Chapter 9
Green Technology Development and Deployment in the ASEAN—Lessons Learned and Ways Forward

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Abstract Southeast Asia faces one of the fastest growths in energy demand in the world, driven by increasing incomes, urbanisation, and industrialisation. The development and deployment of green energy technologies offer a natural conduit to meet the growing energy needs in the Association of Southeast Asian Nations (ASEAN). This chapter undertakes a case study approach in reviewing green energy deployment in the context of green growth and energy transition and discusses the current status of renewable energy development in ASEAN. The study aims to formulate policy lessons for the ASEAN economies in facilitating the development and deployment of green technologies and alternative energy options based on a case-study approach for delivering sustainable economic growth and in combating climate change in the region. The review suggests that carbon capture and storage (CCS) technologies will allow ASEAN to continue to use fossil fuels whilst achieving sustainable economic growth as coal demand increases in the region. The deployment of CCS technologies is also an enabler of hydrogen energy as a green energy solution in the region in the longer term. The shorter-to-medium-term policies include boosting public acceptance to nuclear energy, implementing energy efficiency improvement policies, and

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eliminating fossil fuels consumption subsidies. Increasing both public and private sector energy investments and the development of CCS technologies in the longer-term are necessary complementary policies for maximising the benefits of greater deployment of renewable energy sources in the region.

Keywords Green technology · Sustainability · Climate change · Southeast Asia · Energy policy

9.1 Introduction

Sustainable development is about achieving a more sustainable global future and holds significant importance as a powerful development concept as it integrates economic, societal, and environmental aspects. Developing sustainably ensures the availability of critical resources, such as energy, water, and food, be available to both present and future generations but also emphasises mitigating the risks posed by planetary boundaries (Steffen et al. 2015). However, the transition towards sustainability is still at an early stage in developing economic regions, whilst economies around the world have been struggling to balance their economic growth without depleting the natural resources. The coronavirus disease (COVID-19) pandemic brings further uncertainty in adapting sustainability reforms given the economic downturn and border closures in many regions affecting resource mobility. Whilst the COVID-19 pandemic has pushed back the immediate urgency to tackle climate change as global emissions have decreased in the short term, the role of green technology has always been crucial in providing a new perspective on sustainable development.

Southeast Asia currently faces paramount challenges as well as opportunities in matching its increasing energy demand due to rising incomes, industrialisation, and urbanisation with a sustainable energy supply considering the transition to a lower-carbon economy. In recent decades, greenhouse gas emissions have been rapidly rising at an average annual rate of 5% amongst major Southeast Asian economies, such as Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (Raitzer et al. 2015). The region is poised to become a net energy importer of fossil fuels, such as oil, due to growing populations, industrialisation, and urbanisation despite the slowdown in economic growth (IEA 2019a). The total population in the Association of Southeast Asian Nations (ASEAN) region will increase to 715 million by 2025 with the economy growing by more than 5% per year, therefore explaining the rapid rise in energy demand of at least 4% annually (IRENA 2016). The overall growth in energy demand of more than 80% since 2000 has been met by a doubling in fossil fuel use, engendering severe energy security concerns, such as rising import dependence and environmental concerns due to an increase in energy-related carbon dioxide (CO_2) emissions (IEA 2019b). For instance, the share of this geographic region to global emissions increased to 4% in 2018 (3% in 2010), whilst the number of deaths linked to outdoor and household air pollution in Southeast Asia is expected to spike to more than 650,000 a year by 2040, up from around 450,000 in 2018 (IEA 2019c).

Nevertheless, the energy usage is expected to have a much sustainable approach. Moreover, the average temperature in ASEAN has been rising by 0.1–0.3 °C per decade in the last 50 years and is projected to reach 2–4 °C by the end of the twenty-first century (International Resources Group 2010). The electricity demand in the region is growing at an average of 6% and remains amongst the fastest in the world whilst the region's demand for electricity is projected to double by 2040 (IEA 2019a). In 2016, the ASEAN economies set a target of 23% of its primary energy supply to be secured from renewable sources by 2025 (IRENA 2016). However, it is also likely that the overall energy demand will grow by almost 50%, whilst power generation will double by 2025 (IEA 2019a). Although some countries will have to at least double their share of renewable energy every year, this alone may not be enough to combat climate change. The rising energy demand and related CO_2 emissions in ASEAN, therefore, implicate the heightened need for transitioning towards the development and deployment of greener energy sources in the region.

There is also an ongoing discourse in ASEAN to devise policy strategies to mitigate and adapt to climate change threats and balance the trade-offs between economic development and environmental sustainability. Policymakers across Southeast Asia are intensifying their efforts in achieving a common goal of a secure, sustainable, and affordable energy sector even though the region is diverse and dynamic (IEA 2019b). The diversity in the energy mix in the region also offers a viable opportunity to accelerate regional physical interconnections of power grids and make greater use of the resource and demand complementariness (Singh et al. 2018). Boosting regional power grids in ASEAN has also been well advocated in the energy policy agenda (Halawa et al. 2018). Within this context, the need for developing, deploying, and adopting green technologies is imminent for Southeast Asia to address the twin challenges of rising energy demand and increasing emissions in ensuring energy sustainability as well as to mitigate the adverse impacts of climate change. However, the progress towards the adoption of green technology, such as renewables, in Southeast Asia is slower than the anticipated potential. Renewable energy only meets around 15% of demand with the rapid increase in hydropower and modern use of bioenergy in heating and transport (Louis 2020). In addition, countries in ASEAN should increase their share of renewables in the energy mix to 70% by 2040 to meet their Sustainable Development Goals (SDGs). The large potential for the sustainable use of modern bioenergy remains untapped in the region, although electricity from hydropower production almost tripled to 44 gigawatts (GW) in 2016 compared to 16 GW in 2000 (IRENA 2018b). Southeast Asian economies are yet to perform globally in renewable energy deployment due to various challenges despite having huge potential for sustainable energy sources (Erdiwansyah et al. 2019).

The objective of this chapter is to analyse and review the energy–economy–environment interrelationships in ASEAN from an energy sustainability perspective in the context of green energy development and deployment. In doing so, the study recognises the inevitable economy–environment trade-off between regional economic growth and adverse climate change impacts as a policy tool for policymakers to emphasise. Based on our impartial and unbiased analysis, we propose that policymakers need to formulate and implement proper policies that are of short-term,

medium-term, and long-term nature for the scaling of renewable energy deployment; focus on energy efficiency improvements; discourage the use of fossil fuels by undertaking energy pricing reforms; and embrace carbon capture, utilisation, and storage technologies. However, significantly accelerating the deployment of renewable energy in the region requires higher levels of investment. This chapter uses a case study approach as case studies are suitable for examining policy problems that do not easily lend themselves to rigorous quantitative analysis or that cannot be analysed due to the unavailability of disaggregated data (Nepal and Jamasb 2015).

The remainder of the chapter is structured as follows. Section 2 portrays the current status of renewable energy deployment in ASEAN. Section 3 discusses green energy innovation and alternative energy options for ASEAN. The three major policy recommendations are discussed in Sect. 4. Section 5 concludes the chapter.

9.2 Current Status of Renewable Energy Deployment in ASEAN

It is projected that the ASEAN region will have accelerated economic growth over the next decade and experience a 50% rise in energy demand. Importantly, the region has targeted sourcing 23% of its primary energy from renewable sources (IRENA 2016). Global economic and energy indicators show an indication that the ASEAN region is becoming a net importer of fossil fuels given its rapidly growing economies and increasing population size. Southeast Asian countries have a geographic advantage in terms of their diverse natural resource endowments. For example, Indonesia and the Philippines have substantial potential for geothermal energy, whilst Vietnam, Cambodia, the Lao PDR, and Myanmar have mass-scale hydropower potential. Similarly, most areas in these countries have at least 12 h of sunshine on average, which is suitable for solar electrification. Global renewable energy generation capacity stood at 2179 GW by the end of 2017, with the hydro sector holding the largest share with an installed capacity of 1271 GW. In 2019, Asia alone accounted for 54% of the new capacity in renewables, increasing by 95.5 GW to 1.12 TW. The majority of this growth was driven by new installations of solar and wind energy covering 85% of all new renewable capacity installed. Thailand was one of the distinguishable countries from the ASEAN region with the second-highest share in the region in terms of bioenergy capacity at 430 megawatts (MW). The other was Indonesia, which topped the list in expanding its geothermal energy capacity to 306 MW and is soon approaching 2 GW (IRENA 2018a). Similarly, Malaysia is the third-largest producer of photovoltaic cells in the world.

Likewise, the Lao PDR has around 80% of its primary energy demand sourced through renewable energy, and the country has realised its potential. Biomass from forestry and agricultural waste comprises 68% and is used for household cooking and small-scale rural production, whilst the other 12% is from the hydropower sector. The Lao PDR has taken advantage of the 300 days of sunlight it has every year to

equip 13,000 rural homes with solar panels. In Indonesia, the government took the initiative to build its largest solar power plant by 2019 with an investment of $300 million (Kurniawan 2020). The country has huge potential for wind, and a 100-ha wind farm was opened in South Sulawesi with the capacity to power around 70,000 households (Hajramurni 2018).

The Philippines has the largest potential for wind energy in Southeast Asia, although a significant proportion of the population does not have access to electricity, compelling them to use alternate methods for cooking and lighting. Green start-ups have played a major role in the Philippines by benefitting from the natural energy resources. A Filipino start-up named Sustainable Alternative Lighting came up with a saltwater solution-powered lamp that retains power for up to 8 h. Furthermore, the disposable component of the lamp lasts for 6 months and is not expensive to replace. Around 51% of people use firewood or charcoal in the Philippines, and a green-start up named Hi-Gi Energy came up with an alternative cooking fuel by changing water hyacinths, a commonly found plant, into compressed blocks of coal dust, known as briquettes (Clean Cooking Alliance 2020).

However, about 120 million people do not have access to electricity in Southeast Asia, and the rural areas face critical challenges in receiving power (Charlotte Trueman 2018). There are about 45 million people in the region who rely on biomass as a fuel for cooking (Louis 2020). There is a tremendous potential for renewable energy, but it only accounts for 15% of the energy demand. On one hand, hydropower has increased fourfold since 2000 along with the increase in the use of bioenergy in heating and transport (IEA 2019a). On the other hand, the share of solar photovoltaics and wind is small, although the costs have been declining in recent years. An efficient market-based energy efficiency framework could strengthen their deployment.

Based on a stated policies scenario developed by the International Energy Agency (IEA) in 2019, by 2040 Southeast Asia's overall energy demand is expected to grow by 60%. This also implies that the size of the economy will double over the period and the majority of the population will be concentrated in urban areas, with an increase of 120 million (ASEAN Secretariat 2012). A structural economic shift towards less-energy-intensive manufacturing and services sectors is expected along with greater efficiency, which will lower the rate of energy demand compared to previous decades, representing 12% of the global energy rise by 2040. The oil demand will exceed 9 million barrels per day (mb/d) by 2040 from the current 6.5 mb/day (IEA 2019a).

Given the little progress made by countries and major multinational companies in the world on their pledge for net zero carbon by 2050, it is likely that oil will continue to dominate road and transport demand in ASEAN. Similarly, coal demand driven by strong policy settings by countries to meet the economic growth targets set by policymakers will increase. In the case of natural gas, the IEA estimated that industrial consumers drive demand more than power plants, whilst the increase in imports of oil is making sources such as liquified natural gas (LNG) less price-competitive for power plants.

In Fig. 9.1, inferences can be made as a result of having policy targets where the region's energy demand is expected to rise to 60% by 2040. Compared with the energy demand of the previous decades, the growth rate is far lower, which reflects a

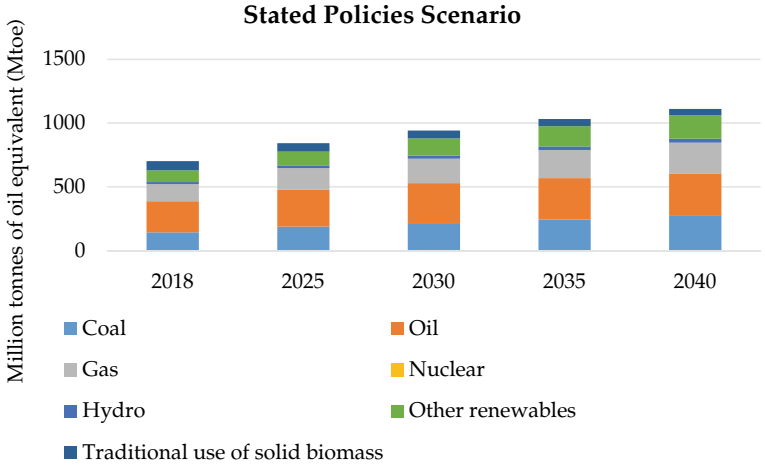

Fig. 9.1 Primary energy demand in ASEAN, 2018–2040. *Source* Adapted from IEA (2019a)

systemic economic shift towards less- energy-intensive sectors along with increasing efficiency. In addition, the renewable share in power generation is expected to rise from 24% today to 30% by 2040. However, this is still short of levels reached by other emerging economies, such as China and India, under the stated policies scenario. The hydropower sector, which accounts for almost 80% of the renewable share, is the cornerstone of ASEAN's energy portfolio, and the rise of wind and solar energy, as well as biofuels and bioenergy from waste products, is likely to deliver promising growth. Furthermore, innovation in hydrogen carbon technologies could change the energy landscape and bring a positive change in the energy landscape of ASEAN.

Figure 9.2 portrays how Southeast Asia has been shaping several aspects of the global economic and energy outlook. Whilst the region remains highest in the world in terms of electricity demand at an average of 6% per year, a number of power systems in the region need major financial support. The use of overall energy demand cannot be undermined either, as the overall energy demand has grown by more than 80% with a doubling of fossil fuel use. This reflects the region's development and industrial growth, but also the negative consequences in terms of public health and environment as a result of air pollution and CO_2 emissions, respectively. As can be observed in the figure, the renewable energy capacity in Southeast Asia is significant enough and is continuously growing. Nevertheless, only 15% of the region's energy demand is met at present, which provides a huge opportunity for the future. Especially for the small economies in the region, such as Myanmar, Cambodia, Viet Nam, and the Lao PDR, the falling costs of solar photovoltaics and wind could be encouraging news for supporting their deployment.

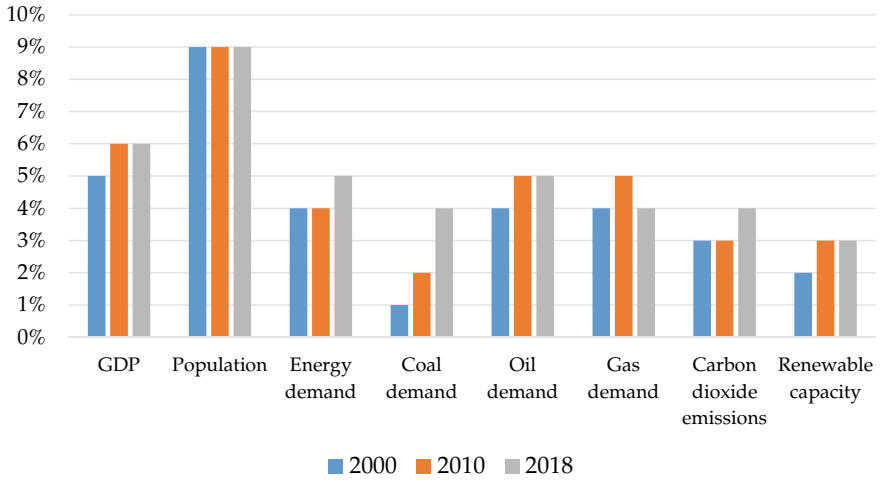

Fig. 9.2 Global economic and energy indicators (growth rates) in ASEAN, 2000–2018. GDP = gross domestic product. *Source* Adapted from IEA (2019a)

9.3 Green Innovation and Alternative Energy Options in ASEAN

Meeting the energy SDGs in ASEAN requires deploying multiple technologies and policy approaches in the energy sector. As there are no silver bullets, international experiences of energy transitions can offer valuable guidance and insights in the development and deployment of green energy technologies in ASEAN considering that fossil fuels have dominated the planet for centuries and will continue to do so. Whilst the replacement of carbon is urgent, innovative solutions should be adopted considering the environmental, technological, and economical aspects. Policymakers need to have a practical orientation towards the frameworks that are being developed internationally for the deployment of green technologies so that the energy transition becomes smooth. A report by IRENA showed that Southeast Asia has the highest share of jobs in renewable energy (83%), but it is lowest in terms of energy efficiency jobs (only 7%) (IRENA 2020a). Renewable energy technology varies significantly across the member states in ASEAN, although there has been some significant progress made in renewable energy development.

9.3.1 Nuclear Energy

Nuclear power systems are comparatively clean and an abundant source of energy with the potential to contribute to the hydrogen economy. Many countries in Southeast Asia have also expressed increasing interest in nuclear energy given its economic

benefits as well as its low carbon emissions for electricity supply (Nian and Chou 2014). In addition to renewables, the technological advancement of nuclear reactors is considered to have the capacity to transform the clean energy sector in Southeast Asia (Nian and Hari 2017). The substantial possibility for the cost-effective, efficient, and large-scale production of hydrogen utilising heat derived from nuclear power station already exists. For example, the US Department of Energy introduced the Advanced High-Temperature Reactor technology built for hydrogen production with high-temperature water electrolysis or thermochemical cycles (Zink 2003). Several studies on the thermochemical cycle have delivered thermal-to-hydrogen energy efficiencies, such as the adiabatic UT-3 cycle with 50% and sulphur-iodine cycle of 52% (Brown et al. 2003). Hence, economically sound and technologically superior hydrogen production capacities could be sourced from nuclear energy. The nuclear energy sector has also gained favour from international organisations like the Intergovernmental Panel on Climate Change as an important energy option for attaining 'zero emissions'. However, cases like the Fukushima nuclear incident in Japan have changed the political environment, and commitments to mitigating greenhouse gases have been revised. Although Japan committed to a 25% reduction in emissions from the 1990 levels by 2020, it only decreased them by 3.8% from 2005 levels, translating to a 3.1% increase in greenhouse gases from the 1990 levels (Thornhill and Roston 2020). The nuclear reactors in Japan also restarted their operations in 2015 despite a lack of public acceptance.

About an 80% increase in global nuclear power production is required by 2040 to achieve the sustainability target, where 85% of the global electricity needs to come from clean sources by 2040 compared with the existing 36%. The use of nuclear power has reduced CO_2 emissions by over 60 gigatons, which is equivalent to 2 years' worth of global energy-related emissions (IEA 2019a). Hence, it would be much harder to achieve a sustainable energy system without proper nuclear investment. Furthermore, nuclear plants also help to keep the power grids stable by limiting the seasonal fluctuation impact from other renewables and reduce dependence on imported fuels, which has been prevalent in major ASEAN countries. However, public acceptance and trust needs to be garnered by informing the public about the importance of the energy source as a viable energy technology to address societal needs.

9.3.2 Carbon Capture and Storage

Achieving long-term economic growth in ASEAN will involve the continued use of fossil fuels. Increasing demand for coal is expected to cause around a 66% rise in emissions by 2040 (IEA 2019b). How can the ASEAN region continue to use fossil fuels to accelerate economic growth without hurting the environment? Carbon capture and storage (CCS) offers a viable pathway to use cheaper energy sources, such as fossil fuels, whilst minimising their environmental impacts as the technology can prevent around 90% of CO_2 from entering the atmosphere by capturing the emissions

produced from fossil-based electricity generation and use. CCS technology is also an enabler to produce clean hydrogen from fossil fuels as the emitted carbon gets captured and is geologically stored. Almost all of the world's hydrogen is sourced from gas and coal, and producing clean hydrogen using CCS technology can be more cost-effective than producing clean hydrogen from renewables using electrolyses. If combined with renewable biomass, CCS allows CO_2 to be taken out of the atmosphere and is carbon negative.

Southeast Asia provides good opportunities for harnessing CCS technology as the region has plentiful geological storage resources. Countries like Indonesia, Viet Nam, the Philippines, and Thailand have 54 gigatons of storage capacity (Zhang 2020), reflecting the sufficient capacity to conceal CO_2. However, countries in the ASEAN region are developing CCS at different speeds. For instance, CCS technologies have gained much attention in Singapore across both the public and private sectors since 2017. Indonesia is also considering the development of large gas projects with high CO_2 concentrations even though there is a need to further codify the CCS legal framework. Malaysia, on the other hand, has been focusing on developing CCS in the power and oil/gas sectors by undertaking capacity development and storage assessments alongside running legal and regulatory workshops. The Asian Development Bank (ADB) has also been promoting carbon capture, utilisation, and storage in Asia since 2009 (ADB 2019). In a report on carbon capture and storage in Southeast Asia, economic analysis by ADB showed that natural gas processing and power plants are the best capture source as they are the lowest-cost option for CCS (ADB 2013). However, the development and deployment of CCS in the ASEAN region need to overcome significant challenges, such as generating investment and attracting climate financing and regional and international collaboration as well as establishing regulatory frameworks for CO_2 storage. Effective stakeholder engagement, especially through a smooth public dialogue, could enhance CCS development, which could increase the commercial viability.

9.3.3 Hydrogen Energy

Hydrogen is the most abundant chemical element available in the atmosphere and can be a viable source to electrify homes and for transport and industry. Hydrogen is being pursued as a potential form of clean energy given its wide use in areas such as ammonia production, petrochemical and oil refining industries, and many others. Currently, around 95% of hydrogen is produced from coal and gas, also called 'grey hydrogen', and a small portion is produced by CCS, called 'blue hydrogen'. Less than 5% of the total hydrogen production is produced from renewables, also known as 'green hydrogen' (Phoumin 2020). Green hydrogen obtained through the electrolysis of water could be a non-polluting alternative for energy. It could be adopted in sectors such as transport, power generation, building construction, and energy storage as it can make a remarkable contribution to clean energy transitions. Hydrogen has the characteristics of being light, storable, and energy-dense, and it has

no direct emissions of greenhouse gases, making it an important part of a clean and secure energy future. It has been found out that if all the current hydrogen production is to be transformed from green sources, electricity demand would reach 3600 TW h, surpassing the total annual electricity generation of the whole of the European Union (Evwind 2020).

Hydrogen fuel has the huge potential to combat climate change by facilitating the transition to low-carbon energy sources despite its low share in global energy consumption. The increase in scope for renewable energy and the continuous decrease in costs will strengthen innovative green technologies, such as storage facilities developed from hydrogen. Furthermore, research has shown that blending hydrogen with natural gas could provide a smooth transition from the current hydrocarbon-based economy to a hydrogen carbon economy (Muradov and Veziroğlu 2005). In a long-term transition towards a clean and sustainable energy future, hydrogen provides a flexible option and a more distributed energy system in the energy system which ensures a clean and sustainable hydrogen future (Barreto et al. 2003). For many countries in ASEAN with infrastructure and high energy demand, the system brought by hydrogen economy could provide an easy transition towards a renewables-based future.

The cost of hydrogen will also decline by over 50% by 2040 if adopted across all sectors making it as competitive as the price of gasoline (Bermudez and Hasegawa 2020). The current cost of supplying renewable is about five times higher than gas, but the cost will come down with investment in hydrogen supply chains. As the world is shifting towards a green economy, green hydrogen will serve as a catalyst to address the integration challenges facing wind and solar. By 2023, many hydrogen projects in Organisation for Economic Co-operation and Development (OECD) countries are expected to be launched and include major pipelines for distribution to end users and electrolysers (IEA 2010). Island countries, especially in the ASEAN region, will benefit substantially as hydrogen will accelerate carbon capture and storage technologies, which are a form of clean energy carrier.

The ASEAN region has not yet included hydrogen in its policy agenda in many countries as an alternative fuel. Nevertheless, policy measures on emerging and alternative technologies, such as hydrogen and energy storage, are likely to be addressed by the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase 2, which is under preparation for endorsement at the ASEAN Ministers on Energy Meeting. The OECD's action plan to increase the share of hydrogen in the energy mix could indeed be fulfilled with support from the APAEC. The energy leaders in ASEAN could also develop a clear strategy on ways to promote hydrogen use in the transportation and power sectors, not limited to the refining, fertiliser, and petrochemical industries. Countries such as Singapore, Malaysia, Thailand, Indonesia, and the Philippines could learn lessons from OECD countries, China, and countries in Europe to guide investment in research and development for hydrogen produced from both renewables and non-renewables.

Southeast Asian countries can learn from neighbouring economies like China, which has already accelerated hydrogen investment support to local industries, and around US $2 billion is being injected. Similarly, Japan has been promoting the

global adoption of hydrogen for vehicles, power plants, and other usages. Brunei Darussalam in the ASEAN region, too, has taken a lead in the supply chain of hydrogen as it has supplied liquefied hydrogen to Japan since last year. However, more energy is consumed by the liquefied hydrogen as it needs a temperature of − 253 °C in order to transform the cooled gas into a liquid form (Phoumin 2020).

Japan has been pioneering the renewable hydrogen economy, in which the production of hydrogen through the reformatting process of renewable electricity such as solar and nuclear is likely to bring a breakthrough in decarbonising emissions. By adopting a basic hydrogen strategy, Japan also became the first country in East Asia to ensure that production will reach cost parity with gasoline fuel and power generation in the long term. Society's willingness to pay is also a major factor despite the efforts by governments and private sectors to adopt hydrogen practices. The Republic of Korea (henceforth, Korea) is another country which set a target for hydrogen usage at 10% of total energy consumption by 2030 and 30% by 2040 in order to power selected cities and towns (Phoumin 2020). The Korean government has also made an announcement to create three hydrogen cities by 2022 where hydrogen will be used for major urban functions, such as cooling, electricity, heating, and transportation.

New research efforts are also underway with regards to investigating new methods for chemical-based liquid hydrogen carriers. Lee et al. (2013) introduced a methodology to quantitatively analyse the energy system by looking into the relationship between green car technology and greenhouse gas reductions in the regions of Korea. The research suggested that technology such as de-carbonisation should be enhanced in the production of hydrogen to replace existing fossil fuel sources in the foreseeable future.

9.4 Policy Recommendations

The development and deployment of green technologies are viable and necessary in Southeast Asia to address the critical issues of climate change and adaptation in the context of increasing energy demands. The development and deployment of green energy technologies will improve environmental quality and human welfare and overall help developing economies to achieve the SDGs. ASEAN as a regional multinational organisation has a pivotal role to play not only to fulfil its global commitments of the United Nations Climate Change Conference (COP 21) but also to facilitate cross-sectoral partnerships for sustainable economic development. This is important for achieving the ASEAN Community Vision 2025, too, which aims to sustain the momentum of regional integration (ASEAN 2015).

There seems to be lack of adequate experience and expertise in some ASEAN Member States, such as Viet Nam, Malaysia, and Indonesia, when it comes to the evaluation of the risk of renewable energy investments, and this has translated into a lack of financial support and public capital immobility for renewable energy investment. The cost of deploying the renewable energy sector has been continuously falling, which has increased prospects for its investment by shifting investors away from fossil

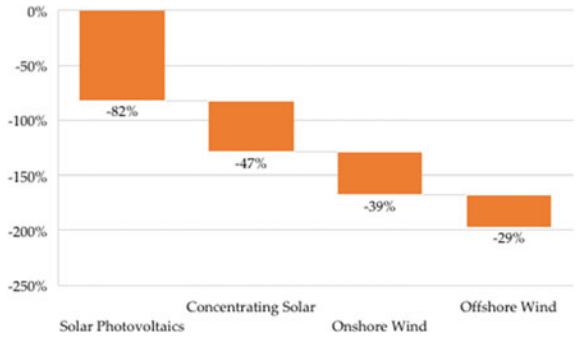

Fig. 9.3 Decline in renewable energy costs, 2010–2019. *Source* Adapted from IRENA (2020b)

fuels. Green technologies, such as hydropower, geothermal, and hydrogen carbon technologies, become substantially competitive. Figure 9.3 shows how renewable energy costs have declined in the past 10 years.

Some 56% of capacity additions for utility-scale renewable power achieved lower electricity costs in 2019 than the cheapest new coal plant. Annual potential costs could be cut by US $23 billion if the existing coal of 500 GW were to be replaced by solar photovoltaic and onshore wind (Creamer 2018). This global trend is an indication for policymakers in ASEAN to also emphasise renewable energy and exploit the huge benefits it can bring.

9.4.1 Transitioning Towards a Hydrogen-Carbon Economy

The development and deployment of certain green technologies like carbon capture, utilisation, and storage require an appropriate institutional and policy set-up as a prerequisite. There are traditional raw materials widely used in infrastructure in the construction, aerospace, and automotive sectors that can be replaced by carbon-based materials, such as carbon composites and manufactured graphite. These materials can absorb enormous amounts of carbon products, and several bridges in Canada, Japan, the United Kingdom, and the United States have already been constructed and developed using such mechanisms (IEA 2019d). One major advantage of carbon-composites in comparison to traditional materials, such as steel, is that they do not erode and are five times stronger than the mainstream heavy construction equipment (Brown et al. 2003).

By replacing concrete with carbon materials, there could be a significant decrease in CO_2 emissions, which would in turn discontinue the cement-manufacturing plants. There has been good progress made in terms of using carbon-based products as additives for substituting cements. Moving towards a hydrogen-carbon economy, ASEAN countries could emphasise the efficient interplay between energy, the environment, and the economy.

Hydrogen has major implications in various sectors, such as transport. Countries like India have welcomed foreign investment in fuel cell vehicles and hydrogen transportation infrastructure has already started in some pilot cities. Similarly, in Japan, the Tokyo Metropolitan Government increased the number of hydrogen buses to 100 in 2020 (Deloitte China 2019). As for the ASEAN region, the Sarawak Local Government in Malaysia is starting to operate hydrogen buses soon. Singapore also seems to be collaborating with companies from Japan to explore the development of hydrogen as a new clean fuel to decarbonise emissions.

It can be observed that support investment for hydrogen technologies has increased recently in many countries, with around 50 targets, mandates, and several policy incentives especially focused on transport. Hydrogen production mostly comes from natural gas as it comprises 70 million tons, or around three-quarters of the annual global share, or 6% of natural gas use. Coal also has an equal contribution as countries like China have a major stake, whilst only some production of hydrogen comes from oil and electricity (Bermudez and Hasegawa 2020).

There is not a 'one size fits all' when it comes to hydrogen policy. The production of both 'blue' and 'green' hydrogen includes several opportunities and risks for the countries following the respective approaches, even though there are options available to deploy hydrogen products from both fossil fuels and low-carbon sources, such as renewable electricity. On one hand, fossil fuel-based hydrogen may enable scale-up in the short term; however, there remain minimal environmental benefits and need for carbon capture or low-carbon hydrogen in the long term. On the other hand, the substantial application of hydrogen in big sectors, such as transport and chemicals, can bring efficiency in the energy system. This could bring numerous opportunities to exploit energy resources that are currently underutilised. ASEAN governments should align their ambitions and approaches for the use of hydrogen by considering international practices as well as the market scope where it can be widely applied.

Despite the wide spectrum of opportunities for hydrogen with its industry application, there still remains a considerable gap in realising its potential. As support for the clean energy transition is growing amongst policymakers in ASEAN, an action-oriented plan and vision are required both for the near future and to make hydrogen feasible for the longer term. An intelligible policy is essential to meet the long-term goals on hydrogen as there are various risks associated in investments which could be detrimental to many stakeholders given the complexity of hydrogen value chains. Standard regulations are required across the ASEAN countries to mitigate uncertainties and coordination problems. The IEA stated four key value chains as opportunities in the coming decade to accelerate the speed of hydrogen deployment focusing on different regions of the world. ASEAN is part of the fourth value chain as a part of Asia–Pacific along with the Middle East, North Africa, and Europe. It has been recommended to establish 'first shipping routes' in order to commence international hydrogen trade for the ultimate goal of setting-up a global low-carbon market (Bermudez and Hasegawa 2020) (Fig. 9.4).

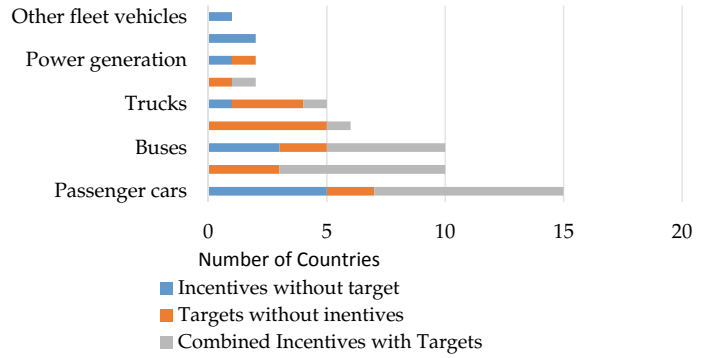

Fig. 9.4 Support policies for hydrogen development, 2018. *Source* Adapted from Bermudez and Hasegawa (2019)

9.4.2 Adapting Green Energy Financing for Green Deployment

Finance is the engine of development for renewable energy projects, whilst the financing of investments that provide environmental benefits through new financial instruments such as green bonds, green banks, carbon market instruments, fiscal policy, green central banking, fintech, and community-based green funds are necessary to achieve the SDGs (Sachs et al. 2019). ASEAN and Southeast Asian governments should adopt these targeted funding channels, also known as green energy financing, for the greater deployment of green technologies in the region. A geographical mismatch between resource endowments and demand centres provides an incentive for the regional integration of power grids in order to bridge the gap but requires investments in physical interconnectors. Therefore, the hindrances to renewable energy development do not only include technological capacity and access to finance (Shi 2016). It is difficult for policymakers to determine ways to make the transition towards a green economy from the existing coal generation in the absence of financing projects when, generally, financial institutions show more interest in fossil fuel projects rather than in green projects. The cross-sector policy framework can enable the integrative financing and development of renewable energy, fostering energy efficiency and replacing fossil fuels.

The Southeast Asia region has played a significant role under the agenda of 'one community for sustainable energy', with initiatives such as the ASEAN Power Grid interconnection, the trans-ASEAN natural gas pipeline, energy efficiency, renewables, and regional policy and planning (Shi and Malik 2013). All these initiatives require costly investments in capital expenditure and, hence, appropriate financing. The breakthroughs in technology in the renewable sector can provide a resilient model for a low-carbon energy system. The stronger regional framework on green project financing can serve as an extensive development plan and ensure a sustainable

energy transition roadmap moving forward. Both regional coordination and cooperation with a strong political will from all the countries in the region will be vital for integrated economic development.

The Belt and Road Initiative introduced by China also has some major implications for Southeast Asian economies, such as promoting infrastructure projects in the region that relate to water resources and transboundary rivers. However, several positive and negative impacts may pertain, creating political issues on the social and environmental fronts (Williams 2019). Therefore, similar concerns should be raised whilst deploying green technology projects, especially when international collaborations take place. A regional governing institution focused on energy and the use of market-based instruments can provide a platform for strengthening energy dialogues and facilitating the mobilisation of green technologies to boost the energy infrastructure. Furthermore, the role of the private sector is also equally important and will not only ensure civic engagement but also support the leveraging of public funds. Policymakers in ASEAN have been increasingly trying to ensure reliable and affordable sustainable energy solutions. It is equally important to focus on efficiency whilst developing investment infrastructure for fuel and power supply.

Since 2000, hydropower output has quadrupled in Southeast Asia (IEA 2019a). The costs for solar PV have been falling over time, but the share in total energy remains small. Market-based instruments along with a better framework are crucial to support their deployment. IEA data also show that there has been a shift towards low energy-intensive manufacturing and services given the projected rate of energy demand growth is lower than it was in the past 2 decades, holding a 12% share of the projected rise in global energy use to 2040.

Achieving a clean energy future in ASEAN also requires electrifying the transport sectors by deploying green technologies like electric vehicles. However, the congested roads and lack of proper infrastructure make it difficult to scale up and replace oil consumption. The rise of middle-income consumers and the increasing demand for household space cooling has increased the energy use of air conditioners in ASEAN by 7.5 times in the past 30 years as revealed in Fig. 9.5. Indonesia, which is the most populated country in ASEAN, only has about 10% of its households with air conditioning, and less than 20% of households in the whole ASEAN region have air conditioning. However, these numbers are likely to keep growing, and an additional 200 GW of capacity needs to be added by ASEAN countries by 2040, which will increase the demand by 30% (IEA 2018). At the same time, there are opportunities to increase efficiency policies, which could in turn enhance efforts to improve building and equipment efficiency. Policymakers must understand that hydrogen is one of the many alternatives available to fossil fuels. It is highly significant for energy storage, long-distance driving, and faster filling.

Figure 9.5 shows that higher levels of investment are required in order to meet Southeast Asia's energy needs and policy priorities. The fastest-growing use of electricity to 2040 is space cooling, which is driven by high cooling needs and rising incomes. Commitments for funding from both public and private entities are crucial. For example, public sources have played an important role in financing thermal power plant projects and large-scale renewables, such hydropower, whilst most wind and

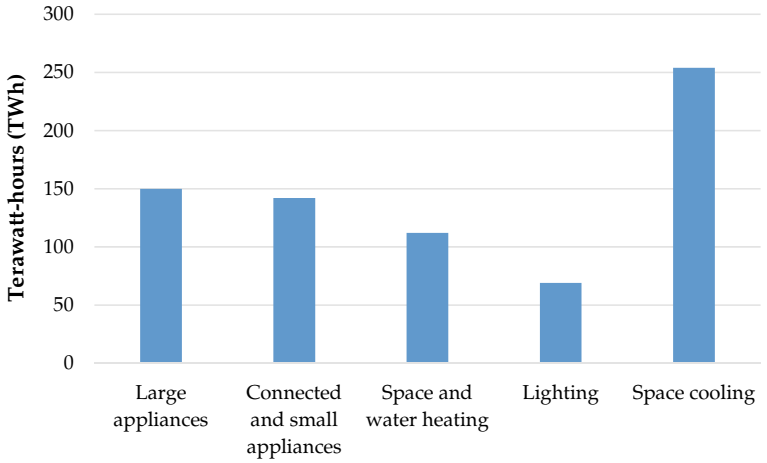

Fig. 9.5 Household electricity demand growth to 2040 in ASEAN by appliance source. *Source* Adapted from IEA (2019a)

solar PV projects have relied on private finance supported by policy incentives. Civic engagement and initiatives from investors and companies also play an equally vital role. Finding by the Korean government showed how both aid and other public finance are deployed.

Figure 9.6 indicates that more investments should be channelled towards sustainable energy, and the deployment of renewables should be scaled up, although notable progress has been made towards disincentivising the consumption of fossil fuels. Technologies to reduce emissions from the power sector, such as carbon capture,

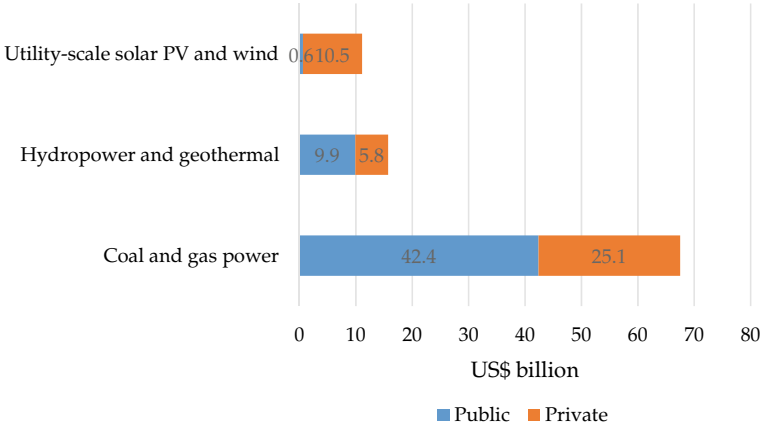

Fig. 9.6 Sources of finance for power generation investment in ASEAN, 2014–2018. PV = photovoltaic. *Source* Adapted from IEA (2019b)

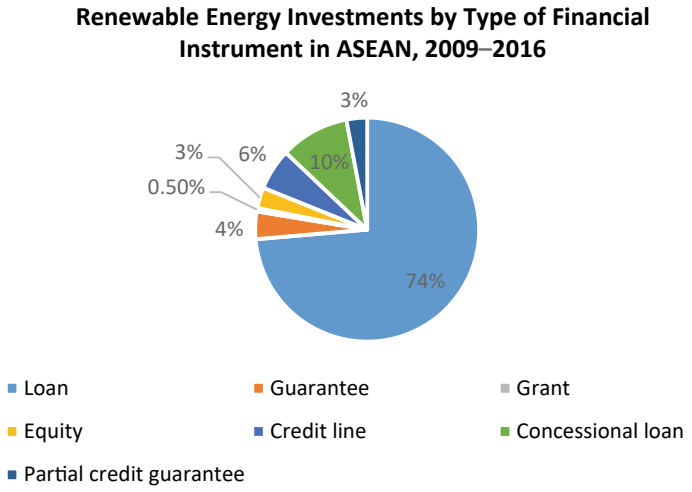

Fig. 9.7 Share of renewable energy investments in ASEAN by Type of Financial Instrument, 2009–2016. *Source* Adapted from IRENA (2018b)

utilisation, and storage, are essential, and efficiency must be achieved in sectors such as vast cooling and road transport. The gasification of biomass and solar-thermal technology create alternatives for producing hydrogen from renewable energy sources. Similarly, surplus wind electricity can also be used for hydrogen production as a means for storing energy (Fig. 9.7).

9.4.3 Managing Risks

Green projects are associated with risks pertaining to new technologies and their relatively lower rates of return. The rapid rise in energy demand in Southeast Asia is poised to bring several risks to the region from an energy financing perspective. The region has been forecast by the IEA to register a net deficit in energy trade of US $300 billion per year due to increasing imports of oil by 2040 (IEA 2019a). Government budgets will likely remain tightened as increases in subsidies for renewable energy can disincentivise market-based energy prices. Setting energy prices based on market signals by reducing fossil fuel consumption subsidies will entice more sustainable energy consumption and investments in ASEAN. Whilst the progress in eliminating fossil-fuel subsidies is notable, the process still remains incomplete. From the standpoint of energy security, the current dependence on imports of oil is 65% and is expected to rise to 80% in 2040, and this overdependence is a serious concern for the region (IEA 2019b). The high carbon-intensive power sector in Southeast Asia especially due to the rise in coal demand is expected to increase CO_2 emissions to almost 2.4 Gt in 2040, an increase by 42% from the current level (IEA 2019b). This

will negatively impact the environment, adding to already existing poor urban air quality and congested transportation infrastructure.

The governments of ASEAN need to address the energy security risks by taking into account the financial, environmental, and social viability of the projects. For this, various frameworks could be developed for the process of procurement and contracting mechanisms in renewable areas. Support for the financial system and the enhancement of sustainability utilities could also strengthen the market. The challenge of limited infrastructure, particularly in the Philippines and Indonesia, which are archipelagic in nature, has obstructed effective renewable energy deployment as the countries have fragmented electricity grids when it comes to transmission. Similarly, the lack of regulatory frameworks on green technology development and deployment brings major challenges. Countries like Brunei do not have a specific policy framework in place to regulate the development of renewable energy, although it has been reported to be in progress. There was major devastation in the Lao PDR due to a lack of coordination creating human risk, as the failure of an auxiliary dam raised heavy water that washed out 13 villages, affecting around 11,000 people (Gnanasagaran 2020). Despite the huge potential for hydropower, with an unrealized power potential of 22.3 GW, the high-risk nature of dam construction should not be underestimated.

Viet Nam is another major player in the hydropower sector, with an estimated capacity of 16.68 GW, but the lessons from the Lao PDR have allowed the country to focus on less intrusive sources of renewable energy. The revised master plan of Viet Nam has not focused on the development of large-scale hydropower as a renewable source of energy but promotes increasing capacity to 21.6 GW in 2020 and approximately 27.8 GW by 2030 with small and multipurpose projects (Greening et al. 2020). Viet Nam has a heavy reliance on coal-fired power as in 2020 alone the country's capacity stood at 49.3%. Despite efforts by the government's revised master plan to reduce reliance on coal, coal's share is expected to reach 53.2% by 2030 as the demand for development projects in the country demands more energy (Vietnam Electricity News 2016). Given the cheaper costs associated with renewables and wind and solar, sources from coal could be shifted and current imports of coal of around 30 million tons could be reduced (Vu and Gloystein 2019).

Proper coordination amongst government agencies and the private sector is crucial for prioritising renewable energy policies for implementation. Awareness amongst the public about the benefits of using green technologies can boost energy efficiency as well as environmental conservation. Multilateral power trading agreements will be crucial along with the expansion of cross-border transmission, which can lower the building and operating costs of ASEAN power systems. The Lao PDR exports 67% of its electricity generated from hydropower, which is almost 30% of all its total exports, with the main buyers being ASEAN countries such as Thailand, Viet Nam, and Cambodia (Gnanasagaran 2020). Regional integration could facilitate the growing demand for energy by deploying green technologies, such as wind and solar PV, and most importantly, the application of hydrogen carbon-based instruments.

9.5 Conclusions

The purpose of this study was to formulate the policy lessons and frameworks in ASEAN economies for facilitating the development and deployment of green technologies and alternative energy options. In doing so, the study reviewed the literature around green energy deployment in the context of green growth and energy transition and discussed the current status of renewable energy development in ASEAN. Alternative energy options such as nuclear and hydrogen energy prospects were discussed, with the study proposing hydrogen fuel as a way forward in meeting the energy and environmental objectives in the ASEAN. The nuclear prospects in ASEAN are complicated by political factors, and public acceptance of nuclear energy needs to be boosted. Likewise, carbon capture, utilisation, and storage will be a vital technology in ASEAN to reduce emissions from the power sector and from industry whilst allowing the use of fossil fuels to achieve economic growth. The study proposes transitioning to a hydrogen-carbon economy, adapting green energy finance for development, and managing financial risks in promoting green energy development. The decreasing costs for renewable electricity, especially from solar PV and wind, seem to support the production of electrolytic hydrogen, making it a low-cost supply technology option for hydrogen. Similarly, increasing pressure from international agreements such as COP21 will demand countries to deploy alternative fuel pathways in their energy mix.

The IMF has forecast the global economy to grow negatively at 4.9% in 2020, and policymakers will need to come up with major economic stimulus packages to combat the COVID-19 crisis (IMF 2016). Investment in clean energy with technological solutions will not only be an ideal option from an environmental standpoint but will also fulfil the unemployment gap that is been created, especially in emerging regions like ASEAN. In addition, the falling costs of renewables can also provide policymakers with the perspective to revisit policy planning documents and create a long-term vision for the deployment of green technologies. It is a crucial time for batteries, hydrogen, and carbon capture as they have the potential to be deployed on a mass scale, which could help in achieving the global clean energy transition. According to a recent analysis done by the IEA, governments are believed to be driving 70% of global energy investments (Birol 2020). Proper government coordination and leadership to engage multiple stakeholders is important to achieve climate goals with the right deployment of green technologies.

Implementing policy for energy efficiency improvements in ASEAN through policy measures such as attracting foreign direct investment and reducing energy consumption in public goods provisions, such as streetlights, is desirable (Nepal 2020). Cross-sectoral partnerships and international power connectivity in the ASEAN region should be the way forward. The European Union provides a perfect example of this case whereby their partnership in renewable energy lowered the energy supply from coal by 3% (Louis 2020). This will not only enable the sustainable sourcing of energy but also increase the share of renewable energy. Future areas of research should investigate the policy frameworks needed to better support the wider

deployment of green technologies, such as carbon capture, utilisation, and storage in the region. The scope for energy efficiency improvements in the region within the context of the push towards greener technology development and deployment also needs to be thoroughly studied. The role of cross-sectoral partnerships between the governments, businesses, and non-governmental organisations in ASEAN to facilitate green financing and investments to help mitigate the threats of climate change also needs to be studied.

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