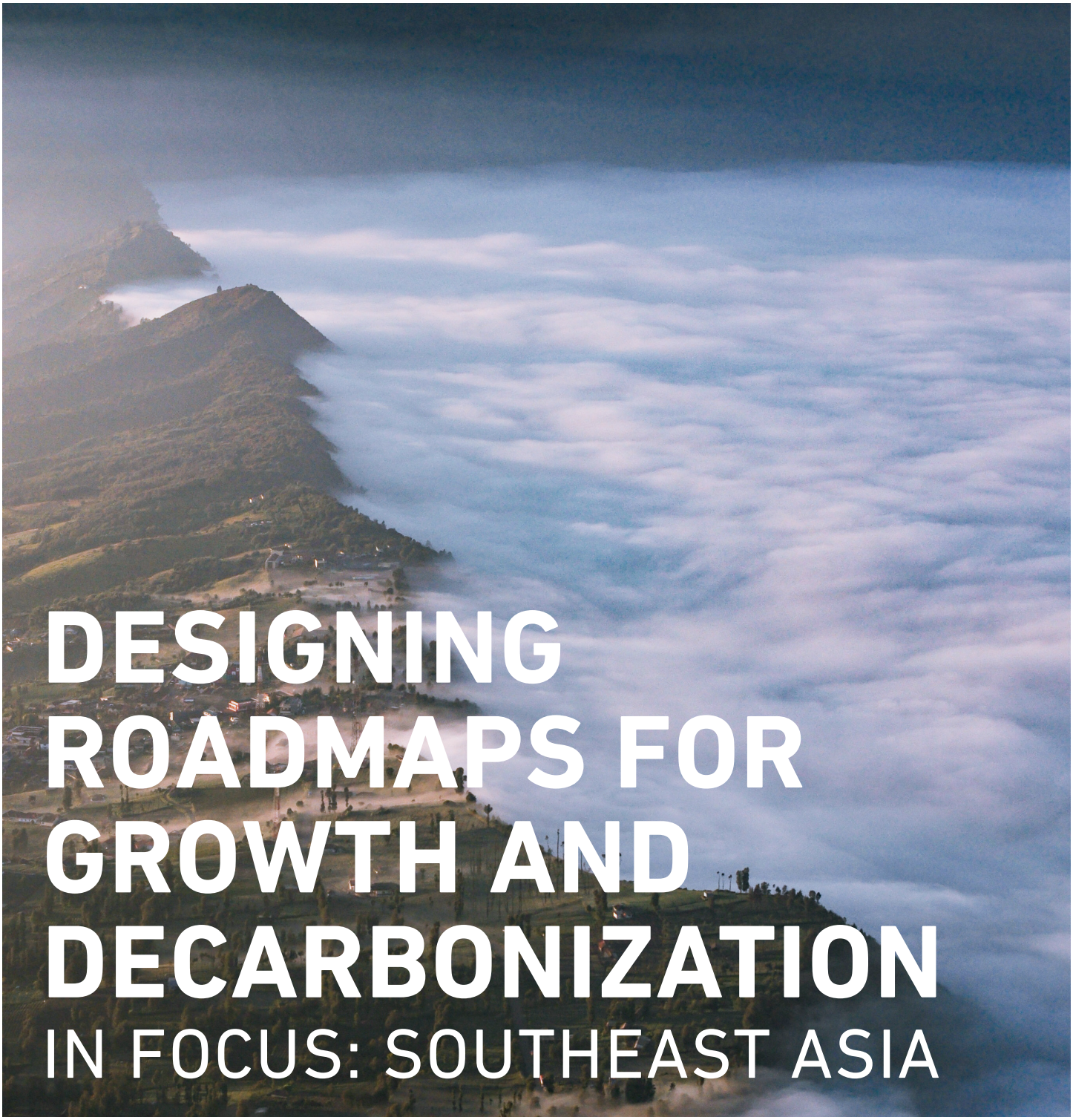
MITSUBISHI POWER



DESIGNING ROADMAPS FOR GROWTH AND DECARBONIZATION

IN FOCUS: SOUTHEAST ASIA

Mitsubishi Power is a power solutions company of Mitsubishi Heavy Industries.

MOVE THE WORLD FORWARD

MITSUBISHI HEAVY INDUSTRIES GROUP

EXECUTIVE SUMMARY

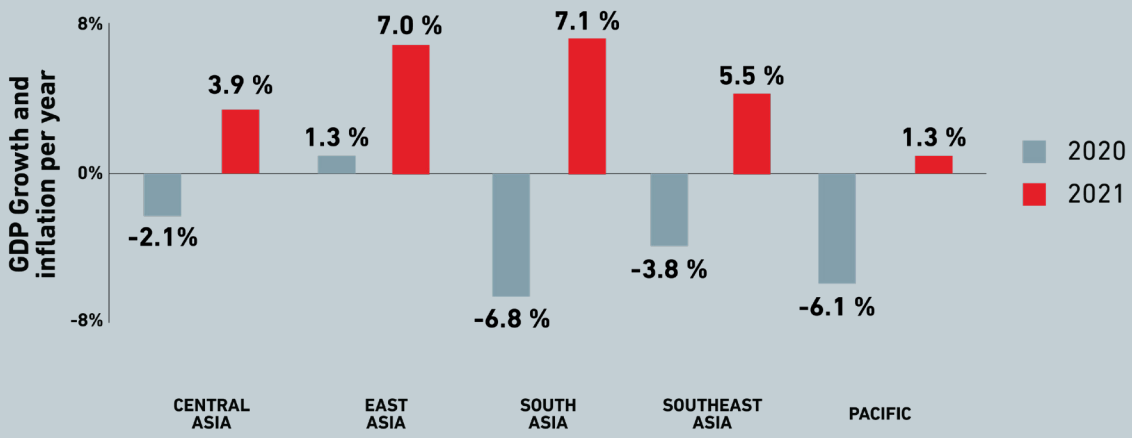
The world is facing stark choices when it comes to its energy systems. It is almost universally accepted that we must radically decarbonize in the coming decades to protect our planet, with global initiatives such as the Paris Agreement and the United Nations' Sustainable Development Goals setting the agenda for change. Citizens are watching their leaders wrestle with the challenges ahead, and the energy industry cannot sit idly. We must all play our part in making these ambitions a success, spurred by the belief that power plays a critical and inextricable role in improving societies—from reducing poverty and providing clean water to improving health and galvanizing economic development.

There is no escaping the fact that the energy transition is complex, and nations in Southeast Asia feel this pressure acutely. The countries in the region are managing growing populations and heightened power demand while helping their economies thrive. They have to balance the aspiration to move away from carbon-intensive fuels with keeping the cost of electricity affordable and available for citizens. And they must carefully weigh each investment they make to maximize its benefits—whether that is increased stability, wider reach, or lower emissions.

It is also clear that decarbonization is a gradual process. The COVID-19 pandemic has added to the challenge with the International Energy Agency (IEA) stating that "global energy investment [is] expected to shrink by an unparalleled 18% in 2020."[1] With the lasting impact of the crisis still unknown, countries face an unenviably challenging task of reaching international climate targets while delivering a lasting economic recovery.

1 International Energy Agency (2020), World Energy Outlook 2020, IEA, Paris

MOST ECONOMIES IN THE REGION CONTRACT IN 2020 BEFORE RECOVERING IN 2021[2]



Most economies across the Asian continent – including those in Southeast Asia – are set to contract in the last few months of 2020, as a result of the COVID-19 crisis. Still, they are projected to rebound in 2021, though the potential prolonging of the pandemic can derail recovery.

There is no single solution when it comes to decarbonization. What works for one country may be entirely inappropriate for another. But we all must persevere together—national leaders, ministries, utilities, independent power producers, technology and solutions providers, financial institutions, and everyday citizens—on the path to affordable, reliable and clean power.

Mitsubishi Power is stepping forward with Southeast Asia to elevate progress to date and forge a future of sustainable power generation together. This report sets out how any country—even those outside the region—can develop a custom roadmap to transition away from carbon-intensive fuels.

The first section lays out the context in which Southeast Asia finds itself and suggests four criteria for countries to use to assess themselves as they re-evaluate their energy roadmaps. It then outlines three approaches that countries can pursue in order to achieve their decarbonization ambitions.

01

Increasing flexiblity of existing power genrration systems to pave the way for renewables

02

Decarbonizing existing power generation systems

03

Expanding capacity for low- and zero-carbon energy solutions

As a solutions provider, Mitsubishi Power aims to deepen existing partnerships and establish new relationships to address the diverse and increasingly complex energy needs of Southeast Asia. Working together, we can meet growing power demand, increase the region's energy security, and solve the challenges of today and tomorrow

2 Asian Development Bank (2020), Asian Development Outlook Update, September 2020

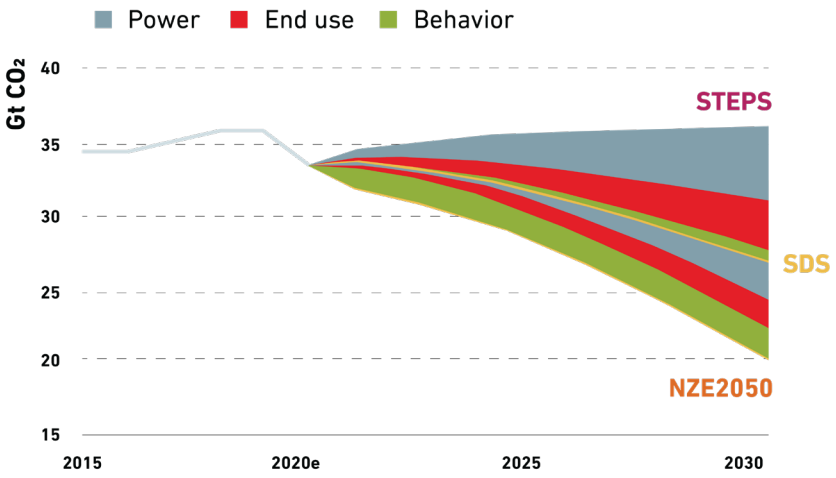
THE SOUTHEAST ASIAN ENERGY LANDSCAPE

ACCELERATING DECARBONIZATION, STIMULATING DEVELOPMENT

In December 2015, after a nearly 15-day conference and countless hours of behind-the-scenes negotiations and planning, 195 countries agreed to pursue maximum efforts to limit global temperature increases to less than 1.5°C above pre-industrial levels. The adoption of the Paris Agreement has prompted nations to evaluate the ways in which their citizens live, work and play, the systems that enable those functions, and their impact on the environment. As a result, industries around the world—from transport and agriculture to hospitality and manufacturing—have also had to evolve to align with the goals set by the countries in which they operate.

Given the role of carbon emissions in hastening climate change, decarbonization has captured the world's attention as a central tenet of this unified effort. In recent years, the global energy sector has taken significant steps to reduce its carbon intensity and ensure global peaking of greenhouse emissions as soon as possible.

GLOBAL ENERGY AND INDUSTRIAL PROCESS CO_2 EMISSIONS AND PROJECTED REDUCTION SCENARIOS[3]



Significant emissions reductions are needed to meet both the Sustainable Development Scenario (SDS) as well as a potential net-zero emissions target by 2050 (NZE 2050). The reductions will be achieved by nations' choices and innovation in power generation, reductions in end-use consumption (e.g., industry, transport, buildings) and behavioral change among citizens.

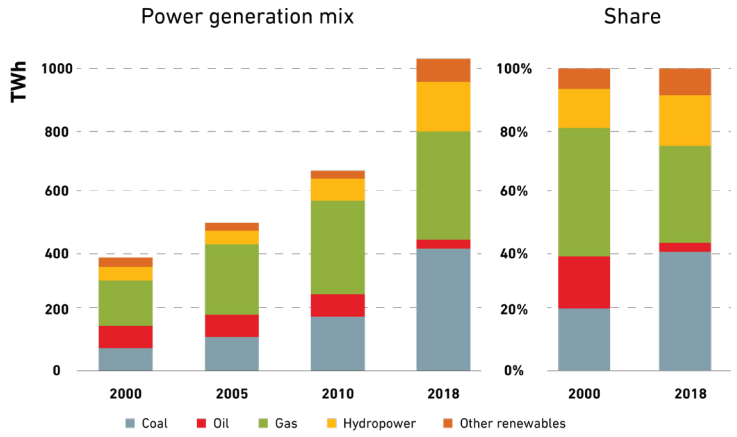
- STEPS: The Stated Policies Scenario provides a detailed sense of the direction in which today's policy ambitions will take the energy sector.
- SDS: The Sustainable Development Scenario is fully aligned with the Paris Agreement aiming to hold the rise in global temperatures to well below 2°C and pursuing efforts to limit it to 1.5°C.
- NZE 2050: The Net Zero Emissions by 2050 case examines how the world could achieve net zero global CO_2 emissions by 2050.

Here in Southeast Asia—with its trajectory of rapid development, growing populations and geographic susceptibility to extreme weather conditions—the need to ensure power is both reliable and decarbonized is even more pronounced. There has been a long-standing commitment in the region to secure 23% of primary energy from renewable sources by 2025[4] as well as meet the seventh goal of the United Nations' Sustainable Development Goals to provide universal access to affordable, reliable, and modern energy to all by 2030.

By reaching such aspirational targets, the region would be able to improve air quality and obtain the resultant economic and public health benefits. This would also ensure energy security, create millions of jobs in the sector, and ultimately increase economic competitiveness[5].

3 International Energy Agency (2020), World Energy Outlook 2020, IEA, Paris
4 IRENA & ACE (2016) Renewabale Energy Outlook for ASEAN: a REmap Analysis. International Renewable Energy Agency (IRENA), Abu Dhabi and ASEAN Centre for Energy (ACE), Jakarta
5 IRENA (2020), Global Renewables Outlook: Energy transformations 2050

POWER GENERATION MIX AND SHARED BY FUEL IN SOUTHEAST ASIA, 2000-18[6]



Notes: TWh = terawatt-hours. Other renewables include solar PV, wind, geothermal and modern use of bioenergy.

Southeast Asia's power generation capacity has dramatically increased. While the proportion of coal has grown in the regional energy mix, utilization of renewables, including solar photovoltaic (PV) , wind, geothermal and bioenergy, has increased somewhat as well.

Southeast Asia is a very dynamic region, with each member state differing in terms of economy, energy infrastructure, culture, and geography. But there are commonalities that bind the countries together and make it possible to discuss decarbonization of energy as a collective. These include:

01

Widespread and growing use of fossil fuels

02

Rising populations and energy demand

03

Energy secruity challenges

04

Growing economies

WIDESPREAD AND GROWING USE OF FOSSIL FUELS

Since 2000, the region has seen share of coal double, with fossil fuels now accounting for three-quarters of primary energy demand[7]. Based on governments' stated policies, demand for fossil fuel power is also projected to rise from 522 million tons oil equivalent (Mtoe) in 2018 to 847 Mtoe in 2040. This use of fossil fuels has expanded because of homegrown utilization of resources to spur economic growth. It has also kept energy prices affordable for citizens—granting millions access to electricity over the past two decades—and is due in no small part to the ASEAN bloc's consolidated efforts to connect communities to the grid.

RISING POPULATIONS AND ENERGY DEMAND

Data from the United Nations forecast that the population in Southeast Asia will increase from 633 million people in 2015 to 717 million in 2030, with three countries exceeding 100 million people: Indonesia (284 million), the Philippines (127 million), and Vietnam (103 million). Alongside other factors like industrialization, this population boom will drive energy demand an estimated 34% higher than 2018 levels[8].The region will thus have to redouble its efforts to connect the 45 million people still not connected to the grid and ensure this number falls even as populations grow.

6 IEA (2019), Southeast Asia Energy Outlook 2019, IEA, Paris, p32
7 IEA (2019) Southeast Asia Energy Outlook 2019, IEA, Paris
8 IEA (2019), Southeast Asia Energy Outlook 2019, IEA, Paris: 2018 primary energy demand: 701 Mtoe. 2030 estimate of primary energy demand: 942 Mtoe

ENERGY SECURITY CHALLENGES

According to the Asian Development Bank, six of the ten ASEAN economies are energy net exporters, but many of them would not be able to sustain self-sufficiency over the coming decade, as energy use tends to quickly surpass domestic energy production[9]. Indeed, energy demand in the region has grown by more than 80% since 2000 and increases at an average of 6% per year, while power generation capacity has not risen at a similar pace[10]. There are many reasons for this demand increase, but even seemingly innocuous functions like space cooling can have a major effect, accounting for up to 50% of demand during peak hours[11]. Although only 15% of Southeast Asian homes have air-conditioning units today, rising regional prosperity will only push ownership higher. The IEA predicts that the overall number of air-conditioner units in Southeast Asia could rise from 40 million units in 2017 to 300 million units in 2040, half of which will be in Indonesia[12]. This will further strain domestic power supplies and needs to be addressed.

GROWING ECONOMIES

Before COVID-19, the Organisation for Economic Co-operation and Development (OECD) forecasted that ASEAN would grow at an annual rate of 5.2% from 2018 to 2022[13] and become the world's fourth largest trading bloc by 2030[14]. While making predictions is particularly difficult due to the pandemic, the Asian Development Bank has predicted that the region will bounce back to 4.7% growth in 2021[15]. The rate of growth will have a bearing on regional supply and demand for electricity.

9 Asian Development Bank (2019): Toward Energy Security in ASEAN: Impacts Of Regional Integration, Renewables and Energy Efficiency
10 IEA (2019) Southeast Asia Energy Outlook 2019, IEA, Paris, p32
11 ASEAN SHINE (2015), Promotion of Higher Efficiency Air Conditioners In ASEAN: A Regional Policy Roadmap
12 IEA (2019), The Future of cooling in Southeast Asia, IEA, Paris
13 OECD (2018), Economic Outlook for Southeast Asia, China and India 2018: Fostering Growth through Digitalisation
14 UK Foreign and Commonwealth Office (2012)
15 Asian Development Bank (2020), Asian Development Outlook Update, September 2020

NO SINGLE SOLUTION: FOUR KEY CRITERIA FOR ENERGY ROADMAP

Looking at the complexity of this shared decarbonization challenge, it is unrealistic to assume that there exists a silver bullet that will immediately bring carbon emissions to zero while still raising living standards and advancing economies. Many within the region—across both public and private sectors—find themselves embarking on their own analysis on how to solve this puzzle. That is why it is helpful to have a frame that all can use to assess the status quo and establish their own unique path—including policies and investments—towards modern power systems that will make a lasting difference.

In this calculus, four criteria are particularly important:

01	02	03	04
Domestic energy resources and geopolitical circumstances	Economic and political drivers	Legacy Infrastructure	Economic viability of renewable energy

A country's **domestic energy resources and geopolitical circumstances** strongly influence the type of energy mix that it will prioritize for development. If a nation sees a path to self-sufficiency, it will place the utmost importance on building the infrastructure around that resource. This can be a challenge as identifying and exploiting these resources requires deep understanding of a nation's geography and shoring up the capital to make the requisite investments across the energy value chain—from extracting the fuel to building transmission lines and pipelines to transport it.

Countries may rely on other nations or have certain preferences when importing energy resources, especially given geography and existing foreign policy. They must balance the present economic benefits of such import relationships with the corollary increase in foreign reliance that could potentially threaten future energy security.

Economic and political drivers will dictate a country's capacity to invest in decarbonization and provide the required incentives to power providers, industry, and citizens to do so. Economically, countries will need to balance their visions against immediate financial realities—something that is acutely challenging now due to the COVID-19 pandemic. Politically, choosing to decarbonize energy systems is not a decision that can be made in isolation as energy policy exists among many other national priorities such as public health, education and defense. Further complicating matters is the fact that these issues are often deeply intertwined, and even small budget movements can have large repercussions on many seemingly unrelated initiatives. Leaders will have to build consensus and convince the public that transitioning to cleaner energy and more modern systems is worth both the attention and investment.

The importance of **legacy energy infrastructure**—existing plants, power lines, highways, technologies—in determining the roadmap and timeframe to improve energy systems cannot be overstated. Naturally, a country's existing infrastructure will form the foundation of any short- or medium-term energy plans. Even then, a long-term plan (20 to 50 years, for example) must rely on facilities that exist at the time of the plan's initial draft as a way of mitigating and forecasting the great investment needed in the future. Countries know that transitioning away from legacy infrastructure takes decades and often requires addressing potential legal, political, and socio-economic challenges.

Finally, the **economic viability of renewable energy** varies by region or country, in part due to its domestic availability but also to the fact that power generation and system costs are not uniform, even within a single country. For example, power generation costs for wind and solar have been decreasing in Europe and North America, but to a lesser extent in Southeast Asia. Moreover, while the impact of system cost is critical, there are additional considerations when introducing renewable capacity including:

- Profile cost: An increase in power generation cost due to the much lower capacity factor of renewables compared to coal or gas, which have higher ramping and cycling rates. For example, wind or solar power generation requires back-up either through batteries or a fallback to flexible power from fossil fuels to address load fluctuations. Incidentally, the introduction of more renewables to the system will result in the gradual underutilization of existing assets, which in turn will decrease the capacity factor of these existing fleets and further raise costs.

- Balancing cost: The system cost for carrying a higher level of reserves.

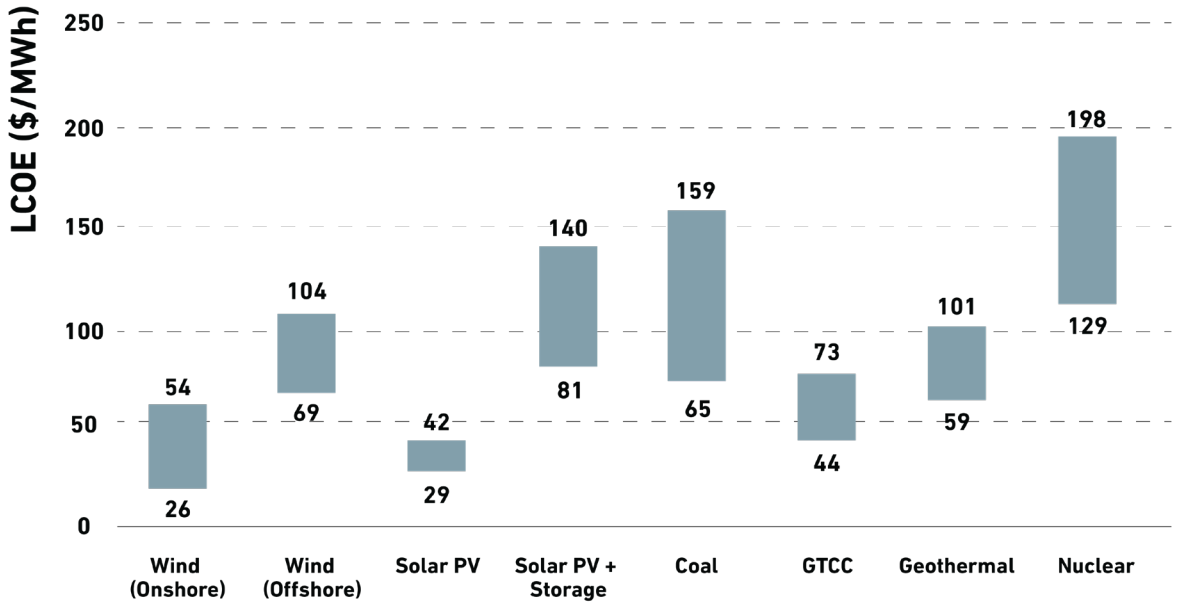
- Grid, transmission and distribution (T&D) costs: The required investment in capacity expansion of the grid and network systems to accommodate remote location constraints. T&D systems will also need to be modernized to accommodate new fuel mixes and ensure flexibility as demand increases with the introduction of renewables.

Such system cost factors can be a serious burden for countries, depending on existing infrastructure and geography, and must therefore be properly reflected in analysis to evaluate the financial feasibility of renewables in each country.

To be sure, Levelized Cost of Electricity (LCOE) from renewables has been in sharp decline. Since 2010, the prices of solar photovoltaic power, concentrated solar power, offshore wind and onshore wind have decreased, 90%, 78% , 49%, and 50%, respectively.[16] Yet, these energy sources are not dispatchable. They all need energy storage systems to become valuable assets for a country to rely on them for on-demand power. This requirement pushes the cost of renewables up considerably, making them even more expensive than existing coal or gas power generation. However, such investments do have long-term benefits such as harnessing excess electricity from renewables to turn it into molecular hydrogen through electrolysis and then using it to fire gas turbines for additional power generation.

While it is true that these options are still more expensive in Southeast Asia than globally, the case can be made that systematic investment in renewables coupled with concurrent enhancements to existing fossil fuel infrastructure will usher in the envisioned zero-carbon future.

LOWER COMPARISION BY POWER SOURCE[17]



Levelized Cost of Electricity for power from renewables like wind and solar have gone down. However, dispatchability of these energy sources remains an issue – making traditional fuels still relevant and important at least in the medium-term.

16 IRENA (2020), Global Renewabales Outlook: Energy transformation 2050
17 Lazard Frers & Co. LLC (2020), "Lazard's Levelized Cost of Energy Analysis version 14.0" and 'Lazard's Levelized Cost of Storage Analysis version 6.0"

THREE APPROACHES TO ACHIEVING DECARBONIZED AND RELIABLE POWER

A country must understand where it sits within these four criteria so that it can establish its vision for decarbonization and build a roadmap that includes milestones for modernizing its energy systems.

The long-term vision must lay out the desired future energy mix in the decades to come and take into account the "3E+S" perspectives of Environment, Energy Security, Economic Efficiency, and Safety. It must balance global ambitions and local priorities, which include:

- Minimizing adverse effects on the environment
- Accomplishing maximum energy self-sufficiency
- Providing affordable power to residents
- Ensuring the health and safety of workers and communities by reducing pollutants from power plants (for example, by installing air quality control systems)
- Maximizing economic impact including job creation.

With a long-term vision set, short- or medium-term plans can then be developed factoring in the feasibility of all available technologies and outlining tangible moments in time to be met. As individual power projects and legislative incentives take shape, these plans must be sufficiently flexible to adjust to shifting financial and political environments while remaining grounded in the reality of what can be achieved with prevailing resources. Utility companies and independent power producers (IPPs) should take note too that their plans will have to adapt as policy directives evolve.

Governments must establish these long-term visions and shorter-term plans in cooperation with private sector players who can bring more niche expertise to the table, complementing the more macroeconomic views from the public sector. This collaborative approach will help ensure that recommendations are comprehensive, actionable and tailored to each country's individual circumstances, all with the common aim

While the details of the specific paths will differ from country to country, there are three key approaches that are imperative to the success of these efforts regardless of geography:

01

Increasing flexibility of existing power generation systems to pave the way for renewables

02

Decarbonizing existing power generation systems

03

Expanding capacity for low and zero-carbon energy solutions

INCREASING FLEXIBILITY OF EXISTING POWER GENERATION SYSTEMS TO PAVE THE WAY FOR RENEWABLES

The first approach is to improve the flexibility of coal and gas plants to accommodate intermittencies as more renewables enter the grid. By increasing the start-up and ramp-up rates of legacy power infrastructure for both base and ancillary load, utilities and IPPs will be able to maintain reliable supply even as they work to enhance the output and stability of power from renewables, especially during peak production hours.

Another crucial area to consider is the introduction of digital technologies to improve plant performance and profitability. By analyzing the data collected from thousands of sensors throughout a plant, anomalies can be automatically detected, and remedies actioned, far faster than by manual observation. This ensures that faults do not escalate, potentially resulting in forced outages, load reductions or equipment degradation, saving plant operators significant amounts in maintenance expenditure.

With these improvements to fossil fuel power generation, the opportunities for renewables and other less carbon-intensive fuels can expand in exciting new ways, overcoming a significant barrier to viable adoption.

DECARBONIZING EXISTING POWER GENERATION SYSTEMS

The second approach is to reduce the environmental impact of existing infrastructure, especially coal plants. Here, the most realistic tactic is to improve fuel efficiency by upgrading existing power generation facilities. Emissions can also be mitigated by installing carbon capture and air quality control systems at the facilities. This reduction of CO_2 and other greenhouse gases from power plant operations is critical for countries to move the needle in terms of attaining long-term ambitions.

EXPANDING CAPACITY FOR LOW- AND ZERO- CARBON ENERGY SOLUTIONS

The third approach is to progressively raise the proportion of fuels with inherently lower carbon intensity in the energy mix. This requires developing systems with the capacity to deploy these fuels optimally for power generation as well as capture and potentially synthesize usable carbon compounds from the remaining CO_2.

This begins by tapping relatively abundant lower carbon options, which in this region often are natural gas and biomass. Concurrently, plans to introduce more zero-carbon fuels such as ammonia and hydrogen, as well as renewables like geothermal, wind and solar into the mix should be built. In these cases, reaching the ideal energy mix will depend largely on the ability to create viable supply chains for these fuels.

Where possible, these three approaches should be pursued in parallel, based on each country's realistic assessment of their own circumstances. A gradual but concerted approach, working in partnership with the private sector, towards reducing fossil fuel reliance and progressively increasing renewable energy adoption will ensure that countries can implement realistic and achievable plans. They must make the right investments for the future, while ensuring that lights are still kept on—and economies keep moving—today.

WHY MITSUBISHI POWER

At Mitsubishi Power, we are creating an energy future that works for people and the planet. We are committed to accelerating the shift towards a decarbonized global energy landscape while maintaining reliability of power supplies. We do this in part by helping power generators determine how to best use existing assets and which investments to make, in order to address current needs and obtain future ambitions.

As a Japanese organization, we have been proud partners with the Japanese government to modernize the national grid and diversify the country's fuel mix to advance decarbonization and build resiliency into the system. Currently, Japan's emissions are already below 1990 levels and with continued collaboration, we hope to play a role in achieving its newly stated pledge to achieve carbon neutrality by 2050.

Combining the lessons that we have learned in Japan and across our global operations with our deep knowledge of Southeast Asia's specific needs, we have been supporting countries in the region on their energy transition journeys for nearly half a century.

In Indonesia, Mitsubishi Power has been working with the government for 50 years, and more recently with IPPs, to deliver the technology that powers the country. We continue to grow our footprint and are working towards increasing our contribution to 17 GW–nearly a third of the nation's 56 GW total output. Similarly, in Thailand, our installed base is well over 25 GW, equivalent to 50% of the country's current power generation capacity.

Our work in these countries has helped guide a shift away from coal to natural gas, and installing our gas turbines has reduced carbon emissions in those plants by up to 65%. We are also looking to the future to add decarbonized fuels such as biomass and ammonia. For example, in October 2020, we signed an MOU with Indonesia's PLN Group and Bandung Institute of Technology to explore the adoption of biomass co-firing in thermal power plants to improve environmental sustainability and economic efficiency. We are also increasing geothermal power generation in countries where such resources are available.

Ultimately, we know that easing economies off dependence on fossil fuels cannot happen overnight, but steps can—and must—be taken now to move countries closer to a zero-carbon society at a suitable pace.

This progress goes beyond meeting international targets such as those set out in the Paris Agreement. The future is within sight, with new digital solutions making use of Artificial Intelligence to optimize operations on the horizon. Similarly, the path to power generation with hydrogen and ammonia is becoming clearer, and with sufficient initial adoption, countries may be able to develop a decarbonized society domestically, increasing their energy security in the process.

Together, we can all unite to play a significant role in improving the lives of citizens in the near-term and shaping a positive future for generations to come.

We have the global reach, local expertise and deep technical knowledge to support at every stage of the decarbonization journey. Southeast Asian nations are striving to deliver reliable and affordable energy, improve their citizens' lives and keep economies growing. Mitsubishi Power can be a trusted partner with you on your long-term resource planning. We understand what is needed, and can analyze and craft a practical decarbonization pathway to meet each specific situation. Please get in touch to start a conversation:

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