Contribution of the AFOLU sector to Indonesia's long-term strategy for low carbon and climate resilience 2050 (LTS-LCCR 2050)

Tarigan Elieser[1*] , *Fitri Dwi* Kartikasari[2], *Fenny* Irawati[3]

[1]Electrical Engineering Department, and Center for Environmental and Renewable Energy Studies (PuSLET), University of Surabaya, Jl. Raya Kalirungkut, Indonesia.
[2]Informatics Engineering Dept., University of Surabaya, Jl. Raya Kalirungkut, Indonesia
[3]Biotechnology Faculty, University of Surabaya, Jl. Raya Kalirungkut, Indonesia

Abstract. The Agriculture, Forestry, and Other Land Use (AFOLU) sector is central to Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050), particularly in reducing greenhouse gas (GHG) emissions and enhancing climate resilience. This study evaluates the sector's contribution through a combination of policy document review, secondary data analysis, and comparative benchmarking. Historical GHG data from 1990 to 2022 and projections to 2050 were analyzed using Indonesia's National GHG Inventory, the Climate Transparency Report, and World Bank datasets. Results indicate that in 2022, the sector accounted for approximately 55% of national emissions, with forestry and land-use change as primary sources. Under LTS-LCCR 2050, the sector targets a net sink status by 2030 via reduced deforestation, peatland restoration, sustainable agriculture, and improved land governance. Persistent challenges include enforcement limitations, financing gaps, and competing land demands. The study concludes that achieving net-zero emissions by 2060 or earlier will require stronger policy coherence, increased investment in low-emission agricultural practices, and adaptive land management to fully realize the AFOLU sector's potential in supporting Indonesia's low-carbon and climate-resilient development goals.

1 Introduction

In an era marked by surging climate-related crises, building resilience has become a fundamental global priority. Between 1993 and 2022, more than 765,000 lives were lost and approximately USD 4.2 trillion in direct economic losses were recorded due to over 9,400 extreme weather events, underscoring the urgent need for resilient systems and policies [1] Yet, as the UNEP Adaptation Gap Report 2023 notes, annual adaptation finance for developing countries remains critically insufficient at USD 21.3 billion, while the actual

* Corresponding author: elieser@staff.ubaya.ac.id

need is estimated between USD 215 and 387 billion—requiring a 16% annual increase in investment from 2022 to 2025 [2].

On the international stage, coalitions such as the Vulnerable Twenty (V20)—encompassing 68 nations representing around 20% of global population and accounting for 5% of global emissions—advocate for enhanced climate finance, knowledge sharing, and policy innovation to safeguard vulnerable communities [3]. The Coalition for Disaster Resilient Infrastructure (CDRI), established at the UN Climate Action Summit in 2019, now comprises 55 members and aims to advance climate- and disaster-resilient infrastructure across research, standards, and financing domains [4]. At COP28 in December 2023, the UAE Framework for Global Climate Resilience was adopted—marking the first international declaration to elevate adaptation as a policy forefront, emphasizing sectors like food, water, infrastructure, nature, health, and livelihoods [5].

These global initiatives highlight a broader transformation: from merely understanding climate risks to actively mobilizing funds, enhancing infrastructure, and embedding adaptation into national strategies. Nonetheless, challenges persist. For instance, only 43% of global cities had adaptation plans as of 2021, while 41% had not performed climate risk assessments [6]

Fig.1. Front cover of Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050), submitted to the UNFCCC in July 2021.

Within this contested global context, Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050), submitted to the UNFCCC in July 2021, represents a comprehensive national framework addressing both mitigation and resilience [7]. Modeling under scenarios aligned with the 1.5 °C goal projects peak GHG emissions reaching 1.24 $GtCO_2$ eq by 2030, decreasing to around 0.54 $GtCO_2$ eq by 2050, with net-zero emissions targeted by 2060—or sooner—with continued technological and policy support. The strategy also anticipates that failure to adapt could reduce GDP by approximately 3.45% by 2050, whereas proactive resilience-building could mitigate such losses.

Currently, the AFOLU sector (Agriculture, Forestry, and Other Land Use) remains Indonesia's largest GHG emitter, contributing roughly 55% of the nation's emissions in 2022, with forestry and land-use activities as central sources of carbon flux [8].

Encouragingly, Indonesia aims to reach net zero emissions in the Forestry and Other Land Use (FOLU) sector by 2030, leveraging reduced deforestation and ecosystem restoration—a strategy supporting both its climate mitigation and adaptation commitments [9].

Moreover, Indonesia's emissions (excluding LULUCF) surged by 193% between 1990 and 2019, reaching 933 $MtCO_2e$/year, while methane emissions rose by 180% to 232 $MtCO_2e$/year, driven notably by a staggering 3,703% increase in methane from the waste sector [10]. Despite this trend, the renewable energy outlook within LTS-LCCR envisions a transformative energy mix by 2050: 34% coal, 25% natural gas, 8% oil, and 33% renewable energy—indicative of a shift toward decarbonization and resilience [11]. Complementing this, aggressive deployment of solar photovoltaics (PV)—targeted to reach 113 GW by 2050—could slash an estimated 794.87 million tons of CO_2 annually, contingent on sustained policy and financial support [12].

In light of this integrated landscape, this paper seeks to explore the strategic function of the AFOLU sector within Indonesia's LTS LCCR 2050 framework. Specifically, it aims to assess how AFOLU contributes to greenhouse gas reduction and climate resilience, evaluate the degree of alignment between current sectoral policies and the LTS-LCCR roadmap, investigate key trends, opportunities, and persisting challenges, and ultimately provide evidence-based policy recommendations to enhance the AFOLU sector's effectiveness in achieving net-zero emissions and bolstering Indonesia's adaptive capacity.

2 Methods

This study employs a mixed-methods research design, combining qualitative and quantitative approaches, to assess the contribution of the Agriculture, Forestry, and Other Land Use (AFOLU) sector to Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050). The methodology integrates three main approaches: policy document analysis, secondary data analysis, and comparative benchmarking.

A policy document analysis was conducted to examine the alignment between Indonesia's LTS-LCCR 2050 and national policies related to the AFOLU sector, including the Enhanced Nationally Determined Contribution (Enhanced NDC), the Forestry and Other Land Use (FOLU) Net Sink 2030 operational plan, and relevant ministerial regulations from the Ministry of Environment and Forestry (MoEF) and the Ministry of Agriculture. Policy review techniques follow the framework suggested by Bowen [13], which emphasizes systematic content analysis to identify strategic objectives, targets, and measures within official documents.

Secondary data analysis was employed using historical and projected GHG emission data from the AFOLU sector. Data sources include Indonesia's National Greenhouse Gas Inventory (SIGN-SMART) [14], the Climate Transparency Report [10], and World Bank climate and development datasets [9]. The data set covers the period 1990–2022 for historical trends, and 2023–2050 for projections under the LTS-LCCR 2050 scenario. Emissions are disaggregated into sub-categories such as forestry and land-use change, agriculture (including rice cultivation and livestock), and land management practices, following IPCC 2006 Guidelines for National Greenhouse Gas Inventories [15]. Quantitative analysis includes calculating the AFOLU sector's relative share of national emissions and its projected contribution to achieving Indonesia's emission reduction targets. During manuscript preparation, artificial intelligence–assisted tools (such as ChatGPT) were used solely for minor editorial purposes, including grammar correction, sentence rephrasing, and improving readability. All substantive tasks—such as literature review, data interpretation, synthesis of findings, and formulation of conclusions—were conducted and critically reviewed by the authors. The AI tool did not generate or

summarize content independently, and all analyses and interpretations presented in this paper are entirely the authors' own work.

3 Results and discussion

The trajectory of Indonesia's total greenhouse gas (GHG) emissions from 2030 to 2050 under the Low Carbon Compatible with Paris (LCCP) scenario within the Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR) framework is illustrated in Fig.2. In 2030, total emissions are projected to reach 1.24 $GtCO_2e$, marking the national emissions peak according to the Enhanced NDC. From this peak, the chart shows a significant and nearly linear decline to 0.54 $GtCO_2e$ by 2050 — equivalent to a reduction of approximately 56% from 2030 levels.

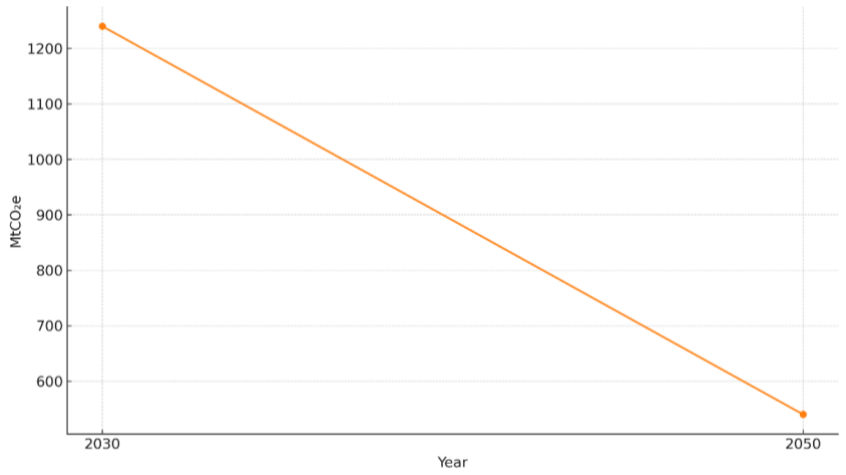

Fig.2. Indonesia's total GHG emission under LTS-LCCR (LCCP)

The trajectory implies that Indonesia must reduce emissions by an average of about 35 $MtCO_2e$ per year between 2030 and 2050. This is significantly higher than the historical average annual reduction rate observed during the period of slowed deforestation and early renewable energy adoption (which has been estimated at below 10 $MtCO_2e$/year). Achieving this ambitious pathway will require major contributions from:

- The energy sector through large-scale renewable energy deployment, electrification, and efficiency improvements.
- The AFOLU sector, especially by realizing the FOLU Net Sink 2030 target and further enhancing carbon sequestration by 2050.
- Complementary reductions in transportation, industry, and waste sectors through integrated and cross-sectoral policy implementation.

This trendline also emphasizes the critical importance of sustaining policy continuity and financing mechanisms over two decades to bridge the gap between historical progress and the accelerated pace required for the LCCP pathway.

The analysis shows (Table 1) that Indonesia's success in achieving the LTS-LCCR pathway is highly dependent on the AFOLU sector, particularly FOLU (Forestry and Other Land Use). In the Enhanced NDC (2022), the government targets a national emissions peak at 1.24 $GtCO_2e$ in 2030 under the LCCP scenario, declining to 0.54 $GtCO_2e$ by 2050, with NZE targeted by 2060 or sooner.

At the sectoral level, the FOLU Net Sink 2030 has been designated as the backbone of emissions reduction: from BAU 714 $MtCO_2e$ to 214 $MtCO_2e$ in 2030 (contributing more than 60% to the NDC reductions) and further towards a net sink of −140 $MtCO_2e$ in 2030, strengthening to around −304 $MtCO_2e$ by 2050. This downward trend is supported by recent achievements, where FOLU emissions fell from an average of ~490 $MtCO_2e$ (2016–2019) to ~165 $MtCO_2e$ in 2020, in line with deforestation control, peat/mangrove restoration, and fire reduction. The operational policy for achieving −140 $MtCO_2e$ (2030) and strengthening towards −304 $MtCO_2e$ (2050) is stipulated in the Minister of Environment and Forestry Decree No. 168/2022.

Table 1. Summary of AFOLU Sector and National GHG Emissions Targets in the LTS-LCCR Framework (LCCP Scenario)

Indicator	Value	Notes
AFOLU BAU 2030 ($MtCO_2e$)	714	Projection without additional policy
AFOLU NDC (Uncond.) 2030 ($MtCO_2e$)	214	Unconditional NDC target
AFOLU FOLU Net Sink 2030 ($MtCO_2e$)	-140	Net absorption target
AFOLU FOLU Net Sink 2050 ($MtCO_2e$)	-304	Strengthened net absorption target
National total emissions 2030 (LCCP) ($MtCO_2e$)	1240	Peak under LCCP scenario
National total emissions 2050 (LCCP) ($MtCO_2e$)	540	2050 target under LCCP scenario

In the Agriculture subsector, emissions are mainly from methane (CH_4) generated by rice cultivation and enteric fermentation, as well as N_2O from soils and fertilizers. The latest estimates show that agriculture contributes around ~8% of national emissions, with internal composition roughly rice ~34%, enteric fermentation ~26%, and the remainder from manure management, synthetic fertilizers, and agricultural burning. Although its share is smaller than FOLU, agricultural mitigation strategies (e.g., AWD for rice paddies, ruminant feed/biotechnology, and fertilizer efficiency) are a crucial complement to keeping AFOLU totals consistent with the LCCP pathway.

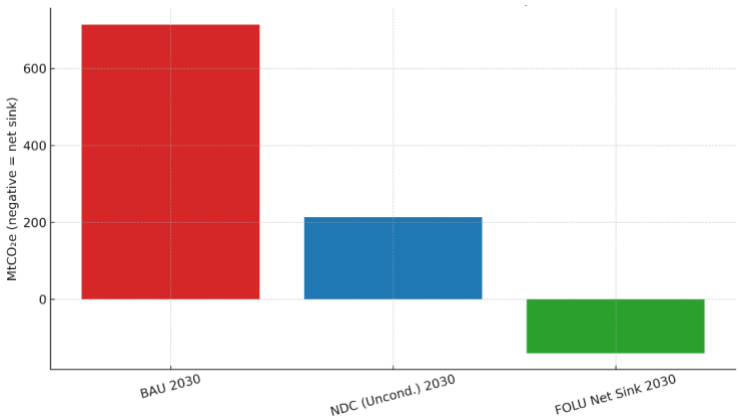

Fig.3. Indonesia AFOLU Emissions- 2030 scenario comparison

The “AFOLU 2030 Scenario Comparison” chart (Fig.3) summarizes three reference points from official documents:

- BAU 2030: 714 $MtCO_2e$ (FOLU projection without additional policy).
- NDC (Unconditional) 2030: 214 $MtCO_2e$ (more than 60% of total NDC reductions from FOLU).
- FOLU Net Sink 2030: −140 $MtCO_2e$ (net absorption).

These figures are sourced from the World Bank/Partnership for Transparency (2023) case study, synthesizing Indonesia's Enhanced NDC and FOLU Net Sink Roadmap.

The second chart, "Indonesia Total GHG Emissions under LTS-LCCR (LCCP)," visualizes the macro-level national trajectory: 1.24 $GtCO_2e$ (2030) declining to 0.54 $GtCO_2e$ (2050). This reinforces that achieving the 2050 target heavily depends on realizing the FOLU net sink status and strengthening emissions reductions in energy, waste, and IPPU.

Significance of AFOLU. LTS-LCCR positions AFOLU—especially FOLU—as the major net sink "pulling down" national totals while other sectors (energy, transport) remain in transition. Without the FOLU net sink as planned, the LCCP trajectory towards 0.54 $GtCO_2e$ (2050) will be difficult to achieve. Although deforestation trends are declining and regulations have strengthened (moratoriums, peat/mangrove restoration, stricter concessions), independent assessments highlight implementation risks—particularly if LULUCF trends rebound. Consistent financing and governance across sectors and local governments is a prerequisite for achieving −140 $MtCO_2e$ (2030) and sustaining the reduction to −304 $MtCO_2e$ (2050).

Methane reduction from rice fields through Alternate Wetting and Drying (AWD), low-emission rice varieties, as well as feed management and biogas/anaerobic digestion in livestock can deliver additional reductions to "lock in" AFOLU decreases, while offering co-benefits for productivity and water/air quality. Given agriculture's ~8% contribution and CH_4/N_2O profile, these measures are low-cost abatements that reduce deviation risks from the LCCP pathway. AFOLU strategies intersect with energy and disaster management: preventing peat/land fires during extreme years (El Niño) avoids episodic emissions spikes; bioenergy expansion must comply with no-deforestation/moratorium principles; and carbon finance (REDD+, Article 6) can accelerate implementation at the regional level.

Beyond the quantitative trajectory, the real-world implications of these findings emphasize the need for systemic solutions to bridge identified gaps in financing and governance. The observed financing shortfall suggests that Indonesia's AFOLU sector requires a diversified funding strategy—combining public expenditure, private investment, and international climate finance mechanisms such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), and REDD+ results-based payments. Public-private partnerships (PPP) can be particularly effective in mobilizing resources for large-scale peatland restoration, community-based reforestation, and sustainable agriculture initiatives.

However, such financing channels remain underutilized largely due to limited institutional readiness, insufficient project pipelines, and perceived investment risks. The absence of a fully operational legal framework for carbon pricing and domestic carbon markets has further constrained private sector participation. Clearer regulatory guidance and transparent verification systems for emission reduction credits would help de-risk investments and attract both domestic and international stakeholders.

To address enforcement and governance challenges, stronger inter-ministerial coordination—particularly between the Ministry of Environment and Forestry, the Ministry of Agriculture, and regional governments—is essential. Establishing a national AFOLU coordination platform could align sectoral policies, monitor progress, and ensure accountability. Capacity-building programs for provincial and district-level authorities are equally critical to improve land monitoring, compliance with forest moratoriums, and implementation of sustainable land-use practices.

By linking these institutional and financial reforms with Indonesia's LTS-LCCR 2050 roadmap, the AFOLU sector could transition from being a constraint to becoming a driver of low-carbon growth, unlocking long-term benefits for climate resilience, livelihoods, and biodiversity conservation.

4 Conclusions

Achieving Indonesia's LTS-LCCR 2050 targets relies heavily on the AFOLU sector, particularly Forestry and Other Land Use (FOLU) as the main driver of emission reductions. Meeting the FOLU Net Sink 2030 target of −140 $MtCO_2e$ and strengthening it to −304 $MtCO_2e$ by 2050 requires unprecedented cross-sectoral acceleration. The LCCP pathway—from 1.24 $GtCO_2e$ in 2030 to 0.54 $GtCO_2e$ in 2050—demands consistent annual reductions of about 35 $MtCO_2e$. Success depends on sustained policy commitment, strong governance, and reliable financing. Without transformative actions in funding, institutional coordination, and law enforcement, implementation gaps will persist. Turning the AFOLU sector from a vulnerability into a driver of transformation is vital for Indonesia to achieve a low-carbon, climate-resilient, and sustainable future.

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