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REPORT >>

Getting Indonesia to Net Zero

GETTING ASIA TO NET ZERO

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

Getting Indonesia 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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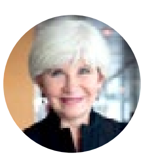

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The appendix to this report and its findings are solely the work of Cambridge Econometrics. The Asia Society Policy Institute and members of the commission are not responsible for the content of the findings within.

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 the commission's recommendations for how Indonesia can achieve net zero emissions in a manner that is beneficial to its economy, society, and place in the world. This summary was prepared by members of the High-level Commission and is aimed at elevating political and policy strategies to help Indonesia realize its vision of achieving net zero emissions.

- The second part — which informed the development of the summary — is an **appendix** that contains **new research and modeling** to show the opportunities and trade-offs associated with Indonesia'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 INDONESIA TO NET ZERO: FOREWORD

As host of the G20 summit in November 2022, President Joko Widodo of Indonesia sent a clear message to world leaders: climate action is an integral component of the engine that will drive inclusive, sustainable, and equitable economic growth. "Indonesia is committed to using our energy transition to achieve a green economy and drive sustainable development," he remarked at the summit, noting in his opening speech that "we do not just talk, but we take concrete steps."

Indonesia's recent actions underscore its commitment to green growth. The country is one of the world's largest coal exporters and consumers and still relies on fossil fuels for more than 80 percent of its energy needs. Yet even when grappling with impacts from the COVID-19 pandemic, Indonesia has continued to strengthen its climate ambition. This includes releasing a plan to achieve net zero emissions by 2060, endorsing the Global Coal to Clean Power Transition Statement at COP26 in Glasgow and taking additional steps to phase out coal, and enhancing its Nationally Determined Contribution (NDC) in September 2022 ahead of COP27.

That climate action is increasingly regarded as a linchpin rather than a luxury item by the highest levels in Indonesia could be seen as a bellwether by other developing countries, especially in Asia. The country's ambitious *Visi Indonesia 2045* sets a goal for Indonesia to become an advanced economy by 2045, only 100 years after gaining independence. Climate change threatens this objective, especially for an archipelago nation that is particularly susceptible to sea level rise and harsher extreme weather, such as tropical cyclones.

In fact, embracing an ambitious net zero pathway could help Indonesia realize its shared national vision, according to new analysis commissioned by our High-level Policy Commission on Getting Asia to Net Zero. As the enclosed modeling from Cambridge Econometrics illustrates, implementing Indonesia's current net zero strategy could boost midterm GDP by as much as 5 percent above the projected baseline in the 2030s, with little trade-off in long-term growth. Economic impacts would be largely driven by higher levels of investment in the short and medium terms, supported by investment in energy efficiency in the longer term. Reduced reliance on fossil fuel imports due to the transition could also improve Indonesia's trade balance by $48bn and provide long-term energy security from external disruptions.

Particularly enticing are the potential benefits should Indonesia incentivize lower-cost renewable technologies, namely solar and wind. In comparison to Indonesia's current pathway in its Long-Term Strategy, which maintains a significant amount of coal with carbon capture and sequestration (CCS), focusing on solar and wind could vastly reduce Indonesia's investment needs while reducing negative impacts on household spending by more than half. In the most ambitious scenario where Indonesia achieves net zero by 2050 while emphasizing solar and wind, Indonesia could peak emissions as soon as 2027 and achieve net zero by 2050 for as little as $1.2trn in investment above baseline levels from now until 2060, compared to $5trn for its current pathway to net zero by 2060.

The analysis also provides useful nuance to help Indonesia navigate the various economic and social trade-offs of the transition. The road to net zero could increase employment in the midterm, with up to 2 million new jobs potentially created under Indonesia's current pathway – but a significant number of jobs could ultimately be lost in fossil fuel sectors. Policies to support reskilling and upskilling could help workers take full advantage of new employment opportunities in a low-carbon economy, especially in sectors that may see significant job creation, such as manufacturing, construction, and business services. Proactively developing and leveraging green export industries that support other countries' transitions could help Indonesia avoid the worst impacts altogether.

Indonesia's current targets and recent policies, especially the September 2022 presidential regulation (112/2022) to accelerate renewable energy deployment, are an admirable and important start. But clearer policy signals are urgently needed to minimize the costs and maximize the benefits of the transition. Committing to an optimal pathway could unlock additional pools of finance and supercharge Indonesia's transformation into a prosperous and powerful economy – all while creating an example for other emerging Asian economies to emulate.

We thus recommend three priority actions for Indonesia to consider as it looks to seize the benefits of green growth and ensure that decarbonization enhances livelihoods.

First, Indonesia could prioritize green instruments and policies that advance decarbonization while addressing more immediate development challenges, such as poverty, inadequate infrastructure, and lack of access to quality education and health care. Achieving net zero could lead to a range of favorable economic and social outcomes, but many of the greatest impacts could take time to manifest – years, if not decades. The transition could also be uneven, especially in the near and midterm when the vast majority of investment will take place and could negatively impact household spending. By providing consistent and tangible aid to vulnerable populations, such as through conditional cash transfers, Indonesian policymakers could buttress popular support for the green transition today while shifting incentives to benefit people rather than entrenched fossil fuel interests.

A logical starting point could be phasing out and reallocating existing fossil fuel subsidies to compensate vulnerable groups and build green infrastructure, including by accelerating clean energy growth and access. Research indicates that redirecting revenues from transporting fossil fuels and other coal subsidies could provide more than half of the investment needed for Indonesia to achieve its 2025 target of 23 percent new and renewable energy. A portion of revenues could also be redirected toward social programs in other critical areas, such as health and education, to build goodwill among citizens for the green transition.

Indonesia could concurrently implement mechanisms to enable its trial emissions trading system (ETS) for the power sector, which is set to become mandatory in 2023, to reflect carbon costs in power station dispatch decisions and retail electricity prices. This could accelerate the power sector's switch away from coal and toward renewables and other low-carbon fuels and enable auctioning, which could further strengthen this effect. With these mechanisms in place, and as emissions targets are tightened in line with the pathway to net zero, the ETS could be a powerful driver for power sector decarbonization. Furthermore, the revenue generated from auctioning could be used to finance investments to achieve the net zero transition across the economy, protect vulnerable stakeholder groups from excessive energy costs, and support just transition programs.

The enclosed modeling illustrates how repurposing fossil fuel subsides and recycling carbon-pricing revenues is smart economics. In the most ambitious scenarios where Indonesia achieves net zero emissions by 2050, repurposed coal power subsidies and the availability of international financial support could more than offset all costs accrued to the government and neutralize pressure on government budgets. This could ultimately help shield consumers from deficit-inducted tax increases and higher prices. Should low-cost renewables be prioritized over more expensive decarbonization options like coal with CCS, the estimated funding from avoided subsidies alone could be sufficient to cover net costs of policy implementation.

Second, to minimize the overall cost of the transition, Indonesia could continue reforming its energy market structure to favor lower-cost renewables, namely solar and wind. The analysis makes it clear that the chosen power sector technology mix could vastly influence the cost of the net zero transition and related social impacts. Phasing out coal is an essential part of the equation – but what replaces it is also critical. By revising Indonesia's Long-Term Strategy and near-term targets to prioritize solar and wind, Indonesia could minimize investment needs and increase policy savings while enhancing long-term GDP growth. This could also help rightsize the role of higher-cost renewable energy sources like hydropower and geothermal to where they have the greatest added value, while limiting the need for inefficient, high-cost coal with CCS.

Creating economies of scale for solar and wind could dramatically bring down costs, as evidence from China and India shows. Yet solar and wind currently account for less than one percent of Indonesia's power generation. Changing this status quo could require revisiting and rewriting power market incentives. The most impactful steps could implement recommendations from the International Energy Agency (IEA) to adapt power sector operating practices to prioritize generation from variable resources and improve the financial competitiveness of solar by revising local content requirements to balance optimizing deployment and shoring up manufacturing capabilities. The IEA also endorses leveling the playing field by removing implicit and explicit coal subsidies and accelerating the rollout of carbon pricing. By creating consistent and favorable incentives for solar and wind, Indonesia could de-risk additional pools of finance while lowering the overall costs of the transition.

Third, Indonesia could leverage green industries to advance a just transition. While the transition will come with trade-offs, the good news is that Indonesia has massive potential to develop competitive low-carbon industries. By articulating a vision for Indonesia's sustainable future that includes flagship projects in green manufacturing and clean exports, Indonesia could benefit economically while enhancing the appeal of efforts to reskill and upskill workers. In other words, Indonesia's plan for a just transition could empower citizens to actively take advantage of new opportunities. This could help mitigate the social and economic impacts of job losses in fossil fuel industries for a nation that is widely expected to become the world's fourth-largest economy by 2050.

Indonesia could start by ensuring new mega-development projects are truly green. The country has been positioning itself to leverage its endowments of resources that will be essential for the global transition, such as the nickel needed to make batteries for electric vehicles. As firms sourcing green products are increasingly compelled to achieve net zero supply chains, major prestige projects such as those in Kalimantan, Sulawesi, and Maluku could be powered by clean energy and ensure nearby forest cover and habitats are protected – otherwise, these projects risk becoming stranded assets in the global transition. New projects' energy and governance choices could signal decision-makers' high-level commitment to net zero, especially with captive coal at industrial parks already comprising 15 percent of Indonesia's coal power output. Prioritizing clean, reliable, and affordable energy over captive coal could also provide a major boost toward achieving Indonesia's clean energy targets.

Another way Indonesia could accelerate this vision is by drawing up a comprehensive green hydrogen strategy. The country's significant geothermal endowments provide continuous, clean energy that is ideal for lowering the costs of green hydrogen needed to decarbonize Indonesia's domestic energy-intensive industries.

In the longer term, exporting green hydrogen could also help bring down costs of the energy transition in key Asian markets. In other words, a robust green hydrogen industry could be a win-win for decarbonizing the Asian region while providing an incentive for trading partners to invest in Indonesia's transition. For instance, a partnership between Indonesia and South Korea is currently undertaking feasibility studies for a 10-megawatt green hydrogen pilot facility in North Sumatra.

Beyond these three actions, Indonesia could go one step further by centering net zero as a core element of its *Visi Indonesia 2045*. Indonesia's Paris Agreement commitments already reference this ambitious national vision and how climate targets have been designed with development in mind. But a more powerful plan could supersede the current approach in Indonesia's enhanced NDC, which considers "the need to balance between emissions reduction and economic development" by acknowledging and elevating net zero as an essential driver of Indonesia's future growth.

Taken together, a powerful net zero vision and greater policy certainty could be a potent cocktail empowering Indonesia to de-risk capital and attract investment on its own terms. Indonesia's ratcheting of ambition in recent years has already drawn attention from financing mechanisms aimed at accelerating coal phaseout from the power grid. For instance, the landmark Just Energy Transition Partnership (JETP) launched in parallel with the G20 summit intends to mobilize $20bn in public and private financing for Indonesia's transition over three to five years. As part of this deal, Indonesia agreed to stop building most new coal plants and achieve a set of even stronger targets, including peaking power sector emissions by 2030, bringing them to net zero by 2050, and achieving at least 34 percent of power generation from renewables by 2030. This greater ambition should certainly be lauded.

But Indonesia could further advantage itself by elaborating a comprehensive and visionary green transition beyond the terms set by international funders. While Indonesia's transition will require considerable investment, the modeling shows that a more ambitious pathway could minimize these figures. With Indonesia agreeing under the JETP to develop an investment policy plan within six months that articulates the opportunities to deliver a just transition, now is an opportune moment for Indonesia's stakeholders to consider exactly how green investments can enhance the country's economy and deliver concrete benefits that improve people's livelihoods.

As Indonesia throws more political weight behind its energy transition, decision-makers could continue paying attention to the role of actions to transform its land-use and forestry sector from an emissions source to an emissions sink. Indonesia has made significant progress in tackling deforestation and decreasing annual tree cover loss. But challenges persist, including a lack of financing and demand leakage to other countries with major tracts of rainforests, prompting emissions progress to oscillate dramatically. Indonesia's new effort with Brazil and the Democratic Republic of the Congo to jointly negotiate a new funding mechanism to preserve forests is a promising start. By further strengthening high-quality efforts to protect emissions sinks, Indonesia could attract more finance, such as from market mechanisms under Article 6 of the Paris Agreement, while accelerating overall mitigation progress.

Indonesia could also seriously consider the benefits of faster, more ambitious action to achieve net zero by mid-century. In the JETP announcement, Indonesia acknowledged its aspiration of an "ambitious just energy transition that supports a trajectory that keeps a warming limit of 1.5°C." Moving up Indonesia's net zero target to 2050 to align with such a trajectory could significantly reduce the total amount of investment required to meet the target, from $5trn above baseline needs to as little as $1.2trn extra, while reducing impacts on households and accruing net policy savings. Especially with the Asia-Pacific Group hosting COP28 and the Global Stocktake assessing global climate progress, 2023 presents a pivotal opportunity for Indonesia to ratchet up its net zero ambition in a win-win for its people and the planet.

Across the board, one thing is clear: the ball is in Indonesia's court to define its own future. Indonesia has elevated the importance of green recovery and energy transition globally as host of the G20. The conditions are ripe for Indonesia's leadership to use its own domestic example to demonstrate how green growth can be an economic driver while enhancing prosperity. And as the evidence shows, the more decisively Indonesia acts, the more benefits it could reap.

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APPENDIX: RESEARCH & MODELING

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ACRONYMS

BECCS	Bioenergy with carbon capture and storage
CCS	Carbon capture and storage
CGE	Computable General Equilibrium
COP26	26th United Nations Climate Change Conference
DMO	Domestic market obligation
EU27	Current member states of the European Union
EV	Electric vehicle
FTT	Future Technology Transformation
G7	Group of Seven
G20	Group of Twenty
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
RES	Renewable energy sources
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

DELIVERING INDONESIA'S NET ZERO TARGETS IN FIGURES				
	NET ZERO 2060 (BASED ON LTS, WITHOUT INTERNATIONAL SUPPORT)	NET ZERO 2060 (BASED ON LTS, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (BASED ON LTS, WITH INTERNATIONAL SUPPORT)	NET ZERO 2050 (COST OPTIMIZED, WITH INTERNATIONAL SUPPORT)
Earliest year in which carbon emissions peak in Indonesia to deliver net zero emissions and realize economic benefits	2030	2030	2028	2027
GDP impact relative to baseline	Peaking at +5.0% in 2032 −0.7% in 2060	Peaking at +5.0% in 2032 −0.6% in 2060	Peaking at +5.3% in 2031 −0.5% in 2060	Peaking at +2.0% in 2031 +0.1% in 2060
Cumulative economy-wide investment required from now for achieving net zero emissions	$5.0trn	$4.9trn	$3.0trn	$1.2trn
Change to Indonesia's trade balance by 2060	+$48bn	+$52bn	+$50bn	+$52bn
Absolute jobs impact compared to baseline	Peaking at +2.0 million in 2039 +163,000 in 2060	Peaking at +1.9 million in 2039 −118,000 in 2060	Peaking at +1.7 million in 2030 −810,000 in 2060	Peaking at +0.5 million in 2030 −988,000 in 2060
Change in household spending by 2060	−$189bn	−$167bn	−$122bn	−$63bn
Net policy savings (gains) over 2022-2060	$48bn	$274bn	$46bn	$59bn

- Indonesia is currently the fourth most populous country in the world and a member of the G20, with major influence on the global economy. As one of the world's largest coal producers and consumers with more than 80 percent of its power generation from fossil fuels, Indonesia is faced with the substantial challenge of decarbonizing its energy system without hindering its economic growth and progress on poverty reduction.

- **Indonesia's most recent NDCs (updated in 2021 and 2022) do not appear ambitious enough given current policy trajectories.** The Indonesian Long-Term Strategy sets out a plan to deliver net zero emissions by 2060. While this represents a major step-up from the NDCs, it is not yet aligned with the Paris Agreement goal of reaching global net zero before 2050 and limiting global warming to 1.5°C by 2100.

- This report provides economic analysis to show the opportunities and trade-offs associated with Indonesia's options to meet its existing emissions reduction targets (of 31.9 percent reduction in emissions by 2030 relative to a business-as-usual (BAU) baseline, or 43.2 percent with international support, retiring 9.2GW of coal capacity by 2030 to be replaced with renewables, and net zero emissions by 2060) and increase its medium- and long-term ambitions. The goal of the research is to evaluate the macroeconomic impacts of a range of policy options and provide recommendations for policymakers to address the social and other challenges of an accelerated energy transition. Six core scenarios with different levels of decarbonization ambition (pre-COP26 baseline; baseline plus 2030 targets; all COP26 commitments, including Indonesia's current net zero 2060 commitment; all COP26 commitments and conditional 2030 targets with international support; accelerated unabated coal phaseout by 2040; and an ambitious net zero 2050 goal) were modeled, complemented by sensitivities around power technology mixes.

>> The modeling, carried out using the global E3ME model, shows that **additional and more ambitious policies are needed to deliver long-term net zero emissions targets.** Accelerated action in the short- and medium-terms, such as **banning new coal constructions from 2023, phasing out unabated coal power by 2040, kick-starting the deployment of low-cost solar photovoltaic and promoting EVs, will help the country transition to a low-carbon economy more rapidly.**

>> **Indonesia can see CO_2 emissions peak this decade, as early as 2027 in the most ambitious 2050 net zero scenarios, and decline consistently thereafter**. Such a transition will be driven by rapid decarbonization of the whole energy system and economy, including moving away from fossil fuels to renewable electricity generation, increased electrification, procurement of low-carbon solutions, promotion of electric vehicles for road transport, and low-carbon technologies and alternative fuels in other sectors.

>> With international support and reinvestment of removed coal power subsidies into green initiatives, increasing climate ambition and action have the potential to generate noticeable macroeconomic benefits in GDP and employment for the Indonesian economy in the medium term without substantial compromise on economic growth in the long term, despite the country's heavy fossil fuel dependency. **The most ambitious decarbonization goals (achieving net zero in 2050) could boost the Indonesian economy by up to 5.3 percent ($106bn) in GDP terms and create almost 1.7m additional jobs by 2030–2031,** the peak years of impact, compared to a baseline pathway of pre-COP26 policies.

>> **The long-run effects are milder and subject to a larger margin of uncertainty depending on the power sector technology mix ultimately pursued.** The Indonesian government's current strategy to utilize coal with CCS and other high-cost renewables power generation technologies over low-cost renewables involves trade-offs between economic growth and employment, which have welfare implications for the population. Focusing on cost-competitive renewables technologies will result in a similar level of GDP by 2060 as the baseline, and 989,000 fewer jobs (less than 1 percent of total employment) by 2060 than baseline. At the other end of the range, using more capital-intensive low-carbon technologies could lead to a mild reduction of 0.5 percent ($22bn) in GDP and 810,000 fewer jobs compared to baseline by 2060.

>> **The positive economic impacts in the medium term are primarily due to a substantial required investment**. It is estimated that **$5trn of additional investment compared to baseline are needed between now and 2060 to deliver net zero emissions by 2060 in Indonesia, while a lower figure of $3trn additional investment compared to baseline is required to reach carbon neutrality 10 years earlier, by 2050**. The investment needed to decarbonize Indonesia is lower in the more ambitious scenario. This is driven by great potential for future renewable cost reductions (which become larger with faster deployment) given that Indonesia is largely fossil fuel based and at a relatively early stage of renewables deployment. Currently, domestic content requirements and auction and pricing regulations for energy suppliers have limited the scope of renewables. This means that Indonesia has not yet achieved cost reductions associated with economies of scale and learning-by-doing effects, compared to neighboring countries such as China and India where wind and solar are already highly cost competitive and widely deployed. Furthermore, achieving net zero emissions by 2050 requires very large deployments of renewables, rapidly bringing down annual investment costs, while net zero emissions by 2060 can be achieved through using alternative technologies that do not achieve the same cost reductions.

- However, the medium-term benefits come with long-term trade-offs. Even with international support and additional domestic funding (from carbon pricing and the reinvestment of avoided coal power subsidies) to fund the transition, **Indonesian households are on average worse off. Household consumption is reduced by between $122bn and $189bn by 2060 due to higher prices as a result of costs associated with transforming a heavily fossil fuel–based power system.** This results from increasing energy costs, partly due to the repurposing of subsidies on coal production and the resultant energy from burning coal,[1] and the additional carbon price being levied on the use of coal in the power sector. It is also partly because the cost of wind and solar deployment is currently twice as high in Indonesia as in other developing countries. Despite the substantial energy demand reductions by consumers and an improved trade balance resulting from reduced demand for imported fossil fuels, per unit energy costs would increase by a greater extent than the volume reduction, leading to higher economy-wide prices.

- Similar to GDP, additional jobs will be created in the medium term, but there is a mild net contraction of the total workforce in the long run with many jobs lost in fossil fuel supply sectors, particularly coal mining and wider coal networks, posing a social challenge for local communities.

- **To achieve a more rapid and just transition in Indonesia, a combination of policies will be needed, prioritizing those that best mitigate social impacts that come with the transition.** Coal regulation in power generation (particularly a ban on the construction of new coal-fired capacity from 2023) is very effective at delivering large emissions reductions in the medium term and prevents high future costs of stranded assets. Alongside taking advantage of low-cost renewables options, the most important policies to minimize the social impacts of moving away from cheap coal generation are international support, repurposing coal power subsidies [2] (which result from coal phaseout) and leveraging carbon pricing as sources of domestic finance to fund investments. Policies to support reskilling and upskilling of the workforce across industries will also allow workers to take full advantage of new employment opportunities that arise in a low-carbon economy.

1 Note that while India and other coal producers in the region have subsidies on the production of coal, they do not have the same scale of subsidies for the use of coal in the power sector.

2 In the context of this study, "coal power subsidies" represent the effects of Domestic Market Obligations (DMOs), regulatory measures that require coal producers to prioritize domestic supply (mostly used for power generation) at below-market prices. This has a similar effect as subsidizing coal-based power generation and compromises potential royalties from exporting high volumes of coal given Indonesia's low domestic extraction costs. The repurpose of this regulation means that the price of coal will increase to be on par with global prices (raising the cost of coal-based power generation), whereas coal exporters will benefit from competitive pricing and increased profits (some of which will accrue to the government, an owner of local coal assets, as additional revenues).

INTRODUCTION

BACKGROUND

Economic and social characteristics

Indonesia is the fourth most populous country, the 16th largest economy in the world and the largest country in Southeast Asia (see World Bank 2020a, 2020b, 2022). Table 1.1 presents some economic and social indicators for Indonesia, Asia, and the world. Indonesia's GDP growth rates in the past 15 years were only outpaced by China among all major economies.

TABLE 1.1: ECONOMIC INDICATORS FOR FOR INDONESIA, ASIA AND THE WORLD 2020-2021

	POPULATION (MILLIONS OF PEOPLE)	GDP, CURRENT PRICES (BILLIONS OF U.S. DOLLARS)	GDP PER CAPITA, CURRENT PRICES (U.S. DOLLARS PER CAPITA)	GDP GROWTH RATE (%PA)
	2021	2021	2021	2005-2020
Indonesia	272	1,060	4,357	9.2%
Asia	3,310	29,584	8,938	6.9%
Asia incl. AU and NZ	3,341	31,465	9,418	6.8%
World	7,693	96,293	12,517	4.3%

Note(s): "Asia" denotes a specific group of countries in the continent, specifically China, India, Indonesia, Japan, the Republic of Korea, Malaysia, Taiwan, Brunei, Cambodia, Laos, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.
Source(s): IMF.

The COVID-19 pandemic hit Indonesia hard and hindered its strong recent progress in poverty reduction (World Bank 2022). Overall, the pandemic's effects were so severe that the official World Bank classification of the country went from upper-middle income to lower-middle income status as of July 2021 (World Bank 2021).

The Indonesian economy is now recovering with a projected growth rate of 5.1 percent for 2022. The recovery package to kick-start the economy included support for fossil fuels as well as green elements. Of this, $28.5bn was earmarked to be spent on sustainable, labor-intensive infrastructure development, which includes the construction of a natural gas network for households and support for rooftop solar. Biodiesel subsidies and value-added tax (VAT) and income tax reductions for renewable projects were also included in these recovery policies. However, the overall environmental impact is worsened by other elements of the recovery packages, such as weakening environmental regulation, extending available mining areas, providing fiscal stimulus to environmentally harmful state-owned enterprises, and subsidizing fossil fuel–generated electricity (Vivid Economics 2021).

Environmental and energy characteristics

Indonesia's energy system and economy are heavily based on fossil fuels. Indonesia is one of the world's largest coal producers and consumers with more than 80 percent of its power generation from fossil fuels (see Table 1.2). Recent commitments, including Indonesia's updated NDCs, aim to promote renewables in the power sector ((Ministry of Environment and Forestry, Indonesia 2021; UNFCCC 2022). The forestry sector is currently the highest single-sector emitter of the Indonesian economy (accounting for between 30 percent and 60 percent of total GHG emissions since 2010) and has also been the focus of emissions reduction commitments for the past decade. Sustainable forest management is equally important for mitigation and conservation (Indonesian REDD+ Task Force 2012).

TABLE 1.2: ELECTRICITY GENERATION BY SOURCE (SHARE OF TOTAL) AND CO_2 EMISSIONS IN INDONESIA, ASIA AND THE WORLD IN 2020

	FOSSILS	NUCLEAR	RENEWABLES	CO_2 EMISSIONS, $MTCO_2$
Indonesia*	83%	-	17%	626
Asia**	72%	2%	25%	14,935
Asia + AU, NZ	72%	2%	20%	15,345
World	63%	10%	26%	33,622

Note(s): * Indonesia does not currently have any nuclear power but has been carrying out feasibility tests and has ambitions to develop it in the future.
** "Asia" denotes a specific group of countries in the continent, specifically: China, India, Indonesia, Japan, the Republic of Korea, Malaysia, Taiwan, Brunei, Cambodia, Laos, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.
Source(s): IEA.

Climate change is expected to bring increasingly severe challenges for Indonesia in the coming years. Water availability, health and nutrition, disaster risk management, and urban development are all areas where the country will face serious challenges, particularly in its coastal zones. At the same time, Indonesia is home to the third-largest tropical rainforest, as well as the largest tropical peatlands and mangrove forests in the world, which are all natural resources that store large amounts of carbon; thus, they can be of great assistance in global decarbonization efforts (World Bank 2022).

Like many developing countries in Asia, Indonesia faces a difficult situation: the government needs to find an appropriate strategy for mitigating the challenges of climate change. This strategy has to keep concerns about the economic well-being of Indonesian citizens at the forefront, while shifting the country away from fossil energy sources. The latter will prove especially challenging, given the fact that Indonesia currently owns the world's fourth-largest pipeline of new coal-fired power plants (Kurniawan et al. 2020) and is one of the world's largest coal exporters (IEA 2022a) .

Current policy landscape for decarbonization

Indonesia submitted its most recent NDC in September 2022 as an update of its previous NDCs from July 2021 and November 2016. The targets set out in the latest NDC commit Indonesia to an unconditional 31.9 percent reduction in emissions below a business-as-usual (BAU) scenario, and a conditional 43.2 percent reduction in emissions by 2030 (UNFCCC 2022), a minor enhancement to previous targets of 29 percent and 41 percent set out in the 2021 NDC (Ministry of Environment and Forestry, Indonesia 2021). The new NDC has not changed Indonesia's primary energy supply mix targets but has increased adaptation ambitions and forestry sector commitments. According to the latest data, Indonesia will likely meet not just its unconditional but also its conditional target as well with its current policy objectives. However, these objectives are still not sufficient for mitigating the effects of climate change to the extent committed to in the Paris Agreement (Climate Action Tracker 2022).

Indonesia also submitted a Long-Term Strategy (LTS) document along with its NDC in 2021, formalizing a goal to reach net zero emissions by 2060 (Ministry of Environment and Forestry Indonesia 2021). As earlier versions of the strategy targeted 2070 for delivering net zero, this is a major step toward the Paris Agreement goals. Nonetheless, the implementation details are yet to be clarified (Climate Action Tracker 2022).

Commitments outline strong efforts to reduce emissions for Indonesia, but several open questions remain on how these targets will be met. Retiring inefficient coal plants, canceling new capacity in the pipeline, and replacing these with renewables are all needed for achieving the set emissions pathway. However, delivering a just phaseout with new employment opportunities for displaced fossil fuel supply workers is a major policy challenge.

Indonesia held the G20 presidency this year and encouraged all countries to work together toward a stronger and sustainable recovery through strengthening global health architecture, digital transformation, and energy transition (Ministry of Foreign Affairs Indonesia 2022). The G20 presidency presented an opportunity to accelerate decarbonization and strengthen emissions reduction policies in Indonesia.

OBJECTIVES

This report provides economic analysis to support the High-Level Policy Commission in providing guidance and advice to Indonesia on the net zero transition. The analysis aims to identify the impacts and benefits of decarbonization under different policy combinations and ambition levels. The study also considers the potential synergies and/or trade-offs between decarbonization and development goals.

Given the strong case for Indonesia to decarbonize, the economic impacts of Indonesia choosing different potential emissions reduction pathways including progressing toward net zero, compared to its pre-COP26 policies baseline, are analyzed in detail as part of the report.

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 narratives of the modeled scenarios.

Chapter 3 shows the findings of the modeling for the different climate ambition levels analyzed. Results are included for the pre-COP26 policies baseline, for scenarios achieving current commitments (2030 and 2060), and for scenarios featuring accelerated coal phaseout and stronger policies to reach net zero emissions by 2050.

Chapter 4 summarizes key conclusions and policy implications from the modeling results.

Detailed policy assumptions, detailed results, and a comparison with results from a similar study for India are included in the appendices. Given that both country studies were carried out under under a similar modeling framework, the comparison of findings is intended to present their narratives in a consistent and comparable manner and clarify differences that are driven by specific country characteristics and modeling differences.

SCENARIO FRAMEWORK

MODELING FRAMEWORK

This report presents a set of scenarios describing alternative decarbonization pathways for Indonesia using E3ME, a global macroeconometric model, developed and maintained by Cambridge Econometrics. The Asia Society Policy Institute and local experts with strong knowledge of Indonesian decarbonization and other policies 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, and support for new technologies. The model solves annually and has detailed sectoral coverage including bottom-up technologies in key sectors (e.g., power and road transport). 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 2023–2060, the end of which is determined by the model setup (the model currently 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. When 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 policies and commitments need to be to deliver the 2060 net zero target? How must this ambition level shift if the date of the net zero target is brought forward? Is the conditional target achievable without or with less international support?
- **Support implementation** – Which policy package is expected to deliver the most economic, social, and climate benefits? Which policies should be prioritized to further accelerate climate action without significantly compromising economic and social outcomes? What are the associated policy costs? What are potential barriers or trade-offs (and how can they be addressed)?

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

- **Pre-COP26 policies (*baseline*):** This scenario is our reference case for Indonesia to benchmark other scenarios against. It represents the least ambitious pathway, taking into account enacted decarbonization policies for Indonesia implemented before COP26 with no additional policies modeled thereafter.
- **Baseline + 2030 targets (*2030 targets*):** This scenario represents a pathway in which Indonesia's 2030 commitments announced before January 2022[3] are met, but no new policies are implemented thereaf-

3 Since the analysis started, new policy and political developments have been taking place that are acknowledged in the report but are not in the modeling, including Indonesia's enhanced NDC submitted in September 2022. However, the increase in ambition compared to the 2021 NDCs is incremental and does not have a noticeable influence on the results.

ter. It is intended to highlight how current policies need to be adjusted to enable Indonesia to meet its announced 2030 power sector targets in addition to the economy-wide emissions targets (which are on track to be achieved with current policies in the baseline). This scenario treats short-term pledges to 2030 as credible and enforced, but it does not assume an increase in ambition beyond those policies.[4] In this and all subsequent scenarios, a cap-and-trade system is imposed on emissions from the power sector from 2022 and stays in place. This carbon-pricing mechanism was originally written into law in 2021 for implementation in 2022 but is yet to be realized at the time of writing..

- **All COP26 unconditional commitments including 2030 targets and 2060 net zero commitment *(2060 net zero)*:** This narrative represents a pathway beyond 2030 commitments that includes additional policies to deliver Indonesia's announced net zero commitment as outlined in its LTS. The scenario is designed to understand how Indonesia's near-term, mid-term, and long-term ambitions need to be calibrated to achieve its 2060 net zero target, including how its current 2030 targets stack up with the pathway toward its net zero goal. In this and all subsequent scenarios, it is assumed that the cap-and-trade system extends to non-power energy-intensive sectors from 2025, and that government subsidies for coal power are removed and reinvested in green initiatives such as support for renewables. Based on a similar approach (IESR 2022a), the value of avoided subsidies is estimated by multiplying an average subsidy rate of $6/MWh to the reduction in coal-based power generation from baseline levels. The average subsidy was calculated based on support for below-market coal price on Domestic Market Obligations (DMOs) in 2020 (OECD 2022).

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

  - In the **LTS-inspired variant**, the power generation mix is inspired by the LTS with a major role for existing technologies (such as hydro and geothermal) and new technologies such as coal with carbon capture and storage (CCS). The policies that support this include carbon pricing, renewables subsidies, and public procurement to kick-start CCS. This is the central scenario referred to in most of this report.
  - In the **minimal coal CCS, renewables-based (*coal CCS-limited RES*) variant**, we explored a power sector pathway that assumes a minimal role of coal-based CCS. Instead, it allows for higher levels of existing renewables, including hydro, geothermal, biomass, wind, and solar. This pathway is comparable to modeling done by IESR (2021) and is supported by the same policies as the LTS variant with the procurement policy replaced by regulation to limit coal with CCS.
  - 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, considering relative costs and capacity restrictions (due to either natural resource or regulatory constraints). In contrast with the LTS variant, kick-start policies focus on solar PV, which is cost competitive in Indonesia but has not seen strong uptake to date, while capacity regulation is imposed to limit the use of high-cost technologies such as hydro, geothermal, and CCS.

4 Note that pre-COP26 announcements that had not been made into policies are only included in the 2060 net zero and 2050 net zero scenarios.

- **COP26 commitments conditional on international support including 2030 targets and 2060 net zero commitment (*conditional 2060 net zero*):** This narrative represents a pathway in which international support is available for Indonesia to deliver conditional emissions targets by 2030 and better position itself for achieving net zero by 2060. In this and all subsequent scenarios, funding for renewable subsidies and compensation for stranded fossil assets is assumed to be provided by the international community and allows for more rapid decarbonization in the medium term. Indonesia's NDCs identify research, development, and transfer of innovative technologies as target areas for international support without specifying details; as such, international support is assumed to focus on the power sector, similar to the scope of the Just Energy Transition Partnerships proposed by the G7. The country also takes stronger action to phase out unabated coal by 2049.
- **Accelerated coal phaseout:** This scenario represents a pathway in which Indonesia meets its current targets along with an additional effort to phase out unabated coal power generation from the economy by 2040, more rapidly than current policies imply. It is designed to understand how Indonesia'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).
- **2050 net zero:** Under this narrative, the climate policy applied in Indonesia is increased well beyond committed targets to reach net zero emissions by 2050 to understand what needs to happen to fully align Indonesia's near-, mid-, and long-term ambitions with a 1.5°C pathway. All COP26 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 including other Asian economies is assumed to act in line with a 1.5°C global pathway. Similar to the *2060 net zero* scenario, this narrative is analyzed with alternative power sector decarbonization pathways:
  - A central **LTS variant** with substantial use of coal with CCS alongside renewables (particularly hydro and geothermal) in the power mix.
  - A **coal 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, 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.

The evolution of different technologies is determined within the model, based on historical cost and market shares data (which drive future cost changes) and subject to technical potential constraints (particularly for relatively new solutions such as CCS that will need time to become economically competitive).

Extended narratives and a description of scenario assumptions can be found in the technical appendices, while detailed policy assumptions are described in Appendix B. Specific assumptions are informed by or sense-checked against government announcements, expert advice, and the wider academic literature.

Interpreting Indonesia's updated targets

Indonesia's most recent enhanced NDC submission and Long-Term Strategy are not highly detailed regarding their implementation, thus leaving some room for interpretation and the feasibility of some targets open to debate (Ministry of Environment and Forestry, Indonesia 2021; Ministry of Environment and Forestry Indonesia 2021; Climate Action Tracker 2022; UNFCCC 2022). The interpretation of targets in this analysis is consistent with the available literature and the opinions of local experts. They are modeled as follows:

- **31.9% (unconditional) and 43.2% (conditional) GHG emissions reductions by 2030:**
  - The frequently cited total GHG emissions reduction targets of 31.9% (unconditional) and 43.2% (conditional) (previously 29% and 41%, respectively) are inclusive of LULUCF emissions. The LTS envisions that forestry and land use (LULUCF) emissions reductions will make considerable contributions to overall GHG emissions reductions without detailed policy implementation plans. The trajectory of LULUCF emissions in Indonesia is highly uncertain because of substantial historical volatility. Therefore, our modeling does not rely on negative LULUCF emissions (natural carbon sinks) to achieve the emissions targets. Because LULUCF emissions are excluded, 2030 GHG emissions targets of 19% (unconditional) and 24% (conditional) are used to evaluate the modeling results.
  - The BAU scenario described in the NDC documents assumes rapid growth in GHG emissions by 2030 that is substantially above current policy projections (Climate Action Tracker 2022). Therefore, current targets are not sufficiently ambitious given current trajectories. In this modeling exercise, emissions reductions are presented with respect to both the original NDC BAU and the modeled (pre-COP26 policies) baseline.
- **Net-zero target:** The NDC and LTS documents refer to the achievement of net-zero GHG targets. However, they include limited detail on strategies to reduce non-CO_2 emissions, especially methane emissions, which are largely generated by agricultural activities and represent the second-largest source of GHG emissions (after CO_2) in Indonesia. Taking a more conservative approach similar to IESR (2021), our modeling assumes net-zero CO_2 targets (excluding LULUCF). In other words, the modeling scope for net zero is energy-related CO_2 emissions.
- **Retirement of 9.2GW of coal power capacity by 2030:** Indonesia currently has 26GW of coal capacity. Assuming 9.2GW to be retired under Indonesia's PLN plans and 13.8GW of additional capacity in the pipeline (OECD 2021), this implies a net capacity addition of 4.6GW by 2030 compared with current levels and an absolute capacity of 30.6GW.
- **50% of power capacity additions to be renewables by 2030** (OECD 2021): Renewables are assumed to include solar, wind, hydro, geothermal, bioenergy, and BECCS.

STRENGTHS AND LIMITATIONS

E3ME's key strengths for supporting this analysis follow:

- The close integration of the economy, energy systems, and the environment, with two-way linkages between all components.
- 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.
- A wide range of climate policy options are available, including regulations, taxes, tariffs, and subsidies, especially for the largest emitters in the economy (power, steel, road transport, and residential buildings), which also feature a detailed representation of technology diffusion.
- The shift of focus away from just determining a least-cost policy implementation and toward identifying potential opportunities and trade-offs arising from decarbonization.

On the other hand, the analysis has several limitations:

- The modeled scenarios incorporate only information available in the public domain until December 2021. Recent major events including Russia's war in Ukraine and fossil fuel price spikes, as well as increases in countries' climate ambition since January 2022, are not included but all are likely to impact the results to some extent. In particular, Indonesia's enhanced NDC announced in September 2022 includes only an incremental increase in emissions reduction targets for 2030; therefore, its impact on the modeling is likely minimal. On the other hand, our own previous research (Cambridge Econometrics 2022) suggests that high prices and fossil fuel supply disruptions would encourage investment in low-carbon alternatives; however, they still lead to long-term economic scarring in the largest economic blocs, which would eventually spread to Indonesia.
- As with any modeling tool, E3ME is an imperfect representation of reality. Both gaps in the data and an inability to predict the future contribute to uncertainty in the model results. Given the diverse characteristics of the economy and the energy system, it is not technically possible to account precisely for every possible energy source and technology in each sector. For example, the model accounts for seasonal variations, implied demand for backup generation, and storage and technological constraints in Indonesia's context to determine the technology mix, but it does not fully capture detailed power grid balancing requirements (which can only be accounted for using real-time hourly data).
- 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 the uptake of low-carbon technology options and makes a simplified assumption about the role of international support in financing the transition. 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 INDONESIA'S DECARBONIZATION TARGETS

Identified pathways for short-term targets

Driven by strong economic growth, increasing energy demand, and continued fossil fuel use, emissions under the baseline scenario grow steeply in Indonesia. Most of the emissions increase can be attributed to the power sector and the increasing share of coal in electricity generation. Although there is some pickup of renewables (solar in particular), the shift is very modest. Emissions remain high in industry as well as in the transport sector, which is dominated by motorcycles and ICEs with limited electrification. As a result of the slow rate of decarbonization, emissions are projected to increase by about 30 percent by 2030 compared to current levels. This trajectory implies a much lower emissions level than that set out in the NDCs (see Table 3.1); however, it is aligned with other external current policy projections such as Climate Action Tracker (2022) and IEA (2022c).

Without any new policy action, the long-term net zero and power sector targets are not met in the baseline. However, relative to the original NDC BAU that was used to set the NDC targets and assumes a high level of emissions by 2030, the 2030 unconditional and conditional emissions reduction targets are both already exceeded in the modeled baseline, due to policies that have been implemented since the original targets were set.[5] This is consistent with the conclusion of Climate Action Tracker (2022) and suggests the NDC targets originally set in 2016 (which have not changed significantly in the latest 2022 NDCs) are no longer sufficiently ambitious given progress to date achieved by current policies. As a result, both unconditional and conditional emissions reductions targets for 2030 are also exceeded in all subsequent scenarios, regardless of the presence of additional policies and international financial support.

The modeling assumes that relevant policies are implemented in the *2030 targets* and *2060 net zero* scenarios to achieve Indonesia's targets for reducing cumulative emissions reductions. Indonesia aims to reduce GHG emissions (excluding LULUCF) by 19 percent unconditionally by 2030 and by 24 percent (equivalent to 31.9 percent and 43.2 percent, respectively, on a total GHG basis with LULUCF) if international support is available for decarbonization. Transforming the power sector is the key channel for achieving these targets by reducing the share of coal and increasing the share of renewables in electricity generation. Of those scenarios, the *2060 net zero* scenario has more policies to deliver the additional net zero target of 2060 as outlined in Indonesia's LTS document.

Table 3.1 shows an assessment of the modeling results against the targets. Since E3ME is not an optimization model that solves for exact targets, the results for target indicators vary slightly across scenarios and are driven by the policy assumptions. The modeling thus illustrates the impact of policy combinations to meet or exceed stated targets.

To explore the role of the power sector, two sensitivities around the power technology mix were modeled besides the base case that features a power mix similar to that envisioned in the LTS. Both scenarios allow for a potentially different decarbonization pathway that achieves the same level of emissions reduction as the LTS-inspired variant. Appendix B lists more detailed policies.

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5 The modeling assumes that policies that have been implemented stay in place in the future.

TABLE 3.1: ASSESSMENT OF INDONESIA'S DECARBONIZATION TARGETS IN 2030						
INDICATOR/NDC TARGET	**BASELINE**	**2030 TARGETS**	**2060 NET ZERO**	**CONDITIONAL 2060 NET ZERO**	**ACCELERATED COAL PHASE-OUT**	**2050 NET ZERO**
2030 GHG emissions (excl. LULUCF)						
1739 $MtCO_2e$/a unconditional target	1,305	1,218	1,197			
1647 $MtCO_2e$/a conditional target				1,180	1,162	1,117
Modeled 2030 GHG emissions (excl. LULUCF) compared to the NDC BAU						
- 19% unconditional target	−39%	−44%	−44%			
- 24% conditional target				−45%	−46%	−48%
% reduction in GHG emissions (excl. LULUCF) by 2030 compared to the modeled baseline						
- 19% unconditional target	-	−7%	−8%			
- 24% conditional target				−10%	−11%	−14%
Net zero CO_2 emissions year	-	-	2060	2060	2058	2050
% of renewables in cumulative capacity additions over 2022–2030 (50% target)	3%	76%	77%	83%	84%	81%
Coal capacity in 2030 (30.6GW target)	38GW	31GW	31GW	29GW	26GW	25GW

The implementation of policies in the pipeline in the *2030 targets* scenario ensures short-run power sector targets are met. In this scenario, the renewables share targets and the lower levels of coal capacity than in baseline are achieved through the government's program to retire 9.2GW of coal capacity by 2030, establishing carbon pricing for the power sector and renewables subsidies. Compared to the baseline where only 3 percent of new power being built between now and 2030 is with renewables, in this scenario, the majority of new additions are built with renewables due to renewables subsidies and carbon pricing.

In the short term, carbon pricing and renewables subsidies signal investors to shift activity toward fossil fuels with a lower carbon content (such as natural gas) or invest in new renewables capacity. While switching to lower-carbon fossil fuels is less costly and can be implemented relatively easily, it is unlikely to be an attractive long-term option – carbon pricing makes fossil fuel generation more costly, while subsidies provide added incentives for new investment in renewables. In the longer term, post-2030, new renewables power capacity comes into operation; electrification of road transport and the decarbonization of other sectors through carbon pricing and energy efficiency all play a stronger role in driving emissions down.

In the *2030 targets* scenario, carbon pricing and renewables support (subsidy and kick-start) policies in particular are strengthened to meet 2030 power sector targets, in addition to the NDC emissions reductions targets that are on track to be achieved in the baseline, but no further action is taken. In this scenario, CO_2 emissions continue to grow until the early 2040s. Although this growth is substantially slower than in the baseline scenario over the same period, it is slightly faster than the increase in emissions in the years to 2030. This is driven by a rebound in fossil fuel use in power generation: as it is assumed that renewables subsidies start to be phased out after 2030 (given that some renewables such as wind and solar are already cost competitive with fossil fuels, at which point other measures would become more effective at inducing change[6]) and carbon pricing remains low, power sector investors have weak incentives to invest in renewables and quickly revert to coal. Toward 2060, the emission pathway flattens out and CO_2 levels start to decrease, due to the cost of renewables falling over time as deployment slowly picks up. By 2060, emissions are 56 percent below the baseline trajectory yet stabilize far above net zero.

Reaching 2030 NDC targets is a step-up in climate action in Indonesia and comes with noticeable environmental and economic benefits. However, net zero emissions are not yet reached by mid-century and emissions do not fall steeply enough to stay on track toward limiting global warming to 1.5°C by 2100. To reach that, global emissions levels need to be 45 percent below 2010 levels by 2030 and reach net zero around 2050 (IPCC 2022), to which Indonesia will contribute its "fair share."[7] Additional long-term policies are needed to steer the Indonesian economy in this direction.

Aiming toward net zero emissions targets

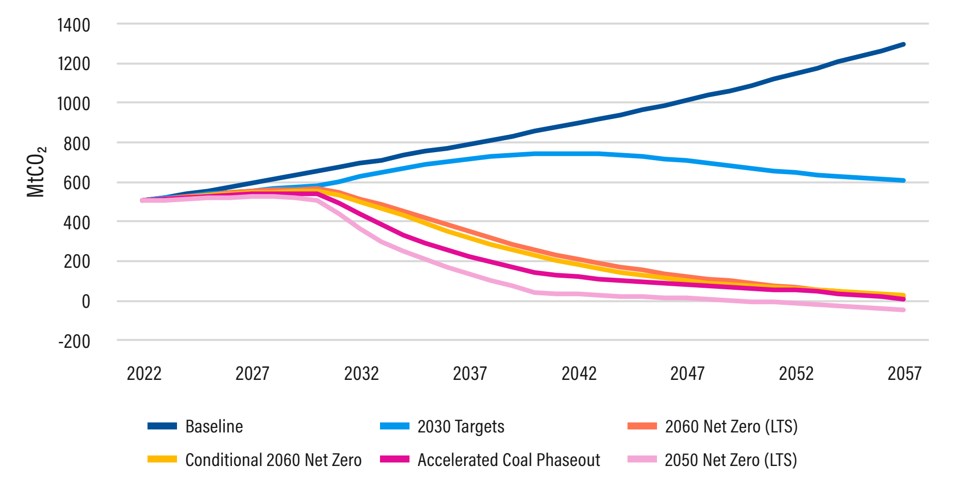
The *2060 net zero* scenarios ramp up policy action especially in the post-2030 period to push renewables in the power sector, transport electrification, and industry decarbonization even further. This occurs mainly by expanding carbon pricing to the rest of the economy (non-power energy-intensive sectors from 2025 and other sectors from 2031), supported by procurement of CCS and an acceleration of existing policies (such as EV subsidies and biofuel mandates). While the short-term 2030 outcomes are similar, these scenarios reach net zero emissions by 2060 as targeted in the LTS documents.

The *accelerated coal phaseout* and *2050 net zero* scenarios are designed to illustrate how Indonesia can further its actions to better align with the Paris Agreement vision. Policies from the *2060 net zero* scenario are strengthened further and a major additional policy is introduced that prevents new unabated coal power plants from being built. This increased level of action opens up the potential for Indonesia to aim for more ambitious short-term targets and meet its net zero target by 2050. CO_2 emissions peak in 2030 under these pathways and lead to a steep reduction in the following decades.

6 This is designed to reflect that policies change and adapt over time. Subsidies are most effective at inducing change before cost parity is achieved. When renewables have become cost competitive with fossil fuels, nonmarket factors are likely to play a greater role in determining the level of deployment. At this point, subsidies become costly with minimal impact while policies such as market reforms and regulations are much more effective.

7 Article 4.3 of the Paris Agreement states that a country's contribution to global effort should be based on "its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

FIGURE 3.1: CO_2 EMISSIONS PATHWAYS FOR INDONESIA UNDER DIFFERENT LEVELS OF AMBITION



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

The net zero year is brought forward to 2058 under the *accelerated coal phaseout* scenario, compared to 2060 in the *2060 net zero* scenarios, due to the no new coal policy preventing new coal power plants from being built to deliver an earlier coal phaseout (by 2030). The greatest difference in the emissions pathway is seen in the medium term, whereas the long-term trajectory is similar to the *2060 net zero* scenarios. This is because coal regulation is assumed to take effect immediately, and the majority of investors would respond to it sooner rather than later.

The policy packages modeled (in particular, the introduction of an accelerated coal phaseout[8]) lead to CO_2 emissions peaking in the last few years of this decade (between 2027 and 2029) in the *accelerated coal phaseout* and *2050 net zero* scenarios before falling rapidly, compared to emissions peaking by 2030 in the *2060 net zero* scenario and not until the early 2040s in the *2030 targets* scenario (see Figure 3.1). The most ambitious pathway for Indonesia therefore is closer to the need for global emissions to peak before 2025 to keep global warming to 1.5°C (IPCC 2022).

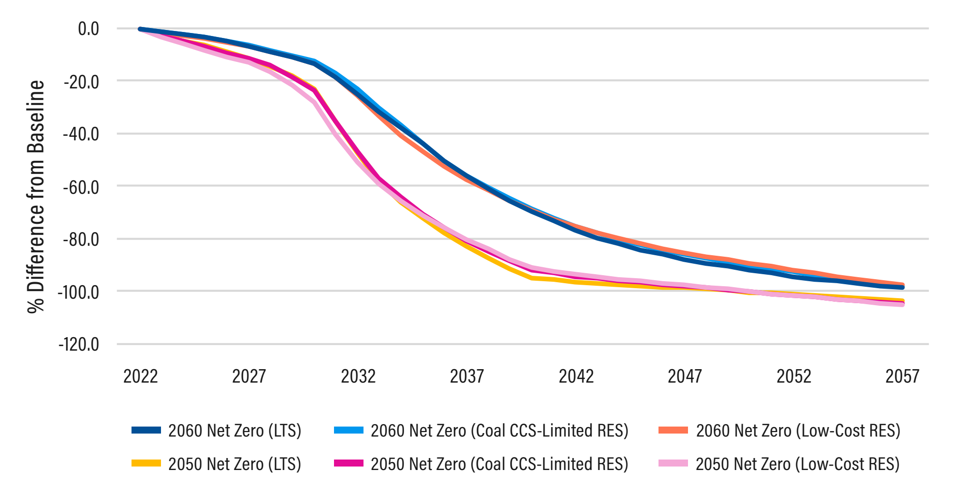
Impact of power mix on meeting targets

Both the *2060 net zero* and the *2050 net zero* pathways are modeled with variants assuming different power technology mixes. While the LTS-inspired variant assumes substantial use of coal with CCS to replace unabated coal power, based on the current plan outlined by the Indonesian government, the other variants allow for a larger role for renewables, in particular, solar and wind. This replacement is stronger in the low-cost RES variant than in the coal CCS-limited RES variant. These variants were constructed in such a way that all of them deliver the predetermined emissions targets; therefore, the CO_2 trajectories are similar across the three. The mild differences in emissions pathways (which have noticeable social and economic impacts that are presented in sections 3.3 and 3.4) are explained by the substitution between coal with CCS that generates emissions[9] and renewables that generate zero emissions.

8 This refers to the no new coal policy from 2023 and unabated coal phaseout by 2040, implemented together.

9 It is assumed that 90 percent of emissions from coal power generation are captured by CCS, with the remaining 10 percent being released.

FIGURE 3.2: IMPACT OF POWER MIX VARIATIONS ON INDONESIA'S CO_2 EMISSIONS PATHWAYS



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

For the *2060 net zero* scenario, the three variants see emissions peaking in the same year (2030), whereas the peaking year of emissions is earliest (in 2027) in the low-cost RES variant of the *2050 net zero* scenario and latest (in 2029) in the LTS variant.

ENERGY AND TECHNOLOGICAL TRANSFORMATIONS

Underlying the emissions pathways described above are a series of technology transformations at the sectoral level. The rate of progress in decarbonizing the power sector aids decarbonization in the rest of the economy, as electricity plays an increasingly large role in meeting energy demand; therefore, the differences in emissions levels between scenarios with different levels of ambition are most clearly seen in the power sector.

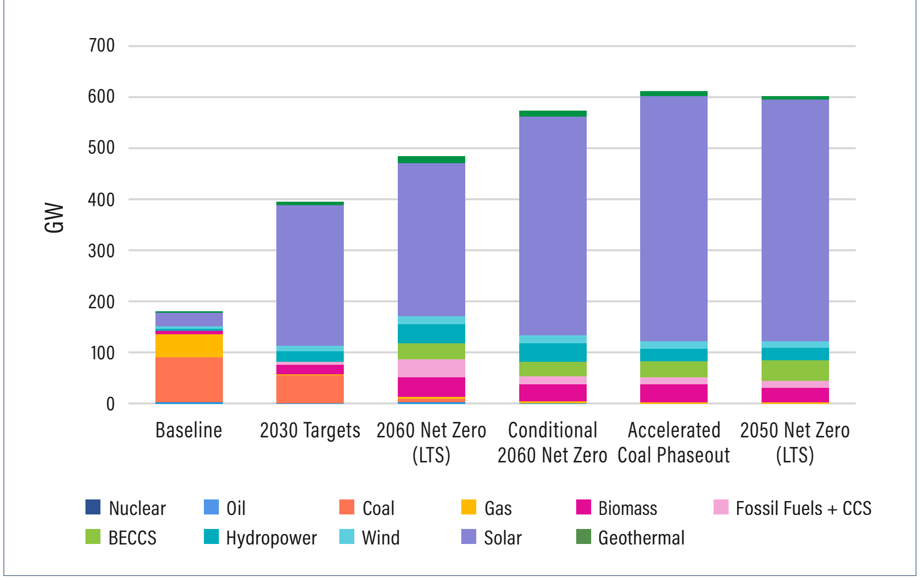
Power sector

By 2050, there is a more than 50 percent higher demand for electricity in all scenarios compared to baseline, apart from the *2030 targets* scenario that sees a 16 percent increase. This demand implies a higher level of total electricity generation and capacity than baseline and is mainly due to higher rates of electrification of the economy (especially in road transport with the uptake of EVs). Higher rates of energy efficiency (particularly in buildings, enabled by additional revenues from higher rates of carbon pricing) mean that the electricity demand is lower in the *2050 net zero* scenario, despite a higher rate of electrification than in the *2060 net zero* and *accelerated coal phaseout* scenarios.

In contrast to a power mix dominated by coal and gas in the baseline, in all accelerated decarbonization scenarios (including the least ambitious *2030 targets* scenario), there is a noticeable increase in new capacities of solar PV and wind to replace fossil fuels (see Figure 3.3).

The comparison between the *LTS 2060 net zero* scenario and the *2030 targets* scenario is particularly interesting, as it highlights the market competitiveness of solar PV over power technologies currently deployed on a large scale or widely considered in Indonesia. On the one hand, there is a lower level of coal capacity and a higher level of capacity for wind, hydro, geothermal, and biomass in the *2060 net zero* scenario, which is in line with the difference in decarbonization ambitions. In addition, electricity generation from renewables reaches 85 percent by 2050 in the *2060 net zero* scenario, higher than the equivalent share of just over 75 percent in the *2030 targets* scenario. On the other hand, the share of solar capacity is higher in the less ambitious scenario of the two (*2030 targets*), accompanied by a lower level of fossil fuels with CCS capacity.

FIGURE 3.3: POWER CAPACITY BY TECHNOLOGY IN 2050 IN INDONESIA



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

The observed trend in the *2030 targets* scenario is a more solar-dominant power mix in the absence of new policies beyond 2030. Solar PV has a lower level of efficiency (captured by load factors[10]) due to intermittency, which means the same amount of electricity requires more infrastructure than if it were generated from burning fossil fuels. In addition, this high level of deployment is driven by solar PV being already available at a much lower cost than most other low-carbon options, including existing options such as hydropower and geothermal and new alternatives that feature CCS. IRENA (2019) shows that the global installed cost of solar in 2019 was already lower than that for hydro, geothermal, and bioenergy,[11] while Hiremath et al. (2021) show that the levelized cost of coal with CCS is several times that of both solar PV and wind in India, which means it would still be higher even if accounting for future cost reductions and the higher renewables costs in Indonesia than India. IEA (2022b) estimates that solar has the highest technical potential in Indonesia but the smallest proportion of that potential being utilized so far among economically viable technologies.

While the *LTS 2060 net zero* scenario features public procurement and subsidy policies beyond 2030 to encourage the uptake of hydro, geothermal, and coal with CCS (in line with the LTS), the *2030 targets* scenario does not include the same policies and relies more on market signals (from the introduction of cap and trade

10 Load factors are a measure of efficiency of power plants and indicate the average amount of electricity generated from the available capacity.

11 The global installed costs were $995/kWh for solar PV, $1704/kWh for hydro, $3916/kWh for geothermal, and $2141/kWh for bioenergy. The installed costs of solar PV in Indonesia were slightly higher than the global average at $1158/kWh and much higher than in China ($794/kWh) and India ($618/kWh).

for the power sector and wind and biomass subsidies in the years to 2030) to simulate the low-carbon transition. According to IESR (2022b), costs of solar have come down significantly within the past few years due to recent redesign of pricing and auction regulations for renewable energy supply. Meanwhile, IEEFA (2019) argues that market regulations that favor fossil fuels by making solar (and renewables) projects unviable, rather than cost or financing, are more responsible for the slow historical uptake. The implication is that with sufficient market reforms to reduce barriers to entry, solar PV has vast potential to power the Indonesian economy in the long term without any financial support from the government, helping Indonesia benefit from further renewable cost reductions sooner and achieve a faster transition at a lower cost. At the same time, it would reduce fossil fuel dependency by almost the same extent as a larger policy package that targets existing (more expensive) technologies. The two scenarios end up with almost the same level of coal being used (capacities of both unabated coal and coal with CCS) by 2050, which is also much higher than in all other scenarios apart from the baseline, including other variants of the *2060 net zero* scenario.

Looking beyond to the *accelerated coal phaseout* and *LTS 2050 net zero* scenarios, the modeling suggests that the power sector has the potential to completely decarbonize by the mid-2030s, driven by a rapid coal phase-down in the short term (enforced by the no new coal policy), full coal phaseout in the medium term (2040), and carbon pricing from now. This results in 65 percent of primary energy demand coming from renewable sources by 2040, compared to 48 percent in the *LTS 2060 net zero* scenario where the power sector does not fully reach net zero until the mid-2040s (around 10 years later). The power mixes in all scenarios in Figure 3.3 except for the baseline and *2030 targets* scenario are similar by 2050, with solar being dominant, supported by wind and other renewables and a small share of fossil fuels with CCS.

In particular, 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). Under this circumstance, immediate impacts of the policy on emissions reductions are more limited than intended. However, as renewable costs decrease 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 coal phaseout regulation, carbon pricing, and renewables subsidies ensures that in the long term when coal plants come to retirement, they are replaced with renewables.

The high share of renewables implies increased pressure on the national grid. The modeling accounts for increased demand for storage and backup generation to accommodate this, with associated investment included in macroeconomic benefits and impacts on the cost of electricity generation reflected in electricity price impacts. Additional investments to develop storage, grid integration, and management technologies are not included.

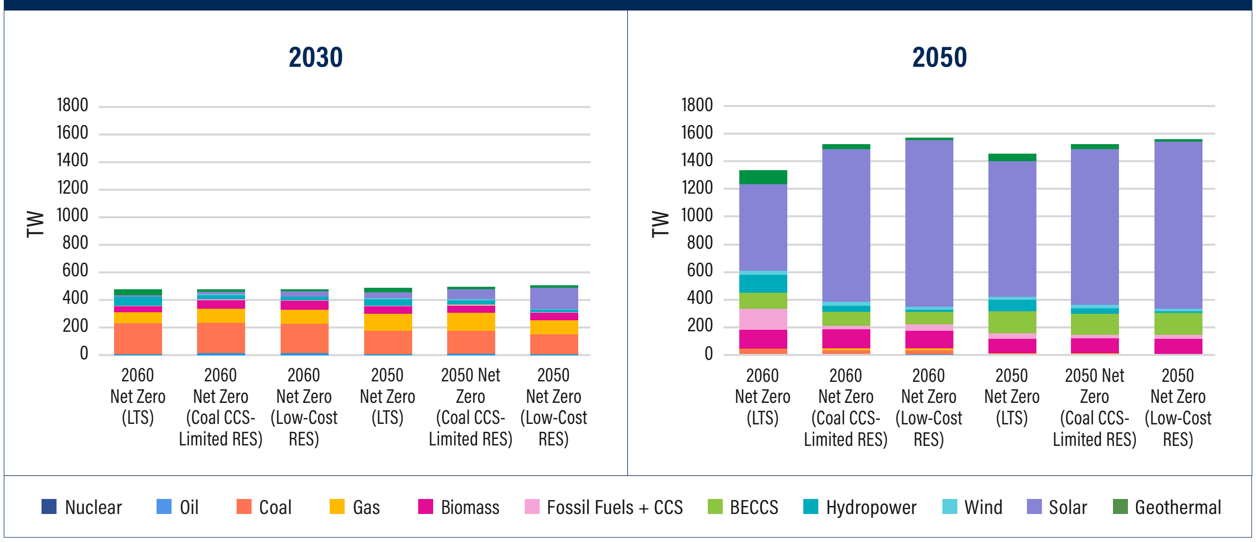
It is acknowledged that biomass cofiring in existing coal plants is an alternative option currently being considered by the Indonesian government to aid the transition away from coal without substantial stranded assets. However, according to analysis by IEEFA (2021), the maximum potential for cofiring in Indonesia is

11TWh by 2030, which equates to only 2.0 percent–2.5 percent of total electricity generation across all scenarios modeled. In addition, there is a high degree of uncertainty about whether and how cofiring will be enforced by policies and will address concerns about biomass availability. Thus, it is not considered in the modeling presented here.

Power mix sensitivity

For the *2060 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 the LTS. Both variants heavily feature renewables integration, as with the LTS. However, the coal 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 hydro and geothermal that are assumed to have limited new potential due to high capital requirements.

FIGURE 3.4: POWER GENERATION BY TECHNOLOGY



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

The procurement policy is an umbrella policy that represents not only direct purchases or constructions of renewables capacity by the state utility but also structural reforms to remove nonmarket barriers preventing cost-competitive renewables from taking off. For example, analysis by IEA (2022c) suggests that the cost of solar and wind in Indonesia is currently twice as high as that in other emerging economies despite vast technical potential. The removal of coal power subsidies and reinvestment of those subsidies into promoting renewables are examples of such measures.

The results for power capacity and power generation (as shown in Figure 3.4) reflect the policy intention. For both scenarios, both variants result in a larger, more dominant role for solar than in the LTS-inspired case. The outcome of the extended no new coal policy in the coal CCS-limited RES variant and the *2050 net zero* scenario is similar to, but slightly less ambitious than, modeling results by IESR (2021). For a *2050 net zero* scenario, the IESR modeling projects 100 percent of electricity generation from renewables (88 percent by solar PV) with complete (unabated and abated) coal phaseout by 2045, compared to 98 percent of renewables and 72.5 percent of solar PV in generation by 2045 with unabated coal phaseout by 2040 in the E3ME modeling. Meanwhile, the low-cost RES variant has similar renewables share as the coal CCS-limited RES variant, but with a higher share of solar PV at 77 percent by 2045 and 30 percent by 2030 (in line with projections by IRENA (2017)). For the *2060 net zero* scenario, the pattern is similar with solar PV reaching 66 percent of generation by 2045 in the coal CCS-limited RES variant and 72 percent in the low-cost RES variant, much higher than the share of 37 percent in the LTS-inspired case.

Comparing the two power mix variants for each net zero scenario shows some switching effect 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 notable, as presented in sections 3.3 and 3.4.

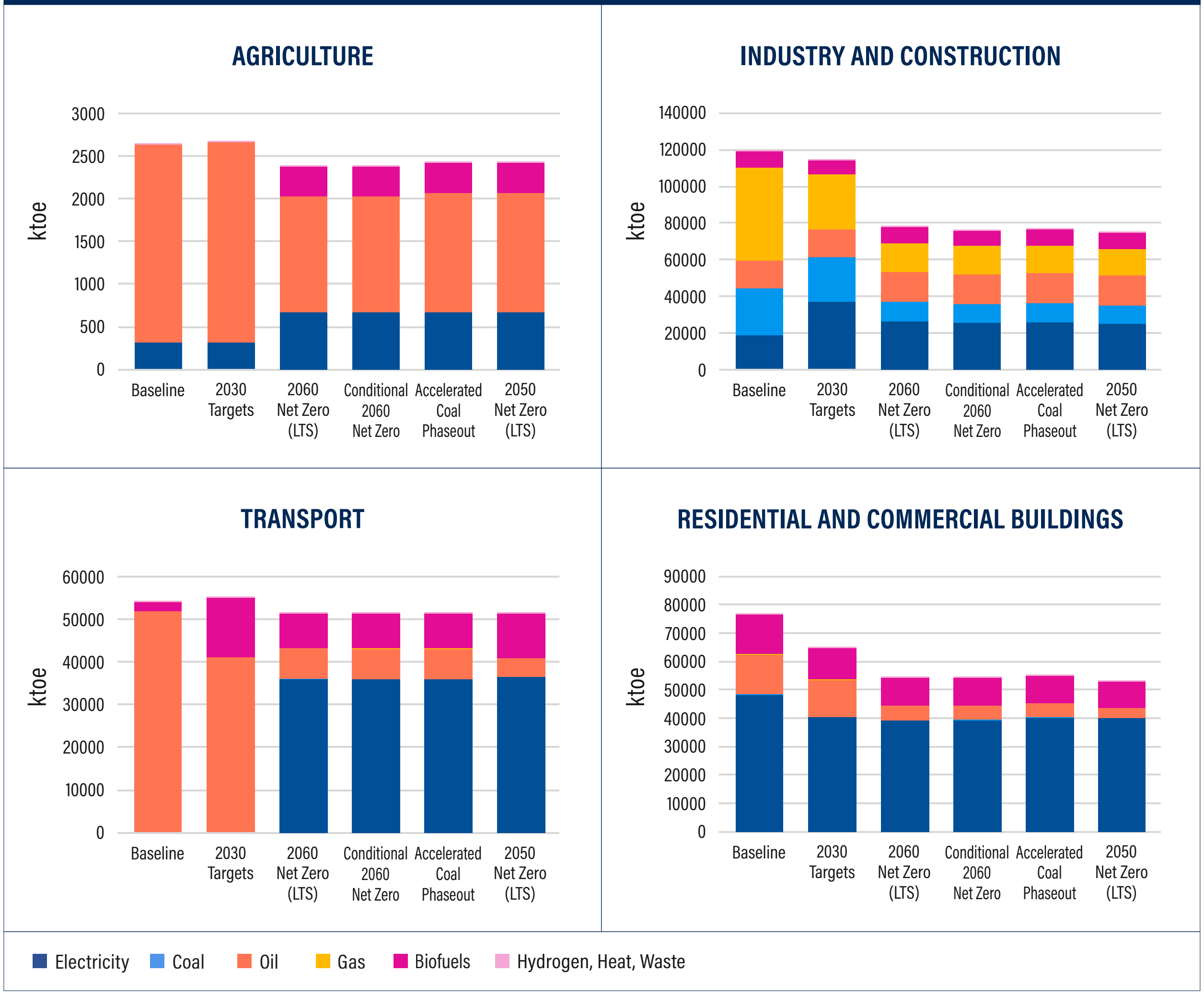
Final energy demand

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 given an accelerated rate of electrification. There is a clear shift from fossil fuels to electricity and biofuels among the baseline, the *2030 targets* scenario, and the *2060 net zero* scenario. However, between the *2060 net zero* scenario and more ambitious scenarios, the difference is minimal (see Figure 3.5), apart from an additional switch from middle distillates to biofuels in transport.

This reason is that 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 decarbonize. 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. The composition of the power mix as explored in the sensitivities, however, does not affect final energy demand noticeably, as the policies and assumptions included in those variants are specific to the power sector. There is, however, a mild 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 response in their demand.

In transport, by 2060, most passenger vehicles are electric (driven by electric vehicle subsidies and ICE sales caps), whereas a share of fuel demand for road freight, 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 creation of natural carbon sinks, and they also have 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.

FIGURE 3.5: ENERGY MIX BY FINAL USER IN 2050 IN INDIA ACROSS SCENARIOS



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

SOCIOECONOMIC IMPACTS

In the baseline, Indonesia is projected to experience strong GDP growth of above 5 percent pa in the next decade, followed by more modest growth of more than 4 percent pa over 2030–2050 and 2.5 percent pa thereafter, as the country becomes more aligned with the development path of current developed economies. Economic growth is supported by household consumption and investment, while employment grows moderately between 0.5 percent and 1 percent pa over the forecast period, in line with population.

GDP impacts

The GDP impacts are positive above baseline for all the forecast period in the *2030 targets* scenario and for most of it in other core scenarios with net zero targets (see Figure 3.6).

The results show two distinct phases of impacts: before and after 2050. Each of these phases is discussed in turn below.

GDP impacts in the medium term are positive and mainly drive by investment

In the years to 2050, the *2030 targets* scenario has the smallest GDP impact, peaking at 3.3 percent above baseline in 2030 before slowing and settling at around 0.8 percent –0.9 percent above baseline levels from 2040 to 2050. In comparison, GDP is projected to be 5.0 percent higher than baseline in the *2060 net zero* scenario at its peak in 2032. The results are similar with international support to deliver more ambitious 2030 targets before reaching net zero by 2060 (*conditional 2060 net zero*).

The *accelerated coal phaseout* sees GDP impacts peaking at a lower rate (3.9 percent above baseline) but around five years earlier than the *2060 net zero* scenario. This implies a more rapid transition taking place earlier; however, it is offset, by a higher cost of compensation for coal stranded assets (due to a strict no new coal regulation) without additional investment boosts and carbon revenues that are present in the *2050 net zero* scenario. Meanwhile, the GDP gains in the *2050 net zero* scenario are relatively similar to those in the *2060 net zero* scenario, although slightly higher in the peaking year (2031) at 5.3 percent above baseline.

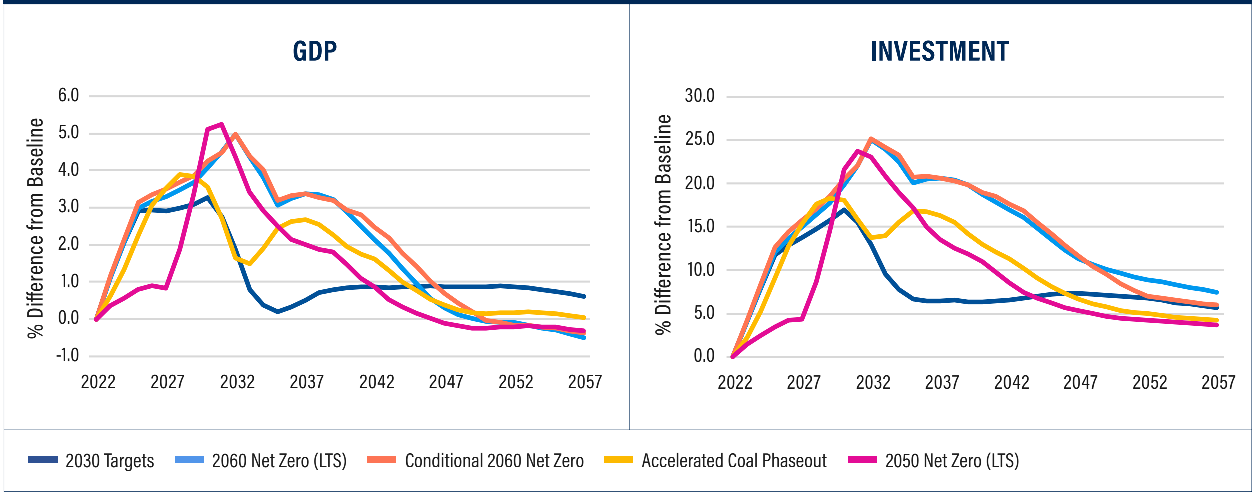
There are two implications from this cross-scenario comparison:

- 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 to support such an ambition.
- The trade-off between economic growth and decarbonization is reduced when climate ambition is increased – a higher level of ambition allows the country to reap additional economic benefits to offset some costs.

The GDP impacts are driven mainly by higher levels of investment in the power sector in the short and medium terms, supported by investment in energy efficiency in the longer term. In all scenarios, the investment profile over time is driven by policy and market interactions:

- In the next few years, investment increases rapidly to build low-carbon infrastructure. In the power sector, it is assumed that large amounts of investment will be frontloaded to facilitate the construction of critical infrastructure for the transition. These investments peak in the years between 2030 and 2035 and level off as key sectors of the economy are decarbonized.
- The period between 2025 and 2040 covers the expansion of carbon pricing to energy-intensive sectors (from 2025, which raises industry costs) followed by a phaseout of renewables subsidies (from 2030, which especially affects capital-intensive technologies). Both lead to a temporary reduction in investment while markets adjust to the implied change in technology costs. This is the period in which the GDP impact fluctuates and varies between scenarios the most, with peaks and troughs in different years, which result from interactions between different rates and sectoral coverage of carbon pricing and the introduction or absence of new policies (such as the no new coal regulation).
- After 2040, energy efficiency investment continues to increase as low-cost measures have been taken advantage of, but overall investment slows down as most major infrastructures are in place and costs of renewables decrease due to learning-by-doing effects. The long-term investment impacts also include a reduction in investment in fossil fuel supply that offsets some of the positive impacts from renewables investment.

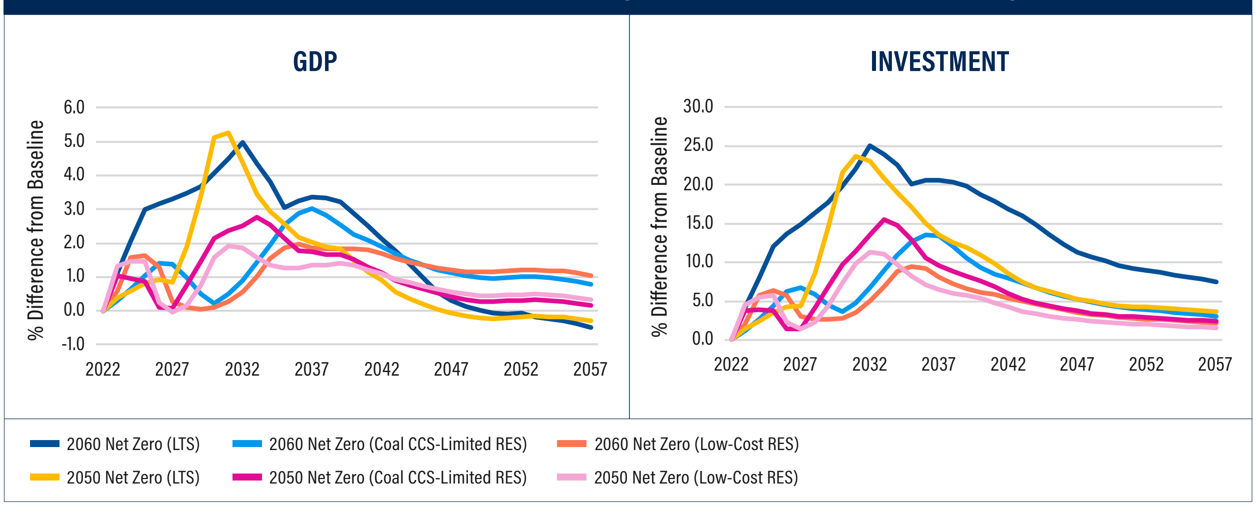
FIGURE 3.6: GDP AND INVESTMENT IMPACTS IN INDONESIA ACROSS SCENARIOS (% DIFFERENCE FROM BASELINE)



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

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 that 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. Because of the role of the power sector in driving investment, the GDP impact profiles are also sensitive to the power technology mix (see Figure 3.7): the higher the share of low-cost renewables, the lower the peak of GDP impacts (because of lower investment requirements that are a direct stimulus to GDP) but the more positive the long-term GDP impacts (because of the less negative impacts on household consumption in response to implied changes to energy prices, which will be discussed in more detail in the rest of this chapter).

FIGURE 3.7: GDP AND INVESTMENT IMPACTS IN INDONESIA ACROSS SCENARIOS WITH DIFFERENT POWER MIXES (% DIFFERENCE FROM BASELINE)



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

Investment requirements for a *2060 net zero* transition in Indonesia are estimated at more than $5trn from 2022 to 2060 compared to baseline to peak at almost 24 percent above baseline levels around 2032. In comparison, to reach net zero emissions by 2050 will require investment of $3trn above the baseline over the same 2022–2060 period (or $2trn less than the *2060 net zero* scenario). The cumulative investment requirement is lower in the more ambitious *2050 net zero* scenario because of more rapid cost reductions, which are driven by a stronger uptake of low-cost renewables in the short and medium terms (forced by the no new coal policy and incentivized by higher rates of carbon pricing that make fossil fuel–based generation more costly).

Given that costs of renewables in Indonesia are competitive with fossil fuels but still higher than in many countries in the region that have already undergone the initial transformation of the energy system (IEA 2022c), such as China and India where wind and solar have been widely deployed in recent years (accounting for around 25 percent of total power capacity in 2022 compared to less than 1 percent in Indonesia), Indonesia can benefit from larger relative cost reductions as it increases renewable uptake and moves up the learning curve. In addition, in the *2050 net zero* scenario, the introduction of the no new coal policy leads to Indonesia achieving a higher share of variable renewables in the power sector sooner due to their existing cost competitiveness and recent market reforms. This reduces the need to invest in other, more capital-intensive technologies (including CCS, biomass, hydro, and geothermal) especially after carbon neutrality is achieved, in comparison with the *2060 net zero* scenario where a substantial amount of investment in these technologies is still required beyond 2050 because of a slower speed of decarbonization and cost reductions. The long-term projected reduction in investment needs in Indonesia in the *2050 net zero* scenario compared to the *2060 net zero* scenario is consistent with modeling results by IEA (2022c). Meanwhile, the finding that cumulative investment requirements are lower for a more ambitious scenario is uncommon among the literature but not without precedent. For example, analysis by Asia Investor Group on Climate Change (2021) of 2°C and 1.5°C scenarios for Japan (another country in the Asia Pacific where installed costs of solar and wind are currently higher than in China and India according to IRENA (2019) shows that under certain assumptions about market and policy conditions, a higher level of decarbonization ambition may have lower financing requirements.

The *2050 net zero* investment requirement between now and 2050 equates to $2.4trn, higher than modeling estimates by IESR (2022a) of a *2050 net zero* scenario with coal phaseout by 2045 and a renewables-based energy system across sectors at $1.2trn. The difference is mainly attributable to the high capital requirement of fossil fuels with CCS and biomass that plays a larger role in the LTS-inspired E3ME scenario (whereas the IESR scenario features a slightly higher share of solar PV, which is less expensive to install). The investment need in the coal CCS-limited RES and low-cost RES variants of this scenario (where solar shares are more comparable to IESR's estimate), at $1.6trn and $1.2trn, respectively, over 2022–2050, is therefore more in line with the IESR outcomes.

Modeling by the IEA (2022c) in collaboration with the Indonesian government also explores a set of *2060 net zero* energy-related emissions and *2050 net zero* (with unabated coal phaseout by 2040) scenarios. Although the IEA report only presents annual average investment needs for selected periods until 2050, it is estimated that the magnitude of total investment in the IEA's *2050 net zero* scenario is within the range of $2–$3trn over 2022–2050, similar to the E3ME estimates. According to the IEA, investment needs for achieving net zero by 2060 are lower than those for the *2050 net zero* scenario (up to 2050), in contrast with the E3ME modeling. This difference is mainly due to the profile of investment: in the *2050 net zero* scenario, both models project frontloaded investment (with annual investment reducing over time). In its *2060 net zero* scenario, the IEA projects a continued increase in annual investment over time (doubling between 2030 and 2050); E3ME again assumes investment to be frontloaded as in the *2050 net zero* scenario. The two approaches (an energy system model and a macroeconomic model with energy linkages) are fundamentally different and represent different pathways to achieve net zero by 2060, with investments required sooner in E3ME (but also with associated economic and environmental benefits).

However, consumers bear the cost of the transition

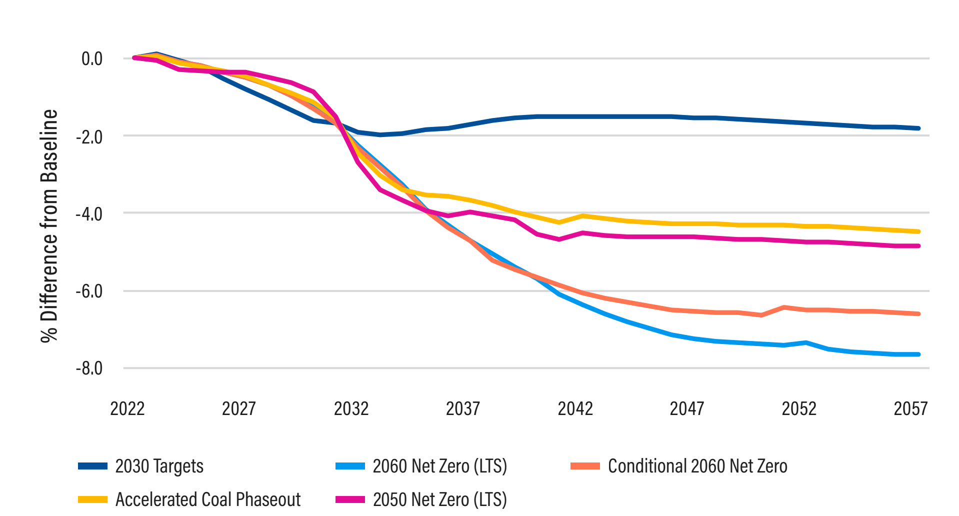
In the years between 2050 and 2060, despite a positive boost from investment, GDP impacts in the *2030 targets* scenario are similar to the impact in the 2040–2050 period, whereas in all other scenarios with higher ambitions, there is a gradual return of GDP to baseline levels and a mild reduction from baseline (at between 0.2 percent and 0.7 percent) by 2060. This is mainly driven by the impact on household consumption, which is strongly negative due to high energy prices and inflation (mainly as a result of switching away from heavily subsidized coal power to imposing carbon pricing and promoting renewables). This consumption effect is a second-order effect that results from economic feedbacks of the initial investment circulating through the economy and therefore takes longer to materialize.

Additional investment represents an economic stimulus but requires funding, which is also a cost to the economy. The modeling assumes that costs of additional investments and policy implementation are funded domestically by the government (through reinvestment of avoided coal power subsidies, carbon pricing, and other tax-raising measures) or by private industries (through increased borrowing), except when international support is available. Privately funded investments and higher industry and energy costs due to carbon pricing (as a result of a high share of fossil fuels in the energy mix) are passed on to consumers in the form of higher product prices, which reduce purchasing power. Investments and policy costs funded by government that are not covered by carbon revenues, reinvested coal power subsidies, or international support are assumed to be funded via additional taxes, directly increasing the tax burden on households and reducing disposable income.

Despite assuming that financial support is available from the international community and coal power subsidies are mobilized to aid the transition, the impacts of both lower purchasing power and a higher tax burden outweigh the positive impact on nominal income associated with a higher level of investment relative to baseline. 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. This leads consumers to reduce their spending throughout the forecast period, although the relative impacts level off after 2050 due to lower annual investment requirements. This reduction in household consumption is equivalent to $189bn (7.6 percent below baseline) by 2060 in the *2060 net zero* scenario and smaller at $122bn (5 percent below baseline) in the *2050 net zero* scenario due to additional funding from avoided coal power subsidies as a result of stronger coal phaseout regulation (see Figure 3.8).

These effects impact low-income households most significantly. As such, shifting (some of) the cost burden away from consumers through other funding mechanisms would help mitigate the risk of pushing vulnerable households into poverty. International support is not only important for Indonesia reaching net zero but also for maintaining the country's economic and social development goals, including tackling poverty and improving energy access for the population.

FIGURE 3.8: HOUSEHOLD CONSUMPTION IMPACTS ACROSS SCENARIOS IN INDONESIA (% DIFFERENCE FROM BASELINE)



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

While international support does not strongly influence the investment requirements or the direction of impacts on household consumption (which is also strongly driven by the mix of technologies being deployed, discussed in detail in section 3.4), its presence does relieve some of the negative impacts. There is a similar case for reinvestment of avoided coal power subsidies to compensate stranded asset holders when coal phaseout regulation is introduced (which on its own would be a costly policy for the government). Other examples of policies that help mitigate the impacts on households include direct and indirect government support for low-income households, repurposing support for other fossil fuels (which would likely see a reduction in demand due to carbon pricing), and other tax-raising mechanisms.

The investment and consumption impacts are reinforced by a long-term improvement to the trade balance

In addition to the contribution to GDP from investment and household consumption, other impacts come from Indonesia's trade balance. In the short and medium terms, the trade balance deteriorates, due to increased domestic demand for machinery and equipment to support renewables deployment within a short amount of time, which leads to a reduction in exports to meet domestic priorities.

Over time, however, as additional investment strengthens domestic capacity to produce these products, and most of the infrastructure has been put in place, this pressure is reduced. At the same time, there is a noticeable improvement from reduced dependency on imported fossil fuels as part of the transition, which leads to a net improvement from baseline by 2060. This improvement is estimated at $48bn in 2060 in the *2060 net zero* and slightly larger at $50bn in the *2050 net zero* scenario, compared to baseline (around 1 percent of GDP).

Improved energy security through lowering import dependency and replacing it with domestically produced renewable energy help maintain an energy supply that is safe from global fossil fuel supply disruptions for the population, especially households at risk of fuel poverty. Manufactured fuel imports into Indonesia are projected to fall by just over 65 percent compared to baseline by 2060 in the *2060 net zero* and *2050 net zero* scenarios, whereas coal imports are 40 percent and 50 percent lower than baseline, respectively, in these scenarios. Even when net zero emissions are achieved, the modeling does not assume the creation of low-carbon–heavy industries to replace industries that traditionally use and import large volumes of fossil fuels (such as steel, chemicals, and cement). Some minimum levels of fossil fuel imports may still be required for those preexisting sectors to operate (their emissions are in turn offset by CCS).

In the least ambitious scenario with 2030 targets and no net zero target (*2030 targets*), there is, however, a deterioration of the trade balance throughout the forecast due to a combination of two factors. First, similar to other scenarios, this scenario faces a short-term shortage of transition-related manufactured goods, causing exports to be diverted to meet the needs of infrastructure investments. Second, imports of fossil fuels rebound after 2030 when the initially strong impact of carbon pricing and renewables subsidies in the power sector wears off and is not reinforced by additional policies to sustain investor behaviors, leading to power companies reverting to coal and gas.

In summary, the direction of the trade impact changes over time (negative in the medium term, positive in the long term) with changes in domestic demand for non-energy and energy trade. Therefore, the trade balance impact offsets some of the positive GDP impact (from investment) in the medium term and offsets some of the negative GDP impact (from household consumption) in the long term.

This analysis does not assess or make assumptions about the trade and supply chain impacts of DMOs for coal producers to cap exports and supply domestic power plants at below market prices. While it is unlikely to impact the technological transition to a visible extent (as it mainly impacts coal producers), accounting for this would exaggerate the worsened trade balance in the medium term as described above because there would be a reduction in coal exports by Indonesian producers. Nonetheless, the impacts are likely small when there is a global reduction demand in coal in all scenarios, and coal is also rapidly phased out of the power system due to the no new coal policy (in the *accelerated coal phaseout* and *2050 net zero* scenarios).

In addition, Indonesia has the potential to create a large-scale low-carbon industry to replace the existing fossil fuel supply, 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 Indonesia to produce and export green steel rather than importing it or using coal for traditional steelmaking), the impacts on the net trade balance would be more strongly positive.

Employment impacts

The employment impacts are smaller in magnitude compared to the GDP impacts, as greater efficiency leads to increases in average wage rates from additional investment. The impact, in percentage terms, is that employment gains are smaller than those seen in output. Similar to GDP, these results are sensitive to the power mix, which is discussed in more detail later in this section.

There are substantial job gains from decarbonization, with winners and losers

In the *2050 net zero* scenario, the impact is initially positive, peaking at 1.0 percent (1.7 million jobs) above baseline by 2030, due to the investment boost; however, over time this is outweighed by a large loss of jobs in fossil fuel supply and agriculture. In this scenario, the negative employment impact by 2060 equates to 0.4 percent below baseline (a loss of 810,000 jobs across the whole economy). The *accelerated coal phaseout* scenario also follows this pattern.

In the *2030 targets* and *conditional 2060 net zero* scenarios, there are 245,000 and 250,000 additional jobs, respectively, by 2050 compared to baseline. Nonetheless, by 2060 the net employment impact also moves in the same direction as the *2050 net zero* scenario, resulting in a loss of around 120,000 jobs.

The employment impact is positive for all years in the *2060 net zero* scenario, reaching 1.1 percent (2 million jobs) above baseline by 2039 before returning to baseline levels by 2060. The reason this scenario is markedly different from the others is twofold. This scenario sees lower costs of compensation for stranded assets and fewer fossil fuel supply job losses due to the long timeline for phasing out unabated coal (by 2056), at the same time benefiting from a high level of investment (almost comparable to that in more ambitious *accelerated coal phaseout* and *2050 net zero* scenarios), leading to a more gradual transition with smaller peaks and troughs in the net employment impacts.

Compared to the *2060 net zero* scenario, the *conditional 2060 net zero* scenario includes international support and a more ambitious 2030 emissions reduction target. The employment impact is less positive by 2050 in the *conditional 2060 net zero* scenario for the following reasons:

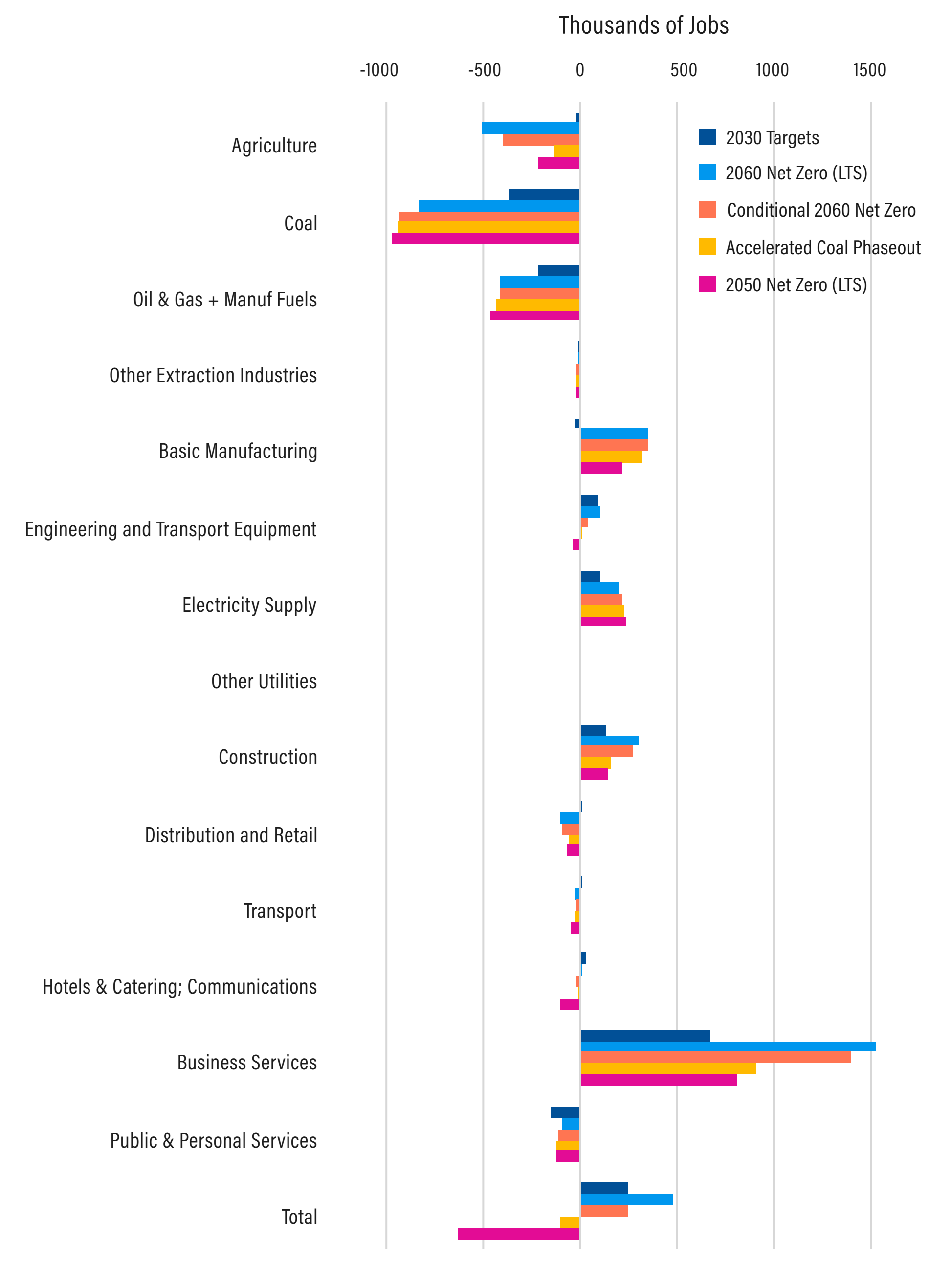
- By design, higher carbon pricing is imposed to induce stronger emissions reductions by 2030, leading to faster switching away from fossil fuels and larger job losses in these sectors by 2050.
- There is a higher level of investment across the economy as a result of a more rapid transition, which contributes to the capital stock and boosts productivity, meaning that the same increase in demand is fulfilled by fewer additional jobs (at a higher wage).
- The presence of international support relieves the cost burden of investment on consumers. Therefore, compared to the scenario without international support, the level of household consumption is higher particularly for categories that are typically considered nonessentials and tend to have higher income elasticities (such as real estate, holidays and personal services such as phones/broadband, education, legal/financial services, etc.). This demand is mainly met by business service sectors, which reinforces the productivity effect mentioned above in those sectors.

Figure 3.9 shows the sectoral breakdown of the overall employment impact in 2050, when most of the transformational changes have taken place.

The most substantial job losses are in the fossil fuel supply sectors (coal and oil & gas) due to the transition to renewables. Social protection policies as well as programs to support education, training, and improved job search are needed to minimize disruption and help workers transition into new jobs created in the low-carbon economy.

The job losses in fossil sectors are followed by milder negative impacts in agriculture, driven by lower levels of consumer spending (considering that foods, the main products of this sector, make up around half of Indonesian households' budgets (DBS Bank 2019), which could be mitigated and potentially reversed by measures such as more international financial support than modeled. The modeling does not take into account policy measures to reduce land-use emissions, create natural carbon sink potentials, or improve farming practices to reduce non-CO_2 greenhouse gas emissions such as methane, which make up a significant share of emissions in Indonesia. These measures could impact agricultural employment in either direction if accounted for, depending on implementation.

FIGURE 3.9: EMPLOYMENT IMPACT BY SECTOR IN 2050 IN INDONESIA ACROSS SCENARIOS



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

All other sectors, however, provide new job opportunities. Most notable are substantial gains in sectors that form the supply chain of the technology transition, including construction (responsible for infrastructure developments), manufacturing (suppliers of machinery, equipment, and manufactured materials), and business services (supporting most other sectors that benefit from investment). The increase in jobs in business services is particularly large because of job opportunities in engineering, IT, and scientific research to drive innovation and infrastructural developments, as well as banking, insurance, and legal services to support legislation and mobilize finances for investment. The estimated increase in jobs excludes future job opportunities that may arise from a low-carbon industry with export competitiveness potentially being developed in Indonesia to replace its fossil fuel specialization, which is likely to benefit manufacturing industries the most.

An increase in employment in the electricity supply sector also occurs for a number of reasons: (1) there is more demand for electricity and therefore more generation in the transition; (2) renewable energy technologies are more labor intensive per unit of capacity than conventional generation; and (3) the load factor of renewables is (mostly) lower than in conventional generation, so the labor intensity per unit of generation increases more than that per unit of capacity.

The employment impact by 2050 in the *2050 net zero* scenario (a net job loss) contrasts with estimates by IESR (2021) which suggest an increase of more than 3 million jobs by 2030 linked to achieving 100 percent renewable energy by 2045. The main reason is that the E3ME figure represents economy-wide impacts (including substantial negative impacts on fossil fuel supply sectors that offset the positive impacts of shifting to renewables), whereas the IESR estimate focuses only on direct jobs in the power sector and does not affect fossil fuel supply jobs.

All scenarios imply a redistribution of job opportunities in the workforce in Indonesia. By 2060, more than 1 million jobs are lost in primary and fossil fuel sectors, which are partly compensated for by opportunities created in industry and services sectors. Despite this, further investment is needed (not modeled in these scenarios) to reskill displaced workers as well as to upskill and train the future workforce to be able to access and take advantage of these opportunities, so that the impact of large-scale labor market restructuring on social welfare is mitigated. The modeling also does not include potential new job opportunities arising from the creation of low-carbon industries in Indonesia to replace fossil fuel supply, which would make the overall employment impacts more positive.

Power sector sensitivities

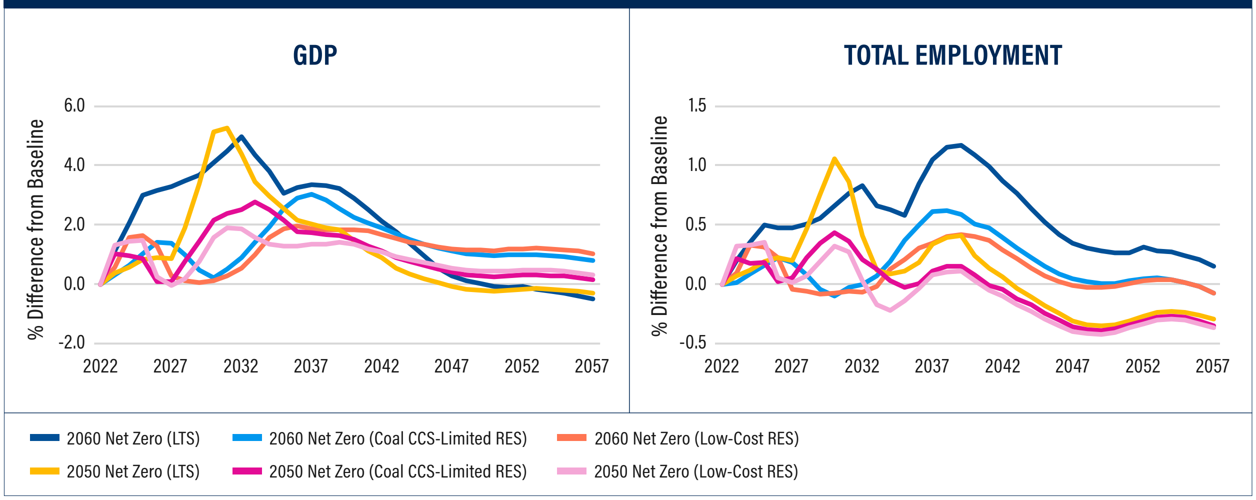
GDP and employment impacts in the power sector sensitivities are presented in Figure 3.10 for the *2060 net zero* and *2050 net zero* scenarios.

For GDP in both scenarios, the net GDP impact is most positive in the long term in the low-cost RES variant and most positive in the medium term in the LTS variant. The lower cost of deploying renewables and especially solar PV rather than fossil fuels with CCS (which are initially capital intensive and then are subject to high rates of carbon pricing[12]) is the main explanation for this. The lower the cost, the lower the rate of inflation and the less burden is placed on consumers – therefore, the large reduction in household consumption observed in the LTS-inspired pathway. This is also accompanied by lower investment requirements as noted above, which are reflected in the lower peak of GDP impacts in the medium term in the coal CCS-limited RES and low-cost RES variants, compared to the LTS variant.

12 It is assumed that 10 percent of emissions are not captured.

For employment, the impact of power mix variations is more dynamic. The lower cost of investment with more focus on renewables and solar PV in particular (rather than CCS) in the power sector leads to less positive net employment outcomes, which are visible in the *2060 net zero* scenario but much less so in the *2050 net zero* scenario. The main explanation for this is the smaller jobs impacts from a lower level of investment. Investment tends to have a larger employment multiplier than household consumption due to more self-reinforcing effects at play (supply chain and induced effects), as such the reduction in employment due to investment effects is likely to outweigh an increase in employment due to improved household consumption outcomes, relative to the LTS-inspired reference. This phenomenon again highlights the trade-off between macroeconomic benefits (in GDP, investment, and employment terms) and social welfare (how the cost of transition is distributed).

FIGURE 3.10: IMPACT OF POWER MIX VARIATIONS ON GDP AND EMPLOYMENT IMPACTS IN THE NET ZERO SCENARIOS IN INDONESIA



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

POLICY COSTS, SAVINGS, AND WIDER BENEFITS

Policy costs and savings

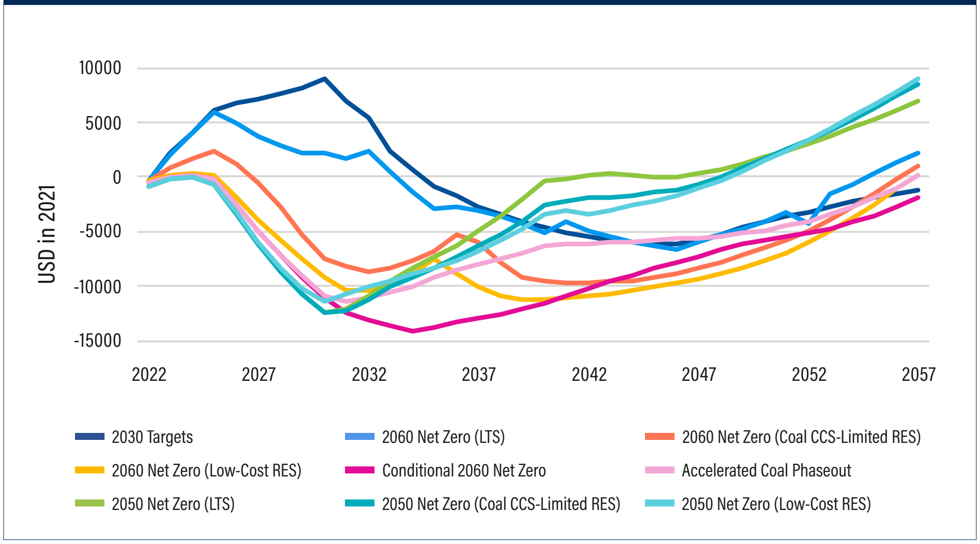
The previous sections showed that decarbonization has high positive short- and medium-term impacts on GDP and employment, which return close to baseline levels toward the end of the time frame. However, costs and savings arise from more ambitious policies that accompany these macro impacts.

Figure 3.11 presents net policy costs across all scenarios and sensitivities. Net policy costs are defined as the difference between the government's revenues from policies (namely, carbon pricing and fuel duties) and costs of policy implementation (including subsidies for renewables and low-carbon technologies, investment in energy efficiency, and compensation for stranded assets due to coal phaseout regulation in the power sector). Positive net policy costs indicate an increase in government deficits that is passed on to households in the form of higher taxes (this effect is responsible for the lower household consumption in the long run described in section 3.3), and vice versa. These policy costs exclude those financed by international financial support (for renewables subsidies and compensation for coal stranded assets) and reinvestment of avoided coal power subsidies into green initiatives (such as subsidizing low-carbon technologies).

Renewables subsidies and stranded asset compensation add to cost, whereas carbon pricing can generate revenues for decarbonization

As can be seen, the costs are the highest for the *2030 targets* scenario and remain positive through the 2030s. In this scenario, the cap-and-trade system only covers the power sector, with no reinvestment of coal power subsidies, both of which mean lower revenues than other pathways to fund decarbonization policies. The *LTS 2060 net zero* scenario, and to a smaller extent the coal CCS-limited RES variant of that scenario, also has positive net policy costs initially. Both of these scenarios feature large amounts of investment in hydropower and geothermal, which are assumed to be subsidized by the government and push up policy costs. While the subsidy rates are the same percentage of the investment cost, additional hydro and geothermal capacities mean a higher cost in the LTS variant than in the coal CCS-limited RES variant of the *2060 net zero* scenario.

FIGURE 3.11: NET POLICY COSTS OF DECARBONIZING THE INDONESIAN ECONOMY



Note: Policy costs exclude those funded by international support and reinvestment of avoided coal power subsidies.
Source(s): Cambridge Econometrics, E3ME modeling result.

Net policy costs reduce substantially after 2025, are negative, and reach their lowest value by the early 2030s in most scenarios. Negative net policy costs mean government surplus from the implemented policies. This is caused by carbon revenues from the power sector and energy-intense industries, which given the high coal share in the Indonesian power mix are substantial. Reinvested coal power subsidies provide additional funding for decarbonization, which also lowers the net policy costs.

After the 2030s, net policy costs rise steadily, reaching high positive values for the *2050 net zero* pathways and staying closer to zero for the rest of the scenarios. Note that decarbonization costs tend to increase over time for various reasons:

- First, the least expensive emissions reduction options tend to be adopted first; in later years, it is more expensive to decarbonize the remaining emissions from hard-to-abate sectors. The low rate of deployment of high-cost options also leads to slower future cost reductions, making them still more expensive than cost-competitive options that are currently available.

- Second, carbon revenues are falling with decreasing emissions in the economy, which further increases the net costs of decarbonization to the government. Growth in carbon pricing is far outweighed by emissions reductions that take place more rapidly because of stronger policy intervention, causing overall carbon revenues to fall rapidly, especially after 2040. This means the government would need to leverage alternative financing measures in the long term to fund investments, such as international support and repurposing of coal power subsidies.
- Additionally, in the net zero pathways, most of the early coal power plant closures fall to the second half of the time frame (over 2030–2040 in the most ambitious *2050 net zero* and *accelerated coal phaseout* scenarios, and over 2040–2060 for the *2060 net zero* scenario). The cost of compensation for the early closure of coal plants due to the unabated phaseout regulation makes this policy an effective but expensive tool.

Policy costs are higher in more ambitious scenarios; however, some can be financed by international support and reinvestment of avoided coal power subsidies

Accumulated over the whole forecast period, net policy savings occur in all scenarios; savings are smaller in more ambitious scenarios and only realized with the help of international support and removal of subsidies for coal power generation (see Table 3.2). The main costs contributing to this are renewable subsidies[13] and stranded asset compensation in the short to medium term, and energy efficiency investments in the long term.

The standard ambition scenarios see larger savings mainly as a result of carbon revenues and lower costs of investment and policy implementation, which are redistributed to households via tax reductions to mitigate social impacts of the transition.

In the *accelerated coal phaseout* and *2050 net zero* scenarios, the availability of international financial support and freed-up coal power subsidies can potentially more than offset all costs accrued to the government (however they are financed) and neutralize pressure on government budgets. Ultimately, this helps shield consumers to some extent from deficit-induced tax increases and higher prices, which are responsible for the negative consumption impacts described in section 3.3.

Reinvestment of avoided coal power subsidies plays a similar role by providing additional revenues for the government to achieve decarbonization ambitions and limiting cost burdens to consumers. The estimated number of avoided subsidies is sufficient to cover net costs to the Indonesian government, even if international funding were unavailable in some of the scenarios with overall net costs of policy implementation (*accelerated coal phaseout* and the low-cost RES variant of the *2050 net zero* scenario).

In particular, the repurpose of coal power subsidies can offset the high cost of compensation for coal stranded assets that results from the coal phaseout, which is estimated to be $36–$51bn over 2022–2050 in the most ambitious *2050 net zero* scenarios. This compares to $37bn estimated by TransitionZero (2022) for buying out long-term power purchase agreements to enable a similar coal phase down and 2040 phaseout in Indonesia. Although TransitionZero's methodology has broader coverage (including capital costs, operating costs, and profit margins, compared to E3ME, which only accounts for capital investment), it assumes compensation for only up to 10 years, whereas E3ME assumes compensation for a plant's remaining lifetime (up to 40 years)

13 These subsidies are set in proportion to investment requirements, so absolute subsidy values are higher in the ***2050 net zero*** scenario with more investment than in the ***2060 net zero*** scenario, even though the subsidy rates are unchanged between scenarios.

at the point of closure, leading to the E3ME estimate being less conservative overall. Both studies suggest a higher cost than the modeling by IESR (2022a), which puts the estimate at around $20bn. The IESR approach is closer to that of E3ME; however, it assumes a shorter lifetime of 30 years and a more gradual phaseout by 2045, which explain the smaller total cost figure.

TABLE 3.2: NET POLICY COSTS AND FUNDING OPTIONS

	TOTAL NET POLICY COSTS (2022-2060)	INTERNATIONAL SUPPORT (2022-2060)	AVOIDED COAL POWER SUBSIDIES (2022-2060)	POLICY COSTS TO BE FINANCED BY THE GOVERNMENT (2022-2060)
				$2021bn
2030 targets	–25	-	-	–25
2060 net zero (LTS)	–16	-	32	–48
2060 net zero (coal CCS-limited RES)	–156	-	35	–191
2060 net zero (low-cost RES)	–214	-	36	–250
Conditional 2060 net zero	–27	212	35	–274
Accelerated coal phaseout	25	175	40	–190
2050 net zero (LTS)	131	136	41	–46
2050 net zero (coal CCS-limited RES)	79	95	42	–58
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.

Energy costs and savings

The household bill and economy-wide energy spending change due to both demand and price impacts. All decarbonization pathways show an overall reduction in energy demand (and energy spending in real terms) that results from energy efficiency improvements and technological transformations. This is consistent with findings by IEA (2022c). On the other hand, per unit energy prices and especially electricity prices increase. Figure 3.12 shows the net impact of the demand and price effects for households. For some of the scenarios, the price increase outweighs the real demand reductions, leading to higher nominal spending on energy.

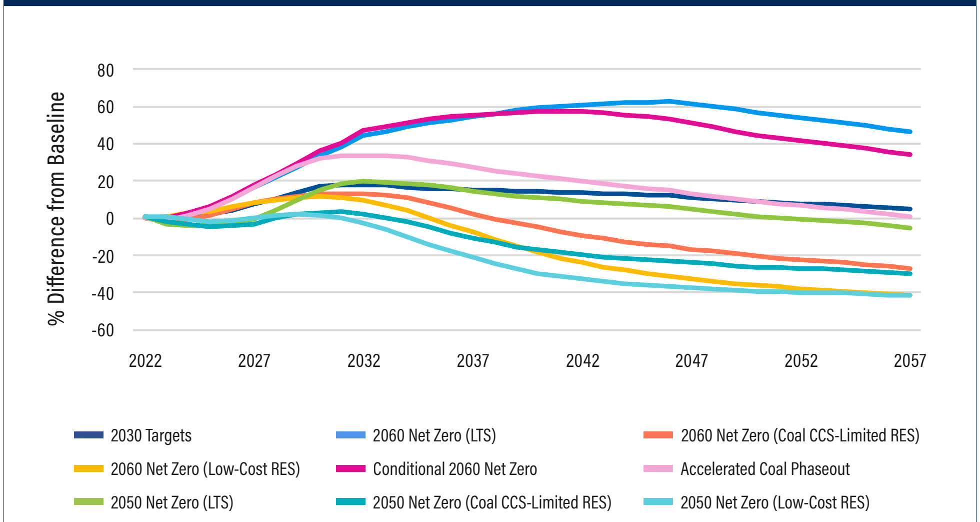
The power generation mix has a major impact on energy prices

Nominal household spending on energy is higher than baseline in scenarios with the highest price increase and below baseline values in the lower price increase pathways. Consumers spend more on energy under the

LTS-inspired pathways and less in the coal CCS-limited RES and low-cost RES variants. Extreme price hikes hurt their welfare especially for those with lower earnings who are likely to spend more of their incomes on energy. Even in scenarios with strong energy savings (in volumes), more electrification means higher exposure to electricity price fluctuations.

Across scenarios, electricity prices grow substantially by 30 percent–200 percent above baseline levels, with most of the increase happening in the short run until 2030. The current coal-based generation is heavily subsidized and switching to cleaner technologies will mean more costly generation. The long-run increase is highest in the *LTS 2060 net zero* scenario and lowest in the low-cost RES variant of the same scenario. The LTS-inspired power generation mix is especially expensive, as it relies on coal CCS (which is subject to carbon pricing) and hydropower and geothermal technologies (which have high capital costs). In the coal CCS-limited RES and low-cost RES variants of this scenario, the impact on electricity prices is much milder due to the larger share of solar PV that is already cost competitive. The *2050 net zero* power mix also results in lower electricity price increases than the *2060 net zero* mix, as it relies on solar generation to achieve the ambitious decarbonization targets.

FIGURE 3.12: HOUSEHOLD ENERGY SPENDING IMPACTS ACROSS SCENARIOS FOR INDONESIA (% DIFFERENCE FROM BASELINE)



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

The observed electricity price increase (even in the low-cost RES scenario variants where it is smallest) contrasts with findings by IESR (2021) for a long-term reduction in electricity generation costs compared to baseline, despite both studies showing an increase from baseline in the medium term. This is likely attributable to methodological differences in the composition and computation of the levelized cost of electricity, as well as model differences. The key difference is that IESR estimates assume a high GHG emissions cost imposed on the fossil fuel–based system in their baseline (which is not included in the E3ME modeling), whereas E3ME incorporates additional costs of storage and backup generation (due to the intermittency of variable renewables) for a renewables-based system. In addition, IESR's levelized cost analysis uses the annuity method that divides the total cost during a power plant's lifetime (which for some plants would extend beyond the forecast period) by its total electricity generation (IESR 2019), whereas E3ME simulates the levelized costs based on the cost and electricity generation in each year. It is noted, however, that the electricity price increase does slowly reduce after the most investment-intensive period (between now and 2030). This is largely the result of fossil fuels being phased out of the system (as a result of carbon pricing and coal regulation) and renewables benefiting from learning-by-doing cost reductions (as a result of subsidies to promote their uptake).

The modeling is likely to illustrate a potential worst-case scenario in which an increase in costs to generators are passed on directly to consumers (i.e., they keep profit margins unaffected), therefore excluding the potential effect of mitigating policies (such as price caps and market reforms) aimed at closing the gap between wholesale and retail prices to utilize clean domestic electricity without hurting consumers. Nevertheless, it is critical that policies aimed at the power sector are well informed of potential social impacts of deploying certain technologies.

Wider benefits

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

While Indonesia is not among the most significant emitters in the world to drive global emissions, it is still among the top 10 contributors whose progress toward carbon neutrality contributes to the global challenge of limiting climate change. Table 3.3 shows the estimated global temperature change[14] by 2100 associated with each scenario, with the most ambitious *accelerated coal phaseout* and *2050 net zero* scenarios assuming that Indonesia's climate action is matched by similar levels of ambition in the rest of the world.

TABLE 3.3: ESTIMATED GLOBAL TEMPERATURE CHANGE ACROSS SCENARIOS

SCENARIO	GLOBAL TEMPERATURE CHANGE BY 2100
Baseline	3.4°C
2030 targets	1.7°C
Unconditional 2060 net zero pathways	1.6°C
Conditional 2060 net zero	1.6°C
Accelerated coal phaseout	1.6°C
2050 net zero pathways	1.5°C

Delayed or insufficient climate action risks additional damage to economic growth, due to the disruption from global warming, causing extreme weather events and lost productivity and livelihoods. These physical

14 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).

risks are widely discussed in the literature, where application of Integrated Assessment Models (IAMs) and econometric analysis has previously been used to estimate the impact of climate change on future economic growth.

The literature reflects 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 baseline) would harm global GDP by 25 percent, whereas a 1.5°C pathway would lead to an 11 percent reduction in global GDP by 2100. Indonesia would bear higher damages compared to the global average through its already warm climate and long coastline that may suffer from rising sea levels. Asian Development Bank (2015) shows that under different policy assumptions, GDP damages faced by Indonesia in scenarios where carbon concentration reaches a level typically associated with 2°–3°C (according to IPCC (2019)) would be larger in percentage terms than for the world as a whole and in some cases larger than the Southeast Asian average.

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

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), and 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 regulation of the use of coal for power generation (because they send reinforcing signals), despite generating additional revenues for the government. On the other hand, coal power regulation alone (particularly an accelerated phaseout) may generate high costs of compensation to the power sector for stranded assets and an excess supply of coal, making it less expensive 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. The policies related to coal power are of particular relevance in Indonesia given its domestic market obligations for coal producers to prioritize domestic demand over exports (which would make a case when a reduction in coal prices and a surge in coal use outside of the power sector, as a result of coal power regulation) much more likely. In addition, as the modeling shows, using avoided coal power subsidies (which are substantial in Indonesia) to pay for stranded asset compensation caused by coal phaseout regulation would also improve the socioeconomic outcomes compared to a case 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 trade-offs.

Additionally, the modeled scenarios illustrate that the Indonesian emissions and renewables share targets set in the NDC, 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 that need to be factored into policy decisions aimed at promoting specific technologies.

In summary, for Indonesia to reach net zero emissions by 2060 and potentially earlier by 2050, the most important recommendation is a balanced policy mix (combining enforced regulation and market-based enablers) covering all sectors, with a particular focus on carbon pricing, unabated coal regulation, and market reforms to promote cost-competitive renewables in the power sector, in particular, the following recommendations:

- Implementation of **carbon pricing** across the economy, starting with the power sector in 2022 and other energy-intensive sectors in 2025, to encourage electrification and innovation in low-carbon solutions.
- **Recycling of carbon revenues and the reinvestment of avoided coal power subsidies** 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 uptake of 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 3.4: KEY POLICY RECOMMENDATIONS

	SECTORS WITH MOST IMPACT	PERIOD WITH MOST IMPACT	OPPORTUNITIES	CONSTRAINTS OR TRADE-OFFS	COMPLEMENTARY POLICIES INCLUDED IN THE MODELING	COMPLEMENTARY POLICIES NOT INCLUDED IN THE MODELING
Carbon pricing from 2022 for the power sector, 2025 for other 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, or otherwise kick-start, for 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., the housing stock, production processes) at least in the short term	Carbon pricing, revenue recycling, the reinvestment of avoided coal power subsidies	-
No new coal regulation from 2023 and the reinvestment of avoided coal power subsidies	Power generation	Short and medium term (especially before 2030)	Most effective at reducing emissions in the short and medium terms 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, the reinvestment of avoided coal power subsidies	-
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

TABLE 3.4: KEY POLICY RECOMMENDATIONS						
	SECTORS WITH MOST IMPACT	**PERIOD WITH MOST IMPACT**	**OPPORTUNITIES**	**CONSTRAINTS OR TRADE-OFFS**	**COMPLEMENTARY POLICIES INCLUDED IN THE MODELING**	**COMPLEMENTARY POLICIES NOT INCLUDED IN THE MODELING**
Biofuel mandates	Transport (especially freight road transport and 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	-
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, the reinvestment of avoided coal power subsidies, 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, which can be substantial with international support and the reinvestment of coal power subsidies	Short to long term	Allows carbon revenues and avoided coal power subsidies to be earmarked for low-carbon measures	Impacts households negatively if there is a large investment requirement and no international support or reinvestment of coal power subsidies	Carbon pricing, the reinvestment of avoided coal power subsidies	Alternative funding mechanisms for low-carbon investments

CONCLUSIONS

SOCIOECONOMIC AND CLIMATE IMPACTS

Our modeling shows that Indonesia has already achieved significant progress toward its current 2030 commitments with policies implemented to date and is well placed to increase its ambition for 2030 (well beyond the recent incremental update to its NDCs in 2022) and its aim toward carbon neutrality by as soon as 2050. There is a strong case for cohesive global action to reach global net zero before 2050 and limit warming to 1.5°C by the end of the century. The adverse effects on ecosystems and human lives, already evident from a temperature increase so far of 1°C compared to preindustrial levels, will be vast and unevenly distributed, with tropical and developing countries such as Indonesia at higher risk.

Utilizing all viable policy options, especially in the power sector, and increasing these ambitions can lead to CO_2 emissions peaking this decade in Indonesia and declining consistently thereafter toward net zero by 2050. Such a transition will be driven by rapid decarbonization of the whole energy system and economy, in particular moving away from fossil fuels to renewable electricity generation, increased electrification, as well as the promotion of electric vehicles for road transport and low-carbon technologies and alternative fuels in other sectors.

The modeling shows that increasing climate ambition and actions has the potential to generate noticeable macroeconomic benefits in GDP and employment terms for the Indonesian economy in the medium term without a substantial compromise on economic growth in the long term (which means the average impacts are overall positive throughout the whole forecast period), despite the country's heavy fossil fuel dependency.

The positive economic impacts are driven by high levels of investment, particularly in the power sector, supported by energy efficiency investments. In addition, the net trade balance improves in the long term due to lower demand for fossil fuel imports. However, Indonesian households are negatively affected through carbon pricing and high costs of investment, leading to higher prices across the economy.

Despite the modest overall impact on employment (relative to the size of the economy) by the end of the forecast period, a significant number of potential job losses in fossil fuel supply industries will occur as a result of the low-carbon transition, which presents a distributional and social challenge for local communities. Government social programs are needed to provide income support and reskilling, so that vulnerable populations can cope with increasing living costs and take advantage of the economic opportunities arising in the low-carbon economy. Such policies and their cost are not modeled in these scenarios.

The low-carbon transition in Indonesia also depends on climate action in other countries. With the rest of the world decarbonizing, the costs of low-carbon technologies will decrease more rapidly, making the transition less expensive. Should Indonesia choose to delay actions 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 countries (which are not quantified in the modeling).

This analysis does not include the costs of inaction (damages due to the impacts of 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 Indonesia will be substantially higher than estimated in this study if avoided climate damages and improved health outcomes are included.

POLICY IMPLICATIONS

The modeling shows that additional and more ambitious policies than the current commitments are needed in Indonesia to deliver long-term emissions targets and align with 1.5°C temperature goals.

More ambitious decarbonization goals could boost the Indonesian economy in the medium term, powered by a substantial volume of investment. As part of the transition, reducing fossil fuel import dependency means improving the trade balance and ensuring energy security from external disruptions in the long term. However, these benefits come with trade-offs for the population, due to higher prices and many jobs lost in fossil fuel supply.

Nonetheless, the costs and savings from policy implementation vary according to how they complement each other. Overall, a comprehensive package with a mix of regulatory and market-based measures is needed and should be tailored to sector characteristics.

In the power sector in particular, 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 (some of which can be offset by the removal of coal power subsidies). In addition, some of the technology options currently featured in policy discussions are some of the most capital-intensive, which could result in substantial increases in electricity prices and energy costs to both households and industries.

It is critical that cost-competitive technologies are taken advantage of and are in the forefront of policy decisions to minimize this impact, especially as Indonesia is at the early stage of the renewables learning curve compared to some of its counterparts. For example, the modeling shows that market reforms are needed to reduce barriers to entry for solar PV, which has vast potential to power the Indonesian economy without any financial support from the government, at the same time reducing fossil fuel dependency by almost the same extent as a larger policy package that targets existing (more expensive) technologies. In addition, 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 of future renewables cost reductions due to widespread deployment.

While investing in low-cost options would imply major market restructures and displacement of existing jobs that need relocating, it can unlock Indonesia's potential to aim for more ambitious climate goals and transition more rapidly with lower investment requirements and social trade-offs.

To deliver a just transition for vulnerable groups, climate policies need to be well informed of potential social implications and be complemented by additional policies and different financing options. While recycling carbon revenues and phasing out coal power subsidies play an important role as potential funding mechanisms for green investments, international financial support specifically aimed at assisting the low-carbon transition will free up additional domestic finance for development, poverty reduction, and the management of social impacts. Policies to support reskilling and upskilling of the local workforce and protect consumers from energy price impacts will also allow them to take advantage of opportunities that arise in a low-carbon economy without bearing substantial costs to welfare.

APPENDICES

APPENDIX A: REFERENCES

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APPENDIX B: POLICY ASSUMPTIONS

Table 0.1 summarizes the policy assumptions modeled for all scenarios and sensitivities.

TABLE 0.1: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	2030 TARGETS	2060 NET ZERO (LTS-INSPIRED)	2060 NET ZERO (COAL CCS-LIMITED RES)	2060 NET ZERO (LOW-COST RES)	CONDITIONAL 2060 NET ZERO	ACCELERATED COAL PHASE-OUT	2050 NET ZERO (LTS-INSPIRED)	2050 NET ZERO (COAL CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
Economy wide	Emissions reductions target	None	Net zero by 2060	Net zero by 2060	Net zero by 2060	Net zero by 2060	Net zero by 2060	Net zero by 2050	Net zero by 2050	Net zero by 2050
	ETS (energy-intensive sectors)	From 2022 for power sector	From 2022 for power sector, from 2025 for other sectors, with cap in line with net zero target	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero	Same as 2060 net zero	Same as 2060 net zero	Same as 2060 net zero	Same as 2060 net zero	Same as 2060 net zero
	Carbon tax (non-ETS sectors)	None	From 2031 at $3/tCO_2$, increasing to $162/tCO_2$ by 2050 and $205/tCO_2$ by 2060	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired) in real terms (higher in nominal terms)	Same as 2060 net zero (LTS-inspired) in real terms (higher in nominal terms)	From 2031 at $6/tCO_2$, increasing to $207/tCO_2$ by 2050 and constant thereafter in real terms	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)
	Revenue recycling to support low-carbon technologies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Energy efficiency programs (applies to non-ETS sectors)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	International support	No	No	No	No	Yes	Yes	Yes	Yes	Yes
	Reinvestment of coal power subsidies in green investments	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Power sector	New coal capacity regulation	Phase out 9.2GW of coal by 2030	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired), coal with CCS is limited to current levels	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	No new coal construction after 2023	No new coal construction after 2023 (including coal with CCS)	Same as 2050 net zero (LTS-inspired)
	Coal phaseout	None	By 2056	By 2056	By 2056	By 2049	By 2040	By 2040	By 2040	By 2040
	Kick-start	From 2023 to 2030, 0.5GW of solar is added each year	From 2023 to 2030, 0.5GW of solar is added each year; from 2031, 1.5GW of CCS and 1.5GW of BECCS are added each year	**From 2023 to 2030, 1GW of solar is added each year; from 2031, 1.3GW of BECCS are added each year**	From 2023 to 2030, 5GW of solar are added each year; from 2031, 1.5GW of BECCS are added each year	From 2023 to 2030, 1GW of solar is added each year; from 2031 to 2040, 1.5GW of CCS and 1.5GW of BECCS are added each year	From 2023 to 2030, 1GW of solar is added each year; from 2031 to 2040, 1GW of CCS and 2GW of BECCS are added each year	From 2023 to 2025, 0.5GW of solar are added each year; from 2031 to 2040, 1.5GW of CCS and 3.5GW of BECCS are added each year	From 2023 to 2025, 1.5GW of solar are added each year; from 2031 to 2040, 3GW of BECCS are added each year	From 2023 to 2025, 5GW of solar are added each year; from 2031 to 2040, 2.8GW of BECCS are added each year

TABLE 0.1: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	2030 TARGETS	2060 NET ZERO (LTS-INSPIRED)	2060 NET ZERO (COAL CCS-LIMITED RES)	2060 NET ZERO (LOW-COST RES)	CONDITIONAL 2060 NET ZERO	ACCELERATED COAL PHASE-OUT	2050 NET ZERO (LTS-INSPIRED)	2050 NET ZERO (COAL CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
	Subsidies for renewables	Bio-based technologies – 15% over 2023–2030, phased out by 2046; geothermal, hydro – 12.5% over 2023–2030, phased out by 2046; wind – 20% over 2023–2030, phased out by 2046	Same as 2030 targets	Same as 2030 targets	Bio-based technologies – 15% over 2023–2030, phased out by 2046; wind – 20% over 2023–2030, phased out by 2046	Same as 2030 targets	Same as 2030 targets	Same as 2030 targets	Same as 2030 targets	Bio-based technologies – 15% over 2023–2030, phased out by 2046; wind – 20% over 2023–2030, phased out by 2046
Industries	Subsidies for EAF steelmaking	No	From 2023 at 25%, phased out over 2045–2055	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)
	Subsidies for CCS steelmaking	No	No	No	No	No	No	From 2023 at 10%, phased out over 2045–2055	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)
	Subsidies for hydrogen steelmaking	No	From 2023 at 25%, phased out over 2045–2055	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)
Road transport	EV sales target	None	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	No addition	From 2023, an additional vehicle subsidy is applied on EV purchases: 8,860.80 $/veh for economy-class EVs, 13,122.70 $/veh for medium-class EVs, and 16,600 $/veh for luxury-class vehicles; subsidies are phased out over 2025–2030 (assuming price parity is reached this decade)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)
	Fuel duties	No addition	No addition	No addition	No addition	No addition	No addition	From 2023, increased by $0.02/liter, increasing to $0.18/liter by 2045 and constant thereafter	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)

TABLE 0.1: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	2030 TARGETS	2060 NET ZERO (LTS-INSPIRED)	2060 NET ZERO (COAL CCS-LIMITED RES)	2060 NET ZERO (LOW-COST RES)	CONDITIONAL 2060 NET ZERO	ACCELERATED COAL PHASE-OUT	2050 NET ZERO (LTS-INSPIRED)	2050 NET ZERO (COAL CCS-LIMITED RES)	2050 NET ZERO (LOW-COST RES)
	Phaseout of ICE sales	No	No	No	No	No	No	Sales cap from 2023, in line with EV sales target	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)
	Ban of the use of ICEs	No	No	No	No	No	No	No new sales from 2040; complete ban by 2050	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)
Other transport and agriculture	Biofuel mandate	Increasing to 10% by 2030 and 40% 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	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)	Same as 2050 net zero (LTS-inspired)
Residential	Regulation of fossil-based heating	No	From 2031	From 2031	From 2031	From 2031	From 2031	From 2023	From 2023	From 2023
Subsidies for renewable boilers	No	From 2023 onward, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)	Same as 2060 net zero (LTS-inspired)

APPENDIX C: MODEL RESULTS

TABLE 0.2: CO_2 EMISSIONS (EXCLUDING LULUCF)

	2022	2030	2040	2050	2060
					MILLION TONNES
Baseline	507	654	854	1,089	1,385
2030 targets	504	582	742	667	601
2060 net zero LTS	504	565	258	87	−2
2060 net zero RES	504	571	268	105	−6
2060 net zero low-cost RES	504	565	261	115	−1
Conditional 2060 net zero	504	552	228	75	−4
Accelerated coal phaseout	504	539	145	64	−26
2050 net zero LTS	504	503	44	−4	−75
2050 net zero RES	504	499	68	−3	−94
2050 net zero low-cost RES	504	469	77	−1	−99

TABLE 0.3: GHG EMISSIONS (EXCLUDING LULUCF)

	2022	2030	2040	2050	2060
					MILLION TONNES OF CO_2-EQUIVALENT
Baseline	1,028	1,305	1,642	2,072	2,723
2030 targets	1,028	1,218	1,488	1,556	1,772
2060 net zero LTS	1,028	1,197	900	825	1,016
2060 net zero RES	1,028	1,198	918	852	1,015
2060 net zero low-cost RES	1,028	1,190	915	872	1,030
Conditional 2060 net zero	1,028	1,180	862	797	996
Accelerated coal phaseout	1,028	1,162	768	795	983
2050 net zero LTS	1,029	1,117	644	715	931
2050 net zero RES	1,028	1,107	674	721	915
2050 net zero low-cost RES	1,028	1,075	687	728	916

TABLE 0.4: GDP IMPACTS (ABSOLUTE DIFFERENCES FROM BASELINE)

	2030	2040	2050	2060
				$2021M
Baseline	-	-	-	-
2030 targets	63,268	24,375	32,641	17,867
2060 net zero LTS	78,955	84,148	−2,241	−33,185
2060 net zero RES	4,320	65,484	36,166	27,456
2060 net zero low-cost RES	2,088	53,622	42,862	38,494
Conditional 2060 net zero	82,440	85,915	−1,669	−28,884
Accelerated coal phaseout	68,847	56,864	5,437	−9,706
2050 net zero LTS	99,043	43,338	−8,577	−22,893
2050 net zero RES	41,588	44,342	9,796	−2,854
2050 net zero low-cost RES	30,202	39,663	16,287	4,589

TABLE 0.5: HOUSEHOLD CONSUMPTION IMPACTS (ABSOLUTE DIFFERENCES FROM BASELINE)

	2030	2040	2050	2060
				$2021M
Baseline	-	-	-	-
2030 targets	−16,137	−21,826	−30,563	−45,710
2060 net zero LTS	−12,914	−82,187	−140,771	−188,667
2060 net zero RES	−3,785	−24,674	−41,477	−63,215
2060 net zero low-cost RES	−2,356	−13,421	−20,821	−38,358
Conditional 2060 net zero	−12,982	−82,121	−126,513	−167,162
Accelerated coal phaseout	−11,371	−59,511	−82,005	−115,968
2050 net zero LTS	−8,593	−65,763	−89,544	−122,013
2050 net zero RES	−3,885	−37,470	−54,568	−82,692
2050 net zero low-cost RES	−2,646	−25,122	−37,955	−63,185

TABLE 0.6: CUMULATIVE ECONOMY-WIDE INVESTMENT REQUIREMENTS (IN ADDITION TO BASELINE)			
	2022-30	2022-50	2022-60
			$2021BN
Baseline	-	-	-
2030 targets	570	2,050	2,929
2060 net zero LTS	624	3,895	5,059
2060 net zero RES	203	1,762	2,250
2060 net zero low-cost RES	173	1,242	1,579
Conditional 2060 net zero	651	3,958	4,890
Accelerated coal phaseout	582	2,766	3,420
2050 net zero LTS	370	2,439	3,003
2050 net zero RES	206	1,629	2,009
2050 net zero low-cost RES	191	1,198	1,452

TABLE 0.7: FINAL ENERGY INTENSITY OF GDP				
	2030	2040	2050	2060
				TOE PER $2021M
Baseline	280.0	72.3	66.8	65.8
2030 targets	85.3	67.9	62.2	62.0
2060 net zero LTS	84.7	58.4	49.2	47.3
2060 net zero RES	87.0	59.1	49.4	47.6
2060 net zero low-cost RES	87.3	59.4	49.6	47.8
Conditional 2060 net zero	84.3	57.9	48.8	47.0
Accelerated coal phaseout	84.7	58.5	49.0	47.2
2050 net zero LTS	81.1	56.2	48.2	47.2
2050 net zero RES	82.9	56.4	48.2	47.3
2050 net zero low-cost RES	83.3	56.5	48.4	47.5

TABLE 0.8: SHARES OF ELECTRIC VEHICLES IN THE PASSENGER CAR FLEET				
	2030	2040	2050	2060
				%
Baseline	0	0	0	0
2030 targets	0	0	0	0
2060 net zero LTS	8	71	98	100
2060 net zero RES	8	71	98	100
2060 net zero low-cost RES	8	71	98	100
Conditional 2060 net zero	8	71	98	100
Accelerated coal phaseout	8	71	98	100
2050 net zero LTS	11	80	99	100
2050 net zero RES	11	80	99	100
2050 net zero low-cost RES	11	80	99	100

TABLE 0.9: POWER CAPACITY AND GENERATION MIX IN THE BASELINE						
		2022	2030	2040	2050	2060
Power capacity	GW	58	79	113	172	282
Coal	% of total	45	48	49	48	46
Oil & gas	% of total	38	39	36	28	16
Fossil fuels with CCS	% of total	1	1	1	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	3	3	4	4
Wind	% of total	0	1	2	2	2
Solar	% of total	0	1	4	14	29
Hydro	% of total	9	6	4	3	2
Geothermal	% of total	3	2	1	1	1
Power generation	TWh	320	437	598	817	1,135
Coal	% of total	59	63	67	71	74
Oil & gas	% of total	27	27	24	16	5
Fossil fuels with CCS	% of total	0	0	0	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	3	3	3	2
Wind	% of total	0	0	1	1	1
Solar	% of total	0	0	2	6	15
Hydro	% of total	6	3	2	1	1
Geothermal	% of total	4	3	2	2	1

TABLE 0.10: POWER CAPACITY AND GENERATION MIX IN THE 2030 TARGETS SCENARIO						
		2022	2030	2040	2050	2060
Power capacity	GW	58	86	161	396	792
Coal	% of total	46	36	39	14	4
Oil & gas	% of total	38	28	4	1	0
Fossil fuels with CCS	% of total	0	1	2	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	8	7	5	3
Wind	% of total	0	1	4	2	2
Solar	% of total	0	5	31	69	85
Hydro	% of total	9	15	11	5	3
Geothermal	% of total	3	6	4	2	1
Power generation	TWh	320	452	659	1,052	1,783
Coal	% of total	60	49	59	24	7
Oil & gas	% of total	27	19	1	0	0
Fossil fuels with CCS	% of total	0	1	1	2	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	9	5	5	4
Wind	% of total	0	1	1	1	1
Solar	% of total	0	2	17	55	78
Hydro	% of total	6	12	9	7	5
Geothermal	% of total	4	9	7	5	4

TABLE 0.11: POWER CAPACITY AND GENERATION MIX IN THE 2060 NET ZERO (LTS-INSPIRED) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	58	90	240	483	720
Coal	% of total	46	35	8	2	0
Oil & gas	% of total	38	27	4	1	1
Fossil fuels with CCS	% of total	0	1	8	7	7
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	9	24	14	11
Wind	% of total	0	1	6	3	2
Solar	% of total	0	5	33	62	71
Hydro	% of total	9	17	12	8	6
Geothermal	% of total	3	6	4	3	2
Power generation	TWh	320	473	896	1,337	1,835
Coal	% of total	60	47	13	2	0
Oil & gas	% of total	27	18	2	1	1
Fossil fuels with CCS	% of total	0	1	11	12	11
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	9	31	19	15
Wind	% of total	0	1	2	2	2
Solar	% of total	0	2	19	47	58
Hydro	% of total	6	13	13	10	8
Geothermal	% of total	4	8	9	7	6

TABLE 0.12: POWER CAPACITY AND GENERATION MIX IN THE 2060 NET ZERO (COAL CCS-LIMITED RES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	58	95	368	655	918
Coal	% of total	45	33	5	1	0
Oil & gas	% of total	38	32	3	1	0
Fossil fuels with CCS	% of total	0	2	2	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	12	17	10	10
Wind	% of total	0	2	5	2	2
Solar	% of total	0	9	64	82	85
Hydro	% of total	9	8	3	2	2
Geothermal	% of total	3	2	1	1	1
Power generation	TWh	320	474	985	1,525	2,068
Coal	% of total	60	47	10	2	0
Oil & gas	% of total	27	23	3	1	1
Fossil fuels with CCS	% of total	0	1	2	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	14	25	16	16
Wind	% of total	0	1	3	2	1
Solar	% of total	0	4	51	73	77
Hydro	% of total	6	6	4	3	3
Geothermal	% of total	4	4	3	2	2

TABLE 0.13: POWER CAPACITY AND GENERATION MIX IN THE 2060 NET ZERO (LOW-COST RES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	58	104	409	687	918
Coal	% of total	45	30	5	1	0
Oil & gas	% of total	38	30	2	1	0
Fossil fuels with CCS	% of total	0	2	2	2	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	12	13	9	9
Wind	% of total	0	2	3	2	2
Solar	% of total	1	17	73	85	87
Hydro	% of total	9	5	1	1	1
Geothermal	% of total	3	2	1	0	0
Power generation	TWh	320	476	1,030	1,569	2,117
Coal	% of total	60	45	9	2	0
Oil & gas	% of total	27	23	2	1	0
Fossil fuels with CCS	% of total	0	1	3	3	3
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	15	19	14	15
Wind	% of total	0	1	2	2	1
Solar	% of total	0	8	61	77	79
Hydro	% of total	6	4	1	1	1
Geothermal	% of total	4	3	1	1	1

TABLE 0.14: POWER CAPACITY AND GENERATION MIX IN THE CONDITIONAL 2060 NET ZERO SCENARIO						
		2022	2030	2040	2050	2060
Power capacity	GW	58	94	291	573	809
Coal	% of total	45	31	5	0	0
Oil & gas	% of total	38	26	3	1	0
Fossil fuels with CCS	% of total	0	1	6	3	2
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	9	18	11	10
Wind	% of total	0	1	4	3	2
Solar	% of total	0	9	49	75	80
Hydro	% of total	9	17	10	6	5
Geothermal	% of total	3	6	3	2	2
Power generation	TWh	320	473	918	1,419	1,923
Coal	% of total	60	44	9	0	0
Oil & gas	% of total	27	18	1	1	1
Fossil fuels with CCS	% of total	0	1	10	4	2
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	10	24	15	15
Wind	% of total	0	1	2	2	1
Solar	% of total	0	4	33	63	69
Hydro	% of total	6	14	13	9	7
Geothermal	% of total	4	9	8	6	5

TABLE 0.15: POWER CAPACITY AND GENERATION MIX IN THE *ACCELERATED COAL PHASEOUT* SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	58	95	342	610	845
Coal	% of total	46	28	0	0	0
Oil & gas	% of total	38	28	2	1	0
Fossil fuels with CCS	% of total	1	2	4	2	2
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	11	20	11	10
Wind	% of total	0	2	5	3	2
Solar	% of total	0	9	60	78	82
Hydro	% of total	8	15	7	4	3
Geothermal	% of total	3	5	2	1	1
Power generation	TWh	320	473	955	1,464	1,972
Coal	% of total	60	39	0	0	0
Oil & gas	% of total	27	21	2	1	0
Fossil fuels with CCS	% of total	0	1	6	3	2
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	13	29	16	16
Wind	% of total	0	1	3	2	1
Solar	% of total	0	4	46	68	72
Hydro	% of total	5	13	8	6	5
Geothermal	% of total	4	8	6	4	3

TABLE 0.16: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (LTS-INSPIRED) SCENARIO						
		2022	**2030**	**2040**	**2050**	**2060**
Power capacity	GW	58	108	383	601	834
Coal	% of total	46	23	0	0	0
Oil & gas	% of total	38	29	1	1	0
Fossil fuels with CCS	% of total	1	1	3	2	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	9	17	12	11
Wind	% of total	0	3	3	2	2
Solar	% of total	0	20	67	78	81
Hydro	% of total	9	11	6	4	3
Geothermal	% of total	3	4	2	1	1
Power generation	TWh	320	487	1,015	1,454	1,966
Coal	% of total	60	35	0	0	0
Oil & gas	% of total	26	27	2	1	0
Fossil fuels with CCS	% of total	0	1	5	3	2
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	10	26	18	18
Wind	% of total	0	1	2	1	1
Solar	% of total	0	9	54	67	70
Hydro	% of total	6	10	7	6	5
Geothermal	% of total	4	6	5	4	3

TABLE 0.17: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (COAL CCS-LIMITED RES) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	58	118	447	657	886
Coal	% of total	46	22	0	0	0
Oil & gas	% of total	38	29	1	0	0
Fossil fuels with CCS	% of total	1	1	1	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	9	14	11	11
Wind	% of total	0	3	3	2	2
Solar	% of total	0	28	78	83	84
Hydro	% of total	9	7	3	2	2
Geothermal	% of total	3	2	1	1	1
Power generation	TWh	320	490	1,085	1,522	2,032
Coal	% of total	60	34	0	0	0
Oil & gas	% of total	26	28	2	1	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	11	22	18	19
Wind	% of total	0	1	2	1	1
Solar	% of total	0	14	67	74	74
Hydro	% of total	6	6	4	3	2
Geothermal	% of total	4	4	2	2	2

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

		2022	2030	2040	2050	2060
Power capacity	GW	58	150	483	686	916
Coal	% of total	46	17	0	0	0
Oil & gas	% of total	37	20	1	0	0
Fossil fuels with CCS	% of total	1	1	1	1	1
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	7	11	10	11
Wind	% of total	0	2	2	2	1
Solar	% of total	1	48	83	86	85
Hydro	% of total	9	4	1	1	1
Geothermal	% of total	3	1	0	0	0
Power generation	TWh	320	502	1,129	1,559	2,071
Coal	% of total	60	29	0	0	0
Oil & gas	% of total	26	21	1	1	0
Fossil fuels with CCS	% of total	0	1	2	2	2
Nuclear	% of total	0	0	0	0	0
Biomass with CCS	% of total	4	10	18	17	19
Wind	% of total	0	1	1	1	1
Solar	% of total	0	31	75	78	76
Hydro	% of total	6	4	1	1	1
Geothermal	% of total	4	3	1	1	1

TABLE 0.19: FINAL ENERGY DEMAND FOR TRANSPORT - BASELINE						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	39,697	48,828	54,052	59,335
Electricity	% of total	0	0	0	0	0
Coal	% of total	0	0	0	0	0
Oil	% of total	98	97	97	96	96
Gas	% of total	0	0	0	0	0
Biofuels	% of total	2	2	3	4	4

TABLE 0.20: FINAL ENERGY DEMAND FOR TRANSPORT - 2030 TARGETS						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	39,926	49,489	55,233	60,984
Electricity	% of total	0	0	0	0	0
Coal	% of total	0	0	0	0	0
Oil	% of total	98	92	82	74	66
Gas	% of total	0	0	0	0	0
Biofuels	% of total	2	8	17	26	33

TABLE 0.21: FINAL ENERGY DEMAND FOR TRANSPORT - 2060 NET ZERO (LTS-INSPIRED)						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	46,255	52,651	51,496	56,197
Electricity	% of total	0	5	45	70	70
Coal	% of total	0	0	0	0	0
Oil	% of total	98	86	33	14	9
Gas	% of total	0	1	3	0	0
Biofuels	% of total	2	9	19	16	20

TABLE 0.22: FINAL ENERGY DEMAND FOR TRANSPORT - 2060 NET ZERO (COAL CCS-LIMITED RES)						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	46,165	52,523	51,354	56,059
Electricity	% of total	0	5	45	70	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	86	33	14	9
Gas	% of total	0	1	3	0	0
Biofuels	% of total	2	9	19	16	20

TABLE 0.23: FINAL ENERGY DEMAND FOR TRANSPORT - 2060 NET ZERO (LOW-COST RES)						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	46,156	52,497	51,327	56,034
Electricity	% of total	0	5	45	70	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	86	33	14	9
Gas	% of total	0	1	3	0	0
Biofuels	% of total	2	9	19	16	20

TABLE 0.24: FINAL ENERGY DEMAND FOR TRANSPORT - CONDITIONAL 2060 NET ZERO SCENARIO						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	46,259	52,586	51,370	56,059
Electricity	% of total	0	5	45	70	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	86	33	14	9
Gas	% of total	0	1	3	0	0
Biofuels	% of total	2	9	19	16	20

TABLE 0.25: FINAL ENERGY DEMAND FOR TRANSPORT - ACCELERATED COAL PHASEOUT						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	46,255	52,510	51,291	55,987
Electricity	% of total	0	5	45	70	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	86	33	14	9
Gas	% of total	0	1	3	0	0
Biofuels	% of total	2	9	19	16	20

TABLE 0.26: FINAL ENERGY DEMAND FOR TRANSPORT - 2050 NET ZERO (LTS-INSPIRED)						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	44,495	49,538	51,341	56,183
Electricity	% of total	0	7	54	71	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	72	21	9	9
Gas	% of total	0	0	0	0	0
Biofuels	% of total	2	21	25	20	20

TABLE 0.27: FINAL ENERGY DEMAND FOR TRANSPORT - 2050 NET ZERO (COAL CCS-LIMITED RES)						
		2022	2030	2040	2050	2060
Total	ktoe	32,899	44,424	49,484	51,292	56,141
Electricity	% of total	0	7	54	71	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	72	21	9	9
Gas	% of total	0	0	0	0	0
Biofuels	% of total	2	21	25	20	20

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

		2022	2030	2040	2050	2060
Total	ktoe	32,899	44,407	49,464	51,272	56,122
Electricity	% of total	0	7	54	71	71
Coal	% of total	0	0	0	0	0
Oil	% of total	98	72	21	9	9
Gas	% of total	0	0	0	0	0
Biofuels	% of total	2	21	25	20	20

TABLE 0.29: FINAL ENERGY DEMAND FOR BUILDINGS - BASELINE

		2022	2030	2040	2050	2060
Total	ktoe	45,449	52,934	62,472	76,487	97,691
Electricity	% of total	34	43	53	63	71
Coal	% of total	1	1	1	0	0
Oil	% of total	22	21	20	18	15
Gas	% of total	0	0	0	1	1
Biofuels	% of total	43	35	26	18	12

TABLE 0.30: FINAL ENERGY DEMAND FOR BUILDINGS - 2030 TARGETS

		2022	2030	2040	2050	2060
Total	ktoe	45,446	48,616	54,210	64,623	84,114
Electricity	% of total	34	44	53	62	71
Coal	% of total	1	1	1	0	0
Oil	% of total	22	23	22	20	16
Gas	% of total	0	0	0	1	1
Biofuels	% of total	43	33	24	17	11

TABLE 0.31: FINAL ENERGY DEMAND FOR BUILDINGS - 2060 NET ZERO (LTS-INSPIRED)

		2022	2030	2040	2050	2060
Total	ktoe	45,446	46,906	47,717	54,083	69,619
Electricity	% of total	34	45	60	73	84
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	13	9	6
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	34	26	18	10

TABLE 0.32: FINAL ENERGY DEMAND FOR BUILDINGS - BASELINE

		2022	2030	2040	2050	2060
Total	ktoe	45,446	46,984	48,713	56,153	72,937
Electricity	% of total	34	45	61	73	84
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	13	9	6
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	34	25	17	10

TABLE 0.33: FINAL ENERGY DEMAND FOR BUILDINGS - 2030 TARGETS

		2022	2030	2040	2050	2060
Total	ktoe	45,446	46,880	47,695	54,252	69,972
Electricity	% of total	34	45	60	73	84
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	13	9	6
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	34	26	18	10

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

		2022	2030	2040	2050	2060
Total	ktoe	45,447	46,892	48,062	55,068	71,267
Electricity	% of total	34	45	61	73	84
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	13	9	6
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	34	26	17	10

TABLE 0.35: FINAL ENERGY DEMAND FOR BUILDINGS – 2050 NET ZERO (LTS-INSPIRED)

		2022	2030	2040	2050	2060
Total	ktoe	45,448	44,367	45,093	53,008	70,445
Electricity	% of total	34	48	64	76	86
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	11	7	4
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	32	25	17	10

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

		2022	2030	2040	2050	2060
Total	ktoe	45,446	44,350	45,683	54,062	71,930
Electricity	% of total	34	48	64	76	86
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	11	7	4
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	32	24	17	10

TABLE 0.37: FINAL ENERGY DEMAND FOR BUILDINGS - 2050 NET ZERO (LOW-COST RES)						
		2022	2030	2040	2050	2060
Total	ktoe	45,447	44,234	45,956	54,711	72,870
Electricity	% of total	34	48	64	76	86
Coal	% of total	1	0	0	0	0
Oil	% of total	22	20	11	7	4
Gas	% of total	0	0	0	0	0
Biofuels	% of total	43	32	24	17	10

TABLE 0.38: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - BASELINE						
		2022	2030	2040	2050	2060
Total	ktoe	61,944	78,625	97,045	119,046	148,528
Electricity	% of total	15	15	15	16	15
Coal	% of total	24	24	23	22	21
Oil	% of total	21	19	16	13	10
Gas	% of total	30	33	38	42	47
Biofuels	% of total	11	10	9	7	6

TABLE 0.39: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2030 TARGETS						
		2022	2030	2040	2050	2060
Total	ktoe	61,984	79,420	93,573	114,278	143,584
Electricity	% of total	15	18	25	32	41
Coal	% of total	24	24	22	21	20
Oil	% of total	21	18	16	13	11
Gas	% of total	30	31	29	26	23
Biofuels	% of total	11	9	8	7	6

TABLE 0.40: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2060 NET ZERO (LTS-INSPIRED)						
		2022	2030	2040	2050	2060
Total	ktoe	61,984	74,919	72,513	77,582	91,771
Electricity	% of total	15	19	27	34	40
Coal	% of total	24	20	15	14	13
Oil	% of total	21	22	22	21	18
Gas	% of total	30	30	25	20	16
Biofuels	% of total	11	10	10	11	12

TABLE 0.41: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2060 NET ZERO (COAL CCS-LIMITED RES)						
		2022	2030	2040	2050	2060
Total	ktoe	61,985	73,096	72,759	78,286	92,580
Electricity	% of total	15	19	27	34	41
Coal	% of total	24	19	16	14	12
Oil	% of total	21	22	22	21	18
Gas	% of total	30	29	25	20	16
Biofuels	% of total	11	10	10	11	12

TABLE 0.42: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2060 NET ZERO (LOW-COST RES)						
		2022	2030	2040	2050	2060
Total	ktoe	61,987	73,472	72,569	78,542	93,009
Electricity	% of total	15	19	27	34	41
Coal	% of total	24	19	16	14	12
Oil	% of total	21	22	22	21	18
Gas	% of total	30	29	25	20	16
Biofuels	% of total	11	10	10	11	12

TABLE 0.43: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – CONDITIONAL 2060 NET ZERO SCENARIO

		2022	2030	2040	2050	2060
Total	ktoe	61,985	74,461	71,231	76,134	90,116
Electricity	% of total	15	19	27	34	40
Coal	% of total	24	20	15	13	12
Oil	% of total	21	22	22	21	19
Gas	% of total	30	30	25	20	16
Biofuels	% of total	11	10	10	11	12

TABLE 0.44: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – ACCELERATED COAL PHASEOUT

		2022	2030	2040	2050	2060
Total	ktoe	61,979	74,119	71,124	76,392	90,547
Electricity	% of total	15	19	27	34	40
Coal	% of total	24	19	15	14	12
Oil	% of total	21	22	23	21	19
Gas	% of total	30	30	25	20	16
Biofuels	% of total	11	10	10	11	12

TABLE 0.45: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2050 NET ZERO (LTS-INSPIRED)

		2022	2030	2040	2050	2060
Total	ktoe	61,990	73,740	69,536	74,537	90,663
Electricity	% of total	15	19	27	34	40
Coal	% of total	24	19	15	13	13
Oil	% of total	21	22	23	22	18
Gas	% of total	30	29	24	20	16
Biofuels	% of total	11	10	11	11	12

TABLE 0.46: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2050 NET ZERO (COAL CCS-LIMITED RES)

		2022	2030	2040	2050	2060
Total	ktoe	61,999	72,606	69,577	74,726	90,860
Electricity	% of total	15	20	27	34	40
Coal	% of total	24	19	15	13	13
Oil	% of total	21	23	23	22	18
Gas	% of total	30	29	24	20	16
Biofuels	% of total	11	10	11	11	12

TABLE 0.47: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION – 2050 NET ZERO (LOW-COST RES)

		2022	2030	2040	2050	2060
Total	ktoe	62,003	72,585	69,353	74,925	91,085
Electricity	% of total	15	20	27	34	40
Coal	% of total	24	19	15	13	13
Oil	% of total	21	23	23	22	18
Gas	% of total	30	29	24	20	16
Biofuels	% of total	11	10	11	11	12

APPENDIX D: COMPARISON OF FINDINGS FOR INDONESIA AND INDIA

This appendix provides a comparison of key findings outlined in Chapter 3 for Indonesia with comparable indicators and figures presented in the *Getting India to Net Zero* report (Asia Society Policy Institute 2022) t to support understanding of differences.

Emissions

Emissions peak in 2025 in the *2050 net zero* scenario for India and between 2027 and 2028 in Indonesia for all variants of the same scenario for two reasons:

The India modeling accounts for reductions in land-use emissions and the creation of natural carbon sinks, which can more quickly reduce emissions, whereas the modeling for Indonesia does not include this, as outlined in the box, "Interpreting Indonesia's Updated Targets," due to volatility and data quality issues for Indonesia.

Explicit and ambitious renewables targets for 2030 are included in the India policy announcements, whereas the trajectories to 2030 in Indonesia as envisioned by the government still include a major role for fossil fuels (with only half of new added capacity being renewables).

Economic impacts

The macroeconomic impacts in Indonesia (in GDP and employment terms) are less positive and more volatile than those for India, due to differences in the core components of GDP (investment, household consumption, and net trade):

- **Investment**: While investment in both countries is driven mainly by the power sector, the time profile of the investment and GDP impacts in Indonesia are more strongly influenced by short-term market volatility caused by minor variations over time in the technology mix in response to policy changes. This is due, in particular, to the greater role of capital-intensive power technologies assumed in the future according to Indonesia's policy announcements (including CCS, hydro, and geothermal).
- **Household consumption**: The household consumption impact is the main driver of the difference between countries. On the one hand, the nominal increase in household income is smaller in Indonesia than that in India, because of the large number of direct and indirect job losses linked to fossil fuel supply. On the other hand, because coal power is currently available at subsidized costs in Indonesia (whereas the Indian government subsidizes coal production but not coal-based electricity), a transition toward renewables with carbon pricing and a removal of coal power subsidies imply noticeably higher costs of power generation for Indonesia reflected in higher costs of production and inflation for households. This higher inflation impact reduces consumers' purchasing power and thus their spending.
- **Net trade**: The difference is also partly explained by a smaller improvement to the trade balance. While India is a net fossil fuel importer, Indonesia is a net exporter, particularly of coal, and faces a global demand reduction in all decarbonization scenarios.

In employment terms, Indonesia sees negative overall jobs impacts in most of the scenarios (more so in more ambitious scenarios), whereas India sees positive impacts in all scenarios:

- This results mainly from a larger number of job losses in coal supply and a smaller number of job gains in construction. Coal extraction is a specialization of Indonesia, whereas the construction sector (which benefits from renewables infrastructures) has higher productivity (greater output per job) in Indonesia than in India, meaning that the same amount of output can be produced with fewer additional jobs.
- Consumer goods and services sectors also see smaller positive impacts in Indonesia due to the larger negative household consumption impacts.
- In contrast, business service sectors respond more positively in Indonesia, because of lower employment intensities than in India, which means an increase in demand for these sectors (due to supply chain impacts of the transition) that leads to more job creation.

Investment requirements

The investment requirements for Indonesia to deliver net zero are lower than those for India. First, the net zero target for India was interpreted to cover all GHG and land-use emissions, a broader scope than the target used in the modeling for Indonesia, which covers only energy-related CO_2 emissions (due to high uncertainty in the trajectory of land use and non-CO_2 emissions). Second, the size of the Indian economy and the level of energy demand and emissions in India are several times larger than the Indonesian equivalents; once the difference in scale has been taken into account, the investment needs equate to a similar proportion (of GDP and relative to baseline) in both countries.

On the other hand, the investment requirements for Indonesia in peaking years (relative to baseline) are higher than those for India. This is also explained by differences in renewables costs. The capital cost of low-carbon power generation technologies in Indonesia, particularly for wind and solar, while domestically competitive with fossil fuels, is still higher than that in India due to nonmarket barriers that favor fossil fuels (such as DMOs for domestic coal producers to supply at a below-market price and local content requirements for renewables projects). As such, in the medium term while costs remain relatively high (before economies of scale and learning-by-doing effects bring costs down), it is more costly to invest in renewables in Indonesia.

In addition, the cumulative investment requirements for Indonesia are higher in the less ambitious *2060 net zero* scenario than in the *2050 net zero* scenario, in contrast with India where the opposite is observed for the *2070 net zero* and *2050 net zero* scenarios (i.e., the later net zero target date requires less investment). Apart from a larger gap in terms of decarbonization ambition between India's scenarios (*2070* and *2050 net zero*), the difference can be explained by two factors: natural carbon sinks and power sector investments. First, the India scenarios include natural carbon sinks targets that are not included in the Indonesia modeling. Carbon sink potentials are assumed to significantly increase in India in the *2050 net zero* scenario compared to the *2070 net zero* scenario, resulting in a marked increase in additional investment (carbon sink investments account for up to a third of cumulative investment in India's net zero scenarios). Second, the larger share of the difference is attributable to the power sector. Because of the current differences in renewables costs mentioned above, strengthened policies that promote renewables uptake lead to larger cost reductions (and lower investment needs relative to baseline) in Indonesia than in India in the long term.

Policy costs

Policy costs in Indonesia in more ambitious scenarios are partly funded by international financial support and the reinvestment of coal power subsidies (which are not present in the India modeling), leading to savings (rather than deficits) for the overall government budget. These alternative funding sources more than offset the reduction in carbon revenues (due to falling emissions) and reduce the negative impact on household consumption compared to when they are not available.

In the *2030 targets* scenario in particular, the modeling shows an increase in policy costs in the long term in Indonesia, compared to a continued reduction in costs (an increase in savings) in India. This pattern is attributable to the emissions trajectories: emissions largely flatten out in India after 2030 in this scenario; in Indonesia, they continue to increase before falling toward 2050, leading to a more visible change in the profile of carbon revenues.

Energy costs

The energy price impacts are much larger (i.e., the price increases compared to baseline) in Indonesia (up to 200 percent) than in India (65 percent) in the central variant of the *2060 net zero* and *2050 net zero* scenarios. This is mainly due to the composition of the power mix modeled for each country:

- The central net zero variants modeled for Indonesia are based on the LTS trajectory, whereas there is no equivalent government announcement for India. Therefore, the modeling for India is truer to the E3ME model dynamics and largely mimics investor decisions that favor cost-competitive technologies (such as wind and solar). This is more in line with the narrative of the low-cost renewables variant of the Indonesia scenarios, where the modeling does not assume compliance with the LTS trajectory. Indonesia's central LTS-inspired variant is heavily reliant on coal with CCS in the long term (which is subject to carbon pricing because not all emissions are captured), as well as hydro and geothermal (which have high capital costs that are passed on to consumers). The India modeling projects a more dominant role for wind and solar, which are less expensive, leading to a smaller increase in electricity prices that is similar to that observed in the low-cost-renewables variant of the equivalent Indonesia scenario.
- Historically, there is also a higher share of wind and solar in the power mix in India; therefore, costs of these technologies in India are lower, reflecting economies of scale and learning-by-doing effects, which make an accelerated transition smoother than that in Indonesia where the share of wind and solar is very low and therefore costs are higher (although with stronger actions Indonesia can reap larger relative cost reductions).
- The modeling for Indonesia assumes a removal of coal power subsidies in addition to carbon pricing (through an emissions trading system (ETS)), which means a larger unit cost increase for power generation from both unabated coal and coal with CCS than that for India (where only the ETS is modeled) and a higher energy price increase overall.

In nominal terms, energy costs faced by households increase from baseline in most scenarios for Indonesia, whereas they reduce from baseline in all scenarios for India. This is mainly driven by the impact on per unit energy prices as mentioned above. It contrasts with energy volume savings seen in both countries due to energy efficiency gains from electrification, fuel switching, and investment in efficiency improvements. In the scenarios that are most comparable between the two countries (the central *2050 net zero* scenario for India and the *low-cost RES 2050 net zero* scenario for Indonesia), there is an overall reduction in energy costs by 2050, at around 70 percent in India and 40 percent in Indonesia. The stronger reduction in India is driven by differences in historical shares and costs of renewables.

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