ASIA SOCIETY POLICY INSTITUTE

REPORT

Getting Asia to Net Zero

GETTING ASIA TO NET ZERO

A High-level Policy Commission Convened by the Asia Society Policy Institute

Getting Asia to Net Zero

A REPORT OF THE HIGH-LEVEL POLICY COMMISSION ON GETTING ASIA TO NET ZERO

CONVENED BY THE ASIA SOCIETY POLICY INSTITUTE AS SECRETARIAT

Appendix & modeling prepared by Cambridge Econometrics

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GETTING ASIA TO NET ZERO

The High-level Policy Commission on Getting Asia to Net Zero aims to urgently accelerate Asia's transition to net zero emissions while ensuring that the region thrives and prospers through this transition. Through research, analysis and engagement, the commission's diverse set of recognized Asian leaders seek to advance a powerful, coherent, and Paris-aligned regional vision for net zero emissions in Asia. The Asia Society Policy Institute serves as the commission's secretariat. For more information and a list of commissioners, visit: AsiaSociety.org/NetZero

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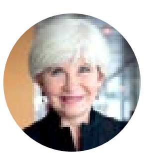

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The appendix to this report and its findings are solely the work of Cambridge Econometrics. The Asia Society Policy Institute and members of the commission are not responsible for the content of the findings within.

ABOUT THIS DOCUMENT

This report was spearheaded by the High-level Policy Commission on Getting Asia to Net Zero, which launched in May 2022 to advance a powerful, coherent, and Paris-aligned regional vision for net zero emissions in Asia. Through research, analysis, and engagement, the commission's diverse set of recognized Asian and global leaders aims to provide recommendations for how Asia and key countries can realize net zero emissions, including how climate action can boost the region's economy, trade, interconnectedness, and livelihoods. The Asia Society Policy Institute serves as the commission's secretariat.

The document itself consists of two core parts:

- The first part is a **foreword** that outlines recommendations for how the Asia-Pacific can achieve net zero emissions in a manner that is beneficial to its economy, society, and place in the world. This summary was prepared on behlaf of the High-level Commission and is aimed at elevating political and policy strategies to help the Asia-Pacific realize its vision of achieving net zero emissions.

- The second part — which informed the development of the foreword — is an **appendix** that contains **new research and modeling** to show the opportunities and trade-offs associated with the Asia-Pacific's options to meet its existing emissions reduction targets and increase its medium- and long-term ambition. The commission and its secretariat at the Asia Society Policy Institute commissioned this analysis from Cambridge Econometrics, an independent organization that specializes in economic analysis. The appendix and its findings are solely the work of Cambridge Econometrics; the Asia Society Policy Institute and the commission are not directly responsible for the content of the findings within.

GETTING ASIA TO NET ZERO: FOREWORD

In September 2020, amid the challenges of the COVID-19 pandemic, Chinese President Xi Jinping took the virtual stage at the UN General Assembly to declare that China would aim to peak its carbon emissions before 2030 and achieve carbon neutrality before 2060. With this announcement, China became the first major Asian emitter to step up and commit to reaching net zero emissions.

A wave of net zero commitments from the Asian region ensued after China's commitment. Japan and South Korea, the largest advanced economies in Asia, swiftly followed suit the next month with their own respective net zero 2050 commitments. By the end of 2021, a number of key emerging economies including Indonesia and India had also pledged to achieve net zero emissions. This momentum from Asian emitters, which account for more than half of global annual emissions, was pivotal to bringing 88 percent of the world's emissions and 92 percent of its GDP under the scope of national-level net zero commitments.

Emphasis on the gargantuan profile of Asia's emissions has frequently overshadowed the scale of the region's real economy progress on climate. In fact, Asia's phenomenal pace of renewable energy expansion, especially in China and India, has already dramatically slowed down the rate of the region's emissions growth. China's renewable energy capacity is more than three times that of the next leading country globally – and it is also on track to potentially more than double its existing target of 1200 gigawatts installed wind and solar capacity by 2030.

Asian emitters' net zero commitments are laudable, and the fact that many were announced during the throes of the COVID-19 pandemic makes them even more so. But the simple truth is that the current state of action is not enough to prevent the most catastrophic impacts of climate change from ravaging Asia, as well as the rest of the planet. The Asian region is particularly exposed to potential impacts: even in a middle-of-the-road scenario where the world warms 2.0°C by 2050, the Asian economy stands to potentially lose 14.9 percent of its GDP by the same date. ASEAN countries are even more exposed and could lose as much as 17.0 percent of GDP.

While net zero commitments have established a goalpost for the pace of mitigation, only nine of the 54 countries in the UN's Asia-Pacific Group have legislated their net zero targets or enshrined them in policy documents. This leaves a major accountability loophole on implementation. Especially without a mechanism to set out and safeguard near-term actions consistent with long-term targets, some jurisdictions are back-tracking on their commitments – turning to energy security, for instance, as cover for expanding fossil fuel production and thermal energy capacity.

In March 2023, the Intergovernmental Panel on Climate Change (IPCC) published the latest authoritative science in the form of the Synthesis Report of its Sixth Assessment Cycle. The Earth has already warmed by 1.1°C; meanwhile, no additional fossil fuel infrastructure can be built and used while still holding warming to less than 1.5°C. On the back of this report, current UN Secretary-General Antonio Guterres called for Parties to hit "fast-forward" on their net zero commitments, with developed economies to aim for net zero by 2040, and emerging economies to target 2050. As part of this "Acceleration Agenda," he also urged countries to take a series of sector-specific actions to phase down fossil fuel production and use and decarbonize energy-related emissions.

Enter the good news. New modeling commissioned by our High-level Policy Commission on Getting Asia to Net Zero illustrates another compelling reason why the Asia-Pacific region could consider aligning behind net zero by 2050: taking more ambitious climate action sooner could enhance Asia's economic and social development.

The bottom line is this: faster climate action is good for the economy, and good for people. Achieving net zero emissions by 2050 could boost the Asia-Pacific's GDP by up to 6.3 percent above predicted levels and create as many as 36.5 million additional jobs by the 2030s – both figures that well exceed the expected benefits from current targets. The transition could also create energy cost savings for households on the order of $270 billion.

Reduced dependence on fossil fuels is a major driver of beneficial outcomes. A net zero 2050 pathway could improve the Asia-Pacific's trade balance by as much at $827 billion, largely due to a decline in fossil fuel imports. This improved trade balance could be responsible for nearly a third of the benefits to GDP. It could also strengthen energy independence by ensuring that economies could meet their energy needs with local resources. These implications are significant in a world where fossil fuel prices are increasingly volatile and unpredictable geopolitics pose an ongoing risk to dependencies on imported fuels.

Asian countries could also decrease transition costs and foster a more energy-secure future by prioritizing lower-cost renewable energy sources, especially solar and wind power. In a net zero 2050 scenario where large-scale deployment of these technologies is prioritized, the Asia-Pacific region could avoid $2.2 trillion in investment requirements while improving its trade balance by another $3 billion, as compared to a scenario where the power sector mix follows currently stated priorities. This could help Asian countries avoid the pitfalls of pathways that extend reliance on fossil fuels or increase the economic and social costs of the net zero transition, such as carbon capture or coal co-firing technologies. The most prosperous transition could also see countries cease building new unabated coal-fired power today.

The modeling also outlines the resources and actions the region could take to realize these benefits. Identifying potential roadblocks as early as possible could help economies adopt preventative policies to mitigate their harms or even avoid them altogether.

Foremost, vast amounts of investment – around $70 trillion – could be required to decarbonize the region by 2050. While political will and policy certainty could help unlock much of the required financing, reforming the multilateral financial system to increase its lending capacity and better target climate change could also accelerate progress. More international financing could help minimize negative impacts on households that result if carbon pricing and taxation are the primary means of providing revenue.

And while the region could see significant growth in net employment, fossil fuel sector jobs could inevitably decline. Countries with fossil fuel–based economies could ensure a smooth and just transition by developing comprehensive plans for reskilling and upskilling displaced workers. Investing in production chains for key decarbonization technologies and colocating clean energy with former fossil fuel sites could help transform job losses into social and economic gains.

While these impacts apply to the Asia-Pacific in aggregate, they could play out unevenly across the economies within the region. This could create opportunities for countries with comparative advantages to scale up climate change technologies and solutions and bring down their cost so that other regional partners could benefit from them.

For instance, a nation with substantial renewables potential, such as India, could become a hub for green hydrogen production, which could then be exported to decarbonize heavy industry in manufacturing centers – or even used locally to produce green exports, like clean steel. Japan, with its tricky geography for renewables but comparative advantage in R&D, could pilot technologies that overcome these challenges, such as floating offshore wind – and then spearhead projects to deploy such advancements in developing economies that could also benefit from them.

In 2023, Asia has another compelling opportunity to globally step up on climate. A confluence of major multilateral processes will take place in the Asian region, including the G7 in Japan, the G20 in India, and the 28th UN Climate Conference in the United Arab Emirates on behalf of the Asia-Pacific Group. With all eyes on Asia, the region could demonstrate to the world that more climate action sooner is firmly in its interests.

Asian countries have already shown leadership on a global level beyond net zero targets. For example, as host of the G20 in November 2022, Indonesia agreed to stop building most new coal plants and achieve a set of even stronger commitments. These targets were announced in conjunction with the landmark Just Energy ransition Partnership, which intends to mobilize $20 billion in public and private financing from developed countries for Indonesia's transition over three to five years – thus underscoring how political will could help attract concrete resources.

India, as host of the G20 in 2023, has further prioritized discussions around financing and how to reform multilateral financial institutions to better serve the needs of developing countries and emerging economies on climate, including those in Asia. This comes on the back of India having officially updated its Paris Agreement commitment with more ambitious near-term targets and officially submitting its Long-erm Strategy for achieving net zero emissions by 2070.

The first Global Stocktake at COP28 in December 2023 will assess the global state of progress and remaining gaps to achieving the Paris Agreement's goals. While this process is expected to expose major deficiencies, it is also a chance to highlight legitimate leadership. Asian countries have an opportunity ahead of then to shift the goalposts on global expectations by collectively aligning their ambition with a 1.5°C trajectory. Our commissioned modeling shows that this is not only possible – it could also be the more beneficial path for the region.

Accelerating climate action, as the analysis shows, is a triple win: for the planet, for its people, and for overall prosperity. The Asian region has a chance to seize these gains – but economies need to act today. Our planet and its people cannot afford to wait any longer.

APPENDIX: RESEARCH & MODELING

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ACRONYMS

ASEAN	Association of Southeast Asian Nations
BECCS	Bioenergy with carbon capture and storage
CCS	Carbon capture and storage
CE	Cambridge Econometrics
CGE	Computable General Equilibrium
COP26	26th United Nations Climate Change Conference
COP27	27th United Nations Climate Change Conference
EU27	Current member states of the European Union
EV	Electric vehicle
FTT	Future Technology Transformation
G20	Group of Twenty
GHG	Greenhouse gas
ICE	Internal combustion engine
ILO	International Labor Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LTS	Long-Term Strategy
LULUCF	Land Use, Land-Use Change and Forestry
NDC	Nationally Determined Contribution
OECD STAN	Organization for Economic Co-operation and Development – Structural Analysis Database
PLN	Perusahaan Listrik Negara (Indonesia State Electricity Company)
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

DELIVERING THE ASIA-PACIFIC'S NET ZERO TARGETS IN FIGURES

	CURRENT UNCONDITIONAL NET ZERO (BASED ON STATED POLICIES, WITHOUT INTERNATIONAL SUPPORT)	NET ZERO 2050 (BASED ON STATED POLICIES, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (COST OPTIMIZED, WITH INTERNATIONAL SUPPORT)
Earliest year in which carbon emissions peak in the Asia-Pacific to deliver net zero emissions and realize economic benefits	2025	2022	2022
GDP impact relative to baseline	Peaking at +5.0% in 2033 +1.9% in 2060	Peaking at +6.3% in 2031 +1.8% in 2060	Peaking at +6.1% in 2031 +1.9% in 2060
Cumulative economy-wide investment required from now for achieving net zero emissions	$53.1trn	$71.2trn	$69.0trn
Change to Asia-Pacific's trade balance by 2060	+$782bn	+$824bn	+$827bn
Absolute jobs impact compared to baseline	Peaking at +25.1 million in 2033 +11.0 million in 2060	Peaking at +36.5 million in 2032 +5.4 million in 2060	Peaking at +34.6 million in 2032 +5.3 million in 2060
Change in household spending by 2060	-$0.7trn	-$1.1trn	-$1.1trn
Household energy cost savings by 2060	$261bn	$265bn	$270bn
Net policy costs over 2022–60 to national governments	+$14.7trn	+$37.4trn	+$37.7trn

>> **The Asia-Pacific region includes some of the world's largest economies and greenhouse gas emitters.** Due to the region's rapid economic growth in recent decades and driven by large industrial emerging economies that have yet to peak their emissions, the Asia-Pacific has become a key driver of global emissions. In 2020, it accounted for around half of global CO_2 and GHG emissions.

>> **Power generation systems that are heavily dependent upon fossil fuels (especially coal) are the main reason behind current high emissions in the region.** While the share of fossil fuels in global power generation is 63 percent, China and India have a 68 percent and 77 percent share, respectively. Slow electrification of transport and a substantial share of energy-intensive industries in economic output also contribute to high regional emissions. However, the faster than expected uptake of renewables, particularly solar PV in the power sector, has slowed down the pace of emissions growth in recent years.

>> Limiting global warming and preventing climate damages are especially important for protecting the vulnerable populations of the Asia-Pacific. Most of the region is highly exposed to climate-related disasters and costly health impacts from pollution and extreme weather events. Action by the Asia-Pacific nations to decarbonize their own economies will help reduce the climate damages they face given the region's significant and increasing share of global emissions.

>> All the Asia-Pacific economies have submitted Nationally Determined Contributions (NDCs), and around half have also submitted long-term strategies (LTSs) to the UNFCCC summarizing their climate action commitments since the Paris Agreement was adopted in 2015.[1] Fourteen economies (out of seventeen Asia-Pacific economies included in this analysis) including China, India, Japan, South Korea, Australia, New Zealand, and Indonesia have also announced net zero targets, aiming to reach emissions neutrality by dates that range from 2050 to 2070. However, some of these targets have been criticized by the scientific research community for not aligning with the Paris Agreement's target of limiting global temperature increases to 1.5°C above preindustrial levels by 2100 and/or lacking implementation plans.

>> This report provides economic analysis to assess the costs and benefits of increasing climate ambition compared to policies currently in place. **Five core scenarios with different levels of decarbonization (including the current net zero commitments and more ambitious net zero 2050 targets for the Asia-Pacific economies) were modeled**, complemented by sensitivities on the power generation mix pursued to achieve these targets.

>> The modeling shows that **the status quo of pre-COP26 policies in the baseline scenario will lead to an above 3°C global temperature increase** by the end of the century (compared to preindustrial temperatures). It is possible to limit this warming to under 2°C if current commitments are also implemented as planned. For full alignment with a 1.5°C pathway, which is expressed as the preferential goal in the Paris Agreement, more ambitious targets and policies beyond those currently committed to will be needed. **The Asia-Pacific can ensure that its CO_2 emissions plateau between now and 2025 before declining under current net zero commitments or declining immediately in the most ambitious 2050 net zero scenarios.**

>> Our modeling shows that **decarbonization comes with substantial economic benefits for the Asia-Pacific.** Achieving current commitments, including COP27 emissions reduction goals, can lead to **4.5 percent greater GDP by 2033** than the trajectory implied by currently enacted pre-COP26 policies. Impacts are smaller in the long run but still equate to almost **1.8 percent of additional GDP in 2060**. Delivering net zero by 2050 will result in GDP impacts peaking at above 6 percent in 2032 with marginally smaller positive impacts on long-term growth (1.7 percent compared to 1.8 percent).

>> The short- and medium-term growth impacts of climate action are largely driven by the substantial stimulus provided by the investment needed to decarbonize the economy. **It is estimated that $54.4trn of additional investment are needed from now until 2060 to deliver current unconditional net zero commitments and a further $18trn for the entire region to reach net zero earlier by 2050,** with most investment required in the power sectors in China and India.

>> **Reducing the dependence on, and therefore the import of, fossil fuels also improves the trade balance of the Asia-Pacific**. This better trade balance is responsible for slightly less than one-third of the long-term economic benefits. Electrification of transport, energy efficiency, and falling energy intensity of production also bring productivity improvements and savings to household energy costs.

1 Taiwan cannot sign onto the UNFCCC; it has not submitted a formal NDC, but it has announced an intended Nationally Determined Contribution. All other economies analyzed in this report have submitted NDCs.

- However, these benefits come with trade-offs. **Asia-Pacific households are on average worse off as a result of the transition**, faced with higher prices and higher taxes to help finance additional investments. **Employment impacts are net positive (5.3–10.9 million additional jobs by 2060), but there will be many jobs lost** in fossil fuel supply sectors. The transition away from coal mining and impacts on wider coal networks poses a challenge for local communities. **The long-run social impacts are also subject to the power sector technology mix ultimately pursued** as governments' strategies vary significantly, each with trade-offs between economic growth and employment that have welfare implications for the population.

- To deliver a just transition in the Asia-Pacific, social policies (such as reskilling schemes to allow workers to take advantage of employment opportunities created in the transition) and additional sources of financing are the most critical public sector support measures needed to complement climate policies, in particular in the poorest regions. For example, while less developed economies can use carbon revenues or other tax-raising mechanisms to fund green investments, **international financial support and climate finance streams would free up domestic finance for development, poverty reduction, and management of social impacts**.

INTRODUCTION

BACKGROUND

The Asia-Pacific[2] makes up about half of the global population. Its relatively high birthrate, the main driver of population growth over recent decades, is however expected to slow, and going forwards economic growth will be driven by industrial strengths in investment and trade instead. The largest economies in the Asia-Pacific, Japan, China, and India, are among the largest economies in the world in terms of their aggregate output (GDP). However, China's and India's per capita income remains below (India) or at (China) the global average. While regional production capacity is vast, poverty rates and levels of inequality are still high in parts of the region.

TABLE 1.1: THE SIZE OF ASIAN ECONOMIES ANALYZED IN THE REPORT, 2021

	POPULATION	GDP	GDP PER CAPITA	GDP GROWTH
	MILLIONS	BN USD	USD	%
	2021	2021	2021	2005–2020
Australia	26	1633	63529	5.2%
China	1413	14863	12359	13.8%
India	1392	3042	2185	8.9%
Indonesia	272	1060	4357	9.2%
Japan	126	4937	39340	0.5%
Korea	52	1799	34801	5.0%
Malaysia	33	373	11399	6.4%
New Zealand	5	248	41428	5.1%
Taiwan	24	790	33775	4.3%
Rest of ASEAN*	361	1800	4984	8.5%
Asia-Pacific	3702	33265	8986	6.9%
World	7693	96293	12517	4.4%
Asia-Pacific / World (%)	48.1%	34.5%	71.8%	

Note(s): For Asia-Pacific weighted average, GDP per capita and growth rates are presented.
* Brunei, Cambodia, Laos, Myanmar, Philippines, Singapore, Vietnam, and Thailand are modeled as a group and are referred to as "Rest of ASEAN."
Source(s): IMF (2022).

2 The Asia-Pacific grouping used in this analysis covers India, Indonesia, China, Japan, South Korea, Malaysia, Taiwan, Brunei, Cambodia, Laos, Myanmar, Philippines, Singapore, Vietnam, Thailand, Australia, and New Zealand.

Energy and electricity demand are on the rise in the Asia-Pacific. Table 1.2 shows that renewable shares in the power sector are close to the global average across much of the Asia-Pacific region, but the share of fossil fuels used in power generation is about 10 percentage points higher. Nuclear shares are lower than in the rest of the world. High coal shares especially are responsible for high emissions from the power sector and overall.

TABLE 1.2: POWER GENERATION SHARES AND CO_2 EMISSIONS, 2020

	FOSSILS	NUCLEAR	RENEWABLES	CO_2 EMISSIONS
	SHARE IN POWER GENERATION			MT OF CO_2
Australia	77%	0%	23%	376
China*	68%	5%	27%	9919
India	77%	3%	20%	2310
Indonesia	83%	0%	17%	627
Japan	73%	4%	19%	1024
Korea	66%	27%	6%	571
Malaysia*	83%	0%	17%	237
New Zealand	19%	0%	81%	33
Taiwan	82%	11%	5%	248
Rest of ASEAN**	77%	0%	22%	788
Asia-Pacific*	73%	2%	25%	16133
World without Asia-Pacific*	55%	17%	28%	17489
World*	63%	10%	26%	33622

Note(s): * Due to data availability, the shares are only valid for 2019
** Brunei, Cambodia, Laos, Myanmar, Philippines, Singapore, Vietnam and Thailand are modeled as a group and are referred to as "Rest of ASEAN."
Source(s): IEA (2022).

An April 2022 report of the Intergovernmental Panel on Climate Change (IPCC) (AR6 WG3) warns that the window to peak global emissions is closing (global emissions need to peak before 2025) and that strong and immediate action is needed to overturn it and keep emissions below 1.5°C or even below 2°C by the end of the century (IPCC 2022).

All Parties analyzed in this report have submitted a Nationally Determined Contribution (NDC) to the UNFCCC, and some have strengthened their commitments based on the Paris Agreement's ratchet mechanism under which Parties revise and recommunicate their NDCs every five years.[3] These NDCs summarize the climate action commitments of each Party to ensure that the Paris Agreement's temperature goals are met. Fourteen economies analyzed in the report (including China, India, Japan, South Korea, Australia, New Zea-

3 Taiwan cannot sign onto the UNFCCC. It has not submitted a formal NDC, but it has announced an intended Nationally Determined Contribution.

land, and Indonesia), currently responsible for almost half of global carbon emissions, have also announced net zero targets, aiming to reach emissions neutrality by dates that range from 2050 to 2070.[4]

While the region has seen strong uptake of renewables (particularly wind and solar in power generation) and committed policies have the potential to reduce emissions substantially by 2030, there is still support for the use and expansion of fossil fuels and coal. This is particularly visible in COVID-19 recovery packages that mixed green elements with support for energy-intense industries as well as fossil fuel extraction (Climate Action Tracker 2020).

Despite the announced NDCs and net zero targets, detailed policies need to be developed and enacted; in addition, greater ambition is needed to achieve the Paris Agreement's temperature goals (Climate Action Tracker 2022; Xinhua 2021; Global Energy Monitor 2021; Jong 2021).

OBJECTIVES

This report provides economic analysis to support the High-level Policy Commission on Getting Asia to Net Zero convened by the Asia Society Policy Institute to provide guidance and advice to economies in Asia on the region's net zero transition. The analysis also considers the potential synergies and/or trade-offs between decarbonization and development goals.

This report focuses on the Asia-Pacific economy as a whole, providing a pan-regional context to complement two detailed country studies on India and Indonesia respectively.

This analysis focuses on a group of Asian economies (henceforth the Asia-Pacific),[5] including India, Indonesia, China, Japan, South Korea, Malaysia, Taiwan, Brunei, Cambodia, Laos, Myanmar, Philippines, Singapore, Vietnam, Thailand[6], Australia, and New Zealand.

REPORT STRUCTURE

The rest of the report consists of three chapters describing the approach and findings, supplemented by technical appendices.

Chapter 2 describes the approach of the analysis, including the structure of the modeled scenarios.

Chapter 3 analyzes the findings of the modeling for different climate ambition levels. Results are included for the pre-COP26 policies baseline, for scenarios achieving current commitments, and for scenarios featuring accelerated coal phaseout and stronger policies to reach net zero emissions by 2050.

Chapter 4 concludes by describing the socioeconomic and climate impacts of those results and analyzing the policy implications that follow to answer the key research questions.

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4 Note that these net zero commitments may differ in form and content. Net zero targets are set largely in response to the Paris Agreement's call that "all Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies." Some Parties have committed to net zero targets in their long-term strategies, while others announced targets in other strategies. Targets differ in the coverage of emissions as well, whether the commitments refer to all greenhouse gases or only CO_2 emissions or are unspecified.

5 Note that the selected grouping covers all economies that could reasonably be considered part of the Asia-Pacific region and are represented in the E3ME. We recognize that there are gaps due to the coverage of the E3ME model, which is limited by data availability.

6 Note that Brunei, Cambodia, Laos, Myanmar, Philippines, Singapore, Vietnam, and Thailand are modelled as a group in this analysis and are referred to as "Rest of ASEAN" economies.

SCENARIO FRAMEWORK

MODELING FRAMEWORK

The report presents a set of scenarios describing alternative decarbonization pathways for the Asia-Pacific using E3ME, a global macroeconometric model, developed and maintained by Cambridge Econometrics. Asia Society Policy Institute and local experts were involved in designing the scenarios and reviewing the results to ensure their robustness and relevance.

E3ME is a simulation-based model that contains many policy instruments including taxes, subsidies, regulations, energy efficiency, and support for new technologies. The model solves annually and has detailed sectoral coverage including bottom-up technologies in key sectors (power, road transport, steelmaking, and heating). It shows where each alternative pathway will get to in terms of economic growth, jobs, emissions, and other key indicators. More details can be found in the technical appendices accompanying this report.

The modeling covers the period 2023–60, the end of which is determined by the model setup (the model does not extend beyond 2060). The results outline impacts across this time frame, acknowledging that additional impacts taking place beyond this point are not included. Where there are targets for specific years before 2060, results for these years are also presented.

SCENARIO NARRATIVES

The scenarios were designed to provide answers for the following key research questions:

- **Identify impacts and benefits** – What would be the short- and long-term economic, social, and climate impacts of different levels of decarbonization effort/ambition?
- **Accelerate ambition** – How strong do current policies and commitments need to be to deliver net zero targets? How must this ambition level shift if the date of the net zero target is brought forward to align with a 1.5°C pathway?
- **Support implementation** – Which policies should be prioritized to further accelerate climate action without significantly compromising economic and social outcomes? Which policy package is expected to deliver the most economic, social and climate benefits? What are the associated policy costs? What are potential barriers or trade-offs (and how can they be addressed)?

The narratives and assumptions adopted in the detailed country modeling for India (Asia Society Policy Institute 2022) and Indonesia (Asia Society Policy Institute 2023) are replicated here for internal consistency. The modeling for the rest of the Asia-Pacific, while reflecting some national and regional policy characteristics, is not intended to incorporate such detailed assumptions; as such, the results are more suitable for understanding the role of constituent economies within the region's overall decarbonization efforts than detailed like-for-like country comparisons. Unique country-specific assumptions in particular are introduced in terms of investment in carbon sink potentials in India and the treatment of coal power subsidies and conditional emissions reductions targets in Indonesia. These assumptions are explained in more detail in the country studies referenced above.

The key narratives explored as part of this study include the following:

- **Pre-COP26 policies (*baseline*):** This scenario is the reference case to benchmark other scenarios against. It represents the least ambitious pathway, taking into account decarbonization policies for Asia-Pacific economies that were implemented before COP26 with no additional policies modeled thereafter.

- **All COP27[7] unconditional emissions reduction commitments including 2030 targets and existing net zero commitments (*current unconditional net zero*):** This represents a pathway beyond 2030 commitments that includes additional policies to deliver Asia-Pacific economies' announced net zero commitments.[8] The scenario is designed to understand how the near-term, mid-term, and long-term ambitions need to be calibrated to achieve these net zero targets, including how the region's current trajectory towards 2030 (implied by national net zero targets) stacks up with the pathway toward achieving net zero across the region as a whole. In this and all subsequent scenarios, a national carbon trading system is imposed on emissions from energy-intensive sectors in all economies in the region from 2023, apart from the least-developed economies (India, Indonesia, Malaysia and Rest of ASEAN), where a similar system is introduced from 2025. Korea, New Zealand and China are the only economies where this mechanism is already in place while Indonesia signed carbon pricing for the power sector into law in 2021 but has yet to implement the scheme.

  Three variants of this scenario, which achieve emissions targets through different power sector pathways, are explored. These scenario variants help us understand the economic impacts and policy costs of different pathways to transition the power sector, which is the largest emitter and policy focus so far in these economies. The modeled power generation pathways affect socioeconomic outcomes differently due to the impact on energy prices and investment requirements.

  - In the stated policies variant, the power generation mix is inspired by government strategies and policy announcements that vary by economy. The policies that support this include carbon pricing, renewables subsidies, and public procurement to kick-start investment in certain technologies. This is the central scenario referred to in most of this report.
  - In the minimal coal CCS, renewables-based (CCS-limited RES) variant, we explore a power sector pathway that assumes a minimal role for coal-based CCS. Instead, it allows for higher levels of all existing renewables, including hydro, geothermal, biomass, wind, and solar.
  - In the low-cost renewables (low-cost RES) variant, we model a scenario in which emissions targets are met through encouraging low-cost renewable technologies. The power sector sub-model within E3ME mimics investor decisions, taking into account relative costs and capacity restrictions (due to either natural resource or regulatory constraints). Kick-start policies in this variant focus on solar PV while capacity regulation is imposed to limit the use of high-cost technologies such as hydro, geothermal, and CCS.

- **COP27 emissions reduction commitments conditional on international support including 2030 targets and existing net zero commitments (*current conditional net zero*):** This represents a pathway in which international support is available for the Asia-Pacific to deliver conditional emissions targets set for 2030, and better position itself for achieving net zero by 2060. In this and all subsequent scenarios, funding for any additional renewable subsidies and compensation for stranded fossil assets (relative to the *current unconditional net zero* scenario) is assumed to be provided by the international community, which allows for more rapid decarbonization in the medium term. International

7 The modeling focuses on net zero emissions targets announced by Parties to date (December 2022) and has not attempted to capture all COP27 commitments (such as loss and damage) in detail, whereas mid-term 2030 targets have been taken into account but not modelled precisely.

8 Some economies (Brunei, Myanmar and Philippines) do not currently have net zero commitments.

support is assumed to focus on the power sector, similar to the scope of the Just Energy Transition Partnerships proposed by the G7. Indonesia and selected ASEAN economies (Cambodia, Myanmar, Philippines, Vietnam, and Thailand) aim for their conditional emissions reduction targets; Indonesia also takes stronger action to phase out unabated coal by 2049. The source of international support is not specified and therefore includes flows between economies in the region as well as support from outside of the region.

- ***Accelerated coal phaseout*:** This scenario represents a pathway in which the Asia-Pacific meets its current targets, and there is an additional collective effort by all constituent economies to phase out unabated coal power generation from the economy by 2040, more rapidly than current policies imply. In addition, countries that are OECD members (Australia, New Zealand, Japan and South Korea) aim to phase out unabated coal earlier, by 2030. This scenario is designed to understand how the region's ambition and overall emissions reductions could shift if it phases out coal in line with calls from the scientific community (UNFCCC 2022). This scenario includes a "no new coal" policy from 2023 for unabated coal power plants (excluding those already under construction) across the region.
- ***2050 net zero*:** Under this narrative, the climate policy applied in the Asia-Pacific is increased well beyond committed targets (including enhanced actions in economies that do not currently aim for net zero) to reach net zero emissions by 2050 for the entire region. This scenario aims to understand what needs to happen to fully align the region's near-, mid-, and long-term ambition with a 1.5°C pathway. All COP27 emissions reduction commitments are strengthened, and a no new coal policy from 2023 (the same as under the *accelerated coal phaseout* scenario) and carbon pricing in the rest of the economy from 2031 are imposed. The rest of the world is assumed to act in line with a 1.5°C global pathway. Similar to the *current unconditional net zero* scenario, this narrative is analyzed with alternative power sector decarbonization pathways:
    - A central **stated and strengthened policies variant** that promotes technologies envisioned by governments in the power mix.
    - A **CCS-limited RES variant** with the no new coal policy extended to cover both unabated coal power and coal with CCS, followed by a complete phaseout by 2040 of unabated coal (however, existing coal with CCS plants can continue operating beyond this date).
    - A **low-cost RES variant** that allows the model to determine a power mix based on investor decisions, subject to unabated coal regulation and limited new capacity of technologies with high-capital requirements.

In all scenarios, it is assumed that governments are responsible for financing investment in energy efficiency measures and giving financial support for low-carbon technologies and compensation to power companies for stranded assets caused by coal regulations. It is also assumed that any carbon revenues received by governments will be specifically earmarked for these transition-related policy costs. The evolution of different technologies is determined within the model, based on historical cost and market shares data and is subject to technical potential constraints (particularly for relatively new solutions such as carbon capture and storage and green hydrogen).

For the purpose of this modeling exercise (which focuses on the overall regional picture), 2030 emissions reduction and net zero targets are assessed on the basis of CO_2 emissions, due to variations in scope at the national level.

Announced targets and commitments taken into account are provided in Appendix B and detailed policy assumptions are described in Appendix C. Extended narratives can be found in the technical appendices.

STRENGTHS AND LIMITATIONS

E3ME's key strengths supporting this analysis are as follows:

- The close integration of the economy, energy systems, and the environment, with two-way linkages between each component.
- The econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to Computable General Equilibrium (CGE) models.
- The econometric specification of the model, making it suitable for short- and medium-term assessment, as well as longer-term trends.
- A high level of disaggregation, enabling detailed analysis of sectoral effects across a wide range of scenarios. The model captures individual country dynamics as well as interactions with other regions of the global economy.
- The availability of a wide range of climate policy options, including regulations, taxes, tariffs, and subsidies, especially for the largest emitters in the economy (power, steel, road transport, and residential buildings) that also feature a detailed representation of technology diffusion.
- The shift of focus away from determining a least-cost policy implementation toward setting out potential trade-offs and opportunities arising from decarbonization.

However, the analysis has a number of limitations:

- The modeled scenarios incorporate information available in the public domain until December 2021 in full and information available between then and December 2022 in part (which includes all significant policy announcements). Recent major events including the Ukraine war, fossil fuel price spikes, and high rates of inflation are not included but are likely to impact the results to some extent. In particular, our own previous research (Cambridge Econometrics 2022) suggests that high prices and fossil fuel supply disruptions as a result of the war would encourage more investment into low-carbon alternatives; however, they still lead to long-term economic scarring (in terms of GDP and household consumption) in some of the largest economic blocs. As these effects spread to the rest of the world through supply chain impacts, the Asia-Pacific would also see greater incentives to adopt a more rapid transition (including economic benefits from investment, improved energy security, and avoided climate and policy costs of delayed action), while facing new challenges in managing the social impacts on local communities.
- As with any modeling tool, E3ME is an imperfect representation of reality, constrained by data availability and quality. Both gaps in the data (particularly for developing economies) and the inability to predict the future contribute to uncertainty in the model results. Given the diverse characteristics of the economy and energy system, it is not technically possible to account precisely for every possible energy source and technology in each sector. For macroeconomic models like E3ME, there is often a balancing act between breadth and depth, requiring simplified assumptions. For example, the model does not fully capture detailed power grid balancing requirements (which can only be accounted for using real-time hourly data) but rather accounts for seasonal variations. Grid stabil-

ity and the implied demand for backup generation and storage during downtime are incorporated to determine the technology mix. In addition, assumptions about technological constraints (based on literature and announcements) are applied to ensure a realistic level of uptake of different technologies.

- The analysis focuses on evaluating the socioeconomic impacts of increased climate action with some consideration for costs, savings, and trade-offs. It does not quantify avoided climate-related physical damages (the cost of inaction) and co-benefits (from improved environmental outcomes), both of which would add more incentives to accelerate the low-carbon transition.
- The modeling considers costs of policies aimed specifically at encouraging take-up of low-carbon technology options and assumes they are mostly financed domestically by a combination of carbon revenues and other taxation. While it accounts for the role of international support, it does not quantify the costs of other policies to manage the transition (such as social and labor market interventions), which do not have a significant impact on emissions but do influence socioeconomic outcomes. The impact of these policies depends directly on their implementation and can be better explored in follow-up analysis.

FINDINGS

DELIVERING THE ASIA-PACIFIC'S DECARBONIZATION TARGETS

Emissions and Emissions Intensity

In the *pre-COP26 policies* baseline, the Asia-Pacific region[9] is projected to experience strong GDP growth of more than 4.2 percent per annum (pa) over 2020–40. Rapid economic growth is supported by growth in household consumption, investment, and exports, while employment is expected to grow modestly in line with population.

Emissions are projected to continue to increase in the Asia-Pacific. Although the rate of growth will slow through the 2030s and 2040s, due to emissions plateauing under current policies particularly in Japan, China, and New Zealand, it is expected to start accelerating again in the 2050s because of continued economic and emissions growth in the rest of the region, notably in India and ASEAN economies. The power sector drives the pattern of overall emissions, where fossil fuels continue to make up a high share of the capacity mix, particularly in China and India. Therefore, the NDCs of the Asia-Pacific economies, apart from India's NDCs that are on track to be overachieved by current policies but have not been updated since 2015 (Climate Action Tracker 2022), are not met in this scenario as economies lack the required policies to achieve them.

In the *current unconditional net zero* scenario, policies are added where they have the most impact to ensure that NDCs and other targets are met. The 2030 targets with the greatest impact on the Asia-Pacific's emissions pathway are China's reduced coal dependency and emissions peaking before 2030 and India's reaching cumulative emissions reductions of 1bn tons this decade, reducing the carbon intensity of GDP by 45 percent by 2030 compared to 2005 levels and achieving 500GW of non-fossil power capacity. China's emissions trajectory is driven by an expansion of carbon pricing from 2023 to cover all energy-intensive sectors[10] and a phase down of unabated coal power from 2026, in line with the government's recently stated ambitions. These policies result in unabated coal power capacity peaking in 2025, with power sector emissions (and therefore total emissions) levelling off from 2023 and declining from 2026, in line with projections from Centre for Research on Energy and Clean Air (2022). Meanwhile, the emissions reductions in India are mainly driven by the 500GW non-fossil capacity target for 2030, as a result of carbon pricing from 2025 and subsidies for renewables. The policy packages modeled lead to CO_2 emissions for the region as a whole plateauing between now and 2025 and declining rapidly thereafter (see Figure 3.1). The faster rate of reduction after 2030 is due to the same policies continuing to have an impact in the longer term as well as the expansion of carbon pricing to all sectors from 2031 onward. In this scenario, the Asia-Pacific's CO_2 emissions reach net zero by 2057.

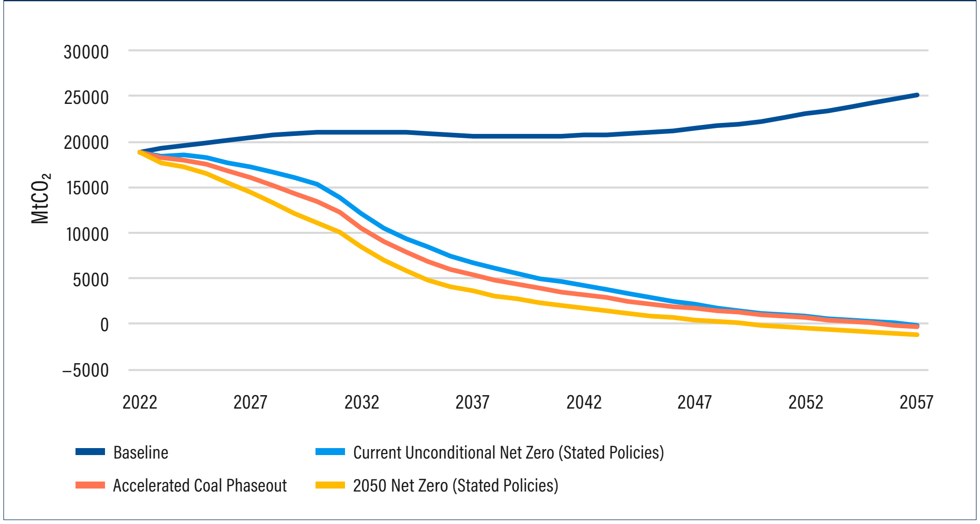
In the *accelerated coal phaseout* and *2050 net zero* scenarios, the introduction of the no new coal policy (a ban on new unabated coal construction from 2023 followed by complete phaseout by 2040) leads to emissions immediately declining in the Asia-Pacific, most visibly in China, the largest emitter in the region. This regulation alone leads to the region achieving net zero emissions by 2056, one year earlier than in the *current unconditional net zero* scenario. In comparison, when coal regulation is combined with higher levels of carbon pricing across the economy, the phaseout of ICE vehicles and fossil fuel use in households and industry, the

9 Asia-Pacific in this modeling includes India, Indonesia, China, Japan, South Korea, Malaysia, Taiwan, Australia, New Zealand, Brunei*, Cambodia*, Laos*, Myanmar*, Philippines*, Singapore*, Vietnam* Thailand*. Economies marked with an asterisk are modelled as part of the "Rest of ASEAN" regional aggregate.

10 The original scheme implemented in 2021 only covers the power sector and only power generators are obligated to comply.

Asia-Pacific can achieve net zero by 2050. The coal regulation by itself only makes a small difference to the net zero year, due to coal phase-down regulation (in the case of China, Indonesia, and New Zealand), and market-based incentives for switching from coal to renewables (carbon pricing and renewables subsidies in all regions) are already inducing the most drastic changes in the *current unconditional net zero* scenario, compared to current policies. This emphasizes the need to target emissions reductions across all sectors to achieve the most ambitious decarbonization goals.

FIGURE 3.1: TOTAL CO_2 EMISSIONS IN THE ASIA-PACIFIC ACROSS SCENARIOS



Source(s): Cambridge Econometrics, E3ME modeling result.

The main contributors to the Asia-Pacific's achieving net zero emissions by 2050, seven years earlier than implied under the *current unconditional net zero* scenario, are China (where emissions are expected to plateau immediately), India (with emissions peaking in 2025 instead of 2030, and net zero emissions achieved in 2050 instead of 2070), and Indonesia (with emissions peaking in 2027 instead of 2030, and net zero emissions reached in 2050 instead of 2060). In other regions, emissions are expected to stop rising from 2023 and reach net zero two-to-five years earlier than currently targeted. The difference in the net zero year in a country, given the same increase in policy strength between scenarios, is driven by national characteristics (e.g., current energy mix, technology costs, and price elasticities) that are captured in historical data.

The Asia-Pacific economies analyzed in this report have set out targets for emissions reductions and renewable energy supply by 2030 in their NDCs and additional pledges before or at COP27. Acknowledging that the Asia-Pacific does not have targets as a region, Table 3.1 shows the regional overview for key indicators typically included as economy-level targets in all core scenarios. The main result to highlight is the high share of non–fossil fuel generation, double the share in the baseline in 2030, which makes the most contribution to emissions reductions achieved in these scenarios by 2030. This is driven by a reduced role for coal accompanied by a rapid uptake of solar in China in particular and followed by similar trends in other economies. Under the *2050 net zero* scenario, regional CO_2 emissions in 2030 are expected to be slightly below 2010 levels, which implies that significantly stronger reductions are required in the rest of the world, particularly in

TABLE 3.1: THE ASIA-PACIFIC'S DELIVERY OF CURRENT 2030 TARGETS

ASIA-PACIFIC, 2030	BASELINE	CURRENT UNCONDITIONAL NET ZERO	ACCELERATED COAL PHASEOUT	2050 NET ZERO
CO_2 emissions reduction by 2030 compared to baseline	-	-26%	-36%	-47%
Change in CO_2 emissions by 2030 compared to 2010 levels	81%	33%	16%	-4%
Reduction in carbon intensity of output by 2030 compared to baseline	-	-17%	-16%	-33%
Reduction in carbon intensity of output by 2030 compared to 2022 levels	17%	-2%	-1%	-19%
Non-fossil share in power generation by 2030	32%	51%	65%	65%
EV fleet share in road transport by 2030	20%	35%	35%	51%
Net zero year	-	2057	2056	2050

Source(s): Cambridge Econometrics, E3ME modeling result.

Europe and North America[11] to achieve a 45 percent global GHG reduction (by 2030 relative to 2010 levels), which is consistent with a 1.5°C target. Since the modeling does not assume above-baseline carbon sink potentials for most economies, there is scope for global emissions to decline faster, and for the region to play a more visible role in global efforts than currently modeled.

ENERGY AND TECHNOLOGICAL TRANSFORMATIONS

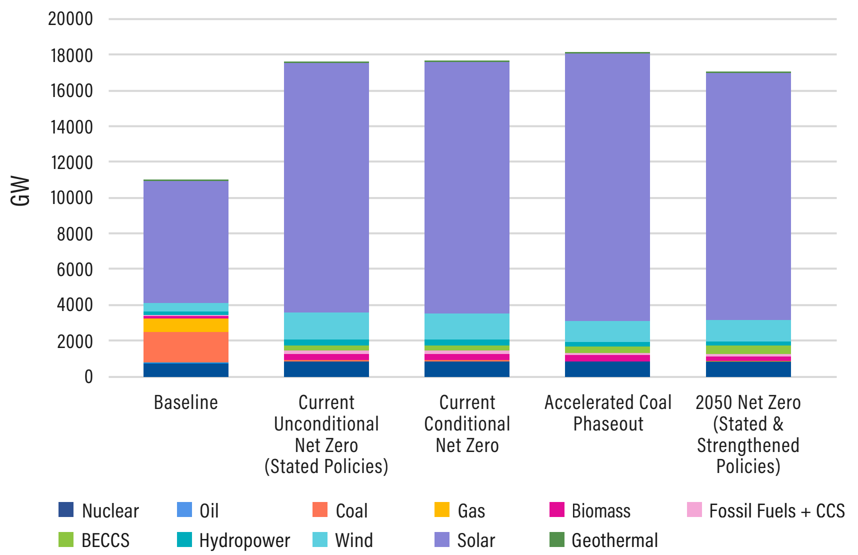
Power Sector

In all scenarios, the demand for electricity is between 15 percent and 22 percent higher than in the baseline by 2060 due to the electrification of the economy. In addition, 98 percent of all electricity generation is from non–fossil fuel sources (compared to 62 percent in the baseline). Higher rates of energy efficiency (particularly in buildings, enabled by additional revenues from higher rates of carbon pricing) mean that there is a lower level of electricity demand in the *2050 net zero* scenario, despite a higher rate of electrification than in the *current unconditional net zero* and *accelerated coal phaseout* scenarios (see Figure 3.2).

The power generation mix is dominated by solar, replacing unabated coal generation, supported by some increase in the capacities of hydro, wind, nuclear, and biomass. This high share of non–fossil fuels in the power mix is supported by short-term battery storage and long-term hydrogen storage, the cost of which is reflected in the cost of generation and electricity prices. Additional investments to develop storage, grid

11 These regions currently account for around 25 percent of global emissions and aim to deliver emissions reductions of around 50 percent on average by 2030 compared to 2010 levels.

FIGURE 3.2: POWER CAPACITY BY TECHNOLOGY IN 2050 IN ASIA-PACIFIC



Source(s): Cambridge Econometrics, E3ME modeling result.

integration, and management technologies are not included. The use of fossil fuels disappearing from power generation is the key driver lowering emissions, brought about primarily by incentives for renewables and coal phase-down regulations.

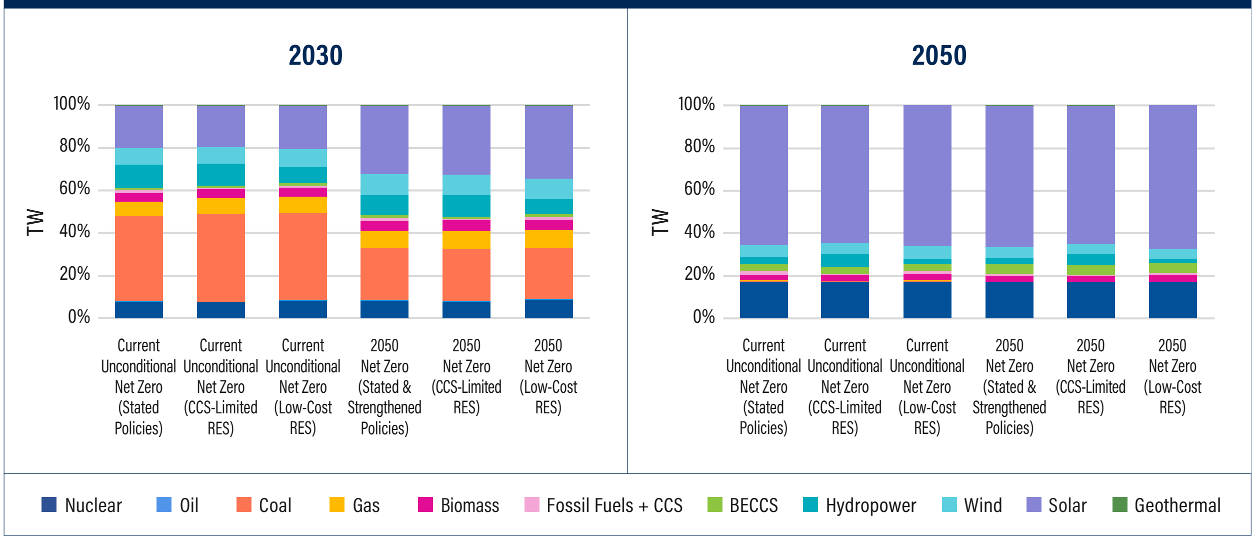
In the most ambitious *accelerated coal phaseout* and *2050 net zero* scenarios, the modeling suggests that the power sector has the potential to completely decarbonize by the mid-2030s. This is almost 10 years earlier than in the *current unconditional net zero* and *current conditional net zero* scenarios.

The no new coal policy adopted in the *2050 net zero* and *accelerated coal phaseout* scenarios plays a critical role in this transition. In the short term, the modeling accounts for the possibility that a ban on new unabated coal plants may trigger increased usage of existing coal plants, as well as other fossil fuel plants and new coal plants fitted with a CCS unit, to meet rising energy demand. Specifically, the potential electricity generation from coal plants that would have been constructed without the no new coal regulation is assumed to be met in part by redistributing coal supply and maintaining or increasing load factors in those plants to be at a similar level as in the baseline (where there is no regulation). With this, immediate impacts of the policy in terms of emissions reductions are more limited than might be intended. However, as renewable costs fall over time with higher adoption rates (supported by government subsidies and endogenous learning-by-doing effects) while the rate of carbon pricing increases rapidly, using natural gas or fossil fuels with CCS will become much more expensive in both nominal and relative terms, making them a less attractive option for investors to sustain in the long term. The combination of the coal phaseout regulation, carbon pricing, and renewables subsidies ensures that in the long term when coal plants come to retirement, they are replaced by renewables.

For the *current unconditional net zero* and *2050 net zero* scenarios, two variants of the power mix were simulated to illustrate some of the alternative pathways besides the one envisioned within governments' announcements and ambitions. Both of these variants feature renewables integration, as with the central case. However, the CCS-limited RES variant does not assume significantly increased use of coal with CCS (by extending the no new coal regulation to all types of coal plants, not only unabated coal, after 2030, but stopping short of phasing out coal with CCS entirely). The second low-cost RES variant includes additional public procurement to promote solar PV alongside renewables subsidies while assuming hydro and geothermal have limited new potential (beyond what has already been built) due to high capital requirements.

The results for power generation (as shown in Figure 3.3) reflect the policy intention. For both scenarios, the variants result in a slightly larger role for solar than in the stated policies and strengthened policies case, although the differences are very small.

FIGURE 3.3: POWER GENERATION SHARES BY TECHNOLOGY IN ASIA-PACIFIC



Source(s): Cambridge Econometrics, E3ME modeling result.

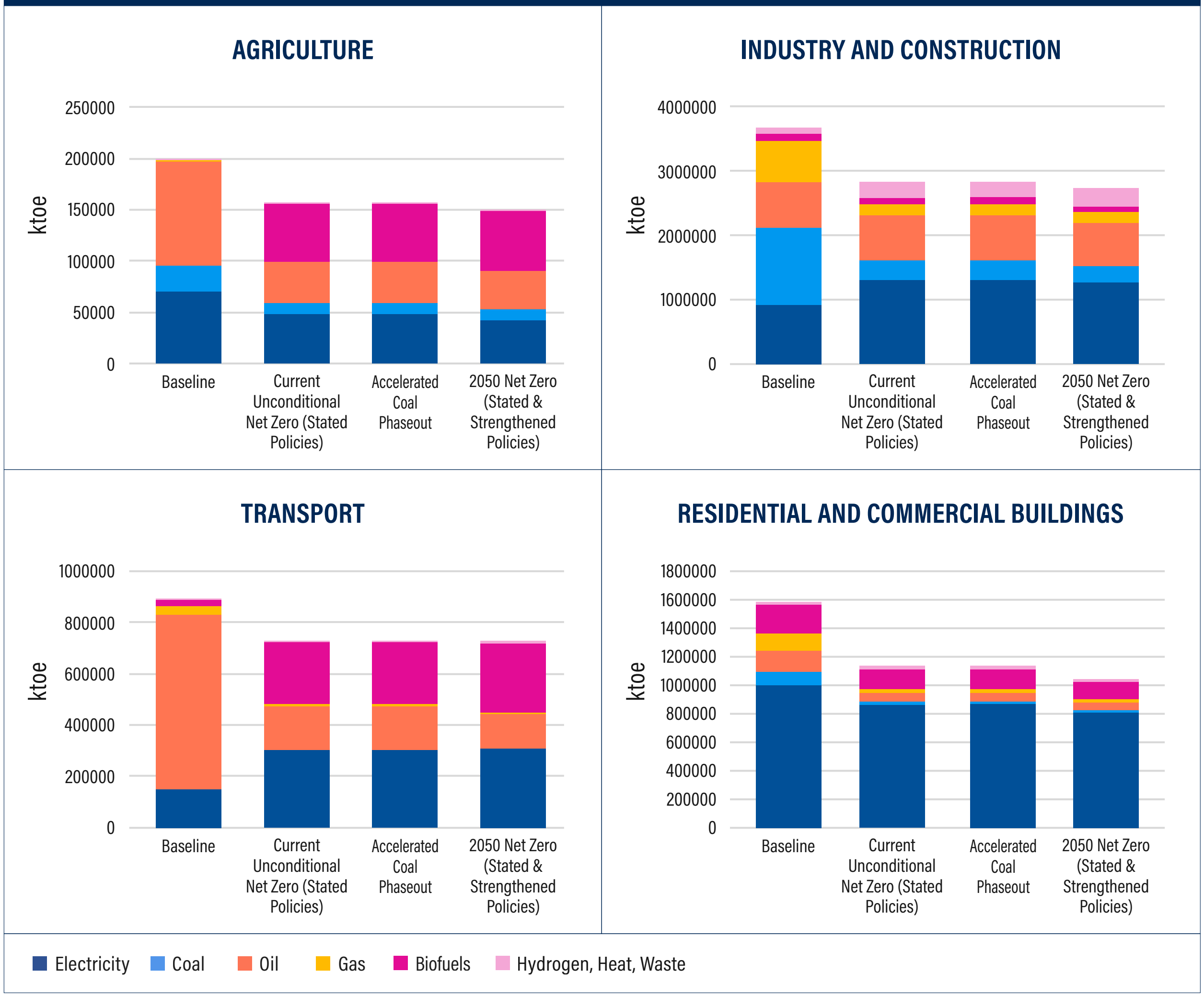
Comparing the two power mix variants for each net zero scenario shows some switching between fossil fuels with CCS and hydro and geothermal to accompany solar deployment. Although these appear to be small shifts in the power mix, the economic and social implications are more notable, as presented in section 3.3 and section 3.4.

Final Energy Demand

Final energy demand by 2050 is lower in all scenarios than in the baseline scenario, primarily as a result of energy efficiency improvements. The modeling of energy efficiency also means that electricity demand is lower than it would be if no efficiency improvement were made, even though it is still much higher compared to baseline due to the accelerated rate of electrification.

There is a clear shift from fossil fuels to electricity and biofuels (see Figure 3.4). However, in all scenarios, a noticeable share of fossil fuel use remains, in particular in the industry sector, despite other sectors being largely decarbonized: once the most cost-effective and easy-to-implement measures have been exhausted, the remaining emissions in industry, agriculture, and buildings are increasingly difficult to remove.

FIGURE 3.4: ENERGY MIX BY FINAL USER IN 2050 IN ASIA-PACIFIC ACROSS SCENARIOS



Source(s): Cambridge Econometrics, E3ME modeling result.

Biofuel mandates and carbon pricing are key policy drivers in these sectors, with energy efficiency investment also facilitating the transition in the buildings sector. The complete decarbonization of the power sector, combined with increased electrification, therefore indirectly plays a crucial role in decarbonizing end-use sectors as well, which also means fewer sector-specific policies are needed.

In transport, by 2060, most passenger vehicles are electric (driven by electric vehicle subsidies and ICE sales caps), while a share of fossil fuel demand for road freight and air and marine transport is replaced by biofuels (incentivized by carbon pricing and biofuel mandates). It should be noted that biofuel mandates, a key policy especially in transport sectors, would compete for available land with agriculture and forestry sectors that are responsible for critical food production and the creation of natural carbon sinks, and would also pose biodiversity and ecosystem trade-offs. Therefore, biofuels have a limited role and electricity is expected to be the dominant energy type in all sectors in the long term.

For net zero emissions to be achieved in the Asia-Pacific, there must be a greater role for carbon sequestration (from forests as well as carbon capture and storage solutions, particularly in the power generation and industry sectors) to offset remaining emissions from fossil fuel use. CCS and BECCS are accounted for in the modeling, whereas additional carbon sink potentials on top of those captured in the baseline, are only modeled in the case of India (under the most ambitious *2050 net zero* scenarios), for consistency with the country study[12], due to uncertainty around carbon sink potentials and policies to deliver them given land availability concerns.

The composition of the power mix as explored in the sensitivities does not affect final energy demand noticeably, as the policies and assumptions included in those variants are specific to the power sector. However, there is a small difference in the absolute level of demand, as demand for fossil fuels by the power sector affects total domestic supply and therefore fossil fuel prices for other energy producers and end-users, inducing a further response in terms of changing demand.

SOCIOECONOMIC IMPACTS

Macroeconomic Indicators

GDP and investment

In all scenarios, decarbonization has a positive impact on both GDP and employment.

GDP is projected to be 4.8 percent higher than baseline in the *current unconditional net zero* scenario at its peak in 2033, maintaining at 1.8 percent above baseline by 2060 (see Figure 3.5). In comparison, in the more ambitious *2050 net zero* scenario, GDP impacts peak at just above 6 percent in 2032 and are at 1.7 percent above baseline by 2060. There are only small variations between the *current unconditional net zero* and *current conditional net zero* scenarios at this aggregate level, due to only a small number of economies[13] within the region having stated conditional emissions reductions targets.

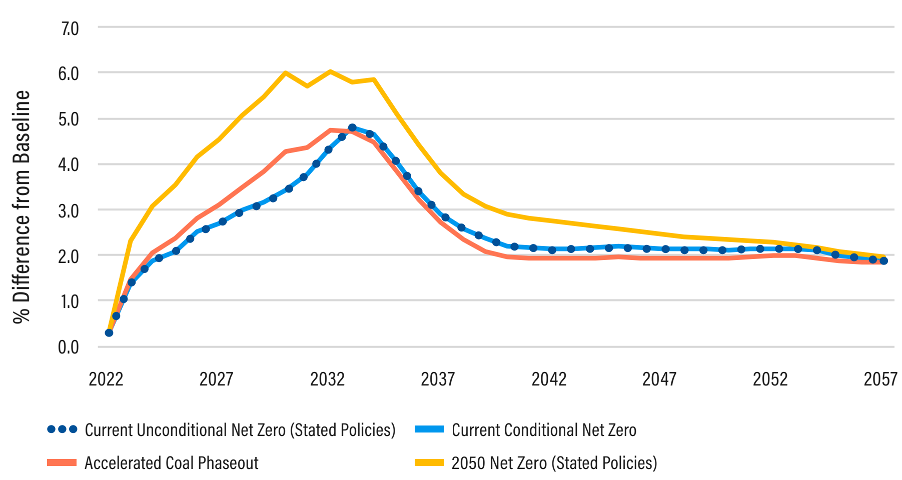
Investment is the strongest driver of overall GDP impacts, which are also influenced by household consumption and net trade. Therefore, GDP impacts follow a similar profile as investment, peaking in the early 2030s, soon after the peak in additional investments but later than the emissions peak year that is driven more by coal regulation policies. The reason is that policies are assumed to take effect immediately, whereas investment decisions have a time lag to materialize, and the wider secondary impacts have an additional time lag to fully circulate through the economy. Higher levels of investment in the power sector in the short and medium terms, supported by investment in energy efficiency in the longer term, are the main investment drivers in the Asia-Pacific.

In the power sector in particular, it is assumed that large amounts of investment will be frontloaded to facilitate the construction of critical infrastructure in time to achieve the 2030 targets. Given the assumption that many new policies are introduced in 2023 to deliver 2030 targets, the modeling suggests that the majority of additional investment is expected in the years between now and 2030. The profile of positive GDP impacts follows that of investment requirements (relative to GDP) over time. Cumulative investment requirements

12 For other economies, the same baseline trajectory is assumed in all scenarios.

13 Indonesia, Cambodia, Philippines, Thailand, and Vietnam, which together account for less than 10 percent of Asia-Pacific emissions.

FIGURE 3.5: GDP IMPACT (% DIFFERENCE FROM BASELINE) IN THE ASIA-PACIFIC



Source(s): Cambridge Econometrics, E3ME modeling result.

for meeting announced net zero targets are estimated at $54.4trn from now until 2060[14] in the *current unconditional net zero* scenario, and $18trn higher ($72.4trn compared to baseline) over the same period in the *2050 net zero* scenario, with most investment in China and India.

The dynamics of different economies on the Asia-Pacific total is especially noticeable in the *accelerated coal phaseout* scenario that shows slightly more positive GDP impacts in the medium term and slightly less positive impacts in the long term, as compared to the *current unconditional net zero* scenario. The medium-term boost to GDP is due to the introduction of the no new coal policy from 2023 (which is region-wide but is most visible in China and India because of their size). This policy forces switching from coal to renewables in the power sector, creating additional investment, which is a direct contributor to GDP. The long-term differences are an indirect impact of the short-term investment boost but are driven more by impacts on economies outside of China and India. By investing in low-carbon power generation technologies earlier, economies in the region are able to reap the benefit of faster cost reductions, particularly where renewables costs are currently relatively high. While China, India, and Australia are already benefiting from low costs of renewables, some of the large economies in the region have not achieved the same level of cost reductions (IRENA 2019). For example, the installed costs of solar PV in Indonesia are slightly higher than the global average at $1158/kWh, and much higher than in China ($794/kWh) and India ($618/kWh), due to market regulations that favor fossil fuels that were prominent in Indonesia until recently (IEEFA 2019; IESR 2022). Meanwhile, slow historical uptake and limited cost reductions in Japan and Korea are attributable to geographical factors: Japan has low technical potential for renewables due to limited land availability and inflexibility linked to the longitudinal structure of the grid (Shiraki et. al 2021), whereas South Korea's mountainous landscape, high population density, and limited transborder interconnections also pose challenges for the scale-up of renewables (IEA 2020).

14 The modelled period ends in 2060, beyond which point further investment will be required to fully achieve net zero targets that have been set at a later date (e.g., 2070 for India).

The implication of the above scenario comparison is that the no new coal policy could lead to a compromise on economic growth if not supported by other decarbonization measures to mobilize investment and funding. This is further demonstrated in the *2050 net zero* scenario; the trade-off between economic growth and decarbonization is reduced when overall climate ambition is also increased, which allows the region to reap additional economic benefits to offset some costs associated with coal regulation.

Energy trade

In addition to contributions from investment, GDP impacts are also driven by the impact on the Asia-Pacific's net trade balance. Reduced dependence on imported fossil fuels as part of the transition leads to a long-term improvement in the Asia-Pacific's trade balance with the rest of the world, estimated at $785–$827bn by 2060 (equating to just under half of the positive total GDP impact). This gain mostly comes from a reduction in fossil fuel imports. Imports into the region of manufactured fuels, oil and gas, and coal are 57 percent, 25 percent, and 75 percent below baseline levels, respectively, in 2060 in all scenarios. Improved energy security through lower import dependence helps maintain a reliable and affordable supply to the domestic population, especially households at risk of poverty and fuel poverty.

Most of the energy trade balance improvements are expected in India, ASEAN economies, Japan, Korea, and Taiwan, which are net energy importers. An exception to this trend is Indonesia, which is a major net coal exporter but a net importer of oil and gas; in terms of net impact in Indonesia, these opposite trends approximately balance out. China and Australia, on the other hand, are expected to see a deterioration in their national energy trade balance. Australia is a major net coal exporter and will lose export revenues due to a reduction in coal demand within the region as well as globally. China, a net importer of oil and gas, is expected to see a slight increase in import dependency of these commodities as a result of a stringent phaseout of coal that leads some users to switch to oil and gas as the next alternatives alongside renewables. Despite this worsened energy trade balance, the overall trade balance (covering both energy and non-energy trade) for China is projected to see a net improvement, due to its manufacturing strengths and a highly integrated supply chain, which positions it well to take advantage of globally increased demand for equipment and materials to support renewable infrastructure deployment. In other words, the expected improvement to non-energy trade in China outweighs the energy trade deficit (relative to baseline).

Similarly, there is potential for the Asia-Pacific region as a whole to create a large-scale low-carbon industry to replace existing fossil fuel exports, which is not assumed in the scenarios (implying that demand is met by current domestic capacity and an increase in imports). If this potential were realized (e.g., allowing the region to produce and export green steel, batteries, and minerals), the impacts on the net trade balance would be even more strongly positive.

Household consumption

The last contributor to the GDP impacts is the change in household consumption. This impact is noticeably negative across the region and in most constituent economies. It is a second-order effect that results from economic feedbacks from the initial investment circulating through the economy; therefore, differences take longer to materialize, particularly those due to high energy prices and inflation as a result of switching away from fossil fuels to renewables under carbon-pricing instruments and strict regulations.

The impact on households of increasing climate ambition is twofold:

- A higher level of aggregate employment in the scenarios relative to baseline, which results in a higher level of income from employment for households.
- In all scenarios, decarbonization is assumed to be primarily financed by private investments or domestic government revenues; only selected policies under the *current conditional net zero*, *accelerated coal phase-out* and *2050 net zero* scenarios are financed by international financial support. On the one hand, privately funded investments and higher industry costs due to carbon pricing are passed on to consumers in the form of higher product prices, which reduces purchasing power. On the other hand, investments and policy costs funded by governments that are not covered by carbon revenues or international support are assumed to be funded via additional taxes, directly increasing the tax burden on households and reducing disposable income.

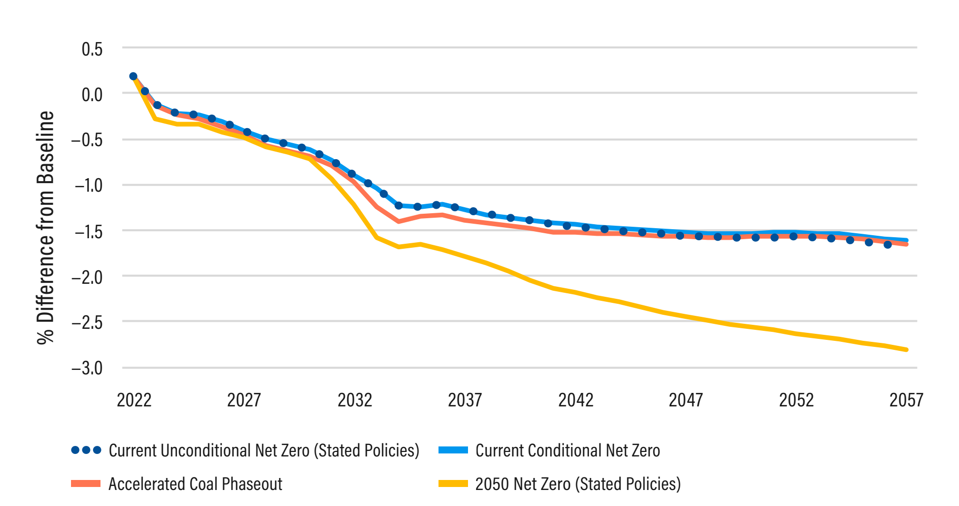
The impacts of both lower purchasing power and the higher tax burden outweigh the positive impact on nominal income described above. The result is a net negative impact on household income and consumption, implying that consumers directly bear some of the cost burden of the transition. In addition to the impact of carbon pricing (which affects the price of non-energy consumption items indirectly and fossil fuel use by households directly), households also face a higher electricity price. This increase is due to the assumption that the cost of power sector investment and renewable electricity generation costs are passed on to consumers rather than being absorbed by energy producers as sunk costs, which would require market reforms and price caps to protect low-income groups from fuel poverty.

The regional level reduction in household consumption is $700bn (about 1.8 percent below baseline) in 2060 in the *current unconditional net zero* scenario and $1.1trn (2.9 percent below baseline) in the *2050 net zero* scenario. This lowers demand for all consumer goods, although GDP impacts remain positive due to large and positive contributions from investment and net trade.

The consumption loss in percentage terms is largest in Australia, Korea, and Taiwan, at 6 percent –11 percent below baseline. Excluding Australia and New Zealand from the regional aggregate reduces the consumption effect to 1.7 percent and 2.9 percent below baseline under the *current unconditional net zero* and *2050 net zero* scenarios respectively. The relatively larger impacts in Australia are driven by significant job losses in fossil fuel supply industries that outweigh new job gains and have a net negative impact on household income. In South Korea and Taiwan, the dampening effect on household consumption is mainly attributable to rising inflation linked to the cost of energy. South Korea is among the economies in the region that are still in the early stages of boosting renewable uptake and reducing costs, which means investment in renewables would be most costly over the next decade. Meanwhile, Taiwan imports most of its energy from abroad, making it extremely vulnerable to external price increases especially in the rest of the region, in addition to the domestic challenge of scaling up electricity generation with ambitious wind and solar targets to replace cheaper coal and gas. The only exception to this trend is Japan, which sees positive consumption impacts (at least 3 percent above baseline by 2060 across all scenarios). This is because of its shrinking labor force and high productivity that generate large wage premiums on new job opportunities created by the transition, thereby boosting nominal household income and consumption by more than potential price increases linked to low historical penetration (and therefore high costs of greater deployment) of renewables.

The household consumption effect in the *current conditional net zero* scenario is marginally less negative than that in the *current unconditional net zero* scenario because of international support. While the modeling included some consideration for the role of international financial support, this is focused on specific policy costs incurred by governments in the transition. If the modeling assumed that more of the Asia-Pacific's decarbonization investment were funded by international support, through expanding the scope of such arrangements to multiple and additional streams of support as called for at COP27, domestic consumption impacts would be less negative. As such, the risk of pushing vulnerable households into poverty would be mitigated and overall macroeconomic impacts would be boosted further.

FIGURE 3.6: HOUSEHOLD CONSUMPTION IMPACTS ACROSS SCENARIOS IN ASIA-PACIFIC (% DIFFERENCE FROM BASELINE)



Source(s): Cambridge Econometrics, E3ME modeling result.

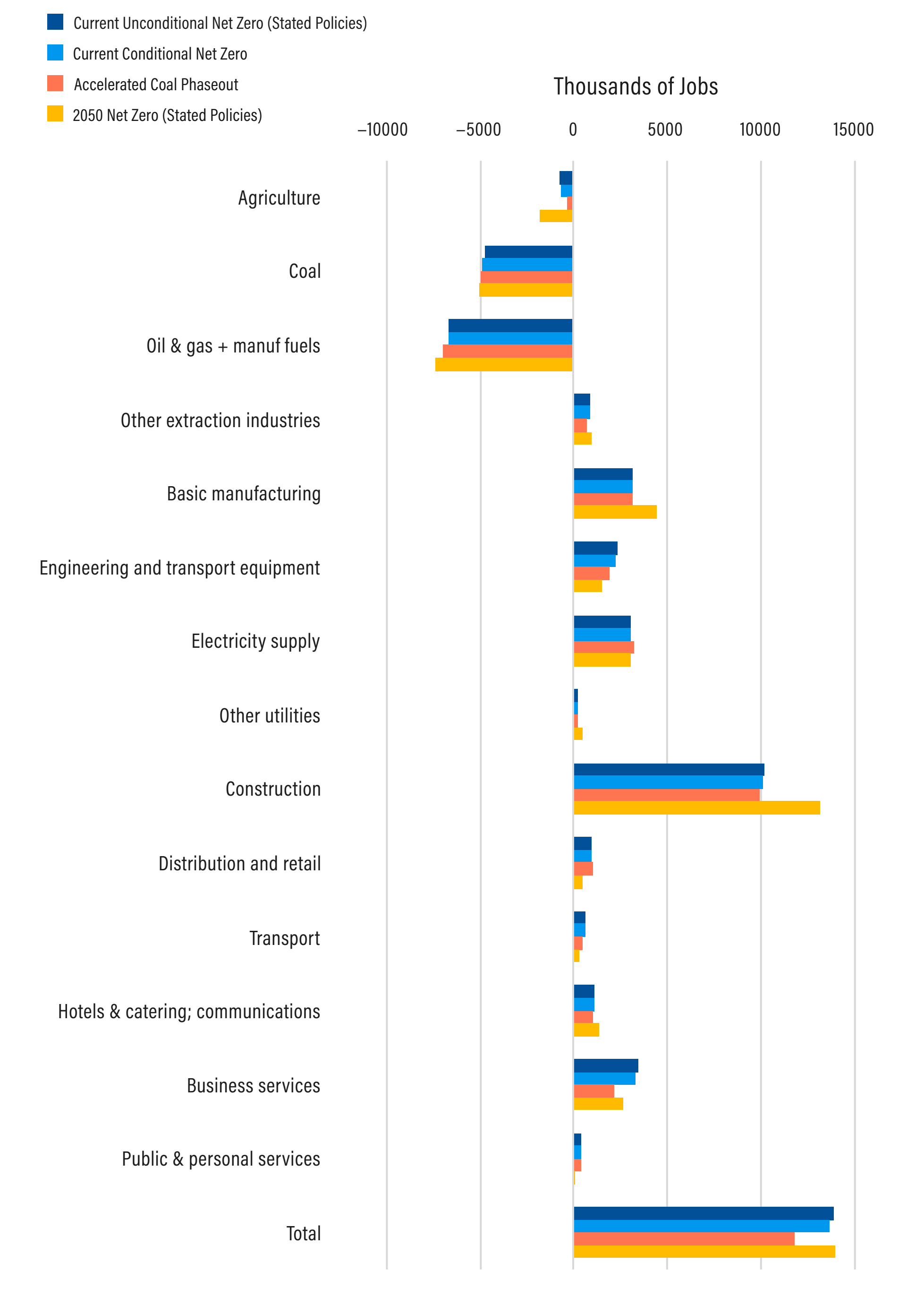
Employment impacts by sector

Employment in the *current unconditional net zero* scenario is estimated to be 1.3 percent higher than baseline in 2033, and 0.6 percent higher than baseline in 2060. In the *2050 net zero* scenario, the impact peaks at 1.9 percent above baseline in 2032 and reaches 0.3 percent above baseline by 2060. The sharp peak is consistent with the investment and GDP impacts, which lead to substantial increases in demand for labor to support the construction of the critical infrastructure needed to deliver 2030 targets. It is also driven by Chinese labor market patterns, in particular that the use of fossil fuels (coal especially) in power generation is phased out quickly due to greater incentives for renewables (which are on average more labor intensive per unit of electricity produced). The 2060 impact is relatively small in percentage terms but is equivalent to 10.9 million and 5.3 million additional jobs across the Asia-Pacific economy in the *current unconditional net zero* and *2050 net zero* scenarios, respectively. The employment impacts are smaller in percentage terms than the GDP impacts due to improved efficiency and associated average wage gains linked to additional investments.

Figure 3.7 shows the sectoral breakdown of the employment impacts in 2050. Job losses occur in fossil fuel supply sectors (coal and oil and gas) due to the transition to renewables.

All other sectors, however, will experience new job opportunities. Most notable are substantial gains in sectors that form the supply chains of the technology transition, including construction (responsible for infrastructure developments), other extraction industries (suppliers of minerals), and manufacturing sectors (suppliers of machinery, equipment, and manufactured materials).

FIGURE 3.7: EMPLOYMENT IMPACTS IN ASIA-PACIFIC, 2050



Source(s): Cambridge Econometrics, E3ME modeling result.

Most economies in the region benefit from increased employment in business services sectors, as these sectors provide research and innovation, as well as legislative, IT, and financing services to support transition activities. India and ASEAN economies, major trading and distribution hubs within the region due to their low production cost, also see new job opportunities in the distribution and transport sectors.

Employment also increases in the electricity supply sector, for a number of reasons:

1. Demand for electricity is greater.
2. Renewable energy generation technologies are more labor intensive per unit of capacity than fossil fuel–based technologies.
3. The load factor of renewables is (mostly) lower than conventional generation, so the labor intensity per unit of generation increases more than the per unit of capacity.

In addition, services sectors benefit from increased investment, as they form the critical supply chain to the sectors that benefit directly.

Economy-Level Impacts

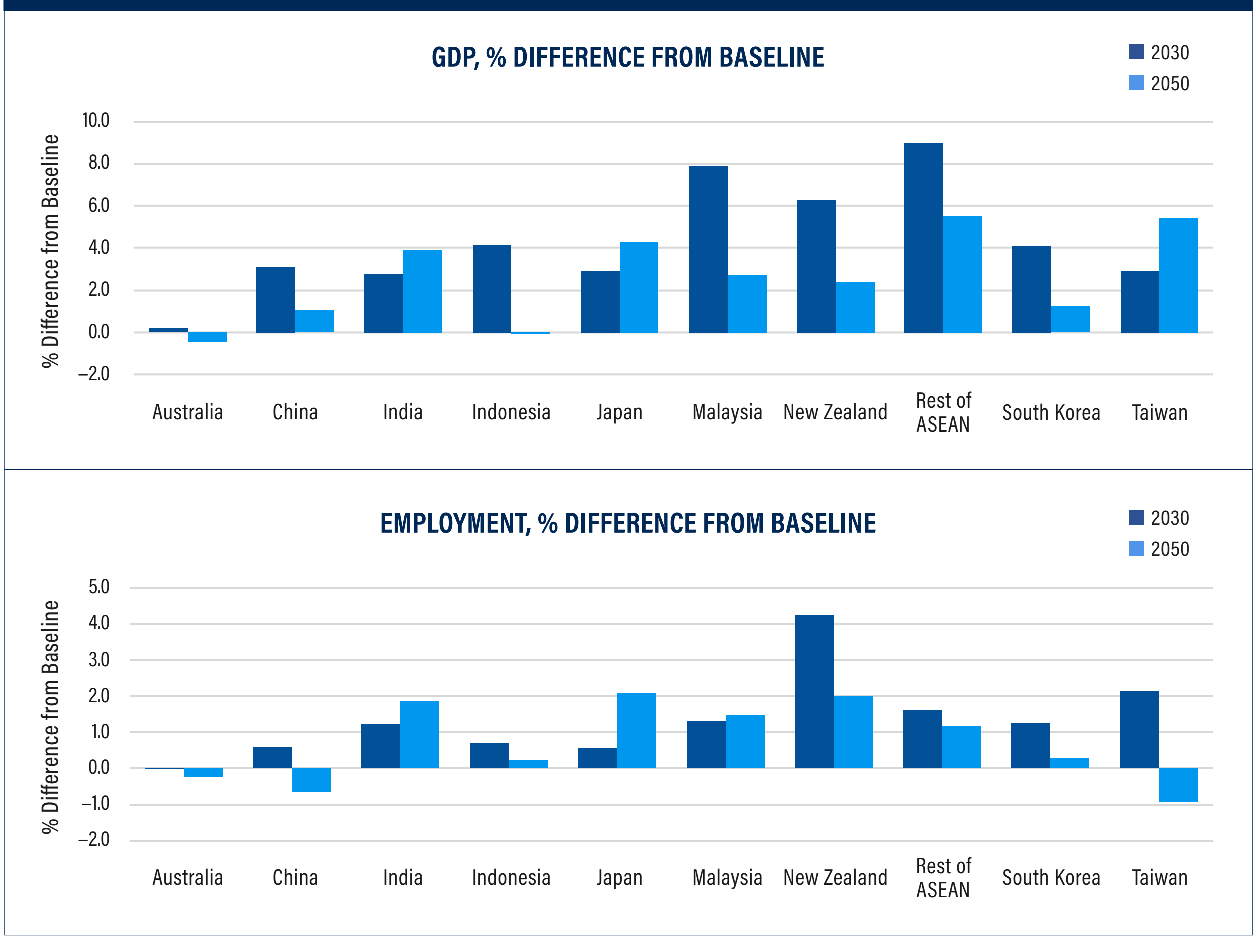
The regional results, described above, are unpacked at the economy level in Figure 3.8 for the *current unconditional net zero* scenario. The narratives follow in a similar manner in the rest of the scenarios. The economies can be grouped as follows:

- *South Korea*, *New Zealand*, *Malaysia*, and *Rest of ASEAN* all experience relatively strong and positive short-term GDP and employment impacts and milder long-term impacts. These economies are most similar to the Asia-Pacific aggregate. There are initially high levels of investment in energy efficiency and renewables (as a result of coal phase down and phaseout). However, consumers bear the costs in the long run because carbon revenues are lower than the costs of policy implementation.
- *China* and *Taiwan* see similar impacts on GDP as the above economies but experience net job losses in the long term. In China, the majority of job losses are attributable to the decline of fossil fuel extraction industries, which is primarily influenced by reduced domestic demand. These losses outweigh the benefit to manufacturing industries (from increased domestic and international demand for machinery, equipment, and vehicles to support the construction of low-carbon infrastructure). If China is able to take advantage of a rapid transition to create greater specialization in low-carbon exports, the gains may offset or outweigh the losses, given China's prominent role in global low-carbon value chains – however this effect has not been included in any of the scenario modeling. In the case of Taiwan, the impact of inflation (due to carbon pricing and investment cost pass-through) on consumers is more sustained than that for the other economies mentioned in the first group, leading to slightly negative employment impacts in the long run. Taiwan's high dependency on imported food and fuels exposes it to potential price increases not only from domestic decarbonization but also from climate action in the rest of the region and the world. In addition, sectors that typically serve households, such as retail and hospitality, tend to have lower productivity than the economy-wide average, which explains job losses due to reduced consumer spending despite a positive GDP stimulus linked to higher investment.
- *India and Japan* have sustained positive GDP and employment impacts over the period to 2050. Together with New Zealand (which currently has the lowest fossil fuel shares in the Asia-Pacific), the long-term employment impacts in these economies, relative to the size of their workforces, are the largest in the region. Along with the initial investment, an improved net trade balance (due to a reduction in fossil fuel imports) and low costs to households help maintain the positive impacts in the long term. India benefits from some of the lowest renewables costs in the region and the world, as well as an abundant workforce, while the energy sector in Japan is relatively small so positive impacts from renewables energy supply dominate over job losses in the existing fossil fuel sectors.

- *Australia* is the only economy that experiences a negative long-term impact on both GDP and employment, following a limited short-term stimulus. Losing fossil fuel exports and low levels of potential carbon revenues (due to its carbon intensity of GDP already being lower than the Asia-Pacific average), Australia is likely to require higher taxes to fund the transition, which lowers real household incomes and consumption. However, the modeling does not assume the creation of a large-scale low-carbon industry to replace the existing fossil fuel supply (implying that demand is met by current domestic capacity and an increase in imports). If this potential were realized, the negative impacts would be alleviated to some extent. Analysis by McKinsey (2021) suggests that export opportunities in green energy, minerals, and low-carbon heavy manufacturing have the potential to add three times more jobs than the number of mining and energy jobs at risk in Australia, implying overall positive employment impacts.

The aggregate Asia-Pacific GDP impacts are driven by the largest economies in the region: China, India, and Japan. These regions share the substantial positive short-run stimulus and have sustained positive impacts in the long run, which show up in the aggregate Asia-Pacific results. Excluding Australia and New Zealand from the regional analysis improves the positive regional GDP impact slightly because of the negative impact in Australia, whereas the regional employment impact is reduced slightly, albeit it is still positive, because New Zealand has the strongest relative increase in employment among all Asia-Pacific economies.

FIGURE 3.8: ECONOMY-LEVEL IMPACTS IN 2050 IN THE CURRENT UNCONDITIONAL NET ZERO SCENARIO

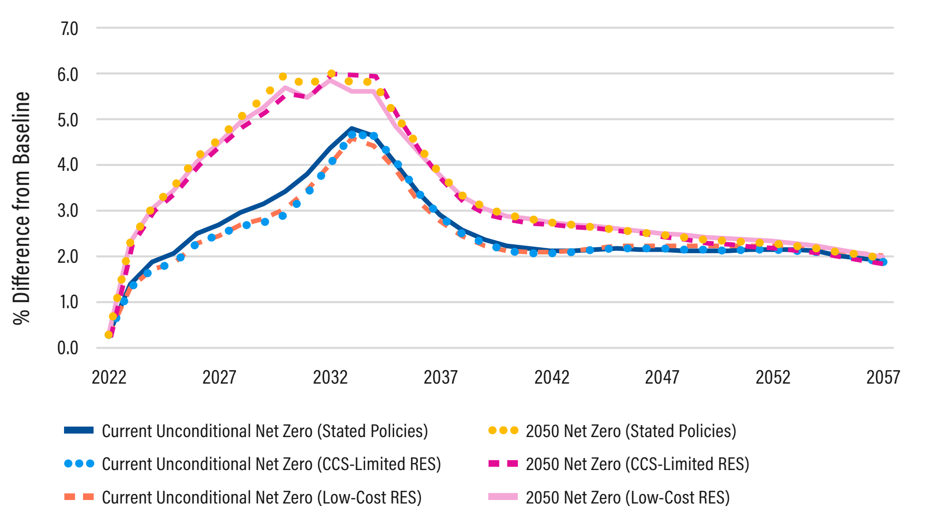


Source(s): Cambridge Econometrics, E3ME modeling result.

Power Sector Sensitivity

As a result of the role of the power sector in driving investment, the GDP impact profiles are also sensitive to the power technology mix (see Figure 3.9): at the regional level, the higher the share of low-cost renewables, the lower the peak in GDP impacts (because of lower investment requirements that are a direct stimulus to GDP) but the more positive the long-term GDP impacts (as a result of the less negative impacts on household consumption in response to implied changes in energy prices). The employment differences track the profile of the GDP differences closely through the years to 2040–45, being most positive in the stated policies / stated and strengthend polciies and CCS-limited RES variants and least positive in the low-cost RES variant. However, from 2050 onward, the difference between variants largely disappears. One reason for this is that policy variations are by design relatively small and implemented within the next decade, so the impacts are also mostly observed over a similar time frame. Another important reason is that the weight of economies where results are most sensitive to power mix variations (Indonesia, New Zealand, Malaysia, and South Korea) is much smaller than the weight of China and India in the region's total GDP.[15] Low-cost renewables (particularly wind and solar) are highly competitive in China and India, therefore reaching a similar share of total electricity generation by 2050 in these economies even in variants where policies are assumed to prioritize other technologies.

FIGURE 3.9: IMPACT OF POWER MIX VARIATIONS ON GDP IMPACTS IN ASIA-PACIFIC



Source(s): Cambridge Econometrics, E3ME modeling result.

The same narrative applies in most of the constituent economies. There are some noteworthy exceptions, however:

- In *New Zealand*, *Malaysia*, and *South Korea*, the CCS-limited RES variant leads to the smallest positive impacts on GDP and employment by 2050. In this variant, policies are aimed at prioritizing a mix of all renewable options including hydro, biomass, wind, solar, and geothermal. It is the role

15 Indonesia, New Zealand, Malaysia, and South Korea together account for around 12 percent of regional GDP by 2050, whereas China and India together make up 65 percent.

of hydro and geothermal in the power mix that drives the results, as these technologies involve the highest capital costs among those mentioned, which can lead to high energy prices and dampened household expenditure. There is currently a very small share of geothermal in these economies, accompanied by high capital costs, which is also true for hydro in Korea. While the presence of hydro in New Zealand and Malaysia is currently substantial, both economies are making efforts to diversify their power system; with faster renewable cost reductions in the future, they would naturally see lower hydro dependence over time even in the baseline. Therefore, efforts to reboost hydro would result in cost increases compared to the baseline.

- In *Indonesia*, the stated policies variant of the *current unconditional net zero* scenario leads to a less positive impact on GDP and more positive (specifically, a less negative impact) on employment by 2060, compared to the CCS-limited RES variant (similarly for the stated & strengthened policies variant and the CCS-limited RES variant of the *2050 net zero* scenario). This contrast with the regional results is due to the focus of the Indonesian LTS on prioritizing fossil fuels with CCS as one of the main low-carbon technology options, ahead of renewables, in both the short and long terms. While fossil fuels with CCS preserve more jobs (given that a large number of jobs in Indonesia are in fossil fuel supply sectors), they are also more capital intensive and expensive to run (because they do not capture all emissions[16] and are therefore still exposed to carbon pricing), which leads to large increases in energy prices that hurt consumers. The low-cost RES variant shows the lowest GDP peak and the most positive long-term GDP impacts, similar to the regional average outcome.

Table 3.2 shows the differences between the three variants, across key socioeconoomic indicators.

TABLE 3.2: IMPACTS OF POWER SECTOR SENSITIVITIES ON KEY SOCIOECONOMIC INDICATORS

	CURRENT UNCONDITIONAL NET ZERO (BASED ON STATED POLICIES, WITHOUT INTERNATIONAL SUPPORT)	CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES, WITHOUT INTERNATIONAL SUPPORT)	CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES, WITHOUT INTERNATIONAL SUPPORT)	NET ZERO 2050 (BASED ON STATED AND STRENGTHENED POLICIES, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (CCS-LIMITED RES, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (LOW-COST RES, WITH INTERNATIONAL SUPPORT)
Earliest year in which carbon emissions peak in Asia-Pacific to deliver net zero emissions and realize economic benefits	2025	2025	2025	2022	2022	2022
GDP impact relative to baseline	Peaking at +4.8% in 2033 +1.8% in 2060	Peaking at +4.7% in 2033 +1.8% in 2060	Peaking at +4.6% in 2033 +1.9% in 2060	Peaking at +6.0% in 2032 +1.7% in 2060	Peaking at +6.0% in 2032 +1.7% in 2060	Peaking at +5.9% in 2032 +1.8% in 2060

16 In E3ME, it is assumed that 90 percent of emissions are captured in CCS plants.

TABLE 3.2: IMPACTS OF POWER SECTOR SENSITIVITIES ON KEY SOCIOECONOMIC INDICATORS

	CURRENT UNCONDITIONAL NET ZERO (BASED ON STATED POLICIES, WITHOUT INTERNATIONAL SUPPORT)	CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES, WITHOUT INTERNATIONAL SUPPORT)	CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES, WITHOUT INTERNATIONAL SUPPORT)	NET ZERO 2050 (BASED ON STATED AND STRENGTHENED POLICIES, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (CCS-LIMITED RES, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (LOW-COST RES, WITH INTERNATIONAL SUPPORT)
Cumulative economy-wide investment required from now for achieving net zero emissions	$54.4trn	$51.3trn	$50.2trn	$72.4trn	$71.6trn	$70.1trn
Change to Asia-Pacific's trade balance by 2060	+$785bn	+$792bn	+$797bn	+$823bn	+$815bn	+$827bn
Absolute jobs impact compared to baseline	Peaking at +25.2 million in 2033 +10.9 million in 2060	Peaking at +25.2 million in 2034 +10.3 million in 2060	Peaking at +23.4 million in 2034 +10.7 million in 2060	Peaking at +36.7 million in 2032 +5.3 million in 2060	Peaking at +36.5 million in 2032 +5.2 million in 2060	Peaking at +34.8 million in 2032 +5.2 million in 2060
Change in household spending by 2060	-$0.75trn	-$0.73trn	-$0.60trn	-$1.2trn	-$1.3trn	-$1.2trn

POLICY COSTS, SAVINGS, AND WIDER BENEFITS

Policy Costs and Savings

It is evident from the modeling results that more ambitious decarbonization goals are beneficial to the Asia-Pacific economy in terms of GDP and employment. Underlying those macro-level benefits, however, are various costs and savings from ambitious policies.

Costs

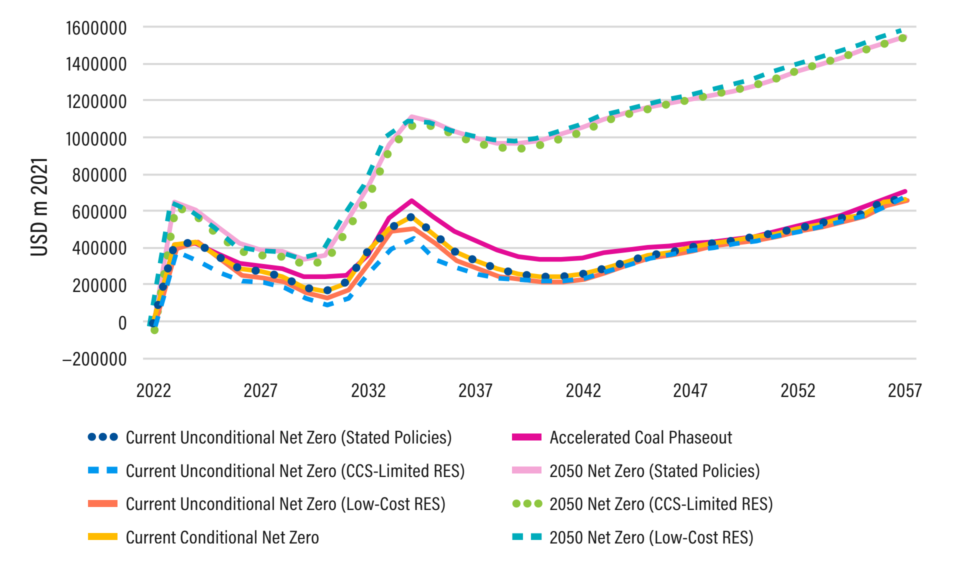
The decarbonization investment requirements (which include capital investment but exclude operating expenses) in section 3.3 reflect costs to the whole economy of decarbonizing.

In addition, governments directly incur costs of policy implementation that significantly affect the macroeconomic results. Net policy costs are defined as the difference between government revenues from policies (carbon pricing and fuel duties) and the costs of policy implementation (consisting of subsidies for renewables and low-carbon technologies, investments in energy efficiency, and compensation to investors for stranded assets due to coal regulation in the power sector[17]). Positive net policy costs indicate an increase in government deficits that are passed on to households in the form of higher taxes (this effect is responsible for the lower household consumption described in section 3.3), and vice versa.

17 It excludes the cost of retraining, relocating, and redundancy compensation for workers of retired coal power plants.

Net costs are volatile over time, reflecting sector readiness and evolving climate goals. In particular, peaks in net costs through the projected period correspond to government compensation to investors for early closures of coal power plants due to regulation. Some economies have already adopted policies on early coal plant closure: Indonesia plans to phase out 9.2GW of coal capacity between now and 2030; India is aiming for 50 percent of renewable energy and 500GW of non-fossil capacity by 2030 (which would require phasing down coal power); China has pledged to stop building new coal capacity overseas and start phasing down coal from 2026; and New Zealand, which has the lowest share of fossil fuels in electricity generation in the Asia-Pacific, is a member of the Powering Past Coal Alliance that aims to phase out coal by 2030. In addition, it is assumed that complete phaseout is reached by 2030 in Australia, New Zealand, South Korea, and Japan and by 2040 in the rest of the region. This makes the combination of accelerated coal phase down in the medium term and complete phaseout of unabated capacity in the long term an effective yet costly policy.

FIGURE 3.10: NET POLICY COSTS OF DECARBONIZING THE ASIA-PACIFIC ECONOMY



Source(s): Cambridge Econometrics, E3ME modeling result.

Delivering current commitments would cost Asia-Pacific governments around $15.8trn for policy implementation throughout the forecast period (see Table 3.2), increasing to $38.5trn in more ambitious *2050 net zero* scenarios. The main costs are renewable subsidies and stranded asset compensation in the short to medium term and energy efficiency investments in the long term. Although carbon pricing plays an important role in lowering costs in the medium term when emissions levels are relatively high, in the long run this source of funding will gradually reduce in line with emissions. Therefore, these are areas where international support, climate finance, and repurposing energy subsidies currently in place would be most constructive. The role of international support is demonstrated to a limited extent in the modeling of the most ambitious scenarios; expanding the scope of international support would yield visibly different (likely more positive) socioeconomic outcomes due to reduced cost burdens on national governments and ultimately consumers to finance the transition. In addition, an example where energy subsidies may be a viable source of alternative funding is explored as part of the country modeling for Indonesia, in the form of a reinvestment of coal power subsidies into green initiatives (Asia Society Policy Institute 2023). In both cases, the availability of additional funding helps reduce net policy costs accrued to governments and relieves the pressure on households.

Savings

Despite the cost of capital investment to adapt to low-carbon technologies, there is a reduction in energy demand by households that results from energy efficiency improvements and technological transformations. On the other hand, per unit energy prices and especially electricity prices increase. Figure 3.11 shows the net impact of the demand and price effects for households.

An increase of up to 12 percent within the next decade in all scenarios is driven by the introduction of policies, particularly carbon pricing, that do not currently exist in the majority of economies in the region, which puts upward pressure on the unit price of energy (especially electricity and gas). Across scenarios, regional average electricity prices increase substantially – by 35 percent –60 percent above baseline levels – with most of the increase happening in the short run until 2030. Fossil fuels are subject to carbon pricing that drives up their costs in all scenarios; however, these increases reduce significantly over the forecast period in line with the reduction in demand.

The impacts of the transition on electricity prices are significant under the stated policies variant of the *current unconditional net zero* scenario and the stated & strengthened policies variant of the *2050 net zero* scenario. New Zealand, where the majority of power generation is already renewables based, is the only economy with almost no impact on electricity prices. The electricity price increases are most prominent in Indonesia, South Korea, Japan, and India for a number of reasons:

- The switching from predominantly coal-based power generation to renewables with carbon pricing, particularly in India, China, and Indonesia.
- The cost of renewables is relatively high because of low historical deployment that is in turn driven by local factors, such as local regulations in Indonesia and geographical conditions in Japan and South Korea.
- Some economies (Australia, Korea, Japan, and Indonesia) aim to deploy CCS technologies, which are capital intensive and may be subject to carbon pricing (for fossil fuel with CCS, at least in the medium term).

TABLE 3.3: NET POLICY COSTS AND FUNDING OPTIONS ($2021BN)				
	TOTAL NET POLICY COSTS (2022-60)	INTERNATIONAL SUPPORT (2022-60)	AVOIDED COAL POWER SUBSIDIES (2022-60) - ONLY FOR INDONESIA	POLICY COSTS TO BE FINANCED BY THE GOVERNMENT (2022-60)
Current unconditional net zero (stated policies)	14,760	-	32	14,727
Current unconditional net zero (CCS-limited RES)	13,800	-	35	13,765
Current unconditional net zero (low-cost RES)	14,195	-	36	14,159
Current conditional net zero	14,727	18	35	14,673
Accelerated coal phaseout	16,483	623	40	15,820
2050 net zero (stated policies)	38,358	923	41	37,394
2050 net zero (CCS-limited RES)	38,086	492	42	37,552
2050 net zero (low-cost RES)	38,502	802	43	37,657
2050 net zero (low-cost RES)	40	56	43	–59

Note(s): Negative costs imply savings that are redistributed to households via tax reductions.
Policy costs to be financed by the government = Total net policy costs – International support – Avoided coal power subsidies.

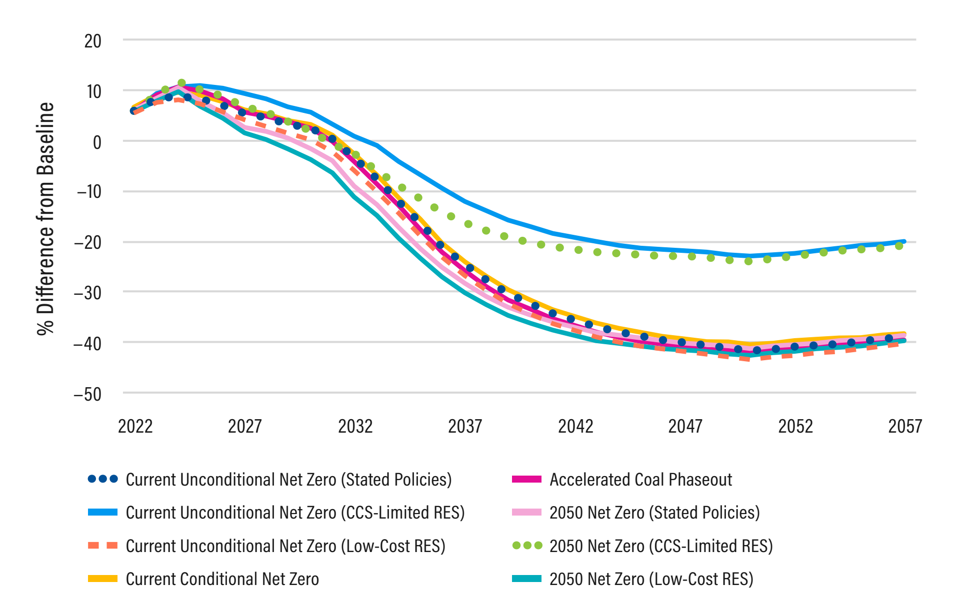
In the long term, in most scenarios, there are savings of around 45 percent on household energy costs by 2050, and slightly lower at 40 percent by 2060 due to rebound effects and continued economic growth. This is equivalent to an absolute reduction of around $305–$310bn across the Asia-Pacific region by 2060. This reduction coincides with lower demand for energy imports that helps protect domestic energy prices from external fossil fuel price volatility.

In the power sector sensitivities with higher shares of wind and solar PV, the energy price increases are substantially reduced. On the other hand, prioritizing hydro and geothermal will lead to the largest energy price increase overall. The latter is clearly seen in the energy spending impacts for the CCS-limited RES variants of the *current unconditional net zero* and *2050 net zero* scenarios where there are much smaller energy cost reductions than in the other scenarios (which are expected to continue beyond the presented timeframe). In this variant, capital-intensive hydro and geothermal technologies are widely deployed across the region, leading to markedly increased costs of electricity generation in economies with a small role for these technologies in the baseline (and other scenario variants) due to continued cost reductions and increased deployment of wind and solar, notably New Zealand, Malaysia, and Rest of ASEAN.

The energy spending impacts across central and low-cost RES variants of the *current unconditional net zero* and *2050 net zero* scenarios become very similar from 2050 onward. Both these scenarios have household energy efficiency savings (the primary driver of energy spending reductions) as a key contributor to net zero emissions. The maximum saving potentials are assumed in both scenarios and the difference in the level of ambition is thus driven by rapid emissions reductions in other sectors such as power generation and industry.

In contrast with the results for household energy spending, economy-wide energy spending increases with a higher level of decarbonization ambition relative to baseline: industries (where many Asia-Pacific economies currently have a comparative advantage) are likely limited to fewer and more costly decarbonization options than households because of the structure of their manufacturing plants and processes. For example, the cost of green hydrogen is higher than that of fossil fuels and hydrogen produced from fossil fuels and CCS due to high costs of electrolysers, whereas biofuels have lower energy efficiency than petroleum-based products, meaning more biofuel is needed to produce the same output.

FIGURE 3.11: HOUSEHOLD ENERGY SPENDING IMPACTS FOR ASIA-PACIFIC (% DIFFERENCE FROM BASELINE)



Source(s): Cambridge Econometrics, E3ME modeling result.

Wider Benefits

In addition to macroeconomic benefits, there are wider benefits from climate action (or costs of no action) that are not quantified as part of this modeling exercise but are noteworthy.

The Asia-Pacific region includes some of the largest national emitters in the world. Therefore, its progress toward carbon neutrality also contributes to global decarbonization. Table 3.3 shows the estimated global temperature change[18] by 2100 associated with each scenario, with the most ambitious *accelerated coal phase-*

18 These estimates are based on cumulative emissions results from E3ME and an average warming coefficient of 1.84°C/TtC, based on Millar and Friedlingstein (2018).

out and *2050 net zero* scenarios assuming that the Asia-Pacific's climate action is matched by similar levels of ambition in the rest of the world. The main drivers of the notable reduction in temperature increase are the short-term and net zero commitments made by China and India, two of the world's largest emitters. However, the current levels of ambition are likely to fall short of the 1.5°C target, suggesting a need for more ambitious targets and policies in the region.

TABLE 3.4: ESTIMATED GLOBAL TEMPERATURE CHANGE ACROSS SCENARIOS

SCENARIO	GLOBAL TEMPERATURE CHANGE BY 2100
Baseline	3.4°C
Current unconditional net zero	1.6°C
Current conditional net zero	1.6°C
Accelerated coal phaseout	1.6°C
2050 net zero	1.5°C

Delayed or inadequate climate action risks additional damage to economic growth due to disruptions from global warming, causing extreme weather events and lost productivity and livelihoods. These physical risks are widely discussed in the relevant literature, where application of Integrated Assessment Models (IAMs) and econometric analysis have previously been used to estimate the impact of climate change on future economic growth.

The literature contains a wide range of estimated GDP impacts associated with future temperature and climatic change. For example, Burke et al. (2015, 2018, 2019), using econometric analysis on national-level data, estimate that a 3°C temperature increase (in line with the *pre-COP26 policies* scenario) would reduce global GDP by 25 percent, whereas a 1.5°C pathway would lead to an 11 percent reduction in global GDP by 2100 (both compared to a global economy absent any climate change). The Asia-Pacific would endure a share of these damages.

Although not quantified as part of this study, additional co-benefits, such as better air quality, other health benefits, and improved biodiversity, are likely to result from enhanced climate protection and benefit the Asia-Pacific's population significantly.

Policy Recommendations

Based on the environmental and socioeconomic impacts presented earlier in this chapter, the key policy recommendations are summarized in Table 3.4. This provides a qualitative assessment of how key policies contribute to decarbonization goals and the opportunities, constraints, and trade-offs associated with them. It is acknowledged that policies are often designed to complement each other in practice, and it is unlikely that one single policy will deliver all desired decarbonization targets at the economy-wide level. As such, the scenarios presented in this study show the combined effects of all policies (policy packages); the impact of individual policies in isolation has not been quantified.

For example, carbon pricing on its own is likely to be less effective in reducing emissions than when combined with low-carbon technology subsidies or regulating the use of coal for power generation (because they together send reinforcing signals), despite generating additional revenues for the government. On the other hand, coal power regulation (particularly an accelerated phaseout) alone may generate high costs of compensation to the power sector for stranded assets and an excess supply of coal, making it cheaper for other sectors to use coal if there is no other policy in place to discourage fossil fuel use and encourage investment in low-carbon alternatives. In addition, as the modeling for Indonesia shows, repurposing energy subsidies to pay for stranded asset compensation caused by coal phaseout regulation would also improve the socioeconomic outcomes compared to when regulation is funded through taxes on consumers.

The results and policy recommendations set out here are intended to inform the design of such policy combinations that best balance the identified opportunities and the trade-offs.

Additionally, the modeled scenarios illustrate that the Asia-Pacific emissions targets set in the Parties' NDCs and LTS strategies can be achieved through different power sector decarbonization pathways. Our modeling shows multiple feasible power sector decarbonization pathways, which come at different costs and social impacts and need to be factored into policy decisions aimed at promoting specific technologies. These pathways can look very different in each economy.

In summary, for the Asia-Pacific economies to reach their current net zero commitments, and potentially earlier than currently agreed (by 2050 for the region as a whole), the most important recommendation is a combination of enforced regulation and market-based enablers covering all sectors, with a particular focus on carbon pricing, unabated coal regulation, incentives for low-carbon options in end-use sectors, and market reforms to promote cost-competitive renewables in the power sector. In particular, note the following:

- Implementation of **carbon pricing** across all constituent economies, starting with energy-intensive sectors as soon as 2023, to encourage electrification and innovation in low-carbon solutions.
- **Recycling of carbon revenues** to fund energy efficiency investments and subsidies for low-carbon technologies.
- Introduction of a **no new coal regulation** (banning new constructions of unabated coal power plants beyond the current pipeline) as soon as possible.
- **Public procurement** to boost the uptake of wind and solar PV within the next few years.
- Strengthening of **financial subsidies for renewables power and electric vehicles** to achieve price parity this decade.
- Enforcing more stringent **biofuel mandates**.

TABLE 3.5: KEY POLICY RECOMMENDATIONS

	SECTORS WITH THE MOST IMPACT	PERIOD WITH THE MOST IMPACT	OPPORTUNITIES	CONSTRAINTS OR TRADE-OFFS	COMPLEMENTARY POLICIES INCLUDED IN THE MODELING	COMPLEMENTARY POLICIES NOT INCLUDED IN THE MODELING
Carbon pricing as soon as possible for energy-intensive sectors, and 2031 for the rest	All sectors especially energy-intensive sectors (power generation and industry)	Short to long term	Incentivizes switching to renewables by making fossil fuels more expensive and acts as a source of funding for other measures	Regressive for low-income households and creates inflationary pressures when costs are passed on to consumers through higher prices	Revenue recycling and policies that include subsidies for, or otherwise kick-start, low-carbon technologies	-
Energy efficiency investments	All sectors, especially buildings	Short to long term	Effective at reducing building emissions (where there are large reduction potentials) at relatively low costs in the short term	Constrained by nonmarket barriers (e.g., housing stock, production processes) at least in the short term	Carbon pricing, revenue recycling	-
No new coal regulation from 2023	Power generation	Short and medium terms (especially before 2030)	Most effective at reducing emissions in the short and medium term s while freeing up revenues that would otherwise be used for coal power subsidies to invest in low-carbon initiatives	Costly to implement due to stranded asset compensation	Carbon pricing, renewables subsidies, innovation, and R&D, complete phaseout regulation	-
Renewables subsidies	Power generation	Short term (before price parity is achieved this decade)	Incentivizes switching to renewables from fossil fuels and allows the market to select cost-competitive solutions	Costly to implement in the short term	Coal power regulations, innovation, and R&D, revenue recycling	-
EV subsidies	Transport	Short term (before price parity is achieved this decade)	Incentivizes switching to EVs by making them more affordable	Costly to implement in the short term and effectiveness constrained by nonmarket barriers (e.g., lack of charging infrastructure) and domestic production capacity	Carbon pricing, revenue recycling	Policies aimed at expanding domestic production capacity to build comparative advantage
Biofuel mandates	Transport (especially freight road transport, air and marine transport) and agriculture	Medium to long term (after 2030)	Enforces fuel switching where market-based incentives are low	Low-carbon or less emissions-intensive alternatives with low market shares may be more expensive in the short term	Carbon pricing, innovation, and R&D	-

TABLE 3.5: KEY POLICY RECOMMENDATIONS

	SECTORS WITH THE MOST IMPACT	PERIOD WITH THE MOST IMPACT	OPPORTUNITIES	CONSTRAINTS OR TRADE-OFFS	COMPLEMENTARY POLICIES INCLUDED IN THE MODELING	COMPLEMENTARY POLICIES NOT INCLUDED IN THE MODELING
Kick-start (public procurement) for cost-competitive low-carbon technologies in the next 5–10 years	Power generation and industry	Short term (before 2030)	Allows low-carbon technologies that are cost competitive but not widely deployed due to nonmarket barriers to participate in the market, leading to learning-by-doing effects and faster future cost reductions	Costly to implement in the short term and may take a long time to see visible effects	Carbon pricing, revenue recycling, policies that include regulation of fossil fuel use and support for low-carbon technologies	Investment in retraining and developing the workforce to adapt to new technologies
Revenue recycling	Secondary impact on all sectors that can be substantial with international support	Short to long term	Allows carbon revenues to be earmarked for low-carbon measures	Impacts households negatively if there is a large investment requirement and no international support	Carbon pricing	Alternative funding mechanisms for low-carbon investments such as repurposing energy subsidies

CONCLUSIONS

SOCIOECONOMIC AND CLIMATE IMPACTS

Decarbonization of the Asia-Pacific region is key to avoiding devastating climate damages and can bring substantially higher economic growth.

The modeling shows that increasing climate ambition and action generates substantial macroeconomic benefits in GDP and employment terms for the Asia-Pacific economies. This growth is driven by high levels of investment, particularly in the power sector. In addition, there is a net trade balance improvement in the long term due to lower demand for imported fossil fuels.

However, households and their consumption levels could be negatively affected as a result of increased taxes and prices, indirectly bearing some of the costs of the transition. Despite an overall positive impact on employment, there is potential for a significant number of job losses in fossil fuel supply industries as a result of the low-carbon transition, which presents a distributional and social challenge for local communities.

The net zero transition in the Asia-Pacific economies depends on climate action within each economy and also in other economies. With the rest of the world decarbonizing, the costs of low-carbon technologies will decrease more rapidly, making the transition less expensive. Should the region choose to delay action or deviate from the rest of the world, it may face higher costs in the form of stranded assets and higher taxes due to carbon border adjustment schemes imposed by other economies (which are not quantified in the modeling).

Current commitments announced in the Asia-Pacific region are insufficient to meet obligations under the Paris Agreement and could contribute to 3°C of global warming. Delivering on NDCs and 2030 targets can limit warming to below 2°C and lead to net zero emissions for the region in the second half of the century. Further strengthening policies would make achieving net zero emissions by 2050 across the region, and keeping to 1.5°C of global warming, possible. This analysis does not include the costs of inaction (climate damages due to impacts of higher temperature increases, extreme weather events, and natural disasters) and health co-benefits from reducing air pollution levels. As such, the total benefits of stronger climate action in the Asia-Pacific will be substantially higher than estimated in this study if avoided climate damages and improved health outcomes are included.

POLICY IMPLICATIONS

The Asia-Pacific's tremendous growth potential but lower than global average per capita income means that aligning decarbonization targets with development goals should be a strong policy priority. The modeling shows that additional and more ambitious policies would allow the region to stay on course for limiting climate change impacts and reap additional economic benefits in the process. However, there are strong trade-offs behind the aggregate impacts, as well as winners and losers among economies within the region.

In the power sector, an unabated coal phaseout regulation is very effective at delivering large emissions reductions in the medium term but can be costly because of the high costs of government compensation for stranded assets (unless offset by other savings such as removal of energy subsidies). In addition, it is critical that cost-competitive technologies such as wind and solar are exploited and are at the forefront of policy decisions to minimize this impact, especially in economies that are in the early phase of the renewables learning curve. Moreover, in net zero pathways that feature a higher share of low-cost renewables and minimal shares of coal with CCS, the increase in electricity prices due to the transition is lowest, because of less exposure to carbon pricing and larger potentials for future renewables cost reductions due to widespread deployment.

To deliver a just transition for vulnerable groups, policies aimed at protecting social welfare and international support for emerging Asian economies analyzed in the report are needed to complement and fund climate policies. While recycling carbon revenues or leveraging other tax-raising mechanisms plays an important role as a potential funding mechanism for green investments, international support specifically aimed at assisting the low-carbon transition will free up domestic finance in low-income economies for development, poverty reduction, and management of social impacts. Policies to support reskilling and upskilling of the workforce will also allow workers to take full advantage of new employment opportunities that arise in a low-carbon economy.

APPENDICES

APPENDIX A: REFERENCES

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APPENDIX B: ANNOUNCED TARGETS AND COMMITMENTS

Key targets included in Parties' official NDCs generally take the form of either a level of emissions reductions or an emissions intensity target, relative to a stated business-as-usual trajectory or a reference year. Some Parties have included additional sectoral targets such as increasing the usage of renewable energy sources and/or decreasing the usage of fossil fuels, mainly coal. These targets vary substantially in their level of ambition and in the detail of supporting policies for implementation.

Some Parties have made additional relevant pledges apart from the above or beyond those explicitly included in their official NDCs. For instance, China has announced that it will "strictly control coal-fired power generation projects and limit the increase in coal consumption" over the period of the 14th Five Year Plan period (2021–25) and will phase it down over the 15th Five-Year Plan period (2026–30) (Xinhua, 2021). In Indonesia, the state-owned electricity utility, PLN, has announced that it will not build further coal-fired power plants from 2023. However, both announcements allow the increase of coal capacity through already commissioned plants and non-state-funded investments (Global Energy Monitor, 2021; Jong, 2021).

Most Asian economies analyzed in the report have announced net zero targets either in long-term strategy documents submitted to the UNFCCC or in government announcements. These commitments vary in their coverage of emissions (i.e., all greenhouse gases or only CO_2) and their target years typically range from 2050 to 2070. Some Parties also have more ambitious targets conditional on international support. Our scenarios capturing current commitments treat all of the above targets as credible; however, there is substantial uncertainty in how these commitments will be realized.

TABLE 0.1: KEY SHORT- AND LONG-TERM TARGETS IN THE ASIA-PACIFIC

	NDC & LTS UPDATE	KEY SHORT-TERM GOALS (2030)	NET ZERO TARGETS
Australia	2022	82% renewables electricity by 2030 43% GHG emissions reduction to 2005	Net zero, including LULUCF by 2050 (GHG)
China	2021	Peaking CO_2 emissions before 2030 Share of non–fossil fuels to ~25% 50% non-fossil power generation (of which 20%–25% wind and solar, 1,200GW of capacity), phasing down coal from 2026 and reducing dependency on nuclear and hydro Increase forest stock	Net zero before 2060 (emissions scope not specified)
India	2016	Increasing non-fossil capacity in power generation to 500GW 50% of energy requirement from RES Reducing emissions by 1 billion tons Reducing emissions intensity of GDP by 45% from 2005 levels	Aiming for net zero by 2070 (emissions scope not specified)
Indonesia**	2022	31.9% reduction in emissions (43.2% with international aid) Phase out 9.2GW of coal capacity and 50% of renewables in new capacity additions by 2030	Exploring net zero by 2060 (emissions scope not specified)

TABLE 0.1: KEY SHORT- AND LONG-TERM TARGETS IN THE ASIA-PACIFIC

	NDC & LTS UPDATE	KEY SHORT-TERM GOALS (2030)	NET ZERO TARGETS
Japan	2021	Reduce GHG emissions by 46% below 2013 levels 36%–38% of total power generation from renewables	Net zero by 2050 (GHG)
Korea	2021	40% GHG emissions reduction to 2018	Net zero by 2050 (GHG)
Malaysia*	2022	45% GHG intensity reduction to 2005 31% of solar and biomass in total installed capacity by 2025	Net zero by 2050 (GHG)
New Zealand	2021	50% GHG emissions reduction to 2005 100% renewable electricity by 2035, phasing out coal in the next 10–20 years	Net zero by 2050 (GHG)
Taiwan	-	50% GHG emissions reduction to 2005 20GW of solar and 5.6GW of offshore wind by 2025, 30GW solar and 13.1GW offshore wind by 2030	Net zero by 2050 (GHG)
Brunei***	2021	20% of GHG reduction to a pre-COP26 policies baseline by 2030	No net zero target
Cambodia***	2022	42% GHG emissions to 2010 (with international support)	Carbon neutral by 2050 (GHG)
Laos***	2021	60% GHG reduction to a pre-COP26 policies baseline scenario	Conditional net zero by 2050 (GHG)
Myanmar***	2021	144 million tCO_2e emissions reduction compared to a pre-COP 26 policies baseline (297 million tCO_2e with international support)	No net zero target
Philippines***	2021	75% reduction of GHG compared to a pre-COP26 policies baseline scenario, of which 72% is conditional on international support	No net zero target
Singapore***	2022	Peak emissions in 2030 to reach 60 $MtCO_2e$.	Aiming toward net zero emissions "as soon as viable"
Vietnam*/***	2022	15.8% reduction in CO_2 emissions to a pre-COP26 policies baseline scenario (43.5% with international support)	Net zero by 2050 (CO_2)
Thailand*/***	2022	30% reduction GHG emissions to a pre-COP26 policies baseline scenario, 40% with international support	Net zero by 2065 (2050 with international support) (GHG)

Note(s): Taiwan cannot sign onto the UNFCCC; it has not submitted a formal NDC, but it has announced an intended Nationally Determined Contribution.
* The asterisk indicates that the net zero targets are not in LTS documents but have been announced by PM or ministries.
** Indonesia has not updated its long-term strategy in 2022 but revised its net zero targets in other strategy documents.
*** These economies are all represented as a part of a "Rest of ASEAN" region in E3ME. Due to the wide range of variation between economies, the individual targets cannot be explicitly modeled and instead are consulted to sense-check the "Rest of ASEAN" results that are based on a Paris-aligned pathway.
Source(s): UN NDC Registry, national LTS documents, climateactiontracker.org.

APPENDIX C: MODELING ASSUMPTIONS

Policy Assumptions

Table 0.2 summarizes the policy assumptions modeled for all scenarios and sensitivities

TABLE 0.2: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)	CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)	CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)	CURRENT CONDITIONAL NET ZERO	ACCELERATED COAL PHASEOUT	2050 NET ZERO (STATED POLICIES)	2050 NET ZERO (CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
Economy wide	Emissions reductions target	No regional target	No regional target	No regional target	No regional target	No regional target	Net zero by 2050	Net zero by 2050	Net zero by 2050
	ETS (energy-intensive sectors)	From 2023 in all countries except India and ASEAN (from 2025), caps in line with countries' targets	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	From 2023 in all countries except India and ASEAN (from 2025), caps in line with net zero targets	From 2023 in all countries except India and ASEAN (from 2025), caps in line with net zero targets	From 2023 in all countries except India and ASEAN (from 2025), caps in line with net zero targets
	Carbon tax (non-ETS sectors)	From 2031 at $5/tCO_2$, increasing to $280/$tCO_2$ by 2050 (regional weighted average, real terms)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	From 2031 at $5/tCO_2$, increasing to $290/$tCO_2$ by 2050 (regional weighted average, real terms)	From 2031 at $5/tCO_2$, increasing to $290/$tCO_2$ by 2050 (regional weighted average, real terms)	From 2031 at $12/tCO_2$, increasing to $340/$tCO_2$ by 2050 (regional weighted average, real terms)	Same as 2050 net zero (stated policies)	Same as 2050 net zero (stated policies)
	Revenue recycling to support low-carbon technologies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Energy-efficiency programs (applies to non-ETS sectors)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	International support	No	No	No	Yes (for renewables subsidies and compensation for stranded assets relative to current unconditional net zero)	Same as current conditional net zero	Same as current conditional net zero	Same as current conditional net zero	Same as current conditional net zero
	Reinvestment of coal power subsidies in green investments	Indonesia only, based on 2018 average subsidy of $6/MWh	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)

TABLE 0.2: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)	CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)	CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)	CURRENT CONDITIONAL NET ZERO	ACCELERATED COAL PHASEOUT	2050 NET ZERO (STATED POLICIES)	2050 NET ZERO (CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
Power sector	Renewables target	China: 50% non-fossil power generation (of which 20%–25% wind and solar) and 25% non–fossil fuel energy consumption by 2030; India: 500GW non-fossil capacity by 2030; Australia: 82% renewables electricity by 2030; New Zealand: 100% renewable electricity by 2035; Taiwan: 20GW of solar power by 2025 and 2GW per year in the 2026–30 period, also adding 5.6GW of offshore wind by 2025 and 1.5GW per year in the 2026–30 period; ASEAN including Indonesia and Malaysia: 23% renewable energy and 35% renewable electricity by 2025	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)
	New coal capacity regulation	China and New Zealand: start phasing down coal from 2026; Indonesia: phase out 9.2GW of coal by 2030	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	No new coal construction from 2023	No new coal construction from 2023	No new coal construction from 2023	No new coal construction from 2023
	Coal phaseout	No regional target (2056 in Indonesia)	No regional target (2056 in Indonesia)	No regional target (2056 in Indonesia)	No regional target (2049 in Indonesia)	By 2040 (2030 in Japan and South Korea)	By 2040 (2030 in Japan and South Korea)	By 2040 (2030 in Japan and South Korea)	By 2040 (2030 in Japan and South Korea)
	Kick-start	From 2023 to 2030, 200GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 5GW of CCS and 5GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031, 1.5GW of CCS and 1.5GW of BECCS are added each year in Indonesia	From 2023 to 2030, 215GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 5GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031, 1.3GW of BECCS are added each year in Indonesia	From 2023 to 2030, 220GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 5GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031, 1.5GW of BECCS are added each year in Indonesia	From 2023 to 2030, 200GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 5GW of CCS and 5GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031 to 2040, 1.5GW of CCS and 1.5GW of BECCS are added each year in Indonesia	From 2023 to 2030, 350GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 5GW of CCS and 5GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031 to 2040, 1GW of CCS and 2GW of BECCS are added each year in Indonesia	From 2023 to 2030, 375GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 5GW of CCS and 10GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031 to 2040, 1.5GW of CCS and 3.5GW of BECCS are added each year in Indonesia	From 2023 to 2030, 375GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 10GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031 to 2040, 3GW of BECCS are added each year in Indonesia	From 2023 to 2030, 400GW of solar are added each year across the region (mainly in China, but also in India, Korea, Taiwan, and Indonesia) From 2023 to 2026, 10GW of BECCS are added each year across the region (mainly in China and Australia, but also in India, Korea, and Taiwan) From 2031 to 2040, 2.8GW of BECCS are added each year in Indonesia

TABLE 0.2: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)	CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)	CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)	CURRENT CONDITIONAL NET ZERO	ACCELERATED COAL PHASEOUT	2050 NET ZERO (STATED POLICIES)	2050 NET ZERO (CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
	Subsidies for renewables	Bio-based technologies, hydro and geothermal – 50% over 2023–30, phased out by 2046 Wind – 20% over 2023–30, phased out by 2046	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)
Industries	Subsidies for EAF steelmaking	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55
	Subsidies for CCS steel making	No	No	No	No	No	From 2023 at 10%, phased out over 2045–55	From 2023 at 10%, phased out over 2045–55	From 2023 at 10%, phased out over 2045–55
	Subsidies for hydrogen steelmaking	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55	From 2023 at 25%, phased out over 2045–55
Road transport	EV sales target	None	None	None	None	None	100% of EVs in new sales by 2040	100% of EVs in new sales by 2040	100% of EVs in new sales by 2040
	EVs subsidies	From 2023, an additional vehicle subsidy is applied on EV purchases: 8860.80 $/veh for economy class EVs, 13122.70 $/veh for medium class EVs, and 16600 $/veh for luxury class vehicles. Subsidies are phased out over 2025–30 (assuming price parity is reached this decade)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)	Same as current unconditional net zero (stated policies)
	Fuel duties	No addition	No addition	No addition	No addition	No addition	From 2023, increased by $0.02/litre, increasing to $0.18/litre by 2045 and constant thereafter	From 2023, increased by $0.02/litre, increasing to $0.18/litre by 2045 and constant thereafter	From 2023, increased by $0.02/litre, increasing to $0.18/litre by 2045 and constant thereafter
	Phaseout of ICE sales	No	No	No	No	No	Sales cap from 2023, in line with EV sales target	Sales cap from 2023, in line with EV sales target	Sales cap from 2023, in line with EV sales target
	Ban on the use of ICEs	No	No	No	No	No	No new sales from 2035, complete ban by 2050	No new sales from 2035, complete ban by 2050	No new sales from 2035, complete ban by 2050

TABLE 0.2: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)	CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)	CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)	CURRENT CONDITIONAL NET ZERO	ACCELERATED COAL PHASEOUT	2050 NET ZERO (STATED POLICIES)	2050 NET ZERO (CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
Other transport and agriculture	Biofuel mandate	Increasing to 10% by 2030 and 100% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use	Increasing to 10% by 2030 and 100% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use	Increasing to 10% by 2030 and 100% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use	Increasing to 10% by 2030 and 100% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use	Increasing to 10% by 2030 and 100% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use	Increasing to 25% by 2030 and 100% by 2050. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use	Increasing to 25% by 2030 and 100% by 2050. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Increasing to 25% by 2030 and 100% by 2050. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use
Residential	Regulation of fossil-based heating	From 2031	From 2031	From 2031	From 2031	From 2031	From 2023	From 2023	From 2023
	Subsidies for renewable boilers	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050

LULUCF Assumptions

The LULUCF modeling assumptions are based on various sources including submitted NDCs, detailed assessments of decarbonization targets, and efforts by region- and economy-level statistics. Table 0.3 presents the assumptions along with the sources for each economy in the regional aggregate.

TABLE 0.3: LULUCF MODELING ASSUMPTIONS BY ECONOMY

ECONOMY	ASSUMED YEARLY LULUCF SINK BASED ON NDCS AND HISTORICAL VALUES, $MTCO_2E$/YEAR	SOURCES
Japan	-10.61 to -47	Climate Action Tracker (2022)
China	700.0	IEA (2021)
Korea	26.7	Climate Action Tracker (2022)
India	306.0–486.2 between 2022–50	TERI (2021) and local experts.
Indonesia	Reaching to 180, 200 $MtCO_2e$ sink by 2060	Government of Indonesia (Government of Indonesia 2021)
Malaysia	54	NDC (2020)
Taiwan	0.0	n.d.
Australia	5.0	Climate Action Tracker (2022)
New Zealand	10.6	Our World in Data (2022)
Rest of ASEAN:	159.5	
Brunei Darussalam	1.2	Our World in Data (2022)
Cambodia	24.5	Our World in Data (2022)
Laos	1.1	National GHG Inventory (2019)
Myanmar	1.0	NDC (2021)
Philippines	9.0	UNFCCC (2000)
Singapore	0.0	Our World in Data (2022)
Vietnam	36.6	Our World in Data (2022)
Thailand	86.0	(Pradhan 2019)

Source(s): Note that for regions committing to yearly LULUCF sinks in their NDCs, we used those data for the whole modeling period; otherwise, historical LULUCF sink levels have been used. See references in the table. For India and Indonesia, see the country reports..

Note(s): For Japan, linear growth of LULUCF is assumed from –10.61 $MtCO_2e$ sinks grow to –46 $MtCO_2e$ linearly up to 2030, when stabilized at this level.

If available, yearly LULUCF levels are consistent with announced policies and committed targets; otherwise, they reflect the latest historical data. For simplicity, the same LULUCF ambition has been used for all scenarios for each modeled Asian economy, with the exception of India and Indonesia for which assumptions are tailored to the policy ambition in each scenario. We assumed constant LULUCF levels over time for all economies except Japan. For Japan, yearly LULUCF sink levels grow linearly up to 2030 to achieve the targeted level (as data are available for both of those data points).

Note that for India and Indonesia, different ambition levels are modeled and growing LULUCF sinks in the pathways. The country reports provide the full details on the modeled assumptions of the two regions.

Other Assumptions

In addition to the policy assumptions, the following assumptions were made:

- Changes to policies start in 2023 in all scenarios.
- In the sensitivities, only existing/announced policies are scaled up and down; no new policy is introduced.
- There is no crowding out of existing investment (but there are endogenous constraints for product, finance, and labor markets).
- The analysis excludes climate risks and co-benefits.
- Outside of target economies and regions with explicit targets, similar policies are set up across all regions that align with the target country's level of ambition; for example, in the net zero 2050 scenarios, all other economies also decarbonize rapidly in line with the Paris Agreement.

APPENDIX D: MODEL RESULTS

TABLE 0.4: CO_2 EMISSIONS

	2022	2030	2040	2050	2060
	MILLION TONNES				
Baseline	18,452	20,672	20,160	21,800	26,077
Current unconditional net zero (stated policies)	18,452	15,211	4,899	1,155	-725
Current unconditional net zero (CCS-limited RES)	18,452	15,419	4,870	1,166	-757
Current unconditional net zero (low-cost RES)	18,452	15,448	5,025	1,159	-786
Current conditional net zero	18,452	15,197	4,869	1,142	-727
Accelerated coal phaseout	18,452	13,278	3,791	964	-991
2050 net zero (stated policies)	18,452	10,964	2,269	-147	-1,547
2050 net zero (CCS-limited RES)	18,452	10,966	2,314	-170	-1,571
2050 net zero (low-cost RES)	18,452	11,002	2,266	-181	-1,610

TABLE 0.5: GHG EMISSIONS

	2022	2030	2040	2050	2060
	MILLION TONNES OF CO_2-EQUIVALENT				
Baseline	23,409	26,557	26,748	29,314	34,975
Current unconditional net zero (stated policies)	23,409	20,077	11,067	9,235	9,154
Current unconditional net zero (CCS-limited RES)	23,409	20,296	11,035	9,233	9,087
Current unconditional net zero (low-cost RES)	23,409	20,321	11,212	9,260	9,101
Current conditional net zero	23,409	20,059	11,028	9,208	9,133
Accelerated coal phaseout	23,409	18,152	10,035	9,044	8,878
2050 net zero (stated policies)	23,409	15,753	8,493	7,800	8,233
2050 net zero (CCS-limited RES)	23,409	15,749	8,529	7,751	8,173
2050 net zero (low-cost RES)	23,409	15,778	8,494	7,767	8,172

TABLE 0.6: GDP IMPACTS (ABSOLUTE DIFFERENCES FROM BASELINE)				
	2030	2040	2050	2060
				$2021BN
Baseline	-	-	-	-
Current unconditional net zero (stated policies)	1,429	1,316	1,579	1,700
Current unconditional net zero (CCS-limited RES)	1,215	1,259	1,592	1,718
Current unconditional net zero (low-cost RES)	1,270	1,256	1,651	1,786
Current conditional net zero	1,433	1,316	1,578	1,704
Accelerated coal phaseout	1,800	1,178	1,449	1,643
2050 net zero (stated policies)	2,520	1,740	1,760	1,650
2050 net zero (CCS-limited RES)	2,359	1,700	1,741	1,659
2050 net zero (low-cost RES)	2,392	1,721	1,800	1,695

TABLE 0.7: HOUSEHOLD CONSUMPTION IMPACTS (ABSOLUTE DIFFERENCES FROM BASELINE)				
	2030	2040	2050	2060
				$2021BN
Baseline	-	-	-	-
Current unconditional net zero (stated policies)	-97	-355	-496	-701
Current unconditional net zero (CCS-limited RES)	-87	-314	-439	-648
Current unconditional net zero (low-cost RES)	-81	-275	-363	-545
Current conditional net zero	-97	-355	-482	-680
Accelerated coal phaseout	-106	-376	-490	-692
2050 net zero (stated policies)	-118	-527	-816	-1,162
2050 net zero (CCS-limited RES)	-112	-512	-818	-1,184
2050 net zero (low-cost RES)	-108	-479	-755	-1,095

TABLE 0.8: CUMULATIVE ECONOMY-WIDE INVESTMENT REQUIREMENTS (IN ADDITION TO BASELINE)			
	2022-30	2022-50	2022-60
			$2021TRN
Baseline	-	-	-
Current unconditional net zero (stated policies)	7.7	38.1	53.2
Current unconditional net zero (CCS-limited RES)	6.7	35.4	49.9
Current unconditional net zero (low-cost RES)	6.9	34.7	49.0
Current conditional net zero	7.7	38.2	53.0
Accelerated coal phaseout	9.0	37.9	51.9
2050 net zero (stated policies)	12.6	52.1	71.2
2050 net zero (CCS-limited RES)	12.1	51.2	70.3
2050 net zero (low-cost RES)	12.2	50.2	69.0

TABLE 0.9: FINAL ENERGY INTENSITY OF GDP				
	2030	2040	2050	2060
				TOE PER $2021M
Baseline	118.7	95.6	86.6	80.8
Current unconditional net zero (stated policies)	103.2	75.8	64.5	59.2
Current unconditional net zero (CCS-limited RES)	103.6	75.7	64.3	58.9
Current unconditional net zero (low-cost RES)	103.6	76.0	64.6	59.3
Current conditional net zero	103.2	75.8	64.5	59.2
Accelerated coal phaseout	102.3	76.0	64.6	59.3
2050 net zero (stated policies)	92.3	70.5	61.5	57.2
2050 net zero (CCS-limited RES)	92.6	70.3	61.2	56.9
2050 net zero (low-cost RES)	92.6	70.7	61.6	57.3

TABLE 0.10: SHARES OF ELECTRIC VEHICLES IN THE PASSENGER CAR FLEET				
	2030	2040	2050	2060
				%
Baseline	23	40	41	40
Current unconditional net zero (stated policies)	35	82	97	100
Current unconditional net zero (CCS-limited RES)	35	82	97	100
Current unconditional net zero (low-cost RES)	35	82	97	100
Current conditional net zero	35	82	97	100
Accelerated coal phaseout	35	82	97	100
2050 net zero (stated policies)	51	91	99	100
2050 net zero (CCS-limited RES)	51	91	99	100
2050 net zero (low-cost RES)	51	91	99	100

TABLE 0.11: POWER CAPACITY AND GENERATION MIX IN THE BASELINE						
		2022	**2030**	**2040**	**2050**	**2060**
Power capacity	GW	2,922	4,356	8,132	10,374	14,127
Coal	% of total	45	37	19	16	15
Oil & gas	% of total	16	13	8	7	7
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	3	4	6	7	5
Biomass with CCS	% of total	2	2	1	1	1
Wind	% of total	10	8	6	4	3
Solar	% of total	12	28	56	62	67
Hydro	% of total	12	8	4	2	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,162	22,693	28,327	36,261
Coal	% of total	65	59	36	31	33
Oil & gas	% of total	10	9	7	6	5
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	6	8	15	19	15
Biomass with CCS	% of total	2	2	2	2	2
Wind	% of total	4	4	3	3	2
Solar	% of total	4	12	32	37	42
Hydro	% of total	9	7	4	2	1
Geothermal	% of total	0	0	0	0	0

TABLE 0.12: POWER CAPACITY AND GENERATION MIX IN THE CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	2,922	5,270	12,783	17,250	24,992
Coal	% of total	45	23	3	0	0
Oil & gas	% of total	16	8	1	0	0
Fossil fuels with CCS	% of total	0	1	2	1	1
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	4	4	3	3
Wind	% of total	10	14	10	8	7
Solar	% of total	12	37	73	80	84
Hydro	% of total	12	8	3	2	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,138	27,933	36,669	49,373
Coal	% of total	65	40	5	0	0
Oil & gas	% of total	10	7	1	0	0
Fossil fuels with CCS	% of total	0	1	2	2	2
Nuclear	% of total	6	8	18	18	11
Biomass with CCS	% of total	2	5	6	6	7
Wind	% of total	4	7	6	5	5
Solar	% of total	4	20	57	65	73
Hydro	% of total	9	11	4	3	2
Geothermal	% of total	0	0	0	0	0

TABLE 0.13: POWER CAPACITY AND GENERATION MIX IN THE CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	2,922	5,236	12,551	16,839	24,057
Coal	% of total	45	24	3	0	0
Oil & gas	% of total	16	9	1	0	0
Fossil fuels with CCS	% of total	0	1	1	0	0
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	4	4	3	3
Wind	% of total	10	14	9	8	7
Solar	% of total	12	37	72	79	83
Hydro	% of total	12	8	4	3	3
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,128	27,607	36,245	48,558
Coal	% of total	65	42	5	0	0
Oil & gas	% of total	10	8	1	0	0
Fossil fuels with CCS	% of total	0	0	1	0	1
Nuclear	% of total	6	8	18	17	11
Biomass with CCS	% of total	2	5	6	6	7
Wind	% of total	4	7	6	5	5
Solar	% of total	4	20	57	64	71
Hydro	% of total	9	10	7	6	5
Geothermal	% of total	0	0	0	0	0

TABLE 0.14: POWER CAPACITY AND GENERATION MIX IN THE CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES) SCENARIO						
		2022	2030	2040	2050	2060
Power capacity	GW	2,922	5,420	12,916	17,554	24,057
Coal	% of total	45	23	3	0	0
Oil & gas	% of total	16	9	1	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	4	5	5	3
Biomass with CCS	% of total	2	4	4	3	3
Wind	% of total	10	16	10	9	8
Solar	% of total	12	38	73	80	84
Hydro	% of total	12	6	2	1	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,222	28,081	36,978	49,831
Coal	% of total	65	42	5	1	0
Oil & gas	% of total	10	8	1	0	0
Fossil fuels with CCS	% of total	0	1	2	1	1
Nuclear	% of total	6	8	18	18	11
Biomass with CCS	% of total	2	5	6	6	7
Wind	% of total	4	8	7	6	5
Solar	% of total	4	20	58	66	74
Hydro	% of total	9	8	3	2	2
Geothermal	% of total	0	0	0	0	0

TABLE 0.15: POWER CAPACITY AND GENERATION MIX IN THE CURRENT CONDITIONAL NET ZERO SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	2,922	5,274	12,835	17,341	25,081
Coal	% of total	45	23	3	0	0
Oil & gas	% of total	16	8	1	0	0
Fossil fuels with CCS	% of total	0	1	2	1	1
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	4	4	3	3
Wind	% of total	10	14	10	8	7
Solar	% of total	12	37	73	80	84
Hydro	% of total	12	8	3	2	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,138	27,956	36,752	49,462
Coal	% of total	65	40	5	0	0
Oil & gas	% of total	10	7	1	0	0
Fossil fuels with CCS	% of total	0	1	2	2	2
Nuclear	% of total	6	8	18	18	11
Biomass with CCS	% of total	2	5	6	6	7
Wind	% of total	4	7	6	5	5
Solar	% of total	4	20	58	66	73
Hydro	% of total	9	11	4	3	2
Geothermal	% of total	0	0	0	0	0

TABLE 0.16: POWER CAPACITY AND GENERATION MIX IN THE ACCELERATED COAL PHASEOUT SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	2,922	6,814	13,916	17,801	25,411
Coal	% of total	45	14	0	0	0
Oil & gas	% of total	16	8	1	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	3	3	3	3
Wind	% of total	10	16	8	7	6
Solar	% of total	12	49	79	83	86
Hydro	% of total	12	6	2	2	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,570	28,917	37,179	49,877
Coal	% of total	65	26	0	0	0
Oil & gas	% of total	10	8	1	0	0
Fossil fuels with CCS	% of total	0	1	2	1	2
Nuclear	% of total	6	9	17	17	11
Biomass with CCS	% of total	2	6	6	6	7
Wind	% of total	4	9	6	5	4
Solar	% of total	4	32	65	68	74
Hydro	% of total	9	9	3	3	2
Geothermal	% of total	0	0	0	0	0

TABLE 0.17: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (STATED AND STRENGTHENED POLICIES) SCENARIO						
		2022	**2030**	**2040**	**2050**	**2060**
Power capacity	GW	2,922	6,865	13,218	16,761	23,893
Coal	% of total	45	13	0	0	0
Oil & gas	% of total	16	7	1	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	4	4	4	4
Wind	% of total	10	16	8	7	6
Solar	% of total	12	50	78	82	85
Hydro	% of total	12	6	2	2	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,815	27,534	35,457	47,498
Coal	% of total	65	25	0	0	0
Oil & gas	% of total	10	8	1	0	0
Fossil fuels with CCS	% of total	0	1	2	1	2
Nuclear	% of total	6	8	16	17	12
Biomass with CCS	% of total	2	6	7	7	8
Wind	% of total	4	9	6	5	4
Solar	% of total	4	33	64	67	73
Hydro	% of total	9	10	4	3	2
Geothermal	% of total	0	0	0	0	0

TABLE 0.18: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (CCS-LIMITED RES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	2,922	6,847	12,926	16,237	23,027
Coal	% of total	45	13	0	0	0
Oil & gas	% of total	16	8	1	0	0
Fossil fuels with CCS	% of total	0	1	1	0	0
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	4	4	4	4
Wind	% of total	10	15	8	7	6
Solar	% of total	12	51	78	80	84
Hydro	% of total	12	6	4	3	3
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,777	27,174	34,898	46,638
Coal	% of total	65	25	0	0	0
Oil & gas	% of total	10	9	1	0	0
Fossil fuels with CCS	% of total	0	1	1	0	1
Nuclear	% of total	6	8	16	17	12
Biomass with CCS	% of total	2	6	7	7	8
Wind	% of total	4	8	6	5	4
Solar	% of total	4	33	63	65	71
Hydro	% of total	9	10	6	5	4
Geothermal	% of total	0	0	0	0	0

TABLE 0.19: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (LOW-COST RES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	2,922	7,110	13,279	16,805	24,187
Coal	% of total	45	13	0	0	0
Oil & gas	% of total	16	8	1	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	3	5	5	3
Biomass with CCS	% of total	2	4	4	4	4
Wind	% of total	10	15	8	7	6
Solar	% of total	12	52	79	82	86
Hydro	% of total	12	5	2	1	1
Geothermal	% of total	0	0	0	0	0
Power generation	TWh	13,295	17,945	27,728	35,651	47,818
Coal	% of total	65	25	0	0	0
Oil & gas	% of total	10	9	1	0	0
Fossil fuels with CCS	% of total	0	1	2	1	1
Nuclear	% of total	6	9	17	18	12
Biomass with CCS	% of total	2	6	6	7	8
Wind	% of total	4	9	6	5	4
Solar	% of total	4	35	65	67	74
Hydro	% of total	9	7	2	2	1
Geothermal	% of total	0	0	0	0	0

TABLE 0.20: FINAL ENERGY DEMAND FOR TRANSPORT – BASELINE

		2022	2030	2040	2050	2060
Total	mtoe	691	756	788	839	890
Electricity	% of total	4	8	15	18	20
Coal	% of total	0	0	0	0	0
Oil	% of total	94	89	81	75	70
Gas	% of total	0	0	1	4	7
Biofuels	% of total	2	2	3	3	3
Hydrogen	% of total	0	0	0	0	0

TABLE 0.21: FINAL ENERGY DEMAND FOR TRANSPORT – CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)

		2022	2030	2040	2050	2060
Total	mtoe	691	716	668	681	749
Electricity	% of total	4	12	33	43	45
Coal	% of total	0	0	0	0	0
Oil	% of total	94	71	37	23	22
Gas	% of total	0	1	3	2	1
Biofuels	% of total	2	16	27	31	31
Hydrogen	% of total	0	0	0	1	1

TABLE 0.22: FINAL ENERGY DEMAND FOR TRANSPORT – CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	mtoe	691	716	668	681	748
Electricity	% of total	4	12	33	43	45
Coal	% of total	0	0	0	0	0
Oil	% of total	94	71	37	23	22
Gas	% of total	0	1	3	2	1
Biofuels	% of total	2	16	27	31	31
Hydrogen	% of total	0	0	0	1	1

TABLE 0.23: FINAL ENERGY DEMAND FOR TRANSPORT – CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	mtoe	691	716	668	681	749
Electricity	% of total	4	12	33	43	45
Coal	% of total	0	0	0	0	0
Oil	% of total	94	70	37	23	22
Gas	% of total	0	1	3	2	1
Biofuels	% of total	2	16	27	31	31
Hydrogen	% of total	0	0	0	1	1

TABLE 0.24: FINAL ENERGY DEMAND FOR TRANSPORT – CONDITIONAL 2060 NET ZERO SCENARIO

		2022	2030	2040	2050	2060
Total	mtoe	691	716	668	681	749
Electricity	% of total	4	12	33	43	45
Coal	% of total	0	0	0	0	0
Oil	% of total	94	71	37	23	22
Gas	% of total	0	1	3	2	1
Biofuels	% of total	2	16	27	31	31
Hydrogen	% of total	0	0	0	1	1

TABLE 0.25: FINAL ENERGY DEMAND FOR TRANSPORT - ACCELERATED COAL PHASEOUT

		2022	2030	2040	2050	2060
Total	mtoe	691	717	668	681	748
Electricity	% of total	4	12	33	43	45
Coal	% of total	0	0	0	0	0
Oil	% of total	94	71	37	23	22
Gas	% of total	0	1	3	2	1
Biofuels	% of total	2	16	27	31	31
Hydrogen	% of total	0	0	0	1	1

TABLE 0.26: FINAL ENERGY DEMAND FOR TRANSPORT – 2050 NET ZERO (STATED AND STRENGTHENED POLICIES)

		2022	2030	2040	2050	2060
Total	mtoe	691	624	634	681	760
Electricity	% of total	4	19	38	44	44
Coal	% of total	0	0	0	0	0
Oil	% of total	94	62	31	18	19
Gas	% of total	0	1	1	1	1
Biofuels	% of total	2	18	29	36	34
Hydrogen	% of total	0	0	1	1	2

TABLE 0.27: FINAL ENERGY DEMAND FOR TRANSPORT – 2050 NET ZERO (CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	mtoe	691	624	634	681	758
Electricity	% of total	4	19	38	44	44
Coal	% of total	0	0	0	0	0
Oil	% of total	94	62	31	18	19
Gas	% of total	0	1	1	1	1
Biofuels	% of total	2	18	29	36	34
Hydrogen	% of total	0	0	1	1	2

TABLE 0.28: FINAL ENERGY DEMAND FOR TRANSPORT – 2050 NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	mtoe	691	624	635	682	760
Electricity	% of total	4	19	38	44	44
Coal	% of total	0	0	0	0	0
Oil	% of total	94	62	31	18	19
Gas	% of total	0	1	1	1	1
Biofuels	% of total	2	18	29	36	34
Hydrogen	% of total	0	0	1	1	2

TABLE 0.29: FINAL ENERGY DEMAND FOR BUILDINGS – BASELINE

		2022	2030	2040	2050	2060
Total	mtoe	1,017	1,167	1,316	1,538	1,882
Electricity	% of total	38	46	55	63	70
Coal	% of total	11	10	8	6	5
Oil	% of total	14	13	11	9	8
Gas	% of total	8	8	8	7	7
Biofuels	% of total	26	22	17	13	10
Hydrogen, heat, waste	% of total	3	2	2	1	1

TABLE 0.30: FINAL ENERGY DEMAND FOR BUILDINGS – CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)

		2022	2030	2040	2050	2060
Total	mtoe	1,017	971	965	1,100	1,403
Electricity	% of total	38	47	65	76	85
Coal	% of total	11	8	3	2	1
Oil	% of total	14	13	8	6	4
Gas	% of total	8	8	4	2	1
Biofuels	% of total	26	22	17	13	8
Hydrogen, heat, waste	% of total	3	3	2	2	1

TABLE 0.31: FINAL ENERGY DEMAND FOR BUILDINGS – CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	mtoe	1,017	970	960	1,092	1,393
Electricity	% of total	38	47	65	76	84
Coal	% of total	11	8	3	2	1
Oil	% of total	14	13	8	6	4
Gas	% of total	8	8	4	2	1
Biofuels	% of total	26	22	17	13	8
Hydrogen, heat, waste	% of total	3	3	2	2	1

TABLE 0.32: FINAL ENERGY DEMAND FOR BUILDINGS – CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	mtoe	1,017	972	967	1,104	1,409
Electricity	% of total	38	47	65	76	85
Coal	% of total	11	8	3	2	1
Oil	% of total	14	13	8	6	4
Gas	% of total	8	8	4	2	1
Biofuels	% of total	26	22	17	13	8
Hydrogen, heat, waste	% of total	3	3	2	2	1

TABLE 0.33: FINAL ENERGY DEMAND FOR BUILDINGS – CURRENT CONDITIONAL NET ZERO

		2022	2030	2040	2050	2060
Total	mtoe	1,017	971	965	1,100	1,403
Electricity	% of total	38	47	65	76	85
Coal	% of total	11	8	3	2	1
Oil	% of total	14	13	8	6	4
Gas	% of total	8	8	4	2	1
Biofuels	% of total	26	22	17	13	8
Hydrogen, heat, waste	% of total	3	3	2	2	1

TABLE 0.34: FINAL ENERGY DEMAND FOR BUILDINGS – ACCELERATED COAL PHASEOUT

		2022	2030	2040	2050	2060
Total	mtoe	1,017	969	965	1,101	1,405
Electricity	% of total	38	47	65	76	85
Coal	% of total	11	8	3	2	1
Oil	% of total	14	13	8	6	4
Gas	% of total	8	8	4	2	1
Biofuels	% of total	26	22	17	13	8
Hydrogen, heat, waste	% of total	3	3	2	2	1

TABLE 0.35: FINAL ENERGY DEMAND FOR BUILDINGS – 2050 NET ZERO (STATED AND STRENGTHENED POLICIES)

		2022	2030	2040	2050	2060
Total	mtoe	1,017	851	839	1,007	1,282
Electricity	% of total	38	50	66	77	85
Coal	% of total	11	7	3	2	1
Oil	% of total	14	13	8	5	4
Gas	% of total	8	6	4	2	1
Biofuels	% of total	26	20	15	12	7
Hydrogen, heat, waste	% of total	3	3	3	2	1

TABLE 0.36: FINAL ENERGY DEMAND FOR BUILDINGS – 2050 NET ZERO (CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	mtoe	1,017	850	834	999	1,273
Electricity	% of total	38	50	66	77	85
Coal	% of total	11	7	3	2	1
Oil	% of total	14	13	8	5	4
Gas	% of total	8	6	4	2	1
Biofuels	% of total	26	20	15	12	8
Hydrogen, heat, waste	% of total	3	3	3	2	1

TABLE 0.37: FINAL ENERGY DEMAND FOR BUILDINGS – 2050 NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	mtoe	1,017	851	841	1,010	1,287
Electricity	% of total	38	50	66	77	85
Coal	% of total	11	7	3	2	1
Oil	% of total	14	13	8	5	4
Gas	% of total	8	6	4	2	1
Biofuels	% of total	26	20	15	12	7
Hydrogen, heat, waste	% of total	3	3	3	2	1

TABLE 0.38: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – BASELINE

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,766	3,201	3,614	4,223
Electricity	% of total	23	23	24	25	26
Coal	% of total	38	36	34	32	32
Oil	% of total	20	20	20	19	19
Gas	% of total	13	14	16	17	18
Biofuels	% of total	3	3	3	3	3
Hydrogen, heat, waste	% of total	4	3	3	3	2

TABLE 0.39: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – CURRENT UNCONDITIONAL NET ZERO (STATED POLICIES)

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,536	2,673	2,777	3,061
Electricity	% of total	23	27	38	47	55
Coal	% of total	38	30	16	11	7
Oil	% of total	20	22	23	25	25
Gas	% of total	13	12	7	6	5
Biofuels	% of total	3	3	3	3	4
Hydrogen, heat, waste	% of total	4	6	14	9	4

TABLE 0.40: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – CURRENT UNCONDITIONAL NET ZERO (CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,532	2,664	2,768	3,046
Electricity	% of total	23	27	38	46	54
Coal	% of total	38	30	16	11	7
Oil	% of total	20	22	23	25	25
Gas	% of total	13	12	7	6	5
Biofuels	% of total	3	3	3	3	4
Hydrogen, heat, waste	% of total	4	6	14	9	4

TABLE 0.41: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – CURRENT UNCONDITIONAL NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,537	2,675	2,783	3,067
Electricity	% of total	23	27	38	47	54
Coal	% of total	38	30	15	11	7
Oil	% of total	20	22	23	25	25
Gas	% of total	13	12	7	6	5
Biofuels	% of total	3	3	3	3	4
Hydrogen, heat, waste	% of total	4	6	13	9	4

TABLE 0.42: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – CURRENT CONDITIONAL NET ZERO SCENARIO

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,535	2,672	2,775	3,059
Electricity	% of total	23	27	38	47	55
Coal	% of total	38	30	15	11	7
Oil	% of total	20	22	23	25	25
Gas	% of total	13	12	7	6	5
Biofuels	% of total	3	3	3	3	4
Hydrogen, heat, waste	% of total	4	6	14	9	4

TABLE 0.43: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – ACCELERATED COAL PHASEOUT

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,539	2,674	2,775	3,067
Electricity	% of total	23	27	38	47	54
Coal	% of total	38	30	16	11	7
Oil	% of total	20	22	23	25	25
Gas	% of total	13	12	7	6	5
Biofuels	% of total	3	3	3	3	4
Hydrogen, heat, waste	% of total	4	6	13	9	4

TABLE 0.44: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2050 NET ZERO (STATED AND STRENGTHENED POLICIES)

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,407	2,562	2,674	2,989
Electricity	% of total	23	29	38	47	54
Coal	% of total	38	27	14	9	6
Oil	% of total	20	22	24	25	25
Gas	% of total	13	10	7	6	5
Biofuels	% of total	3	3	2	2	3
Hydrogen, heat, waste	% of total	4	10	15	10	6

TABLE 0.45: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2050 NET ZERO (CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,403	2,556	2,659	2,972
Electricity	% of total	23	29	38	47	54
Coal	% of total	38	27	14	9	6
Oil	% of total	20	22	24	25	25
Gas	% of total	13	10	7	6	5
Biofuels	% of total	3	3	2	2	3
Hydrogen, heat, waste	% of total	4	10	15	10	6

TABLE 0.46: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2050 NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	mtoe	2,326	2,408	2,567	2,674	2,991
Electricity	% of total	23	29	39	47	55
Coal	% of total	38	26	14	9	6
Oil	% of total	20	22	24	25	25
Gas	% of total	13	10	7	6	5
Biofuels	% of total	3	3	2	2	3
Hydrogen, heat, waste	% of total	4	10	15	10	6

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