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Decarbonising the Indo-Pacific: Energy Security in a Net-Zero Future

By

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Executive Summary

This report examines the prospects for decarbonising the Indo-Pacific's energy systems, with an eye toward potential roles and requirements for enhanced regional cooperation in these efforts.

Main Argument

Decarbonising the Indo-Pacific's energy systems is essential to setting the region on a more secure, sustainable, and advantageous development path. Yet such a transformation is anticipated to be difficult. As the available resources, tools, and even geospatial conditions for such an undertaking can vary dramatically by sector as well as by country, regional cooperation offers the best chance for translating stated ambitions into a viable course of action.

Policy Implications

- Of the region's present-day energy-linked carbon dioxide emissions, roughly half are tied to the power sector; industry and transport each account for an additional 20%. Each of these sectors will need to undergo dramatic changes to maximise potential emission reductions.
- Multiple pathways to net-zero emissions exist, yet four actions play a pivotal role in all pathways: achieving a carbon pollution–free power sector as soon as possible; promoting widespread electrification of other end-use sectors, such as transportation; aggressively pursuing energy efficiency; and minimising (if not fully eliminating) the unabated use of fossil fuels.
- National roadmaps for decarbonisation will inevitably vary, given different developmental starting points as well as views about the relative merits of specific pathways. Even so, cost-minimisation strategies typically leverage international trade, investment, and collaboration. To that end, fora such as the G-20, East Asia Summit, and Asia-Pacific Economic Cooperation can play important roles in bringing together key stakeholders to avoid divergences in technical standards, resolve barriers to cross-border development, and share lessons learned.

Chapter 1
Introduction

As of March 2024, nearly every country in the Indo-Pacific has articulated ambitions to achieve a carbon-neutral energy mix by around mid-century. This list includes all ten of the region's top carbon-dioxide (CO_2) emitting countries: China, the United States, India, Japan, Indonesia, the Republic of Korea (henceforth, Korea), Australia, Thailand, Viet Nam, and Malaysia. As these countries alone account for over 60% of global CO_2 emissions annually, their commitments are not just laudable but essential to global visions for radically reducing greenhouse gas emissions – and, in doing so, avoiding some of the worst-case scenarios for climate change.

Table 1.1. Energy Consumption and CO_2 Emissions in the Indo-Pacific, by Country, in 2019

Country	Energy Consumption (MTOE)	CO_2 Emissions (Mt-C)	Carbon Intensity (Mt-C/MTOE)	Target Year for Carbon Neutrality*
Australia	128.74	103.8	0.81	2050
Brunei	4.57	1.67	0.37	2050
Cambodia	7.17	3.84	0.54	2050
China	3,389.30	2,695.1	0.80	2060
India	1,368.14	929.9	0.67	2070
Indonesia	228.7	164.0	0.70	2060
Japan	415.31	288.9	0.70	2050
Rep. of Korea	280.19	160.0	0.59	2050
Lao PDR	6.30	5.2	0.83	2050
Malaysia	86.36	57.3	0.66	2050
Myanmar	20.48	8.2	0.40	N/A
New Zealand	20.48	9.0	0.44	2050
Philippines	59.7	35.3	0.59	N/A
Singapore	23.51	13.2	0.56	2050
Thailand	133.10	58.4	0.44	2050
United States	2,212.75	1,293.7	0.58	2050
Viet Nam	91.42	78.5	0.86	2050

MTOE = million tonnes of oil equivalent
Mt-C = million tonnes carbon (may be converted to million tonnes of CO_2 by multiplying by 44/12)
Note: * In instances where countries have not articulated a stand-alone deadline for achieving carbon neutrality, their target year for achieving net-zero greenhouse gas emissions is listed.
Source: Kimura, Phoumin, and Purwanto (2023), 'Energy Outlook and Energy-Saving Potential in East Asia 2023.'

Many of these countries are already taking important steps to translate their ambitions into action. Amongst other laudable announcements, India's National Electric Mobility Mission Plan, Viet Nam's latest power development plan, the United States' Inflation Reduction Act, and China's assorted 5-year plans all offer bold visions for how to champion large-scale deployment of zero-carbon technologies. Even so, true decarbonisation is expected to be incredibly difficult. More than 150 million people within the region still lack access to modern energy supplies, suggesting that there is virtually no scenario where at least some aspects of regional energy consumption do not grow – short of leaving some people behind. A 'just' energy transition will thus need to rise to the challenge of radically expanding access to energy while also advancing systemic change, and do so without sacrificing affordability, reliability, or sustainability. In short, it will need to approach decarbonisation as an energy security challenge.

This report examines the prospects for decarbonising the Indo-Pacific's energy systems. Chapter 2 overviews where we are now, while Chapter 3 explores what the Indo-Pacific's pathways to carbon neutrality might look like. Chapter 4 then looks at the tools that can help decision-makers translate a preferred pathway into an explicit course of action. Chapter 5 then teases out how international cooperation can (and must) play a role in various efforts, noting where new mechanisms for cooperation might be required. Finally, this report concludes by offering recommendations for the way forward. It ultimately argues that decarbonising the Indo-Pacific's energy systems will be hard but not impossible – with the right approach to collective action.

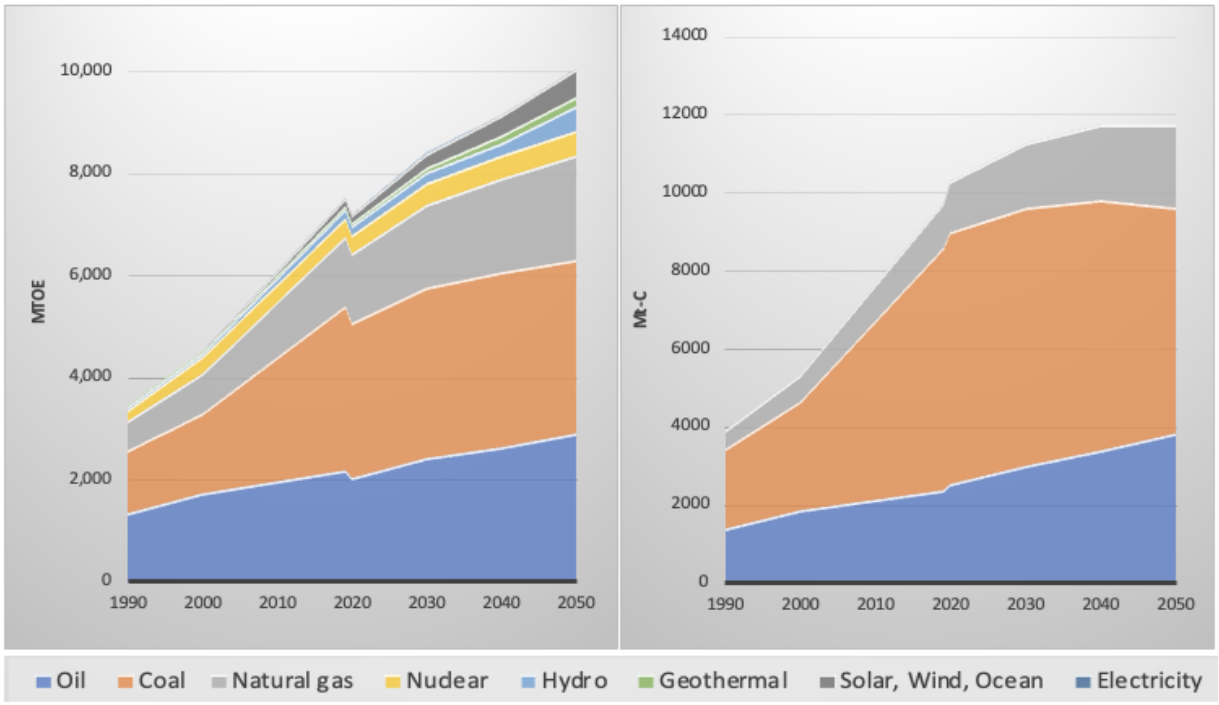
Chapter 2
Where We Are Now

1. The Big Picture

Figures 2.1 and 2.2 illustrate how the Indo-Pacific's energy situation has evolved since 1990 and what it might look like through 2050 based on a conservative-change model produced by the Economic Research Institute for ASEAN and East Asia (ERIA).[1] Taken together, these figures suggest four points about where the region is headed under business as usual – and why reshaping this trajectory is essential and yet challenging to do well.

Figure 2.1. Primary Energy Consumption in the Indo-Pacific, Historical and Projected

Figure 2.2. CO_2 Emissions in the Indo-Pacific, Historical and Projected



MTOE = million tonnes of oil equivalent, Mt-C = million tonnes carbon (may be converted to million tonnes of CO_2 by multiplying by 44/12).
Note: Biofuels and biomass are not included in these figures but typically account for an additional 500 MTOE in primary energy consumption (+/– roughly 100 MTOE), with wide regional variations in calculating and monitoring their CO_2 emissions.
Source: Kimura, Phoumin, and Purwanto (2023), 'Energy Outlook and Energy-Saving Potential in East Asia 2023.'

[1] In this case, 'conservative' means how closely trends for a number of variables – such as available resources and their expected prices, as well as the pace of global technological change – match with the broad trajectories observed in recent years. This is also often referred to as a 'reference' or 'business-as-usual' scenario. For more on this underlying model, see Shigeru Kimura, Han Phoumin, and Alloysius Joko Purwanto, eds., 'Energy Outlook and Energy-Saving Potential in East Asia 2023,' Economic Research Institute for ASEAN and East Asia (ERIA), August 31, 2023, https://www.eria.org/uploads/media/Books/2023-Energy-Outlook/Energy-Outlook-and-Saving-Potential-2023-rev.pdf.

First, as alluded to in the introduction, the Indo-Pacific's requirements for energy continue to rise. China has long been the leading driver of this growth, but the main source of new demand coming online now is shifting to the region's other developing economies, notably India and Southeast Asia at large. Even so, all countries in the ERIA's model, save for Japan, are expected to see at least some demand growth, given expectations that population growth or economic growth (and typically both) contribute to new requirements for energy (Kimura, Phoumin, and Purwanto, 2023).

Second, oil and coal play an outsized role in meeting the region's aggregate needs. While all regions make use of these fuels to some extent, the Indo-Pacific's level of reliance on coal in particular (as shown in Figure 2.1) is especially high in a global context (ADB, 2023). Part of the reason for this is that coal does offer notable advantages: a cheap, versatile source of energy whose associated infrastructure can be scaled up quickly and then operated safely with relatively modest training. This has been an attractive proposition in a region where, even in 2000, one in four people lacked access to electricity (UNESCAP, 2018). For Australia, Indonesia, India, and several others in the region, coal is also an abundantly available domestic resource, providing not only a sense of security of supply, but also an asset whose production adds to employment and state revenues. Such conditions can disincentivise an aggressive phaseout of coal, even as Figure 2.2 makes clear that coal is also by far the largest contributor to the region's CO_2 emissions.

Third, as things stand now, the region's energy mix is becoming cleaner. As shown in Figure 2.1, although low- and zero-carbon energy sources started from a low base in 1990, in recent years, they have seen some of the most robust growth, especially natural gas. Between now and 2050, consumption of solar, wind, and ocean energy is also expected to quadruple. Even so, consumption of existing sources has rarely declined at a regional level or even necessarily at a country level. India, for example, added as much solar capacity in 2022 alone as the United Kingdom's entire solar fleet and yet still consumed record levels of coal (Lee, 2023). This speaks to a key challenge for the region: even a historically unprecedented pace and scale of clean energy deployment might struggle to outpace the equally unprecedented pace and scale of overall energy demand growth.

This leads to the fourth takeaway, which is the one that is impossible to ignore: we are nowhere close to where we want to be. Indeed, under business as usual, the region's CO_2 emissions in 2050 are still expected to be 20% higher than levels observed in 2019. This is an incredible feat given that, under this business-as-usual model, energy consumption grows by 34% during this period, and is something that speaks to the scale of the clean energy transitions already underway in the region (Kimura, Phoumin, and Purwanto, 2023). Yet it is a far cry from promising a decarbonised Indo-Pacific.

2. The Needs behind This Outlook

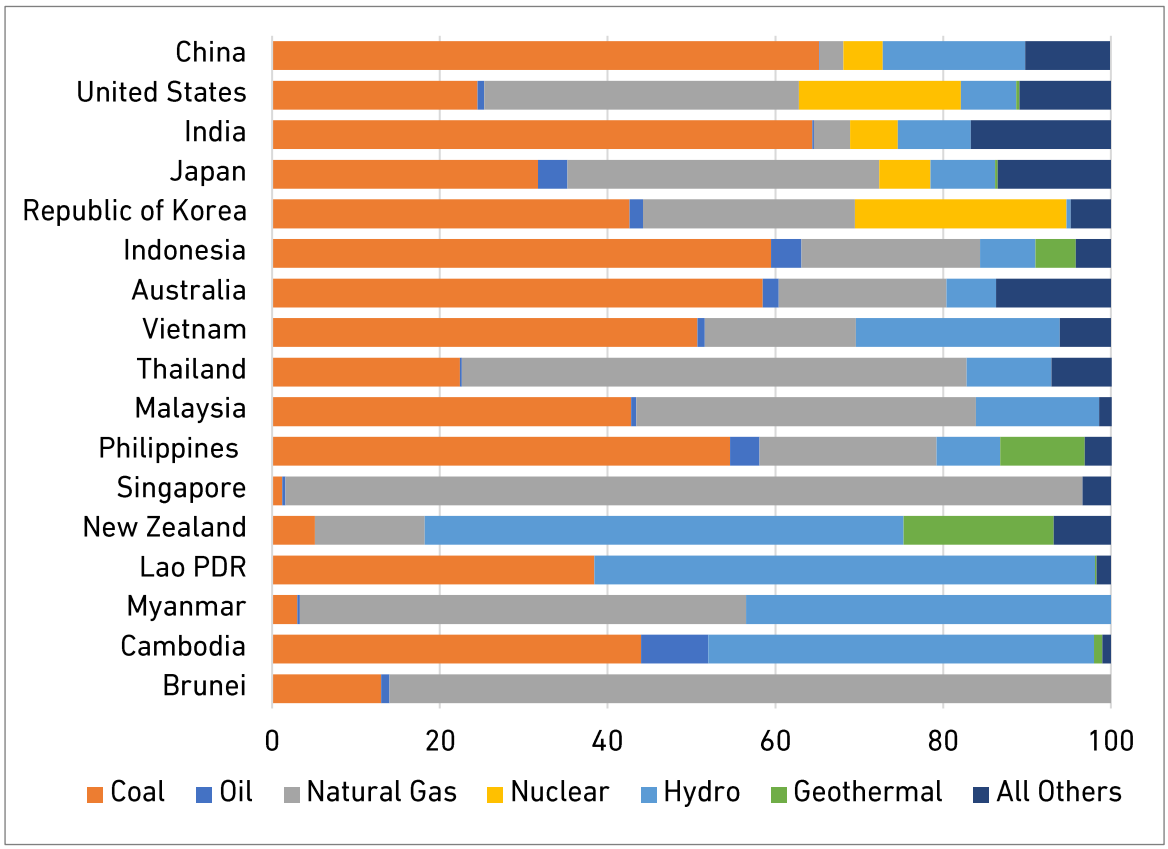
Fully understanding what is driving this outlook – and what is ripe for disruption – requires digging into the activities producing emissions. To that end, roughly 90% of the

Indo-Pacific's energy-linked CO_2 emissions can be tied to just three sectors: electricity, transportation, and industry. The trends and requirements that shape these sectors' needs are examined in the next three subsections.

2.1. Electricity

Of the region's present-day energy-linked CO_2 emissions, roughly half are tied to power generation (APERC, 2022). Key to this picture is both the scale of overall demand – electricity for over four billion people – and the outsized role of coal in meeting it. China, India, and Indonesia, for example, all source over 60% of their power-input needs from coal, while coal's share in Japan and Korea remains above 30% (see Figure 2.3).

Figure 2.3. Power Generation Mix, by Country, in 2019
(Ordered from Largest to Smallest Market Size)



Source: Kimura, Phoumin, and Purwanto (2023), 'Energy Outlook and Energy-Saving Potential in East Asia 2023.'

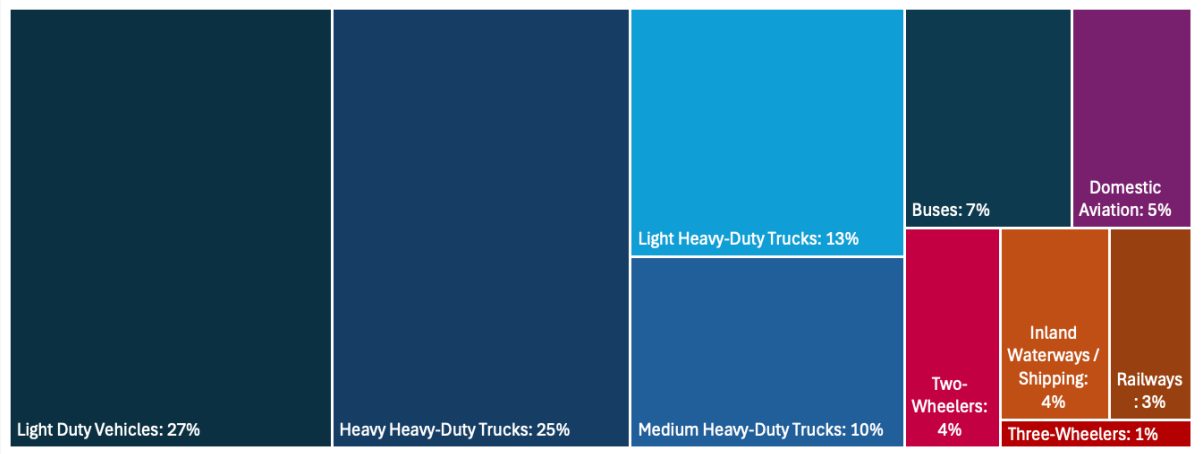
The encouraging news is that signs of a shift to a cleaner mix are already visible in large parts of the region. China's dependency on coal – though still high – has declined by more than 25% in just ten years and is expected to continue to decline as new capacity tied to wind, solar, nuclear, and natural gas comes online. The United States is also seeing coal rapidly backed out of power generation, with wind and solar now offering sources of power generation that are not only cleaner but sometimes cheaper (Antonio, 2023). Meanwhile, in New Zealand, zero-carbon energy sources – primarily hydro and geothermal energy – already reliably account for over 80% of the country's power mix (Kimura, Phoumin, and Purwanto, 2023).

Given the trends above, it is perhaps not surprising that the power sector is often singled out as ripe for decarbonisation at scale, even absent new technological breakthroughs. But this is still a far cry from saying that the Indo-Pacific's power sector is well-positioned to phase out coal based on market conditions alone. Asia's fleet of coal-fired power plants is still young – on average, just fourteen years old – meaning that their natural retirement age is still decades away (IEA, 2022-a). This is to say nothing of the plans for new coal-fired power plants that are currently under consideration in China, India, the Philippines, and even Japan. To bring this back to energy security terms, coal-fired power has regularly provided utility operators with some flexibility in how they guarantee baseload power, having been able to quickly fill gaps in other supplies following Japan's post-Fukushima nuclear shuttering as well as amid global gas market contractions with Russia's invasion of Ukraine. Whatever comes next will need to show that it is cleaner, affordable, and highly reliable – and even so, decision-makers might be hesitant to bet on just one input.

2.2. Transportation

Transportation emissions account for the next 20% of the Indo-Pacific's CO_2 emissions and are generated by a variety of vehicles, including cars, trucks, ships, and airplanes (APERC, 2022; ADB, 2022) (see Figure 2.4). But, by and large, these emissions are overwhelmingly tied to just one fuel: oil. Globally, oil still accounts for 91% of transport's final energy needs (IEA, n.d.-b). And with Asia's auto fleet alone expected to more than triple in size between 2020 and 2050, failure to manage this growth 'well' could lead to an untenable rise in oil-linked CO_2 emissions (Nogimori, 2020).

Figure 2.4. Breakdown of Transport-Linked CO_2 Emissions in Asia, 2018



Source: Asian Development Bank (2022), 'Asia Transportation 2030 Outlook.'

Much like electricity, transportation has tools for unlocking deep decarbonisation that are already commercially viable. Electric vehicles (EVs) are a prominent example, with China, Japan, Korea, the United States, and India (amongst others) aggressively pursuing leadership in both development and deployment. Still, some aspects of transportation –

such as shipping and long-haul trucking – are technically challenging to electrify. In these cases, policymakers and developers are pursuing ways to enable switching to fuels with lower carbon footprints (such as natural gas) as well as reduce the emissions output of gasoline-powered vehicles. Yet, while the pace of deploying these solutions has been remarkable, it is not expected to be on track to peak (much less decrease) the Indo-Pacific's transportation emissions by mid-century, given demands (Kimura, Phoumin, Purwanto, 2023).

Looming beneath the surface are assumptions about why this sector's demands for energy are rising so rapidly. Growing regional desires for mobility and expanding trade are certainly critical factors. Yet the state of available infrastructure also plays a role in amplifying demand. As detailed by the Asian Development Bank (ADB), even in 2019, more than one billion urban residents in Asia lacked efficient access to public transit, increasing reliance on (and the overall frequency of) single-passenger vehicle trips (Gota and Huizenga, 2023). This, in turn, suggests just one of the numerous ways in which governments, industry, and individuals might not be well-positioned to achieve their maximum potential for reducing emissions, absent a comprehensive push to improve a wider range of systems.

2.3. Industry

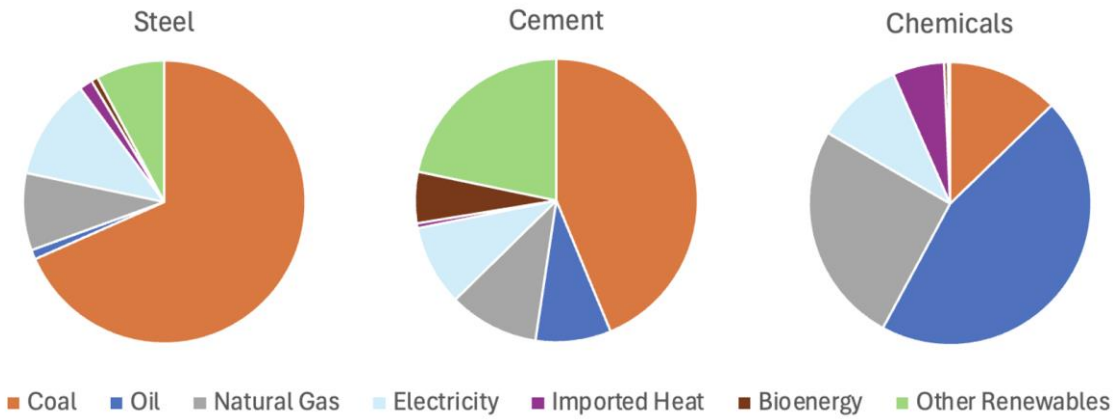
Development, such as those examples noted above, is expected to lead to a boom in regional construction, manufacturing, and production of material goods – in short, an incredible amount of industrial activity. Even so, industrial energy use in the Indo-Pacific is expected to grow at a relatively modest rate. Key to this picture is that China – long the region's largest manufacturing hub – is expected to continue its shift to a more service-oriented economy, supporting faster retirements of some of its production capacity.[2] Although new capacity is expected to be scaled up in South Asia, Southeast Asia, and North America, these new facilities have substantial opportunities to use energy more efficiently from the outset, with the net impact being that the region's industrial energy demand still grows, but at half the pace of that for power and transportation (Kimura, Phoumin, and Purwanto, 2023).

However, industry's modest energy demand growth does not inherently translate into bright prospects for radically reducing its emissions. As shown in the selected snapshots in Figure 2.5, the vast majority of the global industrial sector's energy needs are still met by fossil fuels, and replacing some of these energy sources with alternatives is currently not feasible. For example, the production of steel and cement – key sector outputs – continues to rely on processes that require high-temperature heat and chemical reactions, where coal is often the most (and sometimes only) viable input. Chemical feedstocks are also typically derived from oil and natural gas. While low-carbon

[2] Economic downturns can also check industrial output and thus industrial energy use. However, this does not appear to have occurred amid Covid-19-linked economic downturns as industrial facilities largely remained in operation amid shutdowns and governments targeted stimulus to boosting output. See APERC (2022), *APEC Energy Demand and Supply Outlook.*

technologies and alternative processes are currently under development in these and other areas, based on the current pace of technological change, they are not anticipated to become technically (much less commercially) viable in the near term (IEA, n.d.-a). Yet with industrial emissions currently making up 20% of the region's energy-linked CO_2 emissions, it is difficult to imagine how to reach net zero without some kind of breakthrough.

Figure 2.5 Final Energy Demand of Select Heavy Industry Sectors by Fuel, Globally, 2019



Source: IEA (2020), '*The Challenge of Reaching Zero Emissions in Heavy Industry*.'

2.4. All the Rest

What makes up the remainder of the region's energy-linked CO_2 emissions can vary dramatically by country (and, at times, is shaped by trends in other sectors). Buildings, for example, contribute to energy demand and CO_2 emissions via their consumption of energy to support heating, cooling, cooking, lighting, and appliances. Increasingly, these needs are being met via electricity, but in India and other parts of developing Asia, biomass remains an important input – one that adds to total emissions but also creates local jobs and revenue streams.[3] Likewise, agricultural activities contribute to energy demand, although minutely. But in a handful of countries, including Indonesia and Korea, local conditions also mean that these activities are nonetheless linked to notable CO_2 emissions (Yudha, 2016; IEA and KEEI, 2021). Ultimately, as this review might suggest, each country in the Indo-Pacific is approaching sector-level decarbonisation from moderately different starting points, something which can make specific challenges more or less daunting. Yet no country is exempt from concerns about the road ahead.

[3] This is another situation in which the opportunity to lower emissions from existing energy sources in tandem with pursuing alternatives has strong appeal.

3. Implications of Business as Usual

This section has sought to show both encouraging and discouraging aspects of the Indo-Pacific's energy outlook under business as usual. It has attempted to highlight, for example, areas where clean energy transitions appear to be picking up steam (e.g. in power and transportation) and where observers might feel hopeful that this pace could easily accelerate (e.g. if costs associated with using cleaner consumption tools decline more than expected). At the same time, it has also sought to discourage the idea that all sectors are equally ripe for decarbonisation at scale, as well as hinted at several reasons why countries – both developing and developed – have remained locked into carbon-intensive energy consumption patterns even when lower-carbon alternatives are already technically and economically viable.

Collectively, these trends have both immediate and long-term consequences for the region's environmental outlook, which should factor into how we think about the costs of inaction. A sharp rise in CO_2 emissions, for example, seems likely to exacerbate efforts to tackle the toxic air pollution that has already taken hold in much of the region. This is something that is already decreasing average life expectancies in China (–2.5 years), India (–5.3 years), Viet Nam (–2.0 years), and even areas within developed economies, such as Seoul (–1.7 years) (Greenstone and Hasenkopf, 2023; AQLI, 2019). To place these trends back in a global context, this level of emissions is such that, even if the rest of the world were to decarbonise immediately, the world would still exceed its remaining 'carbon budget' (that is, the limit on aggregate carbon emissions needed to stay under a 1.5°C rise in temperature), making a global climate catastrophe exponentially more difficult (and more expensive) to avoid.

Yet it would be a mistake to think that, save for concerns about emissions, the future depicted above is one that is on course to deliver energy in ways that are more secure, more affordable, and more reliable. The immense amount of demand projected above raises immediate questions about where the underlying supplies will come from – and at what cost. In this light, decarbonisation might be viewed as a different way of thinking about how to best promote energy security: elevating a goal that is often viewed as promising to boost self-sufficiency levels, alleviate import bills, and contribute to economic growth, all while protecting the climate. But taking this view seriously means first addressing what decarbonisation at scale might look like. This is explored in the next section.

Chapter 3
What We Need to Do

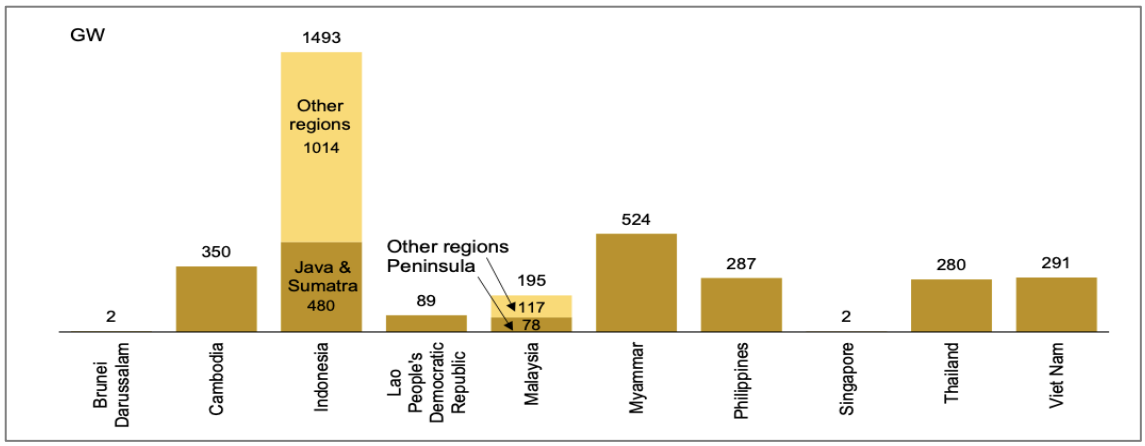
Since the International Energy Agency (IEA) released its first 'Net-Zero Roadmap,' there have been numerous exceptional efforts to translate its high-level, global snapshot of a decarbonised world into implications for individual countries as well as distinct regions. Princeton University's Carbon Mitigation Initiative, the Korea Energy Economics Institute, and various management consultancies, for example, have all dug into specific country studies, lending their own sense of what might be possible within a given set of national borders. Alongside this, the ADB, the Asia Pacific Energy Research Centre (APERC), the ERIA, and the Institute of Energy Economics, Japan (IEEJ) have all crafted models focusing on the wider Indo-Pacific. In doing so, they add additional nuance to an already complex regional picture – indirectly (and sometimes directly) suggesting when more aggressive action in some areas might be able to compensate for areas that struggle to unlock near-term emission reductions.

The different models referenced above vary widely in their baseline assumptions, so it should be noted that none may yet offer policymakers a standalone, definitive answer for how best to proceed.[4] Yet, collectively, their findings are encouraging: they each find multiple pathways for how the Indo-Pacific can achieve carbon neutrality by around mid-century and that a 'one-size-fits-all' approach to national roadmaps is neither required nor inherently what delivers the deepest cuts at the lowest price point. Japan, for example, is expected to benefit from relatively flat energy demand growth that allows policymakers and developers to more fully direct their attention to replacing or upgrading current assets; at the same time, however, the country's high urban density and other spatial limits make some potential solutions (e.g. those involving large land-use footprints) more costly than in other markets (Kuwabara, 2021). In contrast, Indonesia, Viet Nam, and the Philippines are all expected to see sharp increases in their demands for energy and have better material conditions for at least considering the building out of new, large-scale clean energy production capacity instead of using more (increasingly imported) coal. Even so, country views as to what makes for the 'best' way(s) to do this are likely to vary, given differences in their respective renewable resource potentials (see Figure 3.1). Meanwhile, all models also take seriously that countries have articulated different target years for carbon neutrality – several of which extend beyond 2050 – and suggest options for compensating at a regional level, even as they also recommend ways to bring forward these dates.

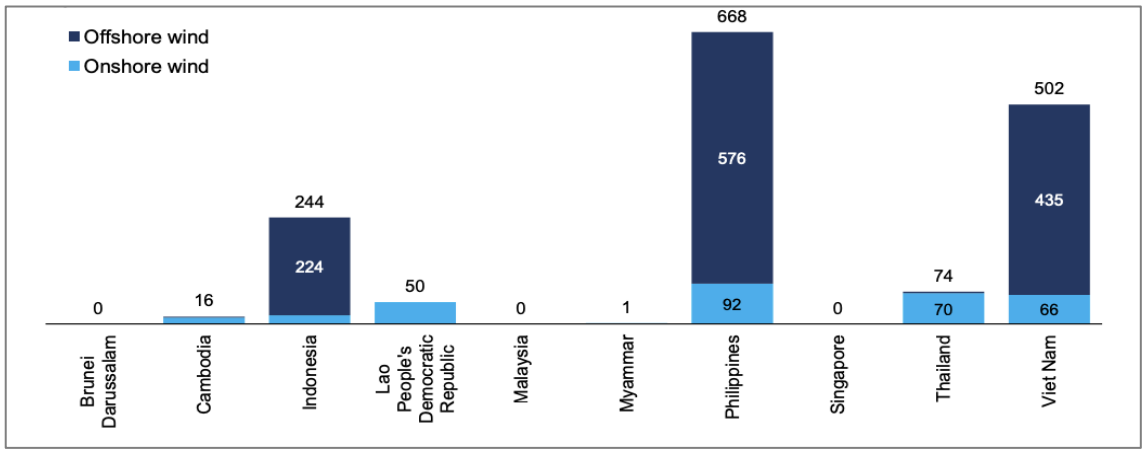
[4] For example, differences in assumptions about GDP and population growth lead to different expectations for overall energy demand in the models produced by the IEA and the IEEJ. See IEA and IEEJ, *Decarbonisation Pathways for Southeast Asia* (Paris, April 2023), https://www.iea.org/reports/decarbonisation-pathways-for-southeast-asia.

Figure 3.1. Solar Photovoltaic, Wind Power, and Hydropower Potential in Southeast Asia, by Country

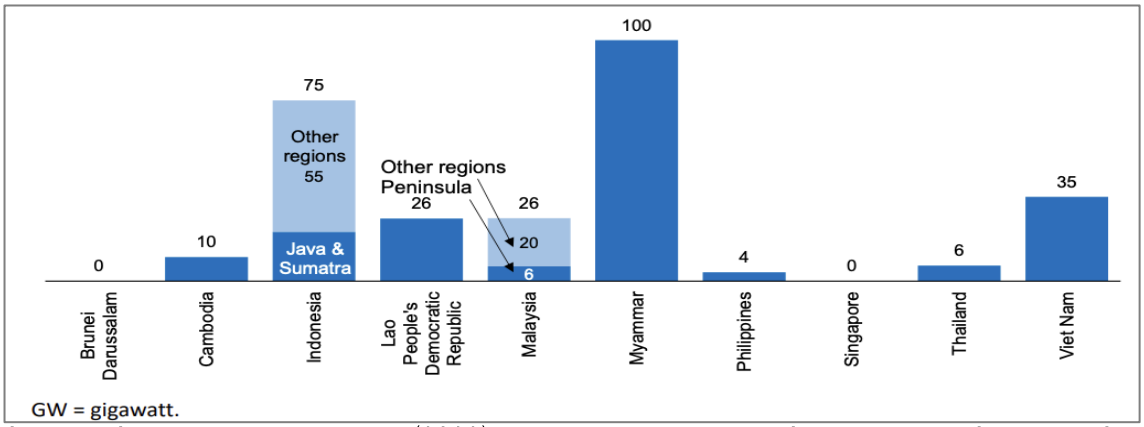
Solar PV



Wind Power



Hydropower



Source: Shigeru Kimura et al. (2022), 'Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060.'

But even with multiple pathways and a healthy respect for regional differences, some needs loom large across all scenarios. In the models cited above, this typically boils down to four essential transformations: achieving a carbon pollution–free power sector as soon as possible, promoting widespread electrification of other end-use sectors, aggressively pursuing energy efficiency, and minimising (if not fully eliminating) the unabated use of fossil fuels. Each of these ideas is explored in greater detail in the next four subsections.

1. Transformation #1: Achieving a Carbon Pollution–Free Power Mix as Soon as Possible

As noted earlier, the power sector is both the single largest source of the Indo-Pacific's energy-linked CO_2 emissions *and* the sector that appears to be most ripe for decarbonisation at scale. Thus, a concerted effort to reshape the Indo-Pacific's power mix could go a long way toward getting the region to carbon neutral – while achieving a carbon pollution–free power mix at an early date would also leave more space in the region's carbon budget for if other forms of energy use remain challenging to positively disrupt. To that end, the IEA's modeling sees a global deadline for decarbonising electricity: no later than 2035 in advanced economies and no later than 2040 in all the rest (IEA, 2022-d).

All of the regional models singled out above see this future power mix as one dominated by variable renewable energy sources. Solar energy in particular is expected to play a central role, providing anywhere between a quarter to over half of overall electricity supply on its own in the regional models of ERIA, APERC, and IEEJ. Likewise, power generation from wind is expected to be well-positioned for sharp growth, based on construction already underway and ongoing trends in declining project and generation costs. Combined, these two sources are generally expected to account for between two-thirds and three-quarters of the Indo-Pacific's overall mix by 2050 (Kimura, Phoumin, Purwanto, 2023; IEA and IEEJ, 2021; APERC, 2022). This is not to say that every country is expected to see robust domestic deployment of one or both of these technologies: Singapore, for example, has fairly weak domestic conditions for wind and solar energy (as might be gleaned from Figure 3.1). Thus, one of the key assumptions in the models above is also a country's potential to *import* electricity (and, in turn, its neighbours' potential to scale up and trade in excess generation from variable renewable sources).

Reducing lingering barriers to the region's use of variable renewable energy is thus a first-order task. Some of these barriers are, undeniably, technical, with (for example) breakthroughs in batteries or other storage tools needed to avoid potential imbalances between peak generation and peak energy demand times. Yet as suggested by numerous government officials and energy specialists interviewed for this report, a more prominent factor is arguably the role of targeted regulations (or the lack thereof) in shaping both what can be built and what can be used or otherwise traded.[5] Cambodia, for example, has

[5] Interviews with government officials, development bank representatives, and other clean energy specialists, in Bangkok, Thailand, and Phnom Penh, Cambodia, March 2023.

substantial solar energy potential – but up until very recently had no protocols for private generators to sell their excess power back to the grid (much less to foreign markets), thus curtailing how much might be usefully generated. Meanwhile, a natural corollary to this point is how the region's substantial coal assets fit into the picture; it will not be enough to ramp up renewable generation capacity if other factors curtail phasing out the use of coal. More bluntly, this involves resolving questions about not only who might absorb various costs associated with early shuttering of existing coal-fired power capacity but also when and how purchasing power agreements can shape the ways in which utilities and other stakeholders might even approach this challenge.

Beyond renewables, multiple models also give good credit to the region's strengths and long history of leveraging other tools for zero-carbon power generation. For example, the pathways for Japan, India, and the United States in the models above all envision that nuclear power can and will play a prominent role in supporting these countries' decarbonisation efforts. Alongside this, hydro energy is typically seen as playing a sustained (though not necessarily growing) role, especially within Southeast Asia. Even so, many of these models stress that delivering on expressed ambitions with these two sources will likely be challenging, as although these technologies are fairly mature, future deployment is expected to hinge upon first resolving lingering social license questions. Ultimately, though, all of this does suggest a robust range of tools for decarbonising the region's power sector. But for this decarbonisation to happen rapidly enough, sound public policy will still be needed.

2. Transformation #2: Electrifying End Uses

As power generation becomes cleaner, shifting other sectors to use electricity can also be a way of lowering their emissions. Key opportunities here include accelerating the rollout of electric cars, buses, and trucks in transportation; heat pumps in buildings; and furnaces in steel production. And, as suggested by the IEA's modeling in particular, the collective impact of these shifts can be substantial, even the equivalent of eliminating multiple countries' worth of CO_2 emissions – with China's potential emission reductions from greater EV deployment alone generating a savings in 2050 that is larger than Japan's current-day emissions (IEA, 2021-a). More broadly, the ADB estimates that by the end of the century, even in what are today the region's developing economies, electricity could be positioned to provide for over 70% of final energy needs (Raitzer et al., 2023). This potential scope for electrification, when combined with the prior subsection's endorsement that total decarbonisation of the power sector is within reach, is at the heart of what makes deep decarbonisation by 2050 viable.

A key challenge here will be that both developing and developed countries in the Indo-Pacific face obstacles in significantly electrifying their economies – and, in some cases, notable bottlenecks that, if not addressed, could undermine the reliability of power systems at large. This projected level of increase in electricity demand is anticipated to

require, for example, major expansions and transformations of transmission and distribution systems to connect existing networks to sites of newly installed capacity (e.g. offshore wind), as well as to add or improve access in underserved communities. Greater reliance on variable energy sources, coupled with the aforementioned surge in EVs, is also expected to increase requirements for flexibility in electrical systems. If not addressed, this issue could make power supply and delivery less stable (and then energy access more subject to interruption) (Wogan, 2023). In short, for electrification to be a viable pillar of decarbonisation, it will need to be done in ways that avoid straining these underlying systems.

3. Transformation #3: Getting Aggressive on Energy Efficiency

Greater attention to energy efficiency improvements can be a way of reducing such strains, as it promises a way of getting more out of the same (or even lower) levels of inputs. It is also often termed the 'low-hanging' fruit of clean energy transitions, as a wide range of possible solutions are already commercially available and can be quickly scaled up (IEA, 2021-b). Thus, energy efficiency is not only an important but an essential part of any decarbonisation strategy. To this point, the ADB's model of developing Asia's net-zero pathways suggests that energy efficiency improvements most likely make up around 40% of the subregion's emissions reduction potential through 2030 (Raitzer et al., 2023).

There is significant scope for realising greater efficiencies in all the major energy end-use sectors discussed in this report. To begin where the last section ended, efforts expected to help alleviate strains on grid and transmission infrastructure include new demand management strategies as well as targeted hardware and software upgrades; the 'digitalisation of energy' is just one example of an undertaking that combines all three of these elements (IEA and KEEI, 2021). Alongside this, other end-use sectors can reduce their final demands for electricity via pursuing their own upgrades. In buildings, this can include installing high-efficiency heating, ventilation, and air conditioning systems; using more efficient appliances; and making improvements to the building envelope (e.g. roofing, siding, and windows). Beyond focusing on how to use electricity more efficiently, the ADB and APERC also take care to note that in their models, several sectors – notably industry – are seen as able to lower their overall demands for energy by deploying materials with improved durability, enabling multi-use and reuse of existing assets (ADB, 2023; APERC, 2022). Last, in transportation, there are a wide range of tools that might be better deployed to help diverse communities to 'avoid, shift, or improve' their oil-linked consumption. This essay has already alluded to one of them (i.e. expanding mass transit systems), while improving pass ways for pedestrians and cyclists can be another. Several countries also have vehicle fuel-efficiency standards that are weaker than those of the European Union and China. Raising relevant standards here in line with what others are already doing is a notable energy savings opportunity – and is something that should not be neglected.

In terms of what an 'aggressive' push looks like, most models assume that what can (and will need to) occur is on the order of an exponential increase in efforts. The ASEAN Centre for Energy, for example, has suggested that Southeast Asia will need to double its current commercial and industrial sector energy-savings efforts to stay on a mid-century decarbonisation pathway (ACE, 2022). Even so, in a December 2022 workshop conducted by the National Bureau of Asian Research (NBR) and the ERIA as part of this study, energy specialists drawn from East Asia Summit (EAS) countries stressed that the EAS's plus-seven economies – that is, the United States, China, India, Japan, Korea, Australia, and New Zealand – would collectively need to push even more aggressively than Southeast Asia ('Getting to Net-Zero,' 2022). This is a reflection of the fact that not only do these countries collectively represent a larger share of regional energy consumption, but also that most have extensive, highly ambitious efficiency initiatives already in place, making breaking new ground relatively more challenging – yet no less imperative.

4. Transformation #4: Minimising the Use of Fossil Fuels

Prior sections have hinted at, but largely skirted, the big question: how much of a role can coal, oil, or even natural gas play in the region's energy mix amid decarbonisation? As suggested by this section's title, many of the models above envision a future in which the use of fossil fuels is minimised. Yet they hold different (and sometimes wildly different) views about what this might look like.

For coal, most models see region-wide consumption as needing to fall dramatically by mid-century – such as by two-thirds in the ERIA's model – but are then more divided on how they see this as translating into specific country and subregional contributions. In looking at Southeast Asia, for example, both the IEA's and the IEEJ's net-zero modeling see the subregion's coal consumption as peaking and then declining, but the IEEJ's model envisions a 'faster and more immediate decline' as both possible and better positioning the region for overall success (IEA and IEEJ, 2023). India's consumption is, likewise, seen as declining but with different models coming to different conclusions about how steep a decline is viable (given, amongst other things, variations in assumptions about available resources). In some areas of the region, though, expectations are less ambiguous: as 65% of the region's current-day coal consumption is linked to China, only large-scale reductions in this country make the above regional numbers work (Kimura, Phoumin, Purwanto, 2023). Likewise, the United States is expected to see coal use in the power sector 'essentially eliminated by 2030' in both the ERIA and Princeton models (Kimura, Phoumin, and Purwanto, 2023; Larson et al., 2021). Even so, qualifiers (and debates) about the country's ongoing industrial coal usage remain.

Views about the outlook for oil are even more divided. In developing Asia, for example, several models disagree as to whether these countries will even see a peak in oil consumption by 2050, while the IEEJ's model also envisions 2050 consumption that is twice that of the IEA's model (IEA and IEEJ, 2023). The challenge here, then, is in easily assessing if a particular geography (much less the wider region) is on track and, in turn,

how aggressively they might need to pursue additional efforts to avoid, shift, or improve oil-linked energy consumption.

Amid the above trends, there is also one fossil fuel often held up as an option where greater consumption might not necessarily add to net overall emissions: natural gas. Natural gas has played an important role in backing out coal requirements in the power sector as well as backing out oil requirements in some areas of medium- and heavy-duty transportation, lowering the emissions profile of these activities as a result. It is also regularly floated as a potential backup for variable renewable energy, as its generation can be ramped up or down as needed (IEA, 2022-d; IEA and KEEI, 2021). That being said, few net-zero models envision a net-zero era as a golden age for gas – with declining demand in Korea, the United States, and the rest of the Indo-Pacific being a 'matter of when, rather than if,' as aptly put by NBR advisor Jeanne Choi. She continues by adding that, even as natural gas may still have a role to play in the region's energy security strategies, '[t]he underlying assumptions are that gas consumption will eventually have to decrease in a decarbonizing world' (Choi, 2022).

It is important to note explicitly, though, that in none of the models above is the use of oil, natural gas, or even coal expected to be fully eliminated by 2050. Thus, even as decision-makers look at how to maximise the roles that wind, solar, hydro, geothermal, and nuclear energy play in a country's energy strategies, there is a strong case for continued attention to how to reduce emissions from fossil sources. In this context, carbon capture, utilisation, and storage (CCUS) is often held up as a game-changer, providing solutions in areas where fuel switching is less viable (e.g. cement) as well as an option for retrofitting existing assets to minimise (if not fully eliminate) their emissions. Perhaps not surprisingly, it thus features prominently in the modeling of net-zero pathways for several economies, with all of Princeton's pathways for the United States relying on large-scale CCUS (Larson et al. 2021). ADB's, IEEJ's, and ERIA's modeling also envisions it as a potentially cost-effective means to more rapidly decarbonise developing Asia's power and transit sectors (Raitzer, Pradhananga, Tian, 2023; IEA and IEEJ, 2021; Kimura, Phoumin, and Purwanto, 2023; Kimura et al., 2022). In each of these scenarios, a key objective is arguably not just fully eliminating carbon emissions by a given date. It is also to maximise *aggregate* emissions avoided in the interim, to avoid overshooting the region's carbon budget.

5. What Role for Hydrogen?

Although it doesn't fit cleanly into any of the above transformations, hydrogen is worthy of special mention because it arguably cuts across multiple transformations and, in some cases, provides partial alternatives. Hydrogen and hydrogen-based fuels can 'fill gaps where electricity cannot easily or economically replace fossil fuels,' including in several areas associated with transportation (e.g. ships and planes) and industry (e.g. steel and chemical production) (IEA, 2021-b). As observed by the IEA, '[w]ith increasing shares of variable renewables in the electricity generation mix, [hydrogen] is also one of the few

technology options for storing large amounts of electricity over days, weeks, or even months' (IEA, 2021-a).

How much of a role for hydrogen might be possible is something that many energy models treat as an open question, subject to significant upward or downward revision based on how its market development progresses in the near term. To that end, several countries – including China, India, Singapore, Japan, Korea, and the United States – have already developed hydrogen-promotion strategies, while others are actively reviewing their own planning needs. Even so, the future of hydrogen remains uncertain because it requires substantial investments and the creation of new supply chains. As aptly put in a prior report for the Energy Research Institutes Network, '[e]ven when a country successfully utilises hydrogen, [a] limited market size could increase hydrogen supply cost, hinder opportunity for innovation, and fail to make it a sustainable economic growth engine' (ERIN, 2019). Meanwhile, for hydrogen to contribute to CO_2 emission reductions at the scale that countries are striving to unlock, it must ultimately be produced from low-carbon energy sources – suggesting an area where its fate will be tied to progress on the other transformations suggested in this report.

6. Getting the Rest of the Way to Zero

The above efforts are intended to serve as a comprehensive, but not necessarily exhaustive, list of the transformations that can deeply decarbonise the Indo-Pacific's energy systems. Even so, an exhaustive list is not expected to show the region's energy systems as truly carbon-emission-free – especially by 2050. APERC's Carbon Neutral Scenario, for example, envisions that energy-linked emissions amongst the member economies of the Asia-Pacific Economic Cooperation (APEC) can fall to one-third of 2020 levels by 2050 – a scenario in which they will still emit 7,000 million tons of CO_2 annually (APERC, 2022). Likewise, models produced by the ERIA, the IEEJ, and Princeton all project a gap between minimised emissions output and zero emissions output from energy use (Kimura, Phoumin, and Purwanto, 2023; IEA and IEEJ, 2022; Larson et al., 2021).[6]

What is expected to close this gap, in part, are efforts that deliver 'negative' emissions – removing CO_2 already in the atmosphere and then sequestering or putting it to other use. Engineered solutions – such as direct-air capture or bioenergy with carbon capture and storage (CCS) – are one way of doing this. Other tools include natural climate solutions, such as tree planting and land-use changes. Notably, several of these tools also benefit initiatives designed to help communities mitigate and adapt to climate change, which, while beyond the scope of this report, suggest ways they can deliver additional value to decision-makers.

The uncomfortable and challenging question, though, is how much these solutions can

[6] Some of this can be explained by countries that have set decarbonisation dates that fall after mid-century. Even so, some sectors (e.g. industry) face material constraints that may be fundamentally difficult to overcome.

(much less 'should') be counted on to close lingering gaps. To this point, in May 2023, the United Nations' Article 6.4 Supervisory Body released its own harsh assessment of engineering-based removal activities to date, describing them as 'technologically and economically unproven, especially at scale, and pos[ing] unknown environmental and social risks' (UNFCCC, 2023). While other groups – including within the United Nations – were quick to push back on this assessment, it nonetheless touches upon a question still debated by both critics and advocates alike: how to best manage expectations about what it will take (and what it might then look like) to maximise these technologies' mid-century contributions to regional decarbonisation.

Natural climate solutions also face their own limitations. One is the scale required for impact: the United States, for example, would need to plant roughly two billion trees to reduce its annual carbon emissions by 1%. Alongside this is the concern that, to the extent climate change remains unchecked, these solutions deliver diminishing returns (e.g. as declining soil quality can leave trees less able to absorb carbon) (Moseman, Harvey, and Terrer, 2024). Land-use changes can also produce their own emissions (e.g. in the clearing of existing vegetation), something that will need to be addressed.

The above is not intended to discourage the pursuit of negative emission tools. Indeed, they will be vital to both widening the path to zero as well as dealing with the immense amount of environmental damage that has already been done. Moreover, some of the concerns noted in this subsection – particularly for near-term viability, scalability, and affordability – also apply to other emerging technologies. Rather, the cautions presented here are intended to serve as a reminder that sound national and regional decarbonisation strategies will ultimately need to be comprehensive in nature. That is: there is no silver bullet that eliminates the need to pursue systemic change.

7. Implications for the Indo-Pacific's Energy Security

This section has sought to show what the Indo-Pacific's pathways to carbon neutrality might look like and, in doing so, sought to underscore two key points. First, many of the solutions that will be needed are already at least technically viable. Here, a key challenge will be deploying these solutions at the scale and speed envisioned, and doing so without increasing strains on the region's energy systems, whether these strains are physical or financial in nature.

Second, some solutions will require new breakthroughs, often not only in terms of technical viability but also in associated market conditions. In turn, unlocking some breakthroughs might be able to support a virtuous cycle in which other breakthroughs accelerate, as progress in one area (e.g. power-sector decarbonisation) might make another solution (e.g. electric or hydrogen-fueled vehicles) able to deliver greater emission savings. But, much like with the first point, the specifics of how decision-makers approach this potential matter greatly. As aptly put by one expert interviewed for this report, some of the solutions proposed above have early decision inflection points, such as prioritising nuclear over variable renewables, and it is unclear if you can switch

pathways repeatedly without having to push out decarbonisation timelines ('Getting to Net-Zero,' 2022). Decision-makers will thus need to carefully consider what pathway(s) they want to prioritise, and back these efforts with resources accordingly.

What, then, does all of this mean for thinking about where decarbonisation can fit into the region's largest energy security goals? Here, virtually all the models above see decarbonisation as leading to incredible, additional net benefits. The models of ERIA, IEEJ, and the IEA, for example, see this transition as producing substantial energy savings and, in turn, sharp declines in spending on fossil fuels that a follow-on study by ERIA estimates is collectively on the order of billions of dollars for the region in 2050 alone (Kimura, Phoumin, and Purwanto, 2023; IEA and IEEJ, 2023; Kimura, Phoumin, and Purwanto, forthcoming). Electricity consumption *does* still grow – and in fact, significantly more than under business-as-usual – but nonetheless appears well-positioned to become more affordable, with modeling by the IEA seeing encouraging signs (but not guarantees) of decarbonisation supporting declines in household electricity prices (IEA, 2022-a).

Early action is also seen as a force multiplier. Not only does it then leave the widest possible pathway to net zero available, but in several of the models above it also substantially reduces the costs of getting there. To that end, modeling by the ADB on developing Asia suggests that if aggressive decarbonisation were to start immediately (versus a delay of less than ten years), its overall cost through 2050 could be reduced somewhere between 10%–20% (Raitzer et al., 2023). The models by Princeton University also draw attention to ways in which first movers can realise additional economic benefits from championing the rise of new industries, including in GDP growth (Larson et. al, 2021).

This future, however, is not without potential risks. The previous section alluded to the idea that clean energy transitions can be a way for countries to increase their self-sufficiency. The models cited here suggest that while there is an extent to which this is true, it is not the full picture. Several of the scenarios outlined above envision a prominent role for international trade in helping to bolster affordability and viability – meaning the risk of market weaponisation undercutting a country's energy security may still be present in this future decarbonised world. Even more distressing is that, under the wrong conditions, decarbonisation efforts could also fail to deliver the emission reductions that they promise. In several of the models noted above, greater levels of demand for batteries to support EVs and other low-carbon technologies, for example, are expected to incentivise increased mining in Australia, China, Viet Nam, Indonesia, and the United States, which will produce its own CO_2 emissions and need to be addressed (APERC, 2022; Larson et. al, 2021).

All of this should serve as a reminder that while there are ways to get the region to net zero, doing so is expected to *require* a well thought-out approach to disrupting the status quo. What successful efforts might look like are explored in the next section.

Chapter 4
The Tools That Support Ambitions

Shifting from business as usual to a radically different system for energy supply, demand, and investment begins with articulating a clear vision for this future. Here, and as alluded to at the outset of this report, leaderships in several capitals are already rising to the challenge. Some countries remain at the stage of a broad declaration of intent to achieve net-zero carbon or overall greenhouse gas emissions by a certain year, while others such as Korea have enshrined their timelines in national legislation.[7] Some countries have also progressed toward producing a detailed national roadmap that breaks down targets for specific sectors (e.g. 100% carbon-pollution-free power generation by 2035, for the United States) or for economy-wide goals (e.g. to peak oil consumption during 2026–30, for China). At the same time, many plans nonetheless leave open-ended the exact contributions of individual technologies or fuels. This is typically with a nod to the idea that policymaking will seek to remove barriers to deploying clean energy solutions, but that markets will determine the relative uptake of particular tools, enabling groups to pursue maximum reductions at the lowest costs.

How do these visions stack up against the suggested transformations in the prior section? Many have substantial and encouraging areas of overlap in goals and tactics, such as prioritising energy efficiency. However, many also feature notable divergences – including (but not only) in their target dates for power-sector decarbonisation. Several have also been criticised for how and where they envision fossil fuels still playing a role in this future. This does not necessarily make these plans incompatible with getting the region to net-zero by mid-century. Some are, for example, more bullish on their ambitions for deploying certain solutions at a larger scale. Even so, assessments by the UN Economic and Social Commission for Asia and the Pacific (UNESCAP), Climate Action Tracker, and others have nonetheless cautioned needs for ongoing attention to at least two points. The first is the need for additional technical review of these plans, which might identify requirements for specific revisions (and where regional modeling may then, in turn, need to reconcile expectations around likely supply and demand for trade in clean energy). The second is that, even if no such revisions were identified, much of the region has not yet updated their climate action pledges under the Paris Agreement – much less their broader suite of energy policies – to align them with these visions.[8] In short, there are real questions about the actual implementation of these plans and what that should look like.

Thus, what comes next is the tricky part: moving from 'what and when' to 'how.' As

[7] It should also be noted that even when reduction targets have been codified in national law, they are not necessarily binding.

[8] See, for example, commentaries in Climate Action Tracker, 'CAT Net Zero Target Evaluations,' Climate Action Tracker, 14 December 2023, https://climateactiontracker.org/global/cat-net-zero-target-evaluations; UNESCAP, 'The Race to Net Zero: Accelerating Climate Action in Asia and the Pacific,' https://www.unescap.org/kp/2023/race-net-zero-accelerating-climate-action-asia-and-pacific.

explored in the following subsections, a number of measures can help decision-makers to navigate this path, including advancing comprehensive policy frameworks, 'quality' infrastructure, innovation, capacity building, and security of supply. And doing all of this, in turn, will require quite a lot of capital investment.

1. Policy Frameworks

As a starting point, for decarbonisation strategies to deliver energy security, they will need to be backed by meaningful frameworks for coordinating the efforts of a wide range of essential stakeholders. Ministries of energy, environment, commerce, and finance, for example, will need to align and sometimes jointly execute major initiatives (Anbumozhi, Setyawati, Aquary, 2022). The private sector, too, will be an important and necessary partner in this process, both in terms of identifying and resolving barriers to commercialising cleaner consumption tools and supporting actual deployment. Alongside this, well-designed frameworks are also vital to sending clear signals to markets about incentives as well as regulatory outlooks, so that additional audiences can also prepare for change.

A review by scholars at the ASEAN Centre for Energy notes that although the nature of such frameworks is 'qualitative and difficult to compare across countries, several initiatives attempt to conceptualise best practices' (Abdullah et al., 2023). One such prominent example is the World Bank's 'Regulatory Indicators for Sustainable Energy' index, which offers metrics for evaluating the health of regulatory frameworks in particular. Amongst other things, such metrics include how and if they are underpinned by legal frameworks; detail network policies, including rate structures; address counterparty risks; and enable monitoring and evaluation.

In applying its rating system to the Indo-Pacific, the World Bank in turn finds good reason to praise the efforts of a diverse range of countries: Korea and India, for example, both score highly in several areas associated with energy efficiency (including on incentives and mandates for industrial and commercial users), while Viet Nam and Thailand are singled out for their formal planning for renewable energy expansion. The index, however, also highlights several deficiencies in policy environments at large. This includes, for example, that only a handful of countries score above 70 (out of 100) on their network access and usage policies.[9]

Addressing such deficiencies is likely to require notable reforms, including the introduction of greater transparency and competitive pressures into markets and, in

[9] Data in this section is derived from the World Bank's interactive 'Regulatory Indicators for Sustainable Energy' index, with 2021 being the last year covered in this analysis as of when this essay went to press. Energy Sector Management Assistance Program, 'Rise: Regulatory Indicators for Sustainable Energy,' World Bank, 2022, https://rise.esmap.org/analytics. For additional narrative on these evaluations, see also Energy Sector Management Assistance Program, 'Rise 2022: Building Resilience,' World Bank, November 2022, https://rise.esmap.org/data/files/reports/2022/RISE%202022%20Report%20Building%20Resilience.pdf.

some cases, major overhauls of utility operations as well as national legislation. Such tasks are not only disruptive by design, but can be painful in the short term – and, as such, carry the risk of undercutting domestic support for clean energy transitions (especially, but not only, amongst the public). Well-designed frameworks thus also need to incorporate one more feature: robust mechanisms for receiving as well as responding to feedback. Although this may not be the same thing as *guaranteeing* social license to operate, it can be a critical way of building and maintaining such support.

2. Infrastructure

Even with robust attention to improving regulatory and operational environments, available infrastructure can nonetheless shape how easily countries can shift to cleaner energy consumption patterns. As suggested by earlier sections, some of the most pronounced needs involve building out significant new generative capacity, extending transmission and distribution infrastructure, and advancing systemic modernisations to account for more variable electricity supply and demand patterns. Greater utilisation of hydrogen will also require that specific structures first be in place, so that available supplies can reach where they are needed (IEA, 2021-a). Likewise, EVs require access to means for recharging on the go, which will need to be scaled up alongside a wider redesign of roadway infrastructure to better enable safe pass ways for walking and cycling.

A coherent approach to these disparate needs requires explicit attention to the importance of prioritising 'quality' infrastructure – that is, not just building more infrastructure on an accelerated timeline, but targeting interventions in ways that deliver maximum value-for-money. Here, Japan stands out as a prominent example of what this can look like, given its longstanding attention to centering flexibility, durability, and inclusivity in development choices – as well as its consideration of when and how to repurpose existing assets, to use resources most efficiently. Alongside this, it is also closely cooperating with Korea, Australia, and the United States, amongst others, to support Southeast Asia in designing and advancing similar efforts.

Several of those interviewed for this report also stressed that flexibility in infrastructure is about more than (and sometimes different from) just deploying 'next-generation' technologies ('Getting to Net-Zero,' 2022; 'International Trade and the Energy Transition,' 2023). For example, power plant operators can navigate unanticipated spikes in power demand or drops in supplies by maintaining high reserve margins. Yet as underscored in prior reporting by ERIA, increasing reserve margins can also raise costs for consumers and, if regularly underutilised, undercut cost recovery and discourage needed investment ('Getting to Net-Zero,' 2022).[10] Thus, another important and complementary way of increasing systemic flexibility is expanding overall balancing areas – that is, building robust interconnections between different grids. To that end, Lao PDR, Thailand,

[10] In the case of variable renewable energy, there are also notable limitations on how excess supplies can be stored even *with* use of the latest technologies.

Singapore, and Malaysia are currently collaborating on a cross-border project that, amongst other things, has been a watershed moment in Singapore's ability to import electricity generated via renewable energy (to date: from hydro power). Similar cross-border grid integration and electricity trade efforts are also underway that involve India and its South Asian neighbors, while various governments and research institutes have expressed at least conceptual interest in the idea of establishing an 'Asian super grid.'

New infrastructure will be vital to unlocking the region's decarbonisation potential. Yet alongside this buildout, the retirement of existing infrastructure will also need to be carefully considered to ensure a 'secure journey to net zero' (IEA, 2022-b). A suggestive example here from the United States involves New York City's electrical grid, with policymakers currently grappling with how to avoid a disruption in power supply amid what popular reporting has characterised as an emerging 'gap between the shuttering of high-polluting power plants in 2025 and a new transmission line from Canada in 2026' (French, 2023). The suggestion here is not that communities should curtail their ambitions for bold transformations. Rather, it is to underscore that these transformations will require an intentional approach to sequencing, and close attention to the tools that are available at different moments in this process.

3. Innovation

In the longer term, some limitations of existing technologies and tools do loom large. As suggested earlier, enhanced energy storage will be critical to supporting greater reliance on variable renewable energy in line with the maximal targets being set in the region. In tandem, technology performance and material efficiency improvements will be critical to unlocking additional decarbonisation pathways, particularly within hard-to-abate sectors. This includes within areas associated with leveraging hydrogen to support 'green' steel production as well as deploying CCS more widely ('Getting to Net-Zero,' 2022).

Innovation is a strength of the Indo-Pacific at large, and numerous countries have robust competitive strengths in one or more areas closely associated with these desired breakthroughs. South Korean firms have distinguished themselves in the ability to produce highly advanced batteries, for example, while the United States' national laboratories have been key drivers of breakthroughs in areas such as energy efficiency and hydrogen storage. China, Viet Nam, and Japan, amongst others, also have formalised industrial clusters that bring together researchers, private developers, and other specialists of different technology backgrounds, something the IEA has characterised as a way of encouraging additional flows of knowledge across fields (IEA, 2021-a). Last, numerous governments are also leveraging their ability to provide grants, tax relief, and other fiscal incentives, as well their status as major technology procurers, to incentivise additional attention to their preferred clean energy solutions. The introduction of this essay has already alluded to the large-scale efforts of the government of China and, more recently, the United States, while Japan, Korea, and India, amongst others, are also highly active here.

A challenging question here involves how to make the 'right' bets on innovation, given an

environment where there are advantages but also risks in being a first-mover. To stay on what role governments might play in this space, industrial policy is often viewed as a way of altering this risk profile for otherwise interested firms and developers – yet it has a spotty track record of project-level success. That being said, even when multiple national bets do not pay off, ambitious industrial policies covering a wide range of technologies and structural needs can still yield significant net benefits – including in job creation – as various reviews of green stimulus measures implemented after the 2008 financial crisis have suggested.[11] As countries such as the United States look to operationalise and even enhance their current industrial policies, this finding should encourage decision-makers to regularly review key programs, adjust focus as needed, and be willing to bet big on innovation. But, it should also not distract from the fact that when attempting to rapidly achieve breakthroughs, multi-country coordination and collaboration can be a strong asset. This is also true when it comes time to then commercialise and ultimately deploy these innovations on a large scale.

4. Security of Supply

As prior sections have alluded to, clean energy transitions are likely to transform, not eliminate, how countries might experience energy insecurity. More precisely, APERC, the IEA, and others have regularly underlined that while their decarbonisation models find reduced demand for fossil fuels, their greater electrification and utilisation of renewable energy sources is expected to lead to a surge in demand for various raw materials (APERC, 2022; IEA 2022-c). Transmission and distribution lines, for example, have notable needs for copper, while lithium-ion batteries require both lithium and cobalt (IEA, 2021-a). And, in these models, the amount of materials needed is expected to well-exceed current trajectories for production growth. Exploitation of many of these materials has also been heavily concentrated in a small handful of countries, producing anxiety in some importers about their heightened exposure to potential supply shocks.[12]

Here, several countries – including Indonesia, the United States, and Australia – have announced ambitious strategies for boosting their capacity in relevant areas of critical mineral production, extraction, and processing. Yet, to an extent, such efforts may still only move so quickly. According to an analysis conducted by the IEA, in recent years it has taken *successful* mining projects an average of over 16 years to reach first production

[11] See, for example, prior analyses by ERIA and the IEA on this topic. Venkatachalam Anbumozhi, Kaliappa Kalirajan, and Xianbin Yao (2022), 'Assessing the Impacts of COVID-19: Regional Policies and Practices for Green Recovery,' ERIA, June 2022, https://www.eria.org/uploads/media/Books/2022-Assessinng-the-Impact-of-COVID-19-for-Green-Recovery/Assessing-the-Impacts-of-COVID-19-Green-Recovery.pdf.; Laszlo Varro, Sylvia Beyer, Peter Journeay-Kaler, and Kathleen Gaffney (2020), 'Green Stimulus after the 2008 Crisis: Learning from Successes and Failures,' IEA, 29 June 2020, https://www.iea.org/articles/green-stimulus-after-the-2008-crisis

[12] More on this dynamics of this topic is explored in, Sharon E. Burke, Llewelyn Hughes, Phung Quoc Huy, Kristin Vekasi and Yu-Hsuan Wu (2022), 'Critical Minerals: Global Supply Chains and Indo-Pacific Geopolitics,' NBR, 2022, https://www.nbr.org/wp-content/uploads/pdfs/publications/sr102_criticalminerals_dec2022.pdf.

(IEA, 2022-c).[13] Complementary initiatives to encourage strategic stockpiling as well as material recycling are thus also necessary, with Japan and Korea both having successful histories here that others in the region might look to. Such initiatives, however, 'can be expensive and hard to implement,' as a working paper commissioned by the Government of Indonesia has observed in its own review (Afifi et al., 2022). Thus, in some cases, they may only become viable if multiple countries are able to successfully coordinate in scaling up projects – and sharing in their expenses.

Last, and in returning to the earlier comments of Jeanne Choi, in a world where the use of fossil fuels is minimised – but not eliminated – both governments and industry will need to grapple with what 'responsible' production would need to look like. This is not an easy determination to make, and something that Indonesia, Australia, and the United States, amongst others, are currently grappling with on a large and existential scale. Though no consensus answers have emerged on this question, one of its starting points mirrors a recommendation that applies to critical minerals and to mining at large: that access to robust, complete, and accurate industry reporting – including (but not only) on things such as their economic, environmental, social, and governance practices – is essential for navigating these determinations.

5. Capacity Building

Pulling off the above requires ensuring that people – not just systems – are ready for change. This is especially (but not only) true of supporting those who will be expected to execute, manage, and adjust the above approaches. Here, and as detailed in a prior NBR study for ERIN, '[l]ags in skill training and other forms of knowledge transfer, for example, have contributed to misconceptions amongst grid operators about existing means for managing variable energy sources' (Gillispie et al., 2021). These gaps can also be a limiting factor on what additional projects can be brought to scale – and by whom. To this last point, an econometric model commissioned by the Asia Society has suggested that decarbonisation could create over 30 million new jobs in the Indo-Pacific by 2060 (ASPI, 2023). Thus, not surprisingly, many governments are keen to see that their citizens are not left out of these opportunities.

Universities, trade schools, and community colleges all play important roles in capacity building, as does the private sector. Alongside this, several more recently established efforts are also seeking to more rapidly close lingering gaps, particularly in the region's developing economies. These efforts include the following examples: directly supporting governments in bolstering their data collection and energy planning processes (the Japanese Ministry of Economy, Trade and Industry's 'Asia Energy Transition Initiative');

[13] Although it should be noted that these strategic initiatives do hope to realise an accelerated timeline, many domestic and international groups engaged in these markets have nonetheless stressed that having high standards around environmental reviews and labor protection should also be a priority – and are considerations that require time and attention to ensure See, for example, discussions in Burke et al., 2022.

providing individuals and firms with free access to high-quality training modules (the ASEAN Centre for Energy's 'Asian Clean Energy Capacity Building Network'); and enabling direct networking and knowledge exchanges between rising leaders and established experts (the United States' 'Clean EDGE Asia' program). These diverse efforts both augment and complement one another, and in the coming years might be further strengthened through greater direct coordination.

Still, though, a lingering question remains of how to best support those negatively impacted by disruptions. In comparing the results of its Current Policies Scenario and Accelerated Net Zero Scenario, ADB modeling suggests that between now and 2050, clean energy transitions could result in the elimination of roughly 1.4 million coal jobs in developing Asia alone (Raitzer et al., 2023; Garrido and Hughes, 2023). Many such lost jobs are also expected to be disproportionately rural while new clean energy jobs are expected to be disproportionately in urban areas, meaning that near-term opportunities to directly transition to new industries may be limited by locational as well as reskilling needs. Thus, the ADB's analysis also stresses that '[d]uring the transition, social protection, including unemployment benefit schemes, are needed so that workers can smoothly transition to new job opportunities' (Raitzer et al., 2023).

6. Critical Investment

So far, this report has been relatively silent on one critical point: that collectively, the above efforts are expected to require incredible amounts of capital. For example, the ADB estimates that its Accelerated Global Net Zero scenario would require an estimated $707 billion in annual investment in developing Asia's power sector alone. This includes '$345 billion [... in investment] in renewable sources of energy, $282 billion in transmission and distribution network and storage to facilitate the increase in power from renewables, and $74 billion in fossil fuel with CCS' (Raitzer et al., 2023). Though prior sections of this report have sought to stress that decarbonisation strategies can lead to substantial savings and new economic opportunities, how and to what extent different countries might be able to secure the upfront capital necessary to pull off these projects is the trillion dollar question.

While investment in green energy and related heavy industries in Asia has doubled over the last decade, the pace and scope of such investment growth is still well short of being able to cover the region's projected capital requirements (Kumra et al., 2022; 'Getting to Net-Zero,' 2022). This gap in financing is more prominent in some areas than others. For example, while investment in wind and solar generation as well as electrifying transport continues to pick up steam, investment in relevant grid and transmission infrastructure has not received similar investor interest (IEA, 2023-a; IEA, 2023-b). Similarly, the ADB estimates that about '80% of all clean electricity supply investments were concentrated in advanced economies and the PRC [i.e. China]' (Raitzer et al., 2023). For this to work, more needs to be done in the developing economies of India and Southeast Asia.

The challenge in addressing these gaps is not a lack of potential investors to tap, but

rather, as a previous section alluded to, obstacles to making these projects 'bankable.' As the ADB has shrewdly observed, '[r]enewable energy projects have higher front-loaded costs than fossil projects and are more capital intensive. Viability depends on reversible policies and complementary investments in grid integration, which amplifies political and regulatory risks' (Raitzer et al., 2023). Likewise, the IEA and the Centre for Climate Finance & Investment at Imperial College London have singled out underdeveloped supply chains as undermining project fundamentals (IEA and Imperial College London, 2023). More broadly, some projects may also 'depend on new technologies or technologies that are new to the project context, which increases technological risks' (Raitzer et al., 2023). While clean energy projects can be attractive when these concerns are addressed, as might be inferred from the examples given here, the success of such undertakings will, in turn, be closely intertwined with how much progress is made in other areas covered in this section.

A green investment push alone is also unlikely to fully address concerns about how to make the region's energy systems more 'sustainable,' as it may still discount the costs of inaction. For example, an earlier section pointed to the societal costs of air pollution, which can be a byproduct of a disconnect between who enjoys the benefits and who bears the costs of implementing (and maintaining) systemic upgrades. Thus, several studies have pointed to the needs for and benefits of carbon-pricing mechanisms in helping to clarify these signals; in turn, the revenues generated by these mechanisms can then be recycled into various strategic initiatives (including as new funding for various decarbonisation projects) (ADB, 2022-b; Carbon Pricing Leadership Coalition, 2021). What this might like could take several forms, with China, Korea, New Zealand, and several US states, amongst others, currently experimenting with emissions trading systems, while Singapore has implemented a carbon tax. Still, though, an important caution is that the direct effects of carbon pricing can be regressive – that is, their costs can be a larger burden on small firms and low-income groups, who may also have more limited access to tools to avoid, shift, or improve their energy consumption. To ensure that these pricing schemes are in line with the vision of a 'just' transition, governments may thus also want to consider using some of these revenues to mitigate strains on these groups.

Last, this report has repeatedly sought to stress that the early retirement of coal-fired power plants is both a social and an economic challenge, with governments facing difficult questions about how to handle cost-recovery concerns. To that end, in the past three years alone, several innovative financing mechanisms have been established for just such a purpose, including Just Energy Transition Partnerships in India, Indonesia, and Viet Nam. Still, as of this writing, governments and other stakeholders in several of these countries have expressed real and important concerns about the types and levels of funding currently available to them under these programs, and in turn if more can and should be done to assist these coal-exposed countries in making a just transition.

Chapter 5

Roles and Requirements for Effective International Coordination

Multiple sections above have touched upon the idea that while national 'net-zero' roadmaps will inevitably vary, international cooperation is both an expected and necessary part of unlocking many decarbonisation pathways. Such cooperation can, for example, help countries to achieve outcomes that might otherwise be economically or technically prohibitive to pursue on an individual basis. It can also help them with weathering supply shocks as well as boost overall flexibility, by expanding balancing areas and allowing for efficient resource sharing. Yet all of this, in turn, is closely intertwined with a point suggested by this essay's earlier discussion on hydrogen – that these ambitions suggest a future that is contingent upon a notable degree of interoperability in regional energy architecture. This includes not only in regulatory approaches but in other fundamentals such as technical standards. Likewise, private sector and civil society interest in cooperation is less meaningful if specific projects nonetheless run afoul of other barriers to cross-border trade, investment, and development. As this list might suggest, some barriers to international cooperation are arguably a byproduct of specific political or geopolitical concerns – but many can also arise out of a lack of clear consensus around the 'best' approach. Yet both arguably demand the same thing for resolution: platforms with the convening power to bring together like-minded *and* oppositional stakeholders, and where, in turn, those engaged in these platforms hold clear authority to both resolve differences and (ideally) advance new ways of working together.

In contrast to ten years ago, there are now a number of well-established fora that can and do support such regional collaboration on energy concerns. Meaningful efforts singled out by discussants in the aforementioned NBR–ERIA workshop included the Quad grouping of the United States, Japan, India, and Australia; the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation; APEC; and the EAS forum. Other forums that are active on energy and climate issues include the G-7, the G-20, and various mechanisms of the United Nations, which offer opportunities for Indo-Pacific countries to engage with additional partners from beyond the region. Though each of these fora have notable divergences in their strategic priorities and overall ambitions, discussants felt strongly that this could nonetheless support interests to 'divide and conquer' various challenges, ultimately allowing for faster gains – so long as open communication and some degree of cross-forum coordination is sustained ('Getting to Net-Zero,' 2022).

Many of those who this author spoke with for this report thus felt that a pressing question was less the need for radically new regional architecture and more how to better enable this cross-body coordination. In this light, several in turn suggested that the region's various Indo-Pacific strategies offer an opportunity to do just that, by bringing together like-minded partners in novel ways outside of these formal mechanisms ('Getting to Net-Zero,' 2022). When well designed, these strategies can also offer an additional opportunity: to better center conversations around the direct experiences and perspectives of those from emerging Asia.

Nonetheless, some felt that specific deficiencies in existing workstreams have continued to challenge how even like-minded stakeholders might be able to engage with decarbonisation as an energy security matter. While this essay has chosen to primarily focus on the importance of renewables in delivering zero-carbon power generation, prior research by NBR has also underscored the extent to which nuclear energy is an expected and important part of a 'net-zero' future.[14] This essay has only scratched the surface on this point, in part due to the limited number of additional, concrete recommendations that project discussions yielded for how to make this energy source which is already 'safe and reliable' also more 'socially acceptable' (and, in several cases: 'affordable'). That being said, several conversations did point to one emerging initiative – the 'Asia Zero Emission Community' – as a useful platform where this conversation could and should be pursued ('International Trade and the Energy Transition,' 2023).

Last, this essay has also sought to stress that a 'just' transition is one whose benefits are enjoyed widely while also providing targeted support to those who are negatively impacted. Yet conversations disagreed wildly as to what this should look like in practice, and emphasised that this is an area that multiple fora have struggled to offer compelling answers on. This is not meant to dismiss the laudable and important efforts of the many of the regional and global fora, research institutes, and other organisations who are actively working in this space. More, it is to underscore how much more remains to be done to ensure that the wide range of stakeholders in the Indo-Pacific's highly diverse economies feel confident that they are poised to act aggressively, effectively, and decisively on advancing decarbonisation.

[14] See, for example, NBR's series on 'U.S.–Korea Technology Cooperation for Climate Change Mitigation' and on 'Achieving Net Zero: Policy Implications for U.S.–Japan Cooperation' at NBR.org.

Chapter 6
The Way Forward

Decarbonising the Indo-Pacific's energy systems requires thinking about energy security differently. In some ways, however, not that differently. Any viable roadmap for decarbonisation must offer decision-makers a response to the questions that they have long raised about the region's energy future: is there a way forward that ensures more reliable, affordable, and sustainable access to energy; what infrastructure will be needed and who will build it; and where will the money for all of this come from? And, in a wider strategic context, is this a future in which the systems that we rely upon in daily life align with an overarching vision for a more prosperous, secure Indo-Pacific?

Innovative and collaborative responses to the above questions will be crucial and begin with a collective acknowledgement of three key facts. First, the task ahead will be incredibly hard. Decarbonising the Indo-Pacific's energy systems will require new technologies, new infrastructure, new supply chains, and, in many cases, major overhauls of existing operational, regulatory, and policy frameworks. If these efforts are to play a meaningful role in averting a global climate catastrophe, the window for doing all of this is fairly narrow.

Second, concerns about the costs of prioritising decarbonisation should not be trivialised. Many estimates assume that decarbonisation will cost the region at large somewhere north of half a trillion dollars. This expense, however, is also expected to reduce energy import bills as well as create new jobs, ultimately providing greater net benefits. Both can be true, but may not offer decision-makers a mechanism for securing the upfront capital and other resources required to pursue these longer-term benefits. This challenge is present in all economies covered in this report, but particularly acute in the region's developing economies.

Third, such an ambitious vision for transforming the region's energy systems is arguably unprecedented, and thus, unsurprisingly, some best practices remain unclear. In seeking to identify such practices, collaboration and data sharing will be key, especially when developing systems that span international boundaries. So, too, will be training (and, sometimes, retraining) individuals to leverage this knowledge. And alongside all of this, ensuring robust mechanisms for regular assessment and (as necessary) adjustment of strategies will be essential. These are all tasks where governments are key stakeholders, but not the only ones who are active in driving and championing initiatives. The private sector, academics, civil society, and the wider public are all active participants and leaders in these spaces, and deserve a seat at the table in shaping development and deployment strategies.

Acknowledging these three points makes one thing abundantly clear: much of what will need to be done can benefit from – and, in some cases, requires – fora that are able to convene a wide range of critical partners on a regular basis. This essay has sought to

stress that fora such as the G-20, APEC, and EAS already play important roles here, and that there are near-term opportunities to bolster how their workstreams can engage with decarbonisation questions. Even so, some gaps in coverage have lingered. Several recently established fora and new financing mechanisms are hoping to close these gaps, and as of this writing are making encouraging – yet not definitive – progress. Ultimately, there is every reason to believe that the region can rise to the challenge of realising a net-zero future. But doing so will require active engagement of everyone.

References

Abdullah, I., D. Warviyan, S. Maulana, A. Abdullah, A. Bilqis, and A. Tirta (2023), 'Mobilising Finance to Support ASEAN's Low Carbon Energy Transition: Challenges and Policy Options,' ASEAN Centre for Energy, April 2023, https://aseanenergy.org/mobilising-finance-to-support-aseans-low-carbon-energy-transition-challenges-and-policy-options.

Afifi, F.A.R., V. Anbumozhi, D. Chen, A. Halimaussadiah, V. Hardjono, R.E.G. Lufti, D. Lutfiana, J. Mauricio, A.J. Purwanto, W.W. Purwanto, J. Roychoudhury, C.E.N. Setyawati, M.A. Suwailem, and W.T. Woo (2022), 'Reframing of Global Strategies and Regional Cooperation Pathways for an Inclusive Net-Zero Strategy in the Energy Transition Framework,' T20 Indonesia, September 2022, https://www.t20indonesia.org/wp-content/uploads/2022/09/TF3_REFRAMING-OF-GLOBAL-STRATEGIES-AND-REGIONAL-COOPERATION-PATHWAYS-FOR-AN-INCLUSIVE-NET-ZERO-STRATEGY-IN-THE-ENERGY-TRANSITION-FRAMEWORK.pdf.

Air Quality Life Index (AQLI), 'South Korea Fact Sheet,' AQLI, 13 March 2019, https://aqli.epic.uchicago.edu/wp-content/uploads/2019/05/EPIC_SouthKorea_FactSheet_31319.pdf.

ASEAN Center for Energy (ACE) (2022). *The 7th ASEAN Energy Outlook (AEO7).* Jakarta: ACE, http://go.aseanenergy.org/D95w0.

Energy Sector Management Assistance Program (2022), 'Rise 2022: Building Resilience,' World Bank, November 2022, https://rise.esmap.org/data/files/reports/2022/RISE%202022%20Report%20Building%20Resilience.pdf.

Energy Sector Management Assistance Program (2022), 'Rise: Regulatory Indicators for Sustainable Energy,' World Bank, 2022, https://rise.esmap.org/analytics.

Anbumozhi, V., C.E.N. Setyawati, and R. Aquary (2022), 'Decarbonizing the Transport Sector through Electrification and Biofuel Use in Emerging Economies of Asia', in D. Azhgaliyeva and D.B. Rahut (eds.), *Climate Change Mitigation Policies and Lessons for Asia*, Tokyo: Asian Development Bank Institute, pp.163-202.

Anbumozhi, V., K. Kalirajan, and X. Yao (2022), 'Assessing the Impacts of COVID-19: Regional Policies and Practices for Green Recovery,' Economic Research Institute for ASEAN and East Asia (ERIA), June 2022, https://www.eria.org/uploads/media/Books/2022-Assessinng-the-Impact-of-COVID-19-for-Green-Recovery/Assessing-the-Impacts-of-COVID-19-Green-Recovery.pdf.

Antonio, K. (2023), 'Renewable Generation Surpassed Coal and Nuclear in the U.S. Electric Power Sector in 2022,' U.S. Energy Information Administration, 27 March 2023, https://www.eia.gov/todayinenergy/detail.php?id=55960.

Asia Pacific Energy Research Centre (APERC), *APEC Energy Demand and Supply Outlook: 8th Edition 2022, Volume 1* (Tokyo: APEC Secretariat, 2022), https://aperc.or.jp/file/2022/9/27/APEC_Outlook_8th_Edition-Volume_1.pdf.

Asian Development Bank (ADB) (2022a), 'Asia Transportation 2030 Outlook,' ADB, November 2022, https://asiantransportoutlook.com/documents/11/Asian_Transport_2030_Outlook_Nov_2022.pdf.

Asian Development Bank (2022b), 'Carbon Pricing for Energy Transition and Decarbonization,' ADB, November 2022, https://www.adb.org/publications/carbon-pricing-energy-transition-decarbonization.

Asian Development Bank (ADB) (2023), *Asia in the Global Transition to Net Zero: Asian Development Outlook 2023 Thematic Report.* Manila: ADB. https://www.adb.org/sites/default/files/publication/876891/ado-2023-thematic-report.pdf.

Asia Society Policy Institute (ASPI) (2023), 'Getting Asia to Net Zero,' Asia Society, 2023, https://asiasociety.org/sites/default/files/2023-04/Getting%20Asia%20to%20Net%20Zero_Report.pdf.

Burke, S.E., L. Hughes, P.Q. Huy, K. Vekasi, and Y.H. Wu (2022), 'Critical Minerals: Global Supply Chains and Indo-Pacific Geopolitics,' *NBR Special Report #102,* December 2022. Seattle: National Bureau of Asian Research, December 2022, https://www.nbr.org/wp-content/uploads/pdfs/publications/sr102_criticalminerals_dec2022.pdf.

Carbon Pricing Leadership Coalition (2021), 'Report of the Task Force on Net Zero Goals & Carbon Pricing,' World Bank, 2021, https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/614b3a242b48a65e02ccc978/1632320041214/CPLC+_NetZero_Report.pdf.

Climate Action Tracker (2023), 'CAT Net Zero Target Evaluations,' Climate Action Tracker, 14 December 2023, https://climateactiontracker.org/global/cat-net-zero-target-evaluations/.

Choi, J. (2022), 'South Korea's Net-Zero Ambitions and Overseas Public Financing,' National Bureau of Asian Research, 14 July, https://www.nbr.org/publication/south-koreas-net-zero-ambitions-and-overseas-public-financing.

Economic Research Institute Network (ERIN) (2019), 'Hydrogen, Make It the Energy of the Future in the EAS Region,' Economic Research Institute for ASEAN and East Asia (ERIA), 13 May, https://www.eria.org/uploads/media/ERIN/ERIN_Hydrogen-make-it-the-energy-of-the-future-in-the-EAS-region.pdf.

French, M.J. (2023), 'New York City's Energy Grid Faces a Power Shortfall. Here's Why', *PoliticoPro,* 21 August 2023. https://subscriber.politicopro.com/article/2023/08/new-york-city-grid-faces-power-shortfall-00111689.

Garrido, L. and K. Hughes (2023), 'Policy Options for Just Transitions in Asia,' Asian Development Bank, 2023, https://www.adb.org/sites/default/files/institutional-document/874256/adotr2023bp-policy-options-just-transitions-asia.pdf.

Gillispie, C., A. Johnson, T. Lutken, and M. Sindelar (2021), 'Investments in Energy Transition, Strengthening the Power Sector in South and Southeast Asia', *NBR Special Report* #92, July. Seattle: National Bureau of Asian Research. https://www.nbr.org/wp-content/uploads/pdfs/publications/sr92_energytransition_jul2021.pdf.

Gota, S. and C. Huizenga (2023), 'The Contours of a Net Zero Emission Transport Sector in Asia.' Asian Development Bank (ADB), April, https://www.adb.org/sites/default/files/institutional-document/874256/adotr2023bp-net-zero-emission-transport-asia.pdf.

Greenstone, M. and C. Hasenkopf, 'Air Quality Life Index 2023,' Air Quality Life Index (AQLI), 29 August 2023, https://aqli.epic.uchicago.edu/wp-content/uploads/2023/08/AQLI_2023_Report-Global.pdf.

International Energy Agency (IEA) (n.d.-a), 'Industry,' https://www.iea.org/topics/industry.

International Energy Agency (IEA) (n.d.-b), 'Transport,' https://www.iea.org/energy-system/transport.

International Energy Agency (IEA) (2020), *The Challenge of Reaching Zero Emissions in Heavy Industry* (Paris, September 2020), https://www.iea.org/articles/the-challenge-of-reaching-zero-emissions-in-heavy-industry.

International Energy Agency (IEA) (2021a), *An Energy Sector Roadmap to Carbon Neutrality in China* (Paris, September 2021), https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china.

International Energy Agency (IEA) (2021b), *Net Zero by 2050: A Roadmap for the Global Energy Sector* (Paris, May 2021), https://www.iea.org/reports/net-zero-by-2050.

International Energy Agency (IEA) (2022a), *Coal in Net Zero Transitions: Strategies for Rapid, Secure and People-Centred Change* (Paris, November 2022), https://www.iea.org/reports/coal-in-net-zero-transitions.

International Energy Agency (IEA) (2022b), 'Energy Security in Energy Transitions,' https://www.iea.org/reports/world-energy-outlook-2022/energy-security-in-energy-transitions.

International Energy Association (IEA) (2022c), *The Role of Critical Minerals in Clean Energy Transitions* (Paris, March), https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

International Energy Agency (IEA) (2022d), 'World Energy Outlook 2022,' IEA, November, https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf.

International Energy Agency (IEA) (2023-a), 'Clean Energy Investment Is Extending Its Lead over Fossil Fuels, Boosted by Energy Security Strengths,' IEA, 25 May, https://www.iea.org/news/clean-energy-investment-is-extending-its-lead-over-fossil-fuels-boosted-by-energy-security-strengths.

International Energy Agency (IEA) (2023-b), *World Energy Investment 2023* (Paris, May), https://www.iea.org/reports/world-energy-investment-2023.

International Energy Agency (IEA) and Imperial College London (2023), 'ASEAN Renewables Investment: Opportunities and Challenges,' IEA, March, https://www.iea.org/reports/asean-renewables-investment-opportunities-and-challenges.

International Energy Agency (IEA) and the Institute of Energy Economics, Japan (IEEJ) (2023), *Decarbonisation Pathways for Southeast Asia* (Paris, April), https://www.iea.org/reports/decarbonisation-pathways-for-southeast-asia.

International Energy Agency (IEA) and the Korea Energy Economics Institute (KEEI) (2021), *Reforming Korea's Electricity Market for Net Zero* (Paris, December), https://www.iea.org/reports/reforming-koreas-electricity-market-for-net-zero.

Kimura, S., H. Phoumin, and A.J. Purwanto (2023), *Energy Outlook and Energy-Saving Potential in East Asia 2023*. Jakarta: ERIA. https://www.eria.org/publications/energy-outlook-and-energy-saving-potential-in-east-asia-2023.

Kimura, S., H. Phoumin, and A.J. Purwanto (forthcoming), *Energy Outlook and Energy-Saving Potential in East Asia 2024*. Jakarta: ERIA.

Kimura, S., Y. Shibata, S. Morimoto, K. Shimogori, and Y. Mizuno (2022), 'Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060,' ERIA Research Project Report FY2022 no.5. Jakarta: ERIA. https://www.eria.org/research/decarbonisation-of-asean-energy-systems-optimum-technology-selection-model-analysis-up-to-2060

Kumra, G., V. Lath, P. Gopalan, and A. Chua (2022), 'Seizing Green Business Growth for Asia's Energy Players,' McKinsey & Company, 21 April, https://www.mckinsey.com/featured-insights/future-of-asia/seizing-green-business-growth-for-asias-energy-players.

Kuwabara, T., D. Mohr, B. Sauer and Y. Yamada (2021), 'How Japan Could Reach Carbon Neutrality by 2050,' McKinsey & Company, 4 August, https://www.mckinsey.com/capabilities/sustainability/our-insights/how-japan-could-reach-carbon-neutrality-by-2050.

Larson, E. et al. (2021), 'Net-Zero America: Potential Pathways, Infrastructure, and Impacts (Final Report Summary),' Princeton University, 29 October, https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20(29Oct2021).pdf.

Lee, U. (2023), 'Solar and Wind Dominate India's Capacity Additions in 2022,' Ember, 17 March 2023, https://ember-climate.org/insights/research/india-data-story-2023.

Moseman, A., Harvey, C., and Terrer, C. (2024), 'How Many New Trees Would We Need to Offset our Carbon Emissions?', Massachusetts Institute of Technology, Climate, 16 June 2022, https://climate.mit.edu/ask-mit/how-many-new-trees-would-we-need-offset-our-carbon-emissions.

National Bureau of Asian Research (NBR) (n.d.-a), 'Achieving Net Zero: Policy Implications for U.S.-Japan Cooperation,' NBR, https://www.nbr.org/program/achieving-net-zero-policy-implications-for-u-s-japan-cooperation.

National Bureau of Asian Research (NBR) (n.d.-b), 'U.S.–Korea Technology Cooperation for Climate Change Mitigation,' NBR, https://www.nbr.org/program/u-s-korea-technology-cooperation-for-climate-change-mitigation-the-path-to-net-zero.

Nogimori, M. (2020), 'Short/Long-term Prospects for Automobile Demand in Asia: Income and Population Growth Expected to Triple Market Size Over Next 30 Years,' *Japan Research Journal*, 3(1), Japan Research Institute, February, https://www.jri.co.jp/MediaLibrary/file/english/periodical/jrirj/2020/01/nogimori.pdf.

Raitzer, D.A., M. Pradhananga, and S. Tian (2023) , 'Asia in the Global Transition to Net Zero,' Asian Development Bank. https://www.adb.org/sites/default/files/publication/876891/ado-2023-thematic-report.pdf.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2018), 'Energy Transition in Asia and the Pacific: Pathways to Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All,' 3–5 April 2018, https://www.unescap.org/sites/default/files/APEF2018_2.PDF.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2023), 'The Race to Net Zero: Accelerating Climate Action in Asia and the Pacific,' https://www.unescap.org/kp/2023/race-net-zero-accelerating-climate-action-asia-and-pacific.

United Nations Framework Convention on Climate Change (UNFCCC) (2023), 'Information Note: Removal Activities under the Article 6.4 Mechanism,' May, https://unfccc.int/sites/default/files/resource/a64-sb005-aa-a09.pdf.

Varro, L., S. Beyer, P. Journeay-Kaler, and K. Gaffney (2020), 'Green Stimulus after the 2008 Crisis: Learning from Successes and Failures,' IEA, 29 June, https://www.iea.org/articles/green-stimulus-after-the-2008-crisis.

Wogan, D. (2023), 'Carbon Neutrality in APEC by 2050: Milestones and Stumbling Blocks,' National Bureau of Asian Research, 13 July, https://www.nbr.org/publication/carbon-neutrality-in-apec-by-2050-milestones-and-stumbling-blocks.

Yudha, S.W. (2016), 'Air Pollution in Indonesia: Challenges and Imperatives for Change,' National Bureau of Asian Research (NBR), 11 April, https://www.nbr.org/publication/air-pollution-in-indonesia.

(2022), 'Getting to Net-Zero: Unlocking Pathways for Decarbonization in the Indo-Pacific,' Workshop, Hosted by the National Bureau of Asian Research (NBR) and the Economic Research Institute for ASEAN and East Asia (ERIA), 12–13 December, Virtual Event.

(2023), 'International Trade and the Energy Transition,' Workshop, Hosted by the National Bureau of Asian Research (NBR), 17–18 August, Seattle.