A GREEN ECONOMY FOR A NET-ZERO FUTURE:

How Indonesia can build back better after COVID-19 with the Low Carbon Development Initiative (LCDI)

Ministry of National Development Planning/Bappenas. 2021

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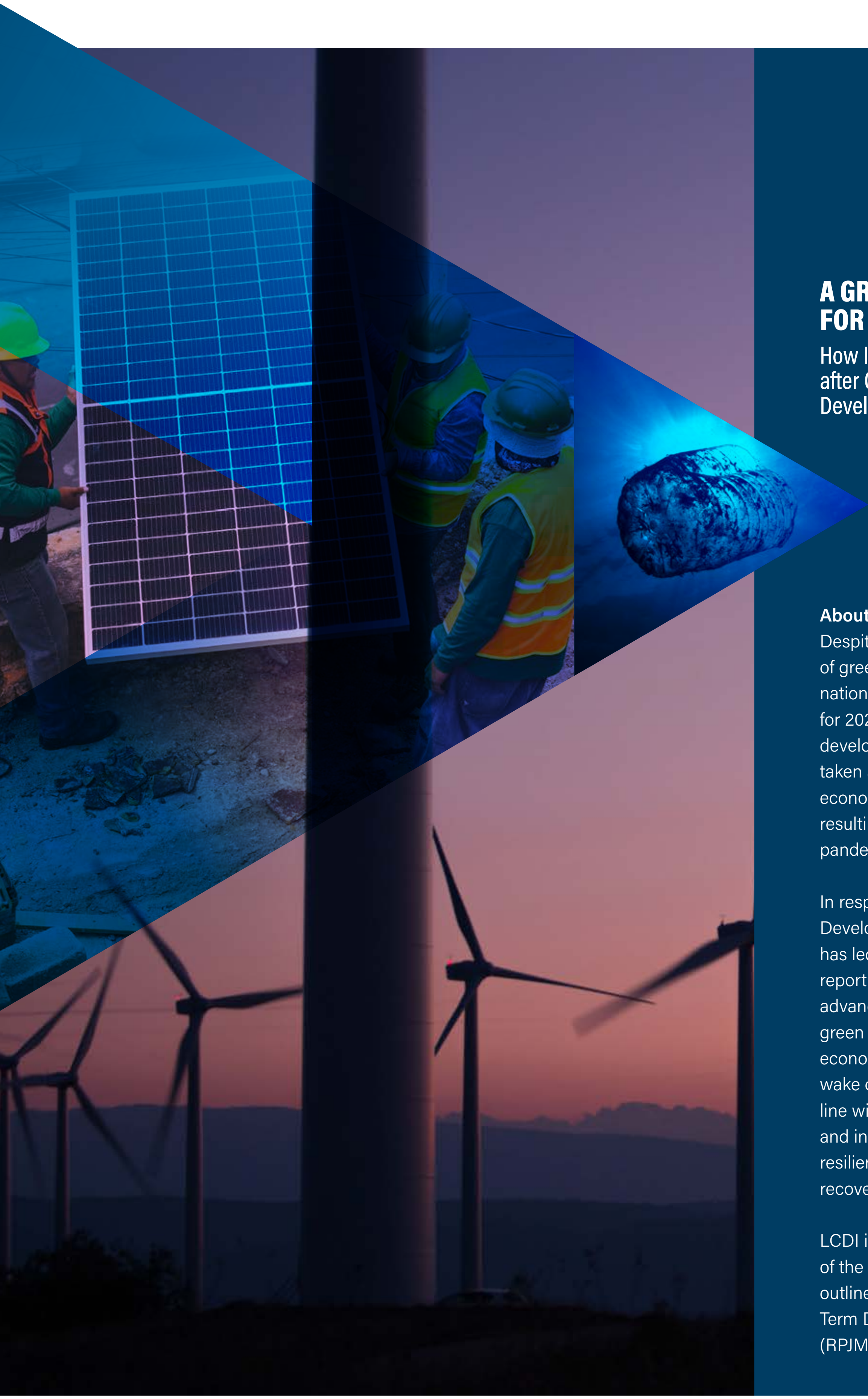

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About this report

Despite the central positioning of green growth in Indonesia's national development plan for 2020–2024, low-carbon development in Indonesia has taken a backseat following economic and social challenges resulting from the COVID-19 pandemic.

In response, the Low Carbon Development Initiative (LCDI) has led the production of a report aimed at informing the advancement of a low-carbon, green recovery and green economic transformation in the wake of the COVID-19 pandemic, in line with the global climate targets and in pursuit of a more robust, resilient, inclusive and sustainable recovery.

LCDI is a national priority program of the Government of Indonesia as outlined in the National Medium Term Development Program (RPJMN) 2020–2024.

Foreword

Indonesia has a strong vision to become the world's fifth-largest economy by 2045, indicated by the rapid decline in poverty rates and steady economic growth. This vision has been reinforced by the commitment to achieve Sustainable Development Goals that promote a balance of economic, social, and environmental aspects. The Government understands that achieving a long-term sustainable future will require a transition from a "business as usual" development approach to a low-carbon path. Therefore, low carbon development policies have been incorporated as one of the national priority programs in the Indonesia National Medium-Term Development Plan (RPJMN) for the period of 2020–2024, allowing Indonesia to perform article 3.4 of the UNFCCC that emphasizes synergy between climate action and development program.

However, the COVID-19 pandemic has created a multidimensional crisis and fundamentally affected macroeconomic stability, resulting in Indonesia's economic contraction by 2.1% in 2020. A slowdown in economic activity disrupts our progress in eradicating poverty. National poverty rate experienced the largest setback of 3.1 years, became equal to the poverty rate in 2017. This situation threatens Indonesia development path set under Indonesia Vision 2045 including the target to escape from the middle-income trap before 2045. On another note, climate change has also triggered more frequent and severe climate-related disasters, creating huge losses, both in terms of lives and finances. Only in 2020, around 99.5 percent of disaster events are categorized as hydrometeorological disasters. These climate-related disasters are predicted to be more intense in the future and will entail externalities that come at very high economic and social cost to recover from if we do nothing.

Indonesia needs to recover immediately and build back better from the pandemic, and bring the economic and development trajectory back to the right path. Hence, Indonesia will require an economic transformation to boost economic growth, creating better jobs, while at the same time maintaining our natural carrying capacity and enhancing resilience for future shocks. The Ministry of National Development Planning (BAPPENAS) has placed the Green Economy as one of the economic transformation strategies.

With regard to this, the Ministry of National Development Planning in collaboration with development partners, particularly the United Kingdom Foreign Commonwealth and Development Office (UK-FCDO) has carried out various studies to advance green economy transformation with low carbon development based on scientific analysis to provide various policy scenarios to build back better from the pandemic, including to achieve a more ambitious climate target: Net Zero Emissions.

This report presents scientific analysis of three scenarios in achieving net-zero emissions for Indonesia and explores how Indonesia would embrace a green economy and net-zero path. The report shows that committing to achieve net-zero emission by 2060 or earlier, would bring multiple benefits to Indonesia. Indeed, transforming Indonesia to achieve net zero emission will require a common vision, major new policies, shifts in existing investments priority and strong collaboration with multi stakeholders. This report can serve as a reference for policymakers across the country as well as the international communities, and encourage policy formulation at all levels to achieve a green economy that is robust, resilient, and sustainable in the future.

Jakarta, September 2021

Suharso Monoarfa
Minister of National Development Planning/Head of Bappenas

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Executive Summary

When Indonesia adopted its National Medium-Term Development Plan (RPJMN) 2020–2024 in January 2020, it signaled a shift towards a new green, low-carbon development path that would enable it to meet its goal of achieving high-income status by 2045. This was an important step, but just the start.

Since then, COVID-19 has caused devastation around the world. In Indonesia, there were nearly 4.2 million confirmed cases as of 21 September 2021 and over 140,000 fatalities. The economy has also suffered, with GDP shrinking by 2.1% in 2020 and poverty and unemployment rates rising. Before the latest spike in COVID cases, GDP had been projected to grow by 4.3–4.8% in 2021, but that could change—and in any case, globally, the socio-economic effects of the pandemic are expected to last for years.

The government has made enormous investments to protect public health, strengthen the social safety net, and stimulate the economy: about Rp. 976 trillion (US$68.5 billion) as of 17 September 2021. Looking beyond the immediate crisis, this report, prepared for the Low Carbon Development Initiative (LCDI) as mandated by the Indonesia Vision 2045 report and the Indonesia National Mid-Term Development Plan (RPJMN) 2020–2024, explores how embracing a path to net-zero emissions by mid-century could accelerate growth, boost employment, and make Indonesia's economy more robust, resilient, inclusive and sustainable. A green recovery from COVID-19 is a key first step.

Net-zero scenarios for Indonesia

Many countries have already adopted net-zero targets, even amid the COVID-19 crisis, recognizing that ambitious climate action can deliver better and stronger growth. As of September 2021, 52 parties representing 63 countries and 54.2% of global greenhouse gas (GHG) emissions has announced net-zero targets: from the European Union, to Brazil, to China, Japan and South Korea. Many companies and financial institutions are adopting them as well. The World Bank, the International Monetary Fund, the Organisation for Economic Co-operation and Development, the United Nations and others have also urged countries to prioritize green investments in their COVID recovery, to "build back better."

Ambitious climate action is crucial to Indonesia's future. A recent analysis by the insurer Swiss Re found that if the world is 2.0–2.6°C warmer by mid-century, as it may be even if current pledges under the Paris Agreement are met, Indonesia's GDP could shrink by 16.7–30.2% due to climate change impacts.

As Indonesia takes on the G20 Presidency in 2022, a net-zero commitment can demonstrate its strong leadership on climate and inspire others to do the same, including through climate finance. The actions needed to achieve net-zero in Indonesia would also end dependency on volatile fossil fuel markets and protect natural capital, securing the country's place as a "carbon superpower."

A 2019 Bappenas scenario analysis to inform the RPJMN 2020–2024 showed a low-carbon growth path could deliver GDP growth averaging 6% per year until 2045, help accelerate poverty reduction and boost jobs, with many other co-benefits.

Recognizing that the policy context has changed significantly, especially due to COVID-19, this report presents an updated analysis with four scenarios:

- **A new Reference Case** that reflects the impacts of the COVID-19 pandemic as well as stimulus interventions to date, but assumes that Indonesia advances no further policy efforts—beyond plans and projects already in the pipeline—to green its infrastructure, protect natural capital, or reduce GHG emissions.
- **Three scenarios for achieving net-zero GHG emissions in Indonesia, by 2045, 2050 or 2060.** They apply the same interventions, but on different timelines, with NZ2045 moving fastest. All would ensure that Indonesia meets or exceeds its unconditional pledge under the Paris Agreement of a 29% emission reduction by 2030, then ramp up ambition across major emission sources. Per LCDI standards and principles, they are scientifically rigorous and ambitious, but recognize political, technical and institutional constraints and reflect, to the extent possible, ongoing discussions within key government agencies.

Expanding on the low-carbon measures included in RPJMN 2020–2024, the net-zero scenarios would fully replace fossil fuels with clean energy (renewables and nuclear); sharply reduce the energy-intensity of the economy; phase out fossil fuel subsidies by 2030 and put a price on carbon; electrify road transport (with biofuels' role gradually declining); protect and restore forests, peatlands and mangroves; adopt sustainable practices in agriculture, forestry, fisheries and aquaculture; improve waste management; and make industry more efficient.

Those measures would stabilize GHG emissions at under 1.9 Gt CO_2e in the period 2021–2024, then start declining. By 2030, GHG emissions would fall by 30.9% in NZ2045, 29.7% in NZ2050 and 29.1% in NZ2060 relative to the Reference Case. Over the 2021–2060 period, 87–96 Gt CO_2e of emissions would be avoided. Two-thirds of those reductions would be in the energy sector, and 25% in agriculture, forestry and other land use (AFOLU).

The net-zero scenarios would also deliver sustained real GDP growth—and at higher rates than the Reference Case: averaging 6.5% per year for 2021–2050 in NZ2045, 6.4% in NZ2050, and 6.1% in NZ2060, then continuing beyond 2050 at a slower growth rate. By 2045, total GDP would be 25–34% greater in NZ2045 than in the Reference Case. Per capita gross national income (GNI), meanwhile, would reach US$14,495 by 2045 in NZ2045, US$14,485 in NZ2050 and US$13,980 in NZ2060. This means that across net-zero scenarios, Indonesia would achieve its goal of becoming a high-income country by 2045 (the current threshold is US$12,535).

Pursuing net-zero would also create large numbers of green jobs, starting in the first year, and thus could be an integral part of a strong recovery from the COVID-19 economic crisis. A bottom-up estimate based on the NZ2050 scenario indicates that it would result in 1.8–2.2 million new jobs in 2030 in renewable energy, electric vehicle technologies, energy efficiency, land use interventions and improved waste management. That would be 1.0–1.3% of the projected labor force in 2030.

With additional strategies that prioritize equity and inclusion, these gains could be used to benefit poor and disadvantaged populations and help close gender gaps. There are also broader societal benefits, such as sharp reductions in air pollution that could save 40,000 lives in 2045 alone.

Indonesia can start realizing those benefits right away by implementing some net-zero measures as part of its COVID-19 recovery, with significant stimulus effects and job creation. This would also help reduce the risk of stranded assets, as new coal power plants may otherwise need to be retired prematurely, with financial repercussions. That said, not all sectors, communities or individuals will gain equally; high-carbon sectors would be expected to decline, shedding jobs. Economy-wide, those losses will be more than offset by new opportunities in low-carbon sectors, but targeted policies and investments are crucial to support a just transition and ensure that no one is left behind.

Figure ES1. The benefits of Indonesia's Net Zero growth path (compared with Reference Case)

Benefits of the net-zero scenarios vs. the Reference Case

87–96
billion tonnes CO_2e
GHG emissions saved over 2021–2060

6.1–6.5%
average annual GDP growth over 2021–2050

25–34%
higher
gross national income (GNI) by 2045

1.8 million additional green jobs
in 2030 in energy sector, EVs, land restoration and waste

40,000
lives
saved in 2045 alone from reduced air pollution

Restore ecosystems with services valued at
US$4.75
trillion/year
by 2060

3.2
million ha
of primary forest protected by 2060

4.1
million ha
of forest coverage added by 2060

Boost
climate resilience
across the economy

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Net-zero targets and strategies in key sectors

Energy

The energy sector is central to achieving net-zero as Indonesia develops and incomes rise, because energy demand is rising quickly. Projections for the Reference Case show demand more than tripling, from 9.3 TJ in 2021 to 31.9 TJ in 2060. If all the added demand were met with fossil fuels, the impact on GHG emissions and air pollution would be devastating.

The RPJMN 2020–2024 already recognizes this challenge and aims to reduce the energy intensity of Indonesia's economy (a proxy measure for energy efficiency) by 2.5% per year and increase the share of renewable energy in the primary energy mix to 23% by 2025. The net-zero scenarios ramp up ambition on both fronts, aiming to reduce the energy intensity of GDP by 3.9–4.5% per year in 2021–2030 and by an average of 6% per year in 2031–2060, and to meet the vast majority of energy needs with renewables and other clean sources (nuclear, hydrogen) by the net-zero target year, and all by 2060.

By 2060, the energy efficiency gains would enable Indonesia to use less than 10% as much energy per unit of GDP as it did in 2021, enabling the economy to grow robustly while keeping energy demand roughly where it is today, or lower. Notably, a large share of those efficiency gains would come from large-scale electric vehicle (EV) adoption, to reach nearly 100% (with some hydrogen-fueled vehicles as well) by the net-zero target year. A recent analysis found that because EVs are so energy-efficient, electrifying almost all the world's road transport by 2050 would only increase global electricity demand by a quarter. President Widodo has already set a goal of having 20% of the country's auto production be EVs by 2025.

Electrifying road transport would address the single largest source of fossil fuel demand today, freeing Indonesia from oil imports without the need for more biofuels (which help reduce emissions, but also require large amounts of land). Eliminating fossil fuels from electricity production is the other major task. The State Electricity Company (PLN) already has plans to stop adding coal power after 2023, increase the share of renewables to at least 48% of total generation capacity by 2030, and reach carbon neutrality by 2060. In the net-zero scenarios, the share of coal power—59% in 2019—would start to decline by the mid-2020s and drop to 5% by 2035. The share of renewables would rise to 60% by 2030 and 82% by 2053, with nuclear power, introduced in 2030, supplying all the rest by 2060.

To accelerate the energy transition, Indonesia is already phasing out fossil fuel subsidies and piloting carbon markets. The net-zero scenarios would completely end fossil fuel subsidies by 2030 and phase in a carbon price, starting low and then ramping up to US$60 (Rp. 873,000) per tonne CO_2 by 2040 in NZ2045 (US$50 in NZ2050 and US$40 in NZ2060), then remaining at that level.

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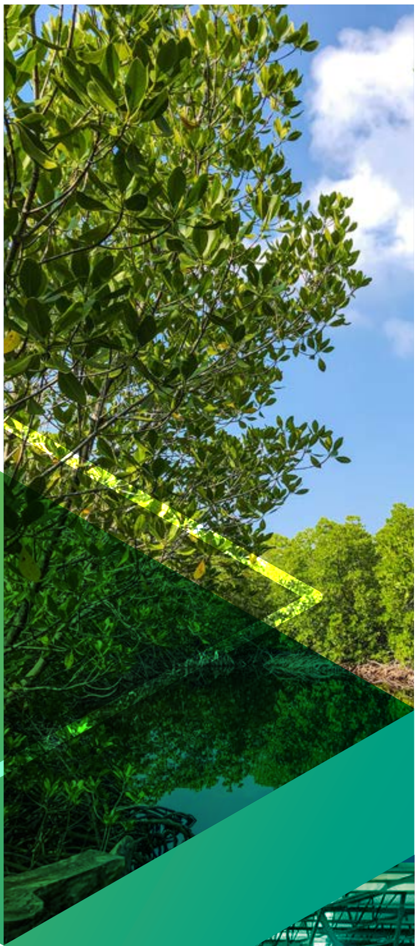

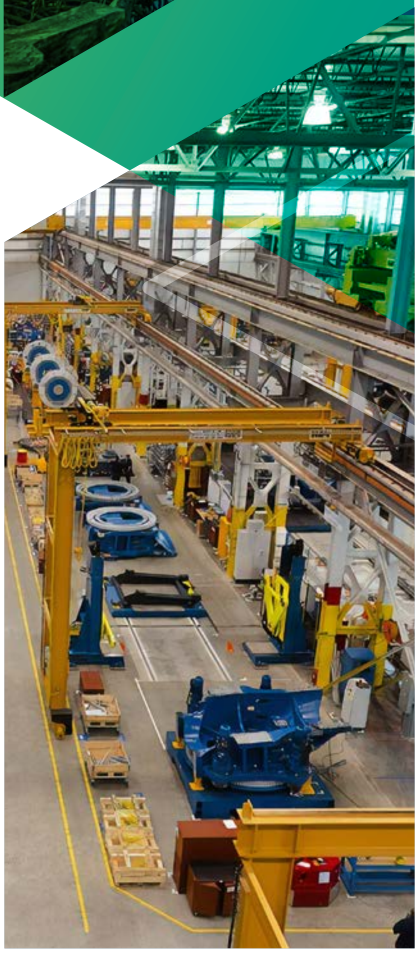

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Agriculture, forests and land use

Natural resources are central to Indonesia's wealth and prosperity, but land use sectors have also produced half to two-thirds of the country's annual GHG emissions over the past 20 years—with disasters such as the 2015 peatland fires causing large spikes in emissions and air pollution. Recognizing the urgent need to protect key ecosystems, the RPJMN 2020–2024 set targets for reforestation, forest protection, peatland and mangrove restoration, and sustainable agriculture.

The net-zero scenarios aim to end all conversion of primary forest to agricultural land by 2025 and scale up forest restoration to 250,000 hectares (ha) per year by 2040, to reach 48.2 million ha of secondary forest in 2060. Peatland restoration would be scaled up to 90,000 ha per year in 2030, rising to 650,000 ha per year in 2038 in NZ2045 (or nearly 400,000 ha in NZ2050 and NZ2060). Mangrove restoration would accelerate to 125,000 ha per year in 2021–2024, then continue at 12,000 ha per year. Peatlands and mangroves are crucial for both carbon storage and resilience, to stem land subsidence due to wetland drainage, reduce flood risks, and protect coastal areas from storm surges and erosion. After reaching their targets, restoration efforts would scale down to maintain those levels and offset any further losses due to economic development.

The net-zero scenarios also aim to expand sustainable agricultural practices to 40% of cropland by 2050, and to slow the rise in demand for land for food production by boosting agricultural productivity and reducing food loss and waste. The latter is a serious and growing problem in Indonesia, with daily losses equivalent to about 618–989 kcal per person, enough to feed 29–47% of the entire population.

Waste management and industry

Reducing food loss and waste would also help reduce GHG emissions from solid waste management. The RPJMN 2020–2024 focused on ensuring proper management of waste, and Vision 2045 also prioritizes circular economy strategies, which a recent Bappenas report showed have many benefits. The net-zero scenarios aim to reduce waste generation per capita by 70% from 2020 levels by the respective net-zero target year. On the same timeline, they aim to increase industrial wastewater recycling, to reach 100%.

Lastly, the net-zero scenarios seek to improve the efficiency of industrial processes and product use (IPPU), with the goal of reducing the emissions intensity of IPPU by a third by the net-zero target year. Though the resulting emission reductions would amount to only 2% of the cumulative abatement achieved by the net-zero scenarios, these efforts can help Indonesia enhance its manufacturing productivity and create new jobs.

Addressing key challenges to achieving net-zero

Committing to achieve net-zero by 2060 at the latest would bring many benefits to Indonesia—the earlier the target date, the better. But it will not be easy. It will require major new policies, changes in investment priorities, and strong collaboration across the government and with international partners and the private sector. Line ministries with very different perspectives will need to embrace a common vision and, in some cases, make substantial changes to programs and policies.

Powerful business interests facing higher costs and/or reduced demand for their products can be expected to push back. Citizens may also resist policies that affect their livelihoods and increase costs of living. Significant efforts will thus be needed to ensure a just and equitable transition.

The COVID-19 crisis has taken a significant toll on Indonesia's economy and on government resources. Unless a net-zero vision is integrated into ongoing recovery efforts, Indonesia could lack the fiscal space for ambitious climate action—and new investments will be needed in any case. There are real capacity gaps as well that will need to be addressed to enable Indonesia's institutions to manage the transition in their respective sectors. Additional expertise will be needed in different ministries, along with reliable data to inform policy-making, technical capacity-building, and enhanced resources.

Along with sector-specific measures, recommendations emerging from this analysis include:

- Commit to a vision of a decarbonized, climate-resilient, sustainable and inclusive Indonesia as the foundation for "building back better" after the pandemic, with a net-zero target consistent with the urgency of the climate crisis.
- Prioritize dialogue across government ministries, and across levels of government (central, regional and local), to ensure a common understanding of the net-zero vision and its implications for public policy and investments.
- Significantly advance the process of institutionalizing the LCDI, including empowering, resourcing and strengthening the capabilities of the LCDI Secretariat, as the agency that coordinates implementation of the low-carbon, green development agenda at both the national and subnational levels.
- Engage stakeholders—including domestic and international businesses, finance sector leaders and civil society—from the outset in the process of translating the net-zero vision into plans.
- Immediately review priority projects and other major expenditures included in COVID-19 recovery and in budget allocations linked to medium- and long-term development strategies, and adjust as needed to ensure that they are aligned with Indonesia's vision for net-zero.
- Seize the immediate opportunities created by international "green recovery" funds through the ADB, the World Bank, and other bilateral or multilateral donors to finance projects to help jump-start key aspects green and low-carbon development.
- Work with development partners to align international finance with Indonesia's net-zero vision and complement domestic public and private finance for LCDI investment needs.
- Assess technical capacity and resource gaps in key ministries and other national institutions engaged in LCDI implementation, prioritize closing those gaps, and build capacity for LCDI implementation at the subnational level as well, including provincial governments and major cities.

Indonesia has made great strides through the LCDI, and even amid the COVID-19 crisis, it has continued to look for opportunities to raise its ambitions. Now is the time to set the country onto a better growth path, starting with a green recovery from the pandemic. By embracing a net-zero target, Indonesia can build a more competitive, sustainable and inclusive economy, secure its natural capital, and ensure a more prosperous and resilient future for its people.

Investment needs and finance options

Transforming Indonesia's economy to achieve net-zero will require shifts in existing investments as well as new financing. The costs of the LCDI pathways would start at around US$20 billion per year in 2021–2022 and average US$150–200 billion per year in 2021–2030 (that is 3.4–4.5% of GDP for the period).

Those figures would represent a significant increase in low-carbon investment, but only about 10% of total projected investment in Indonesia in 2021–2030. Moreover, especially in clean energy, which accounts for 57% of costs in 2021–2030 and about 75% thereafter, those investments would replace large investments in fossil fuel technologies. Still, to ensure a smooth, but rapid transition, additional financing support will be critical, especially in the first decade of implementation.

While today, most of those costs are shouldered by the government—for instance, building power plants—renewable energy and other green technologies already attract substantial private investment worldwide. With appropriate regulatory reforms, as well as de-risking measures such as guarantees, joint operations and public-private partnerships, Indonesia could unlock significant new private finance flows, especially in the late 2020s and early 2030s, when investment needs peak.

Two strategies in the net-zero scenarios would directly contribute to domestic sources of finance: the phase-out of fossil fuel subsidies, and the carbon price, which would generate savings and new revenue, respectively, rising to the equivalent of 2.2% of GDP in 2030 (the peak year) before tapering off as fossil fuels are phased out of the economy. Some of that revenue will be needed for social protection programs and other investments to ensure a just transition, but the balance could finance green infrastructure.

Indonesia's successful efforts to restore and protect forests, peatlands and mangroves, meanwhile, and the very ambitious commitments in the net-zero scenarios, could attract significant finance from REDD+ and from major bilateral and multilateral donors focused on land use emissions. These projects could also be prime candidates for carbon markets, and so could sustainable agriculture initiatives.

All this would still leave large financing gaps, for which other sources of international finance may be needed. Targeted "green recovery" funds set up by the Asian Development Bank, the World Bank and others could help jump-start key projects. As President Widodo has stressed, developed countries also urgently need to scale up climate finance, to meet their commitment to mobilize US$100 billion per year for developing countries. Indonesia will also have to work closely with its development partners, including bilateral donors and multilateral banks, to realign finance flows to advance the net-zero agenda.

1.

A bold vision for Indonesia's post-COVID future

Photo by Tom Fisk via Pexels

When President Joko Widodo signed Presidential Decree No. 18/2020 in January 2020, officially adopting the National Medium-Term Development Plan (RPJMN) 2020–2024, he made history: for the first time ever, Indonesia embraced a vision for a low-carbon, green, climate-resilient pathway to prosperity.[1]

The five-year plan took Indonesia's ambitions to new heights, including 41 priority projects over the period, worth Rp. 7.4 quadrillion (US$540 billion or 10% of the country's GDP during the period)[2] to boost economic growth to 6% per year, build human capital, promote inclusion and sustainability, and put the country on a path to achieving high-income status by 2045, the centennial of its independence—all built on green development strategies.[3]

On 2 March 2020, Indonesia confirmed its first two COVID-19 cases, in West Java.[4] Within 40 days, the virus had spread to all 34 provinces. Within six months, Indonesia had 111,450 confirmed cases and 5,382 fatalities.[5] As of 21 September 2021, the numbers had risen to nearly 4.2 million and over 140,000, respectively.[6]

Indonesia's economy was also hit hard: in December 2019, Indonesia's central bank (BI) had projected upwards of 5.5% GDP growth for 2020,[7] but economic output actually shrank by 2.1%.[8] Before the latest spike in COVID-19, a relatively good recovery was expected in 2021, with projected GDP growth of 4.5–4.8%, though the level of real GDP even in 2025 was still expected to be 5% lower than had been projected before the pandemic.[9] Unemployment rose from 4.94% in February 2020, to 7.07% in August 2020; by February 2021, it was still 6.26%.[10] And the poverty rate, which had dropped into the single digits only in 2018, and reached a historic low of 9.22% in September 2019, rose back to 10.19% in September 2020.

The choices that Indonesia makes as it emerges from the COVID crisis are profoundly consequential. This report, prepared for the Low Carbon Development Initiative (LCDI) as mandated by the Indonesia Vision 2045 report and Indonesia National Mid-Term Development Plan (RPJMN) 2020–2024, explores how embracing a path to net-zero emissions by mid-century could accelerate growth, boost employment, and make Indonesia's economy more robust, resilient, inclusive and sustainable. A green recovery from COVID-19 is a key first step.

Section 1 begins by delving deeper into the global and national impacts of the pandemic, including how Indonesia has responded and how COVID and stimulus measures could affect the achievement of the goals of the RPJMN 2020–2024 and their underlying vision. Next it reviews how national leaders and experts around the world have proposed to "build back better" through green recovery investments, why embracing such a strategy makes sense for Indonesia, and what it might mean in practice.

Section 2 presents new economic modeling of the implications for Indonesia's development goals—and for specific sectors—of embracing a pathway to net-zero greenhouse gas (GHG) emissions by 2045, 2050 or 2060. The scenario analysis includes emission trajectories, GDP growth projections, key policies needed, and the broader economic, social and environmental benefits of implementing such policies.

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[1] Candra, 2020, "Presiden Teken Perpres Tentang RPJMN 2020–2024," *Republika*.

[2] This report presents information and modeling results in both Indonesian rupiah and U.S. dollars. In the modeling, a fixed exchange rate of Rp. 14,550 per US$1 is used, and for simplicity, that same exchange rate is applied throughout the text, even though actual exchange rates have, of course, fluctuated.

[3] Bappenas, 2019, "2020–2024 National Medium-Term Development Plan (Rencana Pembangunan Jangka Menengah Nasional 2020–2024)."

[4] Gorbiano, 2020, "BREAKING: Jokowi Announces Indonesia's First Two Confirmed COVID-19 Cases," *The Jakarta Post*.

[5] Aisyah et al., 2020, "A Spatial-Temporal Description of the SARS-CoV-2 Infections in Indonesia during the First Six Months of Outbreak," *PLOS ONE*.

[6] See Johns Hopkins University COVID-19 Dashboard: https://coronavirus.jhu.edu/map.html.

[7] Bank Indonesia, 2020, "Laporan Perekonomian Indonesia Tahun 2019 (Indonesia Economic Report 2019)."

[8] IMF, 2021, "World Economic Outlook: Managing Divergent Recoveries."

[9] The 4.5% projection, published in April, is from ADB, 2021, *Asian Development Outlook 2021: Financing a Green and Inclusive Recovery.* The 4.8% projection, published in March, and the comparison to pre-pandemic estimates are from IMF, 2021, "Indonesia 2020 Article IV Consultation–Press Release, Staff Report, and Statement by the Executive Director for Indonesia."

[10] Official unemployment ratios do not reflect the significant reduction in labor utilization as a result of the pandemic. Empirical work that supports LCDI indicates that the average number of hours worked per employed person dropped by 21% in 2020 and by 19.3% in 2021.

Section 3 examines the cost of achieving net-zero, including incremental investment needs, as well as their potential fiscal impacts and potential sources of private and international finance.

Section 4 looks more closely at the actions needed to reduce emissions in key sectors, in line with net-zero pathways, focusing on carbon pricing, energy systems, industrial processes and product use, food loss and waste, and forest, peatland and mangrove restoration. It draws on international evidence, sectoral studies, and country-specific analyses to gauge the feasibility of the policies proposed. Section 5 concludes with a discussion of the main challenges in adopting a net-zero pathway in Indonesia, particularly in the context of COVID-19, as well as policy recommendations to address those challenges.

1.1 The economic impacts of COVID-19

The COVID-19 pandemic took an immediate and dramatic toll on the global economy, shutting down entire sectors, disrupting travel and trade, and forcing billions of people to stay home, often with no means of earning income while locked down, or even of securing enough food.

By April 2020, the International Monetary Fund (IMF) reported that the pandemic was "inflicting high and rising human costs worldwide," and projected a sharp global economic contraction in 2020—3%, much worse than during the 2008–2009 financial crisis.[11] In an optimistic baseline scenario, assuming COVID-19 would fade in the second half of 2020 and policy support would help normalize economic activity, the IMF projected global economic growth of 5.8% in 2021.

Yet the pandemic persisted. Case counts continued to soar, exceeding 229 million confirmed cases worldwide as of 21 September 2021, and 4.7 million deaths.[12] Health care systems in many countries were overwhelmed, forcing repeated economic shutdowns and extended restrictions. In October 2020, amid widespread job losses and deepening hunger in many countries, the World Bank projected that 88–115 million people could fall back into extreme poverty due to the pandemic in 2020, and another 23–35 million in 2021, reversing many years of hard-won gains in poverty reduction.[13]

The World Bank also warned of rising inequality, as those with the least resources, such as informal workers, migrant laborers, refugees, and poor and marginalized communities were disproportionately harmed.[14] In January 2021, Oxfam warned that inequality "risks being supercharged," citing a survey of economists in 79 countries and noting that while the wealthiest have already recovered from COVID-related losses, the poor may need 10 years to get back to pre-pandemic conditions.[15]

Around the world, the International Labour Organization (ILO) estimates that 8.8% of working hours were lost in 2020, compared with fourth-quarter 2019 employment levels.[16] This is equivalent to 255 million full-time jobs, and about four times greater than during the 2009 global financial crisis. This translated into US$3.7 trillion in lost job income, or 4.4% of global 2019 GDP. Lower-skilled workers, women and younger people were disproportionately affected by job losses.[17]

Successful pandemic abatement efforts in some countries, coupled with extraordinary levels of policy support to aid vulnerable sectors and populations and stimulate growth, kept the global economic contraction in 2020 to 3.3%,

[12] See Johns Hopkins University COVID-19 Dashboard: https://coronavirus.jhu.edu/map.html.

[13] World Bank, 2020, Poverty and Shared Prosperity 2020: Reversals of Fortune.

[14] World Bank, 2020, Poverty and Shared Prosperity 2020: Reversals of Fortune.

[15] Berkhout et al., 2021, "The Inequality Virus: Bringing Together a World Torn Apart by Coronavirus through a Fair, Just and Sustainable Economy."

[16] ILO, 2021, "ILO Monitor: COVID-19 and the World of Work. Seventh Edition – Updated Estimates and Analysis."

[17] IMF, 2021, "World Economic Outlook: Managing Divergent Recoveries."

Photo by ILO/F. Latief via Flickr

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Photo by ILO/F. Latief via Flickr

though with large differences among countries.[18] Among the ASEAN-5, for instance, Vietnam did best, with 2.9% growth, and Indonesia ranked second with its 2.1% contraction, while Malaysia, Thailand, and the Philippines saw their GDP shrink by 5.6%, 6.1%, and 9.5%, respectively. Projections for 2021 and even 2022 are deeply uncertain, hinging to a great extent on the success of COVID-19 vaccination efforts.

Indonesia is still grappling with the pandemic, with daily case counts dropping sharply over time, but then rising again starting in June 2021 to reach "worst-case scenario" levels by 15 July, when nearly 57,000 cases were recorded.[19] The government has ambitious goals for mass vaccination, and as of 21 September, 125.8 million vaccine doses had been administered, immunizing about 23.2% of the population.[20]

Major investments in social safety-net programs, health care, and economic stimulus have helped mitigate the pandemic's socio-economic impact. Still, unemployment and poverty rates remain elevated and are likely to rise with this latest spike in the pandemic. This calls into question whether Indonesia can still achieve the RPJMN's goal of bringing the poverty count down to 18.34–19.75 million, or 6–7% of the population, by 2024. GDP, which plunged to 5.32% below 2019 levels in the second quarter of 2020, had been rebounding, and was just 0.74% below 2020 levels in the first quarter of 2021.[21] But the setback was enough for Indonesia to be reclassified by the World Bank as a lower-middle-income country.[22]

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[18] IMF, 2021, "World Economic Outlook: Managing Divergent Recoveries."

[19] The "worst-case scenario" assessment was given by Coordinating Minister for Maritime Affairs and Investment Luhut Pandjaitan. See Suroyo and Widianto, 2021, "Grappling with 'Worst-Case Scenario,' Indonesia Faces More COVID-19 Pain," Reuters. Daily case counts have declined since then, but they were still well above 40,000 as of 27 July 2021. See Reuters' Indonesia COVID-19 data dashboard: https://graphics.reuters.com/world-coronavirus-tracker-and-maps/countries-and-territories/indonesia/.

[20] See Johns Hopkins University COVID-19 Dashboard: https://coronavirus.jhu.edu/map.html and Reuters' Indonesia COVID-19 data dashboard: https://graphics.reuters.com/world-coronavirus-tracker-and-maps/countries-and-territories/indonesia/.

[21] BPS, 2021, "Berita Resmi Statistik– 5 Mei 2021 (Official Statistics News– 5 May 2021)."

[22] Hamadeh, van Rompaey, and Metreau, 2021, "New World Bank Country Classifications by Income Level: 2021–2022," *World Bank Data Blog*.

1.2 Indonesia's COVID-19 response and the RPJMN

Even before COVID-19 became widespread across the country, Indonesia's economy began to falter from ripple effects of the global pandemic. With global trade severely disrupted, and international travel halted, business and tax revenue began to drop rapidly. Oil and gas companies were particularly hard-hit, their tax contributions down 29% in the first quarter of 2020, while payments from non-oil and gas firms dropped by 3%.[23]

On 31 March 2020, President Widodo signed the Government Regulation in Lieu of Law (Perpu) on State Financial Policy and Financial System Stability, authorizing three years of increased deficit spending, starting with Rp. 405.1 trillion (US$2.8 billion, or 0.3% of GDP in 2021) for health care, social protection, tax breaks, business loans, and a new National Economic Recovery Program (PEN).[24] Days later, the government raised US$4.3 billion (0.4% of GDP) in the first of several "'pandemic bonds" to finance COVID response.[25]

By the year's end, Indonesia had spent Rp. 579.8 trillion (US$39.8 billion, or 3.7% of GDP) in stimulus and another Rp. 744 trillion (US$52.3 billion, 4.6% of GDP) was budgeted for 2021, of which 53% had been spent by 17 September.[26]

These are massive investments, and to the extent that they directly helped keep Indonesians healthy, safe, and fed, their value is indisputable. However, Energy Policy Tracker estimates that since the start of the pandemic, US$6.54 billion in support for fossil fuel energy had been approved, compared with US$240 million for clean energy.[27] This could undermine Indonesia's vision for a low-carbon, resilient future and the goals of the RPJMN.

Vivid Economics' Greenness of Stimulus Index, which rates the stimulus packages of the G20 economies plus the Nordic countries, Colombia, Switzerland, Spain, Singapore, and the Philippines, ranks Indonesia near the bottom of the pack, noting that it is "pushing environmentally damaging outcomes, by supporting high-carbon industry and energy, and unsustainable agriculture that destroys biodiverse habitats."[28]

The Vivid analysis notes that while Indonesia is making green investments—such as subsidies for rooftop solar and measures to boost renewable energy production—they are eclipsed by high-carbon investments, such as support for "polluting, state-owned enterprises in the energy, industry and transport

[23] Suroyo and Diela, 2020, "UPDATE 1-Indonesia to Expand Tax Breaks to More Sectors to Prevent 'Bankruptcies,'" *Reuters*.

[24] Cabinet Secretariat, 2020, "Press Statement of President of the Republic of Indonesia on Government Regulation in Lieu of Law (Perppu) on State Finance Policy and Financial System Stability"; 2020, "Gov't Issues Fiscal Policy Regulation Amidst COVID-19 Outbreak"; 2020, "President Jokowi Signs Perppu on State Finance Policy, Financial System Stability to Combat COVID-19."

[25] Murdoch, 2020, "Indonesia Raises $4.3 Bln in First 'Pandemic Bond,'" *Reuters*.

[26] Yustina, 2021, "Reviving Investment to Accelerate Economic Recovery," *The Jakarta Post*; CNN Indonesia, 2021. "Dana PEN Baru Terserap 53 Persen per 17 September 2021." *CNN Indonesia*.

[27] See https://www.energypolicytracker.org/country/indonesia (updated 11 August 2021).

[28] Vivid Economics, 2021, "Greenness of Stimulus Index: An Assessment of COVID-19 Stimulus by G20 Countries and Other Major Economies in Relation to Climate Action and Biodiversity Goals (February 2021 Release)."

sectors." Furthermore, Vivid notes, energy subsidies will lower the cost of electricity (84% of which came from fossil fuels as of 2019)[29] and the price of industrial gas.

The Vivid analysis also highlights the Omnibus Bill on Job Creation, approved by Parliament in October 2020, which amends dozens of existing laws, including recentralizing land use and business permitting, relaxing requirements on environmental assessments, and reducing protections for workers. It was framed as an effort to promote investment in Indonesia by making it easier to do business, but Vivid notes that critics have warned of "potentially far-reaching negative consequences for nature and climate alike."

A group of major investors has raised the same concern, warning that the new law could hinder Indonesia's ability to meet its Nationally Determined Contribution (NDC) under the Paris Agreement.[30] They also worried that weakening regulations would hamper the existing progress in environmental protection and restoration efforts, which pose significant risks to their portfolios and the economic and social health of the country. Several other institutions within Indonesia and globally, including Moody's Investors Service and the IMF, have expressed similar views.[31] This means that the Omnibus Bill's approach to attracting capital could potentially discourage some investors instead.

A key question for Indonesia now is, does the current set of stimulus investments and policies align with the RPJMN 2020–2024, and with the long-term vision for a low-carbon, resilient, and inclusive Indonesia that underpins the five-year plan?

In laying out its development agenda, the RPJMN 2020–2024 highlighted the urgency of action through examples of where Indonesia is headed:

Forest cover is projected to decrease

from **50%** of Indonesia's land (93.4 million ha) **in 2017**

to only **45%** of Indonesia's land (84.7 million ha) **in 2045**

Water scarcity on the islands of Java, Bali, and Nusa Tenggara is set to increase, with the share of the country facing a water crisis expected to grow

from **6.0%** **in 2000**

to **9.6%** **in 2045**

Water quality is also expected to decline significantly

The ideal habitat area for endangered species in Sumatra, Java, Kalimantan, and Sulawesi is set to shrink

from **80.3%** **in 2000**

to **49.7%** **in 2045**

Photo by Nanang Sujana/CIFOR via Flickr

Photo by Ryan Woo/CIFOR via Flickr

[29] See International Energy Agency data: https://www.iea.org/countries/indonesia.

[30] Green Century, 2020, "Open Letter on the Omnibus Bill on Job Creation."

[31] Jong, 2020, "Indonesia's Omnibus Law a 'Major Problem' for Environmental Protection," *Mongabay*.

Photo by Moses Ceaser/CIFOR via Flickr

The restoration of forests, peatlands, and mangroves—all major carbon sinks and providers of a wealth of ecosystem services—is Indonesia's greatest opportunity to use its status as a "carbon superpower" to advance its development goals. Healthy forests are also key to supporting rural livelihoods, ensuring food security, providing clean water and hydroelectric power generation, and preventing disasters. This is why the government has set out to stop forest loss and created what is now the Peatland and Mangrove Restoration Agency.[32]

The stakes are very high for Indonesia's ability to meet its Paris commitments: The 2015 peatland fires alone, for example, emitted an estimated 1.75 Gt CO_2e and sharply increased air pollution;[33] coastal peatland subsidence is also causing an estimated 5 cm of subsidence per year nationwide, exacerbating what are already major flood risks.[34] Making it easier to convert land in order to attract investors could thus cost Indonesia far more than any near-term economic stimulus it yields.

Indonesia has also recognized the perils of fossil fuel dependency—both from a climate perspective, and because fossil fuel markets are so volatile, as the world was reminded amid the COVID crisis. This is why President Widodo, addressing the National Development Planning Conference (Musrenbangnas) in April 2020, said the country "must devise strategies to reduce dependence on fossil energy," pointing to bioenergy, battery technologies and renewable energy generation as solutions.[35] Yet, despite investments in renewables, the stimulus package promotes greater fossil fuel use.

It is also crucial to consider how the 89 priority infrastructure projects announced in June 2020, valued at an estimated Rp. 1.422 quadrillion (US$98.14 billion), fit with Indonesia's long-term vision. President Widodo has described them as building "civilization":[36] major railway projects, roads, bridges, dams, irrigation systems, projects, water and energy supply infrastructure, seaports and airports, industrial zones, and more.[37] Much of this work could be transformational, but without due care, much of it could also drive up fossil fuel use, accelerate land conversion, and deepen socio-economic inequalities.

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[32] Jong, 2021, "Indonesia Renews Peat Restoration Bid to Include Mangroves, but Hurdles Abound," *Mongabay*.

[33] See Global Fire Emissions Database: http://www.globalfiredata.org/updates.html#2015_indonesia. It is important to note that there is "substantial uncertainty" about this estimate, but it is provided as an indication of the severity of the fires.

[34] Bappenas, 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia."

[35] Cabinet Secretariat, 2020, "Musrenbangnas Must Be Adaptive to Current Situation, President Jokowi Says."

[36] Cabinet Secretariat, 2021, "President Jokowi: Infrastructure Development to Build Civilization, Increase Competitiveness."

[37] Mufti, 2020, "Indonesia to Develop 89 New 'Strategic' Projects in 2020–2024," *The Jakarta Post.*

Box 1.

The RPJMN 2020–2024: First steps towards transforming Indonesia

The RPJMN 2020–2024, the last phase of the National Long-Term Development Plan (RPJPN), 2005–2024, aims to achieve prosperous, fair, and sustainable development by 2024. It prioritizes accelerating the development of human capital, improving infrastructure and connectivity, simplifying regulations and bureaucracy, and promoting economic transformation. It also includes GHG emission reduction as a key macro-economic indicator alongside GDP growth, poverty reduction and employment.

To close the infrastructure gap, the plan calls for US$450 billion in infrastructure investments. Forty-one Major Projects are outlined with clear targets and implementing agencies, which involve ministries, institutions, local governments, state-owned enterprises, and community and business entities.

Though the RPJMN 2020–2024 is the first five-year plan to incorporate the vision of the Low Carbon Development Initiative (LCDI), it does not yet seek to fundamentally change Indonesia's trajectory but starts by accelerating progress towards key goals.[38] To this end, it outlines a detailed agenda on improving environmental quality, boosting resilience to disasters and climate change, and promoting low-carbon development.

Targets for 2024 for these priorities are:

- Increasing the Environmental Quality Index (IKLH) score from 66.56 in 2019 to at least 75 out of 100, which requires that the Water Quality Index (IKA) increases from 47.0 in 2019 to 55.50; the Seawater Quality Index (IKAL) reaches 60.50; the Air Quality Index improves from 86.8 to 84.5; and the Land Cover Quality and Peat Ecosystem Index (IKL) rises from 60.6 to 65.5.[39]
- Improving disaster and climate resilience, so that GDP loss as a result of disaster and climate impacts decreases by 1.25% of GDP compared to 2018 losses.
- Pursuing low-carbon development, so that GHG emissions are reduced across various sectors from 22.6% under business as usual (BAU)[40] in 2019 to 27.3% under BAU, consistent with Indonesia's unconditional NDC emission reduction target.[41] The GHG emissions intensity of the economy would be reduced from 22.8% under BAU in 2019 to 24% under BAU.

Due to the COVID-19 pandemic, the national priority targets for 2024 under the RPJMN have been updated in the Bappenas Government Workplan for 2021 (Perpres No. 86, 2020):

- The target score for the Environmental Quality Index has now been reduced from 75 to 69.74.
- Reductions for disaster-related GDP loss targets have dropped from 1.25% of GDP to 1.15%. Recent projections estimate losses of 0.1% of GDP by 2024 due to increased seismic activity in 2020, in addition to the impact of the pandemic.[42]
- The GHG emission reduction target has dropped to 26.35% under BAU by 2024. However, a more ambitious emission intensity reduction target has been set, at 29.91% below BAU by 2024.

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[38] ADB, 2020, Indonesia: Country Partnership Strategy (2020–2024).

[39] All environmental quality index scales were developed by the Government of Indonesia, with values ranging from 0 to 100 (100 being the best), except the air quality index, developed by the EU, in which 100 represents the worst quality and 0 the best. See https://www.menlhk.go.id/site/post/124.

[40] Baseline is derived from the Plan for Greenhouse Gas Emissions Reductions (RAN-RAD GRK 2010–2014). Bappenas, 2012, "Laporan_Satu_Tahun_Pelaksanaan_RAN-GRK_RAD-GRK.Pdf." Emissions reductions had exceeded annual targets in 2019.

[41] Republic of Indonesia, 2016, "First Nationally Determined Contribution."

[42] Astutik, 2021, "Jangan Remehkan! Luhut: PDB Tergerus 0,10% Akibat Bencana," *CNBC Indonesia*.

Photo by Dominik Vanyi via Unsplash

Photo by Arya Manggala via Flickr

1.3 Why Indonesia must build back better

Indonesia has experienced many disasters over the decades, so Indonesians understand a core principle of disaster recovery very well: build back better. If a typhoon has wiped out a village, an earthquake crumbled a bridge, or flash floods ruined vital infrastructure, it is not good enough to rebuild them as they were—they have already proven to be inadequate. They must be replaced with something more resilient.

The COVID-19 crisis has shown how fragile countries' economies and social structures are, and how quickly many years of development progress can be unraveled. Recognizing that climate change poses equally serious or worse threats, many political leaders, economists, scientists and advocates have called for pandemic recovery policies to also build back better, both to mitigate climate risks, and to ensure that societies are more resilient to whatever shocks come their way.

Warnings of the threats posed by climate change keep mounting. In April 2021, a report by the insurer Swiss Re showed that if countries meet their current NDC commitments under the Paris Agreement, the world could still be 2.0–2.6°C warmer by mid-century, relative to pre-industrial levels.[43] The resulting climate change impacts would reduce global GDP by 11–14%.

Even if the Paris targets are met, climate impacts from past emissions would still reduce global GDP by about 4% relative to a world with no further climate change, the report notes. If, on the other hand, climate action stalls—a real risk as many countries alter their plans due to COVID—global warming could reach 3.2°C, and the resulting impacts would shrink global GDP by 18%.[44]

Whichever path the world takes, members of the Association of Southeast Asian Nations (ASEAN) have the most at stake, the analysis found, with potential GDP losses of 37.4% with 3.2°C of warming. In Indonesia, if warming is kept well below 2°C, GDP losses are projected to be on par with the global average, 4.0% by mid-century, but at 2.0–2.6°C, the losses would rise to 16.7–30.2%, and at 3.2°C, they would reach 39.5%.[45]

The combination of potential GDP impact, risks from slow-onset climate change impacts and extreme events, and adaptive capacity resulted in Indonesia being ranked the most vulnerable among 48 countries analyzed (Malaysia, the Philippines, India, and Thailand rounded out the top five). The report noted:
"Indonesia is exposed to the full gamut of physical risks emanating from climate change effects, including sea level rise. Both dry and wet weather extremes could impact agriculture yields, and heat stress may weigh on labour productivity. More extreme weather conditions will also take their toll on the tourism sector. The level of adaptive capacity is among the lowest of the sample countries, adding to Indonesia's vulnerability to climate change."[46]

[43] Swiss Re Institute, 2021, "The Economics of Climate Change: No Action Is Not an Option."
[44] Swiss Re Institute, 2021, "The Economics of Climate Change: No Action Is Not an Option."
[45] Swiss Re Institute, 2021, "The Economics of Climate Change: No Action Is Not an Option."
[46] Swiss Re Institute, 2021, "The Economics of Climate Change: No Action Is Not an Option." p. 19.

ASEAN countries increasingly recognize the urgency of climate action, and the ASEAN Comprehensive Recovery Framework for COVID-19 identifies “advancing towards a more sustainable and more resilient future” as its key goal, noting that a return to business as usual may no longer be an option.[47] The framework thus calls for “achieving sustainability in ASEAN in all dimensions” Specific measures include facilitating the energy transition; investing in sustainable transportation; building “smart green cities”; promoting sustainable and responsible investment in food, agriculture and forestry; and strengthening disaster risk reduction and management, among others.[48]

Yet climate resilience is only one of multiple benefits of a green recovery. In a brief urging Southeast Asian nations to adopt green stimulus policies, the Asian Development Bank (ADB) also noted the strong links between the environment and public health, the need to boost the region’s competitiveness in a global market that increasingly demands green practices and products, and the much-greater job creation potential of green investments.[49]

The ADB brief cited a peer-reviewed global analysis[50] showing that every US$1 million spent on renewable energy creates an average of 7.5 full-time jobs, and in energy efficiency, 7.7, while the same investment in fossil fuels would produce only 2.7 jobs. Likewise, the ADB noted, investing in nature-based solutions can provide a “job-intense economic and resilient recovery” and also help advance the Sustainable Development Goals (SDGs).

An analysis by the International Finance Corporation found that in 21 emerging markets, including Indonesia, a green recovery has the potential to generate US$10.2 trillion in investment opportunities and 213 million jobs—and also reduce emissions by 4 billion tonnes of carbon dioxide equivalent (Gt CO_2e) by 2030.[51] A global survey of experts, including senior officials from finance ministries and central banks found that green projects are widely perceived to be capable of creating more jobs,[52] delivering higher short-term returns, and increasing long-term cost savings more than traditional fiscal stimulus.[53] Economic analyses have reinforced that message for the United States, the United Kingdom, the European Union, Japan and other countries.[54]

Within cities in particular, the Coalition for Urban Transitions has identified seven priority areas for green recovery investments with strong job creation potential—double to nearly 10 times as much as equivalent fossil fuel or “gray infrastructure” investments—as well as long-term economic benefits: green construction and retrofits, clean mobility, renewable energy, active transport, nature-based solutions, circular-economy approaches to waste, and research and development for clean technology.[55]

Targeted international funding is available to support a green recovery. In March 2021, the ADB announced that US$300 million had been allocated from the Green Climate Fund for the ASEAN Catalytic Green Finance Facility Green Recovery Program.[56] It aims to catalyze financing from development partners and private sources for more than US$4 billion worth of green infrastructure projects, with priority given to projects in Indonesia, Cambodia, Lao PDR and the Philippines. There are other funding sources as well, such as the Climate Support Facility launched by the World Bank in December 2020, with US$52 million provided by Germany, the UK, and Austria.[57] This is a prime opportunity.

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[47] ASEAN, 2020, “ASEAN Comprehensive Recovery Framework.”

[48] ASEAN, 2020, “ASEAN Comprehensive Recovery Framework Implementation Plan.”

[49] Lim, Ng, and Zara, 2021, “Implementing a Green Recovery in Southeast Asia.”

[50] Garrett-Peltier, 2017, “Green versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-Output Model,” *Economic Modelling.*

[51] IFC, 2021, “Ctrl-Alt-Delete: A Green Reboot for Emerging Markets.”

[52] Hepburn *et al*., 2020, “Will COVID-19 Fiscal Recovery Packages Accelerate or Retard Progress on Climate Change?,” *Oxford Review of Economic Policy.*

[53] Pollitt, 2020, “Assessment of Green Recovery Plans after COVID-19.”

[54] See, e.g., Gunn-Wright *et al*., 2020, “A Green Recovery: The Case for Climate-Forward Stimulus Policies in America’s COVID-19 Recession Response”; Pollitt, 2020, “Assessment of Green Recovery Plans after COVID-19”; CISL, 2020, “Maximising the Benefits: Economic, Employment and Emissions Impacts of a Green Recovery Plan in Europe.”

[55] Gulati *et al*., 2020, “The Economic Case for Greening the Global Recovery through Cities: 7 Priorities for National Governments.”

[56] ADB, 2021, “$300 Million from Green Climate Fund to Support ADB’s First Green Recovery Program in Southeast Asia,” Asian Development Bank – News Releases, 300.

[57] World Bank, 2020, “The Climate Support Facility.”

1.4 Green stimulus measures and climate ambition around the world

Many countries have already adopted net-zero targets, recognizing that ambitious climate action can deliver better and stronger growth. As of September 2021, 52 parties representing 63 countries and 54.2% of global GHG emissions had communicated net-zero targets, either through laws or public policies, or in political pledges: from the European Union, to Brazil, to Japan, South Korea and China.[58]

Many companies, financial institutions and organizations have adopted net-zero targets as well—most prominently, through the United Nations-led Race to Zero, a global campaign to rally leadership and support from businesses, governments and investors.[59] The campaign has grown to include more than 3,000 businesses, 173 of the world's top investors, more than 622 higher education institutions, and hundreds of local, regional and national governments.

The finance sector in particular is rapidly shifting away from high-carbon infrastructure, as investors increasingly see the risks of these assets being prematurely stranded. The Glasgow Financial Alliance for Net-Zero brings together over 160 firms, together responsible for assets in excess of $70 trillion, from the leading net-zero initiatives across the financial system to accelerate the transition to net-zero emissions by 2050 at the latest, with many more rapidly joining.[60]

However, governments' investments in COVID response and recovery are not yet putting us on the path to achieve these ambitious new targets. COVID-related spending around the world has been very mixed, and in most countries, it supports the fossil fuel-powered economy of the past more than a green recovery. A World Resources Institute analysis found that of the stimulus measures announced by 66 economies in 2020, only 27% explicitly incorporated physical climate risk or resilience, and another 14% included emissions reductions.[61] Only China, France, the UK and the EU featured both adaptation and mitigation elements in their stimulus packages.

Similarly, a UN and Oxford University study of the world's top 50 economies, published in March 2021, found that in 2020, they collectively announced US$17 trillion in new spending to address the crisis—US$14.6 trillion excluding European Commission funds not yet allocated to a Member State. Of the latter, US$11.1 trillion went to immediate rescue efforts, and US$1.9 trillion to long-term recovery (the rest was deemed "unclear").

Of the recovery investments, only US$341 billion, or 18%, went to green projects, with South Korea, Spain, the UK, and Germany leading the way. As a share of total COVID spending, green stimulus was only 2.5%.[62] The report found that Indonesia (and fellow ASEAN members Singapore and Vietnam) had spent less than 0.1% of GDP on recovery investments. As countries contain the pandemic and are able to shift their focus to rebuilding their economies, however, spending patterns may shift. There is already some evidence of increased green investments in more recent stimulus and recovery packages.[63]

In thinking about Indonesia's recovery, it may be helpful to consider how other countries are trying to "build back better." Box 2 provides some examples.

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[58] See Climate Watch's Net-Zero Tracker: https://www.climatewatchdata.org/net-zero-tracker and the Energy & Climate Intelligence Unit's "Net Zero Emissions Race" website: https://eciu.net/netzerotracker.

[59] See the Race to Zero website: https://unfccc.int/climate-action/race-to-zero-campaign (accessed 23 July 2021).

[60] See https://unfccc.int/news/new-financial-alliance-for-net-zero-emissions-launches.

[61] Krishnan and Brandon, forthcoming, "Are COVID-19 Stimulus Packages Building Climate Resilience? An Analysis of 66 Countries."

[62] O'Callaghan and Murdock, 2021, "Are We Building Back Better? Evidence from 2020 and Pathways for Inclusive Green Recovery Spending."

[63] OECD, 2021, "The OECD Green Recovery Database: Examining the Environmental Implications of COVID-19 Recovery Policies."

Box 2.
Green recovery efforts around the world

As governments have looked beyond COVID-19 crisis response to recovery, some have seized the opportunity to jump-start ambitious green and low-carbon investments. Here are some examples:

The **European Union**, which unveiled its European Green Deal,[64] a plan to reach carbon neutrality by 2050, just before the pandemic, has specified that 30% of both its €750 billion recovery package, Next Generation EU, and the EU's €1.074 trillion 2021–2027 budget, must advance climate objectives.[65] This includes investments in green technologies, restoring natural capital and building resilience, as well as support for a just transition for fossil fuel-dependent regions. All loans and grants to Member States will also include "do no harm" environmental safeguards.

In July 2020, **South Korea** President Moon Jae-in unveiled a plan for a KRW 160 trillion (US$133 billion) "K-New Deal" with two main pillars: the Digital New Deal and Green New Deal. The Green New Deal, for which Korea has committed KRW 73.4 trillion (US$60.9 billion) by 2025, is expected to create 659,000 jobs through investments in a green transition for infrastructure, low-carbon and decentralized energy supply, and green industries. It aims to grow solar and wind capacity from 12.7 GW in 2019 to 42.7 GW by 2025;[66] invest in smart grids;[67] rebuild or refurbish public rental housing and schools to be energy-efficient and eco-friendly; build 25 smart green cities and city forests; add 1.13 million electric vehicles (EVs) and 200,000 fuel cell cars, with supporting infrastructure and to transform the economy for the post-COVID-19 era. President Moon called the Green New Deal a preemptive response to "a desperate reality" and noted that the COVID crisis had "reaffirmed the urgency" of climate action.[68]

Japan, which for years had lagged behind on climate action, pledged in late 2020 to achieve net-zero by 2050 and launched a 2 trillion yen (about US$19 billion) fund to promote ecological businesses and innovation to achieve its goal of zero net carbon emissions by 2050.[69] In December 2020, Japan followed up with a Green Growth Strategy that aims to generate US$2 trillion in new investment, with targets for 14 industries, including plans to bolster renewables and hydrogen and a call for auto industries to eliminate fossil-fueled vehicles by the mid-2030s.[70]

China has made massive investments in COVID-19 recovery, with about RMB 4.9 trillion in fiscal measures (about US$756 billion, or 4.7% of GDP), announced as of June 3, 2021, of which an estimated RMB 4.2 trillion was implemented in 2020.[71] Among the highlights are about $14.2 billion for surface transportation, including national railway projects, and water conservancy; about US$1.6 billion to extend a subsidy for EVs by two years, about US$1.4 billion to expand the country's EV charging network by 50%.[72] The Chinese government also raised its wind and solar energy targets for 2020 to 240 GW each, from 210 and 110 GW, respectively, and ended 2020 with 136 GW of new renewable capacity.[73] In addition, a new RMB 88.5 billion (US$12 billion) Green Development Fund will invest in environmental protection, pollution control, green space, energy conservation, and more.[74]

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[64] See https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

[65] Council of the European Union, 2020, "EU Budget 2021–2027 and Recovery Plan."

[66] J.-H. Lee and Woo, 2020, "Green New Deal Policy of South Korea: Policy Innovation for a Sustainability Transition," *Sustainability*.

[67] H. Lee, 2020, "Green New Deal to Reduce Economic Dependence on Carbon," *Republic of Korea – Cheong Wa Dae* (blog).

[68] Moon, 2020, "Keynote Address by President Moon Jae-in at Presentation of Korean New Deal Initiative," Republic of Korea – Speeches and Remarks.

[69] Yamaguchi, 2020, "Japan PM Pledges $19B to Promote Ecological Businesses," *Associated Press*.

[70] Yamaguchi, 2020, "Japan Adopts Green Growth Plan to Go Carbon Free by 2050," *Associated Press*.

[71] See the IMF "Policy Responses to COVID-19" tracker: https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19.

[72] See OECD Green Recovery Database: https://www.oecd.org/coronavirus/en/themes/green-recovery#Green-recovery-database.

[73] IRENA, 2021, "World Adds Record New Renewable Energy Capacity in 2020," International Renewable Energy Agency Newsroom.

[74] OECD, 2021, "The OECD Green Recovery Database: Examining the Environmental Implications of COVID-19 Recovery Policies."

New Zealand's COVID response package includes a wide range of measures combining socio-economic goals with environmental benefits: from efforts to prevent food waste, to building drought resilience among rural and fishing communities, to support for energy retrofits for low-income households, to biodiversity and conservation projects, to improving the health of waterways. A 3 billion NZD (about US$2.15 billion) Infrastructure Investment Fund includes support for hydrogen vehicles and fueling stations;[75] projects to make land more resilient to soil erosion, flooding, and other extreme weather events;[76] public transport; and walking and cycling infrastructure.[77]

Chile has boosted public investments by US$4.5 billion, to a total of US$34 billion for 2020–2022.[78] The government also committed itself to having 30% of funded projects contribute to accelerating Chile's climate transition,[79] in line with its NDC. Sustainability-focused projects include water management (including flood control and drought resilience), green urban mobility, reforestation and wildfire management, urban greening, resilient public infrastructure, and sustainable local development.

[75] Woods, 2021, "Government Supports More Low Emission Vehicle Options," New Zealand Government – Press Releases.

[76] Peters and Jones, 2020, "Climate Resilience Packages for Regions," New Zealand Government – Press Releases.

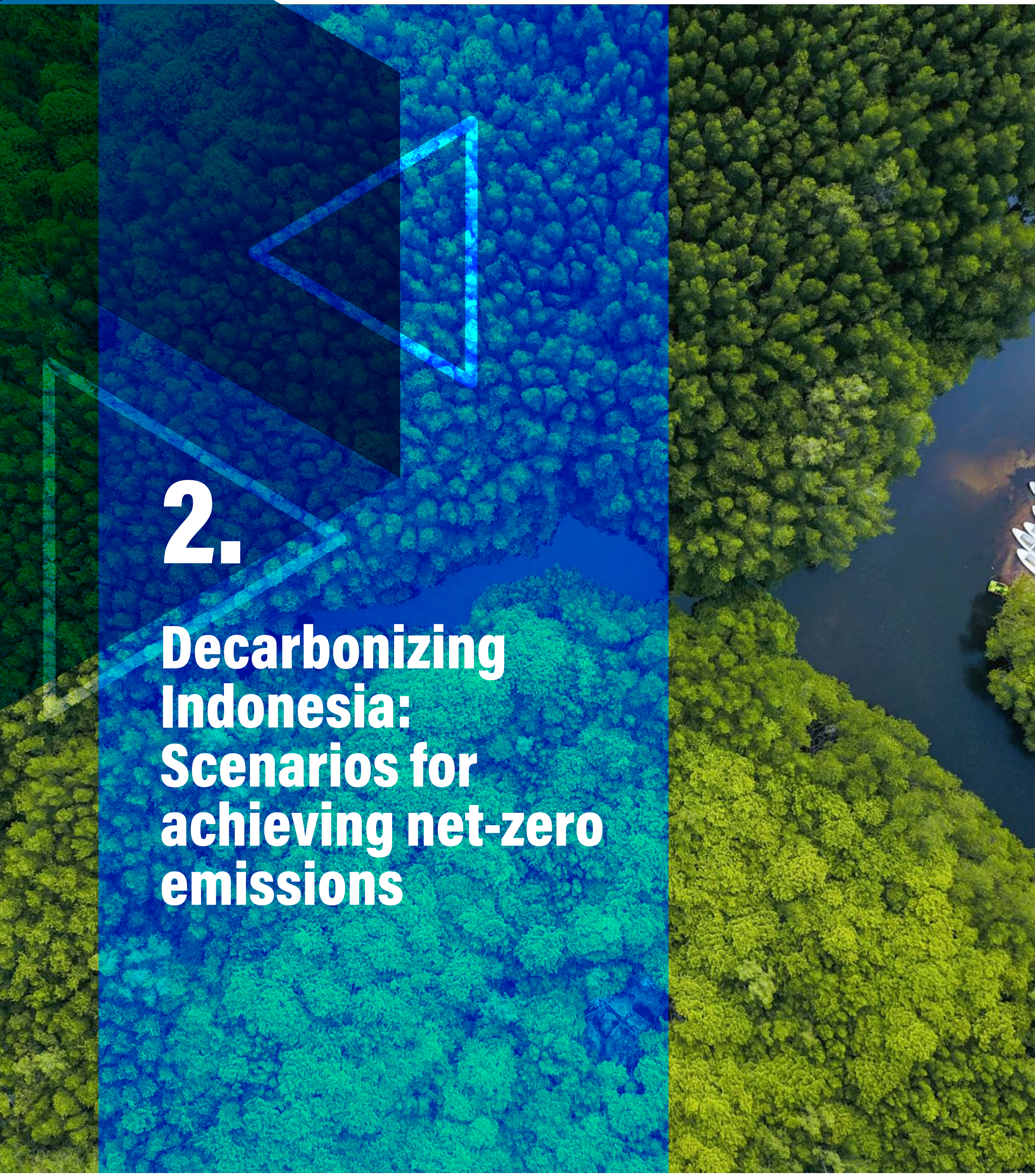
[77] Twyford and Genter, 2020, "Auckland Transport Infrastructure Revealed," New Zealand Government – Press Releases.

[78] See https://www.gob.cl/chileserecupera/.

[79] See https://www.gob.cl/chileserecupera/sustentabilidad/.

As Indonesia looks to a post-COVID future, it has a clear choice: It can continue business as usual or even roll back progress, as many countries have, or it can seize this unprecedented opportunity to use the COVID recovery to catalyze transformative change. With Indonesia taking on the G20 Presidency in 2022, a net-zero commitment can also demonstrate strong leadership on climate and inspire others to raise ambition, including through climate finance.

This is more than an environmental policy choice—the actions needed to achieve net-zero in Indonesia would also end dependency on volatile fossil fuel markets and protect natural capital, securing the country's place as a "carbon superpower." Most important, as outlined in the next section, this is a chance to put Indonesia on a path to robust, sustainable growth, built on the technologies and green practices that will dominate the economy of the future.



2. Decarbonizing Indonesia: Scenarios for achieving net-zero emissions

Photo by Joel Vodell via Unsplash

In 2019, the LCDI completed a scenario analysis to inform the RPJMN 2020–2024.[80] It showed that low-carbon development could deliver GDP growth averaging 6% per year until 2045, help accelerate poverty reduction, boost job creation, and unlock many other economic, social and environmental benefits. This section provides an update to the empirical work that supports LCDI, reflecting significant changes in the policy context since the RPJMN was approved.

First of all, the COVID-19 pandemic has delivered a major economic shock that, as noted earlier, will result in lower-than-expected rates of economic growth relative to pre-pandemic estimates. Total estimated GHG emissions are expected to decrease accordingly, even if LCDI policies are not implemented. As a result, it becomes important to generate a new Reference Case against which LCDI policies can be assessed.

Second, net-zero is becoming an important topic in public policy discussions—globally, but also increasingly within Indonesia. More than five years into the Paris Agreement, policy-makers, business leaders and advocates around the world are thinking more about how to meet the pact's long-term goal of net-zero emissions by mid-century, and adopting their own net-zero targets.

In July 2021, Indonesia submitted an updated NDC and a Long-Term Strategy (LTS) that maintain existing targets to 2030, but increase ambition post-2030 and in adaptation.[81] The country aims to reduce emissions to 540 million tonnes CO_2e by 2050, continuing to decline to reach net-zero by 2060 or sooner. The targets reflect a number of decarbonization efforts already being advanced by various agencies.

At a virtual summit hosted by U.S. President Biden in April 2021, President Widodo welcomed the new targets by many and reaffirmed Indonesia's own commitment to climate action, but noted that developing countries need credible commitments and real support from developed countries to fully realize their own climate ambitions.[82] Though no formal pledges have been made, as reflected in the new NDC and LTS, several institutions, including Bappenas, are already advancing efforts to identify potential net-zero pathways that are consistent with national development goals. This report is part of those efforts.

Third, the green and low-carbon measures included in the RPJMN 2020–2024, which matched the LCDI "Moderate Scenario," were designed to meet Indonesia's unconditional NDC pledge, a 29% reduction in GHG emissions by 2030 relative to the baseline level,[83] but not to keep escalating ambition. As a result, GHG emissions would continue to rise, from 1.8 Gt CO_2e in 2030, to nearly 3.5 Gt CO_2e by 2050. The updated NDC indicates a number of approaches that can help strengthen ambition towards the higher end of the range instead, as will be needed to achieve net-zero emissions by 2060 or sooner.

An assessment of the viability and impacts of higher ambition, including post-2030, is thus needed. It is important to identify ways to ramp up the ambition of existing measures as well as new interventions that could further reduce emissions, boost job creation, advance Indonesia's medium- and long-term development goals, and build resilience to climate change and other shocks.

[80] Bappenas, 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia."

[81] Republic of Indonesia, 2021, "Updated Nationally Determined Contribution"; 2021, "Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Indonesia LTS-LCCR 2050)."

[82] Cabinet Secretariat, 2021, "President Jokowi Addresses Three Issues on Climate Change."

[83] Republic of Indonesia, 2016, "First Nationally Determined Contribution."

2.1 The revised Reference Case and the net-zero scenarios

This section presents an updated Reference Case and three new scenarios examining the implications of adopting more ambitious measures than those in the RPJMN 2020–2024 to enable Indonesia to achieve net-zero GHG emissions by 2045, 2050 or 2060.[84]

The target year 2045 is modeled because it is the centennial of Indonesia's independence—and the year by which the country has set out to become a high-income country. The year 2050, meanwhile, is the most widely used in national, institutional and corporate targets being set around the world (see Box 1). The year 2060 is the late end of what is considered "mid-century" and has been discussed as a possible target in ongoing policy dialogues within Indonesia.

Recognizing the large and continuing impacts of COVID-19, all the scenarios modeled incorporate epidemiological modeling, calibrated using Indonesia-specific data, to project infection and mortality rates, including the impact of vaccinations. They also factor in the use of public resources to expand health care and social safety nets and provide economic relief; the ongoing economic effects of the pandemic and related disruptions; and investments in medium- and long-term recovery, as well as supporting policies.[85]

2.1.1 Reference Case: The costs of inaction

The Reference Case is a scenario in which Indonesia advances no further policy efforts—beyond plans and projects already in the pipeline—to green its infrastructure, protect natural capital, or reduce GHG emissions by improving energy efficiency, shifting to clean energy sources, embracing sustainable transport solutions, or reducing waste. It does, however, reflect the impact of COVID-19 responses in Indonesia to date, including additional social protection, support to businesses, and the relaxation of environmental regulations, including through the Omnibus Law (see Section 1.2).

We avoid the term "business as usual" because in reality, climate change and the degradation and depletion of natural capital associated with the current economic model are likely to disrupt economic activities and impose large new costs over the next few decades. A prime example is the severe land subsidence in Jakarta, referred to as the "fastest-sinking city in the world"—a problem caused, to a great extent, by wetland drainage and groundwater over-abstraction.[86] Without a green recovery from the pandemic and a substantive low-carbon policy agenda that includes system-changing green interventions, "business as usual" will increasingly become infeasible.

The modeling reflects the economic impact of the depletion and degradation of natural capital as a reduction in carrying capacity—that is, the availability of environmental goods and services to support economic activity.[87] The LCDI scenarios include several variables representing the quantity and quality of those environmental goods and services. They are connected to functional forms for output generation (GDP) via total factor productivity (TFP).[88]

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[84] The RPJMN 2020–2024 scenarios ran through 2050, but their presentation focused on results for 2020–2024 and for 2030, with some mentions of results in 2045 (the centennial of Indonesia's independence) or 2050. The new scenarios presented in this report extend to 2070, with results presented mainly for 2021–2060.

[85] For a more detailed discussion of how COVID-19 was incorporated in the model, see Appendix A4.

[86] Erkens *et al*., 2015, "Sinking Coastal Cities," Proceedings of the International Association of Hydrological Sciences; Lin and Hidayat, 2018, "Jakarta, the Fastest-Sinking City in the World," *BBC News.*

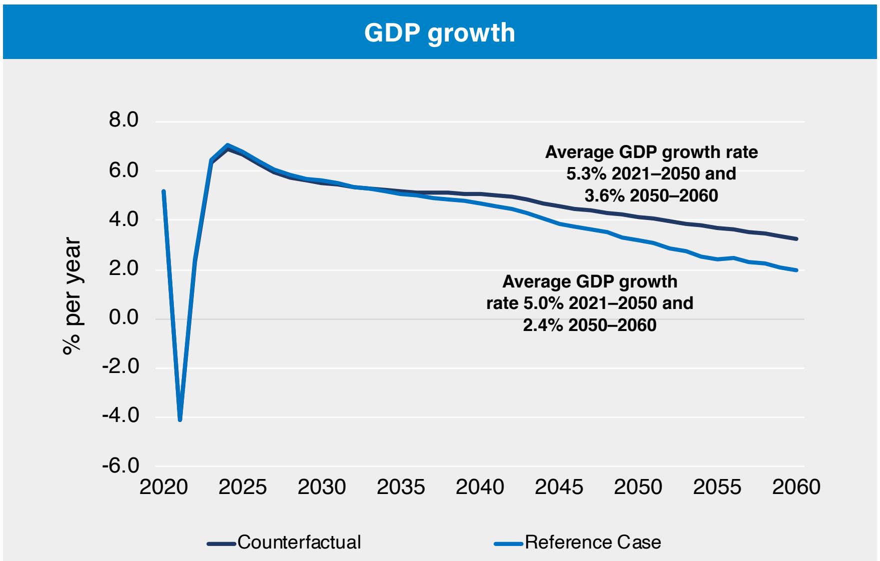
[87] In life sciences, the common definition of carrying capacity refers to the number of living organisms that can be sustained by resources available in a given system. In the context of LCDI, the concept is applied to economic activity in line with the insights of Limits to Growth, the groundbreaking 1972 analysis. See Meadows, Randers, and Meadows, 2004, *The Limits to Growth: The 30-Year Update.*

[88] Total factor productivity (TFP), also known as multi-factor productivity, is a measure of the output of an economy (or industry) relative to the inputs that went into it (such as capital and labor). If outputs are growing faster than inputs, TFP is improving; the opposite means it is declining. For a succinct explanation, see the glossary of the Asian Productivity Organization: https://www.apo-tokyo.org/resources/p_glossary/total-factor-productivity-2/.

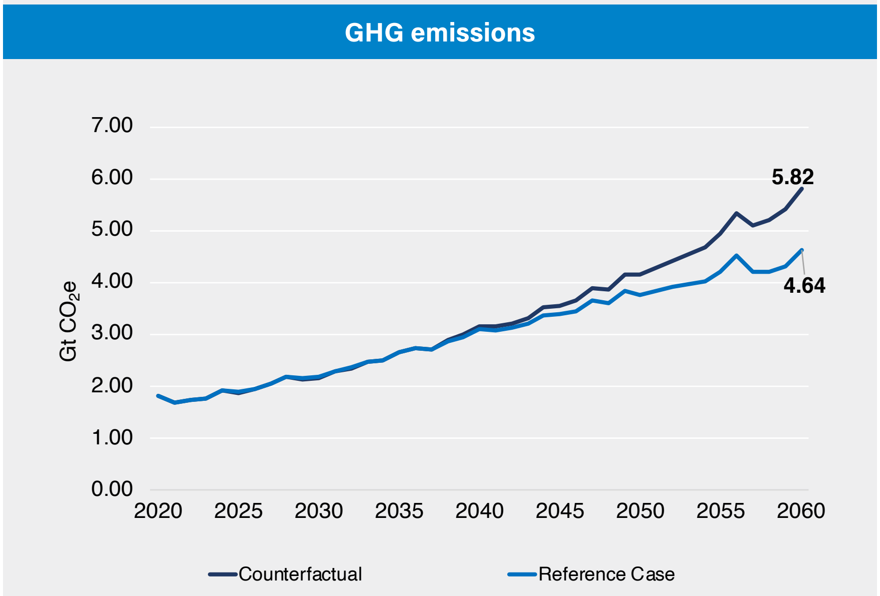
In particular, the variables included are the social cost of carbon,[89] the effects of air pollution, habitat quality, residential and industrial waste, and changes in energy prices that partly reflect availability of energy resources. Incorporating these factors makes it possible to analyze the extent to which failing to act on climate and the environment imposes a burden on Indonesian society. The result is a more accurate baseline against which to evaluate the net-zero scenarios, which also incorporate measures of carrying capacity.[90] Appendices A1 and A3 provide a more detailed technical discussion on the modeling.

For transparency, a second version of the Reference Case was also developed that does not take into account potential changes in carrying capacity. Though implausible, that counterfactual scenario shows how conventional macroeconomic models, including those long used in Indonesia, can skew economic projections, overestimating the benefits of high-carbon growth. The two graphics presented in **Figure 1** compare GDP growth and GHG emission projections in the Reference Case and its counterfactual. When carrying capacity is taken into account, it is clear that if Indonesia does not shift to a low-carbon, green development pathway, it may not be able to achieve even 5% annual GDP growth. Notably, the slower GDP growth in the Reference Case also results in lower GHG emission projections.

Figure 1. GDP growth and GHG emissions in the Reference Case and its counterfactual, 2020–2060



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Note: The Reference Case, which serves as the baseline scenario in the analysis in this report, incorporates variables to reflect changes in carrying capacity; the counterfactual does not. Projections are from the model results.

[89] The social cost of carbon is the net present value of climate change damages caused by every additional tonne of CO_2e emitted, including non-market impacts on the environment and human health that may not be captured by other measurements.

[90] Several measures included in the net-zero scenarios would repair the harm done to Indonesia's ecosystems, and thus significantly improve their carrying capacity. Some would also increase resilience to key climate change risks; for example, by restoring mangroves, Indonesia would help protect its coastal areas from storm surges and from erosion linked to sea-level rise.

2.1.2 The net-zero scenarios

As noted, Indonesia has yet to commit to a net-zero pathway, but discussions of potential pathways for different sectors are already under way. The Ministry of Environment and Forestry (KLHK) initially outlined in early 2021 a scenario for net-zero around 2070,[91] and has since been considering more ambitious scenarios, including reaching net-zero by 2060 or sooner. Similarly, the Ministry of Energy and the State Electricity Company (PLN) are advancing plans to decarbonize power systems by 2060, aiming to meet all electricity demand with renewables or nuclear power.[92]

The three net-zero LCDI scenarios examined here, NZ2045, NZ2050 and NZ2060, share several core features:

- They maintain a level of GHG emission reduction through 2030 that is at least as ambitious, in both absolute and relative terms, as the unconditional pledge in Indonesia's first NDC (a 29% emission reduction by 2030 relative to a baseline scenario, with total GHG emissions being no higher than 2.034 Gt CO_2e).[93] Also, across the three scenarios, the cumulative GHG emission reductions between 2021 and 2030 are at least as large as those implied in the current NDC.
- They significantly scale up ambition post-2030 across all major GHG emission sources, in line, to the extent possible, with exercises conducted by the Ministry of Energy, the Ministry of Environment and Forestry and other agencies to identify the best ways to decarbonize their respective sectors. The net-zero LCDI scenarios should thus be regarded as an inclusive exercise designed to facilitate consensus on targets and avenues for attaining Indonesia's climate and development goals.
- In accordance with LCDI standards and principles, the scenarios were generated through a scientifically rigorous process, aiming to achieve a high but realistic level of ambition, recognizing biophysical limits to GHG mitigation as well as political, technical and institutional constraints.
- All net-zero scenarios include the same set of low-carbon measures (described below) and differ only in the speed at which they move towards their targets. For instance, all the scenarios envision fully decarbonizing the energy supply by 2060, but while NZ2045 achieves 95% clean energy (renewables and nuclear) by 2045, NZ2050 does so in 2048, and NZ2060 in 2054.
- All net-zero scenarios envision some GHG emissions even beyond the target year, from the waste sector, but they would be offset or more than offset by negative emissions from agriculture, forestry and other land use (AFOLU), starting in the net-zero target year.

Photo by Yulia Agnis via Unsplash

Photo coutesy of LCDI Secretariat

[91] ESDM, 2021, "Perubahan Iklim: NDC Indonesia, Ambisi dan Membumi," Kementerian Lingkungan Hidup dan Kehutanan – Berita.

[92] PLN, 2021, "PLN Siapkan Transisi Menuju Energi Bersih Demi Generasi Mendatang," Perusahaan Listrik Negara (State Electricity Company) – Press Releases.

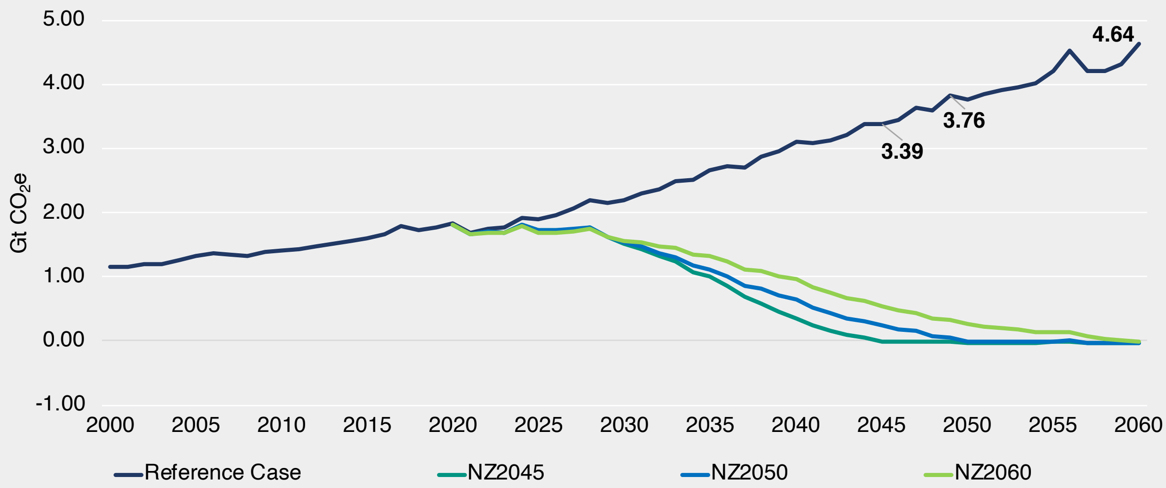
[93] Republic of Indonesia, 2016, "First Nationally Determined Contribution."

Figure 2 shows the path for GHG total emissions for the historical period 2000–2020 and compares projected 2021–2060 emissions in the Reference Case and the three net-zero scenarios. By 2030, GHG emissions would be 30.9%, 29.7% and 29.1% lower, respectively, than in the Reference Case, totaling 1.51, 1.54 and 1.55 Gt CO_2e, respectively. With the implementation of the policies included in the net-zero scenarios, GHG emissions would peak at about 1.8 Gt CO_2e around 2024, then start declining.

Notably, due to COVID-19 and other factors, emission projections for the Reference Case itself are 23.7% lower than the baseline used in the NDC (2.19 Gt CO_2e vs. 2.87 Gt CO_2e), so even though the net-zero scenarios only reduce emissions by about as much as the NDC pledged, absolute emissions in all three net-zero scenarios are well below the 2.03 Gt CO_2e projected in the NDC's unconditional pledge.

Over the 2021–2060 period, the net-zero scenarios would avoid 87–96 Gt CO_2e of emissions. To put this in perspective, the Intergovernmental Panel on Climate Change (IPCC) has estimated that for a two-thirds chance of keeping the global temperature increase within 1.5°C of pre-industrial levels, the total carbon budget available to the world from 2018 until reaching net-zero emissions is 420 Gt CO_2e.[94]

Figure 2. Annual greenhouse gas emissions in the Reference Case and net-zero scenarios



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: Historical data for emissions, based on National Greenhouse Gas Inventory, up to 2020; modeling results for 2021 and beyond.

[94] Rogelj *et al.*, 2018, "Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development," in Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.

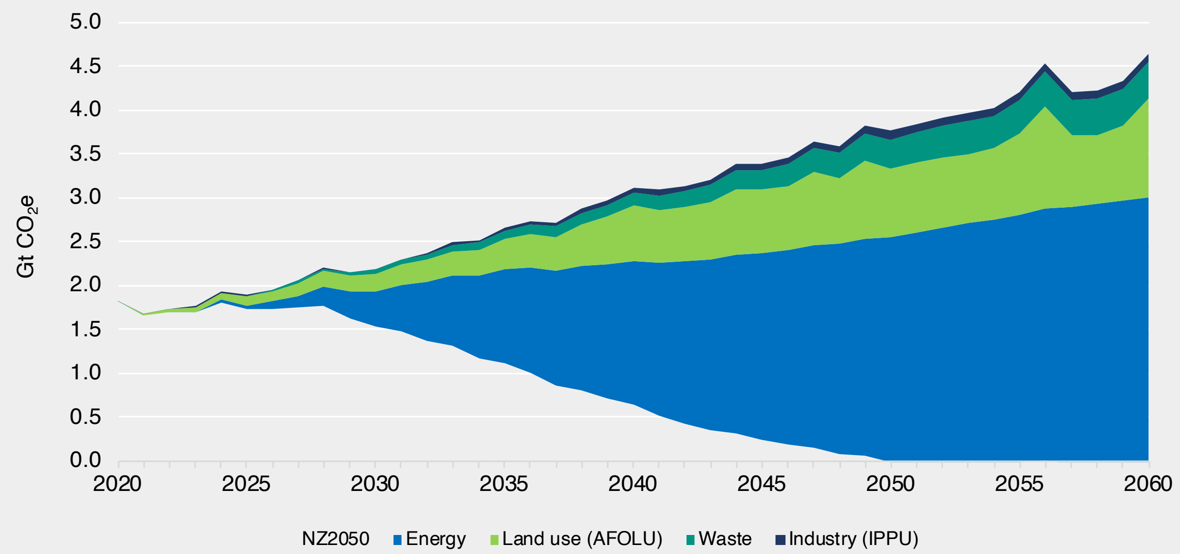
2.2 Net-zero targets in key sectors

The net-zero scenarios expand on the package of low-carbon measures included in RPJMN 2020–2024, which were designed to ensure that Indonesia could meet its GHG emission reduction targets for 2020–2030. To achieve net-zero, they fully replace fossil fuels with clean energy (renewables as well as nuclear); sharply reduce the energy-intensity of the economy; fully phase out fossil fuel subsidies by 2030; electrify road transport (with the role of biofuels gradually declining); protect and restore forests, peatlands and mangroves; adopt sustainable practices in agriculture, forestry, fisheries and aquaculture; improve waste management; and make industry more efficient.

The net-zero scenarios raise the ambition of the measures that are already included in the RPJMN 2020-2024, through 2030 and beyond, and incorporate several new interventions—with the most rapid implementation in NZ2045 and the most gradual in NZ2060:

- Decarbonizing the electricity sector, raising the share of renewables in power generation capacity (about 18% as of 2020, mainly hydropower, geothermal and biomass) to 82% by 2053 (across scenarios) and adding nuclear capacity, starting in 2030 and ramping up until in 2060 and beyond, all electricity comes from clean sources;
- Raising ambition on energy efficiency to reduce the energy intensity of the economy (measured in terajoules of energy demand per Rp. 1 billion, at constant 2000 prices) by 4.1–4.7% per year in 2021–2030 (high end of the range is NZ2045, low end is NZ2060) and about 6% per year from then until 2060;
- Introducing a carbon price, applicable to fossil fuels and electricity, starting in 2022 and ramping up linearly to US$60 (Rp. 873,000) per tonne CO_2 by 2040 in NZ2045, to US$50 in NZ2050, and to US$40 in NZ2060, then remaining at the respective levels;
- Electrifying road transportation—both to phase out petroleum products, and as a key strategy to increase energy efficiency—with targets of 100% of the transport fleet by 2040 in the NZ2045 scenario, by 2045 in NZ2050, and by 2060 in NZ2060;
- Introducing locally produced hydrogen fuel to close the gap in transport fuel demand on the path to full electrification and support the phase-out of biofuels;
- End all conversion of primary forest to agricultural land by 2025 and scale up forest restoration to 250,000 hectares (ha) per year by 2040, to increase secondary forest coverage (that is, regrown forest areas) from the current 45.7 million ha to 48.2 million in 2060;
- Scale up peatland restoration to 90,000 ha per year by 2032, significantly ramping up thereafter to peak at 650,000 in 2038 in NZ2045 and nearly 400,000 ha in NZ2050 and NZ2060; across scenarios, after peaking, peatland restoration efforts would scale down to maintain those levels and offset any further losses due to economic development;
- Expand mangrove restoration efforts to 125,000 ha per year in 2021–2024, then restore 12,000 ha per year through 2060;
- Expand sustainable agricultural practices to 40% of cropland by 2050;
- Green urban landscapes to triple the carbon sequestration potential of urban land by 2050;
- Progressively reduce wastewater generation in the industrial sector, to reach 100% water recycling by the respective target year of each net-zero scenario.

Figure 3. How different sectors contribute to emission reductions in NZ2050



Source: LCDI modeling results.

Figure 3 shows how different sectors contribute to the emission reductions achieved over time in the NZ2050 scenario.[95] Two-thirds of the mitigation effort (50.2% for the period 2021–2030) corresponds to the energy sector, while the AFOLU sector contributes 24.9% (41% for 2021–2030). The waste sector and industrial processes and product use (IPPU) contribute 8% and 2%, respectively.

As crucial a role as energy sector measures play in achieving net-zero, it is important to recognize the critical role of land use sectors as well. They produce more than half of Indonesia's current GHG emissions, and though much more difficult to predict than energy GHGs, extreme events linked to climate change and environmental degradation can cause sharp increases in emissions.[96] **Figure 3** shows the GHG reductions achieved through the protection and restoration of key carbon sinks (forests, peatlands, mangroves); it is only thanks to that improved carbon storage that net-zero can be achieved even before energy systems are 100% decarbonized.

What is not captured in the figure, however, is the broader benefits of maintaining natural capital, as the goods and services provided by healthier ecosystems contribute to economic growth and increase resilience. That fuller perspective on the green economy is central to the LCDI approach. Similarly, although IPPU and waste policies contribute a small fraction of the emission reductions, they are fundamental for value addition and employment generation in a green economy (see Section 4.3).

The sections that follow delve deeper into the policy interventions envisioned in each sector to achieve net-zero, as well as the projected GHG emission reductions from those measures. Section 2.3 then discusses the broader socio-economic benefits, and Section 3 examines the associated investment needs as well as financing options. Section 4 provides a broader discussion of the policy context as well as examples of how other countries have pursued similarly ambitious goals.

[95] Since all the net-zero scenarios share the same policies and ultimate targets, and only differ in the speed with which the targets are reached, the paths for policy proxies (e.g. share of renewables in energy demand), intermediate targets (e.g. energy intensity) and final targets (e.g. GHG emissions, employment, GDP) are similar. For simplicity in the presentation of results, where the three scenarios cannot be easily combined in a single figure, only results for NZ2050 are presented.

[96] A prime example is the 2015 peatland fires in Indonesia, which, as noted earlier, emitted an estimated 1.75 Gt CO_2e and sharply increased air pollution (see Global Fire Emissions Database: http://www.globalfiredata.org/updates.html#2015_indonesia). Similarly catastrophic events are already occurring more frequently around the world.

2.2.1 The energy sector

The energy sector is central to achieving net-zero because, as Indonesia develops and incomes rise, energy demand is rising quickly. Projections for the Reference Case show demand more than tripling, from 9.3 terajoules (TJ) in 2021 to 31.9 TJ in 2060. If all the added demand were met with fossil fuels, the impact on GHG emissions and air pollution would be devastating.

The RPJMN 2020–2024 already recognizes this challenge and aims to reduce the energy intensity of Indonesia's economy (a proxy measure for energy efficiency) by 2.5% per year and increase the share of renewable energy in the primary energy mix to 23% by 2025. As noted above, the net-zero scenarios ramp up ambition on both fronts—and put a price on carbon, starting in 2022, to accelerate the transition. **Table 1** provides a summary of energy sector interventions and how they compare with the RPJMN 2020–2024 and the High scenario in the 2019 LCDI analysis.

Table 1. Key energy sector interventions and targets in the net-zero scenarios

Intervention	RPJMN 2020-2024 Targets	LCDI 2019 High scenario	Net-zero scenarios
Energy efficiency gains (measured as reduced energy intensity of GDP)	Reduce primary energy intensity by 1% per year, to 133.8 BOE per Rp. 1 billion by 2024, and reduce final energy intensity reduction by 0.8 BOE per Rp. 1 billion	3.5% per year during 2019–2030, 4.5% per year post 2030	Reduce energy intensity by an average of 4.5% per year in 2021–2030 in NZ2045, 4.1% in NZ2050 and 3.9% in NZ2060, and by about 6% per year in 2030–2060 across scenarios
Clean electricity generation	Increase installed renewable energy capacity from 10.2 GW (15% of total) in 2019 to 19.2 GW (20%) by 2024	Increase installed renewable capacity to 23% of total capacity by 2025 and to 30% by 2040	Starting from 16.4% in 2022, scale up renewables to reach 60% of total power generation capacity by 2030 and 82% by 2053; introduce nuclear power, starting in 2030, to supply the remaining 18% of power by 2060
Renewables in primary energy mix	19.5% of primary energy mix by 2024, 23% by 2025, 31% by 2050	65% by 2030 (remaining share from coal and natural gas); 85% by 2060 (remaining share from nuclear)	Across scenarios, 65% by 2030 (remaining share from coal and natural gas); 85% by 2060 (remaining share from nuclear)
Biofuels as substitutes for petroleum fuels in transport	Domestic biofuel use increase from 6.9 million kiloliters (kL) in 2019 to 17.4 million kL in 2024	Substitute oil demand with 29.78 million kL of biofuels by 2025 or 30% share of petroleum demand in transport	No dedicated efforts to increase biofuels; instead, as electrification increases and alternatives to fossil fuels are in place (liquid hydrogen), biofuel use drops until it fully disappears with 100% electrification of road transport
Electrification of road transport sector (includes cars, motorcycles, trucks and public transport)	No targets		Starting in 2025, rapidly scale up electrification to achieve 100% EVs by each scenario's net-zero target year

Intervention	RPJMN 2020–2024 Targets	LCDI 2019 High scenario	Net-zero scenarios
Hydrogen fuel for transport	No targets		Starting in 2030, ramp up to assist in phase-out of biofuels and to meet 100% of remaining fuel demand until electrification is fully achieved in each scenario's net-zero target year
Fossil fuel subsidies removal	Improve the efficiency and targeting of fossil fuel subsidies, incorporating them with social assistance	Start phasing out fossil fuel subsidies in 2024, reaching 100% removal by 2030	After RPJMN 2020–2024 ends, start phasing fossil fuel subsidies, to reach 100% removal by 2030
Carbon price	N/A	N/A	Introduce carbon price in 2022 and scale up linearly to US$60 per tonne CO_2 in 2040 and thereafter in NZ2045, US$50 in NZ2050 and US$40 in NZ2060.

Sources: Bappenas, 2019; 2030 and 2050 targets from ESDM, 2014.[97]

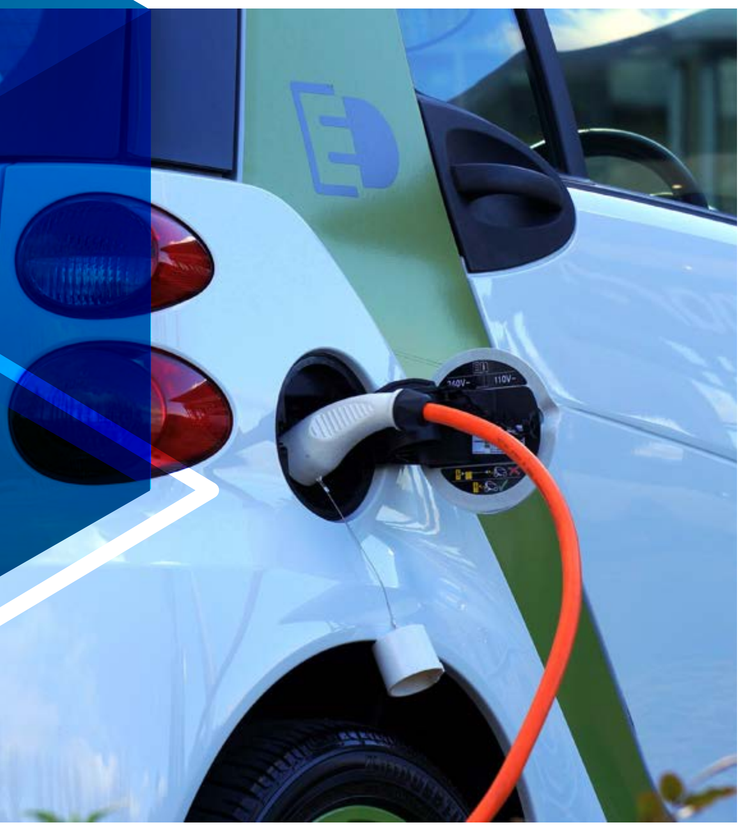


Photo by Mike via Pexels

As outlined above, the energy strategy that underpins the net-zero scenarios has three key elements: improving energy efficiency; decarbonizing the energy supply, through renewable energy combined with electrification and clean alternatives to fill gaps; and realigning incentives by ending fossil fuel subsidies and phasing in a carbon price.

Improved energy efficiency, which the International Energy Agency calls the "first fuel" for its crucial role in meeting countries' energy needs,[98] can be achieved in three main ways:

- By making individual technologies more efficient (e.g. better air conditioners, more fuel-efficient cars);
- By replacing less-efficient technologies with more efficient ones (e.g. LED lighting, electric vehicles); and
- By delivering the same service in a more efficient manner (e.g. using insulation and energy-efficient design measures to reduce a building's cooling needs, or shifting transportation demand from individual cars to public transit, walking and biking).

[97] Bappenas, 2019, "2020–2024 National Medium-Term Development Plan (Rencana Pembangunan Jangka Menengah Nasional 2020–2024)"; 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia"; ESDM, 2014, "Rencana Umum Energi Nasional (National Energy General Plan)."

[98] Motherway, 2019, "Energy Efficiency Is the First Fuel, and Demand for It Needs to Grow—Analysis," International Energy Agency blog.

The net-zero scenarios use a combination of such interventions, discussed in more detail in Section 4.2. The resulting gains are modeled through a proxy measure, the energy intensity of Indonesia's economy (that is, the ratio of energy demand to GDP). In the net-zero scenarios, energy intensity is reduced by an average of 4.5% per year in 2021–2030 in NZ2045, 4.1% in NZ2050, and 3.9% in NZ2060, then by an average of about 6% per year in 2031–2060.

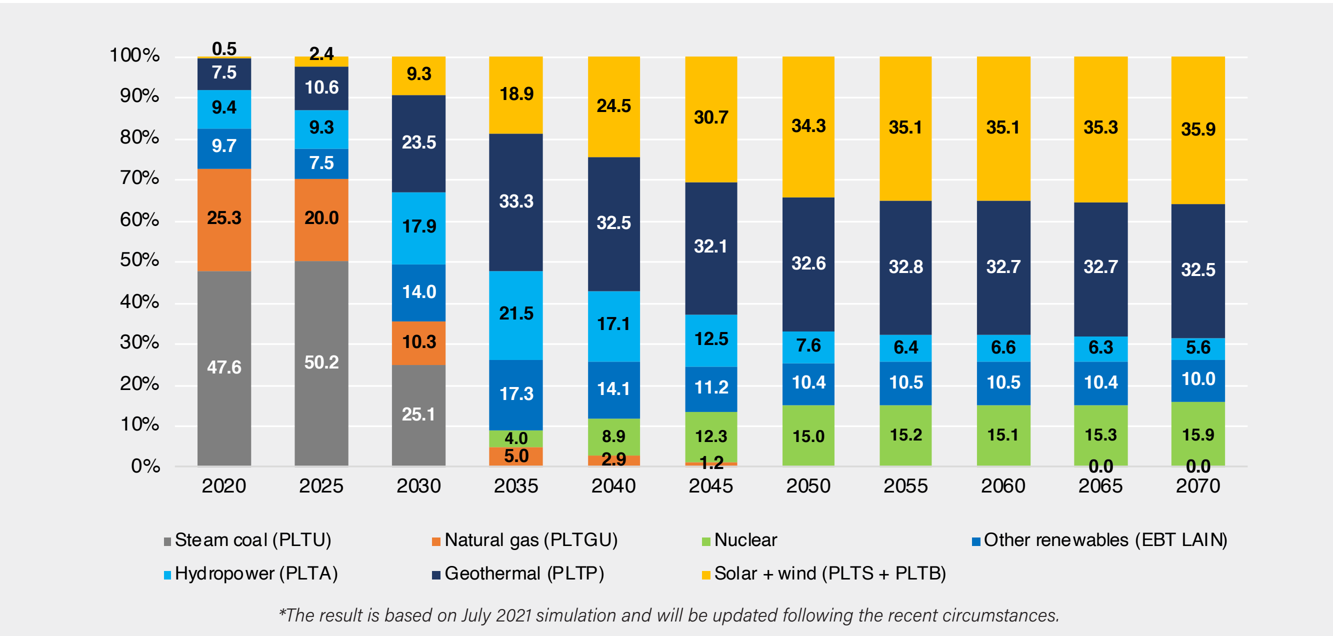
These efficiency gains would enable Indonesia to keep growing its economy and meet the needs of an expanding population without significantly growing the energy supply. In 2060, total energy demand would be roughly the same as in 2019–2020, around 9 exajoules (EJ), or about 215 million tonnes of oil equivalent (Mtoe) per year.

Decarbonizing the energy sector is equally crucial to achieving net-zero—and to enabling continued robust GDP growth without adding new emissions. There is growing consensus worldwide that electrification is key, as the supply of clean electricity can be scaled up far more easily than zero-carbon fuels or feedstocks.[99] In the transport sector, switching to EVs not only removes the need for petroleum products, but also significantly increases energy efficiency (see Section 4.1). To fully realize the climate benefits of electrification, however, it is crucial to quickly decarbonize the electricity supply as well.[100]

The net-zero scenarios thus accelerate the deployment of renewable energy, replacing fossil fuels, to reach 82% of total power generation capacity by 2053 (across scenarios, but moving fastest in NZ2045 and most gradually in NZ2060). Nuclear power would be introduced starting in 2030, to provide the remaining 18% by 2060. The inclusion of nuclear power is in line with business plans by Ministry of Energy and Mineral Resources (ESDM), which contemplate the introduction of the nuclear starting in the 2030s, with the goal of having a clean source of baseload power to complement renewable sources.

Figure 4 shows how the electricity mix would change over time in NZ2050. **Figure 5** shows the impact of electrification on total final energy consumption, with the share of demand met by electricity growing significantly over time. It is the combination of electrification and a decarbonized power supply that enables Indonesia to eliminate fossil fuels—and, with them, its greatest source of GHG emissions.

Figure 4. Share of technologies in power generation capacity in the net-zero scenarios



Source: LCDI modeling results.
Note: Shares of technologies in electricity generation are modeled based on a net-zero scenario for 2060 by the Ministry of Energy and Mineral Resources (ESDM).

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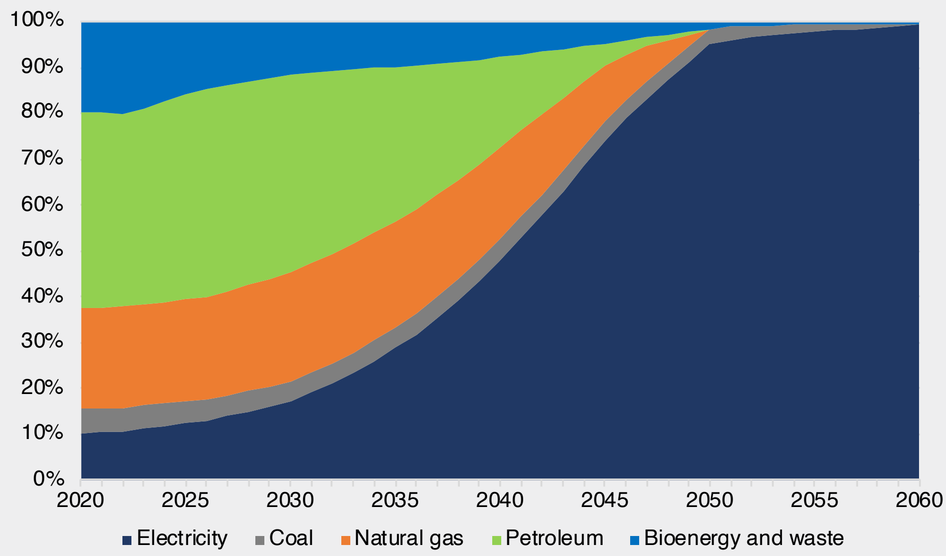
[99] See, for example, Rogelj *et al.*, 2018, "Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development," in *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.*

[100] See, e.g., Vandycke, 2020, "Can Electricity Decarbonize the Energy Sector?" World Economic Forum blog.

Figure 5. Share of technologies in final energy consumption, NZ2050



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results. Note: Coal and natural gas shares in later years reflect some continued use, mainly by households, for heating, not in electricity production.

Notably, even in the net-zero scenarios, the share of coal in the power supply continues to rise until 2024–2025, before dropping rapidly, to less than 5% by 2035, and moving towards zero thereafter. PLN has announced a moratorium on coal power plant construction after 2023, but between now and then, it still plans to add considerable new capacity.[101] It is also important to note that the electricity mix modeled for this study, as shown in **Figure 4**, is aligned with the mix used in ESDM's scenario for achieving net-zero by 2060. As laid out in the 2019 Indonesia Energy Outlook and discussed further in Section 4.1.2, Indonesia has very large renewable energy potential—442 GW in 2018,[102] of which only 2% had been utilized.[103] More rapid and extensive deployment of solar photovoltaics (PV), for instance, might enable Indonesia to accelerate the transformation of its energy sector.

Another issue to consider is that the mix of technologies modeled in this report was developed by ESDM through conventional optimization methods used to determine the lowest-cost mix among available power generation technologies. Those methods do not take major externalities into account, including the social cost of carbon[104] and the impact of air pollution. **Figure 6** shows the costs of coal, natural gas and renewables. A key insight is that when even some externalities are taken into account, renewables are already cost-competitive. Air pollution impacts alone make coal more expensive than solar.

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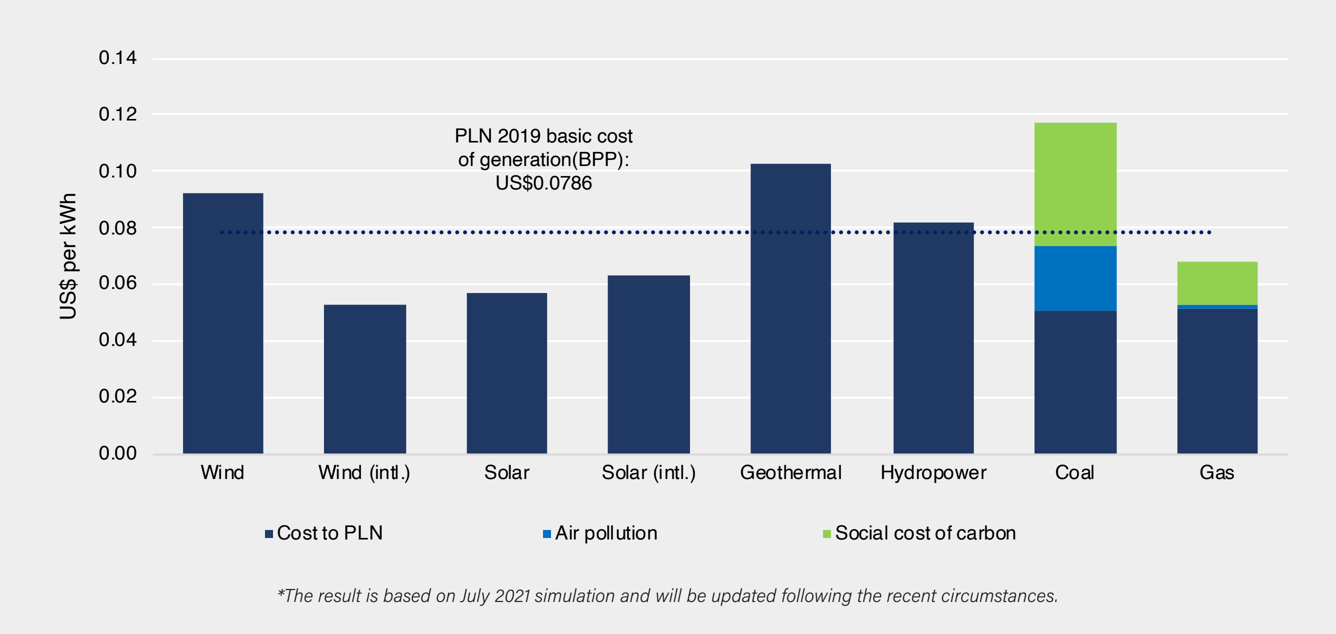
[101] Husaini, 2021, "Demi zero emisi, PLN moratorium pembangunan pembangkit batubara," Kontan.co.id; Jong, 2021, "Indonesia Says No New Coal Plants from 2023 (After the Next 100 or So)," *Mongabay*.

[102] National Energy Council, 2019, "Indonesia Energy Outlook 2019."

[103] OECD, 2021, *Clean Energy Finance and Investment Policy Review of Indonesia*.

[104] The social cost of carbon is the net present value of climate change damages caused by every additional tonne of CO_2e emitted, including non-market impacts on the environment and human health that may not be captured by other measurements.

Figure 6. Relative cost of coal, natural gas and renewables, including key externalities, 2019



Source: Update for this report by the International Institute for Sustainable Development of analysis in Bridle et al., 2019.[105] Note: Unless specified otherwise ("intl." label), all costs are for Indonesia. Wind, solar, geothermal and hydropower costs are from recent power purchase agreements (PPAs) in Indonesia. Coal and gas costs are PLN costs. International wind and solar costs are international benchmarks.

It is important to note that conventional least-cost analyses do not take major externalities into account, including the social cost of carbon[106] and the impact of air pollution. That is a key insight from **Figure 5**. When even some of those costs are taken into account, renewables are already cost-competitive—air pollution impacts alone make coal more expensive than solar.

There is also a significant and growing risk that coal power plants will need to be retired early, becoming stranded assets and thus increasing the relative cost of coal. Indeed, that is already a concern in Indonesia, and a reason cited for phasing coal out far more slowly. The Ministry of Finance has estimated that an immediate decommissioning of coal would result in tens of billions of dollars in stranded assets, straining the financial sector. The net-zero scenarios do not call for shutting down coal power immediately, but the reality is that avoiding catastrophic climate change will require closing coal power plants prematurely all around the world. While historically, these plants have operated for about 50 years, a recent analysis found that to keep global GHG emissions below 2°C, all existing plants would have to be retired at 35 years.[107] If plants that are under construction or at earlier stages of development go online, lifetime limits would drop by another 10 years.

Another important factor is that renewable energy costs have been falling rapidly, to the point that solar photovoltaics (PV) now offer "some of the lowest-cost electricity in history," according to the International Energy Agency. The IEA projects that utility-scale solar PV costs will drop by another 36% worldwide by 2025.[108]

[105] Bridle *et al.*, 2019, "The Case for Renewable Energy in Indonesia: The Cost of Energy, Subsidies, Externalities and Non-Cost Factors."

[106] The social cost of carbon is the net present value of climate change damages caused by every additional tonne of CO_2e emitted, including non-market impacts on the environment and human health that may not be captured by other measurements.

[107] Cui *et al.*, 2019, "Quantifying Operational Lifetimes for Coal Power Plants under the Paris Goals," *Nature Communications*.

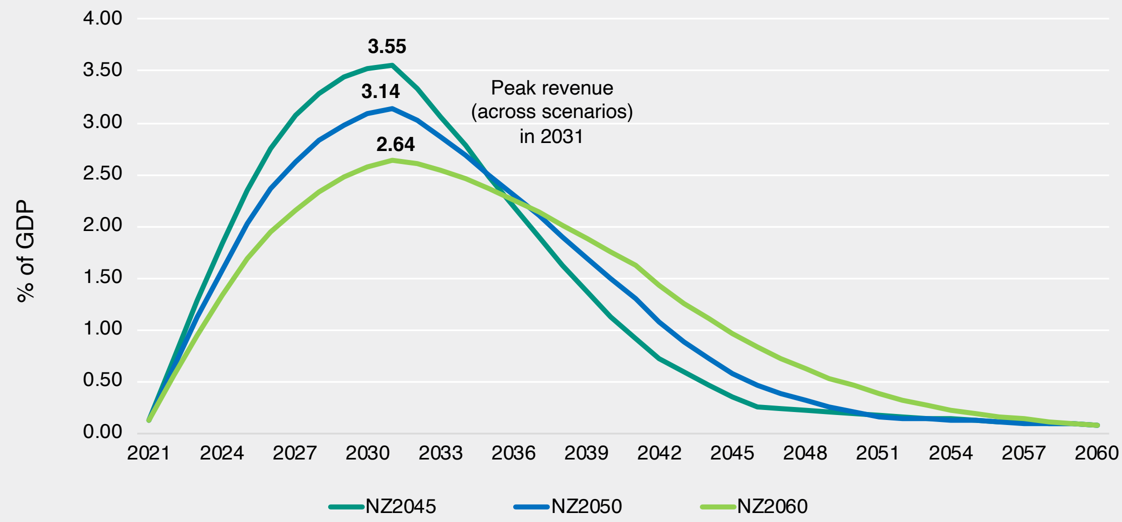
[108] IEA, 2020, "Renewables 2020: Analysis and Forecast to 2025."

The final key element of energy policies to achieve net-zero is a pair of measures to realign economic incentives: phasing out fossil fuel subsidies by 2030, and introducing a carbon price. The latter would be applied, upstream, to coal, petroleum products and natural gas. It would start at less than US$5 per tonne CO_2, on average, in 2022–2023, and increase linearly to US$60 per tonne by 2040 in NZ2045 (Rp. 873,000), remaining at that level until the economy is fully decarbonized.

The Government of Indonesia is already considering a number of carbon pricing and market mechanisms, and—as discussed further in Section 4.1—an emissions trading pilot program is now under way, covering 80 coal-fired power plants.[109] Carbon pricing is widely recognized as a highly effective climate policy tool, as it internalizes the social cost of carbon and creates economic incentives to reduce fossil fuel use while allowing businesses and households to find the most cost-effective solutions.[110] It can also generate substantial amounts of revenue that can be put to a wide range of productive uses: from supporting low-carbon technologies, to providing targeted social assistance to vulnerable populations.

Figure 7 shows the value of revenues from carbon pricing and savings from fossil fuel subsidy removal, as a share of GDP, in the three net-zero scenarios. That value peaks in 2031, at US$168–215 billion (2.64–3.55% of GDP), then drops rapidly as the use of fossil fuels declines (the more ambitious the scenario, the sharper the drop). As discussed further in Section 3.2, revenues peak when they are most needed, both to build infrastructure for the new, green economy, and to provide support to people whose livelihoods were tied to high-carbon sectors, helping to ensure a just transition.

Figure 7. Projected carbon price revenue and savings from fossil fuel subsidy reform



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.

[109] ESDM, 2021, "Uji Coba Perdagangan Karbon Diikuti 80 Pembangkit (Carbon Trading Trial Followed by 80 Generators)," Kementerian Energi Dan Sumber Daya Mineral (Ministry of Energy and Mineral Resources).

[110] See, e.g., Parry, 2019, "The Case for Carbon Taxation," *Finance & Development*; IMF, 2019, "Fiscal Monitor: How to Mitigate Climate Change."

2.2.2 Land use sectors

Natural resources are central to Indonesia's wealth and prosperity, but land use sectors have also produced half to two-thirds of the country's annual GHG emissions over the past 20 years.[111] Recognizing the urgent need to protect key ecosystems, the RPJMN 2020–2024 set targets for reforestation, forest protection, peatland and mangrove restoration, and sustainable agriculture. **Table 2** shows how the net-zero scenarios build on those targets and add new interventions.

Table 2. Key land use sector interventions and targets in the net-zero scenarios

Intervention	RPJMN 2020–2024 targets	LCDI 2019 High scenario	Net-zero scenarios
Avoiding and reversing land conversion			
Reforestation	420,000 ha by 2024	1,000,000 ha by 2024	Scale up to 250,000 ha per year by 2030 in NZ2045 and NZ2050 and by 2050 in NZ2060
Curbing deforestation	No target	Reduce forest loss by 50% relative to baseline scenario through 2024, and by 80% thereafter	Reduce forest loss by 50% by 2030, and end deforestation completely by 2025
Reducing forest degradation	No targets		Across scenarios, rate of degradation reduced from 139,000 ha per year in 2020 to 82,000 in 2030, 44,000 in 2050, and around 1,000 by 2060
Peatland restoration via re-wetting through canal blocking measures, forest fire prevention, and phasing out drainage-based agriculture	330,000 ha per year by 2024	300,000 ha per year through 2024 200,000 ha per year thereafter	Across scenarios, restore 90,000 ha per year in 2021–2030; then scale up to 650,000 ha per year in 2038 in NZ2045, or 390,000 ha in NZ2050 and NZ2060; then scale down, across scenarios, to the levels necessary to offset any further losses due to economic development Cumulative restoration by 2050 is 5.6 million ha in NZ2045 and 5.2 million ha in NZ2050 and NZ2060
Mangrove restoration	50,000 ha cumulatively over 2020–2024	No targets	125,000 ha per year in 2021–2024, to increase stocks by 15% above 2020 levels, then continue to restore at rate of 12,000 ha per year
Greening of urban landscapes	No targets		Triple the carbon sequestration potential of urban land by 2050

[111] See ClimateWatch data for 1999–2018 (agriculture and land-use change and forestry combined): https://www.climatewatchdata.org/ghg-emissions?breakBy=sector&end_year=2018&regions=IDN&source=CAIT&start_year=1999.

Intervention	RPJMN 2020–2024 targets	LCDI 2019 High scenario	Net-zero scenarios
Sustainable agriculture and forest plantations			
Increasing sustainable agriculture	100% of land for paddy fields designated as sustainable by 2024	Increase RSPO and ISPO certified oil palm plantation area from 14% in baseline to 50% by 2045; 11% increase in ISPO Land Management Yield; sustainable forest plantations increase by 50% by 2025	40% of cropland (including oil palm production) is cultivated sustainably by 2050; the impact of certifications and sustainable practices is reflected in this target
Stop clearing forest for cropland	No target		From a forest clearing rate of 141,000 ha per year in 2020, or 0.15% of forest area, for cropland, phase down to zero by net-zero target year
Reduce land concessions for bioenergy crops	No targets		From total of 41,000 ha in 2020, reduce by 2030 to 25,000 ha in NZ2045, 27,000 ha in NZ2050, and 29,000 ha in NZ2060, then phase out to zero by the respective net-zero target year

Source: Bappenas, 2019.[112]
Note: Roundtable on Sustainable Palm Oil (RSPO) and Indonesia Sustainable Palm Oil (ISPO) certifications are issued to oil palm plantations that meet certain sustainability, transparency, compliance, and financial viability criteria.

Land use sectors play an important role in Indonesia's economy, with agriculture alone accounting for an estimated 29% of employment as of 2019[113]—and much more in some provinces. The policies and incentives to achieve net-zero targets are thus designed to support more sustainable economic development and livelihoods in agriculture, forestry, fisheries and aquaculture, while creating new jobs in forest, peatland and mangrove restoration activities. Recognizing that Indonesia's population is set to grow by more than one-fifth by 2060, to over 336 million, the model also includes efforts to reduce food loss and waste. As discussed in Section 4.4, addressing Indonesia's high rates of food waste and loss can ensure ample food production for a growing population without requiring ever more land to be cleared.

In all, implementing the net-zero strategies for the land use sectors can enable Indonesia to strike a good balance between continued value addition from primary sectors and the protection of natural capital. These measures, examined more closely in Section 4, are also crucial to building resilience to climate change. That is an urgent priority both nationwide and within these sectors, which will need to withstand rising temperatures, changes in precipitation, more extreme events, groundwater salinization, and other impacts.[114] As noted earlier, restoring peatlands and mangroves is a key part of the solution to major cities' land subsidence problem; these wetlands also provide much-needed protection from flood risks and coastal storms.[115]

[112] Bappenas, 2019, "2020–2024 National Medium-Term Development Plan (Rencana Pembangunan Jangka Menengah Nasional 2020–2024)"; 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia."

[113] See World Development Indicators data for employment in agriculture (% of total employment), International Labour Organization estimates: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=ID.

[114] Hijioka *et al.*, 2014, "Asia," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* For a look at how climate-smart strategies can boost agricultural productivity and resilience while reducing GHG emissions, see the ASEAN Climate Resilience Network's series of insight briefs on climate-smart land use: https://asean-crn.org/climate-smart-land-use-practice-insight-brief-series/.

[115] For an overview, see CUT, 2021, "Seizing Indonesia's Urban Opportunity: Compact, Connected, Clean and Resilient Cities as Drivers of Sustainable Development."

The targets laid out in Table 2 have several practical implications:

- Urban expansion needs to be significantly reduced, with most future development occurring within the existing urban footprint or on fallow land. A recent analysis for the Coalition for Urban Transitions found that between 2000 and 2014, Indonesian cities grew by 3.9% or 6,904 km^2, more than the land area of Bali, and nearly three-quarters of that expansion was onto cropland.[116] That pattern cannot continue.
- Agricultural expansion needs to occur on what is now fallow land, to the extent possible, and no more primary forest should be cleared for cropland (even for plantation forests) or for bioenergy feedstock production. As discussed further below, the goal of ending all deforestation is ambitious, but it is crucial to preserving Indonesia's carbon sinks.
- Agricultural production is increased through sustainable intensification techniques, and further value is added through agroforestry, which creates new revenue streams (e.g. from growing cocoa on oil palm plantations,[117] or harvesting non-timber forest products).
- The use of biofuels to replace petroleum products in road transport becomes a transitional solution on the path to EVs, not the end-goal. The net-zero scenarios allow for less than 25,000 ha of land for bioenergy crops—enough to meet the demand created by current policies, but not to support significant further growth.
- The area for plantation forests would be capped at 14.2 million ha, allowing modest continued growth (they currently cover 11.2 million ha).

Land use strategies are crucial to achieving net-zero both because these sectors now produce a majority of Indonesia's emissions, as noted earlier, and because Indonesia needs to protect and restore its enormous carbon sinks. Estimates produced for this model analysis, drawing on peer-reviewed literature and official land cover data, show that Indonesia's carbon stock—the amount of carbon stored in all types of forests, mangroves and other types of land (but importantly, excluding peatlands)—amounted to nearly 18.5 Gt of carbon (C) in 2020.[118] The carbon stock of Indonesia's peatlands, meanwhile, is estimated at 13.6–40.5 Gt C, with a best estimate of 28.1 Gt C.[119] Combining the model results with the peatland estimate yields a total stock of carbon of about 46.6 Gt C as of 2020.[120] (Seagrass is also a carbon sink, but it is excluded from the model due to limitations in available evidence,[121] as well as its relatively small scale).

Figure 8 shows how Indonesia's carbon stock (excluding peatlands) has decreased over the past two decades, reflecting land conversion, forest loss and land degradation—and how it would continue to decline in the Reference Case, but start rebounding in the net-zero scenarios. **Figure 9** then provides a closer look at how different types of ecosystems would contribute to that recovery in NZ2050.

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[116] See Figure 1 in CUT, 2021, "Seizing Indonesia's Urban Opportunity: Compact, Connected, Clean and Resilient Cities as Drivers of Sustainable Development."

[117] Khasanah *et al*., 2020, "Oil Palm Agroforestry Can Achieve Economic and Environmental Gains as Indicated by Multifunctional Land Equivalent Ratios," *Frontiers in Sustainable Food Systems.*

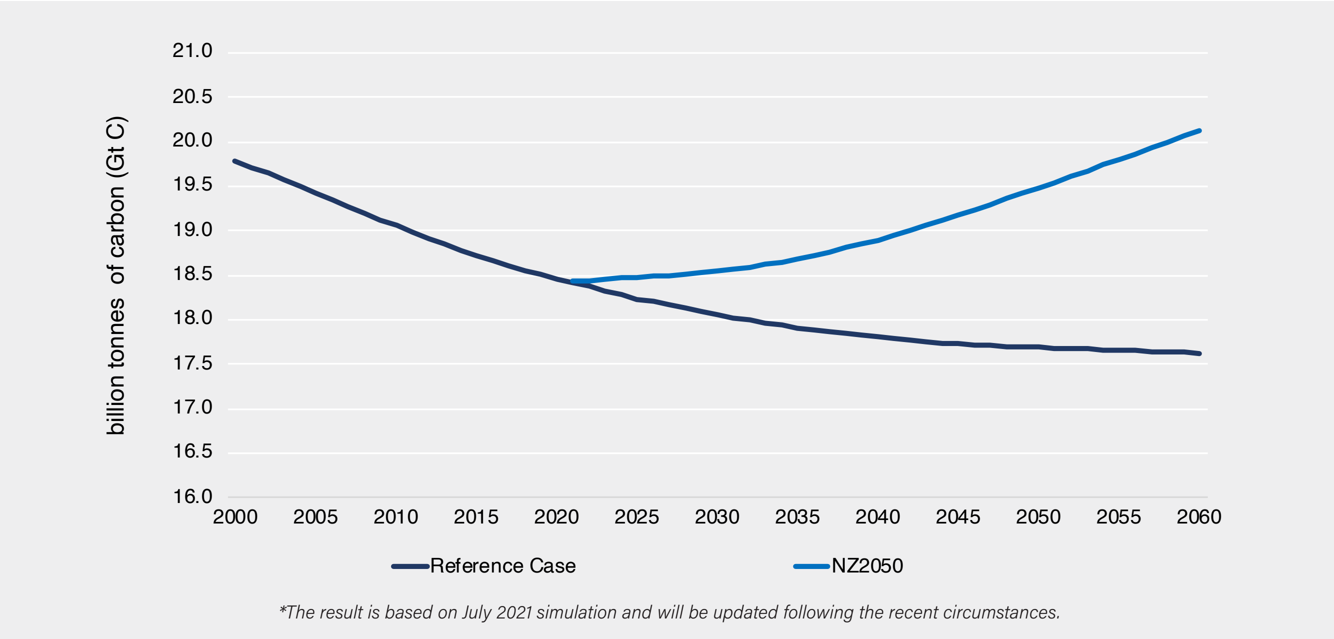
[118] For perspective, Indonesia's GHG emissions in 2018 (the data latest available) are estimated at 1.70 Gt CO_2e (see ClimateWatch data: https://www.climatewatchdata.org/countries/IDN). The conversion factor from C to CO_2 is 3.76; that would mean the carbon stock, excluding peatlands, is equivalent to almost 40 times that year's emissions.

[119] Warren *et al*., 2017, "An Appraisal of Indonesia's Immense Peat Carbon Stock Using National Peatland Maps: Uncertainties and Potential Losses from Conversion," *Carbon Balance and Management.*

[120] Note that this is only an approximation, as the peatland data are highly uncertain.

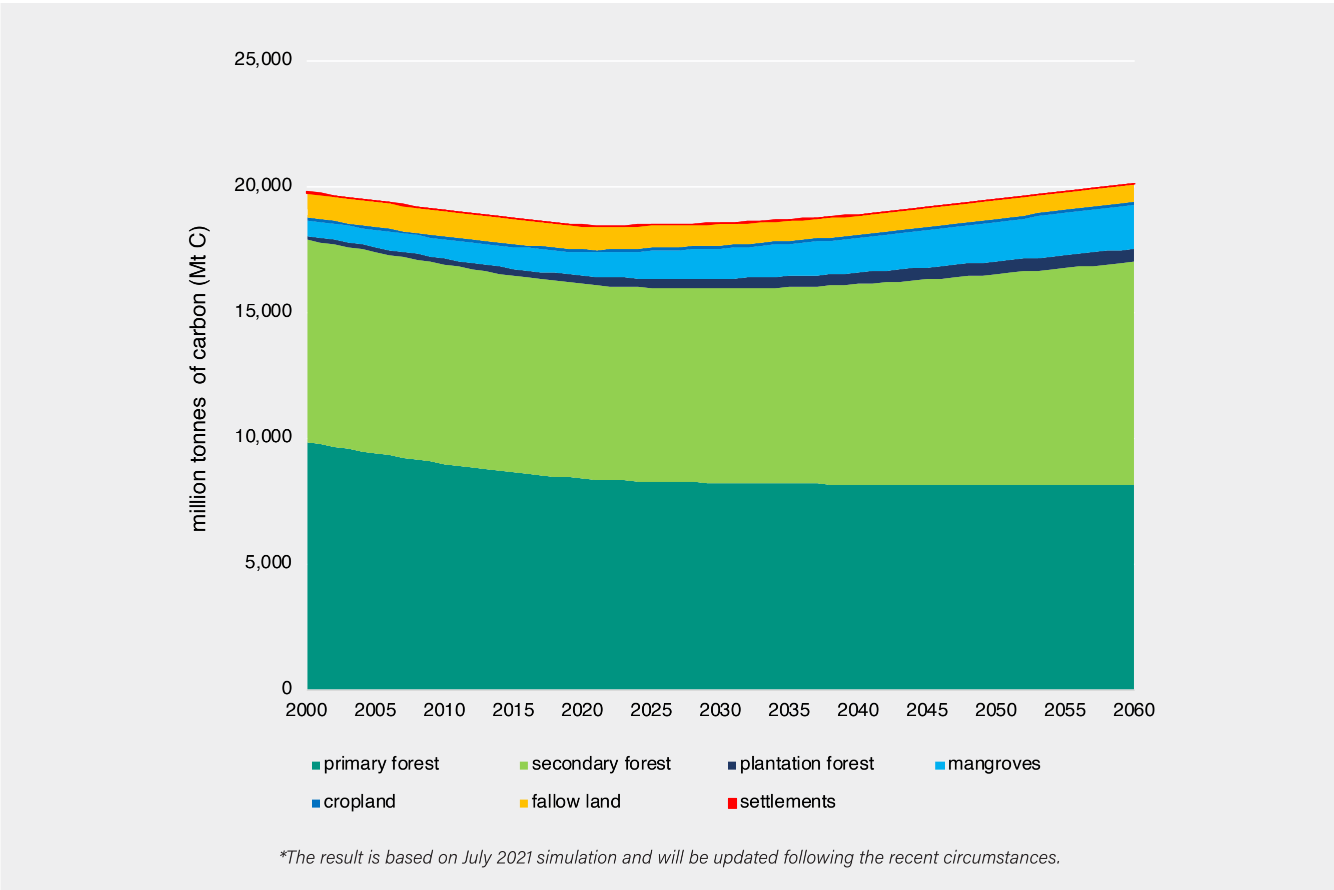
[121] See, e.g., Alongi *et al*., 2016, "Indonesia's Blue Carbon: A Globally Significant and Vulnerable Sink for Seagrass and Mangrove Carbon," *Wetlands Ecology and Management.*

Figure 8. Total carbon stocks in Indonesian ecosystems, Reference Case and NZ2050 (excluding peatlands)



Source: LCDI modeling results.

Figure 9. Carbon stocks in NZ2050, by source, 2000–2060 (excluding peatlands)

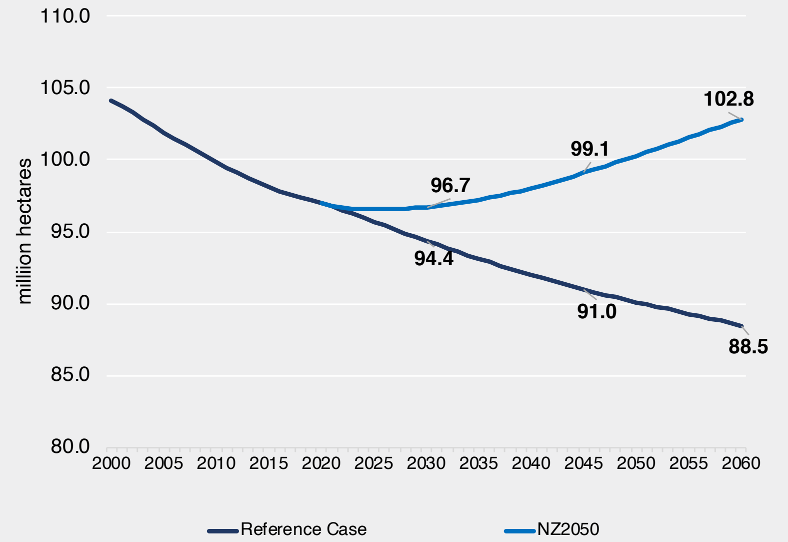


Source: LCDI modeling results.

Figure 10 shows how primary and secondary forest cover in particular would change across scenarios. The net-zero scenarios include more ambitious forest protection targets than those in RPJMN 2020–2024, but build on the same core elements, as outlined in **Table 2**. By 2060, reforestation efforts would increase secondary forest cover by 4.1 million ha (across net-zero scenarios). Avoiding further clearing of forests, meanwhile, would protect 3.2 million ha of primary forest and 11.3 million ha of secondary forest in the net-zero scenarios that would be lost in the Reference Case by 2060. In addition, by 2060, mangrove cover would be nearly 1 million ha greater, and peatland vegetation areas would have increased by 1.5 million ha (both across net-zero scenarios). Altogether, forest, mangrove and peatland cover would be about 105.5 million ha, comparable to 2000 levels. Taking into account these ecosystems' respective carbon storage capacities, these actions would reduce Indonesia's GHG emissions by 48–55 Gt CO_2e between 2021 and 2060.

Lastly, **Figure 11** provides helpful perspective on how ambitious energy policies can have benefits in other sectors as well. It shows how land requirements for bioenergy crop production would sharply decrease with the rapid electrification of road transport. All those savings mean less forest clearing and less competition for existing fallow land.

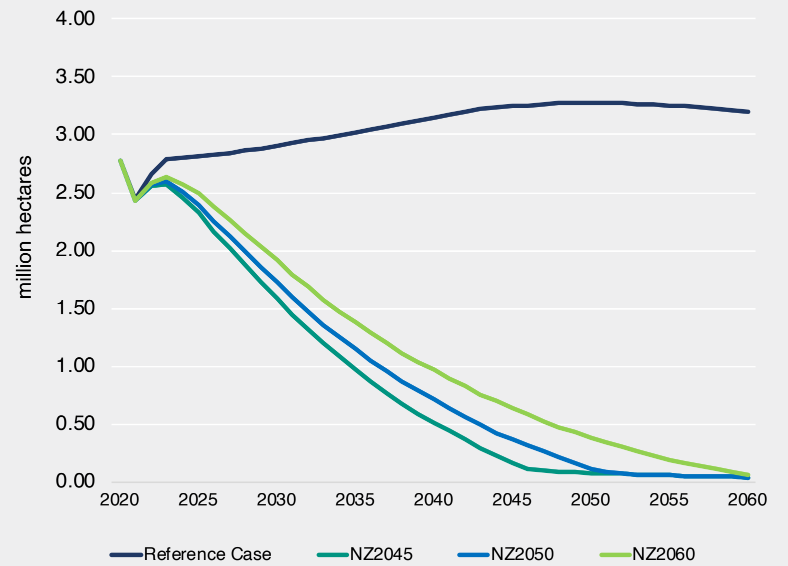
Figure 10. Primary and secondary forest cover (excluding plantations), Reference Case and NZ2050



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.

Figure 11. Total land requirements for bioenergy crops across scenarios



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.

2.2.3 Waste and industrial processes and product use (IPPU)

The waste and industrial sectors play relative small roles in emission reduction efforts in the net-zero scenarios (about 8% and 2%, respectively, of cumulative emission reductions over the period 2021–2060, with the important caveat that the latter includes only GHGs from industrial processes and product use, or IPPU).[122] Still, both these sectors are critically important to the socio-economic development of Indonesia, and measures to reduce emissions can boost job creation. There is growing evidence that investing in wastewater management, for instance, creates jobs that pay better than other options for people with similar skill levels.[123] Moreover, like land use measures, waste sector interventions can have broad benefits, including better air and water quality thanks to reduced pollution.

Table 3 outlines key interventions and targets in the waste and industrial sectors. With regard to waste, it is important to remember that by default, as a country's population and GDP grow, so will waste production—unless policies are put into place and investments are made to reduce waste, including through behavioral change (see Section 4.4). The policies included in the net-zero scenarios target household waste generation, household and industrial wastewater, and solid waste management (including recycling).

Table 3. Key waste and industrial sector interventions and targets in the net-zero scenarios

Intervention	RPJMN 2020–2024 targets	LCDI 2019 High scenario	Net-zero scenarios
Improved solid waste management	339.4 million tonnes of waste to be properly managed over 2020–2024 (from baseline of 67.5 million per year in 2019)	By 2045, reduce waste generation by 30% and emissions by 10% relative to baseline	Across scenarios, reduce waste generation per capita by 70% from 2020 levels by net-zero target year
Industrial wastewater recycling	No targets		100% of industrial wastewater recycled by the net-zero target year
Improved industrial waste management	Increased capacity of B3 waste process up to 26,880 tonnes per year by 2024 (cumulative 539.8 million tonnes) and waste management area of 20 ha by 2022	Reduce emissions by 50% relative to baseline by 2045	No targets (due to limitations of available data)
Reduce IPPU emissions	Reduce IPPU emissions by 2.9% by 2024 from 2019 level	Reduce IPPU emissions by 50% relative to baseline by 2045	Across scenarios, reduce emission intensity of IPPU to one-third of 2020 level by 2060

Source: Bappenas, 2019.[124]
Note: B3 waste is classified as hazardous and toxic waste under Law No.32/2009 on Environmental Protection and Management (Undang-Undang Nomor 32 Tahun 2009 Tentang Perlindungan dan Pengelolaan Lingkungan Hidup) (Presidential Regulation No 79/2018).

[122] This means two kinds of emissions: from industrial processes that chemically or physically transform materials, releasing GHGs, and from GHG use in products such as refrigerators, foams or aerosols. IPPU emissions do not include industrial energy use or fugitive emissions. For a detailed explanation of the scope of IPPU emissions, see this presentation: Shermanau, 2016, "Industrial Processes and Product Use (IPPU)."

[123] WWAP, 2017, "Wastewater: The Untapped Resource – UN World Water Development Report 2017"; Renner, 2017, "Wastewater and Jobs: The Decent Work Approach to Reducing Untreated Wastewater"; Smith, 2021, "Wastewater Has the Best Green Jobs Workers Don't Know About," *Governing*.

[124] Bappenas, 2019, "2020–2024 National Medium-Term Development Plan (Rencana Pembangunan Jangka Menengah Nasional 2020–2024)"; 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia."

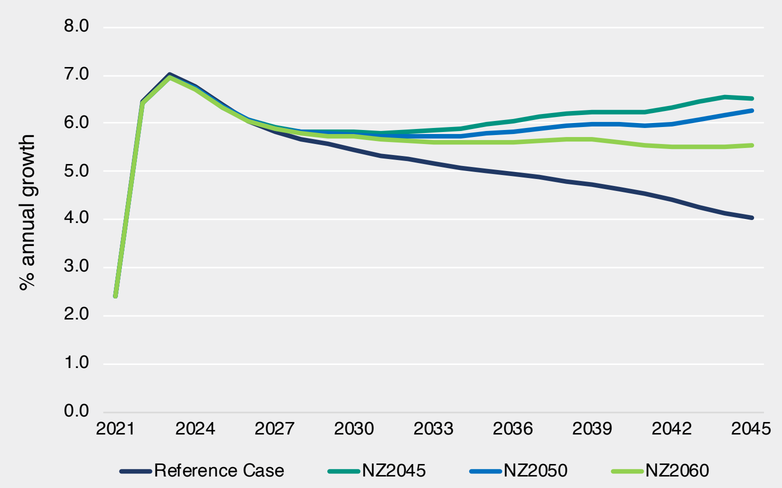
2.3 The socio-economic benefits of net-zero pathways

The vision of the Low-Carbon Development Initiative is to build a strong, sustainable and inclusive economy for Indonesia, maintaining robust growth and boosting competitiveness while protecting the country's natural capital. This means that in order to be viable, net-zero scenarios need to do more than reduce GHG emissions—they must also ensure continued growth, shared prosperity, a high quality of life for all Indonesians, and healthy ecosystems, in the near term and for decades to come.

As **Figure 12** shows, the net-zero scenarios would deliver sustained real GDP growth—and at higher rates than the Reference Case: averaging 6.5% per year for 2021–2050 in NZ2045; 6.4% in NZ2050, and 6.1% in NZ2060, and then continuing beyond 2050 at a slower rate of growth. By 2050, those higher growth rates result in a total GDP that is 56.1% greater in NZ2045 than in the Reference Case, 52.5% greater in NZ2050, and 43.1% greater in NZ2060. This reflects the benefits of restoring and protecting natural capital, which in turn increases carrying capacity (see Section 2.1), and of investments in labor-intensive and fast-growing green economic sectors.

As shown in **Figure 13**, by 2045, per capita gross national income (GNI) would reach US$14,975 in NZ2045, US$14,485 in NZ2050 and US$13,980 in NZ2060. This means that across net-zero scenarios, Indonesia would achieve its goal to become a high-income country by 2045 (the current threshold is US$12,535).[125]

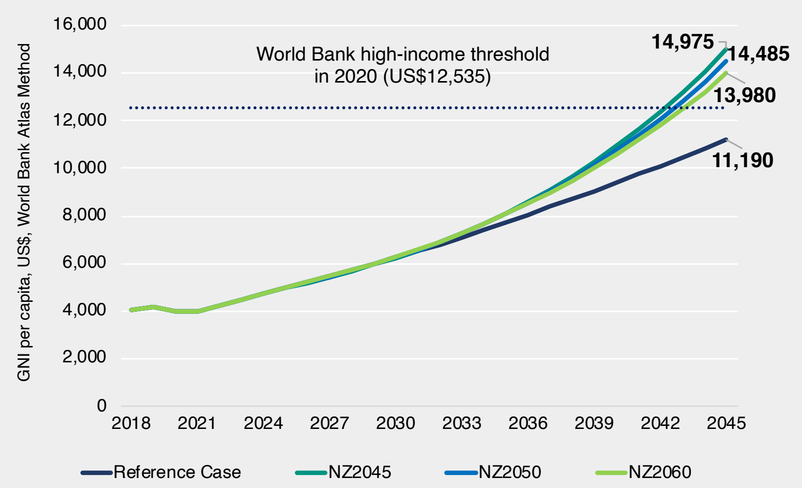
Figure 12. Real GDP growth rate, Reference case and net-zero scenarios, 2021–2060



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.

Figure 13. Per capita gross national income, Reference Case and net-zero scenarios



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

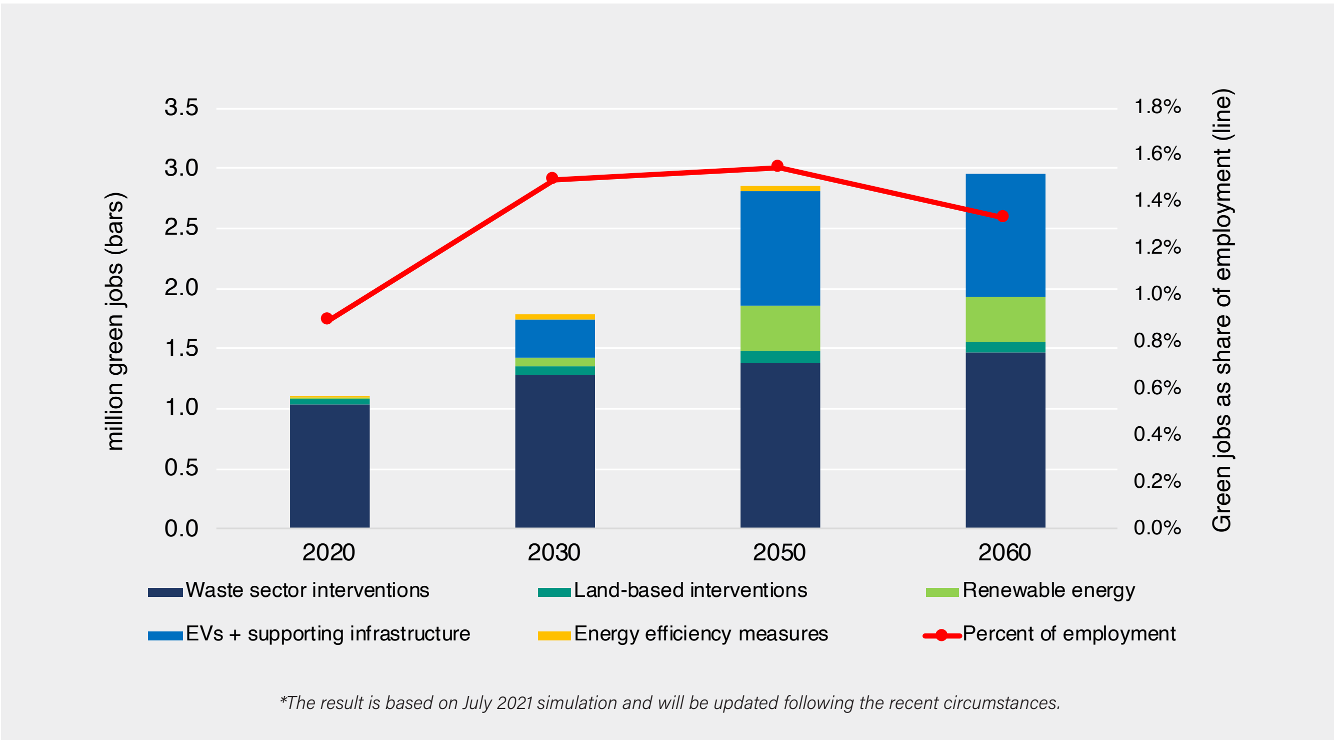
Source: LCDI modeling results.

[125] Hamadeh, van Rompaey, and Metreau, 2021, "New World Bank Country Classifications by Income Level: 2021–2022," *World Bank Data Blog.*

Pursuing net-zero would also create large numbers of green jobs, and thus could be an integral part of a strong recovery from the COVID-19 economic crisis. As outlined in Section 1.3, multiple studies have shown that green investments produce at least twice and up to 7–10 times as many jobs as conventional investments, as renewable energy, energy efficiency, nature-based solutions, recycling, wastewater reuse, and other activities are more labor-intensive than their "gray" or "brown" alternatives.[126]

A bottom-up estimate based on the NZ2050 scenario indicates that it would result in 1.8–2.2 million additional jobs in 2030 in renewable energy, EV technologies, energy efficiency, land use interventions and improved waste management (**Figure 15**). That would be 1.0–1.3% of the projected labor force in 2030. It is important to note that this is a conservative underestimate, as it excludes construction jobs—which other studies have found are created in large numbers when measures are adopted to improve the energy efficiency of buildings. It also uses conservative estimates of the jobs associated with land-based interventions, which are widely considered to be very labor-intensive.[127]

Figure 14. Direct green jobs created by net-zero measures in NZ2050



Source: LCDI modeling results. Note: Job creation estimates exclude construction jobs—which make up a large share of the jobs typically created through energy efficiency programs (e.g. for building retrofits)—and use conservative estimates of the jobs associated with land-based interventions.

[126] IEA, 2020, "Sustainable Recovery"; Gulati *et al.*, 2020, "The Economic Case for Greening the Global Recovery through Cities: 7 Priorities for National Governments"; Garrett-Peltier, 2017, "Green versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-Output Model," *Economic Modelling*.

[127] For example, a recent study estimated that measures to reduce GHG emissions in Indonesia's cities could add 2.3 million jobs in 2030, mostly in energy efficiency (retrofits and new construction) and rooftop solar installation in the buildings sector. See CUT, 2021, "Seizing Indonesia's Urban Opportunity: Compact, Connected, Clean and Resilient Cities as Drivers of Sustainable Development."

Another study found that measures to increase energy efficiency in existing and new buildings would create 8–21 jobs per US$1 million invested, while comparable high-carbon investments would create only three jobs per US$1 million. The same study found that nature-based solutions, such as planting street trees, creating green space and restoring landscapes in and around cities, could create 40 jobs per US$1 million, twice as many jobs as a similar investment in conventional water infrastructure. See Gulati *et al.*, 2020, "The Economic Case for Greening the Global Recovery through Cities: 7 Priorities for National Governments."

In short, the analysis shows that the net-zero scenarios would produce better socio-economic outcomes than the Reference Case. There are also broader societal benefits, such as sharp reductions in air pollution, which the model shows could save 40,000 lives in 2045 alone. With additional strategies that prioritize equity and inclusion, these gains could be used to benefit poor and disadvantaged populations and help close gender gaps.

While the full benefits of green and sustainable development are realized over time—especially in terms of a safer climate, healthier ecosystems, and avoided losses of natural capital—they start right away. Indonesia can begin to reap the rewards immediately by implementing net-zero measures as part of its COVID-19 recovery, with significant stimulus effects and job creation. This would also help reduce the risk of stranded assets, by avoiding the need for new construction of coal power plants, for example, that might otherwise need to be retired prematurely.

That said, not all sectors, communities or individuals will gain equally; high-carbon sectors would be expected to decline, shedding jobs. Economy-wide, those losses will be more than offset by new opportunities in low-carbon sectors, but targeted policies and investments are crucial to support a just transition and ensure that no one is left behind.

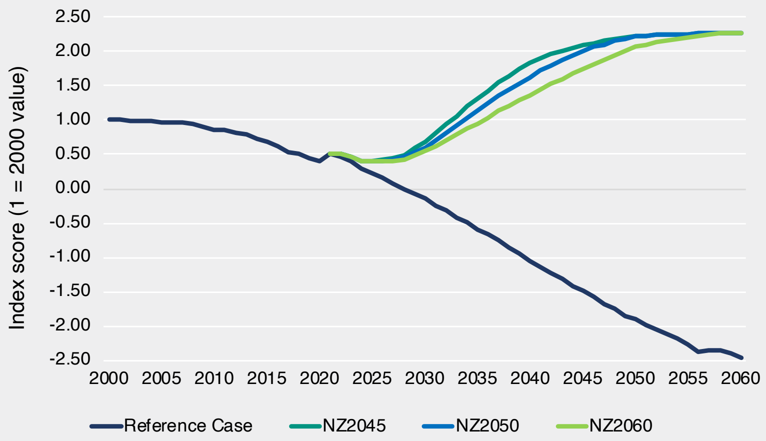
Delving deeper into the model results shows the main sources of improved socio-economic outcomes in the net-zero scenarios include effects on total factor productivity;[128] the higher availability and better quality of environmental goods and services that directly and indirectly contribute to output, income and employment generation; and avoided externalities.

As noted in Section 2.1, conventional macroeconomic models often underestimate or ignore key benefits of low-carbon and green policies, as they fail to recognize core linkages between the environment, the economy, and human well-being, or did not know how to quantify them. Without this crucial knowledge, decision-makers would have a distorted picture of the socio-economic implications of different options, and thus underestimate the benefits of decarbonization and protection of natural capital.

Aiming to fill that gap, as part of the LCDI process, an Environmental Performance Index (EPI) was created to provide a composite metric of environmental elements that directly and indirectly affect well-being. The EPI combines three components: an "ecosystem score" (from availability of forest land, habitat quality and the value of ecosystem services); an "air quality score" (from emissions of particulate matter—$PM_{2.5}$—and nitrous oxide); and a "resources score" (from energy intensity, as defined above, and amount of waste generate). The index is set at a value of 1 for year 2000 and changes over time as a result of changes in those components.

Figure 15 shows trends for the EPI in the Reference Case and across net-zero scenarios, as well as the historical trend, which shows a sustained deterioration in EPI through 2019, and a small improvement in 2020 due to reduced economic activity during the COVID-19 pandemic. Post-2021, the EPI is projected to continue to decline under the Reference Case, whereas it improves in the net-zero scenarios.

Figure 15. Environmental Performance Index trends through 2060 across scenarios



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.

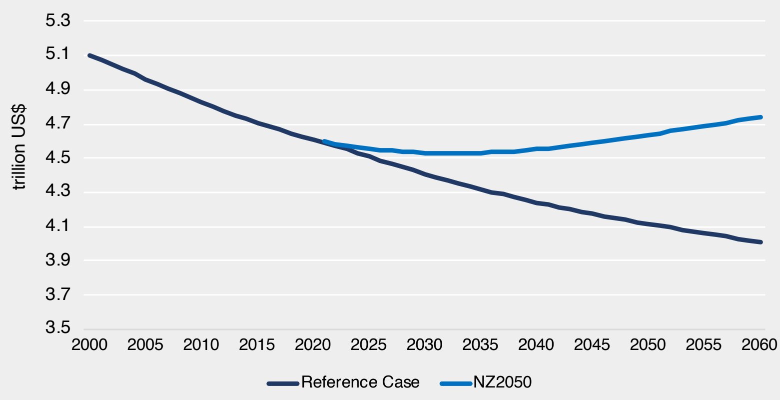
[128] Total factor productivity (TFP), also known as multi-factor productivity, is a measure of the output of an economy (or industry) relative to the inputs that went into it (such as capital and labor). If outputs are growing faster than inputs, TFP is improving; the opposite means it is declining. For a succinct explanation, see the glossary of the Asian Productivity Organization: https://www.apo-tokyo.org/resources/p_glossary/total-factor-productivity-2/.

Another important benefit of net-zero policies is improved ecosystem services. Forest, mangrove and peatland restoration efforts not only boost carbon storage, but also increase the value of the broader services provided by those ecosystems. The model quantifies the value of many, but by no means all, of those services, including the benefits of biodiversity; fire, flood and drought prevention; provisioning (food, medicine, materials and fuel); water supply and other hydrological services; and, in the case of mangroves, coastal protection from storm surges and flooding, healthier fisheries in mangrove-connected areas, and protection from saltwater intrusion.

The net-zero scenarios would allow the recovery of ecosystem services with an aggregate value of nearly US$4.75 trillion per year by 2060 in NZ2050, or 8.1% of the country's GDP that year. **Figure 16** shows that the value of those services has been declining steadily, reflecting the loss in carrying capacity discussed in Section 2.1. The net-zero scenarios would allow the recovery of ecosystem services with an aggregate value of nearly US$4.75 trillion per year by 2060 in NZ2050, or 8.1% of the country's GDP that year.

A final, important consideration is how pursuing net-zero might accelerate Indonesia's structural transformation on the path to becoming a high-income country. Several studies have found that, despite robust economic growth over the last decades, Indonesia appears to be stuck in a "middle-income trap."[129] This is a phenomenon in which increased economic inequality, combined with structural deficits in education and skills, infrastructure and savings (expressed in government and external sector deficits), prevents countries from rising to high-income status. Indonesia's recent reclassification as a lower-income country after a pandemic-related contraction could deepen that concern.[130]

Figure 16. Economic value of ecosystem services across scenarios



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results, based on Bappenas spatial analyses.

While the analytical framework that supports LCDI does not address all supply and demand elements that determine growth outcomes, the empirical results indicate that pursuing net-zero could help the country break away from the middle-income trap by reducing reliance on land-based sectors. By proactively building low-carbon industries, Indonesia can also boost its global competitiveness. This was also a key point made by the ADB in arguing for a green recovery across Southeast Asia.[131]

Structural transformation is crucial to escaping the middle-income trap—moving away from the primary sector, which depends on and often erodes natural resources, and towards the secondary and tertiary sectors. That is the path taken by East Asian economies that have achieved high incomes, such as Japan and South Korea. The net-zero scenarios accelerate growth and create new economic opportunities in the secondary and tertiary sectors.

Such patterns of structural transformation are associated with faster increases in human capital (from development of education, skills and health outcomes) and the closing of fiscal and external sector gaps. For example, reducing dependency on energy imports and developing local manufacturing to supply inputs to low-carbon businesses could help reduce deficits in the current account. In addition, as noted earlier, revenue from carbon pricing and savings from the phase-out of fossil fuel subsidies can provide fiscal resources for growth, while the country develops higher fiscal buoyancy associated with a stronger industrial base and the increase in average incomes.

[129] See, e.g., Lumbangaol and Pasaribu, 2019, "Eksistensi dan Determinan Middle Income Trap di Indonesia [Existence and Determinants of Middle Income Trap in Indonesia]," *Jurnal Ekonomi & Kebijakan Publik*; Setiawan, 2017, "Middle Income Trap and Infrastructure Issues In Indonesia: A Strategic Perspective," *International Journal of Economics and Financial Issues*; Basri and Putra, 2016, "Escaping the Middle Income Trap in Indonesia: An Analysis of Risks, Remedies and National Characteristics"; World Bank, 2014, "Indonesia: Avoiding the Trap."

[130] Hamadeh, van Rompaey, and Metreau, 2021, "New World Bank Country Classifications by Income Level: 2021–2022," *World Bank Data Blog.*

[131] Lim, Ng, and Zara, 2021, "Implementing a Green Recovery in Southeast Asia."

3.

Investment needs, fiscal impacts and financing options

Photo by Sigit Deni Sasmito/CIFOR via Flickr

The discussion so far indicates that it is clearly advantageous for Indonesia to embrace a net-zero pathway, especially as it becomes clear that climate risks and the continued loss of natural capital make the "business as usual" pre-pandemic growth path ever less feasible. The question then is, how much would it cost to pursue a net-zero pathway, and can Indonesia afford it?

In this section, we examine the costs of specific interventions and of policy packages and the options for financing them. First we review overall costs and the extent to which they would be additional to those in the Reference Case; then, in Section 3.2, we examine what can be funded by the government without jeopardizing fiscal stability, what the market can do on its own with the right policies and incentives, what is a good fit with existing external funding sources (e.g. green recovery funds), and what will require new international climate finance. The latter will be crucial information for Indonesia's engagement with bilateral development partners and multilateral development banks. As President Widodo has noted, Indonesia simply cannot reach net-zero without international support.[132]

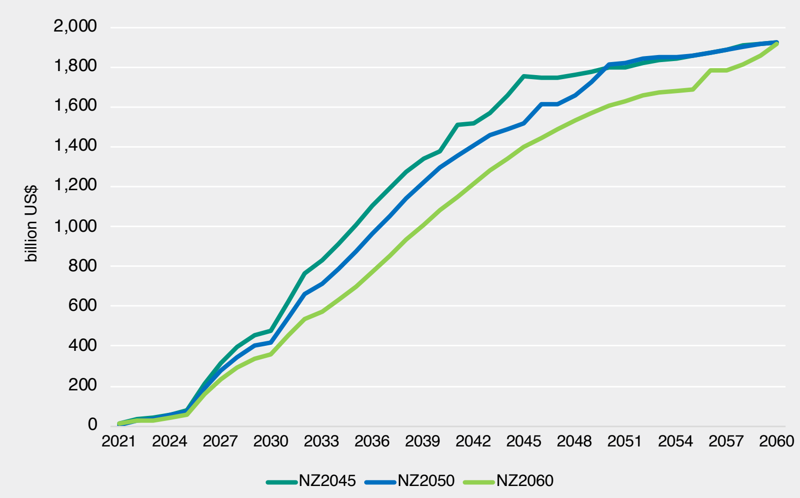
3.1 How much will it cost for Indonesia to achieve net-zero?

For this analysis, we considered both upfront investment needs and recurring costs for operation and maintenance (O&M) for different interventions. Appendix A5 summarizes per unit costs of interventions. These include those in energy efficiency, carbon capture and sequestration, low-carbon energy technologies, land-based interventions, waste management, and waste prevention. Unit costs of low-carbon interventions are extracted from the empirical literature, in many cases from international sources.

Overall investment needs and associated O&M costs vary over time because of changing levels and speed of efforts across interventions. They are, naturally, higher upfront for more ambitious net-zero scenarios. **Figure 17** shows the annual costs of the net-zero scenarios over the period 2021–2070, in absolute terms, and **Figure 18** shows them as a share of GDP.

It is clear that transforming Indonesia's economy to achieve net-zero will require both shifts in existing investments and significant new financing. The costs would start at around US$20 billion per year in 2021–2022 (about Rp. 291 trillion) and average US$150–200 billion (Rp. 2.2–2.9 quadrillion) per year for the period 2021–2030 (that is 3.4–4.5% of GDP for the period). In 2031–2040, investment needs would rise to US$700 billion–$1 trillion per year (7.1–9.8% of GDP); in 2041–2050, they would be US$1.3–1.6 trillion per year (6.6–7.5% of GDP); and in 2051–2070, US$2.1–2.2 trillion per year (3.4% of GDP).

Figure 17. Investment needs for net-zero scenarios, 2021–2060

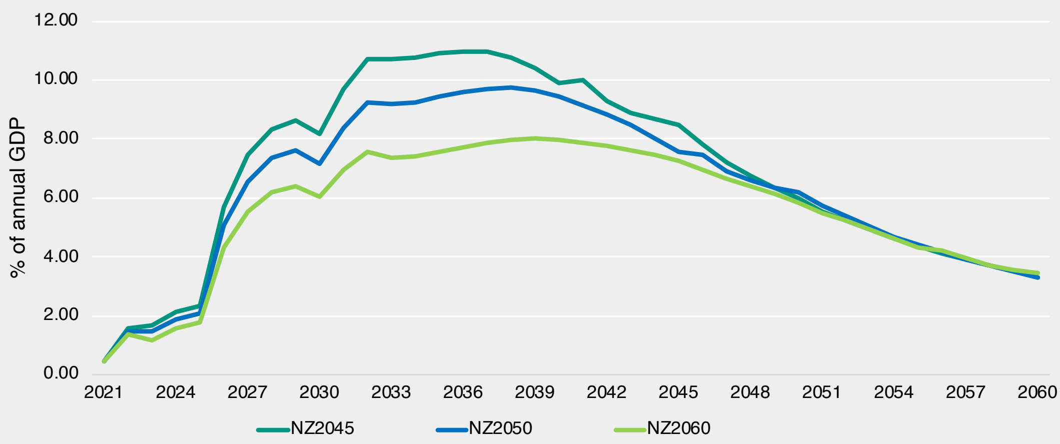


**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.

132 Cabinet Secretariat, 2021, "President Jokowi Addresses Three Issues on Climate Change."

Figure 18. Investment needs for net-zero scenarios, 2021–2060, as share of GDP



Source: LCDI modeling results.

For comparison, those figures would represent only about 10% of the country's total investment needs over the period 2021–2030, and 20% of total investments thereafter through 2060.[133] Still, they would represent a major increase in low-carbon investments, which averaged a fraction of a percentage point of GDP in 2015–2020. To better understand these figures, it is important to consider that:

- Investments, especially in renewable energy, are substitutes for other investments that otherwise would be made in high-carbon sectors. To gauge the burden on government finances, it is important to distinguish between the total cost and the incremental cost, compared with high-carbon energy.
- In order to provide a fair appraisal of differential macroeconomic impacts of LCDI interventions that occur as a result of factors other than a larger aggregate demand effort relative to the Reference Case, the analyzed scenarios are built in such a way that any dollar of additional LCDI investment gets subtracted from other aggregate demand expenditures.
- The costs of LCDI interventions need to be compared with associated LCDI revenues and avoided costs, mainly from applying a carbon price and removing fossil fuel subsidies. As indicated in Figure 7, those revenues peak in 2031 at an amount equivalent to 2.64–3.55% of GDP, depending on the scenario.
- Not all the LCDI effort corresponds to expenditures from the public sector—though, conservatively, the model assumes that the public sector will undertake most, in line with historical patterns. The public sector investments modeled cover waste management, land-based interventions, the development of hydrogen technology for liquid fuels, capital investments in public transportation (buses, charging stations) and their O&M costs, and total capital and O&M for power generation.
- In practice, while today, most of those costs are shouldered by the government—for instance, building power plants—renewable energy, which represents 57% of total investment needs in 2021–2030 and about 75% of the total thereafter, already attracts substantial private investment worldwide, as do other green technologies. As discussed further below, with appropriate regulatory reforms, as well as de-risking measures such as guarantees, joint operations and public-private partnerships, Indonesia could unlock significant new private finance flows, especially in the late 2020s and early 2030s, when investment needs peak.
- The Government of Indonesia may face budget constraints that impede progress on LCDI investments that are typically considered as public, along with their O&M costs. Considerations about deficit and debt ceilings, on revenue recycling mechanisms, sources of international financing, and the financing of O&M need to be made.

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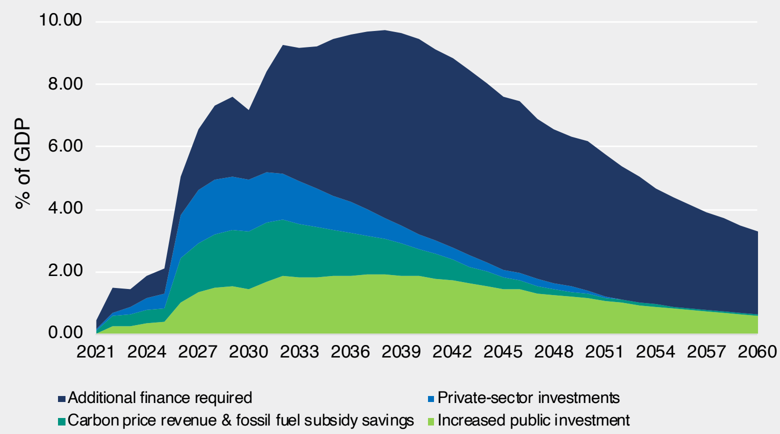
133 Based on investment trends produced by the Bappenas Macroeconomic Directorate.

Of the financing needs identified above, across scenarios, an estimated 81% in 2021–2030, 90% in 2031–2050, and nearly 98% in 2051–2070 correspond to investments (and associated O&M costs) generally advanced by the public sector. **Figure 19** indicates how financing needs might be allocated, including both known and still-unidentified sources of funding. A major potential source of what is labeled "remaining financing," as noted earlier, is the reallocation of resources from high-carbon investments to green investments. Given the escalating stranded-asset risks faced by fossil fuel-dependent sectors, and the global financial sector's ongoing shift towards low-carbon pathways, a significant reallocation of resources would be wise—and indeed, it is likely to occur in the coming years.

Lastly, it is important to recognize and address concerns that the investments needed to achieve net-zero would increase government deficits, which have already grown due to the cost of pandemic response. **Figure 20** shows the historical trend as well as projections across scenarios. Though the deficit would initially grow in the net-zero scenarios, more robust economic growth would help reduce the deficit over time. As economists around the world have recognized amid the COVID-19 crisis, deficit spending is particularly appropriate and even advisable as a mechanism to recover from a sharp economic downturn and to support investments in long-term growth and broader socio-economic development.[134]

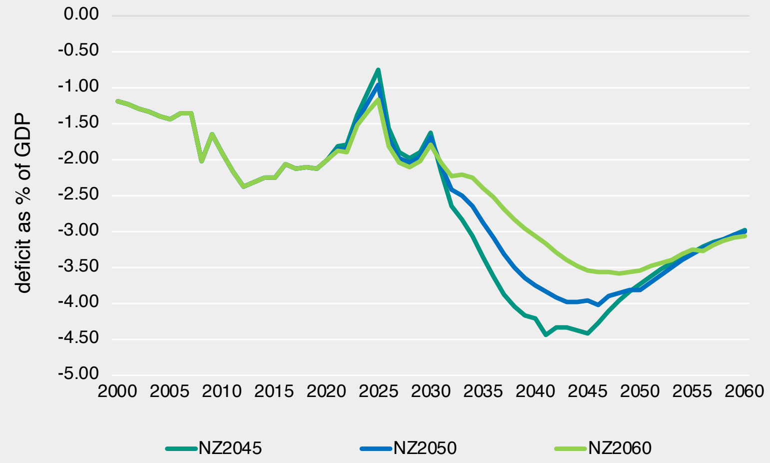
Figure 19. Key sources of finance for net-zero measures, NZ2045, as share of GDP



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LCDI modeling results.
Note: The level of increased public investments is capped to ensure the current accounts deficit never exceeds 4.5% of GDP. The additional finance required could come from multiple sources, including the reallocation of resources by both the public and private sectors from high-carbon to green investments. International finance is also expected to play a crucial role.

Figure 20. Projected national government deficit as share of GDP, across scenarios



**The result is based on July 2021 simulation and will be updated following the recent circumstances.*

Source: LDCI modeling results, including historical data.

[134] It has also been a successful strategy for Southeast Asian countries. See, e.g., Pham, 2018, "Impacts of Public Debt on Economic Growth in Six ASEAN Countries," *Ritsumeikan Annual Review of International Studies.*

3.2 Unlocking finance for key net-zero investments

Two strategies in the net-zero scenarios would directly contribute to domestic sources of finance: the phase-out of fossil fuel subsidies and phasing in of a carbon price. They would generate savings and new revenue, respectively, rising to the equivalent of 2.2% of GDP in 2030 (the peak year) before tapering off as fossil fuels are phased out of the economy. Some of that revenue will be needed for social protection programs and other investments to ensure a just transition, but the balance could finance green infrastructure.

Green finance is another important revenue source. Indonesia has already tested the waters with green finance, through two issuances of Green Sukuk (Islamic bonds) worth US$2 billion in 2018 that were both oversubscribed, showing an appetite among investors for such opportunities.[135] Significantly more progress is now needed to expand green finance in Indonesia, at a pace commensurate with investment needs. The Indonesia Climate Change Trust Fund (ICCTF) could be one avenue for developing creative green finance options.[136] It is also crucial to ensure that revenues raised by green bonds are used exclusively for low-carbon and green projects.

Forest, peatland and mangrove restoration has proven particularly challenging to finance in recent years. With an average annual budget of Rp. 15 billion (US$1.1 million) between 2015 and 2017, Indonesia only achieved 55% and 13% of its annual restoration targets in 2015 and 2016, respectively.[137] Peatland restoration alone is estimated to cost more than US$4.6 billion—substantially more than the funds currently allocated to the challenge across Indonesian and international donor budgets.[138]

Some private investment has mobilized financing for restoration, including blended finance instruments under the Tropical Landscape Financing Facility and provisions in the Green Sukuk and in Natural Capital Bonds. These efforts could be greatly enhanced with a robust market in forestry carbon credits (discussed further in Section 4.2) to direct private sector funds into forestry-related emissions reductions.[139] Progress on carbon pricing regulations would provide guidance on using carbon credits to raise finances for restoration, especially if an offsetting mechanism is in place as well.

Ambitious and high-profile commitments to restore and protect forests, peatlands and mangroves in the context of a net-zero target could also help Indonesia overcome challenges in attracting significant finance from REDD+ and from major bilateral and multilateral donors focused on land use emissions.[140] These projects could also be prime candidates for international carbon markets, and so could sustainable agriculture initiatives. In this context, however, it is important to remember that to avoid double-counting of emission reductions, any carbon credits sold would need to be offset on Indonesia's own emissions inventory. Still, given the large benefits associated with these efforts, it is a key option to explore.

Agricultural subsidies, which amount to over 164 times the REDD+ finance the country received between 2006 and 2014,[141] also need to be reviewed to ensure that they do not hinder the scaling up of finance for restoration.[142] Removal of any harmful subsidies would discourage practices that exacerbate deforestation and land degradation. It would also show investors that Indonesia is committed to protecting its natural capital, which could provide a comparative advantage in future global supply chains. Public endorsement of more sustainable

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[135] Gorbiano, 2019, "Indonesia Issues US$ 2b Global Green, Regular Sukuk," *The Jakarta Post.*

[136] See https://www.icctf.or.id/.

[137] KLHK, 2015, "Rencana Strategis 2015–2019."

[138] Hansson and Dargusch, 2018, "An Estimate of the Financial Cost of Peatland Restoration in Indonesia," *Case Studies in the Environment.*

[139] Tacconi and Muttaqin, 2019, "Reducing Emissions from Land Use Change in Indonesia: An Overview," *Forest Policy and Economics.*

[140] Ambition has paid off before. For instance, in August 2020, the Green Climate Fund approved a US$103.8 million proposal from Indonesia for results-based payments under REDD+. See Cabinet Secretariat, 2020, "Green Climate Fund Approves Indonesia's REDD+ RBP Proposal of USD103.8 Million,"

[141] McFarland, Whitley, and Kissinger, 2015, "Subsidies to Key Commodities Driving Forest Loss."

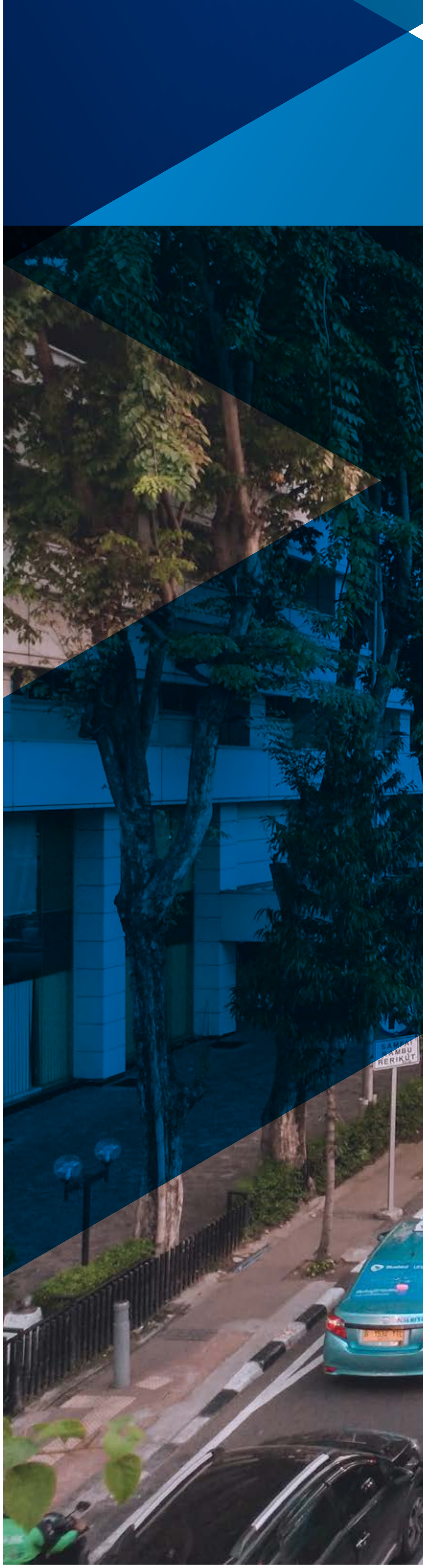
[142] Ding *et al*., 2017, "Roots of Prosperity: The Economics and Finance of Restoring Land."

practices as part of a green recovery would signal the reliable long-term productivity and output gains that investors look for.[143]

In the energy sector, meanwhile, a recent review by the Organisation for Economic Co-operation and Development (OECD) identified several near- and longer-term actions needed to facilitate and encourage private investment in renewable energy,[144] from updated regulations to facilitate renewable energy projects, to a detailed market assessment of financing needs and challenges, de-risking approaches (such as guarantees, blended finance and joint operations), and a shift to public, competitive tenders to procure renewables. Significant capacity-building is also needed to enable the design and development of a pipeline of bankable projects. Development partners, including multilateral banks, can provide expert support, drawing on successful models across Asia and beyond.

Energy efficiency measures and projects, meanwhile, have been impeded both by a lack of finance and by misaligned incentives—such as high import tariffs and taxes—that discourage the use and adoption of more efficient technologies.[145] Realigning those incentives can encourage consumers to adopt energy-efficient technologies in their homes, and firms in commercial buildings. This may come in the form of tax breaks for the purchase of efficient appliances, such as the 50% tax deduction that Italy has provided, or subsidies, such as the ones Mexico funded to cover the costs of new, energy-efficient refrigerators and air conditioners. Mobilizing financing for energy efficiency requires significant government support and flexibility for private sector involvement. Several of these barriers could be addressed through long-term concessional finance or risk-sharing facilities supported by a dedicated energy efficiency fund through, for example, PT SMI's SDG Indonesia One Blended Finance Platform.[146]

Scaling up international finance will also be crucial. Targeted "green recovery" funds set up by the ADB, the World Bank and others could help jump-start key projects (see Section 1.3). But as President Widodo has said, developed countries urgently need to scale up climate finance for developing economies, to meet their commitment to mobilize US$100 billion per year for developing countries. Indonesia will also need to work closely with its development partners, including bilateral donors and multilateral banks, to realign finance flows to advance the net-zero agenda.

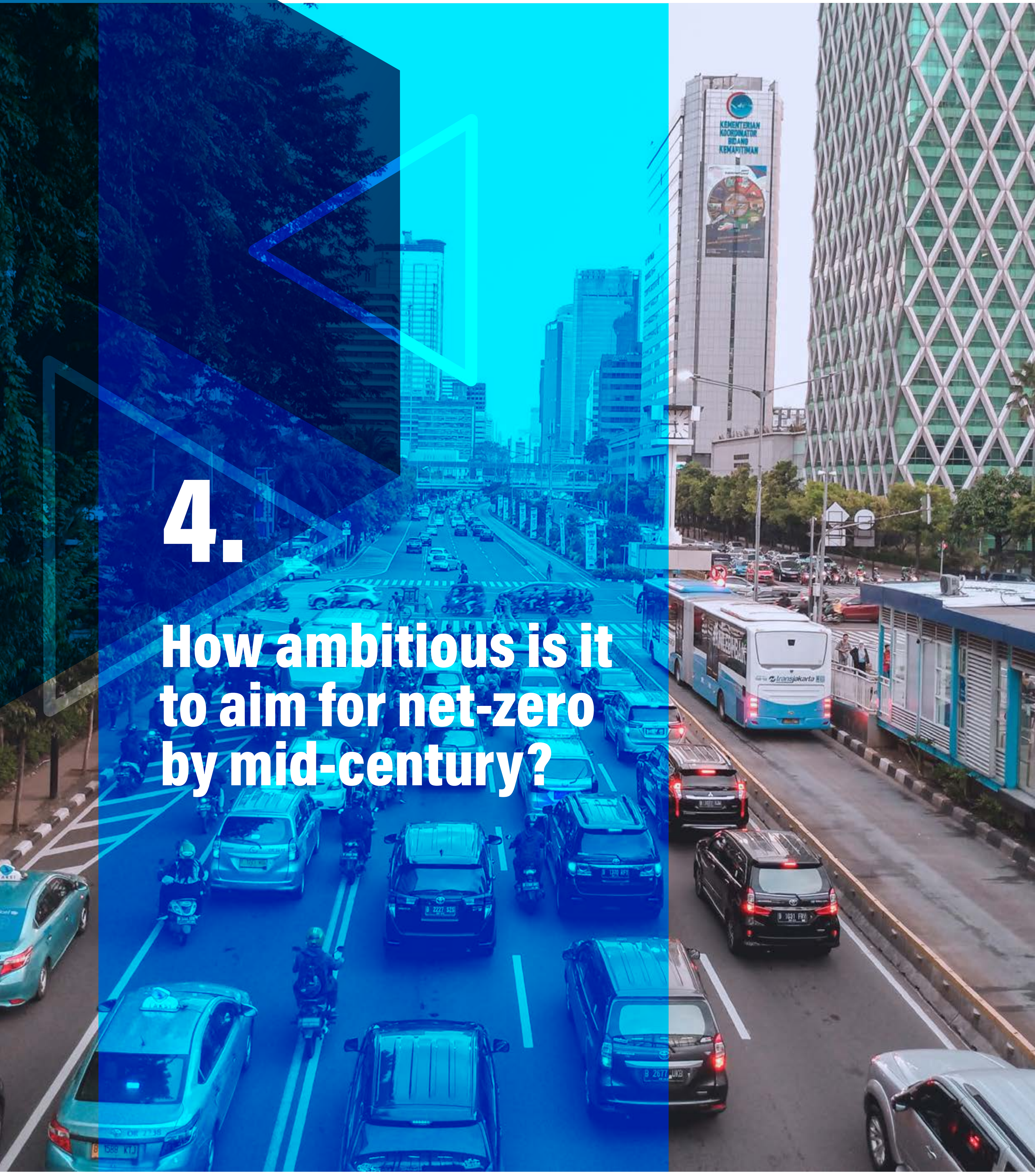


[143] See, e.g., Green Century, 2020, "Open Letter on the Omnibus Bill on Job Creation."

[144] OECD, 2021, *Clean Energy Finance and Investment Policy Review of Indonesia.*

[145] OECD, 2021, *Clean Energy Finance and Investment Policy Review of Indonesia.*

[146] PT SMI is a Special Mission Vehicle under the Ministry of Finance that is engaged in financing and preparing infrastructure projects. To learn more about the Indonesia One platform, see https://ptsmi.co.id/sdg-indonesia-one/.



4.

How ambitious is it to aim for net-zero by mid-century?

Photo by Ngrh Mei via Pexels

The analysis in Section 2 lays out an ambitious agenda for achieving net-zero in Indonesia by 2045, 2050 or 2060 and shows why immediate action would be more beneficial than slower, more gradual pathways. Still, aiming for net-zero as soon as 2045 would put Indonesia on the vanguard of the sustainability transformation, and it would require bold actions that fully align with the vision of the LCDI, but are not yet part of Indonesia's near-term plans.

This section examines just how ambitious the measures described in Section 2 would be, measured against both Indonesia's current trajectory, and what other nations have undertaken. By looking more closely at the progress on energy systems; carbon pricing; industrial processes and product use (IPPU); food loss and waste; forest, mangrove and peatland restoration; and sustainable agriculture, we show that achieving net-zero, while challenging, is well within Indonesia's reach—and worth the effort.

4.1 Energy systems

In line with the increasing global demand for clean energy, Indonesia has kick-started several promising initiatives on clean energy, including ambitious national action plans. **Table 4** compares the net-zero scenarios with existing and announced energy-related targets in Indonesia.

Table 4. Renewable energy targets in existing policies and in net-zero scenarios

Policy/Scenario	Renewable energy targets
National General Plan for Energy (RUEN)/ National Energy Policy (KEN)	23% of primary energy supply by 2025
National General Plan for Electricity (RUKN)	28% of electricity generation by 2025
Electricity Power Supply Business Plan (RUPTL) 2021–2030 (draft)	40.9 GW capacity developed over 2021–2030, 49% of which is renewable
2019 Indonesia Energy Outlook Sustainable Development scenario	23% of primary energy mix by 2025, 32% by 2050
2019 Energy Outlook Low Carbon scenario	36% of primary energy mix by 2025, 58% by 2050
IESR Best Policy Scenario (BPS)	80% of primary energy mix by 2040, reaching 100% by 2050 50% of electricity generation by 2030, reaching 100% by 2045
Net-zero scenarios	65% of primary energy mix by 2030 (rest from coal and natural gas); 85% by 2060 (rest from nuclear); starting from 16.4% in 2022, renewable share of power generation to reach 60% by 2030 and 82% by 2053 (remaining 18% from nuclear by 2060)

Sources: Government of Indonesia,[147] ESDM,[148] Reuters,[149] National Energy Council,[150] IESR.[151]

Building on the Ministry of Energy and Mineral Resources (ESDM) Renewable Energy regulations,[152] the government is finalizing draft regulations to encourage investment in renewables and provide guidelines and policy space for clean energy adoption.[153] Among the planned measures is a new Renewable Energy Fund, sourced from the State Budget (APBN), Regional Budget (APBD), export levies on non-renewable energy, carbon trading funds, Renewable Energy Certificate (REC) funds, and other legal sources. The fund will support renewable infrastructure development as well as incentives, such as compensation for businesses that increase renewable generation capacity.

As noted earlier, PLN has announced a moratorium on coal power plant construction after 2023.[154] After that, all new electricity generation capacity would come from renewables, as part of its plan to reach carbon neutrality by 2060.[155] PLN aims to increase the share of renewable power in the 2021–2030 National Electricity Plan (RUPTL) to at least 48%, from 30% in the 2019–2028 plan.[156] This is certainly a step forward, considering coal-fired electricity generation was

[147] Government of Indonesia, 2014, "Government Regulation No. 79/2014 on National Energy Policy."

[148] ESDM, 2019, "Rencana Umum Ketenagalistrikan Nasional (RUKN) 2019–2038 (National Electricity Plan)."

[149] Reuters, 2021, "Renewables to Make up at Least 48% of Indonesia's 2021–2030 Electricity Plan."

[150] National Energy Council, 2019, "Indonesia Energy Outlook 2019."

[151] IESR, 2021, "Indonesia Energy Transition Outlook 2021."

[152] ESDM, 2020, "Perubahan Kedua Atas Peraturan Menteri Energi Dan Sumber Daya Mineral Nomor 50 Tahun 2017 Tentang Pemanfaatan Sumber Energi Terbarukan Untuk Penyediaan Tenaga Listrik (Second Amendment to Regulation No. 50 of 2017 on the Utilisation of Renewable Energy Resources for Electricity)."

[153] Reuters, 2020, "Indonesian Govt Finalises New Rules for Renewable Electricity."

[154] Husaini, 2021, "Demi zero emisi, PLN moratorium pembangunan pembangkit batubara," *Kontan.co.id*.

[155] PLN, 2021, "PLN Siapkan Transisi Menuju Energi Bersih Demi Generasi Mendatang," Perusahaan Listrik Negara (State Electricity Company) – Press Releases.

[156] Reuters, 2021, "Renewables to Make up at Least 48% of Indonesia's 2021–2030 Electricity Plan."

to contribute 48% of the total additional capacity target in the 2019 RUPTL. At the Indonesia Energy Efficiency and Conservation Conference and Exhibition in June 2021, EDSM Minister Arifin Tasrif called for reducing energy intensity by 1% per year and energy consumption by 17% by 2025.[157]

Only 0.9% of Indonesia's COVID-19 stimulus allocations to date have been identified as supporting the energy transition, including subsidies for biodiesel and renewable energy development for PLN.[158] Energy-related stimulus measures also include efforts to keep the demand-supply gap from growing; subsidies on electricity bills; and allowances for credit restructuring for energy companies to maintain their financial health. A more stable economy with provisions for renewable energy and energy efficiency development could deliver crucial advances in clean energy for Indonesia.

As renewable energy and efficiency measures become more viable and cost-effective, these targets for integrating clean sources are becoming more and more feasible. A recent analysis by the Institute for Essential Services Reform (IESR) laid out an even more ambitious scenario than those modeled in this report, in which Indonesia achieves net-zero by 2050 with electricity powered 100% by renewable energy—without nuclear support.[159] That scenario also envisions 90% of vehicles being EVs by 2050, with biofuels covering for the subsectors that are more difficult to electrify. Though the approach envisioned by IESR is slightly different, the key takeaway, as in this report, is that a clean energy future for Indonesia is very much achievable.

4.1.1 Energy efficiency

Across the three net-zero scenarios, Indonesia needs to reduce the energy intensity of its economy by 3.9–4.5% per year until 2030, then accelerate progress, to about 6% per year until 2060. The targets for 2021–2030, though ambitious, are commensurate with gains made by several countries in recent years, such as Malta (4.9% average annual improvement in energy efficiency in 2005–2017), Ireland (4.5%), Romania (4.4%) and Slovakia (4.1%).[160] ASEAN Member States, meanwhile, surpassed their collective target of a 20% reduction from 2005 levels by 2020 three years early, reaching 21.6% by 2017. The latest ASEAN Energy Outlook shows ambitious policies could achieve a 32.5% reduction by 2025, and almost 50% by 2040.[161]

It is also important to stress that a large share of the projected efficiency gains in the net-zero scenarios comes from large-scale EV adoption, to achieve a 100% electrified fleet by the net-zero target year. Excluding the efficiency gains from EVs, the implied annual change in energy intensity in Indonesia for 2021–2030 in the net-zero scenarios would be about 2.4%. Energy-saving technologies have improved significantly in recent years and are expected to continue to advance.[162]

EVs are so much more energy-efficient than internal combustion engines[163] that BloombergNEF recently estimated that electrifying almost all road transport by 2050, including trucks, would only increase global electricity demand

[157] Liputan6.com, 2021, "Menteri ESDM Buka Gelaran IEECCE 2021, Event Virtual Dukung Transisi Energi Bersih.," *Liputan6*.

[158] Of the US$0.34 billion (Rp. 5 trillion) state capital injection (PMN) to PLN (Perpres no. 37/2020), US$0.07 billion (Rp. 1 trillion) will be allocated to developing 99 MW of renewable energy capacity, with a total investment of US$0.21 billion (Rp. 3.5 trillion). PLN will also use US$0.013 billion (Rp. 200 billion) from the PMN to develop village electricity distribution in Kalimantan (total investment of US$0.08 billion, or Rp. 1.1 trillion). State subsidies (APBN) have allocated US$0.19 billion (Rp. 2.78 trillion) for B30 biodiesel. See Wijaya *et al*., 2021, "Leveraging Fiscal Stimulus to Improve Energy Transition: Case of South Korea and Indonesia."

[159] Tampubolon *et al*., 2021, "Deep Decarbonization of Indonesia's Energy System: A Pathway to Zero Emissions by 2050."

[160] EEA, 2021, "Energy Intensity in Europe," European Energy Agency – Indicator Assessment.

[161] ACE, 2020, "The 6th ASEAN Energy Outlook (AEO6)."

[162] By disrupting how people live, work and travel, the pandemic has slowed some efficiency advances while accelerating others (e.g. in home appliances). The IEA's most recent assessment highlights the importance of policy and COVID recovery investment choices to regain momentum. IEA, 2020, "Energy Efficiency 2020."

[163] Lovell, 2020, "EVs: Are They Really More Efficient?" Australian Energy Council.

by about 25%.[164] The energy efficiency gains are particularly great when using power from renewable sources. In August 2019, President Widodo signed a decree with the aim to start building EVs in Indonesia by 2022 and have 20% of the country's auto production be EVs by 2025.[165] Indonesia exported US$4.52 billion worth of cars in 2019.[166]

Transforming the transport sector is crucial for improving energy efficiency in Indonesia. Already in 2015–2019, it was found to be the largest contributing sector to energy savings.[167] A study by the Coalition for Urban Transitions found that about a quarter of Indonesia's urban GHG abatement potential was in transport and highlighted the benefits of investing in compact urbanization (which reduces travel demand), public transit and EVs, all of which would yield large returns.[168]

Improving energy efficiency in industry is also crucial, as industry today is highly energy-intensive, accounting for almost half of Indonesia's energy consumption.[169] Energy efficiency in commercial and residential buildings will also be increasingly important to offset the impacts of rising incomes (and lifestyle shifts) and a warming climate. Only about 10% of Indonesian homes now have air conditioners, for instance, but the number of residential AC units is expected to rise from 12 million in 2020, to 129 million by 2040.[170]

Photo by Asian Development Bank via Flickr

Photo by Asian Development Bank via Flickr

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[164] BloombergNEF, 2021, "EVO Report 2021."

[165] Reuters, 2019, "Indonesia President Signs New EV Decree to Bolster Industry."

[166] See Observatory of Economic Complexity data for Indonesia: https://app-bee.oec.world/en/profile/country/idn.

[167] Wijaya *et al*., 2021, "Leveraging Fiscal Stimulus to Improve Energy Transition: Case of South Korea and Indonesia."

[168] CUT, 2021, "Seizing Indonesia's Urban Opportunity: Compact, Connected, Clean and Resilient Cities as Drivers of Sustainable Development."

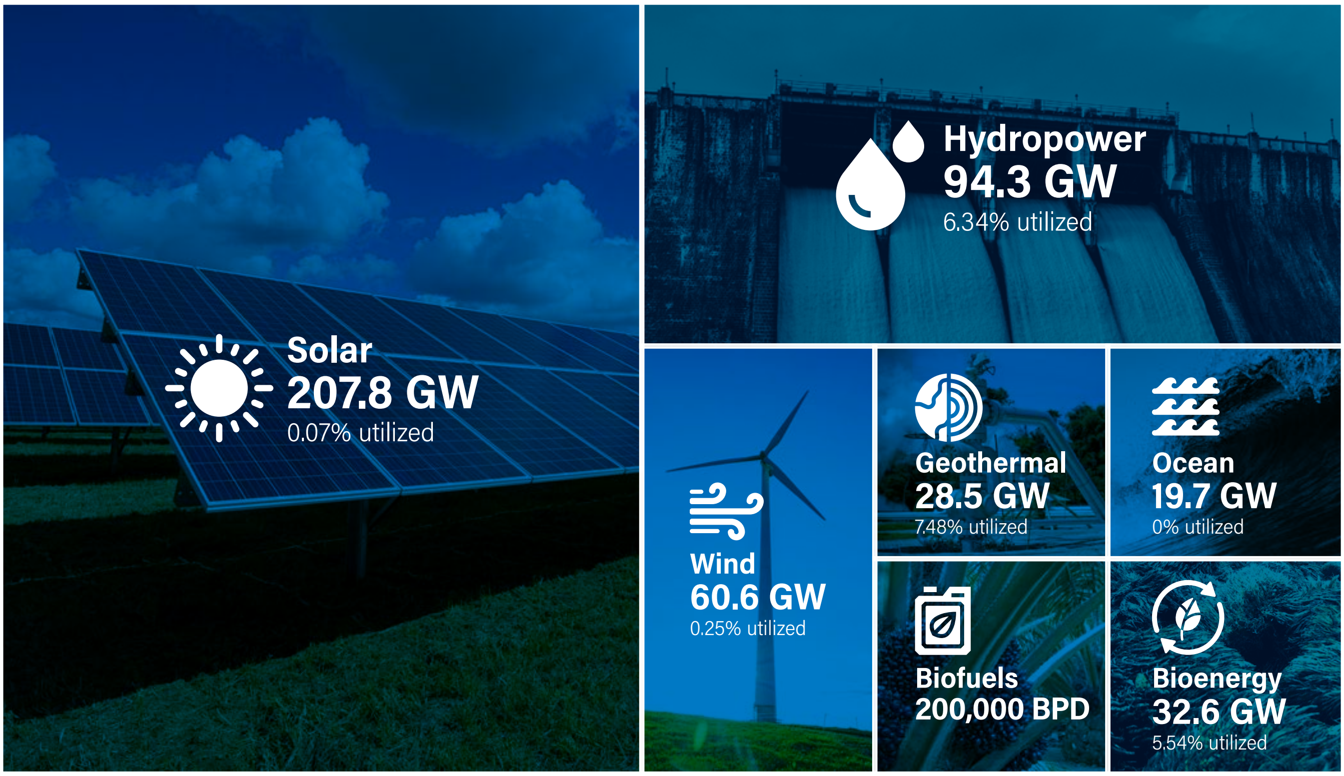
[169] Tharakan, 2015, "Summary of Indonesia's Energy Sector Assessment."

[170] IEA, 2019, "The Future of Cooling in Southeast Asia."

4.1.2 Renewable energy

Although Indonesia's current renewable energy capacity is relatively small, its potential is significant. Total utility-scale renewable energy potential was estimated at 442 GW in 2018,[171] of which only 2% had been utilized.[172] As shown in **Figure 25**, almost half this capacity is solar, and over a fifth is hydropower. As a share of potential, however, geothermal has been most heavily utilized: at 7.5% of total potential as of 2019, compared with 6.3% for hydropower and 0.07% for solar. Indonesia has some of the largest geothermal potential in the world, estimated at 40% of global reserves.[173] The market potential for dispatchable renewable technology is estimated at US$21 billion over 2020–2025.[174]

Figure 25. Indonesia's renewable energy technical potential



Source: LCDI analysis, based on National Energy Council, 2019, and ESDM, 2020.[175]

An energy sector review in Indonesia found that the levelized cost of energy (LCOE) of renewables can be reduced to be competitive with fossil generators, and the government could lower it more through land grants and collaboration with PLN.[176] The procurement of two 25 MW solar power plants in Bali and the successful financing of a 90 MW floating solar plant in Danau Singkarak and a 60 MW plant in Saguling are just a few of several examples of the successful installation of renewable energy in Indonesia.

[171] National Energy Council, 2019, "Indonesia Energy Outlook 2019"; ESDM, 2020, "Handbook of Energy & Economic Statistics of Indonesia.".

[172] OECD, 2021, Clean Energy Finance and Investment Policy Review of Indonesia.

[173] Suharmanto, Fitria, and Ghaliyah, 2015, "Indonesian Geothermal Energy Potential as Source of Alternative Energy Power Plant," *KnE Energy*.

[174] UK Foreign & Commonwealth Office, 2018, "Indonesia Renewable Energy Business Opportunities."

[175] National Energy Council, 2019, "Indonesia Energy Outlook 2019."

[176] METI, 2021, "Energy Sector Review."

As noted earlier, globally, the costs of large-scale solar PV have declined so rapidly that they are already on par with or cheaper than coal power plants in many places.[177] This is why the net-zero scenarios envision rapid deployment: building new solar PVs is expected to be cheaper even than running existing coal plants by the end of the decade. Similar trends are likely to be seen with other, more novel renewable technologies, such as battery storage, which would enable them to scale up rapidly as well. As discussed below, a robust carbon market in Indonesia can help clean energy compete with established technologies.

Globally, as renewables scale up, fossil fuel assets are increasingly at risk of becoming stranded. From 2025 to 2050, for instance, almost US$700 billion in coal assets is projected to be stranded.[178] PLN's plan to stop building coal power plants after 2023 is a first step in addressing this issue, but the large number of new plants still in the pipeline before then poses significant stranded-asset risks.[179] In a coal phase-out scenario, the Carbon Tracker Initiative indicates that Indonesian coal power owners risk losing US$34.7 billion of operating capacity stemming from the premature retirement of coal capacity.[180] PLN, Sumitomo Corporation and Sinar Mas Group are at most risk due to increasing unviability of coal, with stranding asset values of US$15 billion, US$3 billion and US$2.1 billion, respectively.

Another reason to accelerate the switch to clean energy is that the air pollution associated with coal power has costly health impacts.[181] In addition, renewables can increase resilience to extreme weather events, as renewable technologies are often more distributed and less prone to large-scale failure.[182] For example, after Hurricane Sandy in 2012, solar and wind power resources sustained relatively little damage and stayed operational despite widespread power outages in New York and New Jersey.[183]

In the transport sector, meanwhile, the net-zero scenarios would use hydrogen-based fuels to replace petroleum products during the transition to EVs, avoiding the need to scale up biofuels. Several developed countries have included hydrogen fuels in their decarbonization plans.[184] Pertamina is already looking at hydrogen as a renewable source to achieve their target of 10 GW of clean energy power generation capacity by 2026, which it estimates will require an investment of US$12 billion.[185] As with the costs of renewable energy technologies, blue and green hydrogen prices are currently high, but are expected to decrease rapidly over time.

Though our model only accounts for the use of hydrogen in transportation, it is also widely used in chemical industrial processes, which are discussed in Section 4.3. Over 95% of hydrogen is currently produced by fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification.[186] New technologies offer clean alternatives, through the reuse of fossil fuels from carbon capture utilization and storage (CCUS) (blue hydrogen) or through water electrolysis (green hydrogen) that is carbon-neutral if powered by renewable sources.

As noted in Section 3.2, advancing the energy transition in Indonesia still requires regulatory reforms to facilitate the development and scaling up of renewable energy projects.[187] Investors also face challenges in financing clean energy projects in the country due to high interest rates, limited long-term debt financing, and inefficient policy frameworks.[188]

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[177] IEA, 2020, "Renewables 2020: Analysis and Forecast to 2025"; IESR, 2019, "Levelized Cost of Electricity in Indonesia – Understanding The Levelized Cost of Electricity Generation."

[178] IRENA, 2017, "Stranded Assets and Renewables: How the Energy Transition Affects the Value of Energy Reserves, Buildings and Capital Stock."

[179] Husaini, 2021, "Demi zero emisi, PLN moratorium pembangunan pembangkit batubara," *Kontan.co.id*; Jong, 2021, "Indonesia Says No New Coal Plants from 2023 (After the Next 100 or So)," *Mongabay*.

[180] Gray et al., 2018, "Economic and Financial Risks of Coal Power in Indonesia."

[181] Braithwaite and Gerasimchuk, 2019, "Beyond Fossil Fuels: Indonesia's Fiscal Transition."

[182] Davis and Clemmer, 2014, "Power Failure: How Climate Change Puts Our Electricity at Risk—and What We Can Do."

[183] Unger, 2012, "Are Renewables Stormproof? Hurricane Sandy Tests Solar, Wind," *The Christian Science Monitor.*

[184] IRENA, 2019, "Hydrogen: A Renewable Energy Perspective."

[185] Nathan, 2021, "Indonesia's Pertamina Eyes Hydrogen to Meet 2026 Goal," Argus Media.

[186] IRENA, 2019, "Hydrogen: A Renewable Energy Perspective."

[187] OECD, 2021, *Clean Energy Finance and Investment Policy Review of Indonesia.*

[188] Sitorus *et al.*, 2018, "Energizing Renewables in Indonesia: Optimizing Public Finance Levers to Drive Private Investment."

4.2 Carbon pricing

As discussed in Section 2.2.1, changing economic incentives is crucial to a successful energy transition, which is why the net-zero scenarios include both a phase-out of fossil fuel subsidies by 2030, and the introduction of a carbon price in 2022, which would scale up linearly to US$60 per tonne CO_2e by 2040 under NZ2045, US$50 by 2040 in NZ2050, and US$40 by 2040 in NZ2060.

As of July 2021, 64 carbon pricing initiatives were in operation in 45 national jurisdictions and 35 subnational jurisdictions around the world, covering more than a fifth of global GHG emissions.[189] This includes many G20 members, such as Argentina, Canada, China, the EU, Mexico, South Africa and the UK. In 2020 alone, these initiatives generated US$53 billion in revenue.

Though no formal carbon market is yet operational in Indonesia, several promising initiatives are under development, most notably a Presidential Regulation on Carbon Pricing Framework now being finalized that would lay the foundation for carbon pricing mechanisms to curb emissions as well as boost development of renewable energy.

[189] World Bank, 2021, "State and Trends of Carbon Pricing 2021."

In addition, in March 2021, the Ministry of Energy and Mineral Resources launched an emissions trading pilot program for 80 coal-fired power plants, including 59 PLN-owned plants.[190] The trial, which will run through August 2021, covers more than 75% of CO_2 emissions from the power sector. It aims to familiarize stakeholders with the development of a national emissions trading system (ETS), including its compliance procedures and potential offsetting mechanisms, based on guidelines under the Government Regulation on Environmental Economic Instruments (GR 46/2017). The pilot is likely to continue until the full implementation of a national ETS, with annual reviews and trading periods.[191]

Meanwhile, as part of a major tax overhaul, the Ministry of Finance is proposing a carbon tax on fossil fuel emissions generated from economic activities, factories and motor vehicles.[192] The ministry is considering a carbon tax range of US$5–10 per tonne CO_2e and included an initial minimum rate of US$5.15–5.25 per tonne CO_2e in a draft bill in May 2021.[193] Revenues will be regulated by the ministry in coordination with other relevant ministries and agencies.

There is a risk of pushback from the sectors most affected by carbon pricing,[194] but it could also bring unexpected benefits. Fuel price increases give firms an incentive to switch to more efficient capital equipment, often involving electrification—though the effects will vary across firm types and levels of energy dependence. Overall, a World Bank study found that a 10% increase in fossil fuel prices from 1990 to 2015 increased productivity by 1.4% across Indonesian manufacturing plants.[195]

A 2019 Global Subsidies Initiative (GSI) analysis found that Indonesia had some of the world's lowest energy prices, thanks in part to long-standing subsidies.[196] The shortcomings of previous reforms highlight the need for a total phase-out of those subsidies, as envisioned in the net-zero scenarios. For instance, the GSI analysis found that underpricing of Premium fuel alone between 2014 and 2019 had cost Pertamina about Rp. 54.5 trillion (about US$3.7 billion), as price adjustments on subsidized fuels were too infrequent and insufficient to keep up with global prices. Price caps on fuel can significantly reduce economic uncertainty around energy price fluctuations, but they can also lock out renewable energy prospects due to artificially low fossil fuel prices.[197]

Indonesian consumers have come to rely on subsidies to keep energy prices low, but GSI research has shown that more than 90% of subsidies go to the wealthiest 50% of households.[198] While the proposed carbon price would raise electricity rates and fuel prices, this can be coupled with subsidies or other policies that better target low-income households such as revenue recycling through tax cuts or investment in social programs that benefit the poor. For example, in Canada's British Columbia, the provincial government returns a portion of the carbon tax revenue to households, adjusted for family size and income to help offset any financial burden created by the tax. Similarly, in Argentina, revenues from the carbon tax are used to fund housing, transport and social security programs.[199]

The carbon price in the net-zero scenarios, which starts at less than US$5 per tonne in 2022 and rises to US$40–60 by 2040, is well within the range suggested by the High-Level Commission on Carbon Prices, which was US$30–60 by 2025 and US$30–100 by 2030.[200] It is also comparable to or lower than prices being applied in other countries—and significantly lower than some. Canada, for example, set a minimum price for carbon in 2018 of CA$10 per tonne CO_2e, to rise annually to CA$50 (about US$39) in 2022[201] and

[190] ESDM, 2021, "Uji Coba Perdagangan Karbon Diikuti 80 Pembangkit (Carbon Trading Trial Followed by 80 Generators)," Kementerian Energi dan Sumber Daya Mineral

[191] ICAP, 2021, "Indonesia."

[192] Reyes, 2021, "Indonesia Pushes Ahead with Carbon Tax Scheme," *Argus Media*; Reuters, 2021, "Indonesia Considering Carbon Tax under Major Tax Overhaul – Document."

[193] Media reports put it at US$5.25 (see Reyes, 2021, above); Parliament Commission XI cited a Rp. 75/kg CO_2e, which would be US$5.15 per tonne at the Rp. 14,550 per US$1 exchange rate used throughout this report. See Komisi XI, 2021, "Kategorisasi Pajak Karbon Dalam RUU KUP Perlu Tinjauan Kembali."

[194] Ministry of Finance, 2021, "Analysis of Tax Policy and Carbon Levies in Indonesia's Taxation System."

[195] Pigato, 2019, "Fiscal Policies for Development and Climate Action."

[196] Laan and McCulloch, 2019, "Energy Transition in Support of the Low-Carbon Development Initiative in Indonesia: Transport Sector."

[197] Bridle, Suharsono, and Mostafa, 2019, "Indonesia's Coal Price Cap: A Barrier to Renewable Energy Deployment."

[198] Laan *et al*., 2011, "A Citizen's Guide to Energy Subsidies in Indonesia."

[199] World Bank, 2021, "Argentina Carbon Tax," Carbon Pricing Dashboard.

[200] High-Level Commission on Carbon Prices, 2017, "Report of the High-Level Commission on Carbon Prices."

[201] Ricardo Energy & Environment, 2021, "International Experience of Carbon Tax Mechanisms."

then CA$170 by 2030.[202] The revenues generated from the tax are returned to the jurisdictions where they are collected, to support social programs, hospitals, schools, Indigenous communities, and more. In South Africa, the government implemented a carbon tax in 2019 starting at a rate of ZAR120 (US$8.34) per tonne CO_2e, which is increasing at a rate of 2% per year plus inflation until 2022 and will be adjusted annually to match inflation thereafter.

Ideally, the gradual introduction of a carbon price through initially lower rates could ease the transition towards a carbon market system, as has been implemented in Canada and elsewhere. In Colombia, the carbon tax was introduced in 2017 at a low rate (about US$5 per tonne CO_2e), and it did not significantly slow the consumption of fossil fuels, at least initially. Instead, the tax incentivized mitigation activities outside the energy sector, through a carbon offsetting mechanism designed to feed into reforestation and conservation efforts.[203] Colombia's carbon price will continue to increase by 1% per year (plus inflation) until it reaches a final rate of US$10 per tonne CO_2e. Though the tax has spurred greater action in the voluntary carbon offsetting market, it is clear that the price signal it sent was too weak, at least at first, to reduce fossil fuel demand. This means that while even a low tax rate can raise revenue to offset the costs of the energy transition, ultimately the rate needs to be higher if it is to change consumption patterns.

In its 2021 report on the *State and Trends of Carbon Pricing*, the World Bank states that carbon prices should fall in the range of US$40–80 per tonne CO_2e to keep global warming below 2°C.[204] High prices not only better reflect the true costs of carbon pollution to society, but can also drive the decoupling of economic growth from carbon emissions, as was the case in Sweden.[205] The government of Sweden introduced a carbon tax of US$26 per tonne CO_2e in 1990 when economic growth was relatively weak. Despite having the highest carbon tax in the world—both in 1990 and now at a rate of US$126 per tonne CO_2e—Sweden has seen stable and consistent economic growth since implementing the tax, even as industrial emissions fell rapidly through the early 2000s.

To increase the use of carbon markets internationally, these policies can be coupled with other instruments, such as carbon trading. These additions can be lucrative: the recently launched carbon offset trading market in Singapore is already attracting large technology firms, for instance.[206] For Indonesia, an effective approach could be to employ carbon credits for forest conservation alongside a carbon tax, as was done in Colombia. In fact, a similar approach was discussed in 2019, with hopes that it could generate up to US$100 billion per year.[207] The current status of this initiative could not be ascertained for this publication, but in any case, it indicates Indonesia's willingness to adopt a market for carbon offsets.

Establishing a price on carbon has the potential to create many benefits beyond GHG emission reductions in Indonesia. A recent OECD analysis of 15 emerging and developing economies found that the countries could generate an average revenue of about 1% of GDP with a carbon rate of about US$35 per tonne CO_2e, thereby increasing tax revenues by an average of 5%.[208] The modeling results presented in Section 2 project that carbon pricing and fossil fuel subsidy removal combined generate substantial revenue for Indonesia, peaking at US$168–215 billion (2.64–3.55% of GDP) in 2031. These funds can be used in myriad ways-revenue recycling through tax breaks to consumers and the private sector to reduce financial burden, funding for critical government programs, and investment in renewables or energy efficiency measures, to name a few.

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[202] Environment and Climate Change Canada, 2020, "A Health Environment and a Health Economy."

[203] Ricardo Energy & Environment, 2021, "International Experience of Carbon Tax Mechanisms."

[204] World Bank, 2021, "State and Trends of Carbon Pricing 2021."

[205] Ricardo Energy & Environment, 2021, "International Experience of Carbon Tax Mechanisms."

[206] Mookerjee, 2021, "Big Tech Drawn to New Singapore Carbon Offset Trading Market," *Bloomberg*.

[207] Reuters, 2019, "Indonesia Drafting Regulations for the Sale of Carbon Credits."

[208] Teusch and Theodoropoulos, 2021, "Why Should Developing Countries Implement Carbon Pricing When Even Advanced Economies Fall Woefully Short?" *OECD Development Matters* (blog).

4.3 Industrial processes and product use (IPPU)

Indonesia's NDC includes an unconditional pledge to reduce IPPU emissions by 0.10% below baseline levels by 2030 (increased to 0.11% in the conditional pledge).[209] Under the Mitigation Action Implementation Roadmap, achieving these goals assumes the following mitigation activities take place:

- The cement industry reduces the clinker-to-cement ratio (blended cement) from 80% in 2010 to 75% in 2030.
- The petrochemical industry enhances efficiency by feedstock utilization and CO_2 recovery, particularly in ammonia production.
- The steel industry implements CO_2 recovery measures, improving smelter processing and scrap utilization.
- Aluminum smelter Clean Development Mechanism (CDM) activities maintain remaining perfluorinated chemicals (PFCs) claims.

[209] Republic of Indonesia, 2016, "First Nationally Determined Contribution."

In the unconditional pledge, these activities would be met solely through technological improvements. The conditional pledge envisions secondary mitigation activities, such as using selective catalysts for the destruction of nitrous oxide (N_2O) emissions in the nitric acid industry, using scrap for raw materials for the steel industry, and using potential PFC emission reductions through CDM project activities in the aluminum industry.

Though IPPU emissions reductions would contribute marginally to the overall net-zero effort (see Section 2.2), they would support a global effort to tackle industrial emissions that is estimated to have the potential to avoid 4.2–6.6 Gt CO_2e by 2030.[210] They would also contribute to improving energy efficiency and help Indonesia build a green economy with a more sustainable industrial sector.

More broadly, industrial interventions aim to reduce emissions and hazardous pollutants by improving resource and energy efficiency, replacing harmful inputs when possible, and limiting waste production.[211] In 2018, 47% of Indonesia's industrial emissions were energy-related, 27% were attributed to waste generation, and only 26% stemmed directly from material processing.[212] This means a large share of the abatement in industry will be achieved through energy sector interventions, but there are some industry-specific efforts that can further reduce energy use, such as recovering excess heat from cement production.[213]

Other countries are addressing these issues in their industrial policies as well. For example, as part of its Perform, Achieve, Trade (PAT) Scheme, India's Ministry of Power identified promising energy-saving opportunities in the iron and steel industry, including the adoption of multi-slit coke oven gas burners to improve oven ignition efficiency, regenerative burners for reheating furnaces, gas recovery systems, and waste heat recovery strategies.[214] The 67 enterprises in this sector managed to reduce emissions by about 6 million tonnes (Mt) of CO_2, saving an equivalent of 2.1 Mtoe by 2015. Similarly, in the Netherlands, water used to generate steam for processing heat was redirected into cooling towers for a chemical plant, cutting energy costs by 95%.[215]

A Bappenas sectoral analysis has identified the cement and food and beverage subsectors—which contribute 52.42% and 0.1% of industrial emissions, respectively—as having significant abatement potential in Indonesia. Other studies have noted mitigation in steel production, which accounts for 9.17% of total industrial emissions and 18.2% of GDP and is considered the most energy- and emissions-intensive material production.[216] Table 5 outlines mitigation approaches and the types of emissions they address that have been considered for these industries in Indonesia.

It is important for the policies aiming to achieve net-zero to consider the variances in the mitigation potential of these activities. Simply setting a target, such as the 75% clinker-to-cement ratio by 2030 in Indonesia's NDC,[217] without attaching carefully designed policies can negate the overall abatement potential. For instance, importing clinker to achieve this goal, as noted in Table 5, would reduce the emissions profile of the IPPU sector in Indonesia, but it could result in carbon leakage, since emissions would still be generated in the exporting country, not to mention emissions from transport. Making the effort to reduce and manage the CO_2 intensity of clinker production with alternative chemistries is the more effective low-carbon approach to lowering the clinker-to-cement ratio. Increasing the efficiency of materials use is also crucial, as it would reduce the total amount of production needed.

Adjusting the types of materials used in industrial processes can also reduce emissions. Recycling steel scrap, for example, is significantly less energy- and emissions-intensive than ore-based steel production, because it eliminates the need for the coal-

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[210] Blok *et al*., 2020, "Assessment of Sectoral Greenhouse Gas Emission Reduction Potentials for 2030," *Energies*.

[211] Bappenas, 2021, "Industry Study."

[212] KLHK, 2020, "Statistik KLHK 2019."

[213] Lu, 2015, "Capturing the Invisible Resource. Analysis of Waste Heat Potential in Chinese Industry and Policy Options for Waste Heat to Power Generation."

[214] IEA, 2020, "Iron and Steel Technology Roadmap."

[215] World Water, 2013, "Fresh Thinking to Improve Business and Sustainability."

[216] Dewi *et al*., 2019, "AIM/End-Use Model for Selecting of Low-Carbon Technology in Indonesia's Iron and Steel Industry," *IOP Conference Series: Earth and Environmental Science.*

[217] Republic of Indonesia, 2016, "First Nationally Determined Contribution."

Table 5. Potential activities to reduce emissions in industry

Subsectors	IPPU	Waste	Energy
Cement industry	Reduce clinker-to-cement ratio (blended cement) by a) developing new chemistries (e.g. alternatives to limestone, the raw material for clinkers) or improving existing blends, or b) importing clinker for domestic cement production CCUS to captures process emissions from heating limestone	Compact and sustainable packaging/ product Wastewater management Solid waste management	Increase energy efficiency (e.g. waste heat recovery) Energy conservation from increased efficiency in material use Increase share of renewable sources (e.g. green hydrogen) Co-firing of waste as an alternative energy source
Food and beverage industry	Increase efficiency of N_2O product use as a propellant in aerosol products (e.g. pressure-packed whipped cream)		
Steel industry	Reusing scrap metal (as opposed to iron ore), eliminating need for the coal-dependent processes (coking, sintering and blast furnace) to produce pig iron		

Sources: Bappenas, 2021; Dewi et al., 2019.[218]

dependent processes (coking, sintering and blast furnace) to produce pig iron.[219] Sometimes these approaches are not adopted mainly due to resource limitations, especially in developing and emerging economies. In India, for example, steel scrap makes up 20–25% of imports.[220] India's 2019 National Resource Efficiency Policy aims to remedy this by investing in steel recycling schemes, such as a "cash for clunkers" program that would also take inefficient cars off the road. It would also impose an import duty on scrap imports to promote domestic scrap collection, targeting a 90% steel recycling rate and a total elimination of steel imports by 2030. Indonesia could adopt similar policies as part of its efforts to achieve net-zero.

Reducing industrial emissions will require new investments in efficient, low-carbon technologies and processes, as well as better industrial waste management and research and development for alternative chemistries. Energy intensity trends in Indonesia have been found to have a positive correlation with the ratio of income from the industrial sector to gross regional domestic product (GRDP), trade openness, and foreign direct investment per capita, suggesting that energy intensity improvements are driven by increasing energy efficiency in the industrial sector.[221]

Industrial emissions reduction can also create good jobs. The largest opportunities are in improved waste management, and particularly wastewater treatment and reuse, an understaffed field around the world.[222] In the United States, actions to achieve near-zero industrial emissions by 2050 have been projected to boost GDP by 3.3% and create 5 million jobs.[223] These new forms of employment could also bring opportunities for enhanced gender equity. For example, a study found that women held more decision-making positions in water and sanitation industries in the Philippines, and they made up 60% of local water and sanitation committees in Nicaragua.[224] Capacity-building initiatives undertaken by these improved waste management activities contributed to those benefits.

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[218] Bappenas, 2021, "Industry Study"; Dewi et al., 2019, "AIM/End-Use Model for Selecting of Low-Carbon Technology in Indonesia's Iron and Steel Industry," *IOP Conference Series: Earth and Environmental Science.*

[219] Dewi *et al.*, 2019, "AIM/End-Use Model for Selecting of Low-Carbon Technology in Indonesia's Iron and Steel Industry," *IOP Conference Series: Earth and Environmental Science.*

[220] IEA, 2020, "Iron and Steel Technology Roadmap."

[221] Bappenas, 2021, "Industry Study."

[222] Renner, 2017, "Wastewater and Jobs: The Decent Work Approach to Reducing Untreated Wastewater."

[223] Rissman *et al.*, 2020, "Technologies and Policies to Decarbonize Global Industry: Review and Assessment of Mitigation Drivers through 2070," *Applied Energy.*

[224] Renner, 2017, "Wastewater and Jobs: The Decent Work Approach to Reducing Untreated Wastewater."

4.4 Food loss and waste

While policies to improve efficiency and reduce emissions in the energy and industrial sectors are fundamental to Indonesia's low-carbon development strategy, significant emissions reductions can also be realized in other sectors that often garner less attention.

Globally, food loss and waste accounts for 8–10% of all GHG emissions,[225] and according to the Ministry of Environment and Forestry, 44% of all waste generated in Indonesia in 2018 came from food.[226] Indonesians wasted 23–48 million tonnes of food per year from 2000 to 2019, or about 115–184 kg per person.[227] This generated roughly 85 Mt CO_2e of emissions per year, or about 7.3% of Indonesia's annual GHG emissions over the past 20 years. It also cost the economy an estimated Rp. 213–551 trillion per year (US$14.6–37.9 billion), or 4–5% of Indonesia's GDP.

[225] Mbow *et al.*, 2019, "Food Security," in *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems.*

[226] KLHK, 2018, "Waste Management in the Environment and Forestry Sector."

[227] Bappenas, 2021, "Food Loss and Waste in Indonesia: Supporting the Implementation of Circular Economy and Low Carbon Development."

This level of food waste is particularly troubling because, despite significant progress in reducing hunger and food insecurity in Indonesia, 9% of the population is still undernourished, and the growth of more than a quarter of children is stunted.[228] On the 2020 Global Hunger Index, Indonesia ranked 70th out of 107 countries analyzed,[229] putting it on the high end of "moderate" levels of hunger. Yet a recent Bappenas report found that the average food loss per day in Indonesia is equivalent to about 618–989 kcal per person.[230] Saving that food could feed 29–47% of the entire population.

Food loss and waste occurs all across the supply chain in Indonesia, but the consumption stage makes up by far the largest share (58%), so policies to reduce consumption waste are a priority.[231] Research has linked the problem to urbanization and related changes in food retail—from traditional small-scale vendors and street markets, to modern supermarkets selling in larger quantities—as well as cultural shifts and class dynamics.[232]

Even modest reductions in food loss and waste across the supply chain could make a significant impact. Bappenas looked at a "strategy scenario" with several targets (all relative to estimated 2022 levels): to reduce food loss from production from 4.37% to 3% in 2045; reduce post-harvest and storage food loss from 3% to 2.5% in 2045; reduce processing and packaging food loss from 1.2% to 0.8%; reduce food waste from distribution and markets from 5% to 3.8% in 2045; and reduce consumption food waste by 35% from 2022 to 2030.[233] Compared with a baseline scenario for 2020–2045, employing this strategy scenario could reduce total food loss and waste by roughly 37% by 2030 and by 56% by 2045.

Many policy options could help achieve those targets. Consumer education is key: educating households about reducing food waste, interpreting food expiration labels, and alternative protein sources could be an effective tool for catalyzing behavior change. It might also be helpful to support small-scale, traditional food sellers, and to work with larger food retailers to steer them away from marketing strategies that may encourage excessive food purchases.[234] Adopting these types of changes could lead to tipping points in the food system and create momentum for achieving the broader transformation of food and land use systems needed for a sustainable future, as recently outlined by the Food and Land Use Coalition.[235]

There are also opportunities to create new business models that monetize the savings from reducing food waste. The P4G Indonesia National Platform is currently working with the Indonesia Business Council for Sustainable Development to explore such opportunities with key corporate and government stakeholders. While reducing food loss and waste might not have the same emissions reduction potential as other sectors, it does offer multiple co-benefits, including preventing economic loss, improving food security, and reducing malnutrition. It is therefore not only feasible, but a political and economic win.

[228] WFP, 2021, "WFP Indonesia Country Brief – May 2021."

[229] von Grebmer *et al*., 2020, "2020 Global Hunger Index: One Decade to Zero Hunger: Linking Health and Sustainable Food Systems."

[230] Bappenas, 2021, "Food Loss and Waste in Indonesia: Supporting the Implementation of Circular Economy and Low Carbon Development."

[231] Bappenas, 2021, "Food Loss and Waste in Indonesia: Supporting the Implementation of Circular Economy and Low Carbon Development."

[232] Soma, 2020, "Space to Waste: The Influence of Income and Retail Choice on Household Food Consumption and Food Waste in Indonesia," *International Planning Studies.*

[233] Bappenas, 2021, "Food Loss and Waste in Indonesia: Supporting the Implementation of Circular Economy and Low Carbon Development."

[234] Soma, 2020, "Three Solutions for Indonesia to Reduce Food Waste," *The Conversation.*

[235] FOLU, 2021, "Accelerating the 10 Critical Transitions: Positive Tipping Points for Food and Land Use Systems Transformation."

4.5 Forest, peatland, and mangrove restoration

Indonesia's natural capital is central to its economy, so protecting and restoring forests, peatlands and mangroves has become a government priority. As of 2018, Indonesia had an estimated 93.9 million ha of forest area, half its total territory, including 46.1 million ha of primary forest.[236] Indonesia has the world's third-largest tropical forest area,[237] including 19% of the global total mangrove forest area and the third-largest number of forest tree species,[238] However, it has also recorded one of the world's fastest forest loss rates, especially of primary forest.[239]

Despite moratoria on primary forest and peatland conversions, deforestation has persisted, though mainly in secondary forests.[240] The rate of primary forest loss has declined over the last four years,[241] in part due to the moratoria as well as increased government-supported fire prevention and monitoring. Increasing ambition to protect secondary forests could avoid an additional 427 Mt of CO_2 emissions by 2030.[242]

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[236] Ministry of Environment and Forestry, 2018, "The State of Indonesia's Forests 2018."

[237] FAO and UNEP, 2020, *The State of the World's Forests 2020: Forests, biodiversity and people.*

[238] Beech et al., 2017, "GlobalTreeSearch: The First Complete Global Database of Tree Species and Country Distributions," *Journal of Sustainable Forestry.* Another estimate puts Indonesia's share of the world's mangroves at 23%; see Giri et al., 2011, "Status and Distribution of Mangrove Forests of the World Using Earth Observation Satellite Data," *Global Ecology and Biogeography.*

[239] FAO and UNEP, 2020, *The State of the World's Forests 2020: Forests, biodiversity and people.* See also Turubanova et al., 2018, "Ongoing Primary Forest Loss in Brazil, Democratic Republic of the Congo, and Indonesia," *Environmental Research Letters.*

[240] Jong, 2019, "Indonesia Forest-Clearing Ban Is Made Permanent, but Labeled 'Propaganda,'" *Mongabay*.

[241] See the Global Forest Watch dashboard for Indonesia: https://www.globalforestwatch.org/dashboards/country/IDN/.

[242] Bappenas, 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia."

Intact forests are the most valuable and rare forests on the globe. Preserving them is a climate and biodiversity imperative. Indonesia has four "Intact Forest provinces": Aceh, North Kalimantan, Papua and West Papua.[243] Intact forests are global powerhouses for carbon sequestration and storage, biodiversity, rain patterns and water provision, and the survival of indigenous cultures.[244] Climate policies need to restore and protect fragmented and degraded forests as well, but maintaining intact forests is the most immediate and cost-effective way to retain the full spectrum of forest benefits, including the most resilient form of carbon storage.[245]

Most of the communities living within intact forests experience severe poverty and under-development.[246] Papua and West Papua, home to a large number of forest dwellers, have the lowest scores on the Human Development Indicators in Indonesia. A new development pathway is essential—one that rewards the protection of natural capital, such as intact forests, and provides sustainable economic opportunities for communities. Current international biodiversity and climate policy stances do not adequately recognize either the importance of intact forests or the particular development support needed to ensure their preservation and the prosperity of their dependent human communities.

Restoration and reforestation generate significant socio-economic benefits. Globally, investing US$4–4.5 billion annually in restoration is projected to create up to 150,000 new jobs and US$6–12 billion in economic benefits per year.[247] In fact, reforestation is expected to play a significant role in creating the 65 million pandemic recovery jobs promised by a global transition to low-carbon, resilient economies.[248] However, these benefits are impeded by significant legislative challenges, including the rollback of environmental protections under the new Omnibus Law.

Protecting and restoring peatlands and mangroves, meanwhile, is vital for carbon storage, biodiversity and other ecosystem services, and flood prevention.[249] Land subsidence, which is associated with wetland drainage (as well as groundwater over-abstraction), is an urgent crisis: Jakarta is sinking by almost 20 cm per year, and Semarang is sinking by 7–11 cm per year.[250] Wetland drainage for agriculture also continues to drive subsidence.[251] Leading the effort to protect these ecosystems is the Peatland and Mangrove Restoration Agency, which was established in 2016 with a focus on peatlands, and expanded in 2020 to also protect mangroves. It is charged with restoring 1.2 million ha of degraded peatland and 600,000 ha of mangrove ecosystems across 13 provinces through 2024.[252]

There may be opportunities to impose more stringent measures on peatland and forest conservation. Avoiding any further conversions into oil palm plantations generates longer-term benefits, as the naturally high sequestration capacity of peatlands is stunted following conversion.[253] The net-zero scenarios also aim to end the conversion of primary forest to cropland—which will require sustainably boosting productivity, as discussed in the next section, as well as reducing food waste and loss, as discussed in Section 4.4, to ensure that Indonesians' food needs are still met. Urban expansion needs to be addressed as well, as cities are encroaching onto cropland, leading to even more land conversion and depriving cities of crucial protective ecosystems.[254] More compact, connected urban development and nature-based solutions to build urban resilience can help address these issues.

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[243] Potapov et al., 2017, "The Last Frontiers of Wilderness: Tracking Loss of Intact Forest Landscapes from 2000 to 2013," *Science Advances.*

[244] Watson et al., 2018, "The Exceptional Value of Intact Forest Ecosystems," *Nature Ecology & Evolution.*

[245] For example, intact forests are more fire-resistant than degraded forests. See Nikonovas et al., 2020, "Near-Complete Loss of Fire-Resistant Primary Tropical Forest Cover in Sumatra and Kalimantan," *Communications Earth & Environment.*

[246] Bou Dib, Alamsyah, and Qaim, 2018, "Land-Use Change and Income Inequality in Rural Indonesia," *Forest Policy and Economics.*

[247] BenDor et al., 2015, "Estimating the Size and Impact of the Ecological Restoration Economy," *PLOS ONE.*

[248] Mollins, 2020, "Reforestation Could Play Role in Pandemic Recovery Jobs Creation, Says IMF's Georgieva," *CIFOR Forests News.*

[249] Husnayaen et al., 2018, "Physical Assessment of Coastal Vulnerability under Enhanced Land Subsidence in Semarang, Indonesia, Using Multi-Sensor Satellite Data," *Advances in Space Research.*

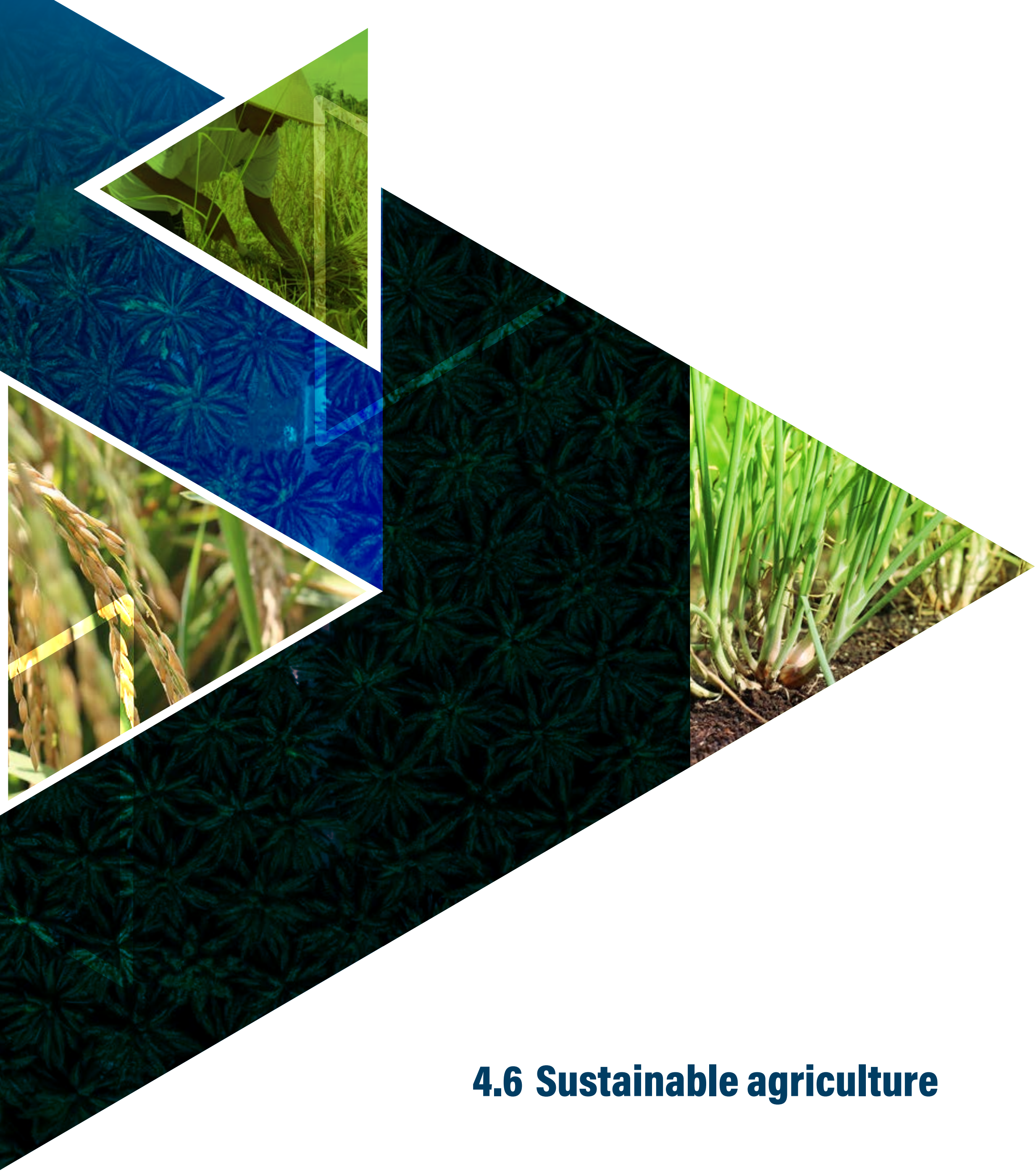
[250] Erkens et al., 2015, "Sinking Coastal Cities," *Proceedings of the International Association of Hydrological Sciences.*

[251] Bappenas, 2019, "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia."

[252] Jong, 2021, "Indonesia Renews Peat Restoration Bid to Include Mangroves, but Hurdles Abound," *Mongabay.*

[253] Warren et al., 2017, "Impacts of Land Use, Restoration, and Climate Change on Tropical Peat Carbon Stocks in the Twenty-First Century: Implications for Climate Mitigation," *Mitigation and Adaptation Strategies for Global Change.*

[254] CUT, 2021, "Seizing Indonesia's Urban Opportunity: Compact, Connected, Clean and Resilient Cities as Drivers of Sustainable Development."



4.6 Sustainable agriculture

Agriculture contributed 12.7% of Indonesia's GDP in 2019, making it the third-largest sector, after manufacturing and trade.[255] The share of workers employed in agriculture has declined, from 43% in 2000 to 28.5% in 2019, but it remains significant. Farmers earn considerably less than other workers, which is driving many away from the sector. Measures to make agriculture more sustainable thus need to provide good economic opportunities for farmers and their communities.

Several government efforts have sought to improve the sustainability of Indonesia's agricultural sector. This is important not only for environmental reasons, but also potentially for global competitiveness. For example, many companies have pledged to use only palm oil that is certified by the Roundtable on Sustainable Palm Oil (RSPO).[256] Under RSPO and Indonesia Sustainable Palm Oil (ISPO) certifications,

[255] BPS, 2021, "Indikator Pasar Tenaga Kerja Indonesia – Februari 2021 (Indonesian Labor Market Indicators – February 2021)."

[256] Progress on this has been slower than expected a decade ago, but it still continues. See, e.g., Slavin, 2020, "Deadline 2020: Big Brands Double down on Efforts to Source Deforestation-Free Palm Oil," *Reuters Events* (blog).

only oil palm plantations that meet certain sustainability, transparency, compliance and financial viability criteria are allowed to plant within designated forest areas.[257]

Another positive development has been the creation of community-based forestry programs to allow people living in villages around forests to sustainably harvest and manage non-timber forest products in protected areas.[258] However, a more recent action aimed at supporting agriculture could harm forests. In October 2020, the Ministry of Environment and Forestry issued the Forest Areas for Food Security Regulation, which allocated a large portion of protected forests to be cleared for farmland.[259] The regulation has been criticized for streamlining land conversion and exacerbating Indonesia's already rapid rates of deforestation and forest degradation.[260] It is important to reconsider that measure.

To reduce trade-offs between agriculture and forest protection, the net-zero scenarios prioritize agricultural intensification to improve yields of rice, maize and oil palm. The gap between average and potential yields—what could be achieved under favorable conditions without limitations from water, nutrients, pests or diseases[261]—is significant for some crops in Indonesia. One study found enhancing conditions could achieve yields of 80% of the potential in irrigated crops and 70% in rainfed crops, which would enable Indonesia to boost its annual production of rice and maize by 31% and 67% respectively.[262] Yet this requires substantial investments in labor and training, as well as more resources.

The investment costs in adopting innovative technologies and practices, however, are greatly offset by their evidently high returns. Rice farmers in Central Java, for example, increased their revenue from US$105 to US$122 per hectare per season after adopting an average of two introduced technologies and practices, including using high-yielding rice varieties, alternate wetting and drying (AWD) techniques, and use of mechanical transplanters and harvesters.[263]

Sustainable agriculture provides both inputs and outputs that can feed into several other sectors. Irrigation, for example, could be a channel for IPPU wastewater reuse, following improvements and advancements in water treatment facilities. In fact, over 20 million hectares (or 7%) of land worldwide has been irrigated with wastewater.[264] This bridge between sectors can generate employment for wastewater management and treatment, including the building and maintenance of the necessary irrigation systems. In India, for example, wastewater was used to irrigate 1–1.5 million ha of farmland, creating 130 million person-days of employment.[265] Such nutrient-rich wastewater, filled with algae and other microorganisms, may also be used to feed fish in aquaculture farms.[266]

[257] IndoFood Agri Resources LTD, 2013, "Sustainability Report."

[258] Leimona *et al.*, 2015, "Indonesia's 'Green Agriculture' Strategies and Policies: Closing the Gap between Aspirations and Application."

[259] KLHK, 2020, *Penyediaan Kawasan Hutan Untuk Pembangunan Food Estate, KLHK.*

[260] Jong, 2020, "New Rule Puts Indonesia's Protected Forests up for Grabs for Agribusiness," *Mongabay*.

[261] Lobell, Cassman, and Field, 2009, "Crop Yield Gaps: Their Importance, Magnitudes, and Causes," *Annual Review of Environment and Resources.*

[262] Agus *et al.*, 2019, "Yield Gaps in Intensive Rice-Maize Cropping Sequences in the Humid Tropics of Indonesia," *Field Crops Research.*

[263] Connor *et al.*, 2021, "Rice Farming in Central Java, Indonesia—Adoption of Sustainable Farming Practices, Impacts and Implications," *Agronomy*.

[264] Corcoran *et al.*, 2010, *Sick Water? The Central Role of Wastewater Management in Sustainable Development: A Rapid Response Assessment.*

[265] Kaur *et al.*, 2012, "Safe Use of Wastewater in Agriculture: 3rd Regional Workshop for Anglophone Africa."

[266] Renner, 2017, "Wastewater and Jobs: The Decent Work Approach to Reducing Untreated Wastewater."

5.

Addressing key challenges to achieving net-zero

Photo by Ave Calvar Martinez via Pexels

Committing to achieve net-zero by 2060 at the latest would bring many benefits to Indonesia—the earlier the target date, the better. But it will not be easy. It will require major new policies, changes in investment priorities, and strong collaboration across the government and with international partners and the private sector. Line ministries with very different perspectives will need to embrace a common vision and, in some cases, make substantial changes to programs and policies.

Powerful business interests facing higher costs and/or reduced demand for their products can be expected to push back. If significant efforts are not taken to ensure a just and equitable transition, citizens may also resist policies that affect their livelihoods and increase costs of living. Effective policies can manage those risks, however, to avoid regressive impacts on low- and middle-income households.

More broadly, it is important to recognize that Indonesia's growth and prosperity has been fueled, to a great extent, by high-carbon development: from coal extraction, to plantation agriculture, to large-scale infrastructure investments aimed at building a modern, well-connected Indonesia, such as major roads, airports and industrial parks. However, the benefits of those investments have come with high costs, such as accelerated loss of forests, wetlands and biodiversity; land subsidence and flooding; severe air pollution; and reduced resilience to disaster risks and other shocks.

The Low Carbon Development Initiative laid out a more sustainable path to continued robust growth. The RPJMN 2020–2024 embraced that vision and took some steps to achieve it. However, considerably more work remains to be done, both to implement the LCDI vision, and to build a common understanding across all relevant institutions of the benefits of green development and the risks of continuing on a high-carbon pathway. Indeed, as noted in Section 2, most macroeconomic models still fail to reflect climate risks or even the costs of ecosystem degradation, so policy-makers lack crucial information as they assess their options.

The COVID-19 pandemic has created new challenges. Protecting public health, ensuring people's well-being, and keeping the economy afloat has required enormous efforts. Indonesia has included some green investments in its stimulus packages, but like many governments around the world, it has also prioritized protecting existing industries. This can help avoid near-term job losses, and policy-makers often perceive investments in well-established industries as "safer" than green investments. However, as the Reference Case analysis in Section 2 shows, over time, those choices are actually riskier, as they "lock in" high-carbon industries and technologies, slower GDP growth, rising GHG emissions and pollution, and the degradation of Indonesia's natural capital. As noted in Section 1.3, there is also significant evidence that investing in renewables, public transport and nature-based solutions can generate more jobs—as much as double or more—than the same investments on oil, gas and coal.[267]

The COVID-19 crisis has also taken a significant toll on Indonesia's economy and on government resources. The country has already borrowed at unprecedented levels to help cover the costs of pandemic response and economic stimulus. Unless a net-zero vision is integrated into ongoing recovery efforts, Indonesia could lack the fiscal space to take ambitious climate action in the coming years. Additional investments will be needed in any case. There are real capacity gaps as well, and they will need to be addressed to enable Indonesia's institutions to steer their respective sectors in the right direction and manage the transition. Additional expertise will be needed in different ministries, along with reliable data to inform policy-making, technical capacity-building, and enhanced resources.

The final subsection of this report lays out recommendations for addressing these challenges.

[267] IEA, 2020, "Sustainable Recovery"; Garrett-Peltier, 2017, "Green versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-Output Model," *Economic Modelling*; see also Lim, Ng, and Zara, 2021, "Implementing a Green Recovery in Southeast Asia"; Gulati *et al.*, 2020, "The Economic Case for Greening the Global Recovery through Cities: 7 Priorities for National Governments."

Photo by Silas Baisch via Unsplash

5.1 An agenda for action: Building on the LCDI

Sections 2 and 4 described key actions needed in priority sectors, placing them in a global context to show that while the net-zero pathways for Indonesia are undoubtedly ambitious, they are well within the realm of the feasible, and of what other countries have already set out to achieve. Foundations for many of those actions have already been laid: for example, Indonesia already has plans to phase out fossil fuel subsidies and is piloting emissions trading; the Peatland and Mangrove Restoration Agency is already in place, with substantive targets.

Yet along with sectoral policies and actions, achieving net-zero by mid-century will require strong leadership and a well-coordinated, whole-of-government approach. The first step is crucial:

- **Commit to a vision of a decarbonized, climate-resilient, sustainable and inclusive Indonesia as the foundation for "building back better" after the pandemic, with a net-zero target consistent with the urgency of the climate crisis.** This can deliver a faster, employment-rich recovery than returning to business-as-usual growth. A formal policy commitment, backed by strong political leadership, would send a powerful signal to markets, the finance community, development partners, ASEAN neighbors and the world that Indonesia is ready to lead in the climate transformation. A clear vision is also essential to guide policy-making, attract investments and trade opportunities, and ensure that actions across sectors are all moving the country in the same direction, and never undermining one another.

Choosing a net-zero target year will require a close review of the scenarios presented in this report and deliberations among key ministries to ensure a common understanding and agree on an ambitious, but feasible, target. Given how fast the climate is changing, and consistent with other G20 countries' ambitions, the target year should be 2060 at the latest. However, the economic analysis in this report suggests that a 2045 or 2050 target would be even more beneficial for Indonesia.

The next two recommendations focus on building support for the net-zero agenda all across the public sector, in the private sector, and throughout Indonesian society:

- **Prioritize dialogue across government ministries, and across levels of government (central, regional and local), to ensure a common understanding of the net-zero vision and its implications for public policy and investments.** This engagement should not be top-down, but rather a true collaboration. This is essential to ensuring that different ministries understand one another's needs, priorities and concerns, and that subnational governments can bring their own knowledge, best practices and pressing needs to the table, and exchange ideas with one another and with other levels of government. Ultimately, Indonesia can only build a net-zero, resilient and inclusive future if leaders at all levels share a common vision.

- **Engage stakeholders—including domestic and international businesses, finance sector leaders and civil society—from the outset in the process of translating the net-zero vision into plans.** The private sector can be a vital partner in transforming Indonesia's economy, or a major obstacle. It is important to understand business leaders' perspectives and find solutions that advance the net-zero agenda while providing flexibility and appropriate incentives and minimizing uncertainty.[268] Civil society also has a crucial role to play in ensuring a just transition and, more broadly, that the new, green economy is equitable and inclusive. Indonesian and international academic experts and non-governmental organizations (NGOs) can also be valuable resources in identifying low-carbon and resilient solutions.

Four other priorities for near-term action focus on ensuring that Indonesia can finance the transition:

- **Immediately review priority projects and other major expenditures included in COVID-19 recovery and in the budget allocations linked to the medium- and long-term development strategies, and adjust as needed** to ensure that they are aligned with Indonesia's net-zero vision for mid-century, and do not create stranded-asset risks or further entrench fossil fuel dependency, unsustainable land use or other unsustainable patterns. This is particularly urgent given the large amounts of debt that Indonesia is incurring to manage the COVID crisis and ensure a strong recovery. Support for additional coal power capacity is of particular concern. Any projects that cannot meet this basic standard should be reconsidered, and their funding allocation should be reassigned. This could also free up fiscal space for investments to jump-start Indonesia's economic transformation.

- **Identify green and low-carbon development projects with significant potential to qualify for green recovery funding internationally, such as those available through the ADB, the World Bank, and other bilateral or multilateral donors.** As noted in Sections 1 and 3, the availability of targeted finance for a green recovery is a prime opportunity for Indonesia to obtain international support for projects that are crucial to achieving net-zero. For example, with minimal solar power developed to date, yet enormous potential, this is a chance to jump-start the country's solar industry through the COVID recovery. Vehicle electrification and EV infrastructure projects could also provide significant economic stimulus while laying strong foundations for net-zero. Another area with great near-term job creation potential is nature-based solutions, such as mangrove restoration in coastal areas with significant vulnerability to storm surge, erosion and flooding.

- **Work with development partners to align international finance with Indonesia's net-zero vision and complement domestic public and private finance for LCDI investment needs.** The analysis presented in Section 3 indicates immediate needs of about US$40 billion per year between 2022 and 2025 (1.5–2% of GDP), scaling up to US$270–350 billion per year in 2026–2030 (5.6–7.4% of GDP) as LCDI investments accelerate and become a central engine for capital formation and green structural transformation. As a developing economy, Indonesia cannot decarbonize without robust international support, especially in that critical first decade. Even if more private investment can be mobilized, climate finance is key to accelerating Indonesia's energy transformation. Substantial support is also needed for Indonesia to continue its important progress on forest, peatland and mangrove restoration and conservation, including direct finance through REDD+ and technical assistance in accessing carbon markets. The multilateral development banks also have key roles to play, to ensure that development finance flows are fully aligned with the net-zero vision.

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[268] See, e.g., https://unfccc.int/news/new-financial-alliance-for-net-zero-emissions-launches.

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Photo by Gunawan Teguh via Pixabay

A final and essential task ahead is to build the necessary capacity to implement the LCDI, both across the national government, and within subnational governments:

- **Assess technical capacity and resource gaps in key ministries and other national institutions engaged in LCDI implementation and prioritize closing those gaps.** The dialogues required to build a common understanding of net-zero pathways are a first key step, but government institutions will need substantial support to translate the LCDI into sector-by-sector policies and programs. Capacity-building is thus crucial—in terms of both technical expertise, and the data and tools needed for implementation as well as monitoring and evaluation. This has implications for institutions' budgets. Centralized, shared resources and continued cross-ministerial collaborations can help meet these needs. Knowledge products created by Bappenas, for example, can ensure that Indonesian policy-makers continue to have the up-to-date knowledge on relevant science, technology and policy innovations. ASEAN's specialized centers (e.g. the ASEAN Centre for Energy and the ASEAN Climate Resilience Network), in which Indonesia is already very active, could play a key role as well. Such engagement could also help raise climate ambition across Southeast Asia and expand markets for Indonesian products—for instance, EVs.

- **Build capacity for LCDI implementation at the subnational level.** The work to achieve net-zero will involve not only national-level policies and investments, but numerous actions at the provincial and even municipal levels (even if they are facilitated by national programs, such as the Smart Cities movement). Since 2019, Bappenas has entered into six memoranda of understanding (MoUs) with provincial governments to build capacity and produce Provincial Green Development Plans aligned with the LCDI. More resources are needed, however, as the LCDI Secretariat and partners are already working at their full capacity, and COVID-19 has further hindered progress. Ultimately, MoUs should be signed with all 34 provinces, and major cities should also be engaged in advancing the net-zero agenda.

Indonesia has made great strides through the LCDI, and even amid the COVID-19 crisis, it has continued to look for opportunities to raise its ambitions. Now is the time to set the country onto a better growth path, starting with a green recovery from the pandemic. By embracing a net-zero target, Indonesia can build a more competitive, sustainable and inclusive economy, secure its natural capital, and ensure a more prosperous and resilient future for its people.

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Technical Appendix

Photo by Tom Fisk via Pexels

A1. Description of the main model supporting LCDI

The model for which results are presented in this report, known within the LCDI team as IV2045, is a System Dynamics model that integrates a set of feedback structures for the macro economy, society, and a representation of natural capital, including energy, land, water resources, biodiversity and carbon emission systems in Indonesia. It is a model that falls into the category of Integrated Assessment Methods and built using System Thinking principles and System Dynamics modeling techniques, enabling a coherent, comprehensive appraisal of social, economic and environmental policies, including low-carbon policies.

Figure A1-1 is a high-level representation of IV2045. Key features of the model include:

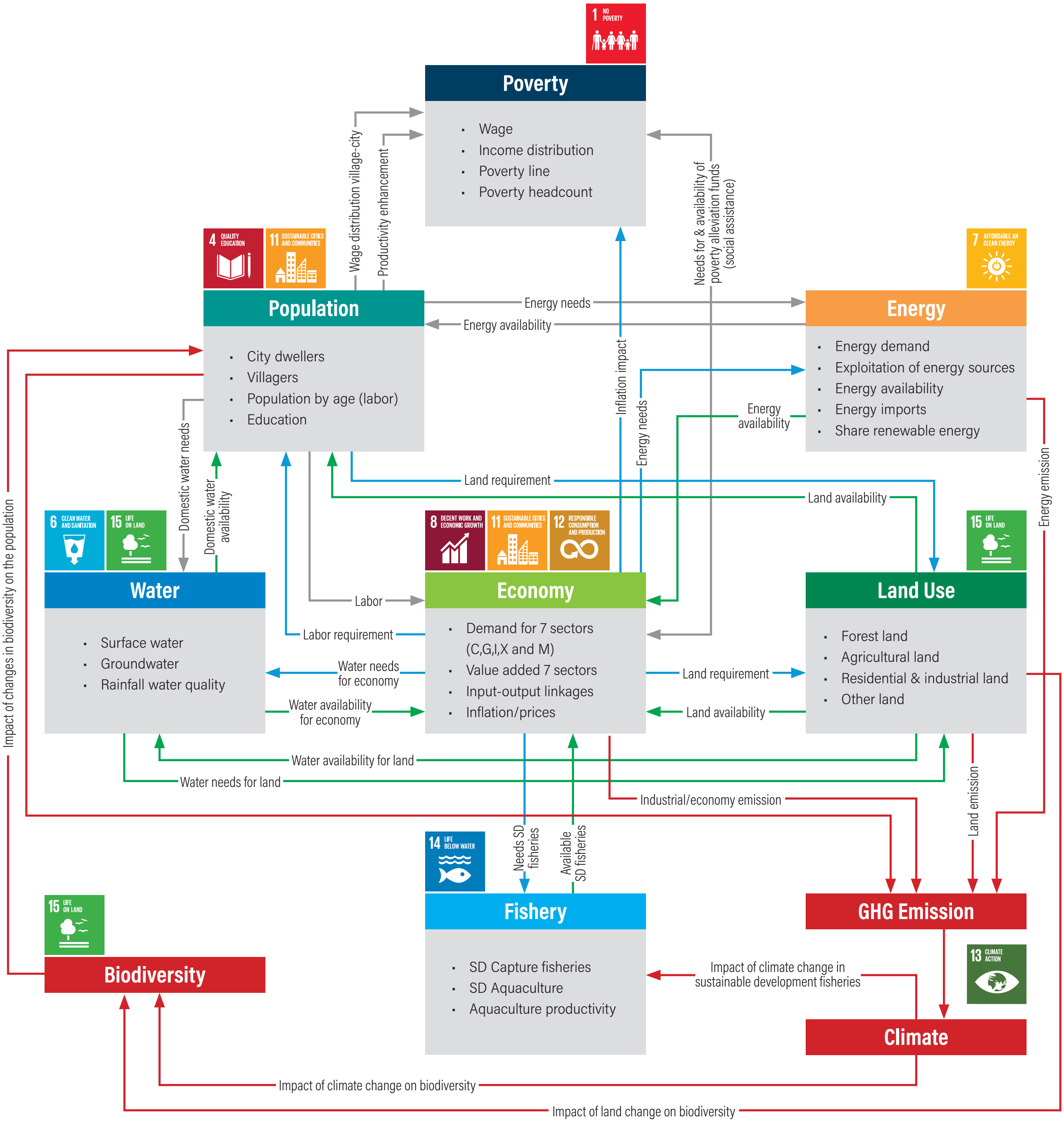
- Ability to represent feedback relationships within and across key model structures and to appropriately incorporate stocks (state variables) and flows that characterize systems, non-linear relationships, and potential delays (material and informational).
- It is built with an explicit goal of addressing key climate and development policies, including those included under RPJMN 2020–2024, and more recently, additional ones that are capable to deliver on Net Zero targets. In this regard, IV2045 is a built around policy problems and not with a goal per se of replicating any specific system structure.
- It is transparent, with model, data and supporting technical documentation being available for peer reviewing.
- A model interface for enabling real-time policy analysis is available for policy consultations.
- It is calibrated for the historical period from 2000–2020 and generates simulated values for selected endogenous variables for the years 2021–2070.
- It is built in a modular way, including sub-structures that can be "switched on or off" in order to build scenarios and counterfactual cases. One such type of counterfactual is: what outcomes would result from a set of endogenous variables such as GDP, employment, and air pollution if Indonesia were not constrained by the quality and quantity of its natural resources.

IV2045 includes feedback relationships for:

- The economy, including the real sector (value addition and employment; total and by main economic activities; and demand and supply components), the government sector, and trade;
- Society, including modules for demographics, labor force participation, and labor supply;
- Natural resources, including land use, biodiversity, energy, water and fisheries;
- Absorptive capacity: a representation of carbon emissions and climate impacts.
- COVID-19 dynamics, as explained in Appendix A4.
- Costs of individual interventions, policy packages, fiscal impacts, financing needs, and inputs for economy-wide cost-benefit analyses.
- Value of externalities, including on air pollution and the social cost of carbon.

Critically, IV2045 is not an optimization model that maximizes or minimizes any objective function subject to constraints, or for given set of policies or shocks. Instead, the economic structure of IV2045 can be placed in the realm of computational integrated models, which abide by standard economic principles, respect fundamental macroeconomic identities, and represent the behavior of macroeconomic agents. The main goal of IV2045 is not that of forecasting a set of endogenous variables or that of finding a hypothetical, optimal solution to some policy question. Instead, it is a tool that allows policymakers to gain valuable analytical insights from the assessment of alternative policy options and shocks while considering the complex relationships among the social, economic, and environmental systems, including climate.

Figure A1-1. High-level representation of the IV2045 model used for this report



A2. Summary of net-zero targets

The tables below summarize the sector-specific targets modeled across scenarios, as discussed in Section 2.2, including intermediate targets.

Energy

Electrification of road transport sector

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	Zero	0.00	0.00	0.00	0.00	0.00	0.00
NZ2045	Ramp up starting in 2025 to 100% by 2040	0.00	33.33	100.00	100.00	100.00	100.00
NZ2050	Ramp up starting in 2025 to 100% by 2045	0.00	25.00	75.00	100.00	100.00	100.00
NZ2060	Ramp up starting in 2025 to 100% by 2060	0.00	16.67	50.00	66.67	83.33	100.00

Improve energy efficiency of industrial and domestic sectors, measured via energy intensity (energy demand per GDP unit)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	Constant at historical levels	0.88	1.50	1.50	1.50	1.50	1.50
NZ2045	Improves to reach 6% by 2030	1.50	6.00	6.00	6.00	5.03	4.61
NZ2050	Improves to reach 6% by 2030	1.50	6.00	6.00	6.00	4.97	4.63
NZ2060	Improves to reach 6% by 2030	1.50	6.00	6.00	6.00	6.06	4.58

Carbon price applied to CO_2 content of coal, petroleum products and natural gas (US$)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No new carbon price	0.00	0.00	0.00	0.00	0.00	0.00
NZ2045	Ramp up starting in 2022 to US$60/tonne by 2040	0.00	30.00	60.00	60.00	60.00	60.00
NZ2050	Ramp up starting in 2022 to US$50/tonne by 2040	0.00	25.00	50.00	50.00	50.00	50.00
NZ2060	Ramp up starting in 2022 to US$40/tonne by 2040	0.00	20.00	40.00	40.00	40.00	40.00

Target share of renewable energy sources in power generation capacity (excludes nuclear)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	Ramp up to 30% in 2030, then hold steady	16.40	30.00	30.10	30.70	30.30	30.30
NZ2045	Ramp up to 82% by 2060 (rest covered by nuclear)	16.40	60.14	75.30	78.63	81.00	82.00
NZ2050	Ramp up to 82% by 2060 (rest covered by nuclear)	16.40	60.14	75.30	78.63	81.00	82.00
NZ2060	Ramp up to 82% by 2060 (rest covered by nuclear)	16.40	60.14	75.30	78.63	81.00	82.00

Residential sector shift from biofuels and waste demand to electrification

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	Maintained at current levels	0.00	30.00	30.10	30.70	30.30	30.30
NZ2045	Ramp up to 100% in 2045	0.00	40.00	80.00	100.00	100.00	100.00
NZ2050	Ramp up to 100% in 2050	0.00	36.00	62.00	80.00	100.00	100.00
NZ2060	Ramp up to 100% in 2060	0.00	22.00	50.00	62.00	80.00	100.00

Fossil fuel subsidy removal (% of existing subsidies)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No subsidy removal	0.00	0.00	0.00	0.00	0.00	0.00
NZ2045	Ramp up to 100% removal by 2030	0.00	100.00	100.00	100.00	100.00	100.00
NZ2050	Ramp up to 100% removal by 2030	0.00	100.00	100.00	100.00	100.00	100.00
NZ2060	Ramp up to 100% removal by 2030	0.00	100.00	100.00	100.00	100.00	100.00

Share of hydrogen in transport sector liquid fuel and natural gas demand

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	Zero	0.00	0.00	0.00	0.00	0.00	0.00
NZ2045	Ramps up to 100% in 2045, starting in 2030	0.00	0.00	70.00	100.00	100.00	100.00
NZ2050	Ramps up to 100% in 2050, starting in 2030	0.00	0.00	50.00	80.00	100.00	100.00
NZ2060	Ramps up to 100% in 2060, starting in 2030	0.00	0.00	35.00	50.00	80.00	100.00

Land

Increase mangrove restoration, in net terms (mangrove restoration minus degradation)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No additional effort	current	current	current	current	current	current
NZ2045	125,000 ha/year in 2021–2024, then 12,000 ha/year starting in 2025	current	12,000	12,000	12,000	12,000	12,000
NZ2050	125,000 ha/year in 2021–2024, then 12,000 ha/year starting in 2025	current	12,000	12,000	12,000	12,000	12,000
NZ2060	125,000 ha/year in 2021–2024, then 12,000 ha/year starting in 2025	current	12,000	12,000	12,000	12,000	12,000

Increase peatland restoration, in net terms (peatland restoration minus degradation)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No additional effort	current	current	current	current	current	current
NZ2045	Ramp up to 650,000 ha/year by 2038, then decline	current	81,250	481,429	60,000	30,000	30,000
NZ2050	Ramp up to 390,000 ha/year by 2038 then decline	current	79,254	299,048	152,763	78,036	57,895
NZ2060	Ramp up to 390,000 ha/year by 2038 then decline	current	79,254	343,860	225,439	107,018	59,649

Increase reforestation, converting fallow land to secondary forest, in net terms

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No additional effort	current	current	current	current	current	current
NZ2045	Ramp up to 250,000 ha/year by 2030	current	250,000	250,000	250,000	250,000	250,000
NZ2050	Ramp up to 250,000 ha/year by 2030	current	250,000	250,000	250,000	250,000	250,000
NZ2060	Ramp up to net 250,000 ha/year by 2040	current	125,000	250,000	250,000	250,000	250,000

Increase share of cropland with sustainable agriculture

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	At current levels	current	current	current	current	current	current
NZ2045	Ramp up to 40% of agriculture sector by 2050	current	13.0	26.0	35.0	40.0	40.0
NZ2050	Ramp up to 40% of agriculture sector by 2050	current	13.0	26.0	35.0	40.0	40.0
NZ2060	Ramp up to 40% of agriculture sector by 2050	current	13.0	26.0	35.0	40.0	40.0

Green urban land, starting in 2030, to increase CO_2 sequestration (multiplier with value 1=current CO_2 sequestration level)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No further greening (multiplier equals 1)	1.0	1.0	1.0	1.0	1.0	1.0
NZ2045	Ramp up to 3x of current level by 2060	1.0	1.0	2.0	2.5	3.0	3.0
NZ2050	Ramp up to 3x of current level by 2060	1.0	1.0	2.0	2.5	3.0	3.0
NZ2060	Ramp up to 3x of current level by 2060	1.0	1.0	2.0	2.5	3.0	3.0

Avoid conversion of primary forest loss to agricultural land

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	Historical trends in loss of forest to agriculture	current	current	current	current	current	current
NZ2045	Ramp up avoided loss of forest to 100% by 2025	current	100.0	100.0	100.0	100.0	100.0
NZ2050	Ramp up avoided loss of forest to 100% by 2025	current	100.0	100.0	100.0	100.0	100.0
NZ2060	Ramp up avoided loss of forest to 100% by 2025	current	100.0	100.0	100.0	100.0	100.0

Waste and industry

Industrial wastewater recycling

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	current	current	current	current	current	current
NZ2045	Ramp up recycling rate to 100% by 2045	current	37.0	78.0	100.0	100.0	100.0
NZ2050	Ramp up recycling rate to 100% by 2050	current	32.0	65.0	85.0	100.0	100.0
NZ2060	Ramp up recycling rate to 100% by 2060	current	22.3	44.5	68.0	75.0	100.0

Share of municipal waste recycled (% of municipal waste generated)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	1.4	1.4	1.4	1.4	1.4	1.4
NZ2045	Ramp up recycling rate to 40% by 2060	1.4	10.5	21.0	25.5	30.5	40.0
NZ2050	Ramp up recycling rate to 40% by 2060	1.4	10.5	21.0	25.5	30.5	40.0
NZ2060	Ramp up recycling rate to 40% by 2060	1.4	10.5	21.0	25.5	30.5	40.0

Change in per capita waste generation (relative to 2020 level)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	0.0	0.0	0.0	0.0	0.0	0.0
NZ2045	Reduce by 70% by 2045, then hold steady	0.0	-25.0	-55.0	-70.0	-70.0	-70.0
NZ2050	Reduce by 70% by 2050, then hold steady	0.0	-22.0	-46.0	-60.0	-70.0	-70.0
NZ2060	Reduce by 56% by 2060	0.0	-13.0	-27.0	-35.0	-42.0	-56.0

Share of municipal waste collected (% of total generated)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	80.0	80.0	80.0	80.0	80.0	80.0
NZ2045	Increase collection rate to 100% by 2040	80.0	90.0	100.0	100.0	100.0	100.0
NZ2050	Increase collection rate to 100% by 2040	80.0	90.0	100.0	100.0	100.0	100.0
NZ2060	Increase collection rate to 100% by 2040	80.0	90.0	100.0	100.0	100.0	100.0

Share of waste composted (% of waste generated)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	10.0	10.0	10.0	10.0	10.0	10.0
NZ2045	Ramp up from 10% in 2020 to 40% by 2060	10.0	17.0	25.0	25.0	32.0	40.0
NZ2050	Ramp up from 10% in 2020 to 40% by 2060	10.0	17.0	25.0	25.0	32.0	40.0
NZ2060	Ramp up from 10% in 2020 to 40% by 2060	10.0	17.0	25.0	25.0	32.0	40.0

Emissions intensity of industrial processes and product use (IPPU), in thousands of tonnes CO_2e per real Rp. 1 billion (year 2000)

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	0.030	0.030	0.030	0.030	0.030	0.030
NZ2045	Ramp down to 40% of 2020 level by 2060	0.030	0.022	0.015	0.014	0.013	0.012
NZ2050	Ramp down to 40% of 2020 level by 2060	0.030	0.022	0.015	0.014	0.013	0.012
NZ2060	Ramp down to 40% of 2020 level by 2060	0.030	0.022	0.015	0.014	0.013	0.012

Carbon capture and storage (CSS) as % of IPPU emissions

Scenario	Description/quantification of policy	2020	2030	2040	2045	2050	2060
Reference Case	No change	current	current	current	current	current	current
NZ2045	Ramp up starting in 2030, reaching 100% by 2045	current	current	75.0	100.0	100.0	100.0
NZ2050	Ramp up starting in 2030, reaching 100% by 2045	current	current	50.0	80.0	100.0	100.0
NZ2060	Ramp up starting in 2030, reaching 100% by 2045	current	current	35.0	50.0	65.0	100.0

A3. Factors that improve socio-economic outcomes in net-zero scenarios

The socio-economic benefits described in Section 2.3 are connected to improvements in total factor productivity (TFP),[269] the availability of natural capital and associated primary resources, and reduced externalities in the net-zero scenarios relative to the Reference Case. This appendix examines each of those factors.

A3.1 Total factor productivity

Traditional approaches, including neo-classical models, incorporate TFP as a proximate source of GDP growth, in excess to that generated by the accumulation of factor inputs included in a representative output function. Generally, TFP is introduced in models either as an exogenous input, or as a composite factor that combines an exogenous parameter or trend, and an endogenous element that responds to changes in other variables, such as the rate of accumulation of human capital or physical infrastructure.

The models supporting LCDI, including IV2045, broaden the spectrum of factors affecting GDP, including from changes in the availability of environmental goods and services, due (on the negative side) to the depletion or degradation of natural capital or (on the positive side) from the rebuilding or from the natural accumulation of such types of capital.

A TFP-comparable variable is included in IV2045. Aside from the formation of human capital from health and education, and from accumulation of public services infrastructure, the variable is affected by changes in the quantity and quality of the natural capital (e.g. forest resources, water, biodiversity), changes in air and water quality, elements associated with haphazard industrialization and urbanization (waste, air pollution), and the social cost of carbon. The formula used is:

$$TFP_t^i = f(TECH_t^i, HEAL_t^i, EDUC_t^i, ENER_t^i, WAST_t^i, INFR_t^i, AIRQ_t^i, QHAB_t^i). \quad \text{eq.1}$$

Where TFP, TECH, HEAL, EDUC, EGHG, ENER, WAST, INFR, AIRQ, QHAB are indexes that proxy for factor productivity, technological progress, health status, education, GHG emissions, energy costs, wastewater, infrastructure, air quality and habitat quality. The superscript “i” refers to sectors of economic activity (primary, industry and services), while the subscript “t” refers to time. Such a characterization provides a basis for understanding the differential impacts of green vs. non-green policies on social and economic outcomes.
In the equation, health (HEAL) is proxied by a variable that measures access to basic health care; education (EDUC) by changes in literacy; the impacts of GHG emissions (EGHG) by the social cost of carbon; waste (WAST) by municipal solid waste flows; infrastructure (INFR) by the provision of roads services; and air quality (AIRQ) by the concentration of particulate matter in the atmosphere ($PM_{2.5}$). Habitat quality (QHAB) is an index that represents the effects of ecological fragmentation and quantity and quality of elements that support biodiversity. Such a specification for TFP sheds light on the role of LCDI policies relative to alternative interventions.

[269] Total factor productivity (TFP), also known as multi-factor productivity, is a measure of the output of an economy (or industry) relative to the inputs that went into it (such as capital and labor). If outputs are growing faster than inputs, TFP is improving; the opposite means it is declining. For a succinct explanation, see the glossary of the Asian Productivity Organization: https://www.apo-tokyo.org/resources/p_glossary/total-factor-productivity-2/.

A3.2 Availability of natural capital and associated primary resources

Aside from the impact through TFP, green policies included in the net-zero scenarios enhance agricultural productivity, improve water quality and availability, expand infrastructure services and energy access, and restore forests, mangroves and peatlands. These actions expand the availability of environmental goods and services, all of which directly (and indirectly) contribute to output.

LCDI policies tackle a primary concern in Indonesia by reconciling the need to expand output in primary activities to meet growing national demand, while preserving forests and the country's biodiversity. Sustainable agricultural practices, including better more effective use of fertilizer; sustainable road construction; tackling pre-harvest losses; treating wastewater; and innovations achieved through research and development (R&D) and additional infusions of human and physical capital would increase yields per hectare. Together with innovative businesses that directly benefit from Indonesia's biodiversity, these measures have the potential to boost the economic contributions of the primary sector while protecting primary forest and restoring degraded land.

A3.3 Externalities

IV2045 includes structural representations of different components of natural capital, trying to capture the provision of environmental goods and services to the economy. Both quantitative and qualitative factors are included. This way, the model can estimate the (generally unintended) consequences of fueling economic activity, including from specific types of policies and investment. The consequences that are assessed are air and water pollution, the generation of solid waste, as well as biodiversity losses (and corresponding ecosystem service losses). The social cost of carbon is also estimated.[270]

Table A3-1 summarizes the externalities computed by IV2045, their definition (how they are computed), and the costs per unit of the different externalities, as identified in the relevant literature.

Table A3-1. Externalities reflected in the scenario analysis

Externality	Computed as (definition)	Costs per unit of the externality
Air pollution (excluding from transport)	Sum of costs of nitrous oxide (NO_X), particulate matter 2.5 ($PM_{2.5}$) and sulphur dioxide (SO_2) emissions; these are health costs (mortality and morbidity) per unit valued at 2010 prices	$PM_{2.5}$ = US$120,000 per tonne SO_2 = US$31,000 per tonne NO_X = US$4,600 per tonne
Solid waste (open dumping and managed landfills)	Environmental cost of open dumping (cost of GHG emissions) plus the total cost of managed landfills (sanitary and others)	Open dumping: cost estimated via social cost of carbon at US$31 per tonne CO_2e emitted by dumped waste Cost of managed waste: US$63.10 per tonne of managed waste

[270] The social cost of carbon is the net present value of climate change damages caused by every additional tonne of CO_2e emitted, including non-market impacts on the environment and human health that may not be captured by other measurements.

Externality	Computed as (definition)	Costs per unit of the externality
Water opportunity cost	Differences in value added by use of water in agriculture, industrial processing and thermal power generation	Value added per acre-foot (1 acre-foot = 0.1233 hectare-meters) used for agriculture production = US$60.49 Value added per acre-foot used for industrial processing = US$228.02 Value added per acre-foot used for thermal generation = US$27.26
Biodiversity loss (change in value of ecosystem services provided)	Net change in value of biodiversity when land is converted from: 1. agriculture to fallow 2. forest to agriculture 3. forest to settlement 4. fallow to forest 5. fallow to settlement	Value of biodiversity of agricultural land = US$1,115 per ha Value of biodiversity of fallow land = US$45,058 per ha Value of biodiversity of forest land = US$50,110 per ha Value of biodiversity of urban land = US$352 per ha

Sources of cost estimates: $PM_{2.5}$, SO_2, NO_X: U.S. EPA, 2013; social cost of carbon: Nordhaus, 2017; cost of managed landfill: Dijkgraaf and Vollebergh, 2003.[271]

What is critical regarding these negative externalities is that, while they do not have a market defined value, they impose a cost to society, which, in first instance may not be manifested in monetary terms, but as a direct reduction in individuals' well-being (including impacts on mortality, morbidity and other elements affecting the quality of life). Those reductions are reflected in economic activity through a reduction, for instance, in the quantity and quality of human capital and through inefficiencies in the production process (e.g. by increasing intermediate costs), all of which reduce potential and effective output. Notably, the monetary costs of mitigating impacts of negative externalities are often registered as positive effects on GDP (e.g. the costs of hospitalization, of waste management, and of public services to ease or solve traffic problems). In these circumstances what happens is that the "value addition" is not incurred to enhance individuals' welfare but to offset (to certain degree) the loss of welfare that occurred as a result of the externality. This reduces the resources (consumption and investment) available for activities that lead to a net increase in individuals' well-being.

The net-zero scenarios reduce those externalities, contributing to enhancing socio-economic outcomes. For example, they reduce wastewater and improve air quality, both of which affect human capital. Reducing those externalities has an unambiguously positive effect on well-being. The values of externalities described in **Table A3-1** can be combined with standard metrics of well-being to discern the economy-wide benefits of the net-zero scenarios. An ongoing challenge under standard national accounting practices is to understand how to combine typical proxies for well-being, such as income and GDP per capita, with other non-market elements that are equally relevant for welfare analysis.

[271] U.S. EPA. 2013. "Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors." Technical support document. Research Triangle Park, NC, US: Office of Air and Radiation, U.S. Environmental Protection Agency. https://www.epa.gov/benmap/estimating-benefit-ton-reducing-pm25-precursors-17-sectors.

Nordhaus, W.D. 2017. "Revisiting the Social Cost of Carbon." Proceedings of the National Academy of Sciences of the United States of America 114 (7): 1518–23. doi:10.1073/pnas.1609244114.

Dijkgraaf, E., and H.R.J. Vollebergh. 2003. "Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods." Nota di Lavoro, No. 46.2003. Milan, Italy: Fondazione Eni Enrico Mattei. https://www.econstor.eu/bitstream/10419/118076/1/NDL2003-046.pdf.

A4. COVID-19 modeling

The COVID-19 pandemic has disrupted socio-economic activity in a way that is unprecedented in modern times. Both the pandemic and the necessary measures to protect human life affect well-being through several channels, including aggregate supply and demand, human capital and investments.

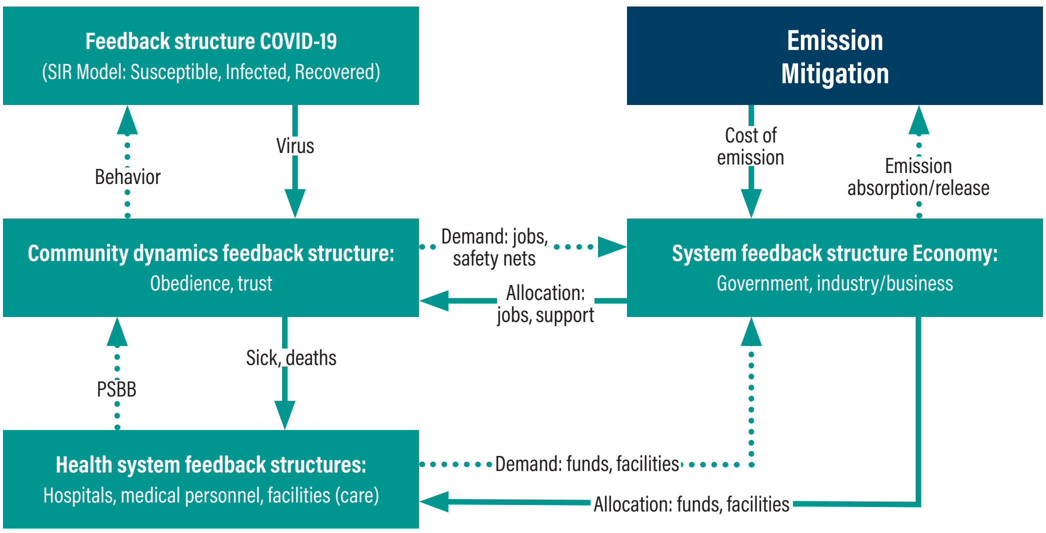
The empirical work that supports LCDI incorporates several structures in the model created for this report that generate endogenous values of susceptible population, infections and deaths from COVID-19; the associated socio-economic impacts; and the effects of policy responses (medical emergency, social assistance, safety nets and stimulus interventions) on variables that are relevant for climate, environment and socio-economic policy analyses.

These structures use the so-called Susceptible-Infected-Recovered model (the "SIR model"), which is utilized in epidemiology to represent the spread (dynamics) of a disease as a result of biological and social factors. The SIR model predicts the spread of a disease, including the number of susceptible individuals, the number infected, and the duration of the epidemic, as well as alternative resolutions, including recovery, reinfection and deaths.

Key epidemiological parameters, such as the basic reproductive number (R0), are incorporated in the model, while other parameters are calibrated from data. SIR models can show how different public health interventions may affect the outcome of the epidemic, including on vaccination (when available), social policy (e.g. lockdowns, social distancing and mask-wearing) and health responses (increasing capacity of hospitals).[272] In the context of Indonesia, the SIR model is calibrated using national-level (weekly) data on infections and deaths, plus information on health sector capacity and social and policy responses. All of this is fully integrated into the model.

The model also brings in structures, following the emerging economic literature,[273] representing changes in aggregate demand (consumption, investments), physical capital, human capital and labor utilization that result from the pandemic, immediate social and economic responses, and stimulus policies. **Figure A4.1** presents a simplified, high-level representation of the main interactions across systems incorporated in the model. They represent the dynamics of the disease (SIR model), community and policy responses, capacity of the health system, socio-economic structures, and feedback effects with GHG emissions and the environment.

Figure A4.1. General framework for the impact of COVID-19 on the economy



[272] For a technical, but accessible explanation of the SIR model using System Dynamics, see: https://vensim.com/coronavirus/.

[273] See, for instance, Olivier Blanchard's chapter on COVID-19 in the 8th edition of his Macroeconomics textbook: https://www.ssc.wisc.edu/_mchinn/Blanchard_chapter.pdf. (The full book is available at https://www.pearson.com/us/higher-education/program/Blanchard-My-Lab-Economics-with-Pearson-e-Text-Access-Card-for-Macroeconomics-8th-Edition/PGM2030616.html).

A5. Unit costs of interventions

The table below summarizes the unit costs of different interventions modeled and provides the sources used for those costs.

Sector	Cost item	Unit costs	Source
Energy	Average cost per charger	Linearly decrease starting at US$1,500 per charger in 2020 to US$750 per charger in 2070	Informed by: EuropeOn. 2018. "Powering a New Value Chain in the Automotive Sector: The Job Potential of Transport Electrification." Brussels: European Association of Electrical Contractors. https://europe-on.org/wp-content/uploads/2020/02/EuropeOn-Powering-a-new-value-chain-in-the-automotive-sector-the-job-potential-of-transport-electrification.pdf.
	Average cost per EV	Linearly decrease starting at US$30,000 per EV in 2020 to US$22,000 per EV in 2070	Source: JATO Dynamics Ltd. 2019. "Electric Cars Cost Double the Price of Other Cars on the Market Today." October 11, 2019. https://www.jato.com/electric-cars-cost-double-the-price-of-other-cars-on-the-market-today/.
	Average O&M cost for EVs	Starting at US$127 per EV per year in 2020 and converging to US$96 per EV per year in 2060	Based on Kimura, S., S. Suehiro, and N. Doi, eds. 2018. "An Analysis of Alternative Vehicles' Potential and Implications for Energy Supply Industries in Indonesia." ERIA Research Project Report 2017 No. 15. Jakarta: Economic Research Institute for ASEAN and East Asia. https://www.eria.org/uploads/media/ERIA_RPR_2017_15.pdf.
	Average cost per electric bus	Starting at US$105,000 per bus per year in 2020 and converging to US$75,000 per bus per year in 2060	Based on Kimura, S., S. Suehiro, and N. Doi, eds. 2018. "An Analysis of Alternative Vehicles' Potential and Implications for Energy Supply Industries in Indonesia." ERIA Research Project Report 2017 No. 15. Jakarta: Economic Research Institute for ASEAN and East Asia. https://www.eria.org/uploads/media/ERIA_RPR_2017_15.pdf.
	Average O&M cost for electric buses	Constant at US$2,000 per bus per year	Based on Kimura, S., S. Suehiro, and N. Doi, eds. 2018. "An Analysis of Alternative Vehicles' Potential and Implications for Energy Supply Industries in Indonesia." ERIA Research Project Report 2017 No. 15. Jakarta: Economic Research Institute for ASEAN and East Asia. https://www.eria.org/uploads/media/ERIA_RPR_2017_15.pdf.
	Capital cost of power generation, by technology (per MW of capacity)	Steam coal = US$950,000; diesel = US$1.81 million; natural gas = US$375,000; nuclear = US$2.65 million; hydropower = US$2.2 million in 2021, rising to US$ 2.4 million by 2060; geothermal = US$2.94 million; solar = US$678,000 in 2021, falling to USR400,000 by 2060; syngas = US$1.98 million; wind = US$2.01 million in 2021, falling to US$1.4 million by 2060	All but diesel and fuel oil based on assumptions in: IEA. 2020. "World Energy Outlook 2020." IEA Flagship Report. Paris: International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2020. Diesel from Tables 4.1 and 4.2 in: U.S. EIA. 2020. "Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies." U.S. Energy Information Administration. https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2020.pdf. Coal is assumed to be supercritical; gas is assumed to be gas turbine; hydropower uses average between small and large scale; synthetic gas based on biogas DG industry; wind uses average between onshore and offshore.

Sector	Cost item	Unit costs	Source
Energy	Average O&M cost of power generation, by technology (per MW of capacity)	Steam coal = US$40,000; diesel = US$35,160; natural gas = US$20,000; nuclear = US$130,000; hydropower = US$47,500; geothermal = US$57,500; solar = US$12,000 in 2021, falling to US$11,000 by 2060; syngas = US$77,500; wind = US$49,000 in 2021, falling to US$37,250 by 2060	All but diesel and fuel oil based on assumptions in: IEA. 2020. "World Energy Outlook 2020." IEA Flagship Report. Paris: International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2020. Diesel from Tables 4.1 and 4.2 in: U.S. EIA. 2020. "Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies." U.S. Energy Information Administration. https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2020.pdf. Coal is assumed to be supercritical; gas is assumed to be gas turbine; hydropower uses average between small and large scale; synthetic gas based on biogas DG industry; wind uses average between onshore and offshore.
	Cost of hydrogen production	US$2 per kg H_2	From Figure 12 in: IEA. 2019. "The Future of Hydrogen." Paris: International Energy Agency. https://www.iea.org/reports/the-future-of-hydrogen.
	Energy efficiency saving costs	US$7,165 per TJ consumption	Assuming US$300 per TOE, equivalent to US$7,165 per TJ, based on: ADB. 2013. "Same Energy, More Power: Accelerating Energy Efficiency in Asia." Manila: Asian Development Bank. https://www.adb.org/sites/default/files/publication/30289/same-energy-more-power.pdf.
	Unit cost of carbon capture and sequestration	US$100.50 per tonne of CO_2 avoided	Values for Indonesia, industry sector, from Irlam, L. 2017. "Global Costs of Carbon Capture and Storage: 2017 Update." Global CCS Institute. https://www.globalccsinstitute.com/archive/hub/publications/201688/global-ccs-cost-updatev4.pdf.
Land	Average cost of land restoration (excluding peatlands and mangroves)	US$1,225 per ha	Planting density partly determines costs, with sparse enrichment planting on degraded peatlands in Indonesia estimated to be between US$235 and US$315 per ha. The cost for enrichment planting increases with density, e.g., 3 meter tree spacing between seedlings costs between US$1,225 and US$1,575 per ha in Indonesia.
	Average cost of mangrove restoration	US$3,000 per ha	Low end; reported costs per hectare range from US$3,000 to US$510,000. Source: Lewis, R. III. 2001. "Mangrove Restoration – Costs and Benefits of Successful Ecological Restoration." Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/forestry/10560-0fe87b898806287615fceb95a76f613cf.pdf.
	Average cost of peatland interventions	Canal blocking = US$1,795 per ha; peatland revegetation = US$931 per ha; vegetative burn block = US$517 per ha; polyculture farming = US$306 per ha	Mumbunan, S. 2019 (unpublished). "A Summary of Peatland Thematic Study for the LCDI Global Report." Prepared by WRI Indonesia in support of the Low Carbon Development Initiative.

Sector	Cost item	Unit costs	Source
Waste	Average capital cost per tonne of waste collected	US$98.2 US$/tonne	Bassi, A., and G. Pallaske. 2021 (unpublished). "Technical Modeling Work in Support of Indonesia Low Carbon Development Initiative."
	Average O&M cost per tonne of waste collected	US$49.8 US$/tonne	
	Average capital cost per tonne of waste landfilled	US$15.4 US$/tonne	
	Average O&M cost per tonne of waste landfilled	US$45.5 US$/tonne	
	Average capital cost per tonne of waste recycled	US$646.95 US$/tonne	
	Average O&M cost per tonne of waste recycled	US$38.11 US$/tonne	
	Average capital cost per tonne of waste composted	US$207.95 per tonne	
	Average O&M cost per tonne of waste composted	US$28.24 per tonne	
	Average capital cost per tonne of waste incinerated	US$320.91 per tonne	
	Average O&M cost per tonne of waste incinerated	US$20.02 per tonne	
	Average capital cost per tonne of waste used for energy recovery	US$641.82 per tonne	
	Average O&M cost per tonne of waste used for energy recovery	US$40.05 per tonne	

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