LPEM-FEBUI Working Paper - 080
July 2024

ISSN 2356-4008

INDONESIA'S DECARBONIZATION PLANS DIAGNOSTIC: A POLICY PAPER

Alin Halimatussadiah
Muhammad Adriansyah
Fachry Abdul Razak Afifi
Muhammad Yudha Pratama
Teuku Riefky
Jiehong Lou

LPEM-FEB UI Working Paper 080

Chief Editor : Chaikal Nuryakin
Editors : Jahen Fachrul Rezki
Setting : Rini Budiastuti

Salemba Raya 4, Salemba UI Campus Jakarta, Indonesia 10430
Phone : +62-21-3143177
Fax : +62-21-31934310
Email : lpem@lpem-feui.org
Web : www.lpem.org

LPEM-FEB UI Working Paper 080, July 2024
ISSN 2356-4008

Indonesia's Decarbonization Plans Diagnostic: A Policy Paper

Alin Halimatussadiah[1,2,★], Muhammad Adriansyah[2], Fachry Abdul Razak Afifi[2], Muhammad Yudha Pratama[2], Teuku Riefky[2], and Jiehong Lou[3]

Executive Summary

One of the central commitments Indonesia is pursuing is integrating a green economy into its economic development framework. This aligns seamlessly with the nation's dedication to fostering sustainable and environmentally friendly development practices. This commitment is underscored by the significant reduction in greenhouse gas emission intensity, targeted to reach 93.5% below 2010 levels by 2045. This goal establishes a clear pathway toward achieving net-zero emissions by 2060. This policy paper provides an in-depth analysis of the strategies and policies outlined by comprehensively maps both current and prospective strategies, policies, and programs aimed at achieving Indonesia's development target that aligned with a green economic approach. They are NDC, LTS-LCCR 2050, LCDI, Roadmap NZE Energy. While all three planning documents elaborate long-term plans for Indonesia's journey toward reducing its carbon footprint, they encompass divergent approaches, targets, and commitment periods, leading to varied strategies and programs. The differences among these documents could potentially send mixed signals, affecting planning and budgeting, especially crucial up to the end of the Paris Agreement period in 2030, after which the discrepancies can be re-evaluated. To ensure cohesive and effective climate action, it is imperative for the Indonesian government to unify its approach by creating a dynamic, iterative planning document. This document should be continuously updated to ensure the convergence of all planning efforts, thereby enhancing the effectiveness of Indonesia's climate actions.

JEL Classification: Q50; Q54; Q56; Q58

Keywords
green economy — net-zero emission — climate action — Indonesia — climate policies

[1] *Department of Economics, Faculty of Economics and Business, University of Indonesia, West Java, Indonesia*
[2] *Institute for Economic and Social Research, Faculty of Economics and Business, University of Indonesia, Jakarta, Indonesia*
[3] *Center for Global Sustainability, School of Public Policy, University of Maryland, College Park, USA*
★**Corresponding address**: Institute for Economic and Social Research (LPEM) Universitas Indonesia, Gedung Ali Wardhana, Campus UI Salemba, Salemba Raya St., No. 4, Jakarta, 10430, Indonesia. Email: alin.halimatussadiah@ui.ac.id.

1. Introduction

Indonesia's 2045 Gold Vision aims to transform the nation into a "*Negara Nusantara Berdaulat, Maju, dan Berkelanjutan*" (An Archipelago that is Sovereign, Advanced, and Sustainable). As a nation dedicated to upholding the principles of sustainable development, Indonesia's robust economic growth is in sync with social progress, the sustainable management of natural resources, environmental quality, and effective governance.

In pursuit of its vision, Indonesia has set its sights on transcending the middle-income threshold to ascend as a high-income nation. This necessitates attaining an economic growth rate ranging from 6% to 6.6% within the 2025–2045 timeframe. Concurrently, Indonesia aims to elevate its Gross National Income (GNI) per capita from US$5,500 to US$30,300 while addressing socioeconomic disparities.

One of the central commitments Indonesia is pursuing is integrating a green economy into its economic development framework. This aligns seamlessly with the nation's dedication to fostering sustainable and environmentally friendly development practices. This commitment is underscored by the significant reduction in greenhouse gas emission intensity, targeted to reach 93.5% below 2010 levels by 2045. This goal establishes a clear pathway toward achieving net-zero emissions by 2060.

The dedication to incorporating the principles of a green economy into Indonesia's framework is evident in various official documents, including the Nationally Determined Contribution (NDC), Long Term Strategies for Low Carbon and Climate Resilience (LTS-LCCR 2050), and Low Carbon Development Initiatives (LCDI). Additionally, the Ministry of Energy and Mineral Resources released Indonesia's energy sector roadmap for NZE (Roadmap NZE Energy) to complement the decarbonization plan of the energy sector in the LTS-LCCR 2050. These documents primarily center on formulating strategies to address climate-related concerns by setting emission reduction targets. Nevertheless, a coherent and detailed blueprint for the actual implementation of a green economy is conspicuously absent from these documents.

The purpose of this policy paper is to comprehensively map both current and prospective strategies, policies, and programs aimed at achieving Indonesia's development target that aligned with a green economic approach. They are NDC, LTS-LCCR 2050, LCDI, Roadmap NZE Energy. This mapping serves as a policy analysis tool, revealing key issues in climate document planning and fostering productive discussions among policymakers, the public, and economic-wide climate modeling communities to enhance the credibility of Indonesia's climate targets. By outlining existing initiatives and potential pathways to meet Indonesia's green economic goals, this policy paper provides a strategic roadmap, enabling more effective and data-driven decision-making in the pursuit of sustainable and impactful climate action.

Table 1. Projected BAU and Emission Reduction From Each Sector Category

Sector	GHG Emission Level 2010* (MTon CO2-eq)	GHG Emission Level 2030			GHG Emission Reduction				Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012
		MTon CO_2-eq			MTon CO_2eq		% of Total BaU			
		BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1. Energy*	453.2	1,669	1,311	1,223	358	446	12.5%	15.5%	6.7%	4.50%
2. Waste	88	296	256	253	40	43.5	1.4%	1.5%	6.3%	4.00%
3. IPPU	36	69.6	63	61	7	9	0.2%	0.3%	3.4%	0.10%
4. Agriculture	110.5	119.66	110	108	10	12	0.3%	0.4%	0.4%	1.30%
5. Forestry and Other Land Uses (FOLU)**	647	714	214	-15	500	729	17.4%	25.4%	0.5%	2.70%
TOTAL	**1,334**	**2,869**	**1,953**	**1,632**	**915**	**1,240**	**31.89%**	**43.20%**	**3.9%**	**3.20%**

Notes: **CM1**= Counter Measure 1 (*unconditional mitigation scenario*)
CM2= Counter Measure 2 (*conditional mitigation scenario*)

*) Including fugitive.
**) Including emission from estate and timber plantations.

Source: UNFCCC, 2021

2. Indonesian Climate Pathways

2.1 The Enhanced Nationally Determined Contribution

Indonesia updated its NDC in September 2022, improving its unconditional target from 29% to 32% below its business-as-usual scenario (BAU) and its conditional target from 41% to 43% below its BAU. These emission reduction targets are considered an ambitious step, considering its development challenges in eradicating poverty and creating a better quality of life for its citizens.

The main contributors to greenhouse gas (GHG) emissions come from forestry and other land use (FOLU) and the energy sector, with a GHG emission share of around 48% and 34%, respectively (Table 1). On the other hand, the cumulative emission share of waste, industrial processes, and product use (IPPU) and agriculture only account for around 18% of total GHG emissions. Reflecting this situation, the strategy put in place by Enhanced NDC suggested the most emission reduction will come from FOLU, with around 17.4% to 25.4% of emission reduction from BAU. Also, the reduction of the energy sector's GHG emission is around 12.5% to 15.5% of total BAU.

Currently, Indonesia's climate policies are failing to put the country on a development pathway that uses its vast renewable energy potential. Several studies have demonstrated how Indonesia could increase the use of its renewable energy potential far beyond current plans and supply 100% of its electricity with renewable sources by 2050. With renewables accounting for just 10.8% of the electricity generation mix in 2022, Indonesia needs to make substantial progress in this sector to meet its target of 23% renewables by 2025. In September 2022, Indonesia published a presidential regulation that aims to support the achievement of this target by addressing some of the major financial and regulatory barriers facing renewables.

Indonesia has embarked on a mixed energy use policy in the energy sector and has established the development of clean energy sources as a national policy directive. Collectively, these policies will eventually put Indonesia on the path to decarbonization. For the waste management sector, the Government of Indonesia is committed to developing a comprehensive strategy to improve policy and institutional capacity at the local level, enhance the management capacity of urban wastewater, reduce landfill waste by promoting the "Reduce, Reuse, Recycle" approach, and the utilization of waste and garbage into energy production. The Government of Indonesia is committed to further reducing emissions from the waste management sector by 2030 and beyond through comprehensive and coherent policy development, institutional strengthening, improved financial and funding mechanisms, technology innovation, and socio-cultural approaches.

In the forestry sector, Indonesia has set up an ambitious target by 2030 in peat land restoration of 2 million ha and rehabilitation of degraded land of 12 million ha. Indonesia will continue to work on Article 5 of the Paris Agreement, which sends a clear political signal on the recognition of the roles of forests and REDD+, which remain important components of the NDC target from the land use sector. Existing Conference of the Parties (COP) decisions have provided sufficient guidance to implement and support REDD+ implementation. As policy approaches and positive incentives, REDD+ should be able to support the achievement of Indonesia's emission reduction target in the forestry sector.

FOLU Net Sink 2030 target (-140 MtCO2 emission level) will be achieved through the following policy measures: reducing emissions from deforestation and forest degradation, increasing carbon sequestration capacity of natural forests, increasing carbon sequestration of land systems, reducing emissions from fires and peat decomposition, and law enforcement.

The mitigation actions in industrial solid waste handling include the utilization of wastewater treatment plant (WWTP) sludge and industrial solid waste through composting, reusing it as raw material, and using it as energy. In industrial liquid waste handling, mitigation actions include wastewater treatment in palm oil, pulp and paper, fruits/vegetables and juices processing, and other industries, as well as implementing methane capture and utilization (biogas).

Apart form it's mitigation action, Indonesia also in-

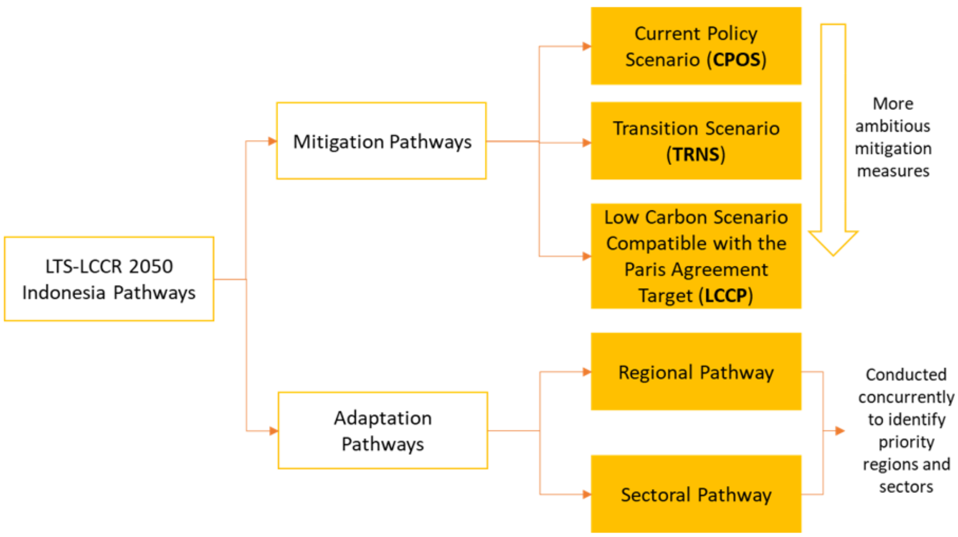

Figure 1. LTS-LCCR 2050 Indonesia Pathways
Source: UNFCCC (2021)

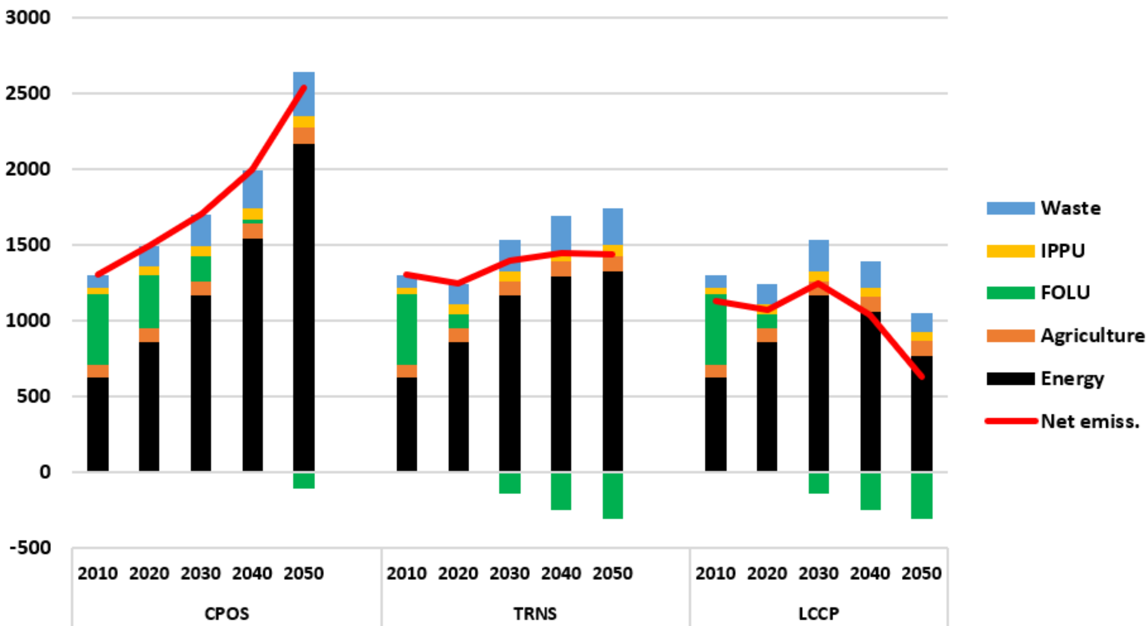

Figure 2. Projection of Emissions Under the CPOS, TRNS, and LCCP
Source: UNFCCC (2021)

cludes their adaptation goal in the NDC. Indonesia focuses on three areas of resilience: economic resilience, social and livelihood resilience, and ecosystem and landscape resilience. These three areas of resilience have been elaborated in the NDC Adaptation Road Map of 2022 (Enhanced NDC), which is operationally prioritized into several fields, namely food, water, energy, health, and ecosystems. Ideally, NDC achievement is measured in terms of reduction of potential losses of national GDP due to climate change, decrease of vulnerability, and increase of adaptive capacity and resilience. For this reason, the enabling conditions need to be strengthened, which include policy instruments for climate change adaptation and disaster risk reduction; integration into development planning and financial mechanisms; improved climate literacy on vulnerability and risk; landscape-based approaches, such as spatial planning, investment; strengthening local capacity on best practices; improved knowledge management systems, including reporting, monitoring and evaluation; stakeholder participation; and application of adaptive technology.

In general, the key programs, strategies, and actions on adaptation aim at the following:

a) reducing drivers of vulnerability to climate change impacts,
b) responding to climate change impacts and managing risks,
c) enhancing the capacity of communities and sustainability of ecosystem services, and
d) enhancing the engagement of stakeholders at all levels in building climate resilience.

2.2 The Long-Term Strategy for Low Carbon and Climate Resilience

In response to the Paris Agreement mandate, Indonesia submitted the Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050), which aims to support global goals and achieve national development goals by balancing the development of climate resilience, economic growth, and emission reduction. LTS-LCCR 2050 Indonesia represents a significant step towards a climate-resilient future for the nation. The LTS-LCCR 2050 Indonesia aligns climate objectives with national, sub-national, and international goals, including the Sustainable Development Goals (SDGs). The document also considers the role of non-party stakeholders (NPS) and communities to reap the benefits of early climate efforts.

In general, LTS-LCCR 2050 Indonesia has proposed different pathways for mitigating climate change and adapting to its impacts. LTS-LCCR 2050 also refers to several documents related to climate efforts to determine and formulate pathways. First, LTS-LCCR 2050 takes into account Indonesia's targets and commitments stated in Indonesia's Updated NDCs (2021). LTS-LCCR 2050 also refers to development plan documents, including the National Long-Term Development Plan (RPJPN) 2005–2025, the National Medium-Term Development Plan (RPJMN) 2020–2024, the National Energy General Plan (Presidential Regulation No. 22/2017), and the Revised National Forestry Plan 2011–2030. This ensures alignment between sustainability goals and broader economic and social development objectives.

The proposed pathways of LTS-LCCR 2050 are divided into mitigation and adaptation pathways, as shown in Figure 1. The mitigation pathways consist of three scenarios: the current policy (CPOS), the transition (TRNS), and the low carbon scenario compatible with the Paris Agreement target (LCCP). The CPOS is built upon Indonesia's unconditional target in Updated NDC (2021), which has the least ambitious target of the three mitigation scenarios. The LCCP has the most ambitious target—achieving net-zero emissions in 2060 or sooner. The TRNS has ambitions that are between CPOS and LCCP.

For the adaptation pathways, regional and sectoral pathways should be conducted simultaneously. Those pathways come from the climate resilience concept of the Paris Agreement, which emphasizes the principle of no one left behind. It requires local wisdom to implement the adaptation through investment in human resources, infrastructure, and land & seascape management. The focus of adaptation in LTS-LCCR 2050 also aligns with NDC areas (water, food, energy, environmental health, ecosystem, and disaster). The regional pathway identifies the climate hotspots and determines which regions are affected in the six areas. For example, in the area of disaster, regions that are more prone to climate-related disasters are the focus of adaptation action. The sectoral pathway identifies which sectors are more susceptible to climate impacts. The impacts to each sector must be measured first. LTS-LCCR 2050 has provided a preliminary impact assessment of climate change impact translated into GDP loss. Even though the impacts were estimated by sector, multi-sectoral actions are required to build an effective adaptation program. The combination of regional and sectoral pathways will create a comprehensive adaptation policies for priority regions and sectors.

Figure 2 presents emission projections between the three mitigation pathways. The CPOS has the highest net emission trajectories of the other scenarios. The LCCP has the most aggressive trajectories, with net emissions reaching their peak in 2030 and declining at a pace of around 30.7 Mton CO2e per year. If the emission rate continues to decline beyond 2050, Indonesia will have a better chance of progressing toward net-zero emissions by 2060 or earlier. In contrast, neither CPOS's nor TRNS's net emissions trajectories reach a peak. The year in which Indonesia achieves net zero is beyond 2050, according to CPOS and TRNS.

Based on the projections for each scenario, the energy sector is the largest contributor to total emissions in year 2030–2050. Under the CPOS scenario, emissions from this sector are expected to rise rapidly, reaching around 40 Mton of CO2e annually. The TRNS scenario forecasts a lower emissions growth rate in the energy sector than the CPOS. In the LCCP scenario, emissions from the energy sector are projected to peak in 2030 and then decline. The FOLU sector is projected to become a net sink by 2050 under the CPOS scenario, while under both TRNS and LCCP, it will achieve net sink status in 2030.

2.3 The Low Carbon Development Initiative

In 2019, the Ministry of National Development Planning (Bappenas) introduced a significant report titled "Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia," commonly known as the LCDI. This initiative is more than just a policy measure; it serves as a comprehensive blueprint for transforming Indonesia's economy from a traditional, business-as-usual growth model to a more sustainable low-carbon economy. The goal is to help Indonesia break free from the persistent middle-income trap, aligning with the long-term aspirations outlined in Indonesia Vision 2045. The importance of LCDI is reflected in the fact that it has been integrated into the National Medium-Term Development Program (RPJMN) for the period from 2020 to 2024, aligning with Indonesia's broader development goals. The initiative promotes a holistic approach to economic growth that integrates environmental sustainability, recognizing that the conventional model of growth, based on the unchecked exploitation of natural resources, is no longer viable for achieving Indonesia's long-term goals.

Despite the progress made under the LCDI, the COVID-19 pandemic, along with a series of climate-related events such as extreme weather patterns, and other natural disasters, created a multidimensional crisis that undermined the macroeconomic stability of Indonesia. This crisis disrupted various sectors and derailed many of the gains made in previous years, prompting a reassessment of national priorities, particularly in environmental sustainability and economic recovery. In response, Bappenas conducted a thorough reassessment of the LCDI in 2021, resulting in a new document titled "A Green Economy for A Net-Zero Future: How Indonesia Can Build Back Better after COVID-19 with the Low Carbon Development Initiative." This report provides a range of policy scenarios to help Indonesia not only recover from the pandemic but also achieve a more ambitious climate target of net-zero emissions, presenting a strategic path for leveraging the crisis to accelerate the

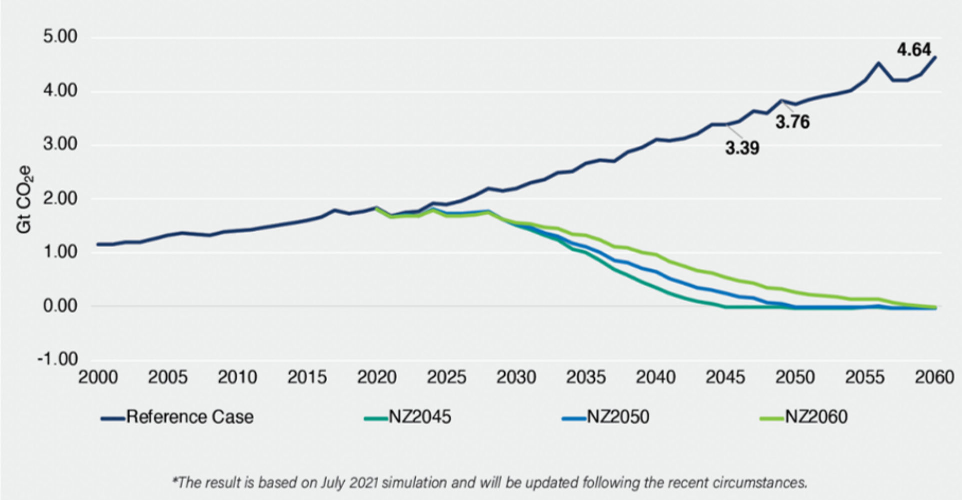

Figure 3. Projection of Emissions Under the Reference and Net-zero Scenarios
Source: Bappenas (2021)

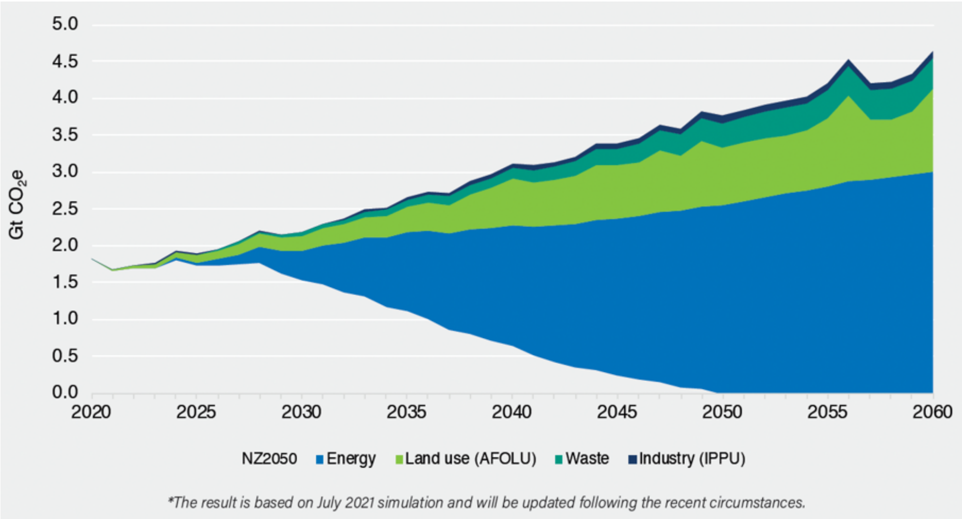

Figure 4. Key Sectors' Contribution to Emission Reduction in NZ2050
Source: Bappenas (2021)

transition to a low-carbon economy.

The new iteration of the LCDI report delineates a new reference (BAU) case and three distinct scenarios for Indonesia achieving net-zero emissions. The scenarios are for achieving net-zero emissions by 2045 (NZ2045), 2050 (NZ2050), or 2060 (NZ2060). They apply the same interventions but on different timelines. All would ensure that Indonesia meets or exceeds its unconditional pledge under the Paris Agreement of a 29% emission reduction by 2030[1].

Figure 3 compares annual greenhouse gas pathways in the reference case and three net-zero scenarios. Through implementing policies in net-zero scenarios, GHG emissions are projected to peak in 2024 at approximately 1.8 Gt CO_2e before initiating a decline. Following this trajectory, all three net-zero scenarios are anticipated to achieve GHG emissions of 1.51, 1.54, and 1.55 Gt CO_2e, respectively. These values are well below the 1.95 Gt CO_2e projected in the Enhanced NDC unconditional pledge.

The net-zero scenarios build upon the comprehensive suite of low-carbon measures outlined in RPJMN 2020–2024, crafted to facilitate the nation's attainment of its GHG emission reduction objectives for 2020 to 2030. To achieve net zero, the Indonesian government has formulated strategies in four key sectors: (1) energy, (2) agriculture, forestry and other land use (AFOLU), (3) waste, and (4) IPPU. These strategies encompass complete substitution of fossil fuels with clean energy; substantial reduction in the energy intensity of the economy; full phase-out of fossil fuel subsidies by 2030; electrification of road transport; protection and restoration of forests, peatlands, and mangroves; adoption of sustainable practices in agriculture, forestry, fisheries, and aquaculture; improvement of waste management; and increased efficiency in the industrial sector.

Figure 4 illustrates how different key sectors contribute to emission reduction in the NZ2050 scenario. The emission reduction strategies place a strong emphasis on the energy and land use sectors. Notably, two-thirds of the mitigation effort corresponds to the energy sector, while 24.9% corresponds to the AFOLU sector. The waste sector and IPPU contribute 8% and 2%, respectively.

[1]The unconditional target has now been updated to 31.89% based on Enhanced NDC.

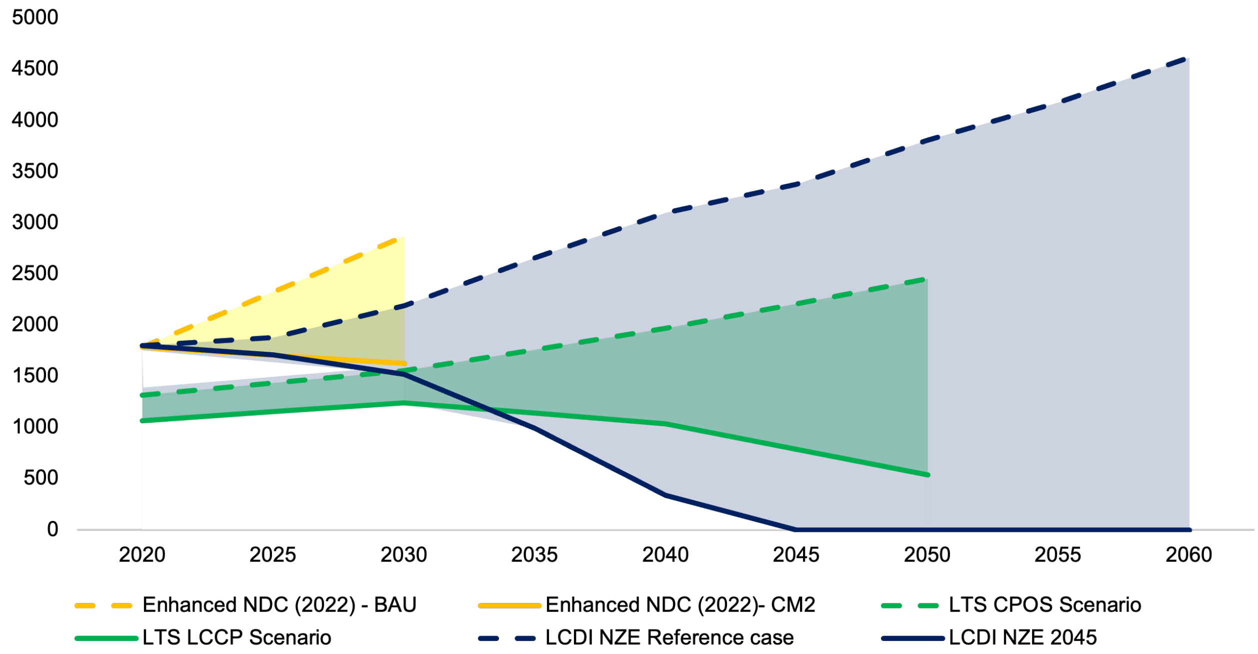

Figure 5. GHG Emission Gap from Indonesia's Document Planning
Source: NDC (2016, 2021, 2022), LCDI (2019; 2021), LTS-LCCR 2050 (2021)
Note: The line graph shows the trajectory of each document scenario consisting of an orange line for NDC, green for LTS LCCR, and Blue for LCDI. Meanwhile, the shading shows the gap from the most ambitious target on the documents to the least ambitious target.

2.4 Comparative Analysis of Indonesia's Decarbonization Pathways

In the unfolding trajectory towards a sustainable future, Indonesia has articulated its commitment to reducing emissions through several strategic planning documents, each presenting a distinct pathway and timeframe to achieve pivotal milestones in emission reductions. This section unfolds a comparative analysis, accentuating the disparities and commonalities between the three main planning documents—Enhanced NDC, LCDI NZE 2045, and LTS-LCCR 2050. Each framework maps out a roadmap for Indonesia's journey toward diminishing its carbon footprint, yet they harbor divergent approaches, targets, and commitment periods, reflecting varied potential strategies and assumptions about future economic and technological developments.

Figure 5 illustrates the upper and lower limits of emission reduction scenarios from various planning documents with different time frames. These scenarios represent different levels of ambition and underlying assumptions about economic growth, technology deployment, and policy interventions. There are at least two noticeable differences between those documents, which are the initial emission point and the timeframe. Firstly, the NDC and LCDI have shown higher initial levels of GHG compared to LTS LCCR 2050. This could happen due to the assumption in each modeling level that the NDC and LCDI are using a modeled emission while LTS LCCR 2050 is following the historical trend of GHG emissions. In addition, the Land Use, Land-use Change and Forestry (LULUCF) in 2020 LTS is based on three different scenarios. Secondly, the one with the shortest timeframe is Enhanced NDC, which targets emission reduction up to 2030 aligning with the commitments under the Paris Agreement, followed by LTS LCCR up to 2050, and LCDI up to 2060. Due to having the shortest time frame, Enhanced NDC has the biggest gap with the Net Zero Emission Plan. Only LCDI NZE 2045 explicitly states the target of reaching net zero by 2045. The emission reduction plan described in LTS-LCCR 2050, on the other hand, has a timetable until 2050, with scenarios still aiming for a near zero emission level at the conclusion of the term with the future target to reach NZE by 2060 or sooner.

The main difference could be attributed to the energy sector when comparing the two planning documents with the longest timeframe, LTS-LCCR 2050 and LCDI. By 2050, the LTS-LCCR 2050 scenario estimates that there will still be emissions produced by the energy sector, amounting to around 766 Mt CO2e. In comparison, LCDI NZE 2045 specifies various strategies to achieve totally clean energy that encompass the complete substitution of fossil fuels with clean energy, a substantial reduction in the energy intensity of the economy, full phase-out of fossil fuel subsidies by 2030, and electrification of road transport. As the net emission target of LTS-LCCR 2050 in 2050 is roughly 766 Mt CO2e, a complete emission reduction in the energy sector of LTS-LCCR 2050 could result in total net-zero achievement. Therefore, the analysis underscores the importance of bridging the gap between these varying emission reduction pathways by enhancing efforts in key sectors, particularly energy. Strengthening the energy sector's transition to complete decarbonization is critical to ensuring that Indonesia can meet its net-zero commitments by 2045 or 2060, as outlined in these planning documents. This approach would not only fulfill Indonesia's climate commitments but also foster sustainable development across all sectors of the economy.

Indonesian Roadmap of Net Zero Emission in the Energy Sector

The Roadmap NZE Energy 2060 is a long-term document containing strategies and policy directions specifically in the energy sector to support the Indonesian net-zero target by 2060. The roadmap was published by Indonesia's Ministry of Energy and Mineral Resources and was the result of a collaboration with the International Energy Agency (IEA). The roadmap targets the emission reduction from the energy sector to 129.4 million tons (from the BAU scenario of 1,927 million tons of CO_2), which is built upon macroeconomic assumptions that have been agreed in the LTS-LCCR 2050 document.

The roadmap comprehensively delineates both supply and demand-side pathways. It has considered the policies implemented in the upstream energy sector, such as oil and gas, mineral and coal, and electricity. In terms of the downstream side, energy demand analysis is focused on the transportation, industrial, household, and commercial sectors.

The targets set in this roadmap have been through a series of stages and coordination with various stakeholders and sectors. This document is also expected to be a reference for energy stakeholders such as Ministries/Agencies, financial institutions, the private sector, as well as the community in significantly implementing emission reduction mitigation actions in the energy sector by 2060.

Given the detailed analysis, it is indispensable to incorporate the strategies and policy directions in this roadmap into the green growth projection assumptions.

3. Sectoral Strategies to Achieve Climate Pathway

This section analyzes the emission reduction pathway advances to the sectoral level. The examination will be conducted based on the categorization of emission sources into four sectors: energy, Agriculture, Forestry, and Other Land Use (AFOLU), waste management, and Industrial Processes and Product Use (IPPU). The existing policies and strategies within these domains will be scrutinized under the following four constructs:

- Strategy/Intervention: Overarching direction adopted to curtail emissions, providing a strategic framework for action.
- Program and Targets: More detailed programs that operationalize the overarching strategy, complete with specific targets they aim to achieve.
- Enabler: Facilitative factors that empower the execution and effectiveness of each program or policy.
- Gap: Potential obstacles that would hinder the program/policy from achieving its full potential.

3.1 Energy Sector

The energy sector stands out for having the most comprehensive strategic documentation among all climate mitigation domains, including enhanced NDC, LTS -LCCR, LCDI, and Roadmap NZE Energy specific to the energy sector. One noticeable difference in each sector was the level of detail in each sector, which varied from NDC -the least comprehensive- to LTS LCCR and Roadmap NZE Energy. With this difference in climate action plans in energy sectors, the NDC set the least ambitious goal, aiming to limit emissions to between 1,669 and 1,223 million tonnes of CO2 equivalent (MT CO2-eq) by 2030. This is followed in ambition by the LTS-LCCR 2050 and, subsequently, by the NZE roadmap, which sets a target of 0 MT CO2-eq by 2060. To realize these objectives, 16 distinct programs have been delineated across ten identified strategic areas planned for implementation. Nonetheless, each program encounters unique barriers and catalysts, as the accompanying table details.

3.1.1 Energy Efficiency Measures in All Subsectors

The LCDI documents targeted to reduce energy intensity from 6% in the NZE 2060 scenario to 4.1% in the NZE 2045 scenario. The Efforts to reduce energy intensity are supported by several key enablers. Firstly, the Ministry of Energy and Mineral Resources (MEMR) is overseeing a pilot project focused on this goal (Lestari, 2107). Additionally, there exists a capacity to conduct energy audits with an emphasis on non-market elements, which is crucial for identifying and implementing efficiency improvements. However, these efforts face significant challenges. The capital and developmental costs associated with energy efficiency initiatives are substantially high, posing a financial barrier.

Furthermore, the lack of financial incentives to promote energy efficiency is another gap that needs to be addressed. These financial challenges hinder the broader adoption and implementation of measures necessary to effectively reduce energy intensity.

In the NDC, the strategy for energy efficiency measures in all subsectors is pursued by two programs, which are the improvement of energy efficiency in appliances and the usage of solar panel lamps for road lighting. Firstly, Energy efficiency improvement in equipment targeting electricity savings is enabled through the implementation of the Standard and Labelling Program (SKEM), which has been initiated for specific appliances[2]. In the Roadmap NZE Energy, SKEM is planned to be implemented in 11 appliances. However, gaps hindering the achievement of these targets include a lack of public awareness and the need for behavioral change to support energy conservation efforts.

Regarding street lighting with energy-efficient lamps, a pilot program is already in place, supported by initiatives from both central and local governments, as well as the private sector (Ditjen EBTKE, 2022). This approach promotes energy savings. Nonetheless, challenges exist, such as a substantial number of Solar Power Street Lights (PJUTS) not functioning properly, mainly due to damage and frequent

[2]According to the MEMR website for conservation energy (https://simebtke.esdm.go.id/sinergi/program_konservasi_energi/detail/3/skem-dan-labeling), there are already 7 appliances that have been regulated.

Table 2. Analysis of Strategies in the Energy Sector

No	Strategy/Intervention	Program and Targets	Emission Target	Enabler	Gap
1	Energy efficiency measures in all subsectors	**Enhanced NDC** Energy efficiency improvement of equipment that targets electricity saving	***Emission Level***: **Enhanced NDC**	- The implementation of the Standard and Labelling Program (SKEM) has been initiated for certain appliances, with a strategic roadmap targeting its application to 11 appliances in the context of the Net Zero Emissions (NZE) initiative.	- Lack of awareness and behavioral change to support energy conservation efforts
2		**Enhanced NDC** Street lighting with efficient lamp that save energy	*2030* - BAU: 1,669 MT on CO_2-eq - CM1: 1,311 MT on CO_2-eq	- There is already a piloting program in various regions supported by central and local government or private sector initiatives	- A significant number of Solar Power Street Lights (PJUTS) are malfunctioning, primarily due to damage and frequent theft incidents involving these lights. - The functionality of many solar-powered public street lights is compromised by the limited lifespan of their batteries, often only around two years. - There is an evident shortfall in the maintenance and monitoring of these solar lighting products.
3		**LCDI** Reduce Energy Intensity NZ 2060: 6% (Yearly) NZ 2050: 4.1% (yearly) NZ 2040: 4.5% (yearly)	- CM2: 1,223 MT on CO_2-eq **LTS-LCCR 2050** *2030* - CPOS: 1,164 MT on CO_2-eq - TRNS: 1,164 MT on CO_2-eq	- There is a pilot project that is being overseen by the Ministry of Energy and Mineral Resources (ESDM). - There is already the capacity to perform energy audits, emphasizing non-market elements.	- The capital and developmental expenditures for energy efficiency initiatives are significantly high. - There is a notable absence of financial incentives.
4	Development of Renewable Energy Power Plan	**Enhanced NDC** Additional RE PP Capacity: 20.9 GW (According to 2021–2030 RUPTL). **LCDI** - Renewable Energy in Power Generation Capacity: 60% by 2045 and 82% by 2060	- LCCP: 1,164 MT on CO_2-eq *2040* - CPOS: 2,040 MT on CO_2-eq - TRNS: 1,543 MT on CO_2-eq	- Initiatives such as the Just Energy Transition Partnership (JETP) and Energy Transition Mechanism (ETM) provide financial support for the energy transition process. - Coal Phase-Out Initiatives are in place, aiming to reduce the dependence on Coal-Fired Power Plants (CFPP) in the energy mix.	- The high requirement for local content in Renewable Energy Power Plants (RE PP). - Complexities in the procurement process for Renewable Energy Power Plants (RE PP). - The political economy dynamic of fossil fuels in Indonesia. - Inadequacies in the governance of the electricity market impede progress in the energy transition.

Note: *The emission reduction values are approximations derived from a graphical representation in the LCDI. These values may not precisely reflect the official targets.

... continued

Table 2. Analysis of Strategies in the Energy Sector

No	Strategy/Intervention	Program and Targets	Emission Target	Enabler	Gap
		Roadmap NZE Energy - RE PP Capacity: 768.2 GW (Solar: 421 GW, Wind: 94 GW, Geothermal 22 GW, Hydro: 72 GW, Bioenergy: 60 GW, Ocean: 8 GW, Storage: 4.2 GW)	- LCCP: 1,293 MT on CO_2-eq *2050*		- The lack of sufficient grid connection and infrastructure to support RE PP hinders the effective integration of renewable energy sources. - Unproven sources for power production, such as ocean and offshore wind energy.
5	Development of New Energy	**Roadmap NZE Energy** - Nuclear PP: 31 GW, starting from 2039	- CPOS: 2,171 MT on CO_2-eq - TRNS: 1,327 MT on CO_2-eq - LCCP: 766 MT on CO_2-eq	-The successful operation of the Triga Mark nuclear reactor in February 1965 marked a significant milestone in nuclear technology. - Existing regulations pertaining to nuclear energy have been established to facilitate the utilization of nuclear power, including its application in electricity generation. - This technology has been adopted in various countries as a dependable energy source.	- Public acceptance of Nuclear Power Plants is challenged by concerns over the potentially hazardous impacts of radioactive waste. - The investment costs associated with nuclear energy are significantly high.
6		**Roadmap NZE Energy** -Green Hydrogen from RE (2031), replacing gas (2041)	***Emission Reduction***: **LCDI*** *2040*	- Indonesia's inaugural Green Hydrogen Plant (GHP) is operational, aiding PLN in the production of 51 tons of green hydrogen annually.	- The production cost of this technology is economically uncompetitive when compared to alternative technologies. - There is a deficiency in the necessary infrastructure to support this technology effectively. - Policymakers are yet to fully acquaint themselves with the nuances of this technology.
7	Development of BECCS PP	**LTS LCCR** Connect biomass-coal cofiring power plants to CCS (Biomass Energy with Carbon Capture and Storage or BECCS)	- NZ 2050: 1,850 MT on CO_2-eq *2050* - NZ 2050: 2,863 MT on CO_2-eq	- Carbon Capture and Storage (CCS) has gained recognition as a prominent program in the oil and gas industry.	- There is a notable lack of public awareness and familiarity with the technology. - The investment cost for this technology is significantly higher compared to other proven Non-Renewable Energy Power Plants. - Challenges exist in securing and managing the necessary feedstocks.
8		*Roadmap NZE Energy* Massive implementation of BESS starting by 2034: 56 GW by 2060	*2060*		

... *continued*

Table 2. Analysis of Strategies in the Energy Sector

No	Strategy/Intervention	Program and Targets	Emission Target	Enabler	Gap
9	Biofuels development	*Enhanced NDC* - 18 million kL FAME in B-40	- NZ 2050: 3,000 MT on CO2-eq	- Implementation of pilot projects is underway. - Regulations and incentives have been established to support this initiative.	- Challenges with feedstock, including issues related to both quantity and quality. - The complex interplay between land usage for food production and biofuel feedstock cultivation.
10		**LTS LCCR** - Develop biofuels for transport and power plants, including biofuel resource base (feedstock, plantation). - Mandatory B30 by 2025		- A replanting program for palm oil has been instituted.	- The pricing dynamics of biofuels are affected by an unclear strategic plan.
11		**Roadmap NZE Energy** Biofuel mix in industry and transportation sectors of 40% by 2060			
12	Biomass for Co-firing	**Enhanced NDC** - Biomass utilisation for cofiring purposes of 9 Mton by 2024 - Biomass direct utilisation and biogas for off-grid power generation of 333,776 BOE		- Initiation of pilot projects is in progress.	- Issues concerning the quality and quantity of feedstock. - The interrelation between land use for food production and for feedstock. - Competition with other uses for the same resources.
13	Retirement of CFPP	**Roadmap NZE Energy** -Phasing out 100% of Coal PP by 2060		-Regulatory frameworks have been established. - Financial support is being provided through initiatives like the Just Energy Transition Partnership (JETP) and Energy Transition Mechanism (ETM). - Implementation of pilot projects is ongoing.	- The politics surrounding coal present a significant obstacle in the transition to cleaner energy sources. - The establishment of new Power Purchase Agreements (PPAs) focused on coal highlights a gap in moving towards renewable energy adoption.
14	Electrification in Transportation	**NDC** - Electrification of Transportation by 2030 (15,197,000 units) for passenger car and motorcycle **Roadmap NZE Energy** - Electrification of motorcycle (175 million) and car (65 Million) by 2060		- Existing Fiscal and Non-fiscal policies such as BBNKB and PKB Exemption, sales tax on luxury goods (PPnBM)	- The uneven distribution of Electric Vehicle Charging Stations (SPKLU). - Higher pricing compared to Internal Combustion Engine Vehicles (ICEVs). - Performance concerns, including range, charging duration, reliability, and safety.
15	Electrification for household appliances	**Roadmap NZE Energy** Induction stove use (54.3 M)		- There is a regulation to support the transition	- consumer acceptability for changing their appliances

... continued

Table 2. Analysis of Strategies in the Energy Sector

No	Strategy/Intervention	Program and Targets	Emission Target	Enabler	Gap
16	Expanding Gas Network	**NDC**		- Regulations have been established, as outlined in Presidential Regulation (PERPRES) Number 6 of 2019, concerning the Provision and Distribution of Natural Gas through Transmission Networks and/or Natural Gas Distribution for Households and Small Customers.	- The pricing structure poses a challenge
		Household gas network (22.7 M) by 2060			- There are issues with consumer acceptability for the technology
		Gas pipeline network expansion (10 million connections)			

theft. Moreover, many solar-powered public street lights suffer from reduced functionality due to the limited battery life, which typically lasts only about two years, and a noticeable lack of maintenance and supervision of these lighting systems. These gaps need addressing to fully realize the benefits of efficient street lighting.

3.1.2 Development of Renewable Energy Power Plant

Renewable energy power plants (RE PP) have emerged as a pivotal strategy in achieving the NZE target. This approach is reflected in various planning documents where specific targets for RE PP's share in the energy mix are outlined. For example, the LCDI aims for a 60% share by 2045 and 82% by 2060. Similarly, the NDC set a goal for an additional 20.9 GW of RE PP capacity by 2030, as per the 2021–2030 RUPTL. To achieve NZE, the target is set at 768.2 GW, comprising 421 GW from solar, 94 GW from wind, 22 GW from geothermal, 72 GW from hydro, 60 GW from bioenergy, 8 GW from ocean energy, and 4.2 GW from storage. Key enablers in reaching these targets include financial support initiatives like the Just Energy Transition Partnership (JETP) and Energy Transition Mechanism (ETM), along with Coal Phase-Out Initiatives to diminish reliance on Coal-Fired Power Plants (CFPP).

However, several obstacles persist. High local content requirements for RE PP (Burke et al., 2019), complexities in the procurement process for these plants (MENTARI, 2022), the entrenched dynamics of the fossil fuel economy in Indonesia (Arinaldo & Adiatma, 2019; Gao et al., 2021; Ordonez et al., 2021), complexity in electricity market governance, insufficient grid connection and infrastructure for RE PP (Burke et al., 2019), and the use of unproven energy sources like ocean and offshore wind power, all pose significant challenges to the successful integration and expansion of renewable energy within the country's energy mix.

3.1.3 Development of New Energy

The Roadmap NZE Energy from MEMR outlines the development of two new energy sources: nuclear power plants and green hydrogen. By 2060, the roadmap targets a capacity of 31 GW for nuclear power, with operations commencing in 2039. Key enablers for nuclear power include the successful operation of the Triga Mark nuclear reactor in 1965, a significant milestone in nuclear technology (Wauran, 2022); existing regulations that support the utilization of nuclear power for electricity generation[3]; and the recognition of this technology as a reliable energy source in various countries (Alonso et al., 2015). However, challenges such as public concerns over the potential hazards of radioactive waste (Cho et al., 2021; Sugiawan & Managi, 2019) and the Indonesian government regards nuclear power as an 'option of last resort' and has set the use of nuclear energy as a low priority option (Cho et al., 2021) which hinder its acceptance and implementation.

The second technology, green hydrogen, is set to be sourced from renewable energy starting in 2031 and is anticipated to replace gas by 2041. PLN has pioneered this field with its operational Green Hydrogen Plant (GHP), which produces 51 tons of green hydrogen annually (CNN Indonesia, 2023). Despite this progress, the technology faces gaps like its high production costs compared to alternative technologies, a lack of sufficient infrastructure for effective support, and a need for policymakers to become more familiar with the intricacies of green hydrogen technology. These challenges must be addressed to fully leverage the potential of nuclear and green hydrogen energy in the Roadmap NZE Energy.

3.1.4 Development of BECCS PP

The LCDI targeted to integrate biomass-coal cofiring power plants with Carbon Capture and Storage (CCS), while the Roadmap NZE Energy by the MEMR plans a massive implementation of Battery Energy Storage Systems (BESS) starting in 2034, targeting 56 GW by 2060. CCS, a prominent program in the oil and gas industry, supports these targets. However, there are notable gaps in achieving these objectives. Firstly, there is a significant lack of public awareness and understanding of CCS technology. Secondly, the investment required for CCS is substantially higher compared to other established RE PP (IESR, 2023a). Lastly, there are challenges in securing and managing the necessary feedstocks for biomass-coal cofiring power plants (Kraxner et al., 2015). These challenges need to be addressed to integrate CCS and BESS successfully into the energy infrastructure as outlined in the LCDI and Roadmap NZE Energy.

3.1.5 Biofuels Development

In the landscape of biofuel strategy across various documents, there is a distinct approach. The LTS LCCR focuses on developing biofuels for transport and power plants. This includes establishing a biofuel resource base, encompassing feedstock and plantation, and implementing a mandatory B30 (30% biofuel blend) by 2025. Similarly, the NDC and the Roadmap NZE Energy set ambitious targets, aiming for an 18 million kL FAME incorporation in B-40 and a 40% biofuel mix in the industry and transportation sectors by 2060.

Key enablers for these strategies include ongoing pilot projects, established regulations and incentives to support biofuel initiatives, and a replanting program for palm oil, which is a significant feedstock for biofuel (Dharmawan et al., 2018). However, these strategies face several gaps that need addressing. These include challenges related to the quantity and quality of feedstock, the complex relationship between land allocated for food production and biofuel feedstock cultivation, and the intricacies of biofuel pricing dynamics, which are currently hindered by a lack of a clear strategic plan (Dharmawan et al., 2018).

3.1.6 Biomass for Co-firing

In the NDC, two primary targets are outlined for biomass utilization: firstly, the use of biomass for cofiring purposes, aiming for 9 million tons by 2024, and secondly, the direct utilization of biomass and biogas for off-grid power generation, targeted at 333,776 Barrels of Oil Equivalent (BOE). The progress towards these goals is supported by the initiation of pilot projects, which are crucial for testing and refining these biomass applications. However, significant

[3] The government already release Government Regulation No. 2 of 2014 about Licensing for Nuclear Installations and use of Nuclear Materials that allows nuclear use for electricity. Additionally, the government intend to put nuclear in the forthcoming regulation on National Energy Planning (Kebijakan Energi Nasional/KEN).

challenges need to be addressed to fully realize these targets. A key issue is the quality and quantity of the feedstock, which is fundamental for both cofiring and direct utilization strategies. Additionally, there is a complex interplay between the use of land for food production versus its use for biomass feedstock, raising concerns about resource allocation. This situation is further complicated by competition with other resource uses, creating tension in prioritizing between energy generation, food production, and other land uses.

3.1.7 Retirement of CFPP

Roadmap NZE Energy includes a comprehensive plan to phase out 100% of CFPP by 2060. This ambitious target is supported by several key enablers. Established regulatory frameworks provide the necessary legal and policy structure for this transition. Financial assistance, essential for such a large-scale shift, is being facilitated through initiatives like the ETM, which provide the required capital and investment support. Additionally, the implementation of pilot projects is underway, playing a crucial role in testing and demonstrating the feasibility of transitioning away from coal. Despite these enablers, significant challenges remain. The political landscape surrounding coal is a major hurdle. Coal has long been a cornerstone of Indonesia's energy sector, and shifting away from it involves navigating complex economic and social dynamics (Arinaldo & Adiatma, 2019; Cui et al., 2022; Gao et al., 2021; Ordonez et al., 2021). Furthermore, the ongoing establishment of new Power Purchase Agreements (PPAs) that focus on coal indicates a persistent gap in fully committing to renewable energy adoption. This not only reflects a resistance to change within the energy sector but also highlights the need for more robust policies and incentives to accelerate the transition towards renewable energy sources.

3.1.8 Electrification in Transportation

The electrification of transportation is a key component in Indonesia's climate strategy, as highlighted in both the NDC and Roadmap NZE Energy. The NDC sets ambitious targets for the electrification of 175 million motorcycles and 65 million cars by 2060. Complementing this, Roadmap NZE Energy aims for the electrification of approximately 15.2 million transportation units by 2030. Key enablers for achieving these targets include existing fiscal and non-fiscal policies, such as exemptions from the Motor Vehicle Tax (BBNKB) and Vehicle Ownership Transfer Fee (PKB), as well as reductions in the Sales Tax on Luxury Goods (PPnBM) for electric vehicles (IESR, 2023b). Despite these supportive policies, there are significant challenges that need to be addressed. One major issue is the uneven distribution of Electric Vehicle Charging Stations (SPKLU), which can impede the widespread adoption of electric vehicles (EVs) (Hardman et al., 2018). Another concern is the higher cost of EVs compared to Internal Combustion Engine Vehicles (ICEVs), which can be a deterrent for potential buyers (Maghfiroh et al., 2021). Additionally, performance aspects such as range, charging duration, reliability, and safety of EVs are crucial factors that can influence consumer acceptance (Mashhoodi & van der Blij, 2021) and the overall success of the electrification program.

3.1.9 Electrification for Household Appliances

In the Roadmap NZE Energy, there is a strategic target to have 54.3 million induction stove users by 2060, a move that signifies a significant shift towards the electrification of appliances. This strategy is underpinned by supportive regulations that facilitate the transition towards using more energy-efficient and environmentally friendly appliances like induction stoves. However, a major challenge in achieving this target is consumer acceptability (Bhutto et al., 2021). The transition to new technologies, such as induction cooking, requires not only a change in consumer appliances but also an adaptation of household cooking habits and preferences. Overcoming this barrier involves not just regulatory support but also consumer education and possibly incentives to encourage the adoption of more sustainable cooking technologies. Thus, while the regulatory framework sets the stage for this transition, the success of this initiative heavily depends on effectively addressing the challenge of consumer acceptability and behavior change.

3.1.10 Expanding Gas Network

The ambitious target of expanding Indonesia's gas network, as outlined in the strategic goals, includes establishing a household gas network for 22.7 million households and expanding the gas pipeline network to 10 million connections by 2030, as stated in the NDC. This expansion is supported by a robust regulatory framework, as detailed in Presidential Regulation (PERPRES) Number 6 of 2019. This regulation focuses on the provision and distribution of natural gas through transmission networks and/or natural gas distribution for households and small customers, laying a solid foundation for the expansion. However, this initiative faces significant challenges. One of the primary hurdles is the pricing structure (Kontan, 2023), which could potentially limit the affordability and, therefore, the uptake of gas connections among the target populations. Additionally, there is a notable issue regarding consumer acceptability of the technology.

3.1.11 Sectoral Conclusion

In terms of emission reduction targets, the documents vary significantly, among others, with the Roadmap NZE Energy being the planning document with the highest emission target of 0 $MTCO_2eq$ by 2060. The NDC outlines the least ambitious objectives, while the Roadmap NZE Energy sets the bar high with targets aimed at achieving net-zero emissions in the energy sector through specific technological interventions. A shared feature among these documents, except for the LCDI, is the detailed strategic framework for technology deployment within the energy generation sector. However, the NDC adopts a broader technological approach, while the LTS, LCDI, and Roadmap NZE Energy delve into more granular specifics, particularly in relation to emerging technologies like nuclear PP and BECCS.

Further analysis into the sectoral gaps and enablers identifies institutional support as a pivotal enabler. This includes the promotion of pilot projects and the facilitation of energy transition through regulatory measures, alongside clearly defined incentives and available funding sources that collectively propel the market towards achieving NZE objectives. Conversely, barriers are prominently rooted in societal resistance to behavioral change and reluctance towards new technologies, which pose significant obstacles to the energy transition. Additionally, governmental shortcomings in regulation enforcement and pilot project management, coupled with adverse political dynamics and unsupportive policies within the energy sector, further complicate the transition towards renewable energy sources. This comprehensive analysis underscores the necessity of a harmonized and supportive framework that addresses strategic, technological, institutional, and societal challenges to navigate the path toward ambitious net-zero emissions goals in the energy sector.

3.2 Agriculture, Forestry, and Other Land Use Sector

The AFOLU sector emerges as the current second-largest contributor to Indonesia's emissions, trailing only behind the energy sector while concurrently occupying the same position in emission reduction targets across our three main planning documents. Notably, the LTS-LCCR 2050 stands out as the most ambitious among the three, with its highest targets even aimed at facilitating emission absorption. This ambition translates into the formulation of six comprehensive strategies, which are further delineated into nineteen specific programs. These strategies encompass the reduction of deforestation and improved forest management, the enhancement of green spaces within urban settings, the restoration of mangroves and peatlands, reforestation and land rehabilitation efforts, the promotion of sustainable crop production, and the implementation of sustainable practices in livestock management. A summary of these strategies and programs, complemented by an analysis of the corresponding enabling environments and identified gaps, is succinctly presented in the Table 3.

3.2.1 Deforestation Reduction and Forest Management

Reducing deforestation is a key strategy in the emission reduction plan for the AFOLU sector, as outlined in three planning documents: the Enhanced NDC, LCDI, and LTS-LCCR 2050. The Enhanced NDC and LTS-LCCR 2050 set deforestation reduction targets in terms of the area of deforestation in hectares. The Enhanced NDC targets a deforestation rate of 359,000 hectares per year under scenario CM1 and 175,000 hectares per year under scenario CM2 for the period 2020–2030. Meanwhile, the LTS-LCCR 2050 limits the cumulative area to be deforested to about 14.6 million hectares in the CPOS scenario (starting from approximately 4.4 million hectares in 2020) and 6.8 million hectares in the LCCP scenario (starting from around 3 million hectares in 2020) by 2050. This averages out to approximately 340,000 hectares per year and 127,000 hectares per year, respectively. Although the Enhanced NDC and LTS-LCCR 2050 have different endpoints (2030 for the Enhanced NDC and 2050 for the LTS-LCCR 2050), both documents show a similar ambition to reduce deforestation when calculated on an annual average basis. The LCDI, however, sets a notably different target. It limits deforestation reduction in terms of a percentage of forest loss, aiming for a 50% reduction by 2030 and ending deforestation completely by 2025 in all Net Zero scenarios for 2060, 2050, and 2045. The LCDI stands as the sole planning document that commits to the complete cessation of deforestation.

Indonesia already has several enablers to support its ambitious deforestation-curbing targets. A major policy is Presidential Instruction No. 5/2019 on the Halt of New Licenses and the Improvement of Primary Natural Forest and Peatland Governance. This moratorium mandates ministers, governors, and other officials to permanently refrain from issuing new permits for clearing primary forests and peatlands for plantations and logging within designated moratorium areas. Indonesia also has integrated, comprehensive, and spatially explicit land-use planning in place at the national and sub-national levels, guided by Government Regulation 46/2016 on Strategic Environmental Assessments. In addition to these key policies, other enablers include REDD+ financing support and strategy guides, which are translated into Indonesia's REDD+ National Strategy for 2021–2030, and government-supported fire prevention and monitoring.

However, Indonesia's mission to achieve its future deforestation targets still faces several gaps and challenges. The current moratorium only covers primary forests, leaving secondary forests vulnerable. Moreover, while the moratorium explicitly bans the issuance of new clearing permits, it does not yet prohibit the conversion of forest areas into APL. Another significant challenge is the presence of natural forests within many concession areas (both timber and estate crop plantations) and non-concession areas designated as APL. Over 9.8 million hectares of natural forests are found within these concessions and APL zones, with 50% of these areas do not fall under protected zones. As a result, they are permitted for the establishment of plantations and for development purposes, posing a substantial risk to forest conservation efforts.

Delving further, the LCDI also sets more detailed targets. The document aims to reduce the forest clearing rate for cropland from an annual rate of 141,000 hectares in 2020, or 0.15% of the forest area, to zero by each net-zero target year in 2045, 2050, and 2060. It also targets a reduction in forest degradation from 139,000 hectares per year in 2020 to 82,000 by 2030, 44,000 by 2050, and approximately 1,000 by 2060, consistently across all net-zero scenarios. These targets are supported by the implementation of various government plans for the AFOLU sector, such as integrated farming or complex agroforestry, improvement of crop productivity and cropping intensity through high-quality seeds, fertilization, and the adoption of agricultural technology, optimization of unproductive (idle) lands for cropland, mandatory certification for sustainable forest management, and the implementation of silviculture and shelterwood cutting techniques. However, several challenges are also faced in achieving these targets. The existing moratorium on clearing natural forests for cropland was enforced only for palm oil commodities and for the 2018-2021 period. Additionally, as the current forest moratorium policy focuses only on primary forests, it inadvertently promotes activities that lead to forest degradation, as forest degradation can lead to a change of status from primary forests to secondary forests.

3.2.2 Greening of Urban Landscapes

This strategy is uniquely outlined in the LCDI, targeting a tripling of the carbon sequestration capacity of urban areas by 2050 across all net-zero scenarios. The 2015–2019 Strategic Plan of the Ministry of Public Works and Hous-

Table 3. Analysis of Strategies in the Agriculture, Forestry, And Other Land Use Sector

No	Strategy/Intervention	Program and Target	Emission Target	Enabler	Gap
1	Deforestation reduction and forest management	**Enhanced NDC** - CM1: Deforestation rate of 359,000 ha/year in 2020–2030 - CM2: Deforestation rate of 175,000 ha/year in 2020–2030 **LCDI** - NZ 2045, NZ 2050, and NZ 2060: Reduce forest loss by 50% by 2030, and end deforestation completely by 2045 **LTS-LCCR 2050** - CPOS: Limit the cumulative area to be deforested by 2050 to about 14.6 Mha - LCCP: Limit the cumulative area to be deforested by 2050 to about 6.8 Mha	***Emission Level:*** **Enhanced NDC** *2030* - BAU: 833,66 MT on CO_2-eq - CM1: 324 MT on CO_2-eq - CM2: 93 MT on CO_2-eq **LTS-LCCR 2050** *2030* - CPOS: 263 MT on CO_2-eq - LCCP: -46 MT on CO_2-eq *2040* - CPOS: 128 MT on CO_2-eq - LCCP: -148 MT on CO2-eq *2050*	- Permanent moratorium on new permits for clearing primary forests and peatlands for plantations and logging - Integrated, comprehensive, spatially explicit land use planning at national and sub-national level - Government-supported fire prevention and monitoring - REDD+ financing support and strategy guides - Implementation of integrated farming or complex agroforestry - Improvement of crop productivity and cropping intensity - Optimization of unproductive (idle) lands for cropland - Mandatory certification for sustainable forest management - Implementation of silviculture and shelterwood cutting	- The current moratorium does not cover secondary forests - The current moratorium explicitly bans the issuance of new clearing permits, but not the conversion of forest areas into APL (other use areas) - The existing moratorium on clearing natural forests for cropland was only forced for palm oil commodities and only for the 2018–2021 period - The current moratorium policy on primary forests inadvertently promotes activities that lead to forest degradation, as forest degradation can alter the status of primary forests to secondary forests
2		LCDI - NZ 2045: Reduce forest clearing rate for cropland of 141,000 ha per year in 2020 to zero by 2045 - NZ 2050: Reduce forest clearing rate for cropland of 141,000 ha per year in 2020 to zero by 2050 - NZ 2060: Reduce forest clearing rate for cropland of 141,000 ha per year in 2020 to zero by 2060	- CPOS: -3 MT on CO_2-eq - LCCP: -202 MT on CO_2-eq ***Emission Reduction:*** **LCDI***		

Note: *The emission reduction values are approximations derived from a graphical representation in the LCDI. These values may not precisely reflect the official targets.

... continued

Table 3. Analysis of Strategies in the Agriculture, Forestry, And Other Land Use Sector

No	Strategy/Intervention	Program and Target	Emission Target	Enabler	Gap
3		**LCDI** - NZ 2045, NZ 2050, and NZ 2060: Reduce the rate of forest degradation from 139,000 ha per year in 2020 to 82,000 in 2030, 44,000 in 2050, and around 1,000 by 2060	*2040* - NZ 2050: 713 MT on CO_2-eq		
4	Greening of urban landscapes	**LCDI** - NZ 2045, NZ 2050, and NZ 2060: Triple the carbon sequestration potential of urban land by 2050	*2050* - NZ 2050: 888 MT on CO_2-eq	- Green urban planning policies, including urban forestry - Government-private collaborations to fund and maintain urban green spaces	- Urban development pressures that prioritize construction over the preservation of green spaces - Spatial changes for established settlements necessitate relocation
5	Mangrove and peatland restoration	**LCDI** - NZ 2045, NZ 2050, and NZ 2060: Mangrove restoration of 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	*2060* - NZ 2050: 1,263 MT on CO_2-eq	- Establishment of the Peatland and Mangrove Restoration Agency - Establishment of Independent Village Cares for Mangroves (*Desa Mandiri Peduli Mangrove*/DMPM)	- High cost of mangrove restoration reaching up to US$9,000 per hectare - The area suitable for mangrove restoration is only about 193,367 hectares, or approximately 30 percent of the existing target area
6		**Enhanced NDC** - CM1 and CM2: Peatland restoration through rewetting and revegetation of 2 million ha of land by 2030. **LCDI** - NZ 2045: Peatland restoration of 90,000 ha per year in 2021–2030; then scale up to 650,000 ha per year in 2038 - NZ 2050 and NZ 2060: Peatland restoration of 90,000 ha per year in 2021–2030; then scale up to 390,000 ha per year in 2038 **LTS-LCCR 2050** - CPOS: Peatland restoration of 1.03 Mha by 2030 and 1.7 Mha by 2050 - LCCP: Peatland restoration of 2.7 Mha by 2030 and 4.2 Mha by 2050		- Promotion of ecotourism in mangrove areas - Establishment of Independent Village Cares for Peatland (*Desa Mandiri Peduli Gambut*/DMPG) - Palmiculture cultivation and other silviculture techniques - Implementation of advanced water table management to maintain optimal water levels in peatlands	- High cost of peatland restoration of more than US$4.6 billion - Inadequate understanding among local farmers of peatland dynamics and the importance of water management

... continued

Table 3. Analysis of Strategies in the Agriculture, Forestry, And Other Land Use Sector

No	Strategy/Intervention	Program and Target	Emission Target	Enabler	Gap
7		**Enhanced NDC** - CM1: Improvement of water management in peatland by increasing water level up to 50 cm from the surface. Its implementation in palm oil plantation: 892,000 ha; in timber plantation: 329,000 ha - CM2: Improvement of water management in peatland by increasing water level up to 50 cm from the surface. Its implementation in palm oil plantation: 892,000 ha; in timber plantation: 548,000 ha **LTS-LCCR 2050** - CPOS: Improvement of peatland and water management of 0.86 Mha by 2030 and 1.04 Mha by 2050 - LCCP: Improvement of peatland and water management of 0.95 Mha by 2030 and 1.04 Mha by 2050			
8	Reforestation and land rehabilitation	**LCDI** - NZ 2045 and NZ 2050: Scale up reforestation to 250,000 ha per year by 2030 - NZ 2060: Scale up reforestation to 250,000 ha per year by 2050		- Enhancement of green financing through Indonesia Environment Fund (Badan Pengelola Dana Lingkungan Hidup/BPDLH), REDD+, and green bonds - Implementation of carbon offsetting mechanism - Seedling distribution programs to support tree planting efforts - Enhancement of community involvement through social forestry program - Technical assistance for social forestry and land rehabilitation	- Rollback of environmental protections under the new Omnibus Law - Lack of long-term monitoring and protection for reforested areas, leading to a risk of re-deforestation - Limited technical expertise to plan and implement effective land rehabilitation
9		**Enhanced NDC** - CM1 and CM2: The annual planting rate of timber plantation will reach 320 thousand ha per year (in total 6.4 million ha by 2030)			
10		**Enhanced NDC** - CM1 and CM2: The annual planting rate for land rehabilitation will reach 280 thousand hectare per year (in total 5.6 million ha by 2030) **LTS-LCCR 2050** - CPOS: Unproductive land rehabilitation of 4.32 Mha by 2030 and 8.6 Mha by 2050 - LCCP: Unproductive land rehabilitation of 5.3 Mha by 2030 and 10.6 Mha by 2050			

... continued

Table 3. Analysis of Strategies in the Agriculture, Forestry, And Other Land Use Sector

No	Strategy/Intervention	Program and Target	Emission Target	Enabler	Gap
11		**LTS-LCCR 2050** - CPOS: Restoring area of production forest through the ENR programme with a target of 0.85 Mha by 2030 and 1.4 Mha by 2050 - LCCP: Restoring area of production forest through the ENR programme with a target of 1.70 Mha by 2030 and 8.8 Mha by 2050			
12	Sustainable crop production	**LCDI** - NZ 2045: Reduce land concessions for bioenergy crops from 41,000 ha in 2020 to 25,000 by 2030 and zero by 2045 - NZ 2050: Reduce land concessions for bioenergy crops from 41,000 ha in 2020 to 27,000 by 2030 and zero by 2050 - NZ 2060: Reduce land concessions for bioenergy crops from 41,000 ha in 2020 to 29,000 by 2030 and zero by 2060		- Bioenergy crops intensification - Enhancement of less land-intensive forms of bioenergy production (e.g., agricultural waste, second-generation biofuels) - Integrated, comprehensive, spatially explicit land use planning at national and sub-national level - Low emission crop seedling subsidy or distribution program	- Economic dependence on bioenergy crops - Inconsistencies between policy formulation and enforcement at the national level and the regional level - Adoption barrier due to uncertainty about the performance or market acceptance of the low emission crops - Limited access, compounded by inadequate local expertise, to water-efficient irrigation infrastructure and technologies in rural or remote areas
13		**Enhanced NDC** - CM1: The use of land for low emission crops up to 902,000 ha in 2030 - CM2: The use of land for low emission crops up to 932,000 ha in 2030 **LTS-LCCR 2050** - CPOS: Adoption of Low emission variety and water-saving paddy cultivation system (SPR/STT) in the rice field for about 0.93 Mha by 2030 and 1.96 Mha by 2050 - LCCP: Adoption of SPR/STT in the rice field for about 0.97 Mha by 2030 and 2.7 Mha by 2050		- Promotion and subsidy for water-efficient irrigation systems, coupled with technical assistance for farmers - Establishment of robust supply chains (e.g., local production facilities) to ensure consistent and affordable access for organic fertilizers - Incentive mechanism (e.g., premium price) for crops grown with organic inputs - Subsidy program for high quality seeds and fertilizers - Enforcement of sustainable commodity certification - Incentive mechanism (e.g., premium price) for sustainably produced commodity	- Organic fertilizers may be more expensive or less readily available than chemical alternatives - High cost of certification or adoption of sustainable practice - Uncertain benefits and market access for sustainable product - Resistance to new farming practices - Lack of financial resources to implement efficient water management
14		**Enhanced NDC** - CM1: Application of organic fertilizer up to 1,287,000 ton in 2030		- Advancement of agricultural technology - Water management policy especially tailored for efficient use of water resource in agriculture	

... continued

Table 3. Analysis of Strategies in the Agriculture, Forestry, And Other Land Use Sector

No	Strategy/Intervention	Program and Target	Emission Target	Enabler	Gap
		- CM2: Application of organic fertilizer up to 1,368,000 ton in 2030 **LTS-LCCR 2050** - CPOS: Substituting urea with organic fertilizer with target of reduction the use of urea of 3,089 ton by 2030 and 58,513 ton by 2050 - LCCP: Substituting urea with organic fertilizer with target of reduction the use of urea of 5,374 ton by 2030 and 65,697 ton by 2050		- Enforcement of water stewardship standard - Community-Based Water Management system	
15		**LCDI** - NZ 2045, NZ 2050, and NZ 2060: 40% of cropland (including palm oil production) is cultivated sustainably by 2050			
16		**LTS-LCCR 2050** - CPOS: Improve Crop Productivity and Cropping Intensity to 6.28 ton/ha - LCCP: Improve Crop Productivity and Cropping Intensity to 6.32 ton/ha.			
17		**Enhanced NDC** - CM1: Implementation of water efficiency up to 2,583,000 ha in 2030 - CM2: Implementation of water efficiency up to 3,376,000 ha in 2030			
18	Sustainable livestock management	**Enhanced NDC** - CM1: Manure used for biogas will come from 166,000 cattle in 2030 - CM2: Manure used for biogas will come from 249,000 cattle in 2030 **LTS-LCCR 2050** - CPOS and LCCP: Utilization of livestock waste for biogas for 41,000 head in 2030 and 94,000 head in 2050		- Government support for the installation of biogas digesters at livestock farms - Government-private collaboration to create scalable biogas projects - Subsidy scheme for sustainable feed options and feed supplement	- High upfront costs for farmers to transition to biogas systems - Limited access to markets for sustainably produced livestock waste products - Farmers' lack awareness of the benefits of feed supplements - Low market accessibility for high-quality feed supplements
19		**Enhanced NDC** - CM1: Up to 6,942.000 of ruminants in 2030 will be supplied by feed supplement - CM2: Up to 8,075.000 of ruminants in 2030 will be supplied by feed supplement **LTS-LCCR 2050** - CPOS: Improvement of livestock feed suplement for 3.42 million head by 2050 - LCCP: Improvement of livestock feed suplement for 6.58 million head by 2050			

ing mandates the development of urban areas to follow green concepts, with 112 cities in the process of being transformed into green cities while opening opportunities for partnerships with the private sector. Several major cities in Indonesia have also collaborated with private entities to develop and manage Green Open Spaces (*Ruang Terbuka Hijau*). However, this green development direction is often challenged by urban development pressures that favor construction over the conservation of green spaces. Furthermore, in densely populated cities, spatial changes for green spaces may also require the relocation of established settlements.

3.2.3 Peatland and Mangrove Restoration

The targets for peatland restoration are detailed in the Enhanced NDC, LCDI, and LTS-LCCR 2050. The LCDI sets a goal for peatland restoration of 90,000 hectares per year from 2021 to 2030; this is then to increase to 650,000 hectares per year by 2038 under the Net Zero 2045 scenario and to 390,000 hectares per year by 2038 under the Net Zero 2050 and 2060 scenarios. The LTS-LCCR 2050 targets the restoration of 1.03 million hectares by 2030 and 1.7 million hectares by 2050 for the CPOS scenario, and 2.7 million hectares by 2030 and 4.2 million hectares by 2050 in the LCCP scenario. The Enhanced NDC sets a slightly more specific goal, with peatland restoration to be achieved through rewetting and revegetation, targeting 2 million hectares for both the CM1 and CM2 scenarios by 2030. Meanwhile, mangrove restoration, though mentioned in all planning documents, has its specific targets only detailed in the LCDI. All three net-zero scenarios within the LCDI set identical goals: a mangrove restoration of 125,000 hectares per year from 2021 to 2024 to increase carbon stocks by 15% above 2020 levels, followed by a continuation of restoration at a rate of 12,000 hectares per year.

The government has bolstered peatland and mangrove restoration efforts by creating the Peatland and Mangrove Restoration Agency (Badan Restorasi Gambut dan Mangrove/BRGM). The BRGM's mandate is to expedite peatland restoration, enhance the welfare of communities in restoration regions, and speed up mangrove rehabilitation in specified provinces. Additionally, the BRGM oversees the Peatland Restoration & Mangrove Rehabilitation Information Management System (PRIMS), which delivers data on peat restoration in seven priority provinces and mangrove rehabilitation in nine priority provinces. To further support these restoration efforts, the BRGM has established the DMPG and the DMPM initiatives. In 2020, 590 villages participated in the DMPG program out of a total of 1,205 villages targeted for peatland restoration, and by 2021, as many as 200 DMPMs had been formed. Nonetheless, these restoration plans face numerous obstacles. The costs for both peatland and mangrove restoration are significant. Hansson & Dargusch (2018) have estimated that the budget required for peatland restoration in Indonesia exceeds USD4.6 billion. Meanwhile, Sasmito et al. (2023) have estimated that funding for mangrove restoration can surge to as much as US$9,000 per hectare. Additionally, for mangrove restoration, the land suitability map from Sasmito et al. (2023) indicates that merely about 193,367 hectares are suitable for restoration, which constitutes approximately 30% of the total targeted area.

Additionally, the Enhanced NDC and LTS-LCCR 2050 specifically aim for the improvement of water management in peatlands. The Enhanced NDC sets a goal to increase the water level up to 50 centimeters, to be implemented in palm oil plantations spanning 892,000 hectares and timber plantations covering 329,000 hectares under the CM1 scenario, and in the same area for palm oil and an expanded 548,000 hectares for timber under the CM2 scenario. Meanwhile, the LTS-LCCR 2050 under the CPOS scenario targets the improvement of water management across 0.86 million hectares by 2030 and 1.04 million hectares by 2050. The LCCP scenario aims for 0.95 million hectares by 2030 and the same target of 1.04 million hectares by 2050. These targets can be enabled through the implementation of advanced water table management practices to maintain optimal water levels in peatlands. A current challenge in realizing these goals is the inadequate understanding among local farmers about peatland dynamics and the critical importance of water management.

3.2.4 Reforestation and Land Rehabilitation

The reforestation strategy is outlined by the LCDI and Enhanced NDC. LCDI aims to scale up reforestation efforts to 250,000 hectares annually by 2030 in NZ 2045 and NZ 2050, and by 2050 in NZ 2060. The Enhanced NDC sets a more specific annual target of planting 320,000 hectares of timber, totaling 6.4 million hectares by 2030, under both CM1 and CM2 scenarios. Meanwhile, targets for land rehabilitation and restoration are outlined in the Enhanced NDC and LTS-LCCR 2050, with the Enhanced NDC aiming for an annual rehabilitation rate of 5.6 million hectares by 2030 for both scenarios. The LTS-LCCR 2050 sets a lower target for rehabilitating unproductive land by 2030, with 4.32 million hectares under the CPOS scenario and 5.3 million hectares under the LCCP scenario. Furthermore, the LTS-LCCR 2050 targets the restoration of production forests through the ENR program, aiming for 0.85 million hectares by 2030 and 1.4 million hectares by 2050 in the CPOS scenario, and 1.7 million hectares by 2030 and 8.8 million hectares by 2050 in the LCCP scenario.

Achieving reforestation and rehabilitation targets is supported by various factors. These include the enhancement of green financing through initiatives like BPDLH, REDD+, and green bonds, the implementation of carbon offsetting mechanisms, and seedling distribution programs to bolster tree planting efforts. Additionally, increasing community involvement through social forestry programs and providing technical assistance for social forestry and land rehabilitation play crucial roles. However, some gaps persist, such as the rollback of environmental protections under the new Omnibus Law, a lack of long-term monitoring and protection for reforested areas, which raises the risk of re-deforestation, and limited technical expertise in planning and implementing effective land rehabilitation strategies.

3.2.5 Sustainable Crop Production

Interventions for sustainable crop production vary widely. The LCDI aims to reduce land concessions to zero by the net-zero achievement years of 2045, 2050, and 2060, and targets 40% of cropland to be cultivated sustainably by

2050 across all scenarios. Both the Enhanced NDC and LTS-LCCR 2050 support programs for low-emission crops and organic fertilizer. The Enhanced NDC sets targets for low-emission cropland use at 902,000 hectares and 932,000 hectares in 2030 for CM1 and CM2, respectively, while the LTS-LCCR 2050 aims for the adoption of low-emission and water-saving paddy cultivation systems covering approximately 0.93 million hectares by 2030 and 1.96 million hectares by 2050 in CPOS, and 0.97 million hectares by 2030 and 2.7 million hectares by 2050 in LCCP. Additionally, the Enhanced NDC targets organic fertilizer application up to 1.29 million tons and 1.37 million tons in 2030 for CM1 and CM2, respectively, with the LTS-LCCR 2050 aiming to substitute urea with organic fertilizer, reducing urea use by 3,089 tons by 2030 and 58,513 tons by 2050 in CPOS, and by 5,374 tons by 2030 and 65,697 tons by 2050 in LCCP.

Beyond the two programs, the Enhanced NDC also set a water efficiency target of up to 2.58 million hectares and 3.38 million hectares in 2030 for CM1 and CM2 scenarios, respectively. Meanwhile, the LTS-LCCR 2050 sets additional targets for improving crop productivity and cropping intensity to 6.28 tons/ha in CPOS and 6.32 tons/ha in LCCP.

The path to achieving sustainable crop production is paved with innovative enablers that promise a greener future. The drive for bioenergy crop intensification and less land-intensive bioenergy, supported by integrated land-use planning, marks a pivotal shift in agricultural practices. Subsidies for low-emission crops and water-efficient irrigation systems, alongside robust organic fertilizer supply chains, reflect a commitment to sustainability that extends beyond mere cultivation techniques. These efforts, complemented by incentives for organic farming and sustainable commodity certification, showcase a holistic approach to agriculture that intertwines environmental stewardship with productivity.

However, this path is fraught with gaps that threaten to undermine these advancements. The economic allure of bioenergy crops, coupled with policy inconsistencies and uncertainties surrounding low-emission crop adoption, highlights the complexities of transitioning to sustainable practices. Barriers such as limited access to organic fertilizers and efficient irrigation technologies, particularly in underserved regions, amplify the difficulties faced by farmers. Moreover, the high costs associated with sustainable certification and persistent resistance to new farming methods underscore the need for enhanced support and education, ensuring that the vision of sustainable crop production does not remain an elusive goal but becomes a widespread reality.

3.2.6 Sustainable Livestock Management

The strategy for sustainable livestock management is only detailed in the Enhanced NDC and LTS-LCCR 2050 documents. It focuses on using livestock waste for biogas production and improving livestock feed supplements. The Enhanced NDC sets goals for using manure from 166,000 and 249,000 cattle for biogas by 2030 in CM1 and CM2 scenarios, respectively, while the LTS-LCCR 2050 aims for the utilization of waste from 41,000 heads by 2030 and 94,000 by 2050 for biogas. In terms of feed supplements, the Enhanced NDC plans to supply 6.9 million and 8.1 million ruminants by 2030 in CM1 and CM2, with the LTS-LCCR 2050 targeting feed improvement for 3.42 million heads by 2050 in CPOS and 6.58 million heads in LCCP.

Supporting these initiatives are enablers such as government backing for biogas digester installations on livestock farms and public-private partnerships for scalable biogas projects, alongside subsidy schemes for sustainable feed and supplements. However, obstacles remain, including high initial costs for farmers adopting biogas systems, limited market access for sustainable livestock waste products, a lack of farmer awareness about the benefits of feed supplements, and poor market availability for quality feed options. These challenges highlight the need for comprehensive support and education to ensure the success of sustainable livestock management practices.

3.2.7 Sectoral Conclusion

In regard to emission reduction, the targets are explicitly outlined only in the Enhanced NDC and LTS-LCCR 2050. The LCDI only stated the targets as proportions of the overall emission reduction mix (instead of in metric tons) for all sectors. When scrutinized against the 2030 terminal period in the Enhanced NDC, the LTS-LCCR 2050 emerges as notably more ambitious, aiming for a CO2-equivalent emission contribution of 263 MT under the CPOS scenario, in contrast to the 324 MT target of the Enhanced NDC's CM1 scenario. Remarkably, the LTS-LCCR 2050 even aspires to a negative emission contribution of -46 MT in its LCCP scenario, diverging significantly from the 93 MT target of the Enhanced NDC's CM2. Across these documents, a wide array of intervention strategies is proposed, with notable exceptions like the greening of urban landscapes, exclusive to the LCDI, and sustainable livestock management, solely addressed by the Enhanced NDC and LTS-LCCR 2050. The diversity extends to the specificity and ambition of programs within each strategy, where, despite thematic overlaps, one document might present more detailed and targeted programs than its counterparts.

Moving to the enablers and gaps, it is imperative for the government to fortify the regulatory environment, particularly in forestry, through strengthened moratoriums, including rigorous monitoring and evaluation mechanisms in their implementation. Collaborations with the private sector, incentive mechanisms, and technical assistance are crucial factors that the government must prepare to support the rest of the spectrum of strategies. Conversely, the current landscape of the sector is still marred by gaps and shortcomings, both within governmental and societal spheres. Weak regulatory enforcement, financing gaps, and the limited capacity of implementing actors to support sustainable programs stand out as critical challenges. Addressing these aspects is essential, echoing the need for a cohesive and supportive framework that spans strategic, institutional, and societal domains.

3.3 Waste Sector

The waste sector mitigation strategies are the simplest out of the other sectors' mitigation strategies. These strategies, outlined in documents such as NDC, LTS-LCCR 2050, and LCDI, can be condensed into three main approaches: municipal solid waste treatment, domestic wastewater treatment, and industrial waste treatment. Notably, both LTS-LCCR 2050 and NDC emphasize landfill management in their respective programs, reflecting a common focus. The emission reduction targets for the waste sector are relatively modest, with NDC aiming for a 1.4 to 1.5% reduction compared to BAU. This reflects the sector's limited mitigation potential, although its contribution to greenhouse gas emissions is relatively low compared to other sectors. Although the potential for reducing emissions from the waste sector is limited, waste management improvement could yield greater benefits. The Table 4 outlines the strategies, programs, enablers, and gaps for the waste sector in Indonesia.

3.3.1 Municipal Solid Waste Treatment

Landfill emission is the largest contributor to GHG emissions in the waste sector. Increasing the capacity of designing sanitary landfills becomes the central strategy for the waste sector. To increase the capacity, NDC requires MSW treatment facilities development: 762 unit waste bank, 2857 unit TPST (*Tempat Pengolahan Sampah Terpadu*), and 3018 unit TPS3R (*Tempat Pengolahan Sampah 3R*). LTS-LCCR 2050's main strategy for MSW is the development of waste-to-energy (WTE), which could be done simultaneously with landfill management. WTE is a process that involves the generation of energy from the combustion of waste materials. It is a form of renewable energy that can help mitigate the environmental impact of waste disposal. WTE requires the development of waste power plants or PLTSa (*Pembangkit Listrik Tenaga Sampah*) to convert landfill gas to electricity. Other forms of energy, such as Refuse-Derived Fuel (RDF), could also be converted from waste.

In comparison to NDC and LTS-LCCR 2050, LCDI emphasizes waste generation reduction more. LCDI targets waste generation reduction per capita by 70% from 2020 levels. LCDI's policy options require changes in consumer behavior to achieve the target. Consumer education on reducing food waste and substituting alternative protein food has become the main pillar of LCDI's policy. Another option to reduce waste generation is to reduce, reuse, and recycle the waste.

The three planning documents complement each other. MSW management improvement is required to support the development of the sanitary landfill and WTE facilities. If waste generation remains unmanaged, it will be difficult to realize the potential benefits of waste facilities. Most of Indonesia's waste sector works informally. Many scavengers and waste pickers highlight the need for formalization and integration into the waste management system (Arisman & Fatimah, 2023). With the formalization of the waste sector, efficient waste collection systems could be developed to ensure that waste is properly sorted and transported to the landfill. Reducing waste generation, as targeted by LCDI, will be difficult without improvement of the recycling rate. Development at the disposal site, the landfill, and WTE facilities also requires large investments. Collaborations with the private sector are necessary as well. The government must formulate proper incentives that will enhance the development of the waste sector.

3.3.2 Domestic Wastewater Treatment

Out of the three planning documents, LCDI does not address the mitigation of wastewater generated by households. Both LTS-LCCR 2050 and NDC have a main policy to increase the development of centralized or integrated wastewater treatment facilities. In contrast, the current wastewater treatment management in Indonesia is lacking. Only 5% of the population has access to a sewerage system, and only 1% of the households nationwide are connected to a centralized wastewater treatment. Improving household access in Indonesia to proper toilets with septic tanks is difficult enough, and it is more difficult to make wastewater treatment centralized (Janetasari & Bokányi, 2022). The target of 36% of urban households utilizing centralized WWT under LCCP is very optimistic. NDC does not specify the targets of centralized WWT. The centralization of WWT may have the advantage of advanced treatment technologies, improving the overall quality of treated wastewater and minimizing environmental impact (Wulan et al., 2022). The technology used typically involved aerobic systems and biogas utilization.

The low-emission technologies for WWT may also be implemented individually. Increasing households' access to low-emission technologies could also be implemented concurrently with the government's policy of improving people's access to toilets. The current low-emission technologies are septic tanks with biogas recovery and aerobic systems.

Similar to the development of MSW facilities, centralized or non-centralized WWT needs sufficient financing. At the household level, they have no incentives to change their WWT to advanced WWT technologies to reduce GHG emissions. For households without a proper toilet, government support will be required to install proper toilets with advanced WWT technologies. Neither NDC nor LTS-LCCR 2050 have addressed the financing constraint.

3.3.3 Industrial Waste Treatment

The treatment strategies for industrial waste are similar to municipal waste. All three planning documents have similar strategies for industrial waste consisting of the development of waste-to-energy (WTE) and wastewater industrial treatment facilities. A particular highlight of industrial waste policy is the utilization of POME (Palm Oil Mill Effluent) for electricity generation, which is a part of NDC's mitigation policy. This strategic support encourages investment in cleaner energy alternatives, contributing to a more sustainable and diversified energy mix. Furthermore, the implementation of methane capture and utilization, particularly through biogas technology, underscores a commitment to harnessing renewable resources. By capturing methane emissions from organic waste, such as agricultural and industrial byproducts, and converting them into biogas, this initiative not only mitigates greenhouse gas emissions but also capitalizes on a valuable energy source (Rishanty et al., 2021; Anyaoha & Zhang, 2022).

LCDI has a simpler policy, that is, the industrial wastewater recycling rate increases to 100% by net-zero year. Because industrial waste typically involves B3 wastes (Hazardous and Toxic Materials), the capacity to process B3 needs to increase. Based on LCDI, B3 waste processing

Table 4. Analysis of Strategies in the Waste Management Sector

No	Strategy/Intervention	Program + Targets	Emission Target	Enabler	Gap
1	Municipal Solid Waste Treatment	**Enhanced NDC**	Emission Level:	- TPA Conversion program from open dumping TPA into a sanitary landfill.	- LFG recovery projects and sanitary landfill development requires large amount of land, which are difficult to obtain near highly populated urban areas
		CM1 & CM2: Utilising 45 MW of power from landfill gas (LFG); Composting 3.7 million tonnes of waste; and using waste-to-energy facilities with 4.6 million tonnes of waste treated	**Enhanced NDC**	- Technological assistance and funding systems to increase the number of household channel networks for the utilization of landfill gas.	- The LFG projects require collaboration with private sector. Developing incentive mechanisms, such as feed-in tariffs or tax credits, can encourage businesses and municipalities to invest in LFG recovery projects by making them financially attractive
		LCDI	2030	- MSW treatment facilities development: 762 unit waste bank, 2857 unit TPST, and 3018 unit TPS3R	- Lack of waste segregation (organic and non-organic) practices makes composting inefficient.
		Across scenarios, reduce waste generation per capita by 70% from 2020 levels by net-zero target year	BAU: Emission level 296 $MTCO_2eq$	- Utilisation of municipal waste by converting to energy through Refuse-Derived Fuel (RDF) or as renewable energy source in PLTSa.	- Limited infrastructure for recycling. The informal recycling sector plays a crucial role to fulfill the recycling rate.
		LTS-LCCR 2050	CM1: Emission level 256 $MTCO_2eq$ (1.4% reduction from BAU)		- EPR implementation is not optimal
		CPOS : The level of GHG emissions from MSW treatments in 2050 is expected to be 65.3 Mton CO2	CM2: Emission level 253 $MTCO_2eq$ (1.5% reduction from BAU)		- Zoning regulations and land-use planning need to accommodate the development of waste-to-energy projects while addressing environmental and social considerations.
		TRNS : The level of GHG emissions from MSW treatments in 2050 is expected to be 52.1 Mton CO2	**LTS-LCCR 2050**		- Diverse technology and infrastructure in across cities creates variability in collection rate and treatment technology.
		LCCP: The level of GHG emissions from MSW treatments in 2050 is expected to be 32.2 Mton CO_2.	*2030*		
2	Domestic Wastewater Treatment	**Enhanced NDC**	- CPOS: 198 MTon CO_2-eq	- Centralised or Integrated IPAL/Instalasi Pengelolaan Air Limbah/waste water treatment plant at the city/communal/region scale operated using aerobic system	- Establishing large-scale IPAL facilities requires significant infrastructure development.
		CM1 & CM2: Developing integrated/centralized wastewater treatment plant (WWTP) and biogas utilisation	- TRNS: 198 MTon CO_2-eq	- IPLT (*Instalasi Pengolahan Lumpur Tinja*) to treat sludge removal from septic system. This process includes utilisation of biodigester and biogas generation.	- The current policy and regulation of wastewater management do not support the option of Wastewater Recovery
		LTS-LCCR 2050	- LCCP: 198 MTon CO_2-eq		- Lack of access to sewarage system. Only 5% of the population has access to sewerage system. Only 1% of the households nationwide are connected to a centralised wastewater treatment

... continued

Table 4. Analysis of Strategies in the Waste Management Sector

No	Strategy/Intervention	Program + Targets	Emission Target	Enabler	Gap
		CPOS : septic tank development with biogas recovery and sludge removal; implementation of aerobic system. TRNS : Centralised aerobic system will be utilized by 14% of people living in urban area by 2050. LCCP: Centralised aerobic system will be utilized by 36% of people living in urban area by 2050.	*2040* - CPOS: 250 MTon CO_2-eq - TRNS: 218 MTon CO_2-eq		- Centralised wastewater treatment operates only in big cities and consists of only two stages (primary/physical and secondary/biological).
3	Industrial Waste Treatment	**Enhanced NDC** CM1 & CM2: WWTP industrial utilisation; Composting industrial waste; Waste-to-energy facilities **LCDI** 100% of industrial wastewater recycled by the net-zero target year **LTS-LCCR 2050** CPOS : Waste treatment for palm oil, pulp paper, vegetable-fruit-juice, organic chemicals, and vegetable oil industries. TRNS : Waste-to-energy implementation for significant emissions contributor industries. LCCP: Waste-to-energy implementation for significant emissions contributor industries.	- LCCP: 175 MT on CO_2-eq *2050* - CPOS: 272 MTon CO_2-eq - TRNS: 223 MTon CO_2-eq - LCCP: 120 MTon CO_2-eq Emission Reduction: **LCDI*** *2040* - NZ 2050: 163 MT on CO_2-eq *2050* - NZ 2050: 375 MT on CO_2-eq *2060* - NZ 2050: 488 MT on CO_2-eq	- The improvement of regulations regarding the utilization of industrial wastewater treatment plant by eliminating the requirement for water content in IPAL sludge. - Supporting conducive power purchase agreements to encourage the development of PLTSa and POME for electricity generation - Implementation of methane capture and utilisation (biogas)	- Waste as an energy source for electricity has highest cost (LCOE) compared to other renewable energy. - Currently, most palm oil companies are located in rural area and outside Java Island. High transportation cost calls for local supply chain development - to compete with oil-fired plants, POME Biogas requires investment grants and tax exemption in the early stages of the construction - BioCNG for POME installation construction technology in Indonesia still relies more on imported components.

Note: *The emission reduction values are approximations derived from a graphical representation in the LCDI. These values may not precisely reflect the official targets.

capability is projected to reach 26,880 tonnes annually by 2024, accumulating a total of 539.8 million tonnes of waste.

Financial constraints are also the gap that needs to be filled for industrial waste treatment. POME Biogas, as a renewable energy source, needs financial support in the form of investment grants and tax exemption, especially during the initial stages of construction. Compared to coal power plants, suggesting that to make POME Biogas economically competitive, financial incentives are crucial, at least in the early phases of the project. The three planning documents have not addressed this gap.

3.3.4 Sectoral Conclusion

The emission targets for the waste sector in each document differ, with the least ambitious target being the ENDC CM1 target emission level of 256 MTCO2-eq and the most ambitious target being the LCCP scenario of 198 MTCO2-eq. Out of the three documents, LCDI does not thoroughly specify the program for waste sector emission reduction. The LCDI program only consists of waste generation reduction. More detailed mitigation programs for the waste sector are explained in LTS-LCCR 2050 and ENDC. ENDC even outlines further the adoption of technology, such as the waste-to-energy program. ENDC explains biogas and POME utilization, which are not explained in LTS-LCCR 2050. Therefore, the mitigation programs in ENDC and LTS-LCCR 2050 are similar, except that ENDC provides greater detail on the mitigation technology.

Overall, the three documents complement each other, with LCDI focusing on the waste generation side while ENDC and LTS-LCCR 2050 focus more on the waste management side. However, the three documents have not addressed the gaps in achieving both the program and emission targets thoroughly. The waste management programs require large infrastructure projects and, in turn, high financing needs. The current issues of informality in the waste sector in Indonesia have become significant challenges. Effective waste management in Indonesia necessitates coordinated efforts across various sectors, including government, private industry, and civil society. Addressing financial gaps, promoting technological innovation, and incentivizing sustainable practices are crucial steps towards achieving environmental sustainability and reducing greenhouse gas emissions in the waste sector. Collaboration and robust policy frameworks that integrate the goals outlined in NDC, LTS-LCCR 2050, and LCDI will be essential for realizing these objectives and fostering a cleaner, more resilient future.

3.4 Industrial Processes and Product Use (IPPU) Sector

Indonesia considered eight priority industries related to the GHG emission intensives, namely cement, metal (iron and steel), pulp paper, ammonium fertilizer, petrochemicals, ceramics, textile and textile products, and food and beverage. Among those industries, cement, basic chemicals (ammonia fertilizer, nitric acid, other petrochemicals), iron and steel making, and metal smelters (nickel, gold, aluminum, and bauxite) are considered as IPPU and energy's GHG emissions intensives. Strategies to reduce carbon emissions from the IPPU sector essentially stem from the activity of increasing the efficiency of production. Generally, strategies outlined to mitigate the emission increase in the IPPU sector target the energy efficiency production rate for cement, nitric acid, ammonia, and iron and steel products. Though the level of emission reduction is varied across documents, the strategies outlined are similar. Specifically, strategies to mitigate emissions in the IPPU sector are materialized in the form of new plant development or technological improvement to enhance the efficiency of energy used to produce industrial products.

3.4.1 Efficiency in the Cement Industry through Blended Cement

The GHG emissions from the cement industry were affected by the clinker-to-cement ratio. The clinker-to-cement ratio was 0.81 in 2010, and the GHG emissions from cement production were 0.445 tons of CO2 per ton of cementitious, while the clinker-to-cement ratio was 0.75, and from cement production, it was 0.419 tons of CO2 per ton cementitious. Efficiency in cement production is to be achieved by reducing the clinker-to-cement ratio. In the enhanced NDC document, the target for blended cement ranges from 70% up to 65% of the clinker-to-cement ratio by 2030. This is to be achieved by increasing the portion of alternative material used to reduce clinker use. The effort is being supported through an enabler, which is the green standard for the cement industry, which requires the industry to reach a clinker-to-cement ratio of 65%. Though less ambitious, LCDI and LTS-LCCR 2050 also aim to reduce the clinker-cement ratio as a target to increase efficiency in the cement industry. LCDI targets 75% of the clinker-to-cement ratio in 2030, while LTS-LCCR 2050 sets the target of 70% of the clinker-to-cement ratio by 2050. Other enablers that accelerate the efficiency improvement in the cement sector are specified in LCDI, including developing new chemistries (e.g., alternatives to limestone, the raw material for clinkers), importing clinker for domestic cement production, and CCUS to capture process emissions from heating limestone. However, improvement efficiency in the cement industry might face a substantial challenge as there is a growing issue of overcapacity in the cement sector. Thus, the potential investment in new plants and capacity improvement by applying more advanced technology and increasing efficiency might be limited.

3.4.2 Efficiency Improvement in Ammonia Production

Similar to efficiency improvement in the cement industry, ammonia production is an integral part of the climate transition strategy in the IPPU sector. In enhanced NDC, the implementation of mitigation actions is set to reduce GHG emissions from ammonia plants by 4.65 Mton CO2 in 2030. Several strategies of mitigation actions include the development of new ammonia plants and ammonia plant revitalization to reduce natural gas consumption intensity, revamping of ammonia plants to increase plant efficiency and reduce IPPU emission, and CO2 utilization as feedstock for Na2CO3 production. In addition, LTS-LCCR 2050 documents also lay out the plant for ammonia production efficiency through the use of advanced and efficient technology with natural gas consumption at a rate of 35 GJ per ton of NH3 in 2050. The effort to improve gas consumption in ammonia production is quite feasible from a technological

Table 5. Analysis of Strategies in the Industrial Processes and Product Use (IPPU) Sector

No	Strategy/Intervention	Program + Targets	Emission Target	Enabler	Gap
1	Efficiency in cement sector through blended cement	**Enhanced NDC** BAU: 80% clinker-to-cement ratio in 2030 CM1: 70% clinker-to-cement ratio in 2030 CM2: 65% clinker-to-cement ratio in 2030 **LCDI** 75% clinker-to-cement ratio in 2030 **LTS-LCCR 2050** CPOS: 75% clinker-to-cement ratio in 2050 TRNS: 75% clinker-to-cement ratio in 2050 LCCP: 70% clinker-to-cement ratio in 2050	**Enhanced NDC** *2030* BAU: Emission level 69.6 $MTCO_2eq$ CM1: Emission level 63 $MTCO_2eq$ (0.2% reduction from BAU) CM2: Emission level 61 $MTCO_2eq$ (0.3% reduction from BAU) **LTS-LCCR 2050** *2050* - CPOS: 70 MTon CO_2-eq - TRNS: 66 MTon CO_2-eq - LCCP: 50.2 MTon CO_2-eq	- Green Industry Standard for Cement Industry require industry to reach clinker to cement ratio of 65%. - Developing new chemistries (e.g. alternatives to limestone, the raw material for clinkers) - Importing clinker for domestic cement production	- There is an issue of overcapacity in the cement sector
2	Efficiency improvement in ammonia production	**Enhanced NDC** BAU: - CM1: Construction of 3 new ammonia plants to replace old plants (specific natural gas consumption decreases from 45 to 40 GJ/ton NH3 in 2030), Revamping of several ammonia plants, CO_2 utilisation as feedstock for Na2CO3 production CM2: Further ammonia plant improvement, with specific natural gas consumption 35 GJ/ton NH3 in 2030, Additional revamping of several ammonia plants, Further enhancement of CO_2 utilisation as feedstock for Na2CO3 production **LCDI** feedstock utilization and CO_2 recovery **LTS-LCCR 2050** CPOS: 38% of national ammonia production using advanced technology with natural gas consumption at a rate of 40 GJ per ton NH3 in 2050	***Emission Reduction:*** **LCDI*** *2040* - NZ 2050: 75 MT on CO_2-eq *2050* - NZ 2050: 125 MT on CO_2-eq *2060* - NZ 2050: 113 MT on CO_2-eq	- Some of ammonia plants in Indonesia are having 33-35 GJ/ton NH3	- Technological improvement in ammonia plants require massive investment

Note: *The emission reduction values are approximations derived from a graphical representation in the LCDI. These values may not precisely reflect the official targets.

... continued

Table 5. Analysis of Strategies in the Industrial Processes and Product Use (IPPU) Sector

No	Strategy/Intervention	Program + Targets	Emission Target	Enabler	Gap
		TRNS: Additional of ammonia production using advanced and efficient technology with natural gas consumption at a rate of 40 GJ per ton NH3 in 2050 LCCP: Increasing ammonia production using advanced and efficient technology with natural gas consumption at a rate of 35 GJ per ton NH3 in 2050			
3	Efficiency improvement in aluminium, iron and steel industry	Enhanced NDC BAU: - CM1: Improvement of smelter processes and scrap utilisation and Maintain improved plants operation (automation of feeding system / hardware improvement from CWPB to bar-brake tech). CM2: Further mitigation activities in process improvement of smelter and scrap utilisation **LCDI** Reusing scrap metal (as opposed to iron ore), eliminating need for the coal-dependent processes (coking, sintering and blast furnace) to produce pig iron **LTS-LCCR 2050** CPOS: - TRNS: Using of improved (advanced) processing technology for aluminium production and utilization of scrap up to 10% as raw material in iron and steel industries LCCP: Using of improved (advanced) processing technology for aluminium production and scrap utilization up to 20% as raw material in iron and steel industries but it is limited by the availability of the scrap materials.		- There are many old plants with short remaining production lifetime	- Current low utilization of domestic iron and steel industry - Massive competition from imported products, reducing financial capacity to adopt higher technology - Increased cost heavily impacted other industries as it has high linkage towards the whole economy
4	Efficiency in nitric acid industry	**Enhanced NDC** BAU: -			- Technological improvement require massive investment

... continued

Table 5. Analysis of Strategies in the Industrial Processes and Product Use (IPPU) Sector

No	Strategy/Intervention	Program + Targets	Emission Target	Enabler	Gap
		CM1:Technology improvement (with EF 8 - 9 Kg N2O/ton HNO3) and installation non-selective catalyst reduction (NSCR) for N2O destruction (EF 2.5 Kg N2O/ton HNO3) CM2: Additional Installation of catalyst for N2O destruction **LCDI** Increase efficiency of N2O product use as a propellant in aerosol products (e.g. pressure-packed whipped cream) **LTS-LCCR 2050** CPOS: - TRNS: Increasing usage of secondary catalyst for N2O digestion/destruction in nitric acid production industry LCCP: Increasing the use of secondary catalyst for N2O digestion/destruction in nitric acid production industry			

perspective. The current world BPT (best practice technology) has a natural gas consumption rate of 32 GJ/ton NH3 while the European best available technology (BAT) has 31.8 GJ/ton NH3, the world BAT has 28 GJ/ton NH3 (IEA, 2015). Furthermore, the replacement of three old plants in Indonesia with new ones was carried out from 2015 to 2020, and some of the ammonia plants in Indonesia already have 33-35 GJ/ton NH3 efficiency. Despite the feasibility of the technology, financing issue remains a challenge in the context of ammonia production efficiency improvement. Renewing ammonia production plants with improved technology requires massive investment, and there is no incentive mechanism that makes investment to improve ammonia production efficiency rather attractive for investors.

3.4.3 Efficiency Improvement in Aluminium, Iron and Steel Industry

Metal productions, including aluminum, iron, and steel, contribute to the progress of IPPU in the context of energy transition. Various strategies are outlined to increase the energy efficiency of the metal production process. In enhancing NDC, mitigation actions include maintaining improved plant operation by automating feeding systems and hardware improvement for the aluminum industry and improving smelter processes and scrap utilization for the iron and steel industry. It is targeted to reduce around 0.3 Mton CO2 from these industries by 2030 in NDC planning. Furthermore, LCDI highlights the strategy of reusing scrap metal (as opposed to iron ore) and eliminating the need for coal-dependent processes (coking, sintering, and blast furnace) to produce pig iron. LTS-LCCR 2050 combines both the approach in NDC and LCDI by improving technology use and material reuse. In LTS-LCCR 2050, the TRNS scenario specifies the strategy of using improved (advanced) processing technology for aluminum production and utilization of scrap up to 10% as raw material in the iron and steel industries. Meanwhile, the CPOS scenario suggests the use of improved (advanced) processing technology for aluminum production and scrap utilization of up to 20% as raw material in the iron and steel industries, but it is limited by the availability of the scrap materials. One potential enabler to accelerate technological improvement and energy efficiency improvement in the metal industry is that current old plants have short remaining production lifetimes. This opens up the opportunity to renew and revitalize the production plants for aluminum, iron, and steel. However, there are several challenges from a financing standpoint to increase investment in the industry. The current low utilization of the domestic iron and steel industry and massive competition from imported products are reducing the financial capacity to adopt higher technology. In addition, increased costs from investment needed to renew production plants will heavily impact other industries as they are highly linked to the whole economy. Without adequate incentives, efforts to improve energy efficiency in this sector might cause greenflation and be relatively unattractive for investors.

3.4.4 Efficiency in Nitric Acid Industry

The profile of Indonesian nitric acid industries shows a significant increase in production capacity, with two additional new plants in 2012 and one plant in 2022. In line with this increase in production capacities, N2O emissions from nitric acid production also increased. These new plants use more efficient technology with a GHG emissions factor (EF) of about 8 to 9 Kg N2O per ton HNO3, compared to the first production plants (1990's technology) with the EF of 10-19 Kg N2O per ton HNO3. In the enhanced NDC document, the mitigation actions include technology improvement and installation of non-selective catalyst reduction for N2O destruction. With this mitigation technology, the EF decreased to 2.5 Kg N2O per ton HNO3. Another selective catalytic process, e.g., secondary catalyst reduction (SCR), will also be applied as secondary mitigation for the N2O emissions destruction in nitric acids productions in 2022, with the EF decreased to 2.5 Kg N2O per ton HNO3. While there is currently no substantial enabler for efficiency improvement in the nitric acid industry, the main challenge comes from the investment needs. Installation of N2O emission destruction is a high cost and might potentially cause the deployment for future mitigation to be relatively small.

3.4.5 Sectoral Conclusion

In terms of emission reduction targets, Enhanced NDC is the most aggressive planning document, with a target emission of 61 MTCO2eq in 2030. However, Enhanced NDC only projects emission reduction until 2030, while LTS-LCCR 2050 projects further until 2050. In 2030, emission projection from IPPU in LTS-LCCR 2050 is above Enhanced NDC, although in 2050, IPPU is estimated to reach 50.2 MTCO2eq in LTS-LCCR 2050. The subsectors' coverage within IPPU across documents is relatively similar, including cement, metal, ammonium, and nitric acid industries. In addition, the mitigation actions in each subsector to reduce emissions across documents are relatively similar. For instance, Enhanced NDC, LTS-LCCR 2050, and LCDI target the ratio of clinker-to-cement for the cement industry as a strategy for emission reduction in cement production. Efficiency improvement and development of new plants for the ammonia and metal industry also serve as a shared strategy across all documents, although with varying degrees of target.

Due to the main strategies formulated for IPPU in all documents revolving around efficiency improvement through the development of new plantations and/or technological improvement, the persisting gap across all strategies is the need for massive financing. In addition, technological upgrades and utilization improvement also serve as other main gaps for IPPU. In terms of enablers, several old plants with short remaining lifetimes could ease the transition towards developing new plants (especially for the metal sector). On the other hand, several ammonia plants in Indonesia are already efficient in reducing emissions, and technological improvement could be resolved by technological import and transfer of knowledge. However, this requires commitment from the Government, business sector, and financiers. Unlike other sectors that face the issue of market distortion due to their nature of being semi-public goods (such as water or waste), subsectors in IPPU are considered as 'private' goods and might relatively need less innovative financing.

4. Conclusion

This policy paper provides an in-depth analysis of the strategies and policies outlined in Indonesia's primary planning documents for low-carbon development: the Enhanced Nationally Determined Contribution (NDC), the Long-Term Strategy for Low Carbon and Climate Resilience (LTS-LCCR 2050), and the Low Carbon Development Initiative (LCDI). A focused evaluation of the Roadmap of Net Zero Emissions (NZE) Energy was also undertaken, given its critical examination of the energy sector, a significant contributor to emissions. By dissecting the enabling environment and identifying gaps within each strategy, this paper aims to inform policymakers and the public about the synthesis of these planning documents and to establish a foundational framework for further modeling exercises on Indonesia's green economy trajectory and decarbonization policy development.

While all three planning documents elaborate long-term plans for Indonesia's journey toward reducing its carbon footprint, they encompass divergent approaches, targets, and commitment periods, leading to varied strategies and programs. The NDC and LTS-LCCR 2050 primarily represent Indonesia's commitments to the international community under the UNFCCC. However, Bappenas, as the main pillar of Indonesia's development planning, places greater emphasis on the LCDI in preparing Indonesia's RPJMN. RPJMN presents a more workable document since it becomes the reference of the Annual Government Work Plan (Rencana Kerja Pemerintah/RKP), which further translates to the government budget. The differences among these documents could potentially send mixed signals, affecting planning and budgeting, especially crucial up to the end of the Paris Agreement period in 2030, after which the discrepancies can be re-evaluated. One of the government's efforts that will be implemented in the near future includes creating the 2nd NDC, updating the LTS-LCCR 2050, and revising the National Energy Plan (*Kebijakan Energi Nasional*/KEN) and National Energy General Plan (*Rencana Umum Energi Nasional*/RUEN) to better align our climate targets, adapting to the next RPJMN 2025–2029 and RPJPN 2025–2045.

To ensure cohesive and effective climate action, it is imperative for the Indonesian government to unify its approach by creating a dynamic, iterative planning document. This document should be continuously updated to ensure the convergence of all planning efforts, thereby enhancing the effectiveness of Indonesia's climate actions.

Acknowledgment

This project was made possible through financial support provided by the Sequoia Climate Foundation through the Center for Global Sustainability University of Maryland (CGS UMD).

We extend our appreciation to Nathan Hultman, Jiehong Lou, and Ryna Yiyun Cui from CGS UMD for their invaluable insights and constructive feedback. We also offer special thanks to Eka Chandra Buana, Director of Macro Planning and Statistical Analysis, Ministry of National Development Planning of the Republic of Indonesia for his input and support for this policy paper.

References

Alonso, A., Brook, B. W., Meneley, D. A., Misak, J., Blees, T., & van Erp, J. B. (2015). Why nuclear energy is essential to reduce anthropogenic greenhouse gas emission rates. *EPJ Nuclear Sciences & Technologies, 1*, 3. doi: https://doi.org/10.1051/epjn/e2015-50027-y.

Anyaoha, K. E., & Zhang, L. (2022). Transition from fossil-fuel to renewable-energy-based smallholder bioeconomy: Techno-economic analyses of two oil palm production systems. *Chemical Engineering Journal Advances, 10*, 100270. doi: https://doi.org/10.1016/j.ceja.2022.100270.

Arinaldo, D., & Adiatma, J. C. (2019). *Indonesia's coal dynamics: Toward-a just energy transition*. Institute for Essential Services Reform. https://www.climate-transparency.org/wp-content/uploads/2019/04/IESR-Coal-Transition-lowres.pdf.

Arisman, & Fatimah, Y. A. (2023). Waste management in Indonesia: Strategies and implementation of Sustainable Development Goals (SDGs) and circular economy. In: Ghosh, S. K., & Ghosh, S. K. (eds), *Circular Economy adoption: Catalysing decarbonisation through policy instruments* (pp. 131-157), Springer Nature Singapore. doi: https://doi.org/10.1007/978-981-99-4803-1˙5.

Bhutto, M. Y., Liu, X., Soomro, Y. A., Ertz, M., & Baeshen, Y. (2020). Adoption of energy-efficient home appliances: Extending the theory of planned behavior. *Sustainability, 13*(1), 250. doi: https://doi.org/10.3390/su13010250.

Burke, P. J., Widnyana, J., Anjum, Z., Aisbett, E., Resosudarmo, B., & Baldwin, K. G. (2019). Overcoming barriers to solar and wind energy adoption in two Asian giants: India and Indonesia. *Energy Policy, 132*, 1216-1228. doi: https://doi.org/10.1016/j.enpol.2019.05.055.

Cho, I., Oh, S., Kim, S., Ardin, F., & Heo, E. (2021). Determinants of nuclear power expansion in Indonesia. *Nuclear Engineering and Technology, 53*(1), 314-321. doi: https://doi.org/10.1016/j.net.2020.06.008.

CNN Indonesia. (2023, 12 Oktober). *Jawab tantangan transisi energi, PLN sukses produksi hidrogen hijau*. https://www.cnnindonesia.com/ekonomi/20231012100332-625-1010210/jawab-tantangan-transisi-energi-pln-sukses-produksi-hidrogen-hijau.

Cui, R., Tumiwa, F., Zhao, A., Arinaldo, D., Wiranegara, R., Cui, D., ... & Hultman, N. (2022). *Financing Indonesia's coal phase-out: A just and accelerated retirement pathway to net-zero*. Center for Global Sustainability at the University of Maryland - Institute for Essential Services Reform. https://iesr.or.id/wp-content/uploads/2022/06/UMD-IESR-IndonesiaCoalPhaseout-3August2022-1.pdf.

Ditjen EBTKE. (2022, 7 Agustus). Kolaborasi Pemerintah Pusat, DPR, Pemda dalam pembangunan lampu surya untuk jalan umum di Kabupaten Lamongan dan Gresik. Direktorat Jenderal Energi Baru Terbarukkan Dan Konservasi Energi - Kementerian Energi dan Sumber Daya Mineral. https://ebtke.esdm.go.id/post/2022/08/07/3224/kolaborasi.pemerintah.pusat.dpr.pemda.dalam.pembangunan.lampu.surya.untuk.jalan.umum.di.kabupaten.lamongan.dan.gresik.

Gao, X., Davidson, M., Busby, J., Shearer, C., & Eisenman, J. (2021). The challenges of coal phaseout: coal plant development and foreign finance in Indonesia and Vietnam. *Global Environmental Politics, 21*(4), 110-133. doi: https://doi.org/10.1162/glep˙a˙00630.

Hansson, A., & Dargusch, P. (2018). An estimate of the financial cost of peatland restoration in Indonesia. *Case Studies in the Environment, 2*(1), 1-8. doi: https://doi.org/10.1525/cse.2017.000695.

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N.,

... & Witkamp, B. (2018). A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D: Transport and Environment, 62*, 508-523. doi: https://doi.org/10.1016/j.trd.2018.04.002.

IESR. (2023). *A 2023's update on the levelized cost of electricity and levelized cost of storage in Indonesia*. nstitute for Essential Services Reform. https://iesr.or.id/en/pustaka/making-energy-transition-succeed-a-2023s-update-on-the-levelized-cost-of-electricity-lcoe-and-levelized-cost-of-storage-lcos/.

IESR. (2023b). *Indonesia electric vehicle outlook 2023: Electrifying transport sector: Tracking Indonesia EV industries and ecosystem readiness*. Institute for Essential Services Reform. https://iesr.or.id/wp-content/uploads/2023/02/Indonesia-Electric-Vehicle-Outlook-2023.pdf.

Janetasari, S. A., & Bokányi, L. (2022). Challenges on creation of sustainable municipal waste and wastewater management in Indonesia using experience of Hungary. *IOP Conference Series: Earth and Environmental Science, 1017*, 012028. doi: 10.1088/1755-1315/1017/1/012028.

Kontan. (2023, 16 Oktober). *Pengembangan jargas hadapi tantangan keekonomian dan konsumsi minim*. https://industri.kontan.co.id/news/pengembangan-jargas-hadapi-tantangan-keekonomian-dan-konsumsi-minim.

Kraxner, F., Fuss, S., Leduc, S., Yowargana, P., Kindermann, G., Pietsch, S., & Hetland, J. (2015). Driving clean energy and green economy with the help of forest-based bioenergy with CCS (BECCS)-A case study on Indonesia. *Congress paper*. XIV World Forestry Congress, Durban, South Africa, 7-11 September 2015. https://foris.fao.org/wfc2015/api/file/5547ee1615ae74130aee6aca/contents/aaffd844-ebc7-4088-811b-aa627b40fdbb.pdf.

Lestari, G. (2017). *Kontribusi program konservasi energi dalam upaya mitigasi gas rumah kaca nasional*. Pojok Iklim. http://pojokiklim.menlhk.go.id/read/kontribusi-program-konservasi-energi-dalam-upaya-mitigasi-gas-rumah-kaca-nasional.

Maghfiroh, M. F. N., Pandyaswargo, A. H., & Onoda, H. (2021). Current readiness status of electric vehicles in indonesia: Multistakeholder perceptions. *Sustainability, 13*(23), 13177. doi: https://doi.org/10.3390/su132313177.

Mashhoodi, B., & van der Blij, N. (2021). Drivers' range anxiety and cost of new EV chargers in Amsterdam: a scenario-based optimization approach. *Annals of GIS, 27*(1), 87-98. doi: https://doi.org/10.1080/19475683.2020.1848921.

MENTARI. (2022). *New paradigm thematic paper - renewable energy procurement in Indonesia*. MENTARI (Menuju Transisi Energi Rendah Karbon Indonesia). doi: https://mentari.info/id/2022/04/08/pengadaan-energi-terbarukan-di-indonesia/.

Ordonez, J. A., Jakob, M., Steckel, J. C., & Fünfgeld, A. (2021). Coal, power and coal-powered politics in Indonesia. *Environmental Science and Policy, 123*, 44-57. doi: https://doi.org/10.1016/j.envsci.2021.05.007.

Rishanty, A., Sambodo, M. T., Silalahi, M., & Hambali, E. (2021). Zero-waste bioenergy to lower energy transition risks in Indonesia. *Working Paper, WP/17/2021*. Bank Indonesia. https://publication-bi.org/repec/idn/wpaper/WP172021.pdf.

Sasmito, S. D., Basyuni, M., Kridalaksana, A., Saragi-Sasmito, M. F., Lovelock, C. E., & Murdiyarso, D. (2023). Challenges and opportunities for achieving Sustainable Development Goals through restoration of Indonesia's mangroves. *Nature Ecology & Evolution, 7*(1), 62-70. doi: https://doi.org/10.1038/s41559-022-01926-5.

Sugiawan, Y., & Managi, S. (2019). Public acceptance of nuclear power plants in Indonesia: Portraying the role of a multilevel governance system. *Energy Strategy Reviews, 26*, 100427. doi: https://doi.org/10.1016/j.esr.2019.100427.

Wauran, M. (2022, 6 Juni). *Tantangan pembangunan PLTN di Indonesia*. Media Indonesia https://mediaindonesia.com/opini/497372/tantangan-pembangunan-pltn-di-indonesia.

Wulan, D. R., Hamidah, U., Komarulzaman, A., Rosmalina, R. T., & Sintawardani, N. (2022). Domestic wastewater in Indonesia: Generation, characteristics and treatment. *Environmental Science and Pollution Research International, 29*(22), 32397-32414. doi: https://doi.org/10.1007/s11356-022-19057-6.

Gedung LPEM FEB UI
Jl. Salemba Raya No. 4, Jakarta 10430
Phone : +62-21 3143177 ext. 621/623;
Fax : +62-21 3907235/31934310
Web : http://www.lpem.org/category/publikasi/workingppers/

9 772356 400001