for Philippines. Palm oil is major feedstock to produce biodiesel, while the Philippines uses coconut oil. Cassava main is feedstock to produce ethanol in Thailand, while the Philippines uses sugarcane (Kumar and others, 2013). Thailand has a mandate for E10, while E20 and E85 were already available at 2,888 stations nationwide, as of July 2014. Furthermore, Thailand has concrete targets to utilise biofuel – ethanol at 9 million litres per day and biodiesel at 7.2 million litres per day by 2021. This target is equal to 15 per cent of the aggregate total of petroleum (including ethanol) and diesel (including biodiesel). Thailand also provides tax reductions for flexible-fuel vehicles that are designed to run on a blend of 20-85 per cent ethanol.

(b) Energy-efficient vehicles

Energy efficiency policies in the transport sector have shown signs of improvement, although no country in the region has introduced fuel economy standards (IEA, 2013). Thailand is developing mandatory standards and has introduced a tax reduction for the purchase of cars with average fuel consumption of no lower than 20 km/litre and meeting at least Euro 4 emissions standards for passenger vehicles (so-called Eco-cars). Governments in ASEAN are promoting green and environmentally-friendly technology. Indonesia is considering a fuel-economy standard, while Singapore already has mandatory fuel economy labelling and rebates for cars with low carbon emissions and a penalty for cars with high emissions. Since 2009, green car demand has been growing at an average of 130 per cent per year in ASEAN; for example, penetration in Malaysia and Thailand is 6 per cent and 17 per cent, respectively (Frost & Sullivan, 2014). Hybrid cars are being promoted with tax incentives in Thailand, Malaysia and the Philippines.

(c) Mass transit systems

Bus services are the basic public transport system for moving people in ASEAN cities. Mass rapid transit (MRT) systems have been steadily developed for several decades to alleviate traffic congestion in mega-cities. However, progress is slow and largely limited by financial and governance factors except in Singapore, which is leading in MRT systems in the region. Bangkok and Kuala Lumpur are expanding MRT lines to provide more network coverage. ASEAN is increasingly focusing on developing sustainable transport systems, and emphasises the development of cost-effective mass-transit systems, i.e., BRT systems. Indonesia is leading in BRT systems in the region, having introduced the first BRT system in 2004 in Jakarta, and since then has launched similar systems in other cities, such as Yogyakarta, Batam and Bandung (Global Mass Transit, 2011)

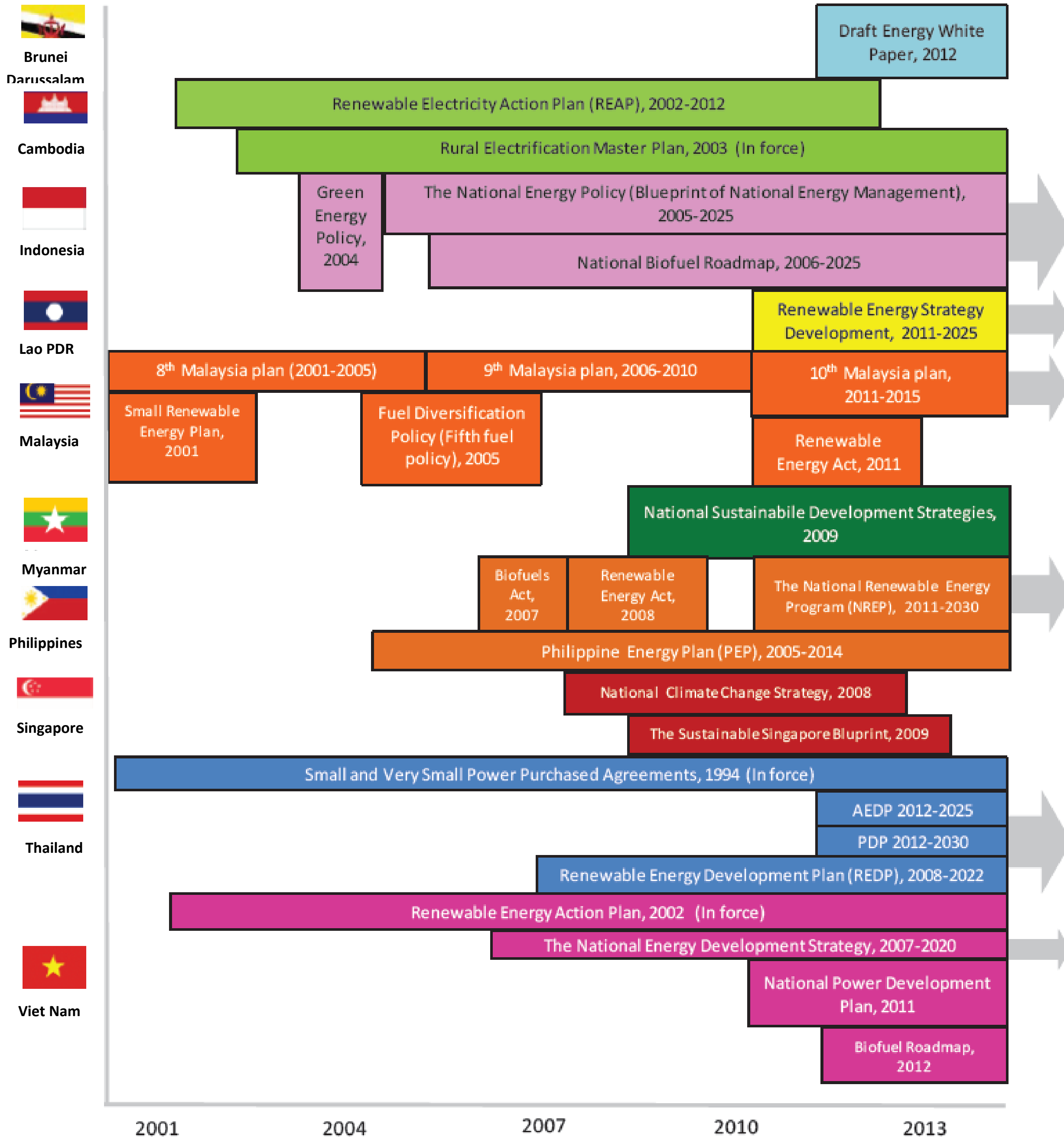
D. Energy technologies with potential for applications in ASEAN by 2030

1. Power production and distribution: Centralised and decentralised

Electricity generation capacity in South-East Asia is expected to grow steadily, from 176 gigawatts (GW) in 2011 to almost 460 GW in 2035 (IEA, 2013). Coal will become a more dominant fuel source for power plants, with 40 per cent of new capacity additions. Gas (26 per cent) and hydropower (15 per cent) also add significant capacity. Although oil-fired capacity will decline, largely because of deteriorating economics as a result of high fuel costs, some capacity will be maintained to serve the region's isolated areas.

Since South-East Asia also has diverse and abundant biomass feedstocks, ranging from agriculture and forestry residues to forestry products, most ASEAN members have set policies and targets for renewable-based capacity and/or generation (figure 4 and table 4), according to the Joint Graduate School of Energy and Environment (JGSEE) (2013). Indonesia, Malaysia, the Philippines and Thailand also have financial support measures such as feed-in tariffs and tax exemptions in order to accelerate renewable energy deployment.

Figure 4. Renewable energy policies in ASEAN members



Source: JGSEE, 2013.

It should be noted that in figure 4, the RE Act has replaced the Small Renewable Energy Plan and the Fifth Fuel Policy). The biofuel policy and the national biomass strategy are more current and relevant initiatives have been updated.

Table 4. Renewable energy targets in ASEAN members

Country	Biomass for heat and power targets	Biofuel mandates/targets
Brunei Darussalam	No biomass target	No biofuel target
Cambodia	To achieve 100 per cent level in village	No biofuel target

	electrification from renewable energy by 2020	
Indonesia	8,149 MW biomass and 107.012 million m^3 biogas by 2025	3,450 million litres ethanol and 9,520 million litres biodiesel by 2025
Lao PDR	58 MW biomass, 51 MW Biogas and 36 MW waste by 2025	150 million litres ethanol and 300 million litres biodiesel by 2025
Malaysia	1,340 MW biomass, 410 MW biogas and 390 MW MSW by 2020	B5/biofuel to replace 5 per cent of diesel in road transport
Myanmar	To achieve a collective target of 15-18 per cent of renewable energy in the total power installed by 2020	Biofuel to replace 8 per cent of conventional oil in road transport by 2020 based on 2005 level
Philippines	276.7 MW biomass by 2030	B20 and E20/E80 in 2030
Singapore	No biomass target	No biofuel target
Thailand	4,800 MW biomass, 3,600 MW biogas and 400 MW MSW by 2021	Ethanol 9 million litres/day, B10 7.2 million litres/day and BHD 3 million litres/day in 2021
Viet Nam	400 MW biomass by 2030	550 million litres of biofuel production by 2020

Source: JGSEE, 2013.

2. Industry

For the industrial sector, two different types of energy technologies are of major importance: (a) cross-cutting energy efficiency technologies (which account for more than 70 per cent of all industrial energy use) for end uses such as motors, fans, pumps, compressors, boilers, furnaces and heat exchangers, and (b) the process-specific technologies for major industrial sectors such as iron and steal or chemicals.

Cross-cutting technologies are normally manufactured by international companies and shipped all over the world. To determine which technologies will get special support within the ASEAN region for further development it is important to: (a) establish which cross-cutting technologies are manufactured by regional companies in ASEAN, in what amounts and their value; and (b) which of those companies have the potential for further own-technology development – such as boilers for biomass combustion or fans for industrial processes – in close co-operation with applied research institutions.

For process-specific technologies it is suggested that focus be placed on some of the major industrial sectors in ASEAN, such as chemicals, cement, and iron and steel. In addition, the agro-industry process sector should be given special recognition, as it is of global importance. International companies, such as Holcim® in the cement sector, are installing international standards for their production facilities worldwide, irrespective of the country of production. Here the highest level of importance must be given to the acceleration of the stock turnover process through stricter environmental standards and the application of better energy efficiency standards (e.g., best available technology concept of the European Union), meaning the best energy efficiency improvement can be achieved by a new process plant in ASEAN that meets international best available technology standards.

In other sectors, such as food processing, ASEAN companies are world leaders and their demand for further process technology development must be assessed to determine in which sector further development of technologies are required. In this approach, assessment of sector-specific technology is required.

3. Transport

The transportation sector is expected by Japan's Institute of Energy Economics (2011), ACE and Energy Supply Security Planning in ASEAN (Third ASEAN Energy Outlook, 2011) to have the highest energy demand growth rate of 5.6 per cent per annum, while an average annual rate of energy demand in ASEAN is projected at 4.4 per cent up to 2030, in a BAU scenario. In the alternative policy scenario, it also has the highest potential for being reduced by about 22 per cent of BAU's energy demand. It is in line with the Efficient ASEAN scenario by IEA and ERIA (2013) that transport energy demand can be reduced by 16 per cent beyond that of the New Policies scenario in 2035. This implies that there is room for energy efficiency technology applications in ASEAN. It would include progressive improvements in energy efficiency in road transport, for example via mandatory fuel-economy standards, fuel-economy labelling, tax breaks and incentives.

Importantly, ASEAN countries are trying to remove inefficient subsidies for fossil fuels that would help investment in mass transit development and encourage more travellers to use public transport. Biofuel as an alternative fuel for transportation will play an important role in energy supply in the ASEAN members. However, current use of biofuel relies on first generation biofuel; therefore, development of second generation biofuel is essential in order to address energy concerns and ensure that there is no competition between energy and food production.

E. Barriers and challenges

Innovation in energy technology is widely regarded as a basis for sustainable energy, which rests on two pillars: (a) energy from renewable sources; and (b) energy efficiency (John and Rubbelke, 2011). Lee (2010) noted that renewable energy needed to provide value-added in terms of cost reduction (compared to unsustainable path) and less greenhouse gas emissions. Energy technology is a key to deep cuts in the anthropogenic greenhouse gas reductions required for climate change mitigation, and energy efficiency also provides more space for easing the risk of energy shocks such as price vulnerability and supply shortage. Similarly, Edenhofer and others (2011) outlined eight climate policies based on technology and innovation:

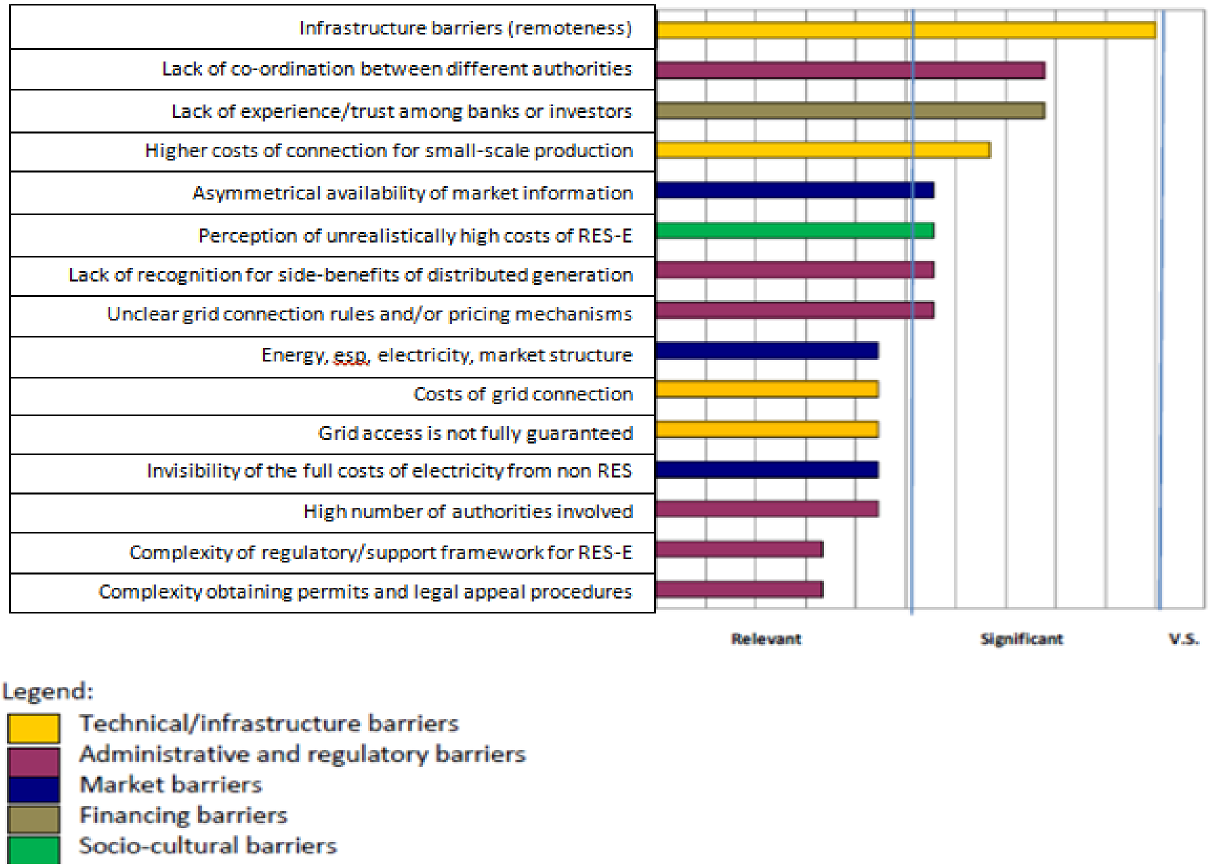
(a) Energy efficiency improvement;
(b) Fuel switching to lower carbon fuels;
(c) Bio-energy;
(d) Other forms of renewable energy;
(e) Carbon capture from fossil fuels and storage;
(f) Nuclear (albeit with substantial risks and side-effects);

(g) Reduction of non-CO_2 greenhouse gases (multi-gas strategy); and
(h) Land use-related mitigation options.

However, most ASEAN developing members (e.g., Indonesia) have difficulties in following, adopting and implementing policies and strategies for the deployment of desired energy technologies to ensure energy security and access on the one hand, and to meet GHG reduction obligations on the other hand. This is mainly due to lack of a promotional incentives system, human skills, technical information and technology support services, finance, and the Government's science and technology policy (Thee, 1998).

For examples at the ASEAN level, 15 non-economic barriers in promoting renewable energy have been identified (IEA, 2010). As shown in figure 5, most of the top five barriers are related to government failure to provide infrastructure, leadership, reliable information and incentives. This indicates that in order to be successful in promoting renewable energy, Governments need to remove all the bottleneck constraints. It is also essential to promote effective and coherent renewable energy policies with a long-term strategic perspective.

Figure 5. Ranking of non-economic barriers in selected ASEAN members



"Relevant", "Significant", and "V.S." refer to a barrier that is deemed "relevant", "significant" or "very significant", ,based on the survey results.

Source: IEA, 2010.

1. Technical aspects

Through the value chain approach, Roland Berger Strategy Consultants (2011) identified five stages across four actors (figure 6). As shown in figure 6, all the actors face their own barriers in promoting energy efficiency. This indicates that promoting energy efficiency needs an integrated approach both on organisational and institutional dimensions. Organisational dimension means that suppliers, producers and Governments need to share a common vision of the importance of energy efficiency. The institutional dimensions need to ensure that all parties (producers and consumers) obtain win-win solutions after implementing regulations. Because most of advanced technology is imported, and is usually produced following the global production networks, the performance standards, product labelling, and certification of suppliers/ESCOs need to be prepared both globally and regionally. However, according to the Center for Strategic and International Studies (2012), energy efficiency standards are mainly voluntary and, where mandatory, are poorly enforced; therefore, it will be necessary to introduce new energy standards and strengthen existing standards for buildings, appliances and automobiles).

Figure 6. Key barriers along the energy efficiency value chain as identified by needs of companies

	1. Identification of demand	2. Manufacture and sale of products	3. Evaluation and investment	4. Delivery and installation	5. Long-term operations and maintenance
Governments	• Overall, lack of an effective overarching and comprehensive EE policy framework • Insufficient role as facilitator to integrate difference stakeholders in the market place				
	• Insufficient provision of information channels to match users and suppliers		• Insufficient financial support and assistance	• Insufficient technical training provided	• Lack of standards on energy auditing methods • Room for improvement in awareness-raising efforts
Suppliers/ESCOs	• Difficulty in identifying demand • Lack of commitment to provide sufficient resources to gauge savings potential	• Difficulty in convincing clients of benefits of EE equipment		• Lack of technical know-how to carry out product installation	• Lack of integration into users' business lifecycle
Users	• EE often not regarded as a business priority	• Lack of confidence that equipment can achieve projected savings • Difficulty in identifying customized products to suit specific needs	• "Quick-win" investments favoured over EE projects with longer payment periods		• Lack of awareness of energy efficiency • Lack of consistent investment plans in EE products and technologies
Financial institutions			• Lack of familiarity with EE financing • Lack of confidence in return on EE projects		

Source: Roland Berger Strategy Consultants, 2011.
Note: ESCOs is energy service companies.

2. Financial and investment barriers

As mentioned in the previous section, energy efficiency is one of the pillars of sustainable energy, and ASEAN has a commitment to reduce regional energy intensity by at least 8 per cent by 2015 (based on 2005 levels). Roland Berger Strategy Consultants (2011) showed that by 2020 the estimated energy saving potential in Indonesia, Malaysia, Singapore, Thailand and Viet Nam) will be between US$ 15 billion and US$ 43 billion. The huge gap between the lower bound and upper boundaries of energy efficiency is due to different assumptions of energy subsidies and prices. However, the ASEAN members need to work hard to remove barriers to the deployment of energy efficiency technologies and measures. Their Governments should make more efforts to formulate energy efficiency targets.

The benefits of energy efficiency are huge. While some technologies or measures can have short payback periods or low cost levels, others may involve substantial up-front costs and long payback periods. This will become a disincentive at the early stage of investment. Further, financial institutions may not find financing energy efficiency projects attractive due to the lack of experience and technical expertise (Roland Berger Strategy Consultants, 2011). This situation is problematic among small and medium-sized enterprises, in particular, where there is a higher perceived risk than for large companies. Therefore, appropriate, measured government intervention is again crucial.

In the case of renewable energy technologies, similar financial barriers exist and are well-known. Although the cost of some renewable energy technologies has declined rapidly in recent years, some still involve a much higher cost than conventional technologies (IRENA, 2012).

3. Cultural, institutional and legal barriers

Cultural barriers often arise from conflicting objectives in promoting new technology, such as with the environment, employment and other sectors. For example, there is always a conflict between geothermal power plants and forest conservation. Some new technologies that are imported may not create jobs in the domestic market, especially in manufacturing activities. There could even be significant competition between locally developed and imported technologies. Further, in some cases, promoting new technology may not benefit the poor. For example, in the case of the Ulumbu geothermal power plant in East Nusa Tenggara, Indonesia, which was commissioned in November 2011, the villagers that provide water to run the plant were only supplied with electricity in March 2014 after a prolonged struggle.

Basically, communities are quite open to adopting new technologies because it is believed that such technologies will improve their quality of life. However, in many cases, new technologies arrive at the village without proper socio-economic and environmental assessment. The lack of information on the nature of the technologies, their likely impacts on the community and the proper handling of the waste after the life time of the equipment concerned is also seen as an important barrier.

4. Human capital capacity

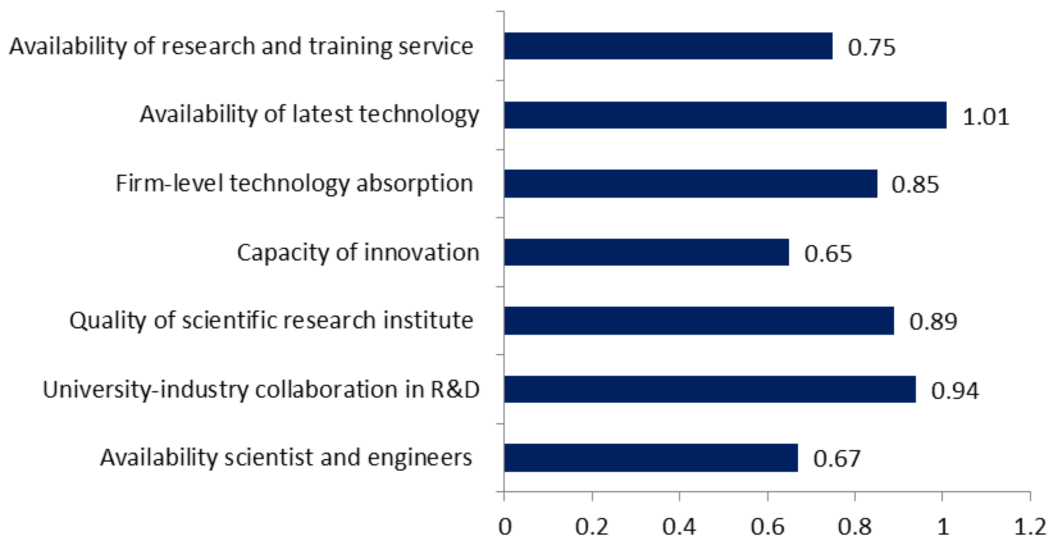
A lack of human capital is widely recognised as one of the key barriers to development, acquisition, deployment and diffusion of sustainable energy technologies. There is increasing concern in the energy supply and final services sectors in many countries that the current educational system is not producing sufficient numbers of qualified workers to fill current and future jobs that increasingly require science, technology, engineering, and mathematics (STEM) skills. This is true not only in the booming oil/gas and traditional power industries, but also in the rapidly expanding renewable energy supply sector. Developing the skills to install, operate and maintain renewable energy equipment is exceedingly important for successful project implementation (National Academies Press, 2013; IPCC, 2014).

The transfer of technology is also an important issue for energy sustainability. For example, the Ulumbu geothermal power plant was designed and constructed by engineers from outside Indonesia. According to discussions with local engineers at the Ulumbu power plant, the lack of capacity-building during construction and start-up of the power plant meant they engineers had to learn how to operate the power plant through "learning by doing", causing unnecessary delays in repair and maintenance.

As shown in figure 7, there is huge gap across the ASEAN members in terms of access to the best available technologies and the capacity to innovate. In any case, there is a general lack of a skilled workforce, technicians, scientists, engineers and R&D personnel as well as a lack of linkage and interaction among academic and research institutions, and industry and government.

Apart from technical skills, institutional and human capacity for policy-making and planning, assessing and choosing technology, and policy options for sustainable energy development are also crucial (IPCC, 2014).

Figure 7. Standard deviation of global competitiveness score for selected indicators among the 10 ASEAN members



Source: WEC, 2014.
Note: Calculated from the global competitiveness report 2013-2014, standard deviation is calculated from value.

F. Recommendations for strategies and mechanisms

1. Effective policies around the world and their relevance to ASEAN

Some of the lessons learnt from international practices on energy policy setting that have proved to be effective, and could therefore be relevant to ASEAN members in general, are discussed in this section.

One of the most important lessons is that in order to establish an energy technology development policy a general energy policy is required. It is only through a clear general energy policy that long-term energy technology development and innovation can be achieved. A case in point is Germany, where the development of wind and PV technologies only took place once the Government had set a long-term feed-in tariff policy in 1990, which was basically an industrial sector development policy. The feed-in tariff mechanism accelerated uptake, and helped to strengthen and expand related manufacturing facilities as well as their R&D activities.

Another important lesson is that policies for accelerating the utilisation of renewable energy and for improving energy efficiency in different end-use sectors have to be sector-specific.

Viewed from this perspective, some general recommendations are:

(a) To ensure a successful energy policy, Governments have to set clear and achievable long-term goals/targets that will be achieved in, for example, 5, 10, 15 and 20 years. Clear implementation strategies must then be directed towards achieving those goals, and the achievements monitored every two to three years against the plan;

(b) Governments have to appoint agencies/ministries/departments that are responsible for establishing implementation strategies, their implementation (e.g., tendering and evaluation of the programmes) and programme monitoring and review;

(c) Once (b) has been achieved a specific energy technology development and innovation policy can then be formulated. The definition and formulation of these policies around the world are based on the setting of clear and achievable objectives that are measured and reviewed regularly. The policies formulated are based on in-depth discussions with all relevant stakeholders – concerned industrial sector representatives, applied and/or basic research institutions, universities and technology consultants/providers. Together with the respective ministries, i.e., economics, industry, finance and energy, a well-defined technology development plan for three to five years can then be developed;

(d) The implementation of research programmes and tendering of R&D as joint projects for academic institutions in co-operation with industry should then be carried out. Once the results of the tendered research projects are presented in public workshops, the achievement of the objectives is reviewed and, if necessary, the next round of research is tendered;

(e) Generally, Governments do not formulate energy technology development targets, but facilitate their realisation by enabling joint research projects by applied research institutions and industry. In addition, Governments provide easy finance access for innovation through various schemes, such as the Private Financing Network approach currently being implemented by the United States Agency for International Development in ASEAN.

Next, the following sector-specific policy for energy development, based on lessons learnt internationally, is recommended.

(a) *Power production and distribution: Centralised and decentralised*

(i) Set long-term policy with targets for different technologies.

(ii) Assign the responsible agency/ministry for policy implementation and monitoring.

(iii) Put in place a promotion scheme, such as a decreasing feed-in tariff for an off-take of technologies.

(iv) Remove subsidies for conventional energy to remove the disadvantage of renewable energy technologies and efficient conventional systems such as co-generation.

(v) Introduce a city-planning concept that explicitly includes a plan for "district cooling", such as the city energy plans of some major European cities.

(vi) Support demonstration projects to disseminate knowledge and create confidence in such newer technologies as tri-generation, district cooling etc.

(vii) Remove subsidies for diesel fuel to promote off-grid and micro-grid systems. Introduce support for demonstration projects to show that a hybrid system consisting of diesel and a combination of PV/wind/biomass/hydropower can be competitive and more cost-effective.

(viii) For the respective energy technology development, identify respective research institutions and existing private or public companies that are capable of applied research.

(b) *Industrial sector*

(i) Apply the best available technology concept for major industrial sectors, similar to that introduced by the European Union for several sectors.

(ii) Introduce an innovation policy for the development of specific promising technologies such as low temperature combustion burners.

(iii) Introduce specific cross-cutting technology deployment programmes, such as the compressor programme in Germany or the high-efficiency motors exchange programme.

(iv) Introduce sector-specific technology and process optimisation programmes for selected industrial sectors, such as a waste heat recovery programme for the iron and steel sector.

(c) *Building sector*

(i) Set mandatory energy building standards as the most effective policy. These standards need to be developed, adopted and then tested.

(ii) Permitting agencies/ministries must be empowered to deny the issuance of the energy impact assessment certificate if a certain standard is not achieved.

(iii) Introduce an energy building labelling scheme that is additionally an effective tool to encourage the development of related technologies.

(d) *Transport sector*

(i) Set Minimum Energy Performance Standards for vehicles as a first and effective step.

(ii) Set requirements for regular technical inspections, e.g., every two years, of all rolling stock in order, to improve the energy efficiency of existing vehicles.

(iii) Encourage non-motorised transport in cities.

(iv) Since transport vehicles are manufactured by few major producers globally, it is advisable for ASEAN countries to focus on the development of technologies for efficient use of alternative fuels.

2. Energy STI policies at the ASEAN level

In the 1980s and 1990s, ASEAN ran some successful science and technology co-operation programmes (including in the field of energy) among its member States and with some of its dialogue partners, with effective co-ordination such as the Non-Conventional Energy Research Subcommittee. There is no reason why such success cannot be repeated, particularly in the light of the new “ASEAN Krabi Initiative”, which is a framework for intraregional co-operation on STI[3] that was agreed upon in March 2014 by the 10 members of ASEAN in 2012 as part of plans for forming the AEC.

In the following sections, several policy actions are proposed for promoting science, technology and innovation at the ASEAN level.

(a) *Promotion of science*

(i) Promote co-operation in the study of energy science. Energy science courses and programmes, aimed at arousing interest and creating better understanding of the subject as well as laying a strong foundation for energy innovation, should be introduced in schools and higher education institutions. At the school level, best

[3] See website at www.sti.or.th/kiworkshop/index.php/krabi-initiative.

practices in curriculum design and delivery, including “training the trainers” programmes, can be shared among ASEAN members. For example, Thailand has had many years of experience in developing and delivering such programmes with the support from the Ministry of Energy. The same approach can be applied to energy studies at the undergraduate level, plus the promotion of e-learning. A case in point is the UNESCO-supported pilot e-learning programme on energy for sustainable development in Asia, which draws on the expertise of professors from throughout the region in developing the courseware and delivering the lectures. At the graduate level, joint international, multidisciplinary energy science programmes should be promoted, allowing student and staff mobility, joint supervision of thesis, and learning different socio-economic and cultural context of sustainable energy development.

Examples of such programmes include those run by Kyoto University and those being initiated by Thailand’s King Mongkut University of Technology Thonburi, in co-operation with several leading ASEAN universities. All these efforts, if adequately supported and well co-ordinated, will lead eventually to smoother ASEAN Energy Market Integration.

(ii) Promote collaborative scientific research. Collaboration – both bilateral and multilateral, and both within ASEAN and with its dialogue partners – in the advancement of energy science is required in order to lay a strong foundation for solving complex, long-term energy problems of common interest to ASEAN members. Examples of such problems include advanced biofuels, photovoltaics, solar-assisted cooling, marine energy, energy storage and CCS etc. To this end, ASEAN-wide joint scientific research programmes should be developed and funded by ASEAN. Since each member State has specific strengths in different areas, which are often complementary, ASEAN centres of excellence in different areas should be established in different countries with ASEAN-level support to act as the focal point of scientific research that would benefit ASEAN as a whole. Strong collaboration with international institutions should be fostered by each centre.

(iii) Promote scientific communication. Programmes should be established to support the creation and operation of networks of excellence or the network of energy laboratories, such as the pilot projects in energy technology supported by the Regional European Union-ASEAN Dialogue Instrument. However funding support should extend beyond researcher mobility expenses, to cover project initiation grants and other activities. Joint bilateral and multilateral scientific workshops, seminars and conferences should be promoted. In particular, holding ASEAN annual or biennial conferences in specific areas with alternate hosts from country to country, similar to the European Biomass Conference, should be supported.

(b) *Promotion of technology*

(i) Promote co-operation in technology R&D. Energy technology development and innovation at the ASEAN level requires a comprehensive and co-ordinated approach with a clear focus on selected technologies in specific sectors. Policies to promote energy technology development should include the establishment of regular, ASEAN-wide energy research programmes that are tendered openly and transparently as research projects. Universities and applied research institutions should be encouraged to form consortia of various players and tender for ASEAN support. Similarly to the practice in the Europe Union, there should be requirements for the minimum number of institutions and/or member States in any specific consortium. The consortia with private sector participation should receive priority in the project proposal evaluation.

It should be noted that in most OECD countries, the introduction of competition as well as open and transparent tendering of research projects has been found to improve the effectiveness of applied research results. The research programmes should also cover pilot scale development and demonstration, which is often lacking in most ASEAN members' research programmes.

(ii) Promote co-operation in R&D personnel development. In the 1980s and 1990s, ASEAN used to operate an effective R&D personnel development programme in energy technology, with the assistance of ASEAN's dialogue partners such as Australia, Canada and the United States, and international organisations such as UNIDO. With specific train-the-trainers programmes such as energy conservation in industry and buildings, and renewable energy technology conducted in those countries, together with funded R&D programmes, a generation of inspired, capable personnel was groomed for Indonesia, Malaysia, the Philippines, Singapore and Thailand. Those personnel are still present and contributing to energy R&D in universities as well as to policy formulation and implementation, and in government offices. Similar programmes should now be re-established in ASEAN.

(c) *Promotion of innovation*

(i) Promote co-operation in technical human capacity development. ASEAN industry needs skilled technicians and engineers who are capable of (a) designing, installing and operating renewable energy technology equipment to the proper industry standards, and (b) implementing energy efficiency measures. Through training programmes and know-how transfers from developed countries, e.g., Germany, some ASEAN members, such as Thailand, have acquired relevant standards and skills such as those for solar thermal systems design and installation. These practices can be shared among ASEAN members.

ASEAN industry in general also lacks capable R&D personnel who are needed for the tasks of technological innovation. In this regard, the scheme called "talent mobility" should be promoted. The scheme is aimed at seconding scientists and engineers from higher education and research institutions to contribute to R&D and engineering tasks in enterprises on a regular basis, be it for a certain number of days per week or full-time for a specified period. Such a practice is being piloted in Thailand and relevant lessons can be shared among ASEAN members. A similar programme aimed at promoting mobility within ASEAN has also been initiated by Thailand and has already won the approval of the ASEAN Committee on Science and Technology.

(ii) Promote technology facilitation. Energy technology facilitation centres, in the form of a one-stop clearing house, should be set up in each ASEAN member and linked as an ASEAN network to facilitate innovation in enterprises, particularly small and medium-sized enterprises. Services provided by the centre should include advice for and access to technical and financial information, university talent research facilities, intellectual property, government incentive schemes and consultancy. Such an ASEAN network should facilitate intra-ASEAN technology and know-how transfer between members as well as from outside ASEAN, particularly in the field of renewable energy and energy efficiency.

(iii) Support industry-targeted translational research. In the Republic of Korea, energy science research programmes are funded by the Ministry of Science and Technology. Funding for applied research aimed at technological innovation, on the other hand, is provided by the Ministry of Knowledge Economy directly to enterprises, which in turn fund their research partners in universities and research institutions. Such practices should be adopted in ASEAN for the funding of translational research at the national and regional levels. At the latter level, the university/research institution partners could be from any country, but must involve at least one local institution.

(iv) Support STI-oriented policy research. To support STI policy decision-making at the enterprise, national and regional levels, STI policy research should be encouraged and STI policy research centres/institutes be set up in each country. Such centres/institutes should be linked as a network of excellence and co-ordinated by such an entity as the ASEAN Centre for Energy.

3. Feasibility of an ASEAN Clean Energy Technology Trust Fund

Because of the huge investment required – amounting to billions of United States dollars – for providing access and transitioning to secure and low-carbon energy systems and services, a number of international entities have introduced initiatives to improve access to, and create incentives for financing and investments. Examples include the Private Financing Network implemented by the United States Agency for International Development, the Asian Development Bank's Clean Energy Financing Partnership Facility and the Clean Technology Fund (CTF).

The CTF, in particular, is currently the largest multilateral mitigation fund, with a large capitalisation in grants and concessional loans. Its objective has been to achieve "transformational change" in developing countries towards low carbon development strategies through public and private sector investments. Administered by the World Bank and implemented through the World Bank Group and regional development banks (including the Asian Development Bank), the Fund aims to achieve this transformational change through financing the deployment of low carbon technologies at scale.

The experience of CTF offers important insights into what it takes to use diverse financial instruments at scale to support developing countries to respond to climate change. In addition to seeking to foster innovative approaches to delivering finance for combatting climate change, it has made investments that seek to reduce the costs of promising new technologies (Nakhooda and Amin, 2013).

While these funds are useful and should continue to be accessed by ASEAN countries, it is felt that an ASEAN-focused trust fund that would support ASEAN-specific clean energy technology development and deployment agenda is desirable. Some proposed ideas for establishing an ASEAN Clean Energy Technology Trust Fund (CETTF) are detailed below (see also figures 8 and 9).

(a) Objectives

As a key instrument for removing financial and other related barriers to the development and deployment of clean energy technologies at the ASEAN level, the objectives of CETTF would be to encourage investments in clean energy technologies, improve energy security in ASEAN countries and slow down the rate of carbon emissions. CETTF would be designed to provide financial support on projects, divert private investors' risks by leveraging with its own funds and to offer technical assistance to investors. The promotion of clean technology will be implemented through the key mechanisms that include project loans, grants through CETTF, and technical knowledge provision and exchange.

(b) Structure

The organisational establishment of CETTF should comprise two main functions, i.e., an advisory committee and a project management office.

(i) Advisory Committee: Representatives from members of ASEAN should form an Advisory Committee whose main responsibilities would include:
   a. Clearly defining the roles and responsibilities of the trust fund;
   b. Provide guidance on policy and strategy;
   c. Recommend for new funding sources;
   d. Ensure effective, efficient and transparent implementation of programme.

(ii) Project Management Office. The office would be led by the Director, who would be appointed by the Advisory Committee. The roles and responsibilities of the project management office would be:

a. The management and co-ordination of the fund;

b. Establishing strategy, policies, guidelines and standards for the fund management;

c. Ensure the effectiveness of implementation according to the strategy, plans, policies, guidelines and standards of the trust fund;

d. Accounting, management and reporting of routine activities of the trust fund;

e. Maintain and share carbon data to national data centre.

(c) Sources of funding (see figure 8)

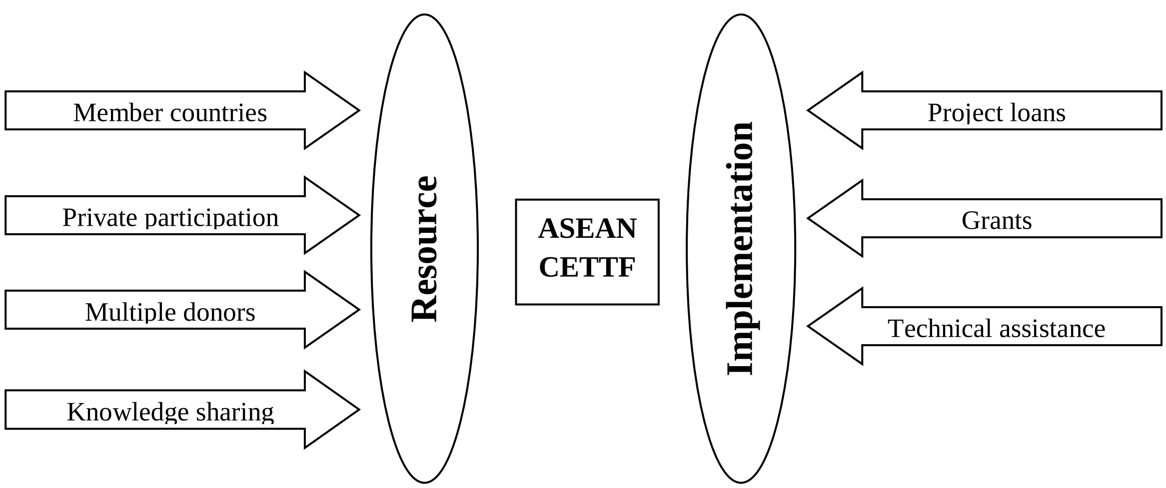
(i) The source of funding for CETTF could start with seed funds from ASEAN members. Although equal seed funds from the members can form the basis of equal responsibility, ownership and voting, unequal seed funds would be acceptable, depending on the different economic situations of the members.

(ii) Contributions to CETTF from individual sources, including private companies and foundations, would be welcome. The public sector could be the key player for public-private partnership programmes that enhance the implementation of clean energy technology.

(iii) Concessional loans that are provided on terms substantially more generous than market loans. They are available at interest below the market rate or with grace periods, or a combination of these two terms. Concessional loans typically have long grace periods.

(iv) In addition to monetary support, knowledge sharing can be considered as a resource provision to CETTF.

Figure 8. ASEAN Clean Energy Technology Trust Fund overview

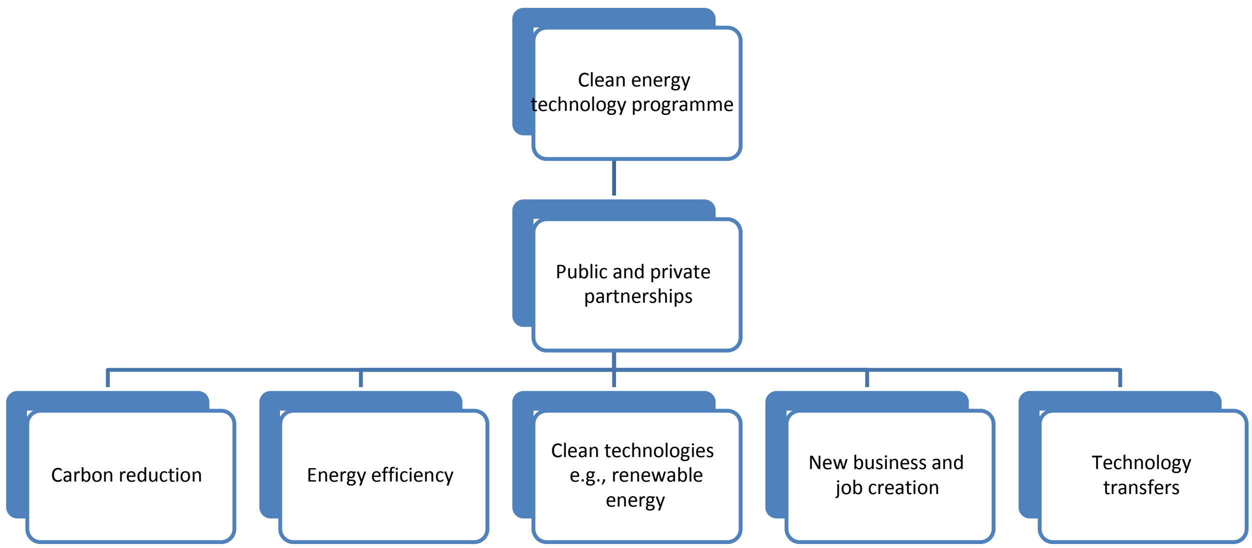


(d) *Procedures and governance*

The CETTF aims to support projects that benefit the public and the economy, such as:

(a) Carbon reduction activities that improve the environment;
(b) Energy efficiency improvement and energy conservation projects;
(c) Job creation, both in urban and in rural areas;
(d) Activities that provide opportunities for new businesses;
(e) Emerging clean technologies related to carbon reduction;
(f) Public and private investments that intend to maintain the competitiveness of traditional industries with clean technologies.

Figure 9. Clean energy technology programmes and partnerships



(e) *Investment projects*

The CETTF will invest in innovative and pioneering clean energy and low carbon projects. The trust fund can work out with private companies and governmental offices to identify and evaluate potential projects. Such investment can help in the development of new technologies by reducing the costs, facilitating their deployment and lowering barriers. Possible qualified projects to be financed include:

(a) Upgrading transmission and distribution systems to reduce system losses;
(b) Retrofitting street lighting with energy efficiency technology;
(c) Urban mass transit that will result in reduced fossil fuel consumption;
(d) Agricultural waste and biomass energy projects;
(e) Manufacturing lower cost solar cells;
(f) Development of wind generation for both private and public sectors;

(g) Refurbishment and management of high-quality, low-carbon office space;
(h) Commercialisation of organic photovoltaics technology;
(i) Development of biofuel to full commercialisation;
(j) Designing and implementing micro-grids, smart grids, as well as energy storage systems;
(k) The reduction of cooling requirements for electronic data centres and telecommunications equipment;
(l) Designing and manufacturing energy-efficient power conversion products.
(m) Community fund initiations for self-reliance and sustainable operation;
(n) Co-ordination of private companies' CSR programmes for clean energy in communities.

(f) Technical assistance

The CETTF would also be used for technical assistance, which would assist in the development of policies, regulations, standards, capacity-building and clean energy projects for financing in order to support the following business decisions and engineering services:

(a) Verification of clean energy to sustainable growth of economic sectors;
(b) Preparation of projects for investment;
(c) Cost-sharing in clean energy investment programmes between donors and the private sector;
(d) Transfer of technology, knowledge and experience;
(e) Capacity-building for potential stakeholders in clean energy investments and programmes.

The CETTF concept outlined above represents only a preliminary concept. A more detailed definition of CETTF, based on broader stakeholder consultations, needs to be conducted; as such, an in-depth investigation should be carried out to test and validate its feasibility and practicality, particularly with regard to the vast resources that are required as well as technical assistance, which may be outside the capacity of ASEAN, at least at the region's present stage of development.

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