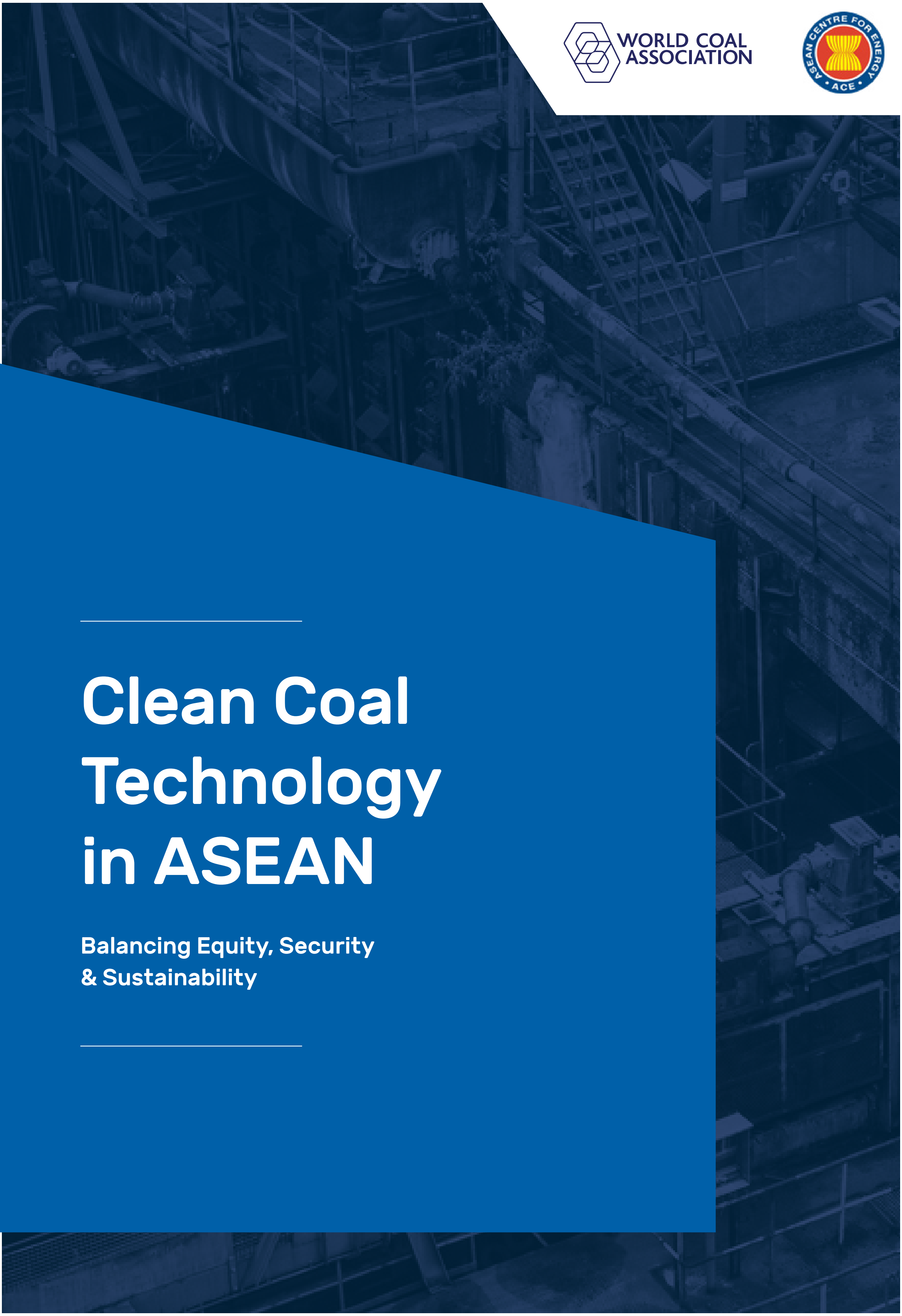

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Clean Coal Technology in ASEAN

Balancing Equity, Security & Sustainability

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Note: unless otherwise indicated, all data and figures are taken from analysis conducted for WCA.
Unless otherwise specified, all figures are in US$.

CONTENTS

Introduction 2
Coal and Energy Security 8
Coal and Equity 12
Sustainability 18
Call to Action 24
Abbreviations 28
References 29

Introduction

The Association of Southeast Asian Nations (ASEAN) region is seeing rapid changes in both demographic and economic profile and is expected to become the world's fourth largest single market by 2030.

With promising signs of digitalisation, this rapidly growing regional intergovernmental association, comprising Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam, is becoming a key manufacturing hub, as firms from around the world seek to diversify supply chains.

Home to nearly a tenth of the world's population, the total population of the region is expected to expand from around 650 million today to almost 770 million by 2040 and is projected to reach a combined GDP of USD 20 trillion (in constant 2011 PPP dollars) by 2040[1]. According to the 6th ASEAN Energy Outlook (AEO6), the region's electricity consumption is expected to grow by 4.1% annually – twice as fast as the rest of the world – doubling by 2040.[2]

The 6th ASEAN Energy Outlook also estimated that the Total Final Energy Consumption (TFEC) in ASEAN will increase by 145% by 2040, rising to 922 Mtoe from 375 Mtoe in 2017, with coal contributing up to 47%[3]. While energy demand per-capita in much of the ASEAN region is currently relatively low by international standards, there is scope for a vast increase.

All sources of energy face different challenges from both local and international perspectives. Delivering robust energy systems, that meet increasing demand and so ensure regional prosperity, presents critical challenges in three core dimensions; security, equity (affordability) and environmental sustainability, collectively known as the 'energy trilemma'.[4] (See Figure 1)

Energy security concerns for most developed economies involve import dependence or aging infrastructure, but developing nations face more acute challenges, including insufficient infrastructure capacity and high energy intensity.

Multiple energy insecurities intersect across the region, associated with ASEAN Member States (AMS) being both energy importing and exporting countries[5]. This makes AMS particularly vulnerable to energy security challenges, such as security of supply, socio-economic and environmental aspects[6].

Alongside these economic and security priorities, policy makers and generators must also consider environmental sustainability. Since the signing of the Paris Agreement, signatories have

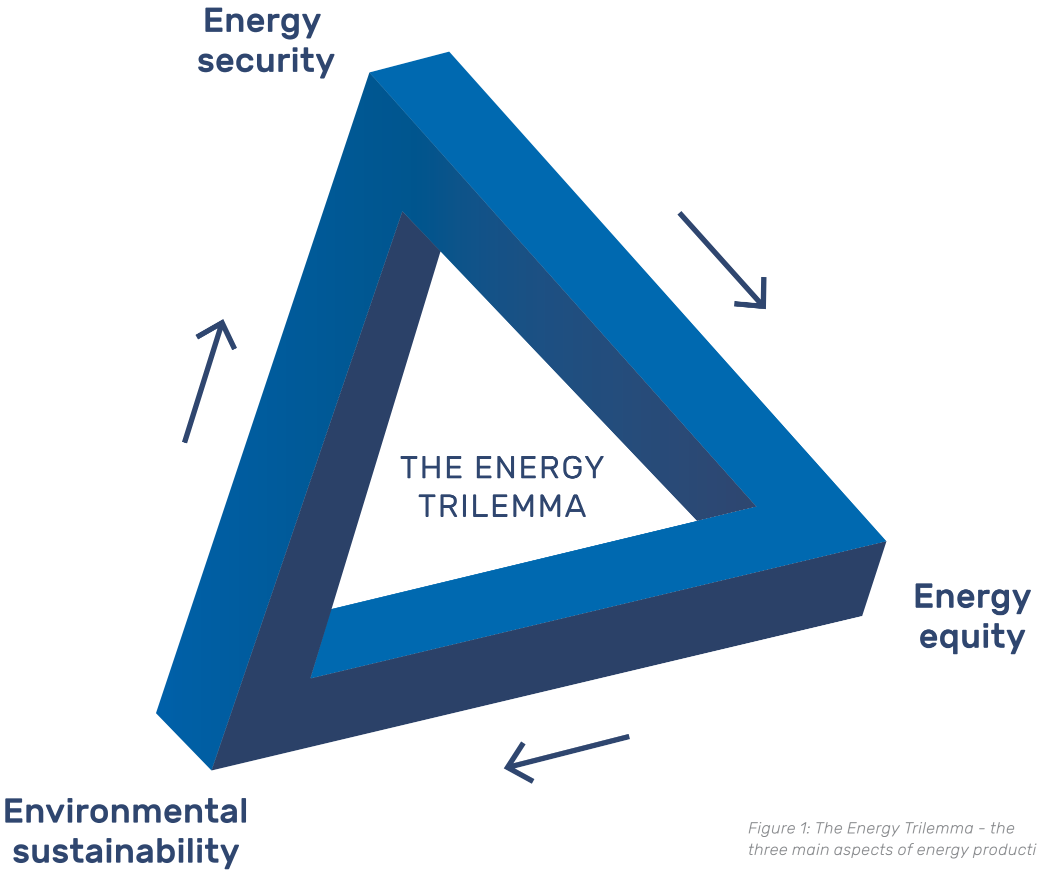


Figure 1: The Energy Trilemma - the three main aspects of energy production

committed to transitioning their energy sectors to lower carbon options, while maintaining security and ensuring affordability. The strength of the Paris Agreement lies within its foundations – the Nationally Determined Contributions (NDCs), based on the principle of common but differentiated responsibilities. These national climate pledges, made prior to COP21, gave countries confidence in the negotiation process.

More than 180 countries, including all the world's major economies, submitted NDCs – and the commitments made and the means to achieve them are as diverse as the economies of those nations. That means countries have chosen to focus on a range of options from forestry and automotive emission standards, scaling up to renewable energy, efficiency in energy consumption and deployment of low-emission fuels in their electricity mix.

Coal within ASEAN's 'Energy Trilemma'

Demand for energy presents challenges and opportunities for ASEAN, as the region's governments seek to deliver an energy mix that balances social, economic and environmental imperatives. Effective and sustainable energy policies integrate environmental priorities with the legitimate aims of energy security and economic development, including poverty alleviation. In recognition of the need to sustainably meet the region's energy challenges, ASEAN's Plan of Action for Energy Cooperation (APAEC), Phase II (2021 - 2025) outlines programme areas designed to *"accelerate energy transition and strengthen energy resilience towards a sustainable energy future"*. The updated blueprint will continue to focus on seven programme areas, with 'Coal and Clean Coal Technology' (CCT) identified as one of the key strategic priorities.

The regional availability of coal across ASEAN, its relatively low cost and proven capacity to provide dispatchable baseload power[7], presents solutions to both security and affordability challenges of the energy trilemma. Since the Paris Agreement, ASEAN economies have increasingly sought to manage sustainability priorities by deploying CCT technologies.

The equal prominence that CCT receives alongside renewable electricity and energy efficiency, is indicative of the current and forecast importance of coal for ASEAN. Optimising the role of CCT is proposed as a key factor in facilitating the transition towards sustainable and lower emission development in the region[8].

The report Clean Coal Technology (CCT) in the ASEAN – Balancing Equity, Security and Sustainability, provides a comprehensive analysis of the energy security and sustainable development opportunities that CCT promotes, as identified in APAEC 2016-2025. The report's insights provide the framework for the 'Call to Action' set out in the conclusion.

What are clean coal technologies

Globally, the environmental challenges associated with older, less efficient, subcritical technologies are well-documented. However, less well known are the efforts of the global coal value chain to eradicate and mitigate these externalities through constant innovation and adaptation.

In recent decades, the energy industry has amassed considerable experience of how to respond to environmental challenges. In the process it has developed effective means of decoupling pollution levels from economic activity, ranging from clean coal technologies (CCT), to renewable energy generation.

CCT can be employed to reduce emissions produced by burning fossil fuels and comprises three main methods:

1

Pollution control technology is used in coal-fired energy production to reduce emissions by between 90% and 99.9%[9]. It controls emissions such as oxides of sulphur and nitrogen (SOx and NOx) and also particulate and trace elements, such as mercury. Electrostatic precipitators, fabric filters, selective catalytic reduction systems, wet and dry scrubbers, solvents and activated carbon injection, remove pollutants before they are emitted into the atmosphere. This has largely been achieved and the issue now is the application of 'off-the-shelf' technology.

2

High-efficiency, low-emission (HELE) coal-generation achieves higher temperatures and pressures compared to older, less efficient, subcritical technologies. HELE technologies include supercritical (SC), ultra-supercritical (USC), advanced ultra-supercritical (AUSC) and integrated gasification combined cycle (IGCC) systems. HELE units emit 25–33% less carbon than the average for the existing global existing power fleet and up to 40% less than the oldest technologies. Although the initial capital costs of HELE units are higher, less coal is required per unit of electricity produced – providing significant operating cost savings over the life of the asset[10]. Major gains have already been achieved with this technology and further potential can be realised. Deploying HELE coal-fired powerplants is also a key first step along a pathway to near-zero emissions from coal with CCUS. While it is technically feasible that almost any coal unit can be retrofitted with CCUS, CO2 capture units can be better integrated with a modern HELE coal power plant.

3

Carbon capture and storage (CCS) captures the carbon dioxide (CO_2) produced by coal combustion, compresses it for transportation and then injects it deep into a rock formation at a carefully selected and safe site, where it is permanently stored. Alternatively, the CO_2 can be used in industrial applications, such as to increase pressures in oil reservoirs, in a process known as enhanced oil recovery (EOR). The development of near-zero emission technologies has commenced and is accelerating rapidly.

Constraints to CCT deployment

ASEAN is making solid progress in moving away from older, subcritical, technologies toward clean coal technology. These gains, however, are now at risk as some commercial banks have introduced policies that limit financing for coal and clean coal technologies. In some cases this has led to the increasing sense that the global climate agenda is being prioritised over the legitimate development aims of the AMS.

Restrictive financing regimes that exclude certain fuels, have ostensibly come about as part of the finance community's response to the Paris Agreement[11]. Yet, several AMS have explicitly identified a role for HELE technologies as part of their NDCs, submitted in the lead-up to the Paris Agreement, with several other AMS separately endorsing coal-fuelled power in their national energy strategies.

Moreover, while the decision to limit coal financing was initially welcomed as a boon by campaigners, it has increasingly become apparent that the move may have led to perverse incentives for the deployment of less efficient, subcritical, technologies, resulting in serious environmental and economic implications. Developments elsewhere support this view. Following the withdrawal of the European Bank for Reconstruction and Development, developers of the Stanari Power Plant in Bosnia-Herzegovina decided to compromise on the original design plans for HELE plant and use a subcritical plant. This resulted in a drop in the design efficiency from 43% to 34.1%.

In the recent past, international investors in coal power projects played an important role in ensuring that internationally recommended emission standards were adhered to and that developers were encouraged to deploy 'Best Available Technology'. Shareholder activism has led to a retreat by some financiers, creating a funding void that has been filled by alternative funding partners.

However, the alternative financiers, who have filled this gap, may not apply the same standards and environmental protections encouraged by commercial banks. Without robust and diverse funding support, developers may choose more polluting, lower efficiency, coal technologies to reduce capital expenditure.

Without international financial, technological, policy and other kinds of support to accelerate deployment of HELE technology, ASEAN's transition away from subcritical technologies will stall, weakening the recent gains in reducing energy intensity and carbon emissions. Third party analysis has indicated that, depending on certain modelling assumptions, phasing out of financial support for coal plants may restrict economic growth in the short- and medium-terms by 0.1–0. 5%[12].

An urgent re-think by financiers is required, to ensure support is made available for the full suite of technologies that countries have identified as important to both their climate mitigation strategies, through the NDCs, and necessary for their economic development.

National governments are entitled to assess which sources of energy are most suitable to their own needs and their own resource availability. Policy decisions about the energy sources to be utilised to support national development plans, should be made by national governments and not dictated by international financial institutions. It is the role of the finance community to support national governments in their decision-making and implementation processes through incentivising standards and best practices attached to funding, not coercion through withholding financing. Improved access to capital would provide incentives to generators to invest the higher initial capital outlay of HELE technology and contribute to further decoupling of emissions from economic growth. The benefits of improved emission rates would be significant.

Coal and Energy Security

According to the International Energy Agency (IEA), the COVID-19 pandemic represents the biggest shock to the world's energy system in more than 70 years.

Even before the crisis, minimising the risk of disruption to energy supply was a central consideration for both generators and policy makers - whether caused by accident, political intervention, terrorism or industrial disputes.

A source of power that is affordable and reliable without vulnerabilities to long-term or short-term disruptions is required to foster economic development in AMS. Building an affordable and reliable power system will require a diverse mix of energy sources, each meeting different power system requirements and national development objectives.

Coal has particular attributes that make a positive contribution to energy security as part of a balanced energy mix.

The global coal market is large and diverse, with many different producers and consumers from every continent. Coal supplies do not come from one specific area, so that consumers need not be dependent on the security of supplies and stability of only one region.

Several AMS, such as Indonesia, Thailand, Vietnam, and the Philippines, rely on domestic supplies of coal for their energy needs. Others import coal from a variety of countries: in 2019, for example, Malaysia imported coal from Indonesia, Australia and South Africa, as well as smaller amounts from several other countries.

Both the ASEAN Centre for Energy (ACE) and the IEA expect ASEAN to rely on coal-fired generation to ensure regional energy security. In 2005, coal contributed 27% of total electricity generation, rising to 41% in 2020.[13] Looking ahead, ACE projects that coal capacity will reach 295 GW by 2040, accounting for 49% of power generation capacity in the region. This represents a 226 GW increase (328%) over the installed coal capacity in ASEAN in 2018. (See Figure 2) The IEA, under its "Stated Policies Scenario" which reflects the impact of existing policy frameworks and today's announced policy intentions[14], predicts that ASEAN's installed coal capacity will reach 165 GW by 2040, providing over 27% of total capacity in the region. This represents a 91 GW increase (123%) over the installed coal capacity in 2018. (See Figure 3)

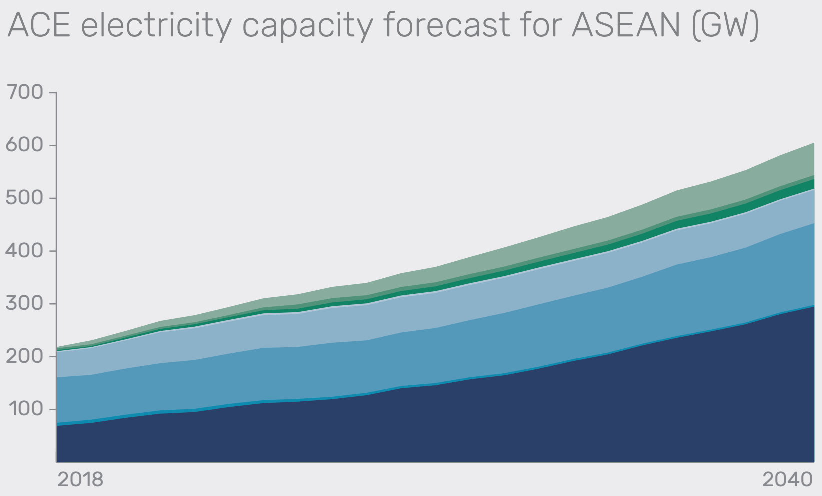


Figure 2: ACE Electricity Capacity Forecast for ASEAN

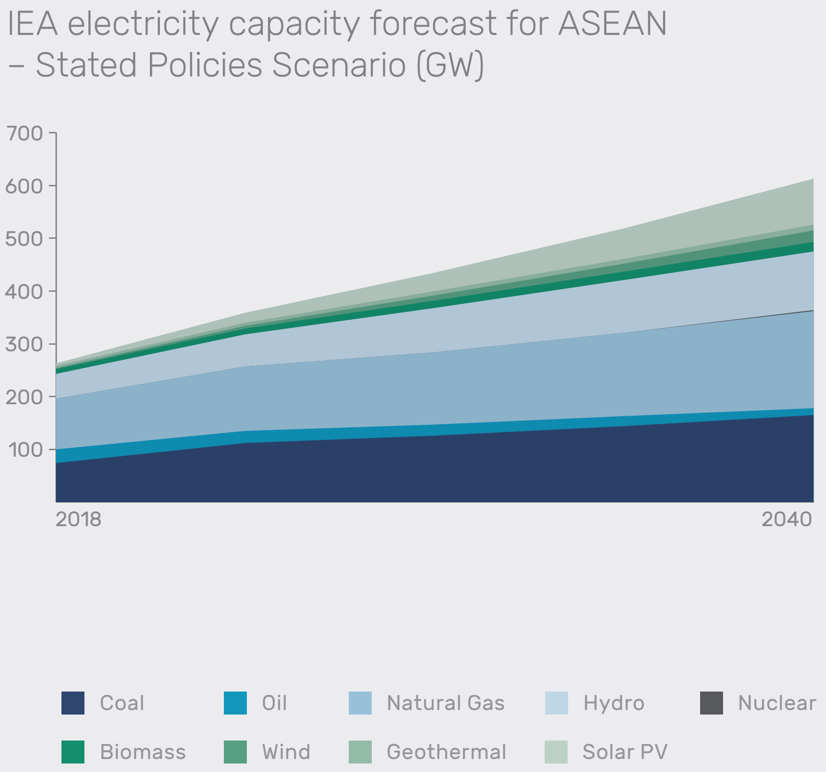


Figure 3: IEA Electricity Capacity Forecast for ASEAN – Stated Policies Scenario

There are several attributes that make coal-fuelled power particularly attractive for ASEAN:

BASELOAD AND DISPATCHABLE POWER

Delivering reliable electricity depends on stable uninterrupted generation, sourced from fossil and/ or nuclear sources. This is commonly referred to as baseload electricity. In contrast, Variable Renewable Energy (VRE) systems, such as wind and solar are limited by their inherent intermittent nature, as the wind and the sun are not constant. Nascent developments in large-scale energy storage appear to be promising and affordable, but available options are likely be limited into the medium-term. The rapidly urbanising and industrialising economies of ASEAN require the development of stable on-grid electricity, such as that delivered by coal, both now and into the future.

The World Energy Council (WEC) produces an annual 'World Energy Trilemma Index'. The report assesses countries' overall performance in balancing and managing the various trade-offs of the energy trilemma. The WEC emphasises system resilience through deployment of a diverse energy mix. It notes that while VRE systems may bring positive environmental benefit, deployment creates a new dependency, based on the weather. In 2015, supporting this, Vietnam's hydropower generation was significantly impacted by El Niño. At the same time, the phenomenon drove domestic power consumption to record levels, as citizens turned to air conditioning to combat the heat wave. At El Niño's height, in the first few months of 2015, power consumption rose by more than 10%, with the share of coal-fired output rising to more than a third of overall generation[15].

RESILIENCE

As highlighted by Vietnam's experience, ASEAN is vulnerable to extreme weather events. Flexibility is critical to a secure energy system. When facing disruptive events, generators must respond by rapidly increasing electricity supply, decreasing demand, or a combination of both.

An economy that has unreliable energy cannot perform to its full potential. Disruptive events, such as black and brown outs, can be incredibly expensive to industries and households. Modelling of an electricity outage event in Italy, which affected 55 million people and left some regions of the country without power for up to 16 hours, reveals that the event cost an estimated €1,182 million. The hardest hit sector was manufacturing, though domestic households bore around 24% of the total costs of the event[16]. With a growing manufacturing and heavy industry sector, it could be credibly argued that the costs for ASEAN could be even more significant.

Modern flexible coal plants can ramp power up and down as needed to meet demand. They also provide essential grid-stabilising services, such as inertia, frequency and voltage control. Such capabilities will be particularly important for meeting the rising electricity demands from the electrification of both transport and industry.

MODERN ENERGY ACCESS

There is no single accepted and internationally adopted definition of modern energy access. The current commonly used definition of "modern energy access," used by the IEA, 'entails a household having initial access to sufficient electricity to power a basic bundle of energy services – at a minimum, several lightbulbs, phone charging, a radio and potentially a fan or television – with the level of service capable of growing over time'.[17]

The ASEAN region has made the greatest strides in delivering universal electricity access across the Asia-Pacific, with only about 10% remaining without access. VRE has proven particularly adept at providing off-grid electricity for remote communities in the least developed economies. Yet, across ASEAN about 20% of the population remains without grid-quality electricity, which constrains economic development[18]. The challenge will be to bring electricity to this remaining group, as well as delivering modern energy services that satisfy the needs of the growing consumer class.

Demographic and economic shifts, coincident with the digital revolution, are expected to transform the consumer goods landscape across ASEAN and cause a sharp rise in energy requirements. The World Economic Forum (WEF) predicts that one in six ASEAN households will enter the world's consuming class, with as many as five million people moving into cities annually[19] with the region's working-age population increasing by 40 million by 2030. Contextually, with more than double the size of the population, China's working-age population is expected to reduce by 30 million in the same period.[20]

Furthermore, rising income levels in the region have led to changes in accessibility to energy. Choices of electrical discretionary goods for lighting, household appliances and residential air conditioning have also increased. Demand in this consumer space has grown by approximately 6% per year over the last two decades and is expected to continue.[21] Broadly distributed increases in wealth have produced an expansion in the number of ASEAN's emerging high- and upper middle-income households, which has nearly doubled from 30 million in 2019, to 57 million in 2030.[22]

Unsurprisingly, these increasingly wealthy households are progressively demanding more discretionary goods, which, in turn, will continue to drive energy demand.[23] Residential space-cooling demand has been particularly strong, with electrical consumption expected to quadruple from around 80 TWh in 2018, to 330 TWh by 2040.[24]

Rising incomes, a burgeoning middle class, industrialisation and urbanisation, require a stable, low-cost energy source to support the demands of this expanding 'consumer class'. Meeting these demands and addressing the energy trilemma will be a difficult task facing policy makers and delivery partners for decades to come.

There is a huge opportunity to ensure that the modern and clean coal technologies can play a role to 'ensure access to affordable, reliable, sustainable and modern energy for all' (Sustainable Goal 7). National and international policy frameworks and financing mechanisms must support the deployment of the cleanest and most efficient coal technology. If these frameworks are not in place, then less efficient technologies, with greater environmental consequences, are likely to prove more attractive on a cost basis compared to the more expensive, but also cleaner and more efficient, technologies.

Coal and Equity

With considerable progress in regulatory reform and economic integration, the ASEAN region is becoming an increasingly valuable destination for foreign direct investment (FDI), with foreign investors harnessing the robust manufacturing and industrial capabilities of the region.

In 2018, FDI in ASEAN reached $155 billion, surpassing other key growth regions, including India, by 3.7 times, and China by 1.2 times.[25]

Given the strength of its industries, including automotive, consumer goods, refined fuels and textiles, the region's flourishing manufacturing sector is predicted to continue to be a key driver of economic growth and foreign investment interest.[26] Predictably, strong growth in these sectors will lead to substantial increases in energy consumption, with industry projected to consume 70% more energy in 2040.[27]

The consensus among economists is that electricity prices are a critical driver of economic competitiveness. Lower electricity prices foster higher production, employment and value-added output to the broader economy. Therefore, regions with a significant number of energy-intensive activities suffer adversely from the rising energy costs associated with unreliable energy sources and lack of access to low-cost power generation.

All fuel sources will be needed to meet ASEAN energy demand. An effective and sustainable energy policy must integrate environmental imperatives with the legitimate aims of energy security and economic development, including poverty alleviation. This means that there must be a role to play for cleaner coal technologies including high efficiency low emission coal-fired power generation and ultimately carbon capture, use and storage.

The real cost of electricity in ASEAN: VALCOE – Value Adjusted Levelised Cost of Electricity

For many years, policy makers and generators used the levelised cost of electricity (LCOE) metric to understand the financial costs associated with generation technologies, presented in $/MWh (Figure 3A). The LCOE considers all the fixed and variable costs over a system's expected lifetime, including construction, financing, fuel, maintenance, taxes, insurance and incentives, which are then divided by the system's lifetime expected power output (kWh).

However, the cost of running a reliable electricity system goes beyond the cost elements captured by the LCOE particularly as intermittent generation increases and customer energy consumption behaviour changes. For example, the system operator in an electricity system with high solar generation may need to procure additional

> **VALCOE builds on the LCOE metric by including three additional considerations of value in power systems, including energy, capacity, and flexibility.**

Energy

This measures the value of electricity generated by the technology. Technologies that can generate electricity during periods of high electricity prices have lower VALCOEs.

Capacity

This measures the contribution of the technology during periods of high demand. Technologies that can reliably generate electricity during periods of high demand have lower VALCOEs.

Flexibility

This measures the ability of the technology to rapidly respond to sudden capacity needs in the system. Technologies that can respond to capacity needs quickly have lower VALCOEs.

generation capacity to ensure sufficient generation capacity to meet electricity demand during evening peaks as the sun sets. The system operator may also need to procure flexibility services such as black start, frequency regulation, and reactive power to maintain system reliability. These costs are not captured by the LCOE.

The IEA recently introduce the VALCOE (value-adjusted levelised cost of electricity) to reflect the full cost to the electricity system associated with the choice of technology deployment. This measure allows the system operator to evaluate different generation technologies on a like-to-like basis, taken into account the different system impacts associated with deploying each technology. The VALCOE builds on the LCOE metric by including three additional considerations of value in power systems, energy, capacity and flexibility.

The VALCOE measure is increasingly considered the preferred model for comparing different generation sources, as it represents a more comprehensive measure of competitiveness than LCOE alone and provides a crucially important means of comparing available technologies for longer-term national and regional energy development planning.

Cost components of LCOE and VALCOE ($/MWh)

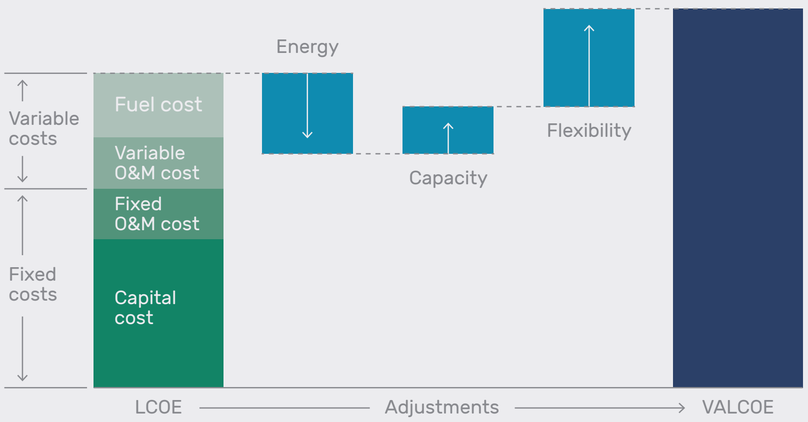


Figure 3: Cost Components of LCOE and VALCOE

For the purposes of comparing energy generation, a lower VALCOE represents a lower cost to the system:

- The VALCOE measure begins with an estimate of the LCOE of the technology before making adjustments for energy, capacity and flexibility.
- The adjustment for energy measures the value of electricity generated by the technology, based on the difference between the system's average electricity price and the average electricity price captured by each technology.
- The adjustment for capacity measures the contribution of the technology during periods of high demand and is represented by the de-rating factor. While the ability of thermal generation to meet peak demand is largely constant over time, that of renewable generation declines as renewable penetration increases.
- The adjustment for flexibility measures the ability of the technology to respond to electricity system requirements due to for example unanticipated changes in supply or demand. Flexibility value is the highest for peaking plant, such as diesel generators and Open Cycle Gas Turbines (OCGTs). To estimate the flexibility value for different technologies, assumptions based on a technology-specific flexibility multiplier are needed using each technology’s operating characteristics.

The IEA’s projected VALCOES indicate that while VRE costs will continue to decline, the value of their output also tends to decline relative to the system average. In India, according to the IEA’s World Energy Outlook (2018), a comparison of VALCOEs in India in 2040 suggests solar PV would be less competitive than coal, even though the LCOE of solar PV is projected to be one-quarter below that of coal and the lowest in the world on average.

The following provides an overview of our implementation of the IEA’s VALCOE methodology with respect to estimating the energy, capacity and flexibility values.

ENERGY

- The energy values for 2018 are estimated based on actual hourly wholesale electricity prices in Singapore and the Philippines
- The energy values for 2040 are estimated based on a simplified hourly dispatch model for a hypothetical pan-ASEAN electricity market
- The 2040 model produces hourly power prices for a representative day, based on a projected hourly electricity demand profile for a representative day in 2040 and a future generation capacity mix. Both are provided by the ACE
- The 2040 model also estimates load factors for combined cycle gas turbine ("CCGT") and open cycle gas turbine ("OCGT") power plants, which are used to estimate the LCOEs for the two technologies

CAPACITY

- The capacity price for each technology is estimated based on the difference between the expected wholesale and flexibility revenues and the combined levelised capital costs and fixed operating and maintenance costs for the technology
- The capacity credit for each technology is a factor from zero to one, representing the technology's ability to contribute to system adequacy during periods of peak demand
- The capacity price for each technology is estimated based on the difference between the expected wholesale and flexibility revenues and the combined levelised capital costs and fixed operating and maintenance costs for the technology
- The capacity value is capped at the estimated LCOE of OCGT in ASEAN

FLEXIBILITY

- The flexibility values for both 2018 and 2040 are estimated based on a technology-specific flexibility score and a basis flexibility value
- The flexibility score is a factor from zero to one, where one is the most flexible technology (i.e. OCGT). The score is based on market studies on the flexibility of each technology
- The base flexibility value is the maximum flexibility payment in a hypothetical ancillary services market
- It is capped at the capital cost of an OCGT
- This assumes that OCGT is the most flexible technology and thus the system operator will not pay more than the capital cost of OCGT for flexibility services
- It increases with the share of intermittent generation in the system, as greater flexibility services will be required to ensure a balanced electricity system

Using VALCOE to estimate the relative costs of ASEAN energy generation technologies

Figure 4 plots the VALCOE costs for various generation options. The cost adjustment for generation options requires an estimate of the energy revenues of different technologies and requires wholesale electricity prices.

Our analysis used the wholesale revenues for today, based on historical market data, and estimated wholesale revenues for 2030 and 2040, based on expected electricity demand and the projected electricity capacity mix in ASEAN in 2030 and 2040 from the ACE.

Current (2018) VALCOE costs for both renewable and thermal energy-generating technologies, suggest that hydroelectric power and solar PV are currently competitive against coal. In both the Singapore and Philippine markets, coal and hydro are among the lowest cost options.

Hydroelectric power generation is the most cost effective in Singapore, with the lowest cost (Figure 4), followed by subcritical coal and supercritical coal. Concentrated Solar Power (CSP) is the costliest technology in Singapore, with the highest VALCOE cost, followed by nuclear (Figure 4). A similar pattern of VALCOE costs is presented from the Philippines, though the position of hydroelectric and SubC Coal are reversed, with the latter being the least costly by 1$/MWh (Figure 4).

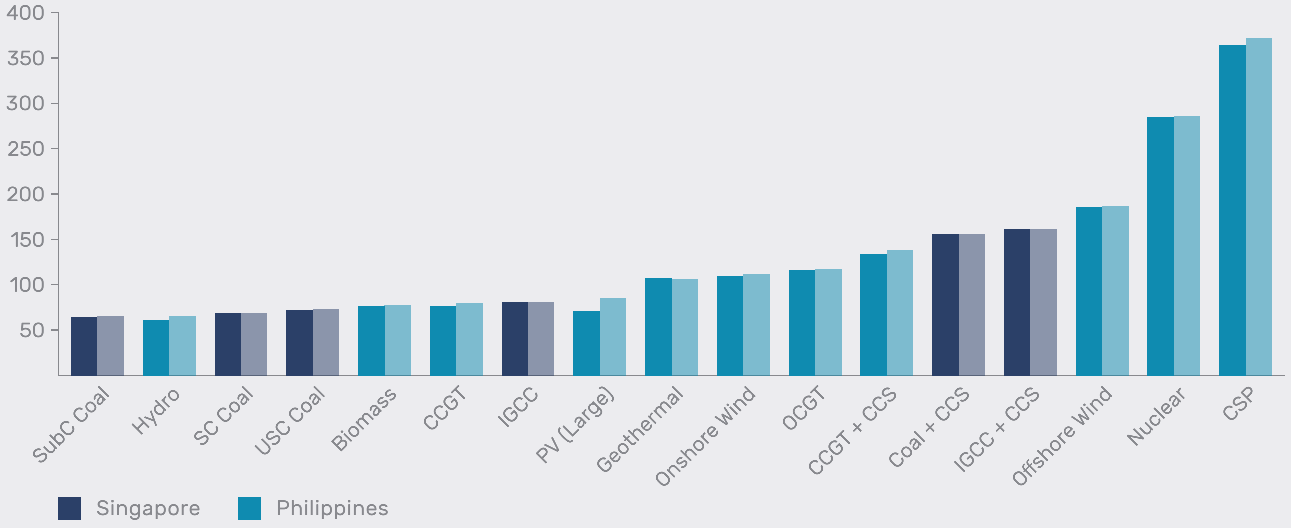
While hydropower energy may compete with coal on a cost basis, it has limited deployment potential beyond certain jurisdictions, therefore limiting its credibility as a baseload source of electricity.

However, more advanced coal technologies have a slightly higher VALCOE compared to subcritical coal, due to the initial higher capital costs. Removing this initial construction component, the operating costs are largely determined by fuel costs, hence cleaner, more efficient plants that burn less coal will have lower operating costs. Moreover, cleaner coal plants tend to have a lower fixed cost, due to higher levels of automation and less maintenance. Today, coal-fuelled power is the least costly way to expand thermal capacity in ASEAN from a total system cost perspective.

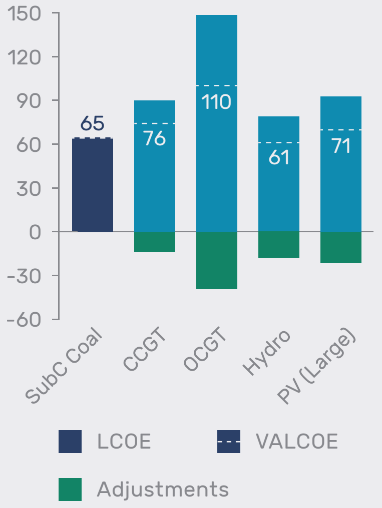
Looking ahead to 2040, coal-based technologies are largely unaffected by the value adjustments (Figures 5 and 6), with more advanced coal technologies (supercritical coal and ultrasupercritical coal) having a slightly higher VALCOE compared to subcritical coal, due to the higher initial capital costs. Conversely, the role of combined cycle power plant (CCGT) and hydro as load-following plants, with an ability to quickly provide generating capacity and flexibility, affords negative value adjustments. Most strikingly though, as shown in Figure 6, coal generation equipped with CCS remains a competitive baseload low-carbon generation option. Coal holds a moderate VALCOE advantage over natural gas equipped with CCS. The removal of subsidies, price volatility and international competition for gas may lead to further price competitiveness.

Despite their relative future competitiveness on a VALCOE basis, due to their intermittent nature, solar PV and onshore wind simply cannot provide the same level of security of power supply as coal. Simply put, these forms of renewable generation are unable to provide stable baseload power when the wind does not blow and the sun does not shine.

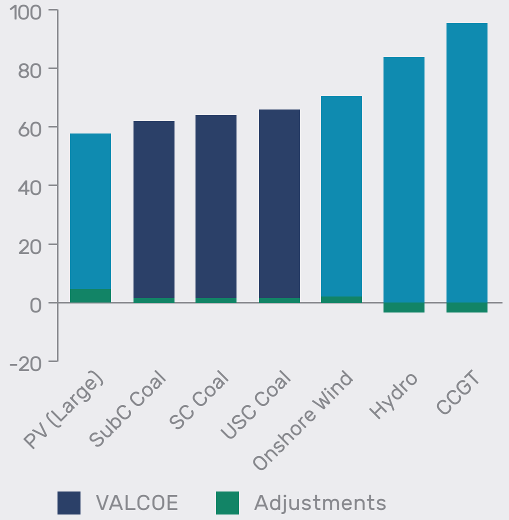
2018 ASEAN VALCOE in Singapore and Philipphines ($/MWh)



ASEAN VALCOE components in Singapore ($/MWh)



2040 VALCOE by component in ASEAN ($/MWh)



Above

Figure 4 (A&B): The 2018 VALCOE costs ($/MWh) for numerous energy-generating technologies in Singapore and Philippines.

Left

Figure 4 (C): A break-down of the 2018 VALCOE components for a sub-set of Singapore's energy generating technologies.

Right

Figure 5: Projected 2040 VALCOE ($/MWh) for renewable and thermal energy-generating technologies in ASEAN, by component. Numbers above bars indicate final VALCOE cost.

2040 VALCOE in ASEAN ($/MWh)

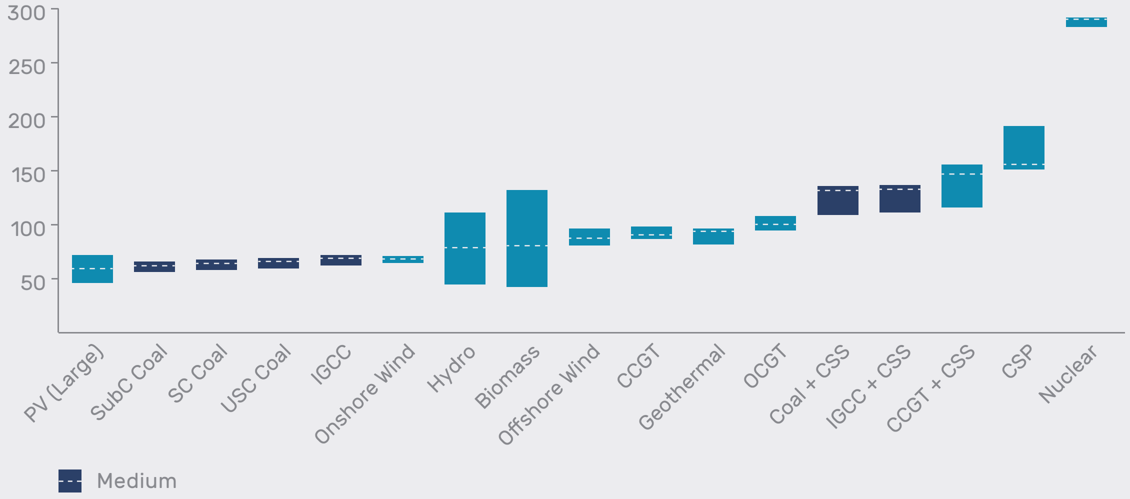


Figure 6: Projected VALCOE costs for renewable and thermal energy generation technologies under low, medium, and high price assumptions.

Sustainability

Most human activities have environmental consequences and all forms of energy raise their own environmental issues. SDG 7— to “ensure access to affordable, reliable, sustainable and modern energy for all”—is a challenge that will require AMS to meet decisions on resources available over the short-, medium-, and long-term.

At the same time, AMS must produce and utilise all these energy sources in a way that minimises adverse impacts on the environment and maximises economic and social benefits. AMS can chart a course to a sustainable energy future, provided support is available to make the necessary investments and policy decisions.

This is a significant challenge – particularly because of surging energy demand, concerns about energy security and the environmental impacts of energy production and consumption.

The Role of CCT in the ASEAN Energy Transition

Since the Paris Agreement, campaigners in some quarters have argued that coal has no place in the future energy mix. However, the energy transition does not necessarily mean the complete move away from coal. HELE coal power plants emit much less CO_2 than subcritical power plants, by increasing the amount of energy that can be extracted from a single unit of coal. Highly efficient modern supercritical and ultra-supercritical coal plants emit almost 40% less CO_2 than subcritical plants.

AMS are transitioning away from older, less efficient, subcritical stations, towards HELE (See Figure 8). In 2014, subcritical technologies represented more than 90% of installed capacity and 70% of coal capacity additions for the year. According to the IEA Clean Coal Centre, around 43% of coal-fired plants planned or under construction after 2015 in Indonesia, were either supercritical or ultra-supercritical, a significant increase from 12% in 2010-2014.[28]

There are clear environmental benefits in deploying super-critical or ultra-supercritical coal energy technologies over traditional systems. While the environmental benefits from deploying HELE technologies are well understood, restrictive financing regimes may lead to developers accepting lower efficiency and poorer emission rates, due to the initial higher construction and material cost differences between subcritical and HELE technologies. (See Figure 7)

Technology differences – New investments in 2018

Technology	**Capital Cost (2018$ Billion/GW)****	**HHV Efficiency**	**Emission Rate (T/MWh)**
Subcritical	1.33	31%	1.04
Supercritical	1.59	38%	0.90
Ultrasupercritical	1.85	41%	0.83

Figure 7: Technology differences – New investments in 2018

ASEAN projected future capacity of coal (GW)

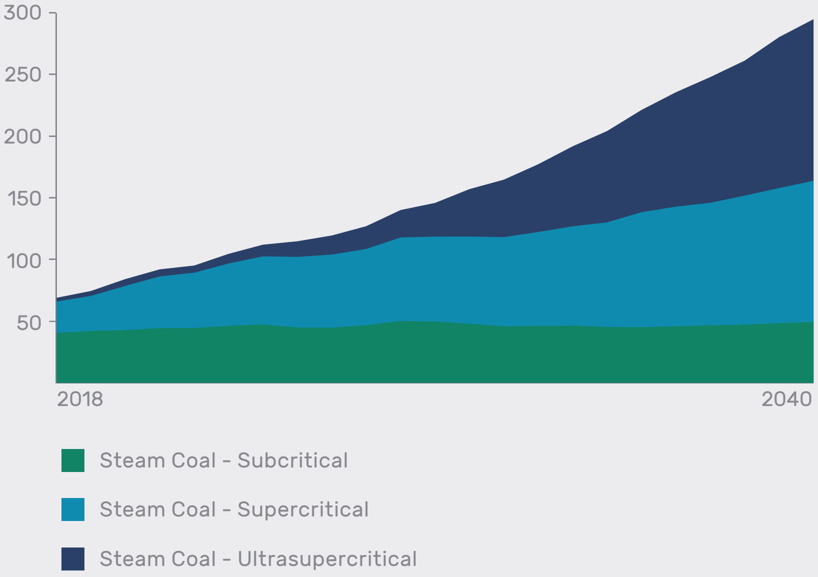
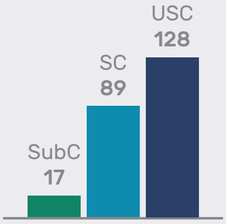
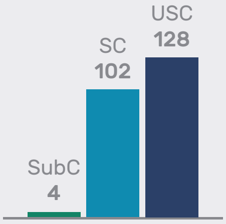
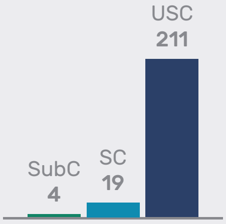


Figure 8: ASEAN projected future capacity of coal

Investment in HELE technologies

	Mix per current pipeline	Shift to Supercritical	Shift to Ultrasupercritical
Scenario description	Total installed coal capacity by 2040 based on ACE data projections	Shift capacity from Subcritical to Supercritical except plants to be constructed before 2022	Shift all capacity from Supercritical in the previous scenario to Ultrasupercritical except plants to be constructed before 2022
Capacity Mix Additions[1]			
NPV Capital Costs[2] **($ Billion)** *(from 2018 through 2040)*	$139.1 Billion	$140.4 Billion	$147.8 Billion
CO_2 Emissions (tCO_2) *(Cumulative from 2018 through 2040, undiscounted)*	18.3 Billion	18.2 Billion	17.8 Billion

$8.7 billion of additional financing required to shift to Ultrasupercritical

Additional funding can reduce carbon emissions by 0.5 billion tons

Figure 9: Investment in HELE technologies can reduce emissions by up to 0.5 billion tons of CO^2 in ASEAN

Notes: *1) Total GW of coal capacity additions based on ACE base scenario projections 2) Costs include only capital costs, including IDC*

Future ASEAN energy requirements

Scenario	CO_2 Emissions (tCO_2) over 30 years	Subcritical Plant Closure[1]	Number of new wind turbines[2]	Cars Removed from the road[3]
Mix per development pipeline	45.2 Billion			
Shift to Supercritical	44.9 Billion	4	1,600	19 million
Shift to Ultrasupercritical	43.4 Billion	22	9,400	111 million

Figure 10: The technology choice to meet ASEAN future energy requirements has significant implications on CO^2

Notes: *1) A subcritical plant with 500 MW capacity, 57% load factor, 30 years asset life, and an emission factor of 1.04 tCO2/MWh 2) An onshore wind turbine with 5 MW capacity, 27% load factor, asset life of 20 years 3) An average car with 12,700 annual kilometres, an emission factor of 123.4 gCO2/km and an asset life of 13.5 years*

Investment in HELE technologies can reduce emissions by up to 0.5 billion tons of CO_2 in the ASEAN

> **“Investing in the most efficient coal plants provides the same level of security of supply with a lower level of emissions.**

Modelling suggests around 234 GW of new coal capacity to be required in ASEAN through 2040 to meet growing energy demand. With a modest increase to this planned capital expenditure, generators could ensure all planned coal plants commit to using ultra-supercritical technology. Financial partners have the opportunity to influence the type of technology that developers select, resulting in significantly lower emissions, for a global benefit.

Our analysis indicates an additional investment of 6.2% (USD 8.7 billion) would be required to incentivise all coal combustion capacity to be built using ultra-supercritical technology. With such investment, it is projected that ultra-supercritical technology could reduce CO_2 emissions by 500 million tonnes cumulatively by 2040 (approximately 25 million tonnes of CO_2 per year), compared to a ‘business as usual’ scenario (See Figures 9 and 10).

ACE modelling assumes a growth of sub critical and super critical coal capacity of around 98 GW in ASEAN between 2018 and 2040, to achieve the security supply targets as set by the relevant national authorities.

ASEAN Investment options

Investment Option	Capacity Credit	Capacity Mix for 98 GW (%)		Required Capacity (GW)		Total CAPEX[1] ($Billion)	% Increase in CAPEX to Baseline	Annual Emission[2] (mtCO$_2$)
		Coal	Other	Coal	Other			
Subcritical Coal and Supercritical Coal as ACE projected	0.90	100	0	106	0	131.5	Baseline	530.5
Upgrade to Ultrasupercritical Coal	0.90	100	0	106	0	157.7	20	470.7
Subcritical Coal, Supercritical Coal and Onshore Wind	NA	92	8	95	24	157.7	20	474.6
Subcritical Coal, Supercritical Coal and Offshore Wind	NA	95	5	99	14	157.7	20	494.7
Onshore Wind Only	0.32	0	100	0	299	488.9	272	0
Offshore Wind Only	0.35	0	100	0	273	677.1	415	0

The capacity credit is 0.90 for coal and 0.35 for offshore wind. Replacing 106 GW of coal therefore requires 106 x (0.90/0.35) = 273 GW of offshore wind to maintain the same level of security of supply

$26 billion of additional funding required

For the same additional financing, investment in Ultrasupercritical coal technology results in the least amount of emissions

Figure 11: For the same CAPEX, upgrading the pipeline of coal power plant to Ultra SuperCritical provides the same level of security of supply with a lower level of emissions

Notes: *1) Based on average of 2018 and 2040 CAPEX assumptions 2) Based on assumed improving coal efficiencies between 2018 and 2040*

Figure 11 illustrates the up-front capital investment required for different capacity mix alternatives that are able to meet the same level of security of supply (Solar PV is not considered as it cannot generate electricity at night). The security of supply is defined as the amount of dependable capacity during time of system peaks, also known as the de-rated capacity or unforced capacity.

Analysis indicates the clear benefits of replacing the current ASEAN coal-powered pipeline with one that uses the most efficient HELE technologies available today.

The baseline assumption of coal capacity expansion requires a capital investment of USD 131.5 billion and will lead to 530.5MTCO$_2$. While this represents a low-cost pathway when only the cost of generation is considered, the imperative to reduce emissions requires consideration of further efficiency gains and alternative energy options:

- upgrading the existing pipeline of less efficient coal power plant to use Ultra Super-Critical technology would reduce annual emissions by 60 million tCO$_2$, from 531 million to 471 million tCO$_2$, would require a modest 20% increase in investment and ensure the same level of security of supply.

The analysis also considers alternative investment options, where the $26 billion investment is used either for building new onshore or offshore wind farms, while preserving the same level of security of supply. The security of supply is defined as the amount of dependable capacity during time of system peaks, also known as the de-rated capacity or unforced capacity:

- using the full sum for onshore wind would only displace 11 GW of less efficient coal capacity, as 1 MW of installed wind capacity only translates to 0.32 MW of de-rated or dependable capacity, requiring additional coal capacity to be available during time of system stress

- Similarly, using the full sum for offshore wind would only displace 7 GW of less efficient coal capacity, leading to an even higher level of emissions of 495 million tCO$_2$/year

Opportunities for further carbon reductions

ASEAN has made solid progress by advancing the deployment of HELE technologies. HELE technology also represents significant progress on the pathway towards near-zero emissions through CCUS.

There is renewed interest in CCUS globally, suggesting the potential for acceleration of investment, greater innovation and wider deployment.

In late 2020, the IEA reported that following years of diminishing investment, plans for more than 30 integrated CCUS facilities have been announced since 2017.[29]
These projects, if realised, will push CCUS further along the learning curve, promoting infrastructure development and further reducing the capital costs of future projects.

Given the planned power generation mix and the region's relatively young coal fleet, it is crucial that AMS are supported in their efforts to advance CCUS deployment.

To date there have been several nascent CCUS developments, demonstrating a growing acceptance among AMS that CCUS will become an integral part of decarbonisation. For example, Singapore recently published its *Long-Term Low-Emissions Development Strategy*, stating that it planned to draw on increased international collaboration to develop CCUS.[30] Similarly, Indonesia has taken credible steps to move forward on CCUS through the Gundih CCS pilot project, which is the first of its kind in ASEAN. The Indonesian oil/gas authority has also proposed a draft legal framework for CO$_2$-enhanced oil and gas recovery. Malaysia also maintains an interest, with high-level participation in capacity development, storage assessments and legal and regulatory workshops.[31]

At a regional level, the recently announced Asia CCUS Network, proposed by Japan and the Economic Research Institute for ASEAN and East Asia (ERIA), will provide excellent opportunities for knowledge exchange, experience sharing, conducting capacity building and, eventually, promoting joint efforts for development and deployment of CCUS.

Call to Action

ASEAN faces challenges in meeting energy demand and balancing the goals of energy security, socio-economic development and poverty alleviation, as well as environmental improvements.

Difficult decisions lie ahead. It will be essential for all available options to be considered and for demands to be carefully balanced. Meeting these challenges will require skilful long-term planning and implementation. Clearly there is no single solution to the global challenges we face. It is therefore important that we effectively mitigate climate change, while also creating sustainable energy systems.

Any response to climate change must recognise the existence of different starting points, perspectives, priorities, and solutions – and provide a long-term vision of the future.

Within this framework, CCT's contribution to ASEAN's energy systems will be vital. As highlighted by the preceding analysis, in simply meeting demand, the use of coal will be essential. When wider priorities are also considered, the role of coal and CCT becomes ever more significant.

Challenges remain with the use of coal, as they do with the use of all energy sources.

Policy support can address environmental concerns in a non-discriminatory manner – while recognising the benefits that a diverse and secure energy mix can bring.

Clear, long-term environmental policies provide certainty, allowing investments to be made in CCT that bring enhanced environmental performance. Progress has been made across ASEAN in recent years. AMS have worked to establish an appropriate and stable policy context to support generators investing in modern HELE coal plants.

> **“Clear, long-term environmental policies provide certainty, allowing investments to be made in CCT that bring enhanced environmental performance.**

Continued agnostic policy support to reduce investment uncertainty, through good governance, transparency and long-term planning, will be critical to facilitate continued investment in the energy sector to meet growing demand.

Policy makers in AMS may consider expanding incentive regimes to encourage continued emission reductions. This may include placing the cleaner and more efficient plants higher in the merit order, or using regulations to encourage more efficient plant builds.

International collaboration and strategic partnerships are also essential. AMS require support to deploy clean coal solutions as all sources of energy will be needed to support delivery of the 2030 Action Agenda for Sustainable Development. National governments are entitled to assess which sources of energy are most suitable to their own needs and their own resource availability.

Decisions on which energy sources and technologies should be used to further national development plans, should be made by national governments. It is the role of international partners, such as the finance sector, to support national governments in their decision-making and implementation processes.

BASED ON THE PRECEDING ANALYSIS, THE WCA AND THE ACE:

1. **Encourage the international community to recognise an inclusive policy of 'all fuels and all technologies' for energy generation in the move toward energy transition and energy resilience.**

- acknowledge the uniqueness of each ASEAN Member State's conditions, policies, circumstances and resources.

- note that there is no single solution to address the challenges of energy transition and sustainability, especially to mitigate climate change.

- encourage the need to assess different types of energy sources equally and expand the options to include all available resources and technology (using VALCOE).

2. **Encourage AMS to commit to rapidly scaling up advanced HELE technologies and establishing a pathway towards CCUS.**

- acknowledge the role of coal and the importance of CCUS in ASEAN to enable the region to facilitate energy transition, balance energy security with sustainable development goals and strengthen energy resilience.

- promote the need for policy support to accelerate the adoption of advanced technologies to assist in the utilisation of CCUS in Coal Fired Power Plants (CFPP).

- encourage AMS to explore the development and implementation of a CCUS roadmap in ASEAN.

3. Call on the international finance and investment community to ensure adequate and diverse financial support for clean coal projects and CCUS deployment in the ASEAN region.

- highlight the challenges of financing for CCT and CCUS and acknowledge the importance of CCT financing for energy transition in ASEAN, including in preventing the development of stranded coal-fired power plant assets.
- explore alternative and various financing platforms, mechanisms and policy support, to ensure adequate and diverse financing in the ASEAN region for CCT and CCUS.
- strengthen the role of the private sector in establishing sustainable clean coal and CCUS financing in the region.

4. The WCA and ACE will strengthen their partnerships and collaboration with Dialogue Partners, International Organisations and relevant stakeholders, through AFOC as the main platform to advance sustainability in coal use.

- encourage partnerships and collaborations with all stakeholders, including private sector and financial institutions, which are essential in facilitating the energy transition of ASEAN.
- conduct outreach initiatives in communicating the role of coal as a transition fuel towards a low carbon economy.

Abbreviations

ACE	ASEAN Centre for Energy
AEO6	6th ASEAN Energy Outlook
AMS	ASEAN Member States
APAEC	ASEAN’s Plan of Action for Energy Cooperation
ASEAN	Association of Southeast Asian Nations
AUSC	Advanced Ultra-Supercritical
CCT	Clean Coal Technology’
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CFPP	Coal Fired Power Plants
CO_2	Carbon Dioxide
CSP	Concentrated Solar Power
ERIA	Economic Research Institute for the ASEAN and East Asia
EOR	Enhanced Oil Recovery
FDI	Foreign Direct Investment
GW	Gigawatt
HELE	High-efficiency, low-emission
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
kWh	Kilowatt Hours
LCOE	Levelised Cost of Electricity
NDCs	Nationally Determined Contributions
NOx	Nitrogen
TFEC	Total Final Energy Consumption
SOx	Sulphur
SC	Supercritical
OCGTs	Open Cycle Gas Turbines
PV	Photovoltaic
SDG	Sustainable Development Goal
SubC	Sub-critical
USC	Ultra-Supercritical
TWh	Terawatt Hours
VALCOE	Value Adjusted Levelised Cost of Electricity
VRE	Variable Renewable Energy
WCA	World Coal Association
WEC	World Energy Council
WEF	World Economic Forum
$/MWh	Dollar per Megawatt Hours

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WORLD COAL ASSOCIATION

The World Coal Association is a global industry association formed of major international coal producers and stakeholders. The WCA works to demonstrate and gain acceptance for the fundamental role coal plays in achieving a sustainable and lower carbon energy future. Membership is open to companies and not-for-profit organisations with a stake in the future of coal from anywhere in the world, with member companies represented at Chief Executive or Chairman level.

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ASEAN CENTRE FOR ENERGY

Established on 1 January 1999, the ASEAN Centre for Energy (ACE) is an independent intergovernmental organisation within the Association of Southeast Asian Nations' (ASEAN) structure that represents the 10 ASEAN Member States' (AMS) interests in the energy sector. The Centre accelerates the integration of energy strategies within ASEAN by providing relevant information and expertise to ensure the necessary energy policies and programmes are in harmony with the economic growth and the environmental sustainability of the region. It is guided by a Governing Council composed of Senior Officials on Energy from each AMS and a representative from the ASEAN Secretariat as an ex-officio member. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE's office is located in Jakarta.

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