THE GOVERNMENT OF THE INDEPENDENT STATE OF PAPUA NEW GUINEA

Technology Needs Assessment for Climate Change Mitigation

Energy Sector
Transport Sector
LULUCF Sector

January 2025

TECHNOLOGY NEEDS ASSESSMENT REPORT: CLIMATE CHANGE MITIGATION TECHNOLOGIES IN ENERGY, TRANSPORT, AND LULUCF SECTORS OF PNG

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Disclaimer

FOREWORD

The impacts of climate change are becoming increasingly evident worldwide, and Papua New Guinea (PNG), like other Pacific island nations, is among the most vulnerable. With its rich biodiversity, extensive coastlines, and heavy reliance on agriculture, PNG faces complex and interconnected challenges that threaten its environment, economy, and communities. However, despite these challenges, PNG remains steadfast in its commitment to addressing climate change through a proactive, multi-faceted approach. The country places a strong emphasis on both adaptation and mitigation strategies, ensuring alignment with its Nationally Determined Contributions (NDCs) under the Paris Agreement to build resilience and reduce greenhouse gas emissions.

The Government of Papua New Guinea (GoPNG) has demonstrated its commitment to international climate obligations under the United Nations Framework Convention on Climate Change (UNFCCC) by integrating climate action into its national development agenda. Climate change has been mainstreamed across key policy frameworks, including Vision 2050, the National Development Strategic Plan 2010-2030, the National Strategy for Responsible Sustainable Development (StaRS), and the Medium-Term Development Plan III. These strategic initiatives aim to not only strengthen and diversify PNG's economic foundations but also enhance the country's resilience to climate change and support efforts to mitigate carbon emissions. By embedding climate considerations into its broader development goals, PNG is taking decisive steps towards a sustainable and climate-resilient future.

The most recent steps taken by the Climate Change and Development Authority (CCDA) to act on climate change have been the development of PNG's SDG 13 Climate Action Roadmap (2020), PNG Enhanced NDC (2020), PNG Revised Enhanced NDC 2020 Implementation Plan (2021-2030), PNG NDC Implementation Roadmap for AFOLU and Energy sectors (2021-2030), PNG Second Biennial Update Report with REDD+ Technical Annex (2022), National Inventory Report (2022), and National Adaptation Plan 2022-2023. These efforts show PNG's dedication to integrating climate action into national development strategies, aiming to build a resilient and sustainable future.

This Technology Needs Assessment (TNA) Report is a key component of PNG's efforts to strengthen its climate action initiatives. It assesses the country's technological requirements for effective climate change mitigation, identifying priority technologies that can significantly reduce greenhouse gas emissions and enhance resilience. As the world transitions to a low-carbon future, technology plays a pivotal role in enabling countries like PNG to meet their climate goals. Through the adoption of appropriate and innovative technologies, PNG can transform its energy systems, improve land-use practices, and enhance sustainable livelihoods, all while contributing to global climate change mitigation efforts.

The successful implementation of PNG's NDCs depends, in large part, on the development, transfer, and diffusion of suitable technologies. These technologies are not only essential for reducing emissions but also for ensuring that PNG can adapt to a rapidly changing climate. This report identifies key areas where technological innovation, coupled with capacity building and financial support, will drive transformative change. It emphasizes the importance of ensuring that such technologies are locally appropriate, affordable, and accessible to all sectors of society.

In the face of climate change, the opportunities to build a sustainable, resilient, and equitable future for PNG depend on our collective ability to embrace and harness technology. This report lays the groundwork for PNG's continued progress in climate change mitigation, contributing to the global climate agenda while safeguarding the future of its people and ecosystems.

It is our hope that this report will serve as a vital tool for decision-makers, policymakers, and stakeholders across PNG, catalysing action and fostering collaboration in the pursuit of a sustainable, climate-resilient nation.

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Climate Change & Development Authority
Common Seal

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This Technology Needs Assessment report has been made possible through the collaborative efforts of various individuals and organizations dedicated to addressing climate change and promoting technological innovation in PNG.

We extend our sincere gratitude to the Climate Change and Development Authority for the leadership and insights which have been invaluable throughout this process.

We also wish to acknowledge the financial support provided by the Global Environment Facility (GEF) and the implementation assistance from the United Nations Environment Programme (UNEP), particularly through the UNEP Copenhagen Climate Centre. Their commitment to promoting sustainable development and climate resilience has greatly contributed to the success of this assessment.

We also wish to recognise the invaluable contributions of stakeholders from the Agriculture, Forestry, and Other Land Use (AFOLU) and Energy sectors, including the PNG Forest Authority, Department of Lands and Physical Planning, Department of Agriculture and Livestock, Department of Transport, PNG Power Limited, and the National Energy Authority. Their provision of data and information has been instrumental in shaping the findings and recommendations of this report.

Finally, we sincerely appreciate the engagement and contributions of all stakeholders who took part in this project. Their collective efforts have been instrumental in demonstrating how important it is to align technology needs with national development strategies to strengthen PNG's resilience to climate change.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
BUR	Biennial Update Report
CCDA	Climate Change and Development Authority
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
CTCN	Climate Technology Centre and Network
GEF	Global Environment Facility
GHG	Greenhouse Gas
Gg CO_2 eq	Gigagrams of carbon dioxide equivalent
HFC	Hydrofluorocarbons
kt CO_2 eq	Kilotons of carbon dioxide equivalent
LULUCF	Land Use, Land Use Change and Forestry
MCA	Multi-Criteria Analysis
NDC	Nationally Determined Contributions
NDE	National Designated Entity
NEA	National Energy Authority
N_2O	Nitrous oxide
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
SDG	Sustainable Development Goal
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNEP	United Nations Environment Programme
UNEP DTU	United Nations Environment Programme and Technical University of Denmark
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

The Technology Needs Assessment (TNA) report for PNG was developed through a stakeholder-driven and inclusive process, guided by the "Guidebook for Countries Conducting a Technology Needs Assessment and Action Plan" by UNEP DTU Partnership. The process integrated gender considerations and was led by the Mitigation Consultant, with support from the TNA Coordinator and Technical Working Groups.

The assessment involves a comprehensive evaluation aimed at identifying and prioritising the technological needs essential for effectively addressing the multifaceted challenges posed by climate change. This report also aligns with global commitments under the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC), emphasising the important role of technology in achieving climate mitigation goals.

The TNA process is structured to be country-driven and participatory, ensuring that it reflects PNG's national development priorities, including Vision 2050 and the Nationally Determined Contributions (NDCs). Implemented by the United Nations Environment Programme (UNEP) in collaboration with the UNEP DTU Partnership, the TNA aims to enhance investments in technology transfer, enabling PNG to address its unique climate technology needs effectively.

PNG's geographical, climatic, environmental, demographic, and economic factors have significantly influence the selection of appropriate technologies. One of the pressing challenges faced by the country is greenhouse gas emissions from deforestation, forest degradation, and energy production. The assessment highlights the importance of adopting environmentally sound technologies to address these challenges and support sustainable development in the country.

The key national policies considered in the TNA process include PNG's Medium Term Development Plan IV (2023-2027), PNG's Enhanced NDC 2020, the Enhanced NDC Implementation Plan (2021-2030), and PNG's Sustainable Development Goal 13 Roadmap, among others. These frameworks guide the identification of priority sectors for technology implementation, which include Energy, Transport, and Land Use Land Use Change and Forestry (LULUCF).

Through extensive stakeholder consultations and workshops, the TNA process engaged a diverse range of participants from government, civil society, and the private sector, ensuring a broad representation of interests and expertise. This collaborative approach led to the identification of specific technologies within the prioritised sectors, considering factors such as cost-effectiveness, environmental and socio-economic benefits, climate change mitigation, and local applicability, and stakeholder acceptance. The final selection includes seven key technologies for Energy sector, five for Transport sector, and seven for LULUCF sector. Technology factsheets were developed, and a Multi-Criteria Analysis (MCA) evaluated the technologies based the mentioned factors.

Results of Technology Prioritisation

1. **Energy**: Section 3.4.6 details the results of the technology prioritisation for the Energy sector. The top-ranked technologies include "Cook Stoves In Biomass Gasification," "Solar Power," "Hydro Power "and "Wind Power." These technologies were selected based on their potential to reduce greenhouse gas emissions, enhance energy security, and align with PNG's renewable energy goals. The prioritisation process utilised a Multi-Criteria Analysis (MCA) to evaluate each technology's cost, benefits, and readiness for implementation.

Rank	Technology	Score
1	Cook Stoves In Biomass Gasification	67.3
2	Solar Power Plant	53.9
3	Hydro Power Plant	53.6
4	Wind Power Plant	40.6
5	Biogas Power Plant	34.6
6	Geothermal Power	33.3
7	Biomass Power Plant	27.9

2. **Transport**: Section 4.4.6 presents the results of the technology prioritisation for the Transport sector. The leading technologies identified include "Electric Vehicles," and "Hybrid Vehicles." These technologies were prioritised for their potential to lower emissions from the transport sector, improve fuel efficiency, and contribute to sustainable urban mobility. The MCA framework was again employed to assess the technologies based on various criteria, including economic viability and environmental impact.

Rank	Technology	Score
1	Electric Vehicles	49.61
2	Hybrid Vehicles	40.49
3	Introduction of biofuel in transport	40.02
4	Compressed Natural Gas in Transport	34.96
5	Improved Urban/Suburban Public Transport System using LPG Buses	26.88

3. **Land Use, Land Use Change and Forestry (LULUCF)**: Section 5.4.6 highlights the results of the technology prioritisation process for the LULUCF sector. The most critical technology identified was "Reduced Deforestation and Forest Degradation" followed by "Sustainable Land Use Planning" and "Reforestation and Rehabilitation." These technologies were recognised for their significant potential to mitigate emissions and enhance sustainability within the LULUCF sector.

Rank	Technology	Score
1	Reduced Deforestation and Forest Degradation	72.82
2	Sustainable Land Use Planning	66.03
3	Reforestation and Rehabilitation	65.45
4	Protected area development and management	62.16
5	Application of Environmental Safeguards	62.08
6	Sustainable palm oil development	51.66
7	Downstream Processing for Forestry Products	47.06

The final prioritisation identified key technologies that will drive PNG's mitigation efforts and align with its climate commitments and development goals. These technologies will proceed to the Barrier Analysis and Enabling Framework phase. The prioritised technologies are summarised below:

Sector	No.	Technologies
Energy	1	Gasifier Stoves Using Biomass
	2	Solar Power Plant
	3	Hydro Power Plant
Transport	1	Electric Vehicles
	2	Hybrid Vehicles
LULUCF	1	Reduced Deforestation and Forest Degradation
	2	Sustainable Land Use Planning
	3	Reforestation and Rehabilitation

These technologies would support PNG's efforts toward achieving sustainable development and climate mitigation objectives.

Chapter One: Introduction

1.1 About the TNA Project

The Technology Needs Assessment process was introduced as part of the Poznan Strategic Programme on Technology Transfer, which was established during the Fourteenth Conference of the Parties (COP 14) to the United Nations Framework Convention on Climate Change (UNFCCC). Its primary goal is to enhance investment in technology transfer, enabling developing countries like PNG to address their needs for environmentally sound technologies to combat climate change.

PNG, like many other countries, faces the pressing challenge of managing the impacts of climate change driven by the accumulation of greenhouse gases (GHGs) in the atmosphere. The primary contributors to GHG emissions in PNG include deforestation and forest degradation, activities that compromise forest cover essential for carbon sequestration. Through the UNFCCC, the global community has committed to stabilising atmospheric GHG concentrations to levels that prevent dangerous anthropogenic interference with the climate system (UNFCCC, 2019). Achieving this requires significant reductions in GHG emissions alongside adaptive measures to manage the unavoidable effects of climate change.

Importance of Technology and the Role of the UNFCCC

The vital role of technology in the global climate response is evident through commitments made at the annual Conference of the Parties (COP) under the UNFCCC. In 2010, the COP established the Technology Mechanism, comprising two key bodies: the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). The TEC acts as the policy-making body, while the CTCN provides technical assistance, facilitates knowledge exchange, and promotes collaboration among stakeholders to accelerate the development and transfer of climate technologies. In PNG, the Climate Change and Development Authority serves as the National Designated Entity (NDE), acting as the focal point for implementing climate-related technology initiatives in collaboration with local and international partners.

The Paris Agreement, adopted in 2015, further underscores the critical role of technology in achieving climate mitigation and adaptation goals. Article 10 emphasises the need for cooperative action on technology development and transfer throughout all stages of the technology lifecycle. It also highlights the importance of balancing support for mitigation and adaptation while aligning technology efforts with national development priorities. To operationalise this, the Agreement introduced the Technology Framework, which guides the Technology Mechanism in enhancing technology transfer and development efforts.

The Technology Needs Assessment (TNA) Process in Papua New Guinea

The UNFCCC supports countries like PNG in identifying and prioritising climate technologies through the Technology Needs Assessment process. Originating from the Poznan Strategic Programme on Technology Transfer, the TNA process aims to scale up investments in technology transfer to meet the unique needs of developing countries. The process is funded by the GEF and implemented by the UNEP in partnership with the Technical University of Denmark (UNEP DTU Partnership).

The TNA process is country-driven, participatory, and closely aligned with PNG's national development plans, including Vision 2050 and the NDCs. It enables PNG to analyse, prioritise, and implement climate technologies that address national circumstances and sectoral needs. According to the Intergovernmental Panel on Climate Change (IPCC), climate technologies are categorised into three components: hardware (physical equipment), software (methods and techniques), and orgware (institutional and organisational frameworks). This comprehensive view ensures that the TNA process considers practical tools alongside the institutional capacity needed to deploy and sustain them.

1.2. Existing National Policies Related to technological innovations, climate change mitigation, and development priorities

1.2.1. Papua New Guinea Vision 2050

PNG Vision 2050 is built upon seven Strategic Focus Areas, known as pillars. One of these is the Environmental Sustainability and Climate Change Pillar, which has set the following mitigation-related targets:

- Reduce greenhouse gas emissions by 90% compared to 1990 levels.
- Implement a Sustainable Development Policy across all sectors, including forestry, agriculture, mining, energy, and oceans by 2015.
- Preserve biodiversity at the current level of five to seven percent of the world's total.
- Establish a total of 20 national reserves, wilderness areas, and national parks.
- Establish at least one million hectares of marine protected areas.
- Provide 100% power generation from renewable energy sources.

1.2.2. Papua New Guinea Development Strategic Plan 2010-2030

The PNG Strategic Development Plan is a comprehensive document outlining long-term national objectives and creating strategies to guide action plans and resource programs. It includes specific strategies for the extractive and energy sectors that emphasise environmental sustainability and address climate change in alignment with PNG's developmental needs. One of the key goals of the climate change strategy is to "Adapt to the domestic impacts of climate change and contribute to global efforts to reduce GHG emissions. The plan aims to enhance access to electricity and promote the adoption of renewable energy sources by 2030 as part of its targets for the energy sector.

1.2.3. National Strategy for Responsible Sustainable Development of PNG

The National Strategy for Responsible Sustainable Development of PNG (StaRS) builds upon the achievements of Vision 2050 and the PNG Strategic Development Plan, offering a new development framework designed to be strategic, forward-looking, and suitable for the future. StaRS represents a shift in long-term planning, aiming to guide both current and future governments in achieving the following objectives: becoming a leader in responsible sustainable development, attaining middle-income status by 2030, and ranking among the top 50 countries on the Human Development Index by 2050.

To facilitate the transition from traditional, brown-driven growth to inclusive green growth, StaRS introduces three key enabling dimensions:

I. A national green growth plan to establish favourable conditions.

II. Green growth mainstreaming mechanisms to explore opportunities within existing economic activities.

III. Green growth policy instruments to capitalise on specific opportunities within spatial and resource systems.

1.2.4. National Climate Compatible Development Management Policy

The National Climate Compatible Development Management Plan (NDDCMP) serves as the government's blueprint for establishing a climate-resilient and carbon-neutral pathway through sustainable economic development in PNG. This strategy integrates economic growth with climate change mitigation and adaptation efforts. The mitigation component includes three key policies:

I. Carbon Neutrality by 2050: PNG aims to achieve carbon neutrality by 2050.

II. Land Use, Land Use Change and Forestry Sector Emissions Abatement: Reducing greenhouse gas emissions in the land use, land use change, and forestry (LULUCF) sector.

III. Green Economic Growth: Ensuring that development is climate-compatible through the use of efficient, low-emission infrastructure and technology

1.2.5. Papua New Guinea's Sustainable Development Goal 13 Roadmap

The Roadmap outlines 30 actions to be accomplished by 2030. It features a Timeline with four phases of milestones that will support Papua New Guinea in achieving these actions and meeting the key targets of SDG13 and the country's NDCs. The Stakeholder Action Plan identifies key groups with whom the PNG Climate Change and Development Authority should collaborate to implement the 30 actions. The Management and Implementation table proposes measurable outcomes that are either already in progress or could be developed to support the achievement of these actions.

The 30 actions aim to address climate change challenges while steering PNG towards becoming a climate-smart, healthy, and prosperous nation, in line with the goals of the country's Medium-Term Development Plan IV (MTDP IV). The actions are organised into 10 sectoral themes: climate governance, energy, forestry, agriculture, infrastructure, fisheries, tourism, biodiversity, minerals, and health. These themes are aligned with the climate change impacts that PNG will experience and the key economic sectors crucial for national development and the livelihoods of Papua New Guineans.

1.2.6. National Energy Policy 2017- 2027

The National Energy Policy aims to ensure an affordable, competitive, sustainable, and reliable energy supply that meets national and provincial development needs at the lowest cost, while also protecting and conserving the environment. To achieve these goals, the policy outlines necessary measures, including the promotion of renewable energy sources. PNG has underutilised indigenous energy resources such as hydro, biomass, natural gas, geothermal, solar, and wind. Developing these resources could enhance the country's electrification rate, boost energy production and exports (where feasible), and support economic growth. The policy includes sections on "Background," "Challenges," and "Strategies" for all renewable energy sources and details approaches to encourage their adoption.

1.2.7. National Transport Strategy

The transportation subsector aims to promote the regulation of clean fuel technologies to establish GHG emission standards and economic incentives for fuel-efficient vehicles. Such actions include the following:

- Reduce vehicle-miles through more compact development patterns;
- Encourage the introduction of fuel-efficient transport equipment;
- Encourage sustainable substitution of fossil fuels with biofuels;
- Monitor vehicle fleet-weighted fuel and CO2 efficiency;
- Eliminate high emission vehicles;
- Establish low carbon fuel standards; and
- Encourage the introduction of hybrid and electric vehicles.

1.2.8. National REDD+ Strategy

The National REDD+ Strategy identifies three key action areas, each with specific actions and designated lead agencies for implementation.

I. **Strengthening Land-Use and Development Planning:**
   - Strengthened and Coordinated National Level Development and Land Use Planning: Managed by the Department of National Planning and Monitoring (DNPM) and the Department of Lands and Physical Planning (DLPP).
   - Integrated Subnational Planning: Overseen by DNPM and the Department of Provincial & Local Government Affairs (DPLGA).

II. **Strengthened Environmental Management, Protection, and Enforcement:**

- Strengthening Climate Change Legislation, Financing, and Management: Led by the Climate Change Development Authority.
- Strengthening Forest Management and Enforcement Practices: Managed by the Papua New Guinea Forest Authority (PNGFA).
- Strengthening Conservation and Environmental Management: Coordinated by the Conservation and Environment Protection Authority (CEPA).
- Strengthening Access to Information and Resource Mechanisms: A multi-stakeholder effort.

III. **Enhanced Economic Productivity and Sustainable Livelihoods:**

- Development of a Sustainable Commercial Agriculture Sector: Led by the Department of Agriculture and Livestock (DAL) and DNPM.
- Strengthened Food Security and Increased Productivity of Family Agriculture: Managed by DAL and the Fresh Produce Development Agency (FPDA).

1.2.9. PNG Enhanced NDC

The Enhanced NDC provides an approach to reduce GHG emissions in the energy and AFOLU sectors, which are the principal emission sources. For the energy sector, PNG is committing to a headline target of carbon neutrality within the energy industries sub-sector. This would be achieved through:

- Enhance levels of renewables in the energy mix from 30% in 2015 to 78% by 2030 for on-grid connection (non-GHG quantitative target);
- Reducing electricity demand through energy efficiency;
- Fossil fuel off-setting from energy industries sub-sector through nature-based solutions;
- Enhanced data collection.

Other potential mitigation measures under the energy sector are from the transport sub-sector, which involves the reduction of fuel consumption.

The overarching target in the AFOLU sector is that PNG will shift the upward trend of GHG emission in the AFOLU sector due to the increase of deforestation and forest degradation to a downward trend in the next 10 years (by 2030). This will be achieved through:

- GHG-Absolute target;
  - ✓ This target outlines that by 2030, annual net emission from deforestation and forest degradation due to agriculture expansion and commercial logging is reduced by 10,000 Gg CO_2 eq compared to the 2015 level.
- GHG-Relative target;
  - ✓ This target outlines that the LULUCF will be converted from net GHG source (1,716 Gg CO2 eq) in 2015 to net GHG sink (-8,284 Gg CO2 eq) by 2030 to mitigate emissions from other sectors.
- Non-GHG Quantitative targets;

This includes the following non-GHG quantitative targets:

- ✓ The area of annual deforestation is reduced by 25 % of 2015 level by 2030 (equating to a reduction of 8,300 ha of annual deforestation);
- ✓ The area of forest degradation is reduced by 25 % of 2015 levels by 2030 (equating to a reduction of 43,300 ha of annual degradation); and
- ✓ The area of planted forest and forest restoration is increased.

- Non-GHG Action based targets

This includes the following non-GHG action-based targets:

- ✓ Enhanced land use planning;
- ✓ Promoting climate-friendly agriculture;
  - Oil palm platform;
  - Cocoa platform;
  - Coffee platform;
  - Enhancing community-level agriculture productivity;
  - Certification system for climate-friendly agriculture products;
  - Enhancing the value chain of climate-friendly agriculture products;
  - Strengthened monitoring of FCA permits
- ✓ Enhancement of timber legality
- ✓ Promoting REDD+
- ✓ Promoting downstream processing
- ✓ Promoting the *Painim Graun Planim Diwai* initiative and planting 10 million trees initiative.

1.2.10. Enhanced NDC Implementation Plan (2021-2030)

The Enhanced NDC Implementation Plan aims to mobilise and coordinate support from the international development community, attract investments from both public and private sectors, and engage key stakeholders, both domestic and international, to help PNG meet its NDC targets. The primary goal of the plan is to achieve emissions reduction targets for the energy and Agriculture, Forestry, and Other Land Use (AFOLU) sectors, as well as adaptation goals outlined in PNG's Enhanced NDC 2020.

For the AFOLU sector, the plan identifies 20 direct action pathways and 5 enabling pathways to reach the sector's targets. In the energy sector, it outlines 36 projects and 6 activities to be implemented to meet the sector's targets

1.2.11. NDC Implementation Roadmap for the electricity sector

The goal of the NDC Implementation Roadmap for the electricity sector is to help PNG achieve a 78% share of renewable energy in the on-grid system by 2030. The roadmap builds on the 36 projects specified in the Enhanced NDC Implementation Plan, providing a detailed pathway for implementing these projects. It also outlines the necessary improvements to the enabling environment that may be required to meet the targets set in the Enhanced NDC.

1.2.12. NDC Implementation roadmap for the Agriculture, Forestry, and Other Land Use sector

The goal of the NDC Implementation roadmap for the AFOLU sector is to enhance coordinated action and investment toward the delivery and further enhancement of PNG's targets within AFOLU sector. Its objective is to provide a clear AFOLU NDC Implementation roadmap around which action and investment can be mobilised. It provides further information on the 20 direct action pathways and 5 enabling pathways outlined in the Enhanced NDC Implementation Plan, their potential impacts on emissions, and other environment and development goals as well as costs and implementation approach.

1.3 Objectives and Outcomes of the TNA Process in PNG

The TNA process in PNG focuses on three core objectives:

I. Identifying and prioritising mitigation technologies in key sectors such as energy, agriculture, forestry, and land use to reduce GHG emissions and enhance resilience.

II. Addressing barriers to technology deployment and diffusion, including the development of enabling frameworks, policies, and institutional arrangements.

III. Developing Technology Action Plans (TAPs) that outline concrete actions and project ideas to implement the prioritised technologies effectively.

The TNA process in PNG is gender-inclusive and stakeholder-driven, ensuring that identified technologies are widely accepted and aligned with existing national policies. By promoting collaboration among diverse stakeholders, the process builds local capacity and ensures that the outcomes are both relevant and sustainable.

Alignment with National Development Goals

PNG's TNA process is closely linked to its climate and development priorities. The outcomes of the TNA are designed to contribute to the country's broader sustainable development agenda, as outlined in Vision 2050, and its commitments under the NDCs. These policies highlight the importance of climate technology in achieving a climate-resilient future for PNG. By integrating the TNA outcomes into national strategies, PNG aims to harness innovative technologies that not only address climate challenges but also drive economic development and improve the well-being of its people.

Through the TNA process, PNG is positioning itself as a proactive participant in global climate action while building a foundation for sustainable, technology-driven growth.

1.4 Vulnerability Assessments in the Country

The last Vulnerability assessment conducted in PNG was part of the Second National Communication, which highlighted significant threats to the nation from climate change. PNG plans to conduct the next vulnerability assessment as part of the Third National Communication. PNG, an island nation, faces increasing risks from global warming and changing climatic patterns that are expected to exacerbate existing natural hazards and introduce new ones. Below is a detailed overview of the key impacts of climate change in PNG:

- ✓ **Coastal Flooding and Sea-Level Rise:** Coastal flooding, driven by rising sea levels, has already affected communities in PNG, with four catastrophic flood events in the past 15 years affecting around 8,000 people annually. These floods result in damages ranging between USD 10-20 million per year, displacing around 500 people and causing approximately five fatalities annually. Areas like the Carteret Atolls and Duke of York Islands are experiencing salinization and flooding, making these regions increasingly uninhabitable. As sea levels continue to rise, further displacements will occur, leading to social and cultural challenges that need to be addressed, including the displacement of vulnerable communities.
- ✓ **Malaria Expansion:** Malaria is a significant public health issue in PNG, affecting 1.7 million people annually. Around 60% of the population lives in areas at high risk for malaria transmission. Climate change has already worsened the malaria situation, as rising temperatures have allowed the parasite to spread to higher altitudes in the highlands where malaria was previously absent. Continued warming over the next 20 years could further expand malaria's reach, worsening the disease's impact both in previously unaffected regions and in low-risk zones.
- ✓ **Inland Flooding:** Inland flooding, driven by irregular and intense rainfall, regularly affects PNG's lowland and highland regions. Flooding is intensified by steep terrain and deforestation, causing an annual impact on 22,000-26,000 people. Typically, 6,000-8,000 people are displaced each year, and floods cause damages estimated between USD 8-12 million annually. The frequency and severity of inland flooding are expected to increase due to both overall increases in precipitation and more extreme rainfall events, posing ongoing challenges to communities, especially those in poorer, less accessible areas.
- ✓ **Coral Reef Degradation:** PNG's coral reefs, the fifth largest in the world, are threatened by rising sea temperatures and ocean acidification. These reefs are crucial for the livelihoods of 50,000-70,000 coastal inhabitants, providing food, shelter, and economic opportunities through fisheries and tourism. Furthermore, the reefs act as a natural defence against storm surges and coastal erosion. As these reefs

degrade, the livelihoods of those dependent on them will be jeopardised, and the ability of the reefs to protect coastlines will diminish, leading to further economic losses and environmental degradation.

- ✓ **Landslides:** Increased rainfall intensity and land-use changes are contributing to a rise in landslides in PNG's mountainous regions. Landslides cause considerable damage to infrastructure, particularly along the Highlands Highway, which serves as a critical lifeline for highland communities and export businesses. While the exact frequency and impact of landslides are difficult to predict due to the unpredictability of precipitation patterns and terrain, ongoing changes in climate and land use are likely to increase the occurrence of landslides in the future.
- ✓ **Agricultural Yield Variability:** Agriculture is another sector heavily affected by climate change in PNG. The highland regions, which are sensitive to changes in climate, rely on crops like sweet potatoes, coffee, and cocoa that are highly susceptible to temperature and rainfall shifts. Subsistence farmers, who are particularly vulnerable to these changes, may need to switch to alternative crops to adapt to the altered climatic conditions. This poses significant challenges to food security and economic stability, particularly in rural areas where agricultural activities form the backbone of the economy.

1.5. Sector Selection

1.5.1. Overview of Sectors, GHG Emissions Status and Trends of the Different Sectors

The selection of sectors for climate change mitigation in PNG followed a participatory process outlined in the TNA guidebook. This process began with the initial identification of sectors, followed by a detailed review of their emissions profiles and trends, and concluded with sector prioritisation. The TNA mitigation consultant, with input and support from CCDA, led the sector identification and emissions analysis.

Broader stakeholder engagement played a critical role in the sector selection process. The finalisation of sector selection occurred during four regional consultation workshops held between August and September 2024. These workshops were conducted in Morobe Province (Momase Region), West New Britain Province (New Guinea Islands Region), Western Highlands Province (Highlands Region), and Port Moresby (Southern Region).

The key sectors and sub-sectors for PNG were initially identified based on the country's Enhanced NDC 2020. These sectors align with the national priorities and national and international frameworks, including the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The sectors prioritised for climate change mitigation in PNG are Energy, Transport, and AFOLU (Agriculture, Forestry, and Other Land Use).

The review of emissions status and trends across various sectors in PNG was conducted using data from the national greenhouse gas inventory and the Second Biennial Update Report. The findings from this review are detailed in section 1.5.1.2.

Figure 1: Stakeholders at regional consultation workshops for Momase and Southern regions

1.5.1.1. Overview

The recent greenhouse gas (GHG) inventory for PNG is detailed in the Second Biennial Update Report (BUR2), submitted to the UNFCCC in 2022. According to BUR2, PNG's GHG status shifted from a net sink of -12,436 kt CO_2 equivalent in 2000 to a net source of 6,897 kt CO_2 in 2016. However, in 2017, PNG returned to being a net sink with total GHG emissions of -1,958 kt CO_2. The fluctuations are primarily driven by the LULUCF sector, particularly due to deforestation and degradation. Excluding the LULUCF sector, total net emissions increased from 8,052 kt CO_2 equivalent in 2000 to 10,767 kt CO_2 equivalent in 2017, marking a 34% rise. This increase is mainly attributed to higher fossil fuel consumption in manufacturing industries and construction, as well as road transportation.

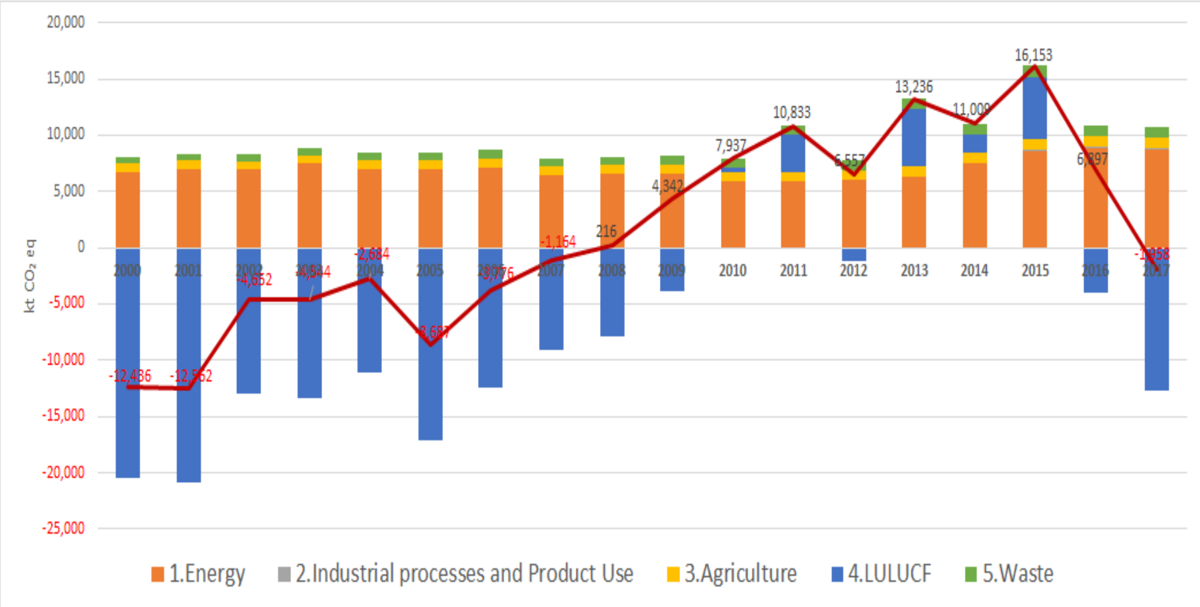

Figure 2: Total GHG emissions with LULUCF from 2000 to 2017

1.5.1.2. GHG emission status and trend of different sectors

Energy

In PNG, fossil fuels are utilised for various energy needs, including energy, transportation, and manufacturing, resulting in the emission of CO_2, CH_4, and N_2O. The country also engages in oil and gas production, including petroleum refining, which contributes to fugitive emissions of these gases. Emissions from the energy sector totalled 8,673 kt CO_2 equivalent, marking an increase of 1,913 kt CO_2 equivalent (28%) since 2000. In 2017, CO_2 from liquid fuel combustion accounted for 68% of the total GHG emissions, followed by CH_4 from fugitive emissions at 16%, CO_2 from gaseous fuel combustion at 12%, N_2O from fuel combustion at 2%, CH_4 from fuel combustion at 1%, and CO_2 from fugitive emissions at 1%. Overall, CO_2 contributed 81% of the total sector emissions, with CH_4 at 17% and N_2O at 2%. The decline in GHG emissions from 2006 to 2013 was attributed to reduced oil production, while the increase in emissions from 2000 to 2003 was due to rising energy demand and increased oil production. The rise in GHG emissions from 2014 to 2017 was linked to growing energy demand and higher production of Liquid Natural Gas.

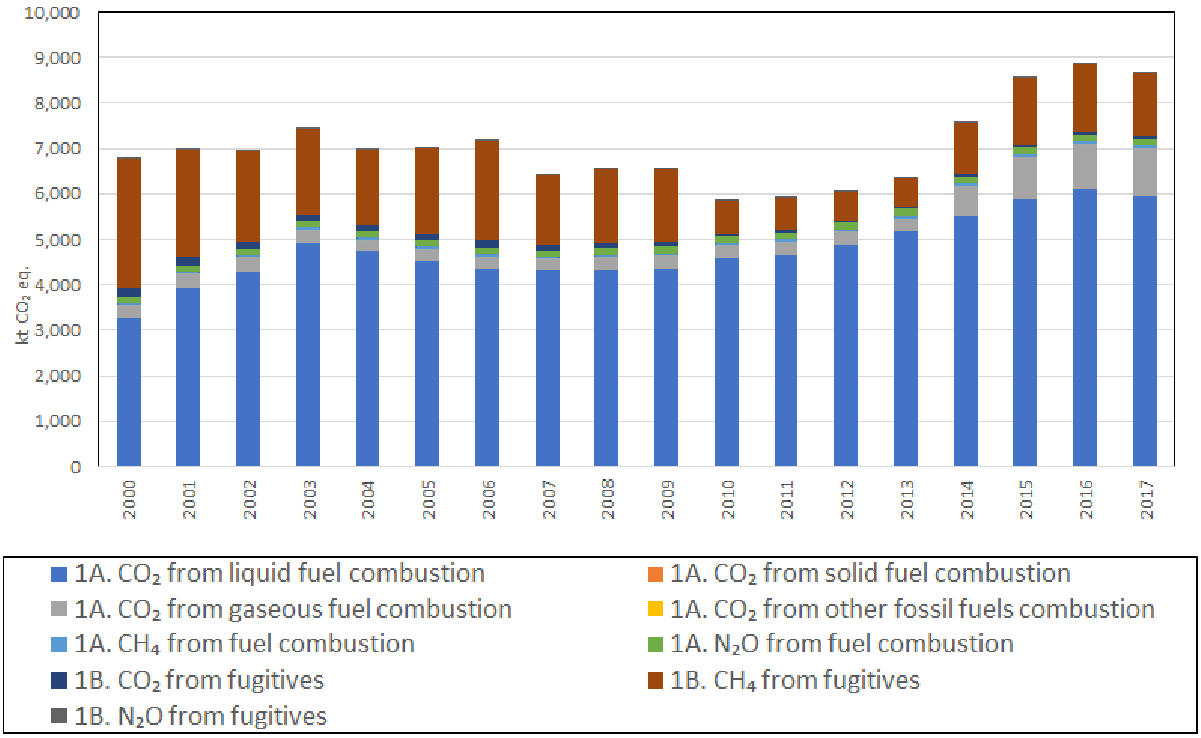

Figure 3: Trend in GHG emissions from the energy sector from 2000 to 2017 (in kt CO2 eq) (Source: National Inventory Report 2000-2017)

On a subsector level, CO_2 emissions from the energy industries1 increased by 248% since 2000 and decreased by 18% compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increase in electricity generation. The emissions from the energy industries increased slightly from 2000 to 2003 due to the increase in demand for electricity then remained constant from 2005 to 2013 and increased rapidly from 2014 to 2016 due to the increasing demand for electricity for the operation of the LNG project.

The CO_2 emissions from transport increased by 119% compared to 2000 and decreased by 0.4% compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increase in emissions from road transportation. Emissions from road transport increased 2.3 times from 2000 to 2017.

The CO_2 emissions from other sectors[2] increased by 14% since 2000 and increased by 1% compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increase in kerosene consumption in residential households.

1 Comprises emissions from fuels combusted conbusted by the fuel extraction such as petroleum refining or energy-producing industries such as electricity generation and heat production.

2 Emissions from combustion activities from commercial/institutional, residential, agriculture, forestry and fishing.

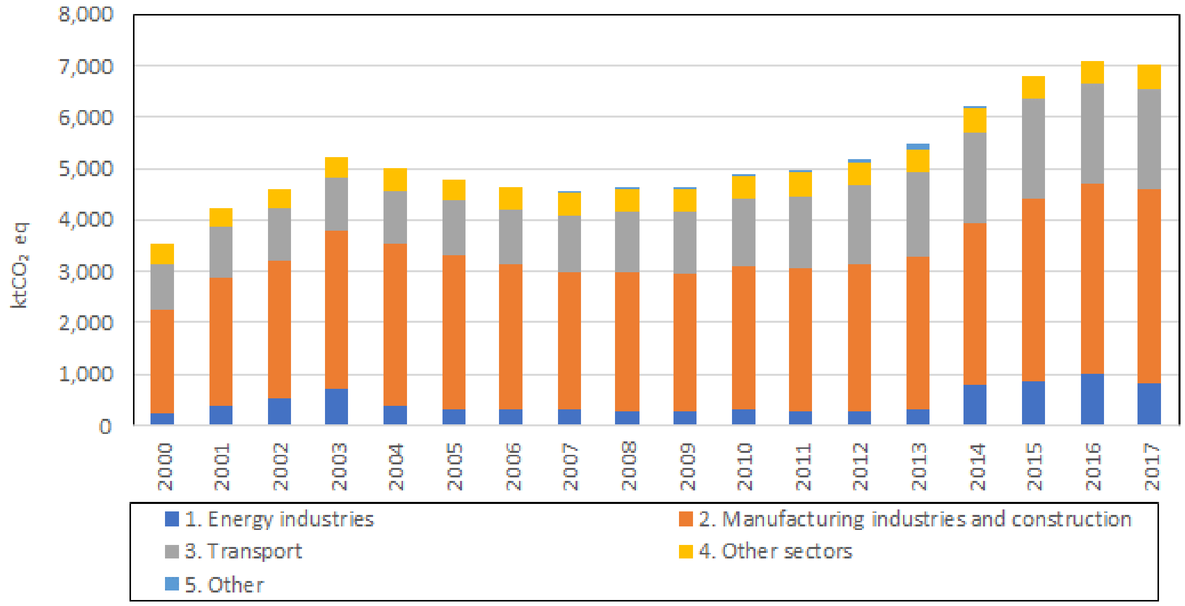

Figure 4: Time series of CO2 emissions from fuel combustion from 2000 to 2017 (in kt CO2 eq) (Source: National Inventory Report 2000-2017)

Industrial Process and Product Use (IPPU)

Total GHG emissions in the Industrial Processes and Product Use (IPPU) sector rose from 0.8 kt CO_2 equivalent in 2000 to 153.3 kt CO_2 equivalent in 2017. The low emission figures reported for 2000, as well as for 2001 and 2002, are due to limited activity data for the reported categories. Recent years show higher total GHG emissions compared to earlier reports because HFC emissions for 2015 to 2017 have now been included. The year 2003 marked the first instance of comprehensive activity data for lubricant use and N_2O emissions from product use.

Since 2003, N_2O emissions have decreased by 4.7%, or 0.042 kt CO_2 equivalent. In contrast, CO_2 emissions from lubricant use have surged by 114.3%, or 0.9 kt CO_2 equivalent, over the same period. HFC emissions reached 150.6 kt CO_2 equivalent in 2017, reflecting an 8.0% increase compared to 2015, the year HFC reporting began.

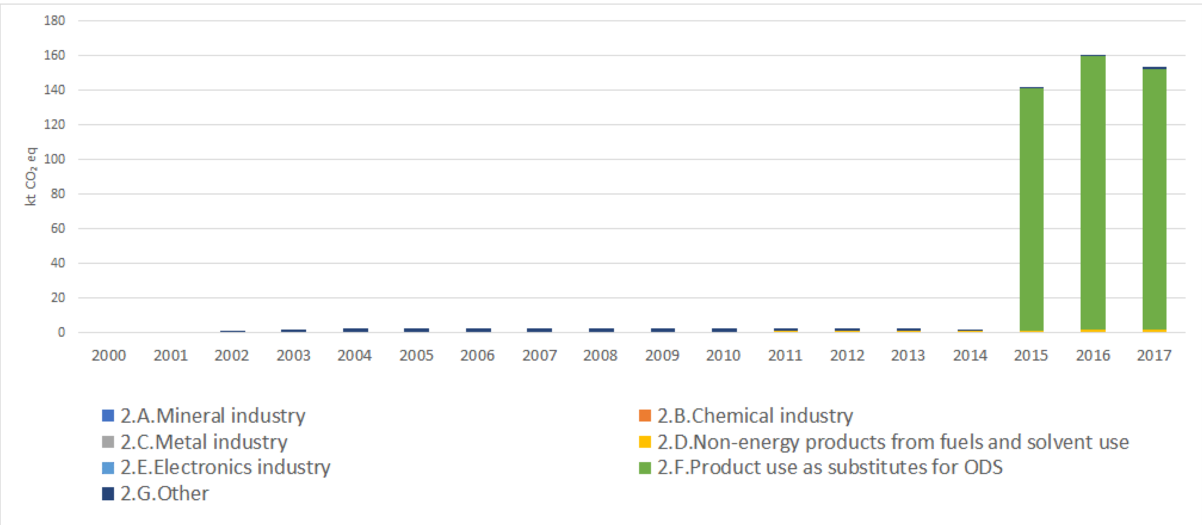

Figure 5: Trend in GHG emissions from the IPPU sector from 2000 to 2017 (in kt CO2 eq) (Source: National Inventory Report 2000-2017)

Land Use, Land Use Change and Forestry (LULUCF)

In the country, the LULUCF sector is the largest among all sectors. Traditionally, this sector functioned as a carbon sink. However, over time, it has become less effective as a sink due to a reduction in forested areas caused by increased logging and agricultural activities. From 2011 to 2015, the sector was a net source of emissions. In contrast, in 2016 and 2017, it turned into a net sink as forest cover increased due to a reduction in logging and agricultural activities.

The majority of emissions in the LULUCF sector arose from forest degradation and deforestation. The annual rate of forest degradation (where primary forests become degraded) more than doubled from 87,618 hectares in 2001 to 200,052 hectares in 2011, and then slightly decreased in the following years. Deforestation also rose significantly during the reporting period, with the average annual deforested area between 2011 and 2015 (30,667 hectares) being over three times greater than the average from 2001 to 2005. Logging was the main cause of forest degradation, accounting for up to 90% of the degradation during the reporting period. Almost all (99.3%) of the deforestation was due to converting forest land to cropland, with subsistence agriculture being the primary driver (69.8%), followed by oil palm plantation expansion (24.4%). However, in 2016 and 2017, logging and forest degradation slowed due to policy interventions.

In 2017, net emissions from the LULUCF sector were -12,724.94 kt CO_2 eq, down from -20,488.12 kt CO_2 eq in 2000, reflecting a total reduction in removals of -7,763.18 kt CO2 eq. This decline follows a rise to 5,617.42 kt CO_2 eq in 2015. The decrease in removals is due to the increasing area of degraded forest. Gross emissions from LULUCF, primarily due to the conversion of forestland to cropland, reached 9,397.82 kt CO_2 eq in 2017, nearly double the 5,886.90 kt CO_2 eq reported in 2000.

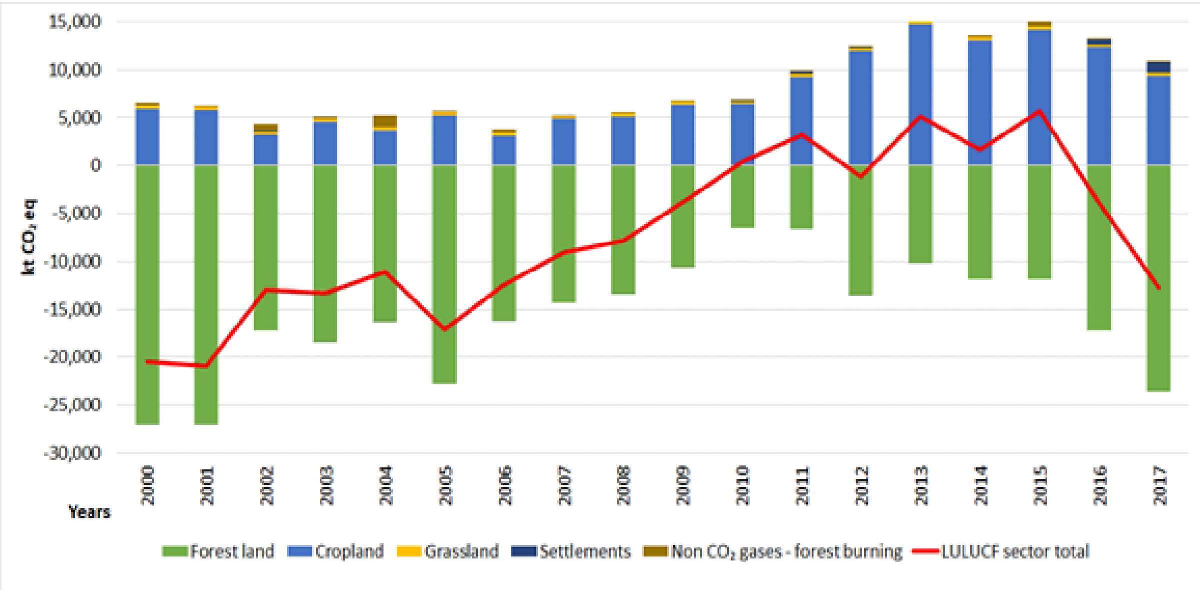

Figure 6: Time series of total GHG emissions and removals from the LULUCF sector by category (in kt CO2 eq) (Source: National Inventory Report 2000-2017)

Agriculture

In 2017, greenhouse gas (GHG) emissions from the agriculture sector totalled 935 kt CO_2 equivalent, representing approximately 9% of the country's overall emissions for that year. Compared to 2000, total GHG emissions from agriculture increased by 203 kt CO_2 equivalent, or 28%. The largest source of emissions in 2017 was direct N_2O emissions from managed soils, which accounted for 57% of the sector's total emissions. This was followed by enteric fermentation at 18%, manure management at 17%, and indirect N_2O emissions from managed soils at around 7%. The smallest contributor in the agriculture sector was indirect N_2O emissions from manure management.

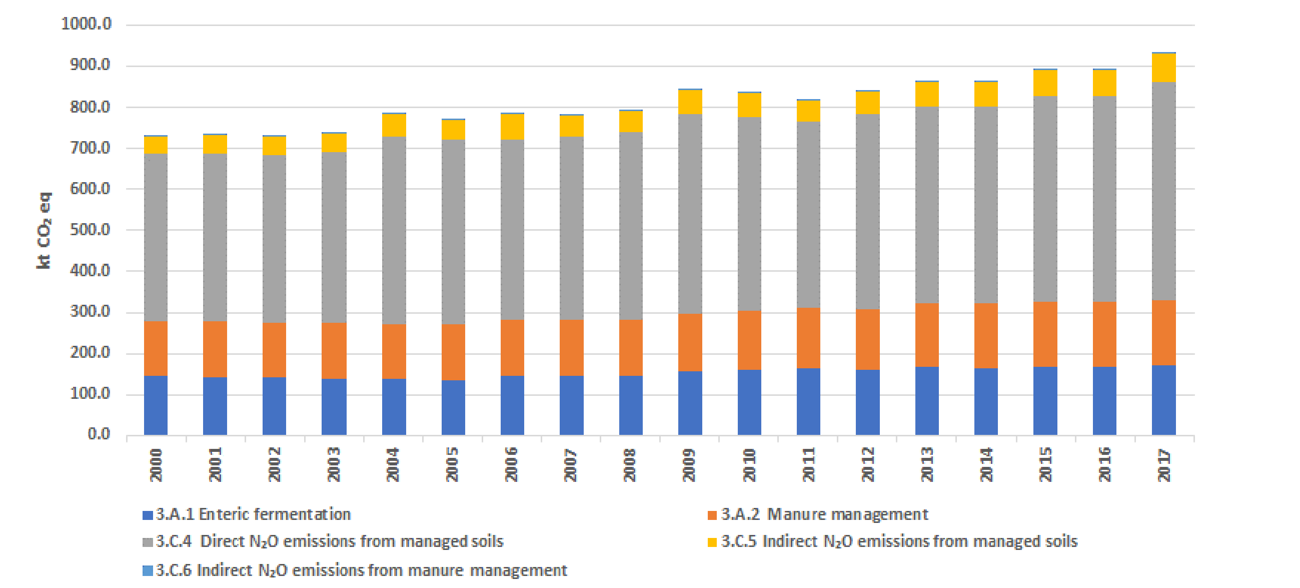

Figure 7: Trend in GHG emissions from the Agriculture sector from 2000 to 2017 (in kt CO2 eq) (Source: National Inventory Report 2000-2017)

Waste

In 2017, emissions from the waste sector resulted in 1,006 kt CO_2 eq. Emissions from the waste sector have risen consistently throughout the entire period from 2000 to 2017. This increase is driven by factors such as population growth, development, consumption rates, and migration from rural to urban areas. In 2017, the breakdown of emissions within the waste sector revealed that wastewater treatment and discharge were responsible for 67% of total sector emissions, followed by solid waste disposal at 27%, incineration, and open burning at 6%, and biological treatment of solid waste at 1%. The contributions of CO_2, CH_4, and N_2O to the sector's total emissions are 3.5%, 79.1%, and 17.4%, respectively.

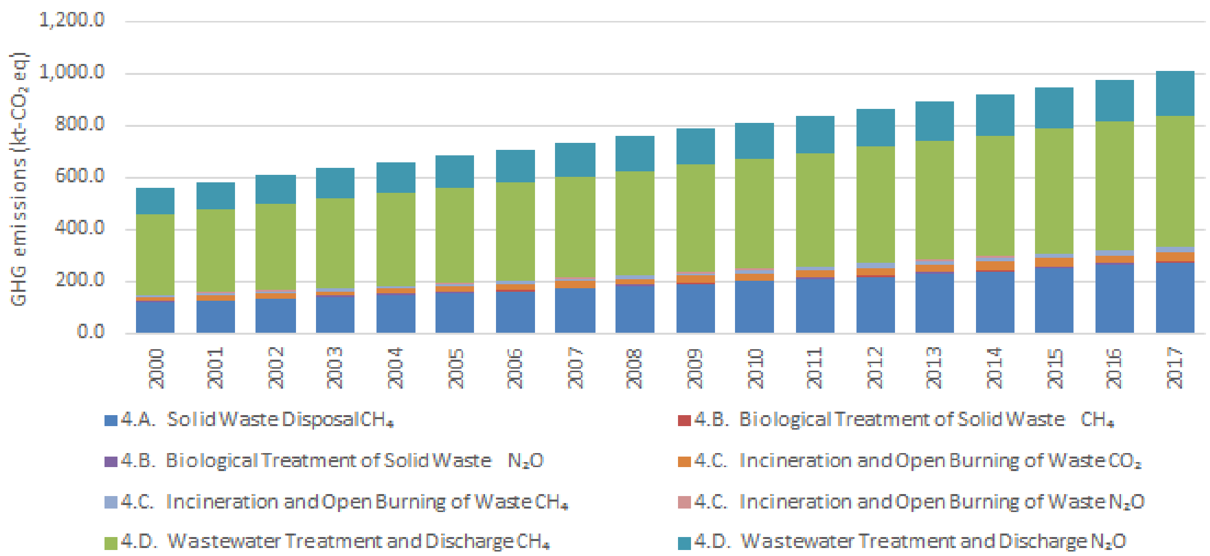

Figure 8:Trend in GHG emissions from the waste sector from 2000 to 2017 (in kt CO2 eq) (Source: National Inventory Report 2000-2017)

1.5.2. Process Involved in Sector Selection

1.5.2.1. Identifying Development Priorities

The process of identifying and prioritising technology options in PNG was closely aligned with the country's development priorities to ensure that technology implementation supports sustainable growth in key sectors.

This alignment was guided by an extensive review of PNG's national development strategies and policies, which provided the framework for addressing both current and future needs.

The identification of development needs was anchored in strategic national documents, including PNG Vision 2050, the Medium Term Development Plan IV 2023-2027 (MTDP IV), the PNG Climate Action Plan/SDG 13 Roadmap 2020, the PNG National REDD+ Strategy 2017-2027, the PNG National Energy Policy 2017-2027, the PNG National Transport Strategy 2013, the National Forest Policy 1991, and the National Climate Compatible Development Management Policy 2014. Additionally, PNG's international commitments under the UNFCCC—such as its National Communications, Biennial Update Reports, and Nationally Determined Contributions—were integral to identifying priority areas. These documents highlighted critical focus areas, including energy security, transport infrastructure development, sustainable land use practices, and biodiversity conservation.

The National TNA Team, in collaboration with relevant stakeholders and sector experts, used these guiding documents to identify and validate PNG's development priorities. Key priorities included enhancing energy access, reducing dependency on fossil fuels, improving transport efficiency, addressing deforestation and land degradation, and protecting biodiversity. This collaborative approach ensured that the identified needs reflected national aspirations while addressing sector-specific challenges.

The TNA process also incorporated forward-looking considerations to address how climate change, economic growth, and demographic shifts could influence PNG's development trajectory. For instance, the country's rapidly growing population and accelerating urbanisation are projected to increase energy demand and place significant pressure on transport infrastructure. Simultaneously, climate change poses risks such as coastal erosion, deforestation, and threats to biodiversity, underscoring the need for sustainable and resilient technologies to mitigate and adapt to these impacts.

By integrating current needs with future challenges, the TNA process ensured that technology choices would not only meet immediate goals but also build long-term resilience and sustainability across PNG's critical sectors.

1.5.2.2. Identifying Sectors with High GHG Relevance

Key sectors with high GHG emissions were identified to determine where PNG could achieve significant mitigation benefits. The National TNA Team assessed PNG's key GHG-emitting sectors based on the IPCC's sector categorisation. Sub-sectors within Energy and AFOLU with the highest emissions were identified using data from national GHG inventories and reports such as PNG's Enhanced NDC 2020 and the Second Biennial Update Report (BUR2) to the UNFCCC.

According to the BUR2, PNG's net GHG emissions have fluctuated significantly due to activities in the Land Use, Land-Use Change, and Forestry (LULUCF) sector. PNG transitioned from being a net sink of -12,436 kt CO2 equivalent in 2000 to a net source of 6,897 kt CO2 in 2016. However, in 2017, PNG returned to being a net sink, with total GHG emissions of -1,958 kt CO_2 equivalent. These fluctuations were primarily driven by deforestation and degradation within the LULUCF sector.

Excluding the LULUCF sector, PNG's net emissions rose from 8,052 kt CO_2 equivalent in 2000 to 10,767 kt CO_2 equivalent in 2017, representing a 34% increase. This rise was mainly due to growing fossil fuel consumption in the manufacturing, construction, and transport sectors. The key drivers included higher emissions from road transportation and energy use in industrial processes.

Table 1: Identification of sectors with high GHG relevance

Sector	Total GHG Emissions in 2017 (kt CO2-eq)	% of Annual GHG Emissions
Energy	8,673	~85% (calculated excluding LULUCF)
IPPU	153.3	~1.5%
Waste	1,006	~9.8%
LULUCF	-12,724.94 (Net Sink)	N/A (sector is a net sink)
Agriculture	935	~9%

Note: *The percentages are approximations based on total emissions excluding LULUCF due to its net sink status*

1.5.2.3. Prioritising Sectors Based on Development and Mitigation Potential

The prioritisation was conducted by evaluating each sector against the development priorities and their GHG emissions and reduction potential. Stakeholders rated each sector's contribution using a scoring system ranging from 1 (very small contribution) to 5 (very large contribution):

1 — very small contribution

2 — small contribution

3 — medium contribution

4 — large contribution

5 — very large contribution.

As result of this assessment, the Energy and LULUCF sectors were the top two prioritised sectors under the TNA project (Table 2).

Table 2: Results of Sector Selection

Sector	Development Priority Contribution (Environment, Economic & Social)	GHG Emissions Reduction Potential	Total Score	Priority
Energy	4	4	8	2
IPPU	3	2	5	5
Waste	3	3	6	4
LULUCF	5	5	10	1
Agriculture	5	2	7	3

PNG Power Limited

As a key energy stakeholder, PNG Power Limited plays a vital role in the Technology Needs Assessment process, contributing insights on sustainable energy solutions and priorities for PNG.

Figure 9: Consultation with PNG Power Limited, a key Energy Sector stakeholder in the TNA process

1.6. National Circumstances

1.6.1. Geographical Overview

PNG is a sovereign nation situated in the equatorial region of Maritime Southeast Asia. It encompasses the eastern portion of the world's second-largest island and ranks as the third-largest island country. PNG borders Indonesia on the mainland and has maritime boundaries with Australia, the Federated States of Micronesia, the Solomon Islands, and New Caledonia. Covering a total area of 461,000 km², PNG has an Exclusive Economic Zone of 3,120,000 km². Its extensive coastline stretches for 21,000 km and includes over 5,000 lakes, extensive river systems, and wetlands. The diverse mainland coast features more than 8,000 km of mangrove swamps, lagoons, wetlands, coral reefs, atolls, island archipelagos, and numerous offshore islands. PNG's varied geography supports a rich diversity of species, landscapes, and ecosystems.

1.6.2. Climate

PNG has a hot, humid tropical climate, which is characterised by high temperatures and humidity throughout the year. PNG has two monsoonal seasons, namely the northwest monsoon that occurs from December to March, and the southwest monsoon, which occurs from May to October. PNG is known to possess one of the wettest climates in the world, and rainfall in many areas can exceed 2,500mm per annum with the heaviest events occurring in the highland regions.

Average monthly rainfall ranges from 250 mm to 350 mm with an average monthly temperature range between 26^{o}C – 28 ^{o}C. More than 50 percent of PNG receives more than 2,500 mm per annum, but average rainfall in the drier regions is much lower. Relative humidity is quite high in PNG and ranges between 70 to 90 percent. Due to PNG's location, its climate and weather is governed by a number of factors. These include trade winds and the movement of the South Pacific Convergence Zone. Variability in the climate experienced year on year is strongly influenced by the El Nino conditions in the southeast Pacific. These conditions can result in drought conditions especially in the drier areas of PNG, and increased extreme weather such as frost, cyclones and flooding.

Climate variability is predicted to accelerate the occurrence of these extreme weather events, and these will have an increased impact on social, environmental, and economic systems, including natural ecosystems, soil productivity through soil erosion and landslides, the agriculture and water resources sectors, food security, and public health.

1.6.3. Population

The 2011 Census of Population and Housing estimated a total residential population of 7.28 million. Current population is forecast to be 10.33 million in 2023 with 24% of this population estimated to live in PNG's urban centres, and more than 40% of the total population estimated to be under the age of 14. According to the 2011 Census data, 40% of the population in the urban areas were not born there, indicating a major internal migration to urban centres.

According to the 2021 population estimates by the National Statistical Office (NSO), PNG has a total population of 11,781,559, comprising 6,142,585 males and 5,638,974 females, resulting in a sex ratio of 108.9 males per 100 females.

Key demographic indicators highlight that 61.6% of the population is of working age (15–64 years), while 2.7% are aged 65 and older, and 21.6% are youth (15–24 years). The total dependency ratio, which compares dependents (children under 15 and adults over 65) to the working-age population, stands at 62.4. Among these, the child dependency ratio is 58.1, and the old-age dependency ratio is 4.3.

The median age of the population is relatively young at 21.2 years, with males having a median age of 20.8 years and females at 21.7 years. Additionally, 57.2% of the population is aged 18 and over, while 55.3% of women are of reproductive age (15–49 years). These figures underline PNG's youthful population and the significant proportion of working-age individuals contributing to the country's labour force.

PNG is currently undergoing the updated National Census and the government plans on completing this by the end of 2025.

1.6.4. Overview of Economy

PNG has the largest economy among the Pacific Islands, driven primarily by its resource extraction, agriculture, forestry, and fishing industries. The economy is characterised by its small size, openness, and focus on exports, with a heavy reliance on resource extraction. Economic growth is closely linked to foreign investment in the resource sector. While the mining and energy sectors generate the majority of export earnings, agriculture employs most of the workforce. Key exports include petroleum gas, gold, palm oil, crude petroleum, and copper ore. PNG's major import partners are China, Australia, Singapore, Malaysia, and Indonesia.

PNG's economy is projected to experience significant growth in 2024, with the World Bank forecasting a GDP increase of 4.8%, a notable improvement from the 2.7% growth recorded in 2023. This acceleration is largely driven by a rebound in the mining sector, particularly the reopening of the Porgera gold mine. However, challenges persist, including inadequate infrastructure and limited investment in education, which are critical for sustaining long-term economic development. Addressing low productivity and diversifying the economy beyond natural resources are vital to achieving sustainable growth in the future.

Chapter Two: Institutional arrangement for the TNA and the stakeholder involvement

Climate change is one of the most pressing environmental challenges facing PNG. The CCDA is the designated national agency responsible for coordinating and implementing climate change-related tasks across all sectors. CCDA plays a critical role in ensuring that climate change considerations are mainstreamed into the development of national and sectoral plans, policies, and programs, in collaboration with relevant line ministries, provincial authorities, and other stakeholders.

As PNG's National Designated Authority (NDA) for climate change, the CCDA serves as the key focal point for communication and coordination with international organizations, including the UNFCCC and various climate-financing mechanisms. The CCDA's core responsibilities include representing PNG in international climate negotiations, preparing and submitting mandatory climate reports to the UNFCCC, and facilitating the implementation of national climate initiatives by aligning global-level decisions with PNG's priorities. This also includes endorsing and overseeing projects supported by international climate finance sources, such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), and other bilateral and multilateral mechanisms.

Stakeholder engagement remains a critical component of PNG's climate change efforts. The CCDA works closely with government ministries, provincial governments, development partners, private sector actors, academia, and civil society organizations to ensure a coordinated and inclusive approach to the TNA process. This collaboration helps identify technology priorities for mitigation and adaptation while reflecting the country's development goals and unique socio-economic and environmental context.

2.1 The National TNA team

The TNA team for PNG comprised the Mitigation Consultant and officers from the CCDA. This team was responsible for coordinating the TNA project, ensuring representation from a broad cross-section of agencies and ministries overseeing the priority sectors identified in the TNA process.

The TNA stakeholders – from the AFOLU, Energy and Transport sectors – included representatives from the following organisations and institutions in PNG:

Table 3: Stakeholder Institutions and Roles for the TNA Project in PNG

#	Organisations/ Institutions	Category	Role in TNA	Description
1	Ministry of Environment, Conservation and Climate Change	Public Sector	Driving Group	• Responsible for developing and implement policies, programs, and regulations to protect and manage the country's environment and natural resources. Also responsible for environmental regulation, pollution control, and collaborating with national and international stakeholders to achieve its objectives.
2	Climate Change and Development Authority	Public Sector	Driving Group	• Responsible for climate change policy and coordination. • Responsible for implementing the TAP.
3	PNG Forest Authority (PNGFA) • PNG Forest Research Institute (FRI)	Public Sector	Political Decision Makers	• Responsible for forest management and conservation. • Provides activity data on forest and land use change in PNG through the Collect Earth land use/land use change assessment. PNGFA also provides emissions factors for the different forest

				types in PNG through the National Forest Inventory (NFI) and the Permanent Sample Plots (PSPs)
4	Department of Agriculture & Livestock (DAL)	Public Sector	Political Decision Makers	• Responsible for agriculture and livestock development. • Provides activity data on agriculture and livestock to CCDA through the four DAL regional offices in the country. • Provides data on Fraction for the open burning activity to estimate the amount of open burned waste mainly in rural areas.
5	Department of Lands and Physical Planning (DLPP)	Public Sector	Political Decision Makers	• Responsible for land use planning and management. • Provides supplementary land use information/data through the National Land Use Information System (currently under development by DLPP and its key stakeholders).
6	Conservation and Environment Protection Authority (CEPA)	Public Sector	Political Decision Makers	• Responsible for environmental protection and conservation. • Provide activity data for industrial wastewater treatment and discharge. • Provide data/information on ration for wastewater treatment systems in PNG.
7	Department of National Planning and Monitoring (DNPM)	Public Sector	Political Decision Makers	• Responsible for national development planning and monitoring. • Responsible for the approval and disbursement of Public Investment Programme (PIP) funds.
8	Department of Finance (DoF)	Public Sector	Political Decision Makers	• Oversee and manage public finance within the country. Additionally, the department supports the government in achieving its fiscal policy initiatives through the development, formulation, and provision of financial policy advice.
9	Department of Treasury	Public Sector	Political Decision Makers	• Serves as the central agency responsible for formulating and implementing economic and financial policies for the government.
10	National Statistical Office of Papua New Guinea	Public Sector	Political Decision Makers	• Responsible for providing population data by region from 1950 to 2022 to estimate the amount of generated waste by using population data of the provinces and the waste generation ratio.
11	Department of Provincial and Local Level Government Affairs (DPLLGA) - Provincial Climate Change Committees (PCCC) or focal points in the 16 provinces of PNG	Public Sector	Political Decision Makers	• Responsible for provincial and local government affairs; oversees the provincial administrations. • Report information to CCDA regarding both mitigation and adaptation at the provincial and regional levels. • CCDA has established Climate Change Focal Points within the Provincial Administrations structure.
12	Department of Transport (DOT)	Public Sector	Political Decision Makers	• Responsible for transportation and infrastructure policy development.
13	National Energy Authority (NEA)	Public Sector	Implementing Driving Group	• Responsible for energy sector development • Leads the development of PNG Energy Balance Table
14	Department of Petroleum (DOP)	Public Sector	Political Decision Makers	• Regulates and administers all petroleum-related projects in the country. The department is responsible for administering PNG's energy sector, combining economic growth through resource

				exploitation with environmental conservation and sustainability.
15	Department of Mineral Policy and Geohazards Management (DMPGM)	Public Sector	Political Decision Makers	• DMPGM balances the economic benefits of mineral resource extraction with public safety from geological risks.
16	Mineral Resource Authority (MRA)	Public Sector	Political Decision Makers	• Responsible for regulating, growing, and sustainably managing the mining industry within the country.
17	Papua New Guinea Chamber of Mines & Petroleum	Public Sector	Political Decision Makers	• Representing and advocating for the interest of mining companies in the country.
18	Department of Commerce and Industry	Public Sector	Political Decision Makers	• Responsible for developing sustainable economic growth, improving the country's competitiveness in international commerce, and creating a favorable economic climate through strategic partnerships.
19	Department of Rural Development and Implementation	Public Sector	Political Decision Makers	• Enhancing rural development and improving service delivery at the grassroots level.
20	Constitutional and Law Reform Commission and Department of Justice and Attorney General	Public Sector	Political Decision Makers	• Ensuring the rule of law, promoting justice, and reforming the legal system to better serve the nation.
21	Department of Religion, Youth and Community Development (DRYCD)	Public Sector	Political Decision Makers	• DRYCD is mandated to promote harmonious society through the promotion of religious harmony, youth and woman empowerment, and community development.
22	Papua New Guinea Customs Service	Public Sector	Political Decision Makers	• Responsible for customs and border management.
23	National Capital District Commission (NCDC)	Public Sector	Political Decision Makers	• Provide data for industrial wastewater treatment and discharge.
24	Department of Labor and Industrial Relations (DLIR)	Public Sector	Political Decision Makers	• DLIR is mandated to promote fair labor practices, protecting worker rights, and promoting industrial peace.
25	Bank of Papua New Guinea	Public Sector	Political Decision Makers	• Responsible for ensuring price stability and maintaining macroeconomic growth within the country.
26	University of Papua New Guinea (UPNG)	Civil Society	Technical Support	• Involved in education and research and development activities, provide technical expertise, capacity building, policy support, and innovation and technology transfer.
27	Papua New Guinea University of technology (UNITECH)	Civil Society	Technical Support	• Involved in education and research and development activities, provide technical expertise, capacity building, policy support, and innovation and technology transfer.
28	Papua New Guinea University of Natural Resource and Environment (UNRE)	Civil Society	Technical Support	• Involved in education and research and development activities, provide technical expertise, capacity building, policy support, and innovation and technology transfer.
29	Papua New Guinea National Research Institute (PNG NRI)	Civil Society	Technical Support	• The PNG NRI has two primary functions: (a) to promote research on Papua New Guinea society and economy, and (b) to conduct research on social, political, and economic issues in the country,

				with the aim of formulating practical solutions to these problems.
30	Papua New Guinea National Agriculture Research Institute (PNG NARI)	Civil Society	Technical Support	• Providing services to the wider agricultural community through scientific research and development with main focus on economic resilience and development, resilience of rural communities and systems (Climate Adaptation), health and sustainable diets, and delivery at scale.
31	Food and Agriculture Organization of the United Nations (FAO)	Civil Society	Technical Support	• Partner with Government of PNG (GoPNG) in implementing climate change mitigation and adaptation projects.
32	United Nations Development Program (UNDP)	Public Sector	Technical Support	• Partner with Government of PNG (GoPNG) in implementing climate change mitigation and adaptation projects.
33	European Union (EU)	Public Sector	Technical Support	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
34	Japan International Cooperation Agency (JICA)	Public Sector	Technical Support	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
35	Global Green Growth Institute (GGGI)	Public Sector	Technical Support	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
36	Asian Development Bank (ADB)	Public Sector	Partner Organization	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
37	UN Climate Technical Centre and Network (CTCN)	Public Sector	Technical Support	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
38	Australian Government	Civil Society	Technical Support	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
39	USAID	Civil Society	Technical Support	• Partner with the GoPNG in implementing climate change mitigation and adaptation projects.
40	Wildlife Conservation Society	Civil Society	Social & Institutional Support	• Engaged in wildlife conservation and research. • Collaborate with the project in addressing climate change issues related to wildlife conservation.
41	Centre for Environmental Law & Community Rights Inc. (CELCOR)	Civil Society	Social & Institutional Support	• Focused on protecting the environmental and customary rights of the people of Papua New Guinea through law and advocacy.
42	The Natures Conservancy (TNC)	Civil Society	Social & Institutional Support	• Aims to protect and restore the lands and waters that are vital for sustaining life on Earth.
19	PNG Power Limited	Private Sector	Interest and Opinion	• Involved in power generation and distribution.
43	Water PNG Limited	Private Sector	Interest and Opinion	• Provide activity data for industrial wastewater treatment and discharge. • Provide data/information on ratio for wastewater treatment systems in PNG. • Provides data on Inlet industrial wastewater con centration.
44	ExxonMobil PNG	Private Sector	Interest and Opinion	• Engaged in energy and resource development.
45	Puma Energy Limited	Private Sector	Interest and Opinion	• Ensures the continuous supply of downstream oil and gas services as well as necessary fuels.
46	Total Waste Management Group	Private Sector	Interest and Opinion	• Provides activity data on incineration.
47	Agribusiness industries	Private Sector	Interest and Opinion	• Involved in agricultural and business activities (I.e., New Britain Palm Oil Limited (NBPOL),

				TrukaiAgri- Industries Limited, Ramu Agri-Industries Limited (RAIL), Rumion Piggery & Cattle Farming; Niugini Table Birds, and a few other private agri-business industries)
48	Oil Palm Industry Corporation (OPIC)	Private Sector	Interest and Opinion	• Plays a crucial part in the growth and sustainability of the oil palm sector in Papua New Guinea, emphasizing the responsible management of the industry's environmental impact as well as the social and economic advancement of smallholder farmers.
49	Papua New Guinea Forest Industries Association (PNGFIA)	Private Sector	Interest and Opinion	• PNGFIA plays a crucial role in advocating for the interests of the forest industry, promoting sustainable practices, and ensuring that the sector contributes positively to the country's economy and environment.
50	Solar Energy Association of PNG	Private Sector	Interest and Opinion	• Promoting the adoption and utilization of solar energy within PNG.

The National Mitigation Consultant and the National TNA Coordinator play critical roles in the TNA project. The Mitigation Consultant focuses on identifying, analysing, and prioritising mitigation technologies, preparing detailed factsheets, engaging stakeholders, and leading the evaluation of technologies using Multi-Criteria Analysis (MCA) tool. Meanwhile, the TNA Coordinator manages and oversees the entire process, ensuring alignment with national policies and commitments, facilitating stakeholder engagement, organising workshops, and acting as the focal point for communication with international partners. Together, they ensure that the TNA delivers feasible, cost-effective, and sustainable technology solutions aligned with PNG's climate change and development goals. The project's institutional arrangement is depicted in Figure 10.

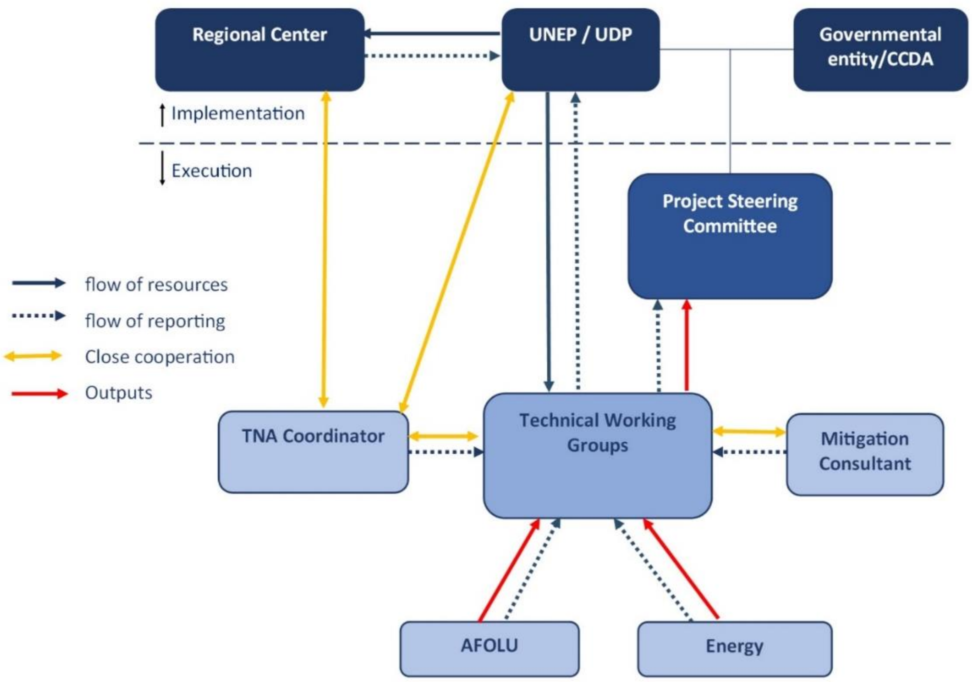

Figure 10: PNG TNA Project's Institutional Arrangements

2.1.1 Roles and Responsibilities

TNA National Steering Committee
This committee is chaired by the CCDA, provides a high-level guidance, political oversight and cross-sectoral coordination throughout the TNA Process in PNG and comprises of senior representatives from the key institutions and organisations listed in Table 3.

AFOLU and Energy Technical Working Committee
Provide sector-specific expertise, guiding the identification, evaluation, and prioritisation of AFOLU and Energy technologies aligned with national goals and climate commitments**.**

TNA Coordinator
The Manager of the Measurement, Reporting and Verification (MRV) Branch of the PNG Climate Change and Development Authority serves as the National TNA Coordinator. He is the focal person overseeing stakeholder involvement, coordination, and communication in the TNA process.

Technical Working Groups (TWG)
Provide technical expertise, identify and prioritise sector-specific technologies, and ensures alignment with national development plans and climate commitments. They support data collection and analysis, and evaluate technologies using the Multi-Criteria Analysis (MCA). The TWG also prepares detailed recommendations for inclusion in the TNA report, ensuring that the identified technologies are sustainable, cost-effective, and tailored to PNG's sectoral needs and priorities.

Mitigation consultant
Responsible for identifying and prioritising technologies, conducting barrier analyses, and performing market assessments. Additionally, the consultant plays a key role in drafting project proposals for priority technologies within their area of expertise.

The TNA Team (Consultant, TWGs and TNA Coordinator) is responsible for conducting assessments, collecting data, and engaging in consultations to support the TNA process. Stakeholders actively contribute by offering input, providing comments, and supporting the process at various stages. External partners play a crucial role by offering technical and financial support while also participating in consultations to ensure the successful implementation of the TNA.

2.2 Stakeholder Engagement Process Followed in TNA– Overall Assessment

To ensure synergy, country ownership, and sustainability, PNG utilised its existing climate change institutional framework to implement the TNA project. The CCDA serves as the Chair of the National TNA Project Steering Committee, providing high-level oversight and coordination. The CCDA also plays the coordinating role, engaging members from various organisations and institutions in the two inter-ministerial Technical Working Groups for AFOLU and Energy sectors. Officers from CCDA's MRV and National Communication Division form the National Climate Change Technical Team for the TNA process and are part of the National TNA Teams for mitigation. These teams are technically supported by the national consultants and experts from UNEP DTU.

The TNA process commenced with a joint Biennial Transparency Report (BTR) and TNA Inception Workshop in Port Moresby in April 2024, facilitated by CCDA, and was followed by the recruitment of the Mitigation Consultant. The workshop brought together participants from government agencies, non-governmental organisations, academia, and the private sector. During the workshop, TNA was introduced, followed by small group discussions aimed at identifying priority mitigation technology options. The outcomes of these discussions served as the basis for further consultations and analysis in subsequent steps of the TNA preparation process.

The TNA built upon PNG's progress in analysing mitigation measures for the prioritised mitigation sectors included in PNG's Enhanced NDC 2020. This progress included conducting cost-benefit analyses, projecting emissions, and identifying technological solutions outlined in the PNG Enhanced NDC 2020 Implementation Plan

(2021-2030), and the PNG NDC Implementation Roadmaps for AFOLU and Energy sectors. NDC Implementation Plan. The TNA focused on these same sectors, namely AFOLU/LULUCF sectors, Energy, and Transport sectors.

Potential technologies were identified through a literature review of key national implementation plans, NDC, Medium Term Development Plan IV 2023-2027, and other relevant overarching sector-specific policies leading to the development of technology factsheets. A Multi-Criteria Analysis (MCA) was applied to evaluate the identified technologies based on factors such as cost, mitigation potential, socio-economic impacts, and climate related impacts.

Key stakeholders previously involved in the development of the NDC, NDC IP, and NDC Roadmap were integral to the TNA process due to their familiarity with mitigation issues and methodologies such as MCA. Many of these stakeholders, who are also part of the TNA Technical Working Groups, provided valuable feedback on the draft TNA report for mitigation. PNG's approach emphasises consistent stakeholder engagement and collaboration, ensuring that mitigation priorities are well understood, inclusive, and effectively implemented across sectors.

2.3. Consideration of gender aspects in the TNA process

The Technology Needs Assessment process actively integrated gender considerations to ensure that technology solutions are inclusive, equitable, and meet the needs of all stakeholders. This was achieved through gender-sensitive stakeholder workshops and the technology selection process.

Workshops were tailored to ensure equal participation from all genders. Efforts were made to create accessible and safe spaces for discussions, including gender-specific sessions when necessary. These workshops also provided opportunities for skill building, with a focus on empowering underrepresented gender groups, particularly women.

The technology selection processes included gender-sensitive questions and analysis to ensure a thorough understanding of the varying needs, experiences, and challenges different genders face in accessing and using technology. This approach helped identify gaps in technology access and usage that may affect specific gender groups. Furthermore, Gender was also used as a key criterion in selecting the technologies assessed during the TNA process. Technologies were evaluated not only for their technical feasibility and effectiveness but also for their potential to address gender-specific needs and reduce barriers faced by underrepresented gender groups. This ensured that the chosen technologies would contribute to greater gender equity and inclusivity in their implementation.

Chapter Three: Technology Prioritisation for the Energy Sector

3.1 Existing Technologies of the Energy Sector

The energy sector in PNG relies heavily on hydropower and diesel-powered generators, along with limited contributions from natural gas, solar energy, and wind. Diesel generators, commonly used in rural and remote areas, are inefficient and contribute significantly to GHG emissions. Transitioning from these inefficient systems to more sustainable options, such as expanding hydropower capacity or incorporating solar photovoltaic (PV) systems, could significantly improve energy efficiency and reduce GHG emissions. Furthermore, adopting energy efficiency measures for buildings and industrial processes would decrease electricity demand, further minimising reliance on diesel and reducing associated emissions.

Electricity in PNG is primarily generated and supplied by PNG Power Limited (PPL), which operates several hydropower plants, such as Rouna (62 MW) and Yonki (273 MW), as well as thermal power plants that rely on diesel and heavy fuel oil. The country has an estimated installed capacity of approximately 580 -900 megawatts, but significant portions of the population, particularly in rural areas, remain without access to reliable electricity (Asian Development Bank 2024).

The high cost of electricity production, coupled with infrastructure challenges and limited subsidies, makes electricity access in PNG among the most expensive in the Pacific region. This presents a barrier to the widespread adoption of renewable energy technologies such as solar PV, as well as energy efficiency measures for residential and commercial users. Addressing these barriers through policy reforms, subsidies, and infrastructure investments is critical for transitioning PNG's energy sector to a more sustainable and efficient future.

3.2 Decision Context for the Energy Sector

Public policy on energy security in PNG is led by the National Energy Authority (NEA) in collaboration with other key government agencies, including the CCDA. These agencies work together to develop and implement policies and strategies guided by key policy frameworks, such as the National Energy Policy (2017–2027), and the National Electrification Roll-Out Plan (NEROP). Private sector participants, including energy importers, producers, and distributors, operate in accordance with the Companies Act 2014, while PNG Power Limited, a state-owned enterprise, has legal authority for electricity generation, transmission, and distribution across the country.

In PNG's rural areas, traditional energy sources such as biomass remain dominant, while modern energy markets rely heavily on petroleum products for electricity generation and transportation. Forest biomass, including firewood, is widely used to meet household energy needs, particularly for cooking and heating. Compliance with energy sector regulations, public safety standards, and private sector participation is overseen by regulatory bodies such as the NEA and the Independent Consumer and Competition Commission (ICCC).

As in many developing countries, PNG's energy sector operates in a dual market system: traditional biomass fuels dominate in rural and peri-urban areas, while modern energy carriers, such as electricity and petroleum products, are concentrated in urban centres. Forest biomass accounts for the majority of household energy consumption in PNG, while petroleum-based products are a significant source of energy for transportation and electricity generation. The country's electricity access remains at 19 percent, meaning that over 80 per cent of PNG's population — mainly in rural areas — lacks reliable access to power (Australia-Papua New Guinea Business Council 2024). Modern renewable energy sources, such as solar and hydropower, contribute only a small fraction to the national energy mix but are increasingly being prioritised for expansion.

In light of the government's commitment to transitioning to a green economy and achieving its NDCs, the TNA analysis has provided critical insights into potential technological interventions. These technologies are vital for the successful implementation of PNG's NDC targets. In addition to identifying suitable technologies, complementary measures are necessary, including policy reforms, strengthened institutional frameworks, energy efficiency initiatives, and effective operation and maintenance systems embedded within dynamic asset management processes. Moreover, public awareness and education on climate change can significantly enhance the adoption and impact of sustainable energy solutions, further supporting PNG's efforts to reduce greenhouse gas emissions and build climate resilience.

3.3. An Overview of Selected Mitigation Technology Options for the Energy Sector

GHG emissions of the energy sector resulting from the energy sector can be mitigated if proper technology options are selected. Seven technologies were assessed in terms of their potential and feasibility of GHG reduction potential. The table below presents the pre-selected technologies will be analysed using the MCA:

Table 4: List of Technologies for MCA of the Energy Sector

No	Technology	Features
1	Biogas Power Plant	- It is a renewable energy - Produces organic fertilizer as a by product - Proven, mature and reliable technology - Very good scalability
2	Biomass Power Plant	- It is a renewable energy - It is a mature technology - Biomass energy generally produces fewer greenhouse gas emissions compared to coal, oil, and natural gas

		- Biomass can be sourced locally, reducing dependence on imported fossil fuels and contributing to energy security.
3	Geothermal Power Plant	- It is a renewable energy - It is a mature technology - Geothermal power plants require relatively small land areas compared to other energy sources like wind farms or solar fields - Geothermal power plants provide reliable, consistent power (baseload energy
4	Hydro Power Plant	- It is a renewable energy - It is a mature technology - Reliable and Flexible: Hydropower provides baseload power and can quickly adjust output to meet demand.
5	Solar Power Plant	- It is a renewable energy - It is a mature technology - Solar energy can be harnessed for decades, with solar panels typically lasting 25-30 years or more with minimal maintenance - Once a solar power plant is installed, its operating costs are relatively low compared to fossil fuel power plants.
6	Wind Power Plant	- It is a renewable energy - It is a mature technology - Scalability: Wind power plants can be scaled according to the region's needs, with installations ranging from small, local turbines to large, utility-scale wind farms.
7	Gasifier Stoves Using Biomass	- It is a renewable energy - It is a mature technology - Reduced Time Spent Collecting Fuel: Biomass gasification stoves require less fuel to produce the same amount of heat, which means that people spend less time collecting firewood or biomass. - Off-Grid Solution: Biomass gasification stoves are especially useful in off-grid or remote areas where access to modern energy sources like electricity or LPG is limited or unavailable.

Information of these technologies was organised and tabulated in seven technologies factsheets, which have been finalised based on the mitigation consultant's assessment and discussions with CCDA. These factsheets contained information on the technology characteristics and potential of applications in the country (see Appendix 4).

3.4. Criteria and Process of Technology Prioritization for the Energy sector

3.4.1. Process of Technology Prioritisation

The process of technology prioritisation for PNG involved reviewing emissions sources and sinks, assessing existing mitigation technologies in the Energy sector, and then prioritising the technologies. The review of emission sources, sinks, and mitigation technologies is detailed in earlier sections. This section focuses on the specific activities and approach used for technology prioritisation, particularly the workshops, including the steps and methodologies employed during this process.

The technology prioritisation workshops were held between August and September 2024, with participation from representatives of various government departments, academic institutions, research organisations, the private sector, and international organisations. The consultations also involved stakeholders at the sub-national level. The list of participants can be found in Appendix 1 and 2. Before the broader stakeholder consultations, key stakeholders were briefed on emission sources, sinks, and mitigation technologies and options during targeted meetings organized by the Mitigation Consultant and the National TNA Coordinator.

These briefings also included technologies recommended in previous national reports, such as the PNG Enhanced NDC 2020 Implementation Plan (2021-2030), PNG Enhanced NDC Implementation Roadmaps for AFOLU and Energy Sectors (2021-2030), AFOLU Mitigation Plan (2022-2024), and Energy Mitigation Plan 2022-2025). During the meetings, key stakeholders were introduced to the MCA process by the Mitigation Consultant to ensure they fully understood the process and could contribute meaningfully to technology prioritization and the overall TNA process.

3.4.2. Identification of Evaluation Criteria

The identification, evaluation, and categorisation of technologies were conducted by stakeholders based on the technology options presented in Table 4 and other sources. Expert judgment was used to assess the applicability and availability of each technology. From this process, seven technology options were selected through expert judgment, and the final three priority technologies were identified using multi-criteria analysis (MCA) and scoring techniques.

The criteria for prioritising these technologies were grouped into three main categories: (1) Cost, covering capital, operating, and maintenance costs; (2) Benefits, including economic, social, environmental, sustainability, and climate-related benefit; and (3) Other, such as readiness and preparedness. These criteria were discussed and agreed upon by stakeholders at both sub-national and national levels, with the TNA guidebook serving as the primary reference. Table 5 outlines weights that were assigned to each category, criteria and criterion. Furthermore, table 6 outlines the scale used by each criterion for scoring the technologies and the preferred value.

Table 5: Weights assigned to category, criteria and criterion

Criteria category	Category Weight	Criteria	Weight within category	Criterion	Weight within criteria	Overall weight
Cost	40%	Capital cost	33%			40%*33 = 13.3%
		Operation	33%			40%*33 = 13.3%
		Maintenance	33%			40%*33 = 13.3%
Benefits	40%	Economic	25%	Technology benefits for the national economy	100%	40%*25%*100%=10%
		Social	25%	Creating new job opportunities & Community contribution	80%	40%*25%*80%=8%
				Gender equity	20%	40%*25%*20%=2%
		Environmental	15%	No waste, pollution or any other environmental impact	100%	40%*15%*100%=6%
		Sustainability	15%	Continuity of the energy source, ensuring the availability of spare parts, possibility of maintenance and ability to withstand under all circumstances	100%	40%*15%*100%=6%
		Climate-related	20%	Reduction of GHG emissions, mainly CO_2 and CH_4	100%	40%*20%*100%=8%
Other	20%	Country readiness and preparedness	100%	National Circumstances	20%	20%*100%*20%=4%
				Topography	30%	20%*100%*30%=6%
				Availability of information and data	25%	20%*100%*25%=5%
				Availability of national experts	25%	20%*100%*25%=5%

Table 6: Criteria, weight and scale score used to prioritise technologies

Criteria category	Criteria	Criterion	Scale Score	Preferred Value	Weight
Cost	Capital cost	Capital costs	0=very high cost --> 100=very low cost	lower	13.3%
	Operation	Operational Cost	0=very high cost --> 100=very low cost	lower	13.3%
	Maintenance	Maintenance Cost	0=very high cost --> 100=very low cost	lower	13.3%
Benefits	Economic	Technology benefits for the national economy	0= Very low --> 100= Very high	higher	10%
	Social	Creating new job opportunities & Community contribution	0= Very low --> 100= Very high	Higher	8%
		Gender equity	0= Very low --> 100= Very high	higher	2%
	Environmental	No waste, pollution or any other environmental impact	0= Very low --> 100= Very high	higher	6%
	Sustainability	Continuity of the energy source, ensuring the availability of spare parts, possibility of maintenance and ability to withstand under all circumstances	0= Very low --> 100= Very high	higher	6%
	Climate-related	Reduction of GHG emissions, mainly CO_2 and CH_4	0= Very low --> 100= Very high	higher	8%
Other	Country readiness and preparedness	National Circumstances	0=Very Difficult -->100=Very Easy	easier	4%
		Topography	0=Very Difficult -->100=Very Easy	easier	6%
		Availability of information and data	0=Very Difficult -->100=Very Easy	easier	5%
		Availability of national experts	0=Very Difficult -->100=Very Easy	easier	5%

After establishing the evaluation criteria, the Consultant presented detailed technology factsheets see (Appendix 4) to the stakeholders for all seven identified technologies. These factsheets provided detail information, highlighting both the costs and the associated benefits, and the country's readiness of each technology, as outlined earlier.

3.4.3 Evaluation of the Technologies

The next step in the technology prioritisation process using MCA involved developing a rating scale. After stakeholders completed their review of the Technology Factsheets (TFS), performance was assessed using a score range of 0 to 100. For costs, the scale ranged from 0 (very high) to 100 (very low), for benefits, it ranged from 0 (very low) to 100 (very high), while for country readiness and preparedness it ranged from 0 (very difficult) to 100 (very easy). The evaluation was based on information from the TFS, national reports, and expert judgments. Using these inputs, a performance matrix for the energy sector was created, as shown in Table 6, following an evaluation of the technologies with the UNEP-DTU MCA Excel-based calculator. The complete scoring scale is as follows:

Table 6: Scoring/Performance matrix for energy sector technologies

Technology	Costs			Benefits						Other			
				Economic	Social		Environmental	Sustainability	Climate related	Country readiness and preparedness			
	Capital cost	Operational Cost	Maintenance Cost	Technology benefits for the national economy	Creating new job opportunities & Community contribution	Gender equity	No waste, pollution or any other environmental impact	Ability to withstand various conditions	Reduction of GHG emissions, mainly CO2 and CH4	National Circumstances	Topography	Availability of information and data	Availability of national experts
Biogas Power Plant	20	30	60	40	40	20	30	40	80	10	10	5	10
Biomass Power Plant	10	10	40	40	40	20	30	40	80	10	10	5	10
Geothermal Power	30	50	20	30	30	20	25	35	70	10	10	70	10
Hydro Power Plant	40	40	50	60	60	20	25	60	100	50	50	70	70
Solar Power Plant	60	40	30	65	65	20	30	70	100	60	60	40	50
Wind Power Plant	50	40	10	40	40	20	70	50	100	40	40	5	5
Gasifier Stoves Using Biomass	99	99	99	25	25	70	60	35	80	90	90	5	10
Criterion weight (%)	13.3	13.3	13.3	10	8	2	6	6	8	4	6	5	5
Data Source	Expert judgement based on the TFS			Expert judgement						Expert Judgement based on National Literature			

3.4.4 Scoring the Technologies

The TNA team prepared Technology Fact Sheets (TFS) for the pre-selected technologies and shared them with stakeholders to guide the evaluation process. Afterward, once the performance matrix was finalised, the Mitigation Consultant, CCDA TNA team, and experts in the energy sector scored each technology against the criteria as part of the fifth step of the MCA process. Preferences were rated on a scale from 0 to 100, as shown in Table 7, which provides detailed information on the total scores for each technology option.

Table 7: Decision matrix for energy sector technologies

Technology	**Costs**			**Benefits**						**Other**				**Total Score**
				Economic	**Social**		**Environmental**	**Sustainability**	**Climate related**	**Country readiness and preparedness**				
	Capital cost	Operational Cost	Maintenance Cost	Technology benefits for the national economy	Creating new job opportunities & Community contribution	Gender equity	No waste, pollution or any other environmental impact	Ability to withstand various conditions	Reduction of GHG emissions, mainly CO2 and CH4	National Circumstances	Topography	Availability of information and data	Availability of national experts	
Biogas Power Plant	2.7	4.0	8.0	4.0	3.2	0.4	1.8	2.4	6.4	0.4	0.6	0.3	0.5	34.6
Biomass Power Plant	1.3	1.3	5.3	4.0	3.2	0.4	1.8	2.4	6.4	0.4	0.6	0.3	0.5	27.9
Geothermal Power	4.0	6.7	2.7	3.0	2.4	0.4	1.5	2.1	5.6	0.4	0.6	3.5	0.5	33.3
Hydro Power Plant	5.3	5.3	6.7	6.0	4.8	0.4	1.5	3.6	8.0	2.0	3.0	3.5	3.5	53.6
Solar Power Plant	8.0	5.3	4.0	6.5	5.2	0.4	1.8	4.2	8.0	2.4	3.6	2.0	2.5	53.9
Wind Power Plant	6.7	5.3	1.3	4.0	3.2	0.4	4.2	3.0	8.0	1.6	2.4	0.3	0.3	40.6
Gasifier Stoves Using Biomass	13.2	13.2	13.2	2.5	2.0	1.4	3.6	2.1	6.4	3.6	5.4	0.3	0.5	67.3
Criterion weight (%)	13.3	13.3	13.3	10	8	2	6	6	8	4	6	5	5	100

3.4.5 Weighing

The total weighted score for each technology option was calculated automatically using the MCA template, based on the predefined criterion weights as shown in Table 5. The MCA template applies the following formula:

- Score of option $i\ S_i = \Sigma_{j}{}^{n}{=}_1\ w_j S_{ij}$
    - w_j weight of criterion *j,*
    - S_{ij} - score of option *I on criterion j*
- S ij - from scoring matrix

3.4.6. Results of Technology Prioritisation for the Energy Sector

The top four mitigation technologies include Gasifier Stoves Using Biomass, Solar Power Plant, Hydro Power Plant and, Wind Power Plant. Table 8 outlines the ranking each technology including their scores.

Table 8: The selected technology for the Energy Sector

Rank	Technology	Score
1	Cook Stoves In Biomass Gasification	67.3
2	Solar Power Plant	53.9
3	Hydro Power Plant	53.6
4	Wind Power Plant	40.6
5	Biogas Power Plant	34.6
6	Geothermal Power	33.3
7	Biomass Power Plant	27.9

Chapter Four: Technology Prioritisation for the Transport Sector

4.1. Existing Technologies of the Transport Sector

In PNG, land transport primarily relies on vehicles powered by internal combustion engines using gasoline and diesel. The country's diverse geography, characterised by rugged mountainous terrain, extensive rainforests, vast river systems, and low-lying coastal plains, poses challenges to road infrastructure. Roads vary widely in quality and type, ranging from unsealed gravel roads in rural areas to asphalt highways in urban centers. These factors significantly affect vehicle efficiency and operational costs.

The demand for vehicles in PNG is steadily increasing, driven by economic development, urbanisation, and population growth. This includes a rise in used-imported vehicles, which are commonly used due to their affordability. Additionally, there is an increasing preference for vehicles with larger engine sizes, particularly four-wheel drives, which are well suited to the challenging terrain but contribute to higher fuel consumption and greenhouse gas emissions.

4.2 Decision Context for the Transport Sector

PNG's long-term transport development goals are outlined in the National Strategic Plan (Vision 2050), which serves as the country's economic development framework. Vision 2050 prioritises service delivery, human capital development, and wealth creation, with the expansion of transport services being fundamental to achieving these objectives. The National Transport Strategy (2014-2030) aligns with these goals, which envisions a resilient and integrated transport infrastructure that facilitates sustainable economic growth and social development in PNG.

According to the PNG National Transport Strategy and the 2020 National Transport Asset Management Plan (NTAMP), the state of PNG's transportation infrastructure remains a major challenge. Many roads, especially in rural and remote areas, are unsealed and poorly maintained, while bridges and culverts are in urgent need of repairs and upgrades. The national focus is shifting towards rehabilitating and upgrading existing infrastructure, rather than constructing new roads and bridges, with an emphasis on improving transport connectivity in the provinces.

In urban areas like Port Moresby, transportation issues are marked by inadequate road infrastructure, which causes frequent traffic congestion. Poor road conditions, including extensive potholes and the absence of effective drainage systems, exacerbate the problem. Furthermore, existing road construction techniques often fail to meet the demands of PNG's tropical climate, leading to rapid deterioration of infrastructure.

PNG's Enhanced NDC 2020 sets an ambitious target to reduce GHG emissions of achieving 50 per cent carbon neutrality by 2030, compared to a business-as-usual scenario. This target includes a focus on sustainable transportation solutions such as the adoption of low-carbon vehicles, including electric vehicles, and the improvement of road infrastructure to be more resilient to the impacts of climate change.

In order to accomplish these goals, it is necessary for all parties involved – government organisations, private sector/businesses, and local communities – to work together to adopt cutting-edge and climate smart technologies that support resilience and sustainability in the Transport sector. In addition to improving the welfare of its people and protecting the environment, PNG can make a substantial contribution to international efforts to mitigate climate change.

4.3. An overview of selected Mitigation Technology Options for the Transport Sector

GHG emissions of the transport sector resulting from fuel consumption can be mitigated if proper technology options are selected. Five technologies were assessed in terms of their potential and feasibility of GHG reduction potential. Table 9 presents the pre-selected technologies to be analysed using the MCA.

Table 9: List of Technologies for MCA of the Transport Sector

No	Technology	Features
1	Electric Vehicles	- The cost of electricity per mile is usually much lower than the cost of gasoline or diesel - Electric motors are much more efficient at converting energy into motion than internal combustion engines - Electric vehicles have fewer moving parts compared to traditional vehicles
2	Hybrid Vehicles	- Hybrid vehicles are designed to optimize fuel consumption by using both an internal combustion engine (ICE) and an electric motor - Powerful Combined Performance - Lower Overall Operating Costs
3	Compressed Natural Gas in Transport	- Reduces dependence on imported oil and enhances local energy security. - Fuel Efficiency - Significantly cheaper fuel costs and more stable prices
4	Improved Urban/Suburban Public Transport System using LPG Buses	- Longer Vehicle Life

		- LPG is generally less expensive than diesel or gasoline, which makes operating LPG buses more cost-effective in the long run
5	Introduction of biofuel in transport	- Biofuels can be produced locally from domestic agricultural resources, decreasing reliance on foreign oil and reducing exposure to fluctuations in global fuel prices - Community Empowerment

4.4. Criteria and Process of Technology Prioritisation for the Transport Sector

4.4.1 Process of Technology Prioritisation

The process of technology prioritisation for PNG involved reviewing emissions sources and sinks, assessing existing mitigation technologies in the Transport sector, and then prioritising the technologies. The review of emission sources, sinks, and mitigation technologies is detailed in earlier sections. This section focuses on the specific activities and approach used for technology prioritisation, particularly the workshops, including the steps and methodologies employed during this process.

The technology prioritisation workshops were held between August and September 2024, with participation from representatives of various government departments, academic institutions, research organisations, the private sector, and international organisations. The consultations also involved stakeholders at the sub-national level. The list of participants can be found in Appendix 1 and 2. Before the broader stakeholder consultations, key stakeholders were briefed on emission sources, sinks, and mitigation technologies and options during targeted meetings organised by the Mitigation Consultant and the National TNA Coordinator.

These briefings also included technologies recommended in previous national reports, such as the PNG Enhanced NDC 2020 Implementation Plan (2021-2030), PNG Enhanced NDC Implementation Roadmaps for AFOLU and Energy Sectors (2021-2030), AFOLU Mitigation Plan (2022-2024), and Energy Mitigation Plan 2022-2025). During the meetings, key stakeholders were introduced to the MCA process by the Mitigation Consultant to ensure they fully understood the process and could contribute meaningfully to technology prioritisation and the overall TNA process.

4.4.2 Identification of Evaluation Criteria

The identification, evaluation, and categorisation of technologies were conducted by stakeholders based on the technology options presented in Table 9 and other sources. Expert judgment was used to assess the applicability and availability of each technology. From this process, four technology options were selected through expert judgment, and the final two priority technologies were identified using multi-criteria analysis (MCA) and scoring techniques.

The criteria for prioritising these technologies were grouped into three main categories: (1) Cost, covering capital, operating, and maintenance costs; (2) Benefits, including economic, social, environmental, sustainability, and climate-related benefits; and (3) Other, such as readiness and preparedness. These criteria were discussed and agreed upon by stakeholders at both sub-national and national levels, with the TNA guidebook serving as the primary reference. Table 10 outlines weights that were assigned to each category, criteria and criterion. Furthermore, Table 11 outlines the scale used by each criterion for scoring the technologies and the preferred value.

Table 10: Weights assigned to category, criteria and criterion

Criteria category	Category Weight	Criteria	Weight within category	Criterion	Weight within criteria	Overall weight
Cost	40%	Capital cost	33%			40%*33 = 13.3%
		Operation	33%			40%*33 = 13.3%
		Maintenance	33%			40%*33 = 13.3%
Benefits	40%	Economic	35%	Positive impacts of the technology on the economy	100%	40%*35%*100%=14%
		Social	15%	Social benefits in terms of society and gender equity	100%	40%*15%*100%=6%
		Environmental	10%	No adverse environmental impacts such as waste and pollution	100%	40%*10%*100%=4%
		Sustainability	20%	Ability to withstand various conditions	100%	40%*20%*100%=8%
		Climate-related	20%	Reduction of GHG emissions, mainly CO_2 and CH_4	100%	40%*20%*100%=8%
Other	20%	Country readiness and preparedness	100%	National Circumstances	10%	20%*100%*10%=2%
				Topography	50%	20%*100%*50%=10%
				Availability of information and data	20%	20%*100%*20%=4%
				Availability of national experts	20%	20%*100%*20%=4%

Table 11:Criteria, weight, and scale score used to prioritize technologies

Criteria category	Criteria	Criterion	Scale Score	Preferred-Value	Weight
Cost	Capital cost	Capital costs	0=very high cost --> 100=very low cost	lower	13.3
	Operation	Operational Cost	0=very high cost --> 100=very low cost	lower	13.3
	Maintenance	Maintenance Cost	0=very high cost --> 100=very low cost	lower	13.3
Benefits	Economic	Technology benefits for the national economy	0=very high cost --> 100=very low cost	higher	14
	Social	Social benefits in terms of society and gender equity	0= Very low --> 100= Very high	higher	6
	Environmental	No adverse environmental impacts such as waste and pollution	0= Very low --> 100= Very high	higher	4
	Sustainability	Ability to withstand various conditions	Very low --> 100= Very high	higher	8
	Climate-related	Reduction of GHG emissions, mainly CO_2 and CH_4	0= Very low --> 100= Very high	higher	8
Other	Country readiness and preparedness	National Circumstances	0=Very Difficult -->100=Very Easy	easier	2
		Topography	0=Very Difficult -->100=Very Easy	easier	10
		Availability of information and data	0=Very Difficult -->100=Very Easy	easier	4
		Availability of national experts	0=Very Difficult -->100=Very Easy	easier	4

After establishing the evaluation criteria, the Consultant presented detailed technology factsheets (Appendix 4) to the stakeholders for all four identified technologies. These factsheets provided detail information, highlighting both the costs and the associated benefits, and the country's readiness of each technology, as outlined earlier.

4.4.3 Evaluation of the Technologies

The next step in the technology prioritisation process using MCA involved developing a rating scale. After stakeholders completed their review of the TFS, performance was assessed using a score range of 0 to 100. For costs, the scale ranged from 0 (very high) to 100 (very low), for benefits, it ranged from 0 (very low) to 100 (very high), while for country readiness and preparedness it ranged from 0 (very difficult) to 100 (very easy). The evaluation was based on information from the TFS, national reports, and expert judgments. Using these inputs, a performance matrix for the transport sector was created, as shown in Table 12, following an evaluation of the technologies with the UNEP-DTU MCA Excel-based calculator. The complete scoring scale are outlined in Table 13.

Table 12: Performance matrix for the Transport sector

Technology	**Costs**			**Benefits**					**Other**			
				Economic	**Social**	**Environmental**	**Sustainability**	**Climate related**	**Country readiness and preparedness**			
	Capital cost	Operational Cost	Maintenance Cost	Positive Impacts of the technology on the national economy	Social benefits in terms of society and gender equity	No adverse environmental impacts such as waste and pollution	Ability to withstand various conditions	Reduction of GHG emissions, mainly CO2 and CH4	National Circumstances	Topography	Availability of information and data	Availability of national experts
Electric Vehicles	20	70	80	50	60	50	50	100	40	10	10	5
Hybrid Vehicles	35	25	70	40	60	50	50	70	40	10	10	5
Compressed Natural Gas in Transport	30	28	50	55	30	40	60	20	50	15	10	5
Improved Urban/Suburban Public Transport System using LPG Buses	40	10	10	55	50	40	30	20	15	15	10	10
Introduction of biofuel in transport	50	30	60	40	40	55	40	70	20	10	10	15
Criterion weight (%)	13.3	13.3	13.3	14	6	4	8	8	2	10	4	4
Data Source	Expert judgment based on the TFS			Expert judgement					Expert Judgement based on National Literature			

4.4.4 Scoring the Technologies

The mitigation team prepared Technology Fact Sheets (TFS) for the pre-selected technologies and shared them with stakeholders to guide the evaluation process. Afterward, once the performance matrix was finalised, the Mitigation Consultant, CCDA TNA team, and experts in the Transport sector scored each technology against the criteria as part of the fifth step of the MCA process. Preferences were rated on a scale from 0 to 100, as shown on Table 11, with Table 12 providing detailed information on the total scores for each technology option.

Table 13: Decision matrix for the Transport Sector

Technology	**Costs**			**Benefits**					**Other**				**Total Score**
				Economic	**Social**	**Environmental**	**Sustainability**	**Climate related**	**Institutional/Implementation**			**Political**	
	Capital cost	Operational Cost	Maintenance Cost	Positive Impacts of the technology on the national economy	Social benefits in terms of society and gender equity	No adverse environmental impacts such as waste and pollution	Ability to withstand various conditions	Reduction of GHG emissions, mainly CO2 and CH4	National Circumstances	Topography	Availability of information and data	Availability of national experts	
Electric Vehicles	2.66	9.31	10.64	7	3.6	2	4	8	0.8	1	0.4	0.2	49.61
Hybrid Vehicles	4.66	3.33	9.31	5.6	3.6	2	4	5.6	0.8	1	0.4	0.2	40.49
Compressed Natural Gas in Transport	3.99	3.72	6.65	7.7	1.8	1.6	4.8	1.6	1	1.5	0.4	0.2	34.96
Improved Urban/Suburban Public Transport System using LPG Buses	5.32	1.33	1.33	7.7	3	1.6	2.4	1.6	0.3	1.5	0.4	0.4	26.88
Introduction of biofuel in transport	6.65	3.99	7.98	5.6	2.4	2.2	3.2	5.6	0.4	1	0.4	0.6	40.02
Criterion weight (%)	13.3	13.3	13.3	14	6	4	8	8	2	10	4	4	100

4.4.5 Weighing

The total weighted score for each technology option was calculated automatically using the MCA template, based on the predefined criterion weights as shown in Table 14. The MCA template applies the following formula:

- Score of option $i\, S_i = \Sigma_{j}{}^{n}{=}_1\, w_j S_{ij}$
    - w_j weight of criterion *j,*
    - S_{ij} - score of option *I on criterion j*
- S *ij* - from scoring matrix

4.4.6. Results of Technology Prioritisation for the Transport Sector

The top two mitigation technologies include electric vehicles and hybrid vehicles. Table 14 below outlines the ranking including their scores.

Table 14: The selected technology for the Transport Sector

Rank	Technology	Score
1	Electric Vehicles	49.61
2	Hybrid Vehicles	40.49
3	Introduction of biofuel in transport	40.02
4	Compressed Natural Gas in Transport	34.96
5	Improved Urban/Suburban Public Transport System using LPG Buses	26.88

Chapter Five: Technology Prioritisation for LULUCF Sector

5.1 Existing Technologies of the LULUCF Sector

PNG has implemented a range of technologies in the LULUCF sector to support sustainable land management, forest conservation, and climate change mitigation. Forest monitoring and measurement systems play a crucial role in managing the country's forest resources. The PNG National Forest Monitoring System (NFMS), utilising Sentinel and Landsat imagery, monitors forest cover and deforestation trends. The monitoring component of PNG's NFMS, called the PNG Near-real Time Deforestation Alerts and Monitoring System, tracks tree cover loss in the country on a near-real-time basis. The PNG NFMS can be accessible at https://png-nfms.org/.

In the area of Sustainable Forest Management (SFM), technologies such as Community-Based Forest Management (CBFM) have been introduced in some provinces, where landowners are supported to sustainably manage forests. Similarly, Reduced Impact Logging (RIL) techniques are being adopted by companies logging companies in the country to minimise environmental damage during timber extraction. Agroforestry systems integrating crops such as cocoa and coffee with native trees have also been implemented in parts of Morobe and Central Provinces to restore degraded land and improve community livelihoods.

Reforestation and afforestation technologies are essential for carbon sequestration and land rehabilitation. The PNG Forest Authority's (PNGFA) national reforestation program aims to plant 800,000 hectares of trees by 2050 for commercial, community, and conservation purposes. In remote and degraded areas, drone-assisted reforestation has been trialled for efficient seed dispersal, particularly in the Western Province, while community-led mangrove restoration efforts in the country (E.g Mangoro Market Meri programme by The Nature Conservancy, Koke Hanua Mangrove Nursery, etc.) support coastal ecosystem rehabilitation.

Technologies addressing soil carbon sequestration and land restoration are also in use. For example, the application of Biochar has been trialled PNG University of Technology (Unitech) Farm in Lae, Morobe Province, to improve soil fertility and increase carbon storage. Additionally, conservation agriculture practices have been promoted in certain parts of PNG to restore degraded lands.

PNG's NFMS enhance transparency and accountability in forest carbon monitoring. The National Forest Inventory (NFI) by PNGFA combines ground-based data collection with remote sensing to assess carbon stocks, while the PNG REDD+ MRV system (a component of the NFMS), provides a robust framework for tracking emissions reductions in REDD+ programs.

Technologies for protected area management have been critical for biodiversity conservation. The Protected Area Network (PAN) Monitoring System, overseen by the Conservation and Environment Protection Authority (CEPA), uses GIS-based tools to monitor protected areas like Varirata National Park and Wildlife Management Areas in the country. In addition, tools such as camera traps and acoustic sensors are being deployed by organisations like WWF-PNG to monitor biodiversity in areas such as the Trans-Fly Eco-region of the Western Province.

The sustainable palm oil sector in PNG has also adopted advanced technologies to reduce environmental impacts. Companies like New Britain Palm Oil Limited adhere to RSPO standards and use GIS monitoring systems to ensure deforestation-free production. Furthermore, precision agriculture tools for efficient water and nutrient management are being applied in West New Britain Province to enhance productivity while minimising environmental damage.

Fire detection and management technologies are critical in protecting forests and grasslands. Satellite-based hotspot detection systems, utilised by the PNG National Weather Service, monitor fire risks in real time. In addition, community-driven fire management plans, including controlled burning practices, have been implemented in fire-prone areas such as West New Britain Province to address the threat of wildfires that are being exacerbated by climate change (Live & Learn 2019).

These technologies, including forest monitoring systems, sustainable forest management practices, reforestation techniques, and fire management tools, has demonstrate PNG's commitment to sustainable land use and climate change mitigation. However, further investments in technology transfer, capacity building, and financial support are needed to scale up these initiatives and address existing gaps effectively.

5.2 Decision Context for LULUCF

The forests in PNG play a critical role in supporting the livelihoods of local communities and contributing to the economic development of the country. These forests provide essential resources such as energy, food, timber, and non-timber forest products, while also sustaining household, community, and national wealth and health. PNG's forests cover approximately 78% of the country's land area (PNGFA 2022), making them one of the largest intact tropical rainforests in the in the world (third largest rainforest in the world). The forestry sector in PNG contributes approximately 7 percent to the nation's Gross Domestic Product (Business Advantage PNG 2012), with potential for greater value if managed sustainably.

Despite this, PNG's forests have been in decline, with deforestation reducing levels of forest cover and degradation changing the nature of a significant portion of PNG's forests. PNG's Forest Reference Level (FRL), submitted to the UNFCCC in 2017, identified that between 2000 and 2015, 261,528 ha of forest was cleared, resulting in average emissions of over 5m tCO2e per annum. This deforestation has been primarily driven by the conversion of forest-land to crop-land which accounts for 87% of deforestation (PNGFA 2022).

Of this shifting agriculture is responsible for 63% of the land deforested and commercial agricultural developments, primarily in the form of oil palm are responsible for 30% of the deforested land. The trend in clearance for commercial agriculture has increased in the past decade following the rapid expansion of Special Agricultural Business Leases (SABLs), which were allocated over 5.1m ha. While only a small number of these have initiated development and there has been an official moratorium and subsequent suspension of them, some logging and conversion has occurred.

The impacts of deforestation and forest degradation in the country are severe and multifaceted. These activities contribute to soil erosion, land degradation, and loss of biodiversity in critical ecosystems such as lowland rainforests and mangroves. Deforestation further exacerbates agricultural productivity decline, disrupts hydrological cycles, and increases the risk of flooding and landslides, particularly in vulnerable highland and coastal areas. Moreover, forest loss significantly affects PNG's ability to act as a global carbon sink, reducing carbon sequestration capacity and contributing to its role as a net greenhouse gas (GHG) emitter.

To achieve PNG's emissions reduction targets and to safeguard the future of one of the country's most important strategic assets, PNG must reduce the impact of the primary direct and indirect drivers of forest cover change. This require action that cuts across government sectors and stakeholder groups and is undertaken at every level from the national to provincial, district, local and ward levels. These actions must not stop the processes of economic and social development but ensure that the country's forests are utilised in ways that are in line with the principles of responsible and sustainable development and that deliver the maximum long-term benefits to the people of PNG.

Under PNG's National REDD+ Strategy, a range of policies and measures have been identified and clustered under three main REDD+ Action Areas to address direct and underlying drivers of deforestation and forest degradation:

I. Strengthened land-use and development planning

- Strengthened and Coordinated National Level Development and Land Use Planning through development of climate and REDD+ relevant development indicators (DNPM) within the national development framework and strengthening of development of national land-use policy, planning and legislation (DLPP).
- Integrated Subnational Planning through strengthening ward and LLG level planning and strategic development planning at provincial, and district level and the linkages between levels of planning (DPLGA and DNPM).

II. Strengthened environmental management, protection and enforcement

- This action will involve reviewing and updating of Climate Change legislation led by CCDA to link with changing domestic and international legislation, development of robust financial management systems to integrate climate finance with work of key sectors, support to development of capacity within Climate Change institutions to effectively support and coordinate action on Climate Change across sectors, levels of government and stakeholder groups.
- It will also involve strengthening of forest management and enforcement practices led by PNG Forest Authority (PNGFA) through updating of forest policy to consolidate amendments and incorporation of legality standards, strengthening capacity of the PNGFA to enforce legislation through review of resources and support to development of management systems, strengthening alternative approaches to timber production and processing through expansion of plantations and small-scale timber producers, increase capacity of PNGFA and training and research institutions to raise awareness of and operationalise improved approaches to timer operations including legislation through support to universities, training colleges, government staff, communities and timber operators.
- Furthermore, it will involve strengthening environmental management, enforcement and protection led by Conservation and Environment Protection Authority (CEPA) through strengthening of environmental policies, regulations and guidelines, strengthening enforcement capacity of CEPA, strengthening the capacity of Provincial governments for environmental management, strengthen conservation planning, financing and management and strengthen access to information and recourse mechanisms: (multi-stakeholder action) through support to civil society groups to increase community and land holder awareness of their legal rights and requirements for environmental management and development planning as well as access to legal support to address breaches in those rights and management systems.

III. 3. Enhanced economic productivity and sustainable livelihoods

- Development of a sustainable commercial agriculture sector led by Department of Agriculture and Livestock (DAL) and Department of National Planning and Monitoring (DNPM) through improvements in guidelines and regulations for sustainable production of commercial products.
- Strengthened food security and increased productivity of family agriculture led by DAL/FPDA through strengthening and expansion of extension services and support to rural communities.

While these action areas are separated within the strategy, they are mutually supportive and coordination between areas is critical to achieving emission reductions and supporting the transformational change towards a responsible and sustainable approach to development (CCDA 2024).

5.3 An Overview of Possible Mitigation Technology Options in the LULUCF sector and their Mitigation Benefits

Seven technologies were assessed in terms of their potential and feasibility of GHG reduction potential and other related benefits. Table 15 provides an overview of potential mitigation technology options for the LULUCF sector in PNG, along with their associated mitigation benefits. These pre-selected technologies will be analysed using the MCA.

Table 15: List of Technologies for MCA of the LULUCF Sector

No.	Technology	Features
1	Reduced Deforestation and Forest Degradation	- Reduces annual deforestation by 25% (8,300 ha/year) and forest degradation by 25% (43,300 ha/year) by 2030. - Converts LULUCF sector from net GHG source (+1,716 Gg CO_2e) to a net GHG sink (-8,284 Gg CO_2e).
2	Reforestation and Rehabilitation	- Restores degraded forest areas and enhances biodiversity. - Includes large-scale and community-based tree planting initiatives, such as PNG's 10-million-trees campaign under the *Painim Graun Planim Diwai* initiative.
3	Sustainable Land Use Planning	- Develops land use plans optimising agriculture, forestry, and conservation. - Balances development and forest preservation
4	Downstream Processing for Forestry Products	- Promotes domestic wood processing and phases out log exports for sustainability. - Encourages carbon-efficient production and responsible forest management, reducing emissions across the forestry value chain.
5	Application of Environmental Safeguards	- Strengthens environmental monitoring and enforcement at the sub-national level. - Ensures compliance with policies like PNG's National Environmental Management Strategy (2021-2025), reducing emissions and promoting sustainable practices.
6	Sustainable Palm Oil Development	- Implements certification schemes and improved practices to reduce deforestation. - Aligns with the PNG National REDD+ Strategy to limit forest loss and promote carbon sequestration.
7	Protected Area Development and Management	- Establishes and manages protected areas to conserve biodiversity and enhance carbon sinks. - Reflects PNG's Protected Area Policy, focusing on community engagement and sustainable ecosystem management.

Information of these technologies was organised and tabulated in seven technologies factsheets, which have been finalised based on the mitigation consultant's analysis and discussions with CCDA. These factsheets contained information on the technology characteristics and potential of applications in the country (see Appendix 4).

5.4 Criteria and process of technology prioritisation for LULUCF sector

5.4.1 Process of Technology Prioritisation

The process of technology prioritisation for PNG involved reviewing emissions sources and sinks, assessing existing mitigation technologies in the LULUCF sector, and then prioritising the technologies. The review of emission sources, sinks, and mitigation technologies is detailed in earlier sections. This section focuses on the specific activities and approach used for technology prioritisation, particularly the workshops, including the steps and methodologies employed during this process.

The technology prioritisation workshops were held between August and September 2024, with participation from representatives of various government departments, academic institutions, research organisations, the private sector, international organizations, and projects. The consultations also involved stakeholders at the sub-national level. The list of participants can be found in Appendix 1 and 2. Before the broader stakeholder consultations, key stakeholders were briefed on emission sources, sinks, and mitigation technologies and options during targeted meetings organized by the Mitigation Consultant and the National TNA Coordinator.

These briefings also included technologies recommended in previous national reports, such as the PNG Enhanced NDC 2020 Implementation Plan (2021-2030), PNG Enhanced NDC Implementation Roadmaps for AFOLU and Energy Sectors (2021-2030), AFOLU Mitigation Plan (2022-2025), and Energy Mitigation Plan (2022-2025). During the meetings, key stakeholders were introduced to the MCA process by the Mitigation Consultant to ensure they fully understood the process and could contribute meaningfully to technology prioritization and the overall TNA process.

5.4.2 Identification of Evaluation Criteria

The identification, evaluation, and categorisation of technologies were conducted by stakeholders based on the technology options presented in Table 15 and other sources. Expert judgment was used to assess the applicability and availability of each technology. From this process, seven technology options were selected through expert judgment, and the final three priority technologies were identified using MCA and scoring techniques.

The criteria used to prioritise these technologies were grouped into two main categories: (1) Cost, which includes capital costs as well as operating and maintenance expenses; and (2) Benefits, encompassing economic, social, environmental, and climate-related benefits. These criteria were discussed and agreed upon by stakeholders at both the sub-national and national levels, using the TNA guidebook as the primary reference document. Table 16 outlines weights that were assigned to each category, criteria and criterion. Furthermore, table 17 outlines the scale used by each criterion for scoring the technologies and the preferred value.

Table 16: Weights assigned to category, criteria and criterion

Criteria category	Category Weight	Criteria	Weight within category	Criterion	Weight within criteria	Overall weight
Cost	40%	Capital cost	50%			40%*50% = 20%
		Operation & Maintenance	50%			40%*50% = 20%
Benefits	40%	Economic	35%	Improve growth and diversification	50%	40%*35%*50%=7%
				Job creation	50%	40%*35%*50%=7%
		Social	25%	Poverty alleviation	60%	40%*25%*60%=6%
				Reduce Inequality	40%	40%*25%*40%=4%
		Environmental	20%	Protect biodiversity	50%	40%*20%*50%=4%
				Support ecosystem services	50%	40%*20%*50%=4%
		Climate-related	20%	GHG emission reduction	100%	40%*20%*10%=8%
Other	20%	Institutional/Implementation	60%	Institutional arrangement and governance	40%	20%*60%*40%=4.8%
				Ease of Implementation	40%	20%*60%*40%=4.8%
				Replicability	20%	20%*20%*20%=2.4%
		Political	40%	Coherence with national development policies and priority	100%	20%*40%*100%=8%

Table 17: Criteria weight and scale score used to prioritise technologies for LULUCF sector

Criteria category	Criteria	Criterion	Scale Score	Preferred Value	Weight (%)
Cost	Capital cost	Capital costs	0=very high cost --> 100=very low cost	Lower	20
	Operating and maintenance Cost	Operating and maintenance costs	0=very high cost --> 100=very low cost	Lower	20
Benefits	Economic	Improve growth and diversification	0= Very low --> 100= Very high	Higher	7
		Job creation	0= Very low --> 100= Very high	Higher	7
	Social	Poverty alleviation	0= Very low --> 100= Very high	Higher	6
		Reduce Inequality	0= Very low --> 100= Very high	Higher	4
	Environmental	Protect biodiversity	0= Very low --> 100= Very high	Higher	4
		Support ecosystem services	0= Very low --> 100= Very high	Higher	4
	Climate related	GHG emission reduction	0= Very low --> 100= Very high	Higher	8
Other	Institutional/Implementation	Institutional arrangement and governance	0=Very Difficult -->100=Very Easy	Easier	4.8
		Ease of Implementation	0=Very Difficult -->100=Very Easy	Easier	4.8
		Replicability	0=Very Difficult -->100=Very Easy	Easier	2.4
	Political	Coherence with national development policies and priority	0=Very Difficult -->100=Very Easy	Easier	8

After establishing the evaluation criteria, the Consultant presented detailed technology factsheets to the stakeholders for all seven identified technologies. These factsheets provided detail information, highlighting both the costs and the associated benefits, and the country's readiness of each technology, as outlined earlier.

5.4.3 Evaluation of the Technologies

The next step in the technology prioritisation process using MCA involved developing a rating scale. After stakeholders completed their review of the Technology Factsheets (TFS), performance was assessed using a score range of 0 to 100. For costs, the scale ranged from 0 (very high) to 100 (very low), for benefits, it ranged from 0 (very low) to 100 (very high), while for country readiness and preparedness it ranged from 0 (very difficult) to 100 (very easy). The evaluation was based on information from the TFS, national reports, and expert judgments. Using these inputs, a performance matrix for the LULUCF sector was created, as shown in Table 18, following an evaluation of the technologies with the UNEP-DTU MCA Excel-based calculator. The complete scoring scale is as follows:

Table 18: LULUCF Sector Performance Matrix

Technology	**Costs**		**Benefits**							**Other**			
			Economic		**Social**		**Environmental**		**Climate related**	**Institutional/Implementation**			**Political**
	Capital cost	O&M Cost	Economic Growth and Diversification	Job Creation	Poverty Alleviation	Reduce Inequality	Protect Biodiversity	Support Ecosystem Services	GHG Emission Reduction	Institutional arrangement and governance	Ease of Implementation	Replicability	Coherence with national development policies and priority
Reduced Deforestation and Forest Degradation	80	50	50	50	75	75	100	100	100	75	75	80	90
Reforestation and Rehabilitation	50	50	50	75	75	50	75	100	100	65	70	80	85
Sustainable Land Use Planning	50	40	75	50	80	80	100	100	75	80	85	90	90
Downstream Processing for Forestry Products	10	25	100	100	75	50	25	50	50	60	55	60	70
Application of Environmental Safeguards	75	25	50	50	50	75	100	75	80	70	75	80	85
Sustainable palm oil development	10	25	100	100	75	50	50	50	75	60	70	80	75
Protected area development and management	50	25	75	75	55	55	100	100	75	85	80	85	90
Criterion weight (%)	20	20	7	7	6	4	4	4	8	4.8	4.8	2.4	8
Data Source	Expert judgement based on the TFS		Expert judgement based on TFS						Expert judgement	Expert Judgement based on National Literature			

5.4.4 Scoring the Technologies

The mitigation team prepared Technology Fact Sheets (TFS) for the pre-selected technologies and shared them with stakeholders to guide the evaluation process. Afterward, once the performance matrix was finalised, the Mitigation Consultant, CCDA TNA team, and experts in the LULUCF sector scored each technology against the criteria as part of the fifth step of the MCA process. Preferences were rated on a scale from 0 to 100, as shown on Table 18, with Table 19 providing detailed information on the total scores for each technology option.

Table 19: LULUCF Sector Scoring Matrix

Technology	Costs		Benefits							Other				Total score
			Economic		Social		Environmental		Climate related	Institutional/Implementation			Political	
	Capital cost	O&M Cost	Economic Growth and Diversification	Job Creation	Poverty Alleviation	Reduce Inequality	Protect Biodiversity	Support Ecosystem Services	GHG Emission Reduction	Institutional arrangement and governance	Ease of Implementation	Replicability	Coherence with national development policies and priority	
Reduced Deforestation and Forest Degradation	16	10	3.5	3.5	4.5	3	4	4	8	3.6	3.6	1.92	7.2	72.82
Reforestation and Rehabilitation	10	10	3.5	5.25	4.5	2	3	4	8	3.12	3.36	1.92	6.8	65.45
Sustainable Land Use Planning	10	8	5.25	3.5	4.8	3.2	4	4	6	3.84	4.08	2.16	7.2	66.03
Downstream Processing for Forestry Products	2	5	7	7	4.5	2	1	2	4	2.88	2.64	1.44	5.6	47.06
Application of Environmental Safeguards	15	5	3.5	3.5	3	3	4	3	6.4	3.36	3.6	1.92	6.8	62.08
Sustainable palm oil development	2	5	7	7	4.5	2	2	2	6	2.88	3.36	1.92	6	51.66
Protected area development and management	10	5	5.25	5.25	3.3	2.2	4	4	6	4.08	3.84	2.04	7.2	62.16
Criterion weight (%)	20	20	7	7	6	4	4	4	8	4.8	4.8	2.4	8	100

5.4.5 Weighing

The total weighted score for each technology option was calculated automatically using the MCA template, based on the predefined criterion weights as shown in Table 20. The MCA template applies the following formula:

- Score of option i $S_i = \sum_{j}^{n}{=_1} w_j S_{ij}$
    - w_j weight of criterion *j,*
    - S_{ij} - score of option *I on criterion j*
- S ij - from scoring matrix

5.4.6 Results of technology prioritisation for LULUCF Sector

The outcomes of the technology prioritisation process after the MCA procedure are displayed in Table 20. According to the table, "Reduced Deforestation and Forest Degradation" is the most important mitigation technology in the LULUCF sector, followed by "Sustainable Land Use Planning." "Reforestation and Rehabilitation" is the third priority technology that from the technology prioritisation exercise.

Table 20: Final Ranking of technologies from LULUCF Sector

Rank	Technology	Score
1	Reduced Deforestation and Forest Degradation	72.82
2	Sustainable Land Use Planning	66.03
3	Reforestation and Rehabilitation	65.45
4	Protected area development and management	62.16
5	Application of Environmental Safeguards	62.08
6	Sustainable palm oil development	51.66
7	Downstream Processing for Forestry Products	47.06

Chapter Six: Summary and Conclusion

A stakeholder participatory process, as outlined in the "Guidebook for Countries Conducting a Technology Needs Assessment and Action Plan" developed by the UNEP DTU Partnership, was utilised in the preparation of the TNA report for PNG. The process was a nationally driven and inclusive process involving relevant stakeholders, ensuring gender considerations were integrated throughout. It was led by the Mitigation Consultant with support from the TNA Coordinator and the TNA Technical Working Groups.

Initial consultations with stakeholders and a comprehensive review of key national policies, including PNG's Vision 2050, Medium Term Development Plan IV 2023-2027, the National Climate Compatible Development Management Policy, the Enhanced NDC 2020 and the Enhanced NDC Implementation Plan 2021-2030, led to the prioritisation of technologies for mitigation. The three sectors prioritised for mitigation technologies were energy, Transport, and LULUCF.

A detailed list of potential technologies was initially identified for each sector, considering factors such as costs involve, the socio-economic benefits, applicability to the local context, availability, and stakeholder acceptance. The list was subsequently refined during stakeholder workshops and one-on-one consultation meetings with the key stakeholders. For the energy sector, seven (7) technologies were shortlisted, five (5) technologies for the Transport sector, and seven (7) for the LULUCF sector.

Technology factsheets were developed for the shortlisted technologies through stakeholders' consultations workshops and one-one meetings with the stakeholders. These technologies underwent further prioritisation and analysis using Multi-Criteria Analysis tools. The evaluation criteria included cost, environmental and socio-economic benefits, sustainability, climate related benefits, and others.

The final technology prioritisation resulted in the identification of key technologies for the respective sectors, which will play a crucial role in advancing PNG's mitigation efforts while aligning with the country's national climate commitments and development priorities. The top seven technologies for the three mitigation sectors will be used for the next step of the TNA Process, the Barrier Analysis and Enabling Framework, and the development of PNG's Technology Action Plan. The technologies are as follows:

Table 21: Mitigation Technologies Prioritised and Selected for the Technologies Action Plans in PNG

Sector	No.	Technologies
Energy	1	Gasifier Stoves Using Biomass
	2	Solar Power Plant
	3	Hydro Power Plant
Transport	1	Electric Vehicles
	2	Hybrid Vehicles
LULUCF	1	Reduced Deforestation and Forest Degradation
	2	Sustainable Land Use Planning
	3	Reforestation and Rehabilitation

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Appendix 1: List of General Stakeholders at the National and Sub-National level Involved in the PNG TNA Process

No.	Name	Gender	Organisation	Email
1	William Lakain	M	Climate Change & Development Authority (CCDA)	william.lakain@ccda.gov.pg
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Appendix 2: List of Key AFOLU/LUUCF and Energy Sectors Stakeholders consulted in the TNA Process

AFOLU/LULUCF Sector – PNG Forest Authority
Energy – National Energy Authority and PNG Power Limited

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FRIDAY 18th October 2024
SIGN SHEET

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Appendix 4: Technology Fact Sheets for Energy, Transport, and LULUCF Sectors

4.1 Energy Sector

I. **Biogas Power Plant**

Technology: Biogas Power Plant	
Defining Characteristics	Narative
Definition and description	Biogas is the product of an anaerobic (without air) process that breaks down biodegradable matter. Various types of microorganisms are involved in the process that finally produces biogas, a mixture of methane and carbon dioxide. Methane is also the main ingredient of natural gas. The methane when oxidized (burned with air) releases thermal energy that can be used for heating and cooking or when burned in a gas engine can produce electricity or propel vehicles. Biogas can be compressed for storage and transportation and it can be purified to increase the methane content to achieve natural gas quality. However, this only makes sense on a large scale as the process is energy intensive. Methane has a very high global warming potential, which is 28 to 33 times higher than that of carbon dioxide. When burnt however, it becomes carbon dioxide. Since the organic matter can only release as much carbon (dioxide) as it previously took from the atmosphere, it is considered climate neutral and a form of renewable energy. This however, only applies if no more than 3% to 4 % of the methane leaks from the closed system to the environment. Digesters and fermenters, that is where the biogas is produced in, are available in all sizes making the actual production of biogas scalable. Certain

	utilizations however, are bound to minimum sizes in order to be economic. Gas engines and generators for example are not economic with small scale systems.
Potential in Papua New Guinea	Small scale biogas systems can be utilised in the rural areas of PNG as majority of PNG population live in the rural areas and rely on subsistence farming for their survival. These produces a considerable amount of organic waste from maure, vegetable waste and green cut to efficients of distilleries. Furthemore, large scale biogas systems can be utilised by the palm oil industry since PNG is a palm oil producing country. Currently there are two palm oil mill effluent methane capture projects in two oil palm processing sites.
Mitigation to Climate	A palm oil mill effluent methane capture project has the potential to reduce 35,261 tCO_2e per year as per the current project in PNG. A small scale biogas project will have the potential to reduce between 1,500 tCO_2e to 1,900 tCO_2e per year.
Advantages	• Proven, mature and reliable technology • Very good scalability • Produces organic fertilizer as a by product • Reduces pollution in waterways becaue organic waste is better managed by the biogas system and the recommended fertilizer management system
Disadvantages	• Especially the operation of small scale systems is relatively labor intensive for a renewable energy source • If more than 3% to 4% of methane leak into the environment there are no climate mitigation benefits
Costs and other financial requirements	Capital cost: approximately $3 million to $6 million per megawatt (MW) of installed capacity Operational cost: Medium to large-scale plants (1–10 MW): Costs might be in the range of $0.04 to $0.08 per kWh, with economies of scale making larger plants more cost-effective. Maintenance cost: Medium to large-scale plants (1–10 MW) Maintenance costs can range from $200,000 to $600,000 per year, depending on scale and operational complexity.
Status of technology in Papua New Guinea	There are no small scale systems in PNG. There are two existing projects that capture methane produced during the treatment of wastewater produced by the Palm Oil Mill and using these to generate electricity.

II. **Biomass Power Plant**

Technology: Biomass Power Plant	
Defining Characteristics	Narrative
Definition and description	This technology involves the use of biomass (fuel wood) for electricity production. It consists of installing a power plant composed of generation units that use wood chips. In addition, it involves the development of an area of grassland dedicated to fuel wood plantations
Potential in Papua New Guinea	Agricultural Residues: PNG is an agricultural powerhouse, with a variety of crops grown throughout the country, including palm oil, cocoa, coffee, coconut, and sugarcane. A large portion of the biomass from these industries, such as husks, shells, leaves, and stalks, can be used for energy production. For example, palm oil plantations could provide substantial waste materials for biomass power plants. Forestry Residues: PNG has extensive forests, which provide a significant amount of wood waste, such as sawmill residues, wood chips, and tree branches, that could be utilized for biomass energy. However, sustainability

	in harvesting forest residues is critical to avoid deforestation and environmental damage.
Mitigation to Climate	Biomass power plants are considered "carbon-neutral" in the long term. The carbon dioxide (CO_2) released when biomass is burned for energy is roughly equivalent to the CO_2 absorbed by the plants during their growth. This makes biomass a much lower contributor to atmospheric greenhouse gases than fossil fuels, though it's important to account for all emissions in the full lifecycle of the biomass.
Advantages	• Biomass energy generally produces fewer greenhouse gas emissions compared to coal, oil, and natural gas • Biomass power plants often rely on locally sourced materials, which can provide a market for agricultural residues, wood products, and waste from forestry operations. This can create jobs and stimulate economic activity in rural areas, especially in industries like farming, logging, and waste management. • Biomass can be sourced locally, reducing dependence on imported fossil fuels and contributing to energy security.
Disadvantages	• Lower Efficiency Compared to Fossil Fuels: Biomass power plants are typically less efficient than natural gas or coal-fired power plants. • High Upfront Investment: The construction of biomass power plants requires significant upfront capital investment, particularly when it comes to creating the infrastructure for fuel collection, transportation, and storage. • Bulk Transport Requirements: Biomass materials have a lower energy density compared to fossil fuels, meaning that they require more frequent transportation to the power plant. This can lead to high transportation costs and increased carbon emissions due to the large quantities of material being moved over long distances.
Costs and other financial requirements	Capital cost: Approximately $3 million to $7 million per MW Opeational cost: Approximately $0.05 to $0.15 per kWh Maintenance cost: Approximately $100,000 for a small 5 MW plant to $2.5 million for a 100 MW plant
Status of technology in Papua New Guinea	Currently a power plant with a total installed average capacity of 30MW is in the construction phase. The project also involves the development of around 15,000ha of dedicated wood plantation.

III. **Geothermal Power Plant**

Technology: Geothermal Power Plant	
Defining Characteristics	Narrative
Definition and description	A geothermal power plant harnesses heat from the Earth's interior to generate electricity. This heat is typically accessed by drilling wells into geothermal reservoirs, where hot water or steam is extracted. The steam is then used to drive turbines connected to generators. There are several types of geothermal power plants, including dry steam plants (directly using steam from the ground), flash steam plants (using hot water that flashes to steam when pressure is reduced), and binary cycle plants (transferring heat from geothermal fluid to another fluid with a lower boiling point to generate steam). Geothermal energy is considered a sustainable and low-emission source of power.
Potential in Papua New Guinea	Papua New Guinea (PNG) has significant potential for geothermal energy development due to its location along the Pacific "Ring of Fire," a region known for volcanic activity and geothermal resources. The country possesses several areas with high geothermal energy potential, making it a promising site for future geothermal power plants.

Mitigation to Climate	Geothermal power plants produce significantly lower carbon emissions than conventional fossil-fuel power plants. While a geothermal plant may emit small amounts of CO_2 and other gases, such emissions are orders of magnitude lower compared to coal, oil, or natural gas plants. For comparison: A coal-fired power plant emits roughly 1,000 grams of CO_2 per kilowatt-hour (gCO_2/kWh) of electricity generated. A natural gas power plant emits about 450-550 gCO_2/kWh. Geothermal plants typically emit less than 100 gCO_2/kWh, and in many cases, emissions can be as low as 10-20 gCO_2/kWh when employing best practices like reinjection of geothermal fluids and using closed-loop systems. This significant difference in emissions shows the potential of geothermal energy to reduce CO_2 emissions across the energy sector
Advantages	• Geothermal power plants provide reliable, consistent power (baseload energy), as geothermal resources are available 24/7, regardless of weather or time of day. • Geothermal energy is **renewable** and **sustainable** as long as the geothermal reservoir is managed properly. • Geothermal power plants require relatively small land areas compared to other energy sources like wind farms or solar fields. This makes geothermal energy a good option for areas with limited available land or where land use is a concern, such as in densely populated regions
Disadvantages	• Geothermal reservoirs may not be stationary; in some cases, the heat source or fluid reservoirs can migrate or change over time, leading to potential resource loss or reduced efficiency. • The development of geothermal power plants typically involves long lead times due to the extensive exploration, permitting, drilling, and construction phases. • Exploration and drilling costs are significant for geothermal power plants, as they require deep drilling to access geothermal reservoirs.
Costs and other financial requirements	<u>Capital cost:</u> Approximately \$2 million and \$5 million per MW of installed capacity <u>Operational cost:</u> Approximately \$0.01 to \$0.05 per kWh <u>Maintenance cost:</u> Approximately \$150,000 to \$7 million per year
Status of technology in Papua New Guinea	Currently a geothermal power plant with a total installed average capacity of 50MW in a gold mining site. The project involves geothermal discharged wells and shallow steam-relief wells have been drilled to decrease geothermal hazards due to steam pressure build u and to depresurise residual steam or gas pockets in the vicinity of the mine.

IV. **Hydro Power Plant**

Technology: Hydro Power Plant	
Defining Characteristics	Narrative
Definition and description	A hydropower plant (also known as a hydroelectric power plant) is a facility that generates electricity by harnessing the energy of flowing or falling water. It is one of the most widely used and oldest forms of renewable energy production. The basic principle involves converting the kinetic energy of water into mechanical energy and then into electrical energy using turbines and generators. The types of hydro power plants include: 1. Run-of River 2. Storage Plants 3. Power-storage plants

Potential in Papua New Guinea	PNG has a wealth of rivers and streams due to its mountainous landscapes, which receive substantial rainfall throughout the year. Many of these rivers have the flow rates necessary to generate hydroelectric power. According to the International Hydropower Association (IHA) and other studies, PNG's potential hydropower capacity is estimated to be over 15,000 MW, though only a small fraction of this has been developed to date
Mitigation to Climate	Lifecycle emissions of hydropower are very low compared to fossil fuel-based energy generation. The emissions mainly come from the construction phase (e.g., cement production, dam construction), but over the operational life of the plant (typically 40–100 years), these emissions are far outweighed by the emission savings from displacing fossil fuels. According to the International Hydropower Association (IHA), hydropower plants have an average carbon intensity of 10–30 g CO_2/kWh, which is much lower than the emissions from coal (900–1,000 g CO_2/kWh) or natural gas (400–500 g CO_2/kWh)
Advantages	• Renewable and Clean: Hydropower is a renewable energy source that produces no direct greenhouse gas emissions or air pollution. • Reliable and Flexible: Hydropower provides baseload power and can quickly adjust output to meet demand. • Storage and Grid Stability: Pumped-storage hydroelectric plants help stabilize the grid by storing excess energy and providing a backup when needed.
Disadvantages	• Environmental Impact: Dams can disrupt local ecosystems, affect aquatic habitats, and displace communities. • High Initial Costs: Building dams and infrastructure can be expensive. • Location-dependent: Hydropower requires a suitable water source, making it location-specific.
Costs and other financial requirements	Capital cost: Approximately $1 million to $5 million per MW Operational Cost: Approximately $0.01 to $0.03 per kWh Maintenance Cost: Approximately $600,000 to $2.5 million per year
Status of technology in Papua New Guinea	As of now, the country's hydropower capacity is relatively underutilized. Only about 10% of the potential has been harnessed, with around 600 MW of installed capacity from both large and small hydro projects.

V. **Solar Power Plant**

Technology: Solar Power Plant	
Defining Characteristics	Narrative
Definition and description	A solar power plant is a facility that converts sunlight into electricity using solar panels (photovoltaic cells) or solar thermal systems. Solar panels capture sunlight and convert it directly into electricity via the photovoltaic effect. In solar thermal plants, mirrors or lenses focus sunlight to generate heat, which is then used to produce steam that drives a turbine connected to an electricity generator. Solar power plants can range from small rooftop installations to large-scale utility plants that supply power to the grid, offering a clean, renewable source of energy with minimal environmental impact.
Potential in Papua New Guinea	Papua New Guinea receives strong and consistent sunlight, with an average daily solar insolation ranging from 4.5 to 5.5 kWh per square meter. This high level of solar energy availability makes it an excellent location for both small and large-scale solar energy projects.

Mitigation to Climate	The carbon intensity of a solar power plant refers to the amount of carbon dioxide (CO_2) emitted per unit of electricity generated (typically measured in grams of CO_2 per kilowatt-hour (g CO_2/kWh)). The carbon intensity of a solar plant is extremely low when compared to fossil fuel-based power generation, because the electricity it produces is carbon-free during operation.
Advantages	• Sustainable Long-Term Solution: Solar energy can be harnessed for decades, with solar panels typically lasting 25-30 years or more with minimal maintenance. • Lower Operational Costs: Once a solar power plant is installed, its operating costs are relatively low compared to fossil fuel power plants. • Energy Independence: Solar power helps reduce reliance on imported fossil fuels, enhancing energy security and energy independence for nations. • Predictable Costs: Unlike fossil fuel prices, which are subject to volatility due to geopolitical factors and market fluctuations, the costs of solar energy are relatively predictable.
Disadvantages	• No Sun at Night: Solar power is only generated during the daylight hours, meaning it cannot produce energy at night. • Large Land Area for Utility-Scale Projects: While solar panels can be installed on rooftops, large-scale solar power plants require a significant amount of land area. • Installation and Infrastructure: The initial capital cost of installing solar panels and the necessary infrastructure (inverters, mounting systems, energy storage solutions) can be high. • Efficiency of Solar Panels: Even with advancements in solar panel technology, solar panels have relatively low efficiency in converting sunlight into electricity (typically around 15-22%).
Costs and other financial requirements	Capital Cost: Approximately $800,000 to $3 million per MW Operational Cost: Approximately $0.01 to $0.03 per kWh Maintenance Cost: Approximately $1 million to $3 million per year
Status of technology in Papua New Guinea	There are no large-scale solar power plants in Papua New Guinea. Only small-scale and rooftop solar.

VI. **Wind Power Plant**

Technology: Wind Power Plant	
Defining Characteristics	Narrative
Definition and description	A wind power plant, also known as a wind farm, is a facility that generates electricity by harnessing the kinetic energy of the wind using large turbines. These plants can be located onshore (land-based) or offshore (in bodies of water) and consist of multiple wind turbines that convert wind energy into electrical power.
Potential in Papua New Guinea	Average wind speeds in PNG typically range between 3 m/s and 6 m/s in coastal areas. According to global wind resource maps and localized studies, areas with wind speeds above 6 m/s (ideal for large-scale

	commercial wind farms) are somewhat limited, but medium-scale systems can still be feasible in areas with wind speeds between 5-7 m/s.
Mitigation to Climate	Total Lifecycle Emissions for Wind Power: Estimates suggest that wind turbines have a carbon footprint of around 10 to 20 grams of CO_2 per kWh, including production, transportation, and installation. This is vastly lower than fossil-fueled power generation systems. Annual CO_2 Avoidance: The amount of CO_2 saved annually depends on the size of the wind farm and its capacity factor (the actual energy output compared to the maximum possible output). For example, a 100 MW wind farm in a location with a 30% capacity factor could generate around 262,800 MWh of electricity per year, potentially avoiding over 200,000 tons of CO_2 emissions annually if it replaces coal or natural gas-fired power.
Advantages	• Low Operating Costs: Once a wind farm is established, the ongoing operational and maintenance costs are relatively low • Compatibility with Agriculture: Wind turbines take up relatively little land space, allowing for dual land use—farmers can continue to use the land for agricultural purposes while the turbines generate electricity. • Scalability: Wind power plants can be scaled according to the region's needs, with installations ranging from small, local turbines to large, utility-scale wind farms. • Job Creation: The construction, operation, and maintenance of wind power plants create numerous jobs in local communities, including in turbine manufacturing, installation, and technical maintenance.
Disadvantages	• Intermittency and Variability: Wind energy generation is intermittent, meaning it is dependent on wind conditions, which can vary from day to day and even hour to hour. This makes wind power less reliable than baseload energy sources like coal or nuclear • Land and Space Requirements: Large-scale wind farms require significant amounts of land to avoid turbulence between turbines and optimize performance. This can lead to land use conflicts. • Noise and Visual Impact: Wind turbines can produce noise from the rotating blades, which can be a concern for nearby residents. • High Initial Capital Costs: While wind energy has low operating costs, the initial capital investment for wind power plants—especially offshore wind farms—can be substantial.
Costs and other financial requirements	<u>Capital cost:</u> Approximately \$1 million to \$2.5 million per MW <u>Operational cost:</u> Approximately \$0.01 to \$0.03 per kWh <u>Maintenance cost:</u> Approximately \$4 million to \$7 million per year
Status of technology in Papua New Guinea	Currently, there are no wind farms in Papua New Guinea

VII. **Gasifier Stoves using biomass**

Technology: **Gasifier Stoves using biomass**	
Defining Characteristics	Narrative
Definition and description	Cookstoves in biomass gasification systems are designed to utilize biomass materials (such as wood, crop residues, and other organic matter) for cooking by converting them into useful energy through a process called gasification. Gasification is a thermochemical process that heats biomass in a low-oxygen environment, producing a combustible gas known as producer gas, which can then be used for cooking. These stoves are typically more efficient and cleaner than traditional open-fire stoves
Potential in Papua New Guinea	Biomass gasification cook stoves have significant potential in Papua New Guinea (PNG), where the majority of the population relies on traditional biomass fuels such as wood, charcoal, and crop residues for cooking. These methods often contribute to indoor air pollution, deforestation, and inefficient fuel use, all of which could be mitigated with the adoption of gasification technologies.
Mitigation to Climate	Traditional Biomass Stoves (three-stone fires or simple biomass stoves) emit approximately 250-350 g of CO_2 per kWh of energy produced. Biomass Gasification Stoves (with high efficiency and clean combustion) emit around 100-200 g of CO_2 per kWh of energy produced, depending on the stove and fuel. This shows that biomass gasification stoves can reduce carbon emissions by up to 50% or more compared to traditional cooking methods, though the carbon intensity still varies depending on: - The efficiency of the gasification process. - The quality and moisture content of the biomass fuel. - The operation and maintenance of the stove.
Advantages	• Health Benefits: By producing fewer harmful emissions, gasification stoves help improve indoor air quality, significantly reducing the risk of respiratory illnesses, eye irritation, and other health issues associated with traditional cooking methods • Lower Fuel Consumption: Because gasification stoves are more efficient, they reduce the amount of wood or biomass needed for cooking. This leads to lower rates of deforestation and environmental degradation, as less biomass is harvested from forests or agricultural land. • Reduced Time Spent Collecting Fuel: Biomass gasification stoves require less fuel to produce the same amount of heat, which means that people spend less time collecting firewood or biomass. • Off-Grid Solution: Biomass gasification stoves are especially useful in off-grid or remote areas where access to modern energy sources like electricity or LPG is limited or unavailable.
Disadvantages	• Upfront Investment: Biomass gasification cook stoves generally have a higher initial cost than traditional stoves. This cost can be a significant barrier for low-income households, especially in rural or off-grid areas where purchasing power is limited.

	• Availability of Replacement Parts: In remote areas, replacement parts or spare components for biomass gasification stoves may not be readily available. • Challenging Performance in Cold or Wet Conditions: Gasification stoves may not perform as well in cold or wet conditions, particularly in areas with high humidity, where the biomass may be harder to dry or burn efficiently. • Storage of Biomass Fuel: Proper fuel storage is critical for the efficient operation of biomass gasification stoves.
Costs and other financial requirements	Initial Cost: $50 to $150 for household stoves, $500 to $5,000 for larger community systems. Fuel Costs: $10 to $50 per month depending on local biomass availability. Maintenance Costs: $5 to $30 annually for general maintenance and occasional repairs.
Status of technology in Papua New Guinea	There is currently a cook stove project in Papua New implemented by a private company. They plan to distribute over 100,000 improved cookstoves to local communities and expand across the country where over 80% of all households still rely on indoor open-fire cooking

4.2 Transport Sector

I. Electric Vehicles

Technology: Introduction of Electric Vehicles.	
Defining Characteristics	Narrative
Definition and description	An electric vehicle (EV) is a type of vehicle that is powered entirely or partially by electricity, rather than by gasoline or diesel. The key components of an electric vehicle include an electric motor, battery pack, and electronic controller.
Potential in Papua New Guinea	The potential for electric vehicles (EVs) in Papua New Guinea (PNG) is promising, but it faces several challenges and opportunities that need to be addressed to enable widespread adoption. PNG is a developing country with a mix of urban and rural areas, and its unique geography and infrastructure pose both hurdles and potential for innovation in the EV market
Mitigation to Climate	The carbon intensity of the electricity used to charge the vehicle depends on the mix of energy sources used to generate power. Here's an example of carbon intensity based on different energy sources: - Coal-powered grid: The carbon intensity of electricity from coal can be around 900 to 1,200 grams of CO_2 per kWh. - Natural gas grid: The carbon intensity of electricity from natural gas is generally around 400 to 500 grams of CO_2 per kWh. - Renewable energy grid (wind, solar, hydro): Zero or very low emissions, typically 0 to 50 grams of CO_2 per kWh, depending on the efficiency and geographical location.
Advantages	• Lower Operating Costs: EVs are more efficient than ICE vehicles. The cost of electricity per mile is usually much lower than the cost of gasoline or diesel. • Lower Maintenance Costs: Electric vehicles have fewer moving parts compared to traditional vehicles. • Highly Efficient: Electric motors are much more efficient at converting energy into motion than internal combustion engines. While ICE vehicles typically convert only about 20-30% of the energy from gasoline into useful power, electric motors can achieve

	efficiency rates of around 85-90%, making them a more energy-efficient option. • Home Charging: One of the greatest advantages of owning an EV is the ability to charge it at home using a standard electrical outlet or dedicated home charger
Disadvantages	• Purchase Price: EVs generally have a higher initial purchase price compared to conventional gasoline or diesel vehicles, primarily due to the cost of the battery • Driving Range: Many EVs still have a limited driving range on a single charge compared to gasoline vehicles, although this is improving. • Insufficient Charging Stations: While the number of EV charging stations is growing, it remains insufficient in many areas, particularly rural regions or developing countries. • Demand on the Grid: As EV adoption grows, there could be significant pressure on the electricity grid, especially in regions with limited energy generation capacity
Costs and other financial requirements	• Average Purchase Price: As of 2023, the average price of a new electric car in the U.S. is typically between $30,000 and $50,000. • Cost per Mile: On average, EVs cost about $0.03 to $0.06 per mile to operate, depending on the vehicle and the cost of electricity • Annual maintenance might cost around $200 to $400.
Status of technology in Papua New Guinea	Electric vehicle penetration in Papua New Guinea is very low with less than 1%. The government is developing an EV policy with the intention of increasing EV penetration.

II. **Hybrid Vehicles**

Technology: Introduction of Hybrid Vehicles.	
Defining Characteristics	Narrative
Definition and description	Hybrid vehicles are cars or trucks that use two or more different power sources to propel the vehicle. Typically, they combine an internal combustion engine (ICE) with one or more electric motors, which are powered by a rechargeable battery. The main goal of hybrid vehicles is to optimize fuel efficiency, reduce emissions, and improve overall performance compared to traditional gasoline-powered vehicles.
Potential in Papua New Guinea	The potential of hybrid vehicles (HVs) in Papua New Guinea (PNG) is significant, especially given the country's unique geographic, economic, and environmental context. However, the adoption of hybrid vehicles faces several challenges, alongside key opportunities.
Mitigation to Climate	On average, full hybrids produce about 70-100 g CO_2/km (112-160 g CO_2/mi) in real-world driving, depending on the model, driving conditions, and fuel economy. This is generally much lower than the carbon intensity of conventional gasoline vehicles, which may range from 120-200 g CO_2/km (193-321 g CO_2/mi). he carbon intensity of mild hybrids tends to be similar to or slightly lower than traditional gasoline cars. They generally fall in the range of 100-150 g CO_2/km (160-240 g CO_2/mi). Since the electric motor cannot drive the vehicle on its own, the gasoline engine is still the main source of power.
Advantages	• Better Fuel Economy: Hybrid vehicles are designed to optimize fuel consumption by using both an internal combustion engine (ICE) and an electric motor. • Less Wear on Brakes: Regenerative braking also reduces wear on traditional braking components, which can lead to lower maintenance costs over time.

	• Lower Overall Operating Costs: While hybrid vehicles often have a higher upfront cost than conventional cars, the improved fuel efficiency can make them more cost-effective in the long term, especially for high-mileage drivers • Powerful Combined Performance: In many hybrid vehicles, the electric motor and internal combustion engine work together to deliver excellent overall performance.
Disadvantages	• Initial Cost: Hybrid vehicles typically cost more upfront than conventional gasoline or diesel vehicles. • High Replacement Costs: Replacing the battery in a hybrid vehicle can cost several thousand dollars, especially for models with large batteries or advanced technology (like lithium-ion batteries). • Battery Placement: In most hybrid vehicles, the large battery pack is often placed in the trunk area or beneath the floor of the car to save space and maintain weight distribution. As a result, many hybrid vehicles tend to have less cargo space than their non-hybrid counterparts • Depreciation: While hybrid vehicles can be a good long-term investment due to their fuel savings, they may depreciate more quickly than traditional vehicles.
Costs and other financial requirements	• <u>Capital cost:</u> $2,000 - $8,000 more • <u>Fuel Cost (Annual):</u> ~$1,000 - $1,500 (for 15,000 miles/year) • <u>Battery Replacement:</u> $1,000 - $6,000 (if needed) • <u>Maintenance (Annual):</u> $400 - $600
Status of technology in Papua New Guinea	Hybrid vehicles have a very low penetration in Papua New Guinea which is less than 1%.

III. **Compressed Natural Gas in Transport**

Technology: Introduction of Compressed Natural Gas in Transport	
Defining Characteristics	Narrative
Definition and description	Compressed Natural Gas (CNG) is a cleaner, more environmentally friendly alternative to traditional fossil fuels like gasoline and diesel. It is primarily composed of methane (CH_4), and is stored at high pressure, typically around 3,000 to 3,600 psi (pounds per square inch), to make it compact and suitable for use in vehicles.
Potential in Papua New Guinea	Papua New Guinea (PNG), with its growing population and expanding economy, faces a combination of environmental, economic, and infrastructural challenges in its transport sector. The potential for Compressed Natural Gas (CNG) as an alternative fuel for transportation in PNG is significant, given the country's abundant natural gas resources, the need to reduce reliance on imported fuels, and its environmental goals.
Mitigation to Climate	<u>Carbon Intensity:</u> About 70-90 g CO_2/km (grams of CO_2 per kilometer) for light-duty vehicles like cars and smaller trucks. <u>Energy Content</u>: Roughly 55-60 MJ/kg of energy in natural gas, but the exact carbon intensity will depend on factors such as vehicle efficiency and driving conditions. <u>CO_2 Emissions</u>: When burned, CNG produces approximately 0.184 kg of CO_2 per MJ (a rough average across the industry). This is lower than gasoline and diesel.
Advantages	• Cost Savings: Significantly cheaper fuel costs and more stable prices. • Energy Security: Reduces dependence on imported oil and enhances local energy security.

	• Fuel Efficiency: Better thermal efficiency and lower engine maintenance costs. • Public Health: Reduced toxic emissions and improved air quality.
Disadvantages	While CNG offers numerous benefits, including lower emissions, cost savings, and energy security, it also faces several significant disadvantages that hinder its widespread adoption in the transport sector. These challenges include: • Limited refueling infrastructure, • High conversion and vehicle costs, • Shorter driving range, • Potential environmental impact from methane leaks, • Dependence on natural gas supply chains.
Costs and other financial requirements	<u>Capital cost</u> - CNG vehicles: 10-30% more than gasoline - Conversion: $2,000 to $8,000 - Refueling stations: $300,000 to $3 million <u>Operational cost</u> - CNG fuel: 30-60% cheaper than gasoline - CNG economy: 1.4 to 1.5 times the volume of gasoline <u>Maintenance Costs</u> - Tank inspection: $2,000-$4,000 per tank every 15-20 years - Regular maintenance: Similar to gasoline, but with CNG-specific checks
Status of technology in Papua New Guinea	This technology does not exist in Papua New Guinea

IV. **Improved Urban/Suburban Public Transport System using LPG Buses**

Technology: Improved Urban/Suburban Public Transport System using LPG Buses	
Defining Characteristics	Narrative
Definition and description	An improved urban/suburban public transport system utilizing LPG (liquefied petroleum gas) buses focuses on enhancing the efficiency, environmental sustainability, and cost-effectiveness of public transportation in cities and surrounding areas. LPG buses offer several advantages over conventional diesel or gasoline-powered buses, such as reduced emissions, lower fuel costs, and quieter operation.
Potential in Papua New Guinea	The potential for an Improved Urban/Suburban Public Transport System using LPG (Liquefied Petroleum Gas) Buses in Papua New Guinea (PNG) is significant, especially given the country's growing urbanization, environmental challenges, and the need for more efficient and sustainable transport solutions. PNG faces a variety of unique challenges and opportunities that could make the adoption of LPG buses a feasible and impactful solution for public transport in urban and suburban areas.
Mitigation to Climate	While LPG emits slightly less CO_2 per unit of fuel compared to diesel, the key factor that influences carbon intensity is fuel efficiency. Since LPG is typically used in lighter and more efficient vehicles (like buses designed for urban/suburban transport), the overall carbon intensity of an LPG-powered public transport system would generally be lower than that of a diesel-powered system.
Advantages	• Cheaper Fuel: LPG is generally less expensive than diesel or gasoline, which makes operating LPG buses more cost-effective in the long run • Longer Vehicle Life: LPG engines typically have lower wear and tear compared to diesel engines, meaning that LPG-powered buses could have a longer operational life with lower maintenance costs.

	• With reduced operational costs, bus operators may be able to offer lower fares, making public transport more affordable for everyday commuters • LPG-powered buses are typically more fuel-efficient than their diesel counterparts, which can translate into longer distances covered on the same amount of fuel.
Disadvantages	• The initial cost of purchasing LPG-powered buses can be higher than diesel or gasoline buses • LPG refueling infrastructure also requires significant investment. • LPG-powered buses may require different types of maintenance and repair expertise compared to traditional diesel buses. This could necessitate training programs for mechanics and technicians, which adds to the operational complexity. • While LPG buses are an improvement over diesel, they still fall short of the zero-emission targets that many cities and countries are striving to achieve.
Costs and other financial requirements	Capital Costs: USD 10.25 million Operational Costs (Monthly): USD 169,000 Maintenance Costs (Annual): USD 95,000
Status of technology in Papua New Guinea	This technology does not exist in Papua New Guinea

4.3 LULUCF

I. Reduced Deforestation and Forest Degradation

Technology Factsheet: Reduced Deforestation and Forest Degradation

1. Introduction
Reduced deforestation and forest degradation aim to limit the loss and degradation of forested areas through sustainable management practices and enforcement of conservation policies. This approach is essential in countries like Papua New Guinea (PNG), where forests are vital carbon sinks and provide ecosystem services that support biodiversity and local livelihoods. By focusing on conservation and improved land-use management, PNG can achieve significant reductions in greenhouse gas (GHG) emissions while strengthening ecosystem resilience.

2. Technology Characteristics

This technology focuses on policies, practices, and enforcement mechanisms that prevent illegal logging, unsustainable agricultural expansion, and other activities that degrade forested areas. Key components include land-use zoning, sustainable forest management (SFM), community engagement, and monitoring systems. Technologies such as remote sensing and geographic information systems (GIS) can aid in monitoring forest cover and degradation rates, making it possible to target conservation efforts and report on progress accurately.

3. Country-Specific Applicability and Potential

- **Capacity**
  PNG has institutions such as the Climate Change and Development Authority (CCDA) and the Papua New Guinea Forest Authority (PNGFA), which oversee forest conservation efforts. However, further capacity-building is needed at regional and local levels, especially in monitoring, enforcement, and data analysis capabilities.
- **Scale of Application**
  This technology can be applied across all major forested regions in PNG, particularly in areas facing high deforestation pressure. It is especially relevant in customary land areas where community-led conservation initiatives can play a central role.
- **Time Horizon**
  Medium to Long Term. Medium to long-term (5–20 years), as efforts to reduce deforestation require sustained policy support, continuous funding, and long-term community engagement.

4. Status of Technology in Country

- **Availability of Technology**
  Monitoring technologies, such as satellite imagery and GIS tools, are available in PNG, with support from international partnerships. However, on-the-ground enforcement tools and resources are limited, and there is a need for improved coordination among stakeholders.

5. Climate Change Mitigation/Adaptation Benefits

- **Mitigation**
  Reduced deforestation directly contributes to PNG’s Nationally Determined Contribution (NDC) by lowering GHG emissions from the AFOLU sector.

6. Benefits to Economic, Social, and Environmental Development

- **Economic**
  Sustainable forestry practices can generate long-term economic benefits through eco-tourism, sustainable timber harvesting, and carbon credit generation.
- **Social**
  REDD+ enhances community resilience by promoting forest-based livelihoods, supporting local culture, and involving indigenous landowners in conservation.
- **Environmental**
  REDD+ helps maintain biodiversity, prevent soil erosion, protect watersheds, and support native flora and fauna critical to PNG’s ecosystems.

7. Financial Requirements and Costs

- **Capital Costs**
  Initial setup costs for REDD+ are high, involving investments in monitoring technology, capacity building, and community engagement programs. Estimated at approximately USD 5,000–10,000 per hectare, depending on the site and infrastructure.
- **Operating Costs**
  Ongoing expenses include MRV, forest management, and community incentives, ranging from USD 100–500 per hectare annually based on project scope and complexity.

II. Reforestation and Rehabilitation

Technology Factsheet: Reforestation and Rehabilitation in Papua New Guinea

1. Introduction
Reforestation and Rehabilitation involve the restoration of degraded land by planting native or adapted tree species to restore ecosystem functions and enhance biodiversity. In Papua New Guinea (PNG), where deforestation and land degradation are significant issues, reforestation can improve soil quality, regulate water cycles, and contribute to climate change mitigation by capturing carbon dioxide. Reforestation initiatives also have the potential to support sustainable livelihoods, aligning with PNG's national climate goals and international commitments.

2. Technology Characteristics

Reforestation and Rehabilitation include planting native and fast-growing species to restore forest cover and degraded lands. Key components include:

- **Species Selection:** Choosing native species to enhance biodiversity and resilience, or fast-growing species for quick carbon sequestration and soil recovery.
- **Soil and Site Preparation:** Preparing land for optimal growth, involving soil improvement, land clearing, or erosion control as necessary.
- **Monitoring and Maintenance:** Regular assessment of tree growth, health, and survival rates to ensure the success of restoration efforts.

3. Country Specific Applicability and Potential

- **Capacity**: PNG has vast areas of degraded land and grasslands suitable for reforestation. The PNG Forest Authority aims to plant **800,000 hectares** by 2050 under its national reforestation program, "Operation Painim Graun na Planim Diwai" (Secure Land and Plant Trees). The country has a solid foundation in forestry and agroforestry, supported by experienced professionals, several nurseries, and active community participation in reforestation projects. Expanding local skills and improving access to resources could further strengthen the success of these reforestation efforts.
- **Scale of Application**: Reforestation is applicable in deforested or degraded areas, particularly in regions previously impacted by logging, mining, and agricultural expansion.
- **Time Horizon**:

  Medium to Long Term. Reforestation projects typically require 5–20 years to establish, grow, and generate full environmental and social benefits, depending on the growth rates of the species used and ongoing maintenance..

4. Status of Technology in Country

- **Availability of Technology**:

  Basic reforestation techniques are available and practiced, particularly in community forestry projects. However, scaling up would require further investment in technology and improved infrastructure for seedling production and land preparation.

5. Climate Change Mitigation Benefits

- **Mitigation**
  Reforestation sequesters atmospheric CO_2, contributing to PNG’s GHG emission reduction targets. Additionally, reforested areas act as long-term carbon sinks.

6. Benefits to Economic, Social, and Environmental Development Economic Development:

- **Economic**
  Reforestation can create jobs in seedling production, planting, and maintenance. Forest products, such as timber, fruits, and medicinal plants, provide additional income streams for local communities.
- **Social Development**

  Strengthens community resilience by involving local communities in sustainable land management, supporting indigenous knowledge, and enhancing food and fuel sources.
- **Environmental Development**

  Reforestation improves biodiversity, enhances soil fertility, and stabilizes ecosystems by providing habitats for native flora and fauna, which supports PNG's rich biodiversity.

7. Financial Requirements and Costs

- **Capital Costs**:

  Initial investments include costs for seedlings, planting equipment, site preparation, and community training programs. Estimated capital costs can vary widely based on project scale but typically range from **$1000 to $3,000 per hectare**, depending on the methods used, site accessibility and the species planted.
- **Operating Costs**

  Ongoing costs involve maintenance activities such as weeding, pest control, monitoring growth, and community engagement. These costs may average around **$100 to $500 per hectare annually**, depending on the intensity of management practices required

III. Sustainable Land Use Planning

Technology Factsheet: Sustainable Land Use Planning

1. Introduction
Sustainable Land Use Planning (SLUP) is an integrated approach to managing land resources that balances social, economic, and environmental objectives. It involves setting strategies for optimal land allocation to reduce deforestation, manage agricultural expansion, conserve biodiversity, and improve climate resilience. For Papua New Guinea (PNG), where land tenure is predominantly customary, SLUP can support sustainable development, enhance livelihoods, and strengthen resilience to climate change.

2. Technology Characteristics
SLUP leverages geographic information systems (GIS), stakeholder engagement, and policy frameworks to guide land-use decisions. Key elements include:

- **Data-Driven Decision-Making:** Using spatial data and mapping to identify optimal land uses and zones.
- **Community and Stakeholder Engagement:** Integrating local knowledge and ownership into planning processes.
- **Regulatory and Policy Support:** Establishing legal and policy frameworks for land management and enforcement.

3. Country-Specific Applicability and Potential

- **Capacity**
  PNG has foundational capacities in GIS, remote sensing, and community land-use management, supported by local agencies and partnerships with international organizations. Expanding training for technical and governance skills will improve SLUP's effectiveness.
- **Scale of Application**
  SLUP can be applied nationwide, with priority on high-risk areas such as forested regions, agricultural frontiers, and areas facing high development pressure.
- **Time Horizon**
  Medium to Long Term. SLUP is an ongoing process with significant benefits expected over 5–20 years as policies and land use patterns stabilize and mature.

4. Status of Technology in Country

- **Availability of Technology**
  SLUP is partially available, with some regional projects and pilot programs active in PNG. However, broader implementation is limited by technology access, data availability, and expertise in land-use governance.

5. Climate Change Mitigation/Adaptation Benefits

- **Mitigation**
  SLUP helps reduce greenhouse gas emissions by preventing deforestation and degradation and promoting sustainable land use that maintains carbon stocks. It aligns with PNG's NDC targets by reducing deforestation and promoting carbon sequestration through sustainable practices.

6. Benefits to Economic, Social, and Environmental Development

- **Economic**
  SLUP supports more sustainable agriculture and forestry, promoting stable, long-term incomes for local communities.
- **Social**
  Enhances land tenure security, promotes equitable resource access, and aligns land use with local cultural practices, benefiting PNG's customary landowners.

- **Environmental**
  SLUP maintains ecosystem integrity by conserving biodiversity, protecting watersheds, and sustaining ecosystem services critical for PNG's natural heritage.

7. Financial Requirements and Costs

- **Capital Costs**
  Initial costs include investments in GIS technology, spatial data collection, training, and community engagement. Estimated initial capital costs may range from USD 1,000,000 to USD 5,000,000, depending on project scale and regional complexity.
- **Operating Costs**
  Ongoing expenses include monitoring, governance, policy development, and community support, estimated at USD 50,000–200,000 per year.

IV. Downstream Processing for Forestry Products

Technology Factsheet: Downstream Processing for Forestry Products

1. Introduction
Downstream processing in the forestry sector involves value-added transformation of raw timber into finished products such as furniture, construction materials, and paper products. For Papua New Guinea (PNG), this approach can shift the country from reliance on raw log exports to a diversified economy that leverages local manufacturing, improves employment opportunities, and promotes sustainable forest management.

2. Technology Characteristics
Downstream processing requires specialized equipment for milling, drying, and finishing, as well as skilled labour and supportive infrastructure. Key components include:

- **Milling and Sawing:** Initial processing to cut timber into usable shapes for further manufacturing.
- **Drying and Treatment:** Removing moisture and treating timber to increase durability and suitability for specific uses.
- **Product Manufacturing:** Crafting final products like furniture, flooring, and building materials.

3. Country-Specific Applicability and Potential

- **Capacity:**
  PNG has foundational infrastructure for primary timber processing but limited capacity for advanced downstream activities. Developing training programs and infrastructure for secondary and tertiary processing is crucial for scaling this technology.
- **Scale of Application:**
  Applicable at both small-scale (community-level operations) and industrial scale, with the potential to reach urban and rural regions to maximize PNG's forestry resources.
- **Time Horizon:**
  Medium to Long Term. Significant investment and capacity-building over a 5–10 year period will enable this transition.

4. Status of Technology in Country

- **Availability of Technology:**
  Downstream processing technology is partially available in PNG, with some sawmills and small-scale facilities operating. However, a lack of advanced equipment, skilled workforce, and supportive policies has limited widespread adoption.

5. Climate Change Mitigation Benefits

- **Mitigation**
  By adding value locally, downstream processing reduces emissions associated with exporting raw logs and promotes sustainable forest management, thereby lowering deforestation rates.

6. Benefits to Economic, Social, and Environmental Development

- **Economic**
  Downstream processing increases the value of PNG's forestry resources, supports local economies, and creates jobs. It also reduces reliance on log exports and enhances trade prospects for high-value products.
- **Social**
  Enhances skills and employment opportunities, supporting local communities through skill-building in carpentry, manufacturing, and machinery operation.
- **Environmental**
  Reduces logging pressure on primary forests by making sustainable use of timber. It also encourages responsible sourcing and land management practices, protecting PNG's biodiversity.

7. Financial Requirements and Costs

- **Capital Costs**
  Initial setup costs are high, requiring investments in milling equipment, drying facilities, and training programs. Initial capital may range from USD 2,000,000 to 10,000,000 depending on scale and level of mechanization.
- **Operating Costs**
  Ongoing costs include equipment maintenance, energy, labour, and sourcing sustainable timber, with estimates ranging from USD 200,000–500,000 per year based on operation size.

V. Application of Environmental Safeguards

Technology Factsheet: Application of Environmental Safeguards

1. Introduction
Environmental safeguards are measures designed to prevent, minimize, and mitigate adverse environmental impacts during development activities. In Papua New Guinea (PNG), implementing environmental safeguards is essential for protecting the country's rich biodiversity, indigenous lands, and natural resources from the adverse effects of industrial projects, including mining, forestry, and infrastructure development. These safeguards help ensure sustainable practices and are aligned with international environmental and social standards.

2. Technology Characteristics
Environmental safeguards are a set of policies, frameworks, and tools used to assess and manage risks associated with development projects. Key elements include:

- **Impact Assessment and Screening:** Evaluating projects for potential environmental impacts and identifying necessary mitigation measures.
- **Monitoring and Compliance:** Regularly assessing project adherence to safeguard protocols and taking corrective actions as needed.
- **Stakeholder Engagement:** Involving local communities and indigenous landowners in decision-making processes to align projects with local needs and knowledge.

3. Country-Specific Applicability and Potential

- **Capacity**
  PNG has basic institutional structures to support environmental safeguards, with established agencies like the Climate Change and Development Authority (CCDA) and the Conservation and Environment Protection Authority (CEPA). However, additional training and resources are needed for effective implementation, monitoring, and enforcement.
- **Scale of Application**
  Applicable across all development sectors, especially in high-impact areas such as mining, oil and gas, forestry, and large-scale agriculture. Safeguards are relevant at local, regional, and national levels.
- **Time Horizon**
  Medium to Long Term. Establishing robust safeguard mechanisms and building capacity requires sustained effort over 5–10 years to achieve full effectiveness.

4. Status of Technology in Country

- **Availability of Technology**
  Environmental safeguard frameworks are available through existing partnerships with international organizations, but localized implementation and enforcement are limited due to capacity and funding constraints.

5. Climate Change Mitigation Benefits

- **Mitigation:**
  By enforcing safeguards, PNG can prevent deforestation, habitat loss, and other activities that contribute to greenhouse gas emissions. Safeguards also support sustainable practices that protect carbon-rich ecosystems.

6. Benefits to Economic, Social, and Environmental Development

- **Economic:**
  Safeguards contribute to sustainable economic growth by encouraging responsible investment and reducing long-term costs associated with environmental degradation.
- **Social:**
  Supports social equity by protecting community rights, promoting fair compensation, and involving indigenous populations in resource management.
- **Environmental:**
  Preserves biodiversity, protects critical habitats, and ensures that ecosystems continue to provide essential services to local communities and wildlife.

7. Financial Requirements and Costs

- **Capital Costs**
  Initial investment includes establishing policies, training personnel, and acquiring necessary monitoring tools and technologies. Capital costs may range from USD 500,000 to USD 2,000,000 based on the scale of implementation.
- **Operating Costs**
  Ongoing costs include staff salaries, monitoring and reporting, stakeholder consultations, and enforcement activities, estimated at USD 100,000–500,000 annually.

VI. Sustainable palm oil development

Technology Factsheet: Sustainable Palm Oil Development

1. Introduction
Sustainable palm oil development aims to produce palm oil in an environmentally friendly, socially responsible, and economically viable manner. This approach minimises deforestation, conserves biodiversity, and supports local communities. In Papua New Guinea (PNG), where palm oil is a significant agricultural export, sustainable palm oil can reduce environmental degradation associated with conventional palm oil production while improving livelihoods through responsible, community-focused production practices.

2. Technology Characteristics
Sustainable palm oil development involves a range of practices and standards designed to ensure that palm oil production is environmentally responsible and socially beneficial. Key characteristics include:

- **Zero Deforestation Commitments:** Avoiding the conversion of high conservation value (HCV) forests and high carbon stock (HCS) areas for palm oil plantations.
- **Certification Standards:** Compliance with standards such as the Roundtable on Sustainable Palm Oil (RSPO) and local certification systems.
- **Improved Agricultural Practices:** Adoption of techniques like integrated pest management, organic fertilization, and sustainable water management to enhance productivity with minimal environmental impact.

3. Country-Specific Applicability and Potential

- **Capacity**

PNG has an established palm oil industry, supported by large and smallholder plantations. Developing sustainable production practices is feasible with additional support for farmer training, certification, and compliance monitoring.

- **Scale of Application**
  Potentially applicable across PNG's palm oil sector, including both industrial-scale operations and smallholder farms. It could also expand to new areas with appropriate environmental safeguards.
- **Time Horizon**
  Medium to Long Term. Achieving widespread sustainable certification and practices may require 5–10 years, depending on capacity building and policy alignment.

4. Status of Technology in Country

- **Availability of Technology**
  While RSPO standards are partially adopted, sustainable palm oil practices are limited by infrastructure and training constraints. However, existing frameworks provide a foundation for scaling up sustainable practices with proper investment.

5. Climate Change Mitigation/Adaptation Benefits

- **Mitigation**
  By avoiding deforestation and employing BMPs, sustainable palm oil production reduces greenhouse gas emissions. Carbon-rich forests are conserved, and emissions from land clearing and fertilizers are minimized.

6. Benefits to Economic, Social, and Environmental Development

- **Economic**
  Access to certified sustainable palm oil markets offers premium pricing, improved market stability, and increased income for smallholders and producers.
- **Social**
  Certification requirements encourage fair wages, safe working conditions, and local community benefits, supporting PNG's social development goals.
- **Environmental**
  Sustainable palm oil practices reduce deforestation, protect biodiversity, and promote habitat conservation, preserving PNG's rich ecosystems.

7. Financial Requirements and Costs

- **Capital Costs**
  Initial costs include investments in BMPs, training, certification fees, and establishing monitoring systems. Capital costs for certification and BMP implementation may range from USD 500,000 to 2,000,000 depending on operation size.
- **Operating Costs**
  Ongoing costs involve compliance monitoring, auditing, certification renewals, and sustainable input materials, estimated at USD 100,000–500,000 per year.

VII. Protected area development and management

Technology Factsheet: Protected Area Development and Management

1. Introduction
Protected area development and management involve creating and maintaining zones designated for conservation to preserve biodiversity, ecosystem services, and cultural heritage. In Papua New Guinea (PNG), these areas protect diverse ecosystems, support indigenous and local communities, and contribute to climate change mitigation and adaptation. Managing protected areas aligns with PNG's commitments under the Convention on Biological Diversity (CBD) and the country's National Biodiversity Strategy and Action Plan.

2. Technology Characteristics
Protected area development includes the establishment of national parks, wildlife reserves, and community-based conservation areas. Key components of effective management include:

- **Zoning and Legal Protection:** Designating areas for conservation and establishing legal frameworks to protect against encroachment and exploitation.
- **Biodiversity Monitoring:** Conducting ecological assessments to monitor species, habitats, and environmental changes.
- **Community Involvement and Co-Management:** Engaging local and indigenous communities in conservation activities and decision-making processes.
- **Resource Management and Restoration:** Managing resources sustainably within the protected area and rehabilitating degraded landscapes where needed.

3. Country-Specific Applicability and Potential

- **Capacity**
  PNG has existing protected areas, but capacity for effective management and monitoring is limited by resources and infrastructure. Training, funding, and institutional support are needed to enhance protected area governance.
- **Scale of Application**
  This technology is applicable across various landscapes, from coastal mangroves to tropical rainforests. Expanding protected areas is feasible at national and regional levels, especially in biodiversity-rich areas.
- **Time Horizon**
  Medium to Long Term. Establishing and effectively managing protected areas is a gradual process requiring continuous support, with potential results emerging over 5–15 years.

4. Status of Technology in Country

- **Availability of Technology**
  Some protected areas exist, but the scope and management effectiveness vary. The National Protected Areas Policy provides a framework, yet local enforcement and technical capacity are limited, especially in remote areas.

5. Climate Change Mitigation Benefits

- **Mitigation:**
  Protected areas prevent deforestation and habitat destruction, preserving carbon sinks like forests and mangroves, which sequester carbon and mitigate emissions.

6. Benefits to Economic, Social, and Environmental Development

- **Economic**
  Protected areas promote sustainable tourism, offering income opportunities for local communities. They also support sustainable resource use, benefiting fisheries, forestry, and agriculture sectors.
- **Social**
  These areas uphold traditional land rights, enabling local communities to maintain cultural practices and benefit from ecosystem services. Co-management structures foster collaboration and empower communities.
- **Environmental:**
  Protected areas contribute to biodiversity conservation by safeguarding habitats for endangered species. They also preserve ecosystem functions, such as nutrient cycling and soil stability, which are critical to environmental health.

7. Financial Requirements and Costs

- **Capital Costs**
  Initial investment for establishing protected areas includes zoning, legal processes, infrastructure, and equipment for monitoring and enforcement. Capital costs range from USD 1 million to 5 million, depending on the area size and level of infrastructure.
- **Operating Costs**
  Ongoing costs involve staffing, community engagement, biodiversity monitoring, and maintenance of facilities, estimated at USD 200,000–800,000 annually.